Population Characteristics of Sturgeon and Asian Carp in the Niobrara River Downstream of Spencer Dam, Nebraska in 2008 and 2009

Final Report

Prepared for Nebraska Public Power District - Columbus, Nebraska

By

Greg A. Wanner, Dane A. Shuman, Kristen L. Grohs, and Robert A. Klumb

U. S. Fish and Wildlife Service, Great Plains Fish and Wildlife Conservation Office, Pierre, South Dakota 57501

August 2010

Summary — The Niobrara River is a large tributary that provides important seasonal increases in discharge, temperature, sediments, and nutrients to an inter-reservoir reach of the Missouri River between Fort Randall and Gavins Point dams. There is evidence of the importance of the Niobrara River to native fish species in the Missouri River including the endangered pallid sturgeon *Scaphirhynchus albus*; however direct fisheries studies in the Niobrara River are limited. Spencer Dam (currently owned and operated by Nebraska Public Power District) was constructed in 1927 on the Niobrara River at river kilometer (rkm) 63.3 stopping upstream fish migration beyond the hydro plant since then. The Niobrara River, including sites upstream of Spencer Dam, may provide critical sturgeon spawning sites, distance necessary for larval sturgeon drift, as well as nursery habitat for young of the year sturgeon, that could contribute to recovery of endangered pallid sturgeon. Anecdotal evidence indicated that pallid sturgeon and shovelnose sturgeon *S. platorynchus* have been captured in the Niobrara River downstream of Spencer Dam; however, the extent of habitat use by sturgeons was unknown. No information exists regarding the distribution of such species as bighead carp *Hypophthalmichthys nobilis*, silver carp *H. molitrix*, grass carp *Ctenopharyngodon idella*, and black carp *Mylopharyngodon piceus*, collectively referred to as Asian carp in the Niobrara River downstream of Spencer Dam. Therefore, our objectives were to determine the temporal and longitudinal relative abundance, size structure, condition, and habitat use of larval, juvenile, and adult pallid sturgeon, shovelnose sturgeon, and Asian carp in the Niobrara River downstream of Spencer Dam. In 2008 and 2009, fish sampling included drifted trammel nets from May through September and collection of fish larvae with drift nets from April or May to August.

During both years pallid sturgeon were found immediately downstream of highly complex river channels during late July and early August in the lower 10 km of the river. Pallid

sturgeon captured in 2008 (age-3 and age-6) and in 2009 (age-1) were of hatchery origin. All pallid sturgeon appeared healthy, in good condition, and growing. Fourteen shovelnose sturgeon were captured in 2008 and three fish were captured in 2009. Shovelnose sturgeon were collected throughout the 63 km study area in 2008, with most fish found near rkm 58.5 to downstream of the Eagle Creek confluence near rkm 52.0. In 2009, all shovelnose sturgeon were collected downstream of rkm 33.5. All shovelnose sturgeon were adults and in good condition. Pallid sturgeon and shovelnose sturgeon were generally collected in deep waters compared to other sampling locations. No larval sturgeon and no Asian carp were collected throughout the study. Both our trammel net and larval fish catches indicated that native fishes such as river carpsucker, channel catfish, sauger, shorthead redhorse, shortnose gar, sand shiners, red shiners, and flathead chubs are in high abundance and successfully spawning and recruiting in the Niobrara River downstream of Spencer Dam. The ability to protect present and future populations of the native fish in the Niobrara River can only be achieved through a scientifically-based long-term monitoring program. A monitoring program would provide timely, meaningful information to managers at a relatively low cost. Long-term monitoring programs have the power to answer ecological and management questions. It is important to continue to monitor the entire fish community in the Niobrara River. Although pallid sturgeon are a protected species, these fish are long-lived; therefore, ecological changes would likely be detected earlier with short-lived native cyprinid species such as chubs and shiners.

Introduction

The Niobrara River in Nebraska is principally groundwater fed. The lower 32 km of this river was added to the Missouri National Recreational River, managed by the National Park Service (NPS). This designation preserves free-flowing rivers that have exceptional natural and recreational values. The Niobrara River 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). This area was selected as a high priority pallid sturgeon recovery site because it retains many natural riverine features including sand bars, islands, side channels, and seasonally flooded shallow water sites. 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 (Junk et al. 1989; Galat and Lipkin 2000; and Pegg et al. 2003). Additionally, asynchronous operations of Fort Randall and Gavins Point dams create highly fluctuating daily and seasonal river stages. As part of recovery efforts to restore a naturally recruiting pallid sturgeon population in this reach of the Missouri River, 10,080 hatchery-reared juveniles were released into RPMA 3 from 2000 to 2009 (Table 1).

The Niobrara River currently retains a natural hydrograph and temperature regime and likely provides important seasonal habitats for native fishes. Water is being diverted from the Niobrara River basin for agricultural irrigation development that could impact in-stream flows in the Niobrara River (Zuerlein 2007). Reduced flows may jeopardize native fish populations and reduce productivity of fish and invertebrates in the Niobrara River and downstream of the Missouri/Niobrara rivers confluence, an area of high pallid sturgeon use (Spindler et al. 2009)

and macroinvertebrate abundance (Grohs 2008). Numerous studies have reported the importance of the Niobrara River to the Missouri River downstream of their confluence. Pracheil et al. (2009) reported that the average discharge from the Niobrara River is 14 times less than the Missouri River, yet positively influenced young-of-the-year paddlefish *Polyodon spathula* recruitment in the Missouri River. The natural flow regime of the Niobrara River, such as magnitude, rate of change, periodicity, and duration of the spring high flow period positively influenced paddlefish recruitment (Pracheil et al. 2009). Sauger *Sander canadense* populations in the Missouri River downstream of Fort Randall Dam demonstrated an affinity to the delta formed with warmer, more turbid discharge, and actively meandering and complex riverine habitats found downstream of the Niobrara River confluence compared to the cold, clear water upstream of the confluence (Graeb et al. 2009). The benthic fish community in the Missouri River downstream of Fort Randall Dam has been monitored since 2003 and Shuman et al. (2010) reported that the relative abundance of native fish, including pallid sturgeon and shovelnose sturgeon *S. platorynchus*, was higher downstream of the confluence. Additionally, shovelnose sturgeon condition (Wanner 2006) and the relative abundance of macroinvertebrates (Grohs 2008) increased downstream of the confluence. Increasing evidence supports the hypothesis that discharges from the Niobrara River positively influences the native fish community in the Missouri River. However, fish community data within the Niobrara River, especially sturgeon data, was limited (Schainost 2008) and knowledge of the larval fish assemblage was non-existent.

Pallid sturgeon (Hurley 1999; Snook et al. 2002; Swigle 2003; Gerrity 2005; Jordan et al. 2006) and shovelnose sturgeon (Hurley et al. 1987; Swigle 2003) are highly mobile and are reported to migrate long distances to spawn (Bramblett and White 2001). Gerrity (2005)

reported hatchery-reared juvenile pallid sturgeon moved up to 74 km during one year and Bramblett and White (2001) reported adult pallid sturgeon moved distances > 200 km during spring and summer. Shovelnose sturgeon in the Mississippi River were reported to move up to 11.7 km/d (Hurley et al. 1987). Juvenile pallid sturgeon dispersed throughout RPMA 3, regardless of stocking site, and move up to 9 km/d (Jordan et al. 2006) while adults moved up to 1.1 km/d (Wanner et al. 2007a) in that same reach of the Missouri River. Unfortunately, these studies did not search for pallid sturgeon in the Niobrara River even though both adults and juveniles were located multiple times at the confluence with the Missouri River (Jordan et al. 2006; Wanner et al. 2007a).

Spencer Dam (owned and operated by Nebraska Public Power District) was constructed in 1927 and has functioned as a complete barrier to upstream fish migration in the Niobrara River since then. Although a physical barrier, Spencer Dam is operated as a run of river dam with little adverse affects to the natural hydrograph and temperature regime. Hesse and Newcomb (1982) recommended a fish bypass at Spencer Dam to provide upstream access for spawning sauger *Sander canadense*, walleye *S. vitreus*, and channel catfish *Ictalurus punctatus*. A fish bypass at Spencer Dam would open 129 km of braided river habitat upstream to Norden Chute at rkm 192.3, which is a natural barrier during normal to low discharge (Schainost 2008).

Anecdotal evidence indicated that pallid and shovelnose sturgeon do migrate into the Niobrara River downstream of Spencer Dam and anglers have reported capturing these fish from the Niobrara River near Nebraska Highway 12 Bridge. However, knowledge is lacking on the extent of pallid sturgeon and shovelnose sturgeon migration upstream in the Niobrara River. In a review of all fish collections in the Niobrara River from 1893 to 2005, only one pallid sturgeon and one shovelnose sturgeon were ever captured (Schainost 2008). Both fish were captured near

the mouth. The fisheries assessments that had been conducted on the Niobrara River used hoop nets, explosives, seines and electrofishing (Hesse et al. 1979; Gutzmer et al. 1996; Gutzmer et al. 2002). However, most of these sampling techniques are ineffective at capturing sturgeon (Wanner 2006; Wanner et al. 2007b; Doyle et al. 2008; Phelps et al. 2009) or can not be used with endangered species (e.g. explosives).

An additional threat to the Niobrara River is invasion by bighead carp *Hypophthalmichthys nobilis*, silver carp *H. molitrix*, grass carp *Ctenopharyngodon idella*, and black carp *Mylopharyngodon piceus*, collectively referred herein as Asian carp (Conover et al. 2007). Asian carp have been found just downstream of Gavins Point Dam (Wanner and Klumb 2009), 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, which are present in the Niobrara River, are ideal spawning conditions for Asian carp (Kolar et al. 2005). If created, a bypass would allow access to upstream reaches for many fish populations, including aquatic nuisance species such as Asian carp. The population characteristics of sturgeon and Asian carp in the Niobrara River downstream of Spencer Dam are needed to gain insight into the benefits of providing a sturgeon bypass. The objectives of this study were to: 1) determine the temporal and longitudinal relative abundance of pallid sturgeon and shovelnose sturgeon in the Niobrara River downstream of Spencer Dam; 2) determine size structure and condition of pallid sturgeon and shovelnose sturgeon in the Niobrara River; 3) determine the seasonal habitat use of pallid sturgeon and shovelnose sturgeon in the Niobrara River; 4) determine the temporal and longitudinal relative abundance of larval fish drift to investigate the occurrence of sturgeon and Asian carp 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; and 5) determine the seasonal use and relative abundance of Asian carp (i.e., bighead, silver, grass, and black carp) in the Niobrara River.

Study Area

The Niobrara River watershed is approximately 34,913 km^2 (13,480 mi^2) and extends approximately 900 km (560 mi) from its headwaters in Wyoming to its confluence with the Missouri River near Niobrara, Nebraska (Alexander et al. 2009). Land use in the basin is predominately livestock ranching with row-crop agriculture in the eastern region (Dappen et al. 2007). The Niobrara River has a relatively steep gradient of 1.4 m/km (7.4 ft/mi) or a mean slope of 0.14% from the Keya Paha River confluence to its mouth. In comparison, the Missouri River on the border of South Dakota and Nebraska falls at 0.2 m/km (1.06 ft/mi), the central Platte River is 1.2 m/km (6.4 ft/mi), and the Middle Loup River gradient is 1.3 m/km (6.6 ft/mi) (Bentall 1991). The average annual precipitation in the basin ranges from 40 cm in the west to over 60 cm in the eastern basin. A high proportion of flow in the Niobrara River is derived from ground water. Around Valentine, Nebraska, 80-90% of the base flow is derived by ground water, while approximately 15% of base flow originates from ground water near the mouth (USDA 1973). Mean annual discharge of the Niobrara River at Spencer Dam is 43.5 m^3/s (1,536 ft^3/s), near Verdel is 48.3 m^3/s (1,708 ft^3/s) (Alexander et al. 2009), and 48.8 m^3/s (1,724 ft^3/s) at the mouth (Schainost 2008).

The lower Niobrara River downstream of Spencer Dam (Figure 1) is characterized as highly braided with multiple river channels and transports an estimated 300 metric tons of

sediment per day (Hotchkiss et al. 1993). Nebraska Public Power District (NPPD) operates Spencer Dam for hydroelectric power generation. Because Spencer Dam traps sediment, the 486 ha upstream reservoir is flushed each spring and fall (Gutzmer et al. 2002).

The Niobrara River downstream of Spencer Dam has a river valley that is wide enough for a floodplain of several channel widths and the effect of the valley geomorphology on the river channel pattern is generally limited to redirection of the channel towards the opposite valley wall at the outer banks (Alexander et al.2009). The Niobrara River downstream of Spencer Dam has 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 thalweg with depths from 0.3 to 2.0 m that alternates from bank to bank with alternating sand bars that may be covered by immature vegetation. The "braided" reach (Bends 6 – 14; 19.3 rkm – 54.7 rkm) is characterized as highly braided with several thalwegs that migrate between complexes of emergent and submergent sandbars and with relatively shallow water depths (0.1 – 0.3 m) (Figure 3). The "delta" reach (Bends 1 – 5; 0.0 rkm – 19.3 rkm) is characterized with several thalwegs that flow between sandbars with mature vegetation and whose dimensions generally are proportional to the active channel width (Figure 4). The thalwegs between the vegetated sandbars are relatively deep (0.5 – 3.0 m) with high water velocity (0.8 – 1.8 m/s).

Methods

Fish sampling

The Niobrara River from Spencer Dam downstream to the confluence with the Missouri River was divided equally into 3.86 km (2.4 mile) "bends" for a total of 16 bends. Eight to twelve randomly selected bends were sampled every month from May to September in 2008 and 2009 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 or 23.0 m 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, and walleye), or invasive (carp) fish were also weighed. Depth, water temperature, dominant substrate, and distance sampled were recorded for each trammel net drift and turbidity, dissolved oxygen, conductivity, and water velocity were measured at nearly every other subsample.

Trot lines were deployed in April 2008 as an added gear to target sturgeon. 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.

Larval fish sampling

Larval fish were sampled from 23 April to 20 August 2008 and 5 May to 18 August 2009 nearly every week at two sample sites. One sample site was 0.6 km above the confluence of the Missouri and Niobrara rivers. This site was immediately downstream of the railroad bridge that crosses the Niobrara River on the east shoreline where most of the river flows, and is referred herein as the "mouth site". The second site was 0.4 km downstream of Spencer Dam. This site was immediately downstream of the U.S. Highway 281 bridge on the south shore where most of the river flow occurs and herein is referred to as the "Spencer Dam site". Larval fish drift can vary throughout the day, therefore, each site was sampled at a minimum of once in the morning (0600 to 1200 hours) and once in the afternoon (1500 to 2200 hours) per week to address diel occurrence of larval fish. A target of eight subsamples was conducted at each site per diel period. Larval nets were fished on the bottom of the river for a maximum of 10 min (one sub-sample), depending on detrital loads. Because of high detrital loads, each sub-sample at the mouth site was generally sampled for 0.5 to 1 min while low detritus allowed the Spencer Dam site to be sampled for 5 to 10 min for each sub-sample. The larval sampling net mouth opening was 0.5 m high, 1 m wide, and 5 m long with 500 µm Nitex nylon mesh. The sampling net was held stationary on the bottom of the river. River depths at the sampling sites varied with the continuous shifting sand bars, but ranged in depths of 0.5 to 0.7; therefore, the entire water column was sampled with the drift nets. Each net was outfitted with a mechanical flow meter (General Oceanics Inc., Miami, Florida) to determine the water velocity (m/s) at the mouth opening and volume (m^3) of water sampled. Turbidity (nephelometric turbidity unit [NTU]) was measured using a Hach Turbidimeter, model 2100P (Hach Company, Loveland, Colorado), water temperature (°C), dissolved oxygen (DO) (mg/L), and conductivity (µS/cm) were

measured with a Hach HQ40D multimeter, (Hach Company, Loveland, Colorado), water velocity (m/s) was measured using a Marsh-McBirney Flo-Mate portable flow meter, model 2000 (Marsh-McBirney Inc., Frederick, Maryland), and depth was measured at each larval net sub-sample. Larval fish samples were stored in a 10% buffered formalin solution containing "Rose Bengal" dye. All larval fish were identified at a minimum to family and enumerated. Larval fish were identified using keys from McGuire (1981), Auer (1982), Fuiman et al. (1983), Wallus et al. (1990), Kay et al. (1994), Simon and Wallus (2003), and Wallus and Simon (2008). Specific keys designed to differentiate sturgeons in the genus *Scaphirhynchus* was found in Snyder (2002) and for Asian carps in Soin and Sukhanova (1972) were also used.

Water temperature was monitored downstream of Spencer Dam with HOBO waterproof temperature loggers (Onset Computer Corporation, Bourne, Massachusetts). Temperature was recorded every 0.5 h at three sites in 2008 (Spencer Dam, Redbird Bridge, and the Railroad Bridge) and two sites in 2009 (Redbird Bridge and the Railroad Bridge) (Figure 1). The most upstream site was at the intake of Spencer Dam (rkm 63), another logger was set at the Redbird Bridge (rkm 43), and a logger was placed at the Railroad Bridge near the mouth of the river (rkm 0.6) (Figure 1). River discharge data was recorded by the U.S. Geological Survey (USGS) gage station (USGS 06465500 Niobrara River near Verdel, Nebraska) located at the Pischelville Bridge (Figure 1) (http://waterdata.usgs.gov/usa/nwis/uv?site_no=06465500).

Statistical Analysis

A one-way analysis of variance (ANOVA) was used to test for differences in water temperatures at Spencer Dam, Redbird Bridge, and the Railroad Bridge in 2008. When differences in mean temperatures were significant ($P \leq 0.05$), a Bonferroni multiple range test

was used to determine which means varied significantly ($P \leq 0.10$). Another ANOVA was used to test differences in water temperatures between the Redbird Bridge and the Railroad Bridge in 2009.

Mean catch per unit effort (CPUE) was calculated as number of fish/100 m for drifted trammel nets and number of larval fish/100 m^3 of water filtered. The mean CPUE data were checked for normality. The data were not normally distributed; therefore, we $\log_{10}$ (CPUE+1) transformed the data and normality improved based on residual and normal probability plots of the residuals (Neter at al. 1996). Pallid sturgeon, shovelnose sturgeon, and Asian carp mean CPUE was compared among months (May to September) and geomorphic reaches (single thread, braided, and delta) along the Niobrara River using a two-way ANOVA. When differences in mean CPUE were significant ($P \leq 0.05$), a 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 pallid sturgeon and shovelnose sturgeon. 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 Anderson 1978). Pallid sturgeon fork length groups (sub-stock (SS), <330 mm; stock (S), 330 mm; quality (Q), 630 mm; preferred (P), 840 mm; memorable (M), 1040 mm; and trophy (T), 1270 mm) were proposed by Shuman et al. (2006). Shovelnose sturgeon fork length groups (SS, <250 mm; S, 250 mm; Q, 380 mm; P, 510 mm; M, 640 mm; and T, 810 mm) were developed by Quist et al. (1998).

Relative condition (K_n) is an appropriate index for local and regional summaries of condition (Murphy and Willis 1992). Relative condition was calculated for all pallid sturgeon using the formula K_n = (W/W'), where W is the weight of the individual and W' is the length-specific mean weight for a fish in the population being studied (LeCren 1951; Anderson and Neumann 1996). Shuman et al. (in review) provided a weight-length regression [$\log_{10}$W' = -6.2561 + 3.2932 $\log_{10}$FL (r^2 = 0.98)] for 2,268 pallid sturgeon from throughout the Missouri River basin.

Relative weight (W_r) is a commonly used condition index (Anderson and Neuman 1996) and changes in W_r values may indicate changes in prey availability (Blackwell et al. 2000) or be associated with gonadal development during spawning (Pope and Willis 1996). Relative weight was calculated as: W_r = W/Ws X 100, where W is the actual weight and Ws is the length-specific standard weight for that species (Wege and Anderson 1978). A standard weight (Ws) equation ($\log_{10}$Ws = -6.287 + 3.330 $\log_{10}$FL) was developed for shovelnose sturgeon by Quist et al. (1998). A one-way ANOVA test was used to compare mean K_n for pallid sturgeon and mean W_r for shovelnose sturgeon among months. If significant differences were found among months, a Bonferroni multiple range test was used to determine where differences occurred ($P \leq 0.10$). All ANOVA's were performed with Number Cruncher Statistical Software (NCSS; Hintze 2006).

Results

Water temperature and discharge

The water temperature in the Niobrara River varied greatly with ranges of 0 to 32.8 °C in both 2008 and 2009. The highest temperature during 2008 was 32.8 °C at the mouth on 28 July at 1830 hours and the highest temperature during 2009 was 32.8 °C at the mouth on 25 June at

1800 hours. No significant differences were found among the three logger sites in 2008 (F = 0.38, df = 2, P = 0.684) or in 2009 (F = 0.95, df = 1, P = 0.331) (Figure 5). Water temperature had substantial diel fluctuations that ranged from 0.2 to 11.6 °C in 2008 and from 1.5 to 11.5 °C in 2009 in a 24-h period at the mouth of the Niobrara River (Figure 6).

Water discharge was variable, especially during the spring and early summer months (Figure 7). 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).

Trammel net fish results

On 7 April 2008, fish sampling began using a 15.2 m trammel net. 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. With 180 hook-nights of effort over three days, only three channel catfish (237 – 309 mm) and two common carp *Cyprinus carpio* (388 and 500 mm) were sampled. 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. Therefore, trammel net drifts in April and trotlines were discontinued in 2009.

Over 67,000 m of river bottom were drifted each year with the 23.0 m trammel net in May through September in 2008 and 2009. A total of 304 trammel net drifts for a total distance of 81,726 m (mean drift distance = 269 m; SD = 102.2) were conducted in 2008. In 2009 drifts totaled 299 for a total distance of 67,885 m (mean drift distance = 227 m; SD = 97.5) (Table 2). A total of 705 fish were captured that included 19 species of fish in 2008 and a total of 561 fish

from 12 species were captured in 2009 (Table 3). The most abundant species captured with this gear were river carpsucker, channel catfish, sauger, shorthead redhorse, and shortnose gar *Lepisosteus platostomus*. No Asian carp were collected or observed during both years of sampling. Trammel net catch statistics for all species by month and geomorphic reach are reported in Table 3. Common and scientific names of all fish discussed in this report are found in Appendix A.

Two pallid sturgeon (460 mm FL and 280 g; 514 mm FL and 370 g) were captured on 29 July 2008 by drifted trammel nets. Pallid sturgeon were captured 1.9 km upstream of the mouth, with both fish caught in the same sample (Figure 8). 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 (released 26 July 2003 at 294 mm and 91 g and 25 August 2006 at 299 mm and 97 g, respectively), four miles downstream of the Niobrara/Missouri river confluence near the Standing Bear Bridge, South Dakota and Nebraska. One pallid sturgeon (388 mm FL; 190 g) was captured 12 August 2009 located 9.7 km upstream from the mouth (Figure 8). This fish was marked with a vertical yellow elastomer on the left side of the rostrum and vertical purple on the right side indicating that this fish was age-1 and released near the standing bear bridge on 13 April 2009. A new PIT tag (4719131C0F) was inserted in this fish at time of capture before being released. All pallid sturgeon were stock to quality length and relative condition (K_n) ranged from 0.79 to 1.02 (Table 4). Detailed information of pallid sturgeon tag information, capture location, distance net drifted, and water conditions (temperature, turbidity, maximum and minimum depths the net encountered, bottom water velocity, and mid-column water velocity) are presented in Table 5.

Pallid sturgeon were exclusively found in the delta reach of the Niobrara River. This reach of river has the most complex diversity of habitats with multiple river channels migrating through permanent islands and ephemeral sandbars and many backwater areas. Both pallid sturgeon capture locations were located just downstream of large complexes of islands (Figure 8). Of the habitat variables measured, pallid sturgeon were generally collected in areas that were deeper compared to other sampling locations (Table 6).

Shovelnose sturgeon were captured throughout the study area in 2008 (Figure 9). 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. In 2009, only three shovelnose sturgeon were captured in the Niobrara River. One was captured in June at rkm 33.5 and two shovelnose sturgeon were collected in the same sample in September at rkm 12.2. Shovelnose sturgeon ranged in length from 548 to 690 mm (Figure 10), were preferred to memorable (510 to 639 mm) or memorable to trophy length (640 to 809 mm), and relative weights (W_r) ranged from 64 to 103 (Table 4). Shovelnose sturgeon mean W_r = 92 (SE = 2) in 2008 and mean W_r = 82 (SE = 9) in 2009 with no substantial differences between length groups (Table 7). No significant differences were found in mean W_r among months in 2008 (F = 1.60, df = 1, P = 0.246) or 2009 (F = 0.24, df = 1, P = 0.709). Detailed information of shovelnose sturgeon tag information, capture location, distance net drifted, and water conditions (temperature, turbidity, maximum and minimum depths the net encounter, bottom water velocity, and mid-column water velocity) are presented in Table 5.

Although shovelnose sturgeon were collected throughout the study area in 2008, most were collected in the single thread reach immediately downstream of Spencer Dam near rkm

58.5 and just downstream of the Eagle Creak confluence (rkm 54.5) from rkm 52.0 to 53.9 (Figure 9). In 2009, shovelnose sturgeon were collected only in the braided and delta reaches. As with pallid sturgeon, shovelnose sturgeon were generally collected in areas that were deeper compared to other sampling locations (Table 6).

All shovelnose sturgeon captured in the Niobrara River were floy tagged in 2008 and 2009. One shovelnose sturgeon that was captured in August 2008 had a floy tag (#C08644) 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 (rkm 1,349) in April 2007. One shovelnose sturgeon that was floy tagged (#C83526) in the Niobrara River on 25 August 2008 at rkm 5.3 was recaptured on 9 September 2009 at rkm 12.2.

Due to the low catches of sturgeon and no Asian carp collected, no further mean CPUE or habitat analyses were performed.

Larval fish results

We sampled for larval fish from 23 April to 20 August in 2008 and 5 May to 18 August 2009. In 2008, 600 sub-samples were collected while 468 sub-samples were collected in 2009 (Table 8). Total volume of water filtered through drift nets were 22,509 m^3 in 2008 and 25,146 m^3 in 2009 (Table 8). Substantial variation was found in the measured environmental variables throughout the study (Table 9). In total, 2,516 larval fish were collected in 2008 and 2,631 larval fish were collected in 2009 at the mouth site (Table 10) and Spencer Dam site (Table 11). In both years, the majority of larval fish captured were sand shiners (45% in 2008; 58% in 2009), river carpsucker (36% in 2008; 12% in 2009), red shiners (12% in 2008; 10% in 2009), and

centrarchids (bluegill *Lepomis macrochirus*, green sunfish *Lepomis cyanellus*, largemouth bass *Micropterus salmoides*, and white crappie *Pomoxis annularis*; 3% in 2008; 8% in 2009) of which most were *Lepomis* spp. (2% in 2008; 6% in 2009). No larval sturgeon or Asian carp were collected in the Niobrara River downstream of Spencer Dam in 2008 or 2009; therefore, no further mean CPUE or habitat analyses were performed for larval fish.

Discussion

Dangerous high flows, large woody debris, and cold water temperatures precluded safe conditions for drifting trammel nets during April of each year; therefore, trammel net sampling began in May. Large amounts of small and large woody debris persisted in May 2008 making drifting trammel nets difficult and substantially increased sampling time for each sub-sample. Since June of that year, reduced woody substrate made drifting trammel nets more effective, which resulted in increased sampling effort the rest of the sampling year. Woody debris collected in trammel nets was low with concurrent low river discharge in May 2009, but increased with subsequent increases in discharge throughout the rest of the sampling period. Trammel nets could only be effectively drifted from 1 km downstream of Spencer Dam to the mouth. The area within 1 km of Spencer Dam is characterized by a degraded stream bed with shale bedrock outcroppings, cobble, gravel, and bridge construction materials (concrete blocks and rebar) near and downstream of U.S. Highway 281 Bridge. The furthest upstream site sampled with trammel nets was at rkm 62.3 on 19 May 2008 and 14 May 2009. This was because sediment that was trapped upstream of Spencer Dam was sluiced through the dam. The sluiced sand temporarily covered the exposed bedrock and cobble before being transported downstream, which allowed trammel net sampling further upstream. By June of each year, the

sand was eroded away exposing bedrock, cobble, and construction materials. Trotlines would likely be the most effective gear for sampling sturgeon upstream of rkm 62 to Spencer Dam.

The two individual pallid sturgeon collected in 2008 were from different year classes, stocked at different times, appeared to be healthy and growing, and moved upstream into the Niobrara River into the same habitat and at the same time during the last week of July. A single pallid sturgeon was collected during the second week in August 2009 in the Niobrara River also appeared healthy and growing. During both years, pallid sturgeon were found immediately downstream of highly complex river channels (delta reach) during the same time of year. These fish are likely keying in on habitats that provide an abundant source of prey that are likely drifting from these complex habitats immediately upstream. Pallid sturgeon are opportunistic feeders that prey on aquatic macroinvertebrates and fish (Wanner et al. 2007c; Grohs et al. 2009). In the Missouri River downstream of Fort Randall Dam, juvenile pallid sturgeon preyed mostly upon chironomids and ephemeropterans (specifically *Isonychia* sp.) during late July and early August (Wanner et al. 2007c). A high abundance of macroinvertebrates, especially chironomids and ephemeropterans were observed in larval drift samples collected immediately downstream of Spencer Dam and at the mouth during this study and during a macroinvertebrate study in 1979 (Hesse and Newcomb 1982).

The age-3 (2005 year class) pallid sturgeon (460 mm, 280 g, K_n = 0.86) collected in the Niobrara River in 2008 was above average when compared to the average lengths (444 mm; ±2SE = 23), weights (257.5 g; ±2SE = 51.4), and relative condition (K_n = 0.781; ±2SE = 0.100) of the 2005 year class in the Fort Randall reach of the Missouri River (Shuman et al. 2009). The age-6 (2002 year class) pallid sturgeon (514 mm, 370g, K_n = 0.79) captured in the Niobrara River in 2008 was below average when compared to the average lengths (541 mm; ±2SE = 22),

weights (529.8 g; ±2SE = 82.3), and relative condition (K_n = 0.815; ±2SE = 0.041) of the 2002 year class in the Fort Randall reach of the Missouri River. The age-1 (2008 year class) pallid sturgeon (388 mm, 190 g, K_n = 1.02) collected in the Niobrara River in 2009 was above average when compared to the average lengths (299 mm; ±2SE = 42) and weights (87.3 g; ±2SE = 41.3), but below average for relative condition (K_n = 1.058; ±2SE = 0.122) of the 2008 year class in the Fort Randall reach of the Missouri River (Shuman et al. 2010). The pallid sturgeon that were collected in the Niobrara River obviously migrated from the Missouri River because stocking locations are known. These juvenile pallid sturgeon may only migrate into the Niobrara River in the summer for short time periods. Further study is needed to determine if pallid sturgeon reside in the Niobrara River year round. However, it does appear that pallid sturgeon in the Niobrara River are healthy, growing, and are in good condition, indicating favorable habitat and prey availability exist in this river.

Most monitoring and research on pallid sturgeon has concentrated in large rivers such as the Missouri (Welker and Drobish 2010) and Mississippi (Garvey et al. 2009) rivers. In recent years, pallid sturgeon monitoring activities have expanded to tributaries. Different life stages of pallid sturgeon have been documented using tributary streams to the Missouri River such as the Kansas River (Niswonger et al. 2008), the Platte River (Hamel and Pegg 2010), and the Yellowstone River (Jager et al. 2008). Angler reports have documented pallid sturgeon in the Big Sioux River and pallid sturgeon are commonly caught in the confluence of the James and Missouri rivers (Stukel et al 2010). All pallid sturgeon captured in the Niobrara River were juveniles and likely searching for preferred habitats to efficiently forage. The population of pallid sturgeon in the Fort Randall reach of the Missouri River is dominated by hatchery-stocked juvenile pallid sturgeon with a few remnant adults (Shuman et al. 2010). Pallid sturgeon do not

reach sexual maturity until ages 5-7 (≥ 710 mm FL) for males and 9-12 years (≥ 850 mm FL) for females (Keenlyne and Jenkins 1993). As the pallid sturgeon population in the Missouri River matures, adults may begin seeking spawning habitat in the Niobrara River because this river continues to retain a natural hydrograph and temperature regime compared to the Missouri River. Continued monitoring of the pallid sturgeon population in the Niobrara River is warranted. Juvenile pallid sturgeon were only found in the lower 10 km of the Niobrara River.

In both years, adult shovelnose sturgeon were first collected in June. Shovelnose sturgeon spawn at temperatures ranging from 17 to 21 °C (Keenlyne 1997), which coincided with observed temperatures in mid-May to mid-June in the Niobrara River. The fish collected in June may have migrated upstream in an attempt to spawn, although there is no evidence of successful spawning in this reach from the larval fish collections during this study or in the Fort Randall reach of the Missouri River based on lengths of fish collected (Shuman et al. 2010). Although no larval sturgeon were collected in the Niobrara River, we can not exclude the possibility that larval densities were are at such low levels that they were not detected. Shovelnose sturgeon are likely finding abundant prey in the Niobrara River as these fish feed primarily on aquatic macroinvertebrates (Wanner et al. 2007c). Immature macroinvertebrates were found in high abundances in the Niobrara River downstream of Spencer Dam indicating exceptional habitats and water quality; however, following sluicing operations, it has been reported that there is a reduction in the gross numbers of many macroinvertebrate species (Hesse and Newcomb 1982). Changes in operations at Spencer Dam followed the Hesse and Newcomb (1982) study and sluicing operations at Spencer Dam now occur during cooler water and high flow conditions (April and September every year) to reduce impacts to riverine fish (Gutzmer et al. 2002). Current sluicing activities at Spencer Dam in April may still be disrupting

macroinvertebrate populations in the Niobrara River. Large environmental disturbances such as the sluicing activities can cause temporary or long term changes in the aquatic invertebrate populations (Lehmkuhl 1979).

In 2008, abundances of shovelnose sturgeon remained the same in July, and then there was a substantial increase in August, while no sturgeon were collected in September. In 2009, shovelnose sturgeon were only collected in June and September. One explanation for the number of shovelnose sturgeon collected at different times of the year is water temperature. During 2008, mean daily water temperature gradually increased from May through August with a sharp decline in September during the time frame we were sampling. Shovelnose sturgeon may have left the study area when temperatures dramatically decreased. Shovelnose sturgeon have been reported to move great distances downstream post-spawn (DeLonay et al. 2007). During 2009, mean daily water temperatures increased sharply in June to > 23 °C, where they remained for the rest of the sampling year.

Shovelnose sturgeon were collected within 1.5 km (rkm 61.8) of Spencer Dam in 2008. We can not exclude the possibility that sturgeon were above this location and may have been immediately downstream of Spencer Dam. The area immediately downstream of Spencer Dam (within 1 km) was not sampled with drifting trammel nets because the shale bedrock outcroppings, cobble, and bridge construction materials were present. Unlike pallid sturgeon that restricted their movements to the delta reach, shovelnose sturgeon were found throughout the study area. However, most were found above rkm 51.5 in the single thread reach and in the area immediately downstream of Eagle Creek confluence (54.5 rkm) where the Niobrara begins to transition into the braided reach. This transitional area of the Niobrara River likely has preferred habitats with an abundance of prey. In 2009, shovelnose sturgeon were only found in

the braided reach in June and in the delta reach in September. The hydrograph was substantially different from 2008 to 2009. During 2008, there was a major flood event during early June with a dramatic decrease in discharge where it remained low for the rest of the year. During 2009, there was no major flood event during the summer, while periodic rain events kept river discharge unseasonably high compared to the long-term average (http://waterdata.usgs.gov/usa/nwis/uv?site_no=06465500). Therefore, shovelnose sturgeon likely found preferred habitats in the upper reaches of the study area during low discharge and preferred habitats in the braided and delta reaches during high discharge.

The two pallid sturgeon captured in a single trammel net drift in July 2008 and the two shovelnose sturgeon captures in September 2009 in a single trammel net drift indicates that sturgeon are keying into specific habitats in the Niobrara River and were not randomly distributed. Juvenile pallid sturgeon have been found in clusters in the Missouri River (Jordan et al. 2006; Shuman et al. 2010) and Spindler (2008) reported that clusters of sturgeon occurred in a combination of deep water, sand substrates, and high prey availability (i.e., dipterans and ephemeropterans).

A single recapture event of a shovelnose sturgeon that was tagged in the Niobrara River in 2008 and recaptured the following year provides limited information. The movements of this fish are completely unknown from the time that this fish was first tagged to the recapture event. Interestingly, this fish was recaptured at nearly the identical place in 2009 (within 6 km) that it was first captured and tagged in 2008 during the same time of year. Without radio tracking or a long-term monitoring program, it can not be determined if there is a resident population of shovelnose sturgeon in the Niobrara River or if they return to the Missouri River each year.

No shovelnose sturgeon were smaller than preferred length category (FL ≤ 510 mm) collected in the Niobrara River downstream of Spencer Dam in 2008 and 2009. During the same time, no shovelnose sturgeon smaller than preferred length were captured in the Fort Randall reach of the Missouri River (Shuman et al. 2009; Shuman et al. 2010). Lack of small sized shovelnose sturgeon indicates that this population in this stretch of the Missouri River and Niobrara River is ageing with no observed recruitment. Shovelnose sturgeon mean W_r in the Niobrara River was similar to mean W_r of shovelnose sturgeon in the Missouri River in 2008 (mean W_r = 94) and 2009 (mean W_r = 92) (Shuman et al. 2009; Shuman et al. 2010). The shovelnose sturgeon population in the two rivers is in good condition indicating an abundance of prey available in both rivers

No larval sturgeon or Asian carp were collected in the Niobrara River downstream of Spencer Dam in 2008 or 2009. Asian carp have not been detected in the Niobrara River during this study or the Fort Randall reach of the Missouri River above Gavins Point Dam (Shuman et al. 2010). Based on this 2-year sampling effort, a bypass at Spencer Dam would not introduce these exotic species to upstream reaches of the Niobrara River at this point in time. However, bighead carp, silver carp, and grass carp have been captured each year from 2005 to 2009 in the Missouri River downstream of Gavins Point Dam (Stukel et al. 2010). Therefore, the Niobrara River and the Fort Randall reach of the Missouri River are vulnerable areas for range expansion of Asian carp. The absence of larval sturgeon indicates that these fish are not spawning in the Niobrara River or are at such low abundance that their larvae were not detected. A bypass at Spencer Dam would open up 129 rkm of braided river habitat. Upstream of Spencer Dam there are highly complex river channels that are similar to the delta reach downstream of Spencer Dam where we captured pallid sturgeon in both years of this study. These complex habitats upstream

of Spencer Dam occur in areas immediately downstream of tributary confluences (Brush Creek [rkm 77], Keya Paha River [rkm 95], and Plum Creek [rkm 175]). Availability of river habitat above Spencer Dam may provide the needed minimum drift distance for pallid sturgeon (≥ 245 km) and shovelnose sturgeon (≥ 94 km) larvae to drift, depending on water velocity (Braaten et al. 2008). The entire length of the Niobrara River downstream of Norden Chute is 192 km and with the additional distance in the Missouri River downstream of the Niobrara River confluence (30 km) would provided the needed distance for slowest drifting larval pallid sturgeon and most larval shovelnose sturgeon to survive, transition to a benthic behavior, begin exogenous feeding, grow, and recruit to the population.

Both our trammel net and larval fish catches indicated that native fish such as river carpsucker, channel catfish, sauger, shorthead redhorse, shortnose gar, sand shiners, red shiners, and flathead chubs are in high abundances and successfully spawning and recruiting in the Niobrara River downstream of Spencer Dam. All of these species are also located upstream of Spencer Dam with the exception of sauger and shortnose gar (Schainost 2008; Wanner, unpublished data). Hesse and Newcomb (1982) recommended developing conceptual plans for a bypass at Spencer Dam. Based on the results of this study and past monitoring of the Niobrara River upstream of Spencer Dam, sturgeon, sauger, and shortnose gar would be the species that would benefit most from a constructed bypass. However, all native species would likely benefit from a bypass that would open hundreds of kilometers of Niobrara River main channel habitat providing access to tributaries above Spencer Dam.

Management Recommendation

The ability to protect present and future populations of the fish community in the Niobrara River can only be achieved through a scientifically-based long-term monitoring program. Monitoring programs provide timely, meaningful information to managers at a relatively low cost and are requisite to apply adaptive management to decision making (Walters and Holling 1990). Continued monitoring would build on the existing data collected in Niobrara River during 2008 and 2009 and would enable the distinction of beneficial or effective management actions from less effective management or even harmful actions. Therefore, we recommend continued monitoring of the entire fish community, not only sturgeon, in the Niobrara River. Although pallid sturgeon are rare and protected, this species is long-lived; therefore, ecological change would likely be detected earlier with short-lived native cyprinid species such as chubs and shiners whose abundance varies inter-annually.

Acknowledgments

We thank Nebraska Public Power District (NPPD), the National Park Service (NPS), U.S. Fish and Wildlife Service (USFWS) Region 6 - Water Resources Division, USFWS Region 6 - Aquatic Nuisance Species Coordinator, Nebraska Game and Parks Commission, Missouri Department of Conservation, and U.S. Army Corps of Engineers for funding this study. We thank the field technicians that included Jake Billings, Dan Dembkowski, Terry Hall, Jordan Hull, Alexis Maple, and Kevin Peery from the USFWS, Stephen Wilson, Jessica Howell, Kyle Hubert, Brandon Tycz, and Blake Yonke from the NPS, and Justin King, Rocky Plettner, and Paul Spencer from NPPD. In addition, we thank all the landowners that gave access to boat

launch sites along the river. Landowners also assisted in locating sampling sites and pulling the airboat out to the river with utility vehicles.

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Table 1. Mean fork length and weight with standard error (±1SE) in parentheses, date released, stocking site with river kilometer (rkm) in parentheses, and year class of hatchery-reared juvenile pallid sturgeon (HRJPS) stockings in the Missouri River downstream of Fort Randall Dam, South Dakota from 2000 to 2009.

Date released	Stocking site (rkm)	Year class	n	Mean length (mm) (SE)	Mean weight (g) (SE)
6 Jun 2000	Verdel, NE (1,376)	1997	416	524 (0.0)	585 (0.2)
6 Jul 2000	Verdel, NE (1,376) and Standing Bear Bridge (1,360)	a	6	1,321 (55.0)	15 (1.9)
1 Aug 2000	Verdel, NE (1,376)	1997	22	567 (7.6)	916 (25.6)
20 Sep 2000	Verdel, NE (1,376)	a	3	1,403 (33.0)	15 (5.7)
20 Sep 2000	Verdel, NE (1,376)	1998	98	472 (6.9)	382 (20.4)
21 Apr 2002	Verdel, NE (1,376) and Standing Bear Bridge (1,360)	2001	558	200 (0.2)	33[b]
27 Apr 2002	Sunshine Bottoms (1,394)	1999	181	417 (0.5)	295 (1.3)
26 Jul 2003	Sunshine Bottoms (1,394) and Standing Bear Bridge (1,360)	2002	601	244 (0.0)	60 (0.8)
7 Oct 2004	Sunshine Bottoms (1,394) and Standing Bear Bridge (1,360)	2003	515	313 (2.0)	123 (2.1)
30 Aug 2005	Standing Bear Bridge (1,360)	2004	868	294 (1.0)	108 (1.0)
25 Aug 2006	Standing Bear Bridge (1,360)	2005	1,005	305 (1.0)	126 (1.3)
9 May 2007	Standing Bear Bridge (1,360)	2006	600	181 (1.8)	24 (0.8)
17 Apr 2008	Standing Bear Bridge (1,360)	2007	600	243 (1.1)	51 (0.9)
8 May 2008	Sunshine Bottoms (1,394)	2007	569	188 (1.1)	25 (0.6)
14 Sep 2008	Verdel, NE (1,376)	2008	3,410	118 (2.0)[b]	5.9 (0.21)[b]
13 Apr 2009	Standing Bear Bridge (1,360)	2008	340	202 (6.5)[b]	24 (2.6)[b]
28 May 2009	Verdel, NE (1,376)	2008	297	239 (2.2)	47 (1.3)

a = brood stock and rehabilitated fish stocked due to irodovirus issues at Gavins Point National Fish Hatchery.
b = Individual lengths and weights were not recorded. Batch lengths and weights are presented.

Table 2. Number of samples for each gear deployed in the Niobrara River downstream of Spencer Dam, Nebraska from April to September 2008 and 2009.

Gear	Month					
	April	May	June	July	August	September
		2008				
Trammel net (15.2 m)	4					
Trammel net (23.0 m)		38	57	65	72	72
Trot lines (20 hooks/line)	9					
Larval drift net	40	184	138	143	95	
		2009				
Trammel net (23.0 m)		47	54	66	67	65
Larval drift net		121	139	98	79	

Table 3. Trammel net total catch and mean catch per unit effort (CPUE; fish/100 m) with standard error (±1SE) in parentheses for each month and reach in the Niobrara River downstream of Spencer Dam from May to September 2008 and 2009.

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
2008																	
Bigmouth buffalo	1	0.001 (0.001)	0	0	0	0	0	0	0	0	0.012 (0.012)	0	0	0	0	0	0
Bluegill	4	0.005 (0.004)	0	0	0.180 (0.018)	0	0	0.051 (0.051)	0	0	0	0	0	0	0	0	0
Blue sucker	1	0.001 (0.001)	0	0	0.180 (0.018)	0	0	0	0	0	0	0	0	0	0	0	0
Channel catfish	138	0.187 (0.032)	0.155 (0.100)	0.028 (0.028)	0.127 (0.076)	0.522 (0.397)	0.090 (0.034)	0.145 (0.054)	0.527 (0.216)	0.227 (0.055)	0.097 (0.042)	0.763 (0.423)	0.105 (0.042)	0.084 (0.040)	0.757 (0.371)	0.029 (0.022)	0.070 (0.040)
Common carp	28	0.037 (0.008)	0.068 (0.045)	0	0.055 (0.040)	0	0.008 (0.008)	0.047 (0.036)	0	0.019 (0.019)	0.104 (0.038)	0.087 (0.059)	0.034 (0.024)	0.047 (0.026)	0.029 (0.029)	0.015 (0.015)	0.014 (0.014)
Flathead chub	1	0.001 (0.001)	0	0	0	0	0	0	0	0	0.013 (0.013)	0	0	0	0	0	0
Freshwater drum	2	0.002 (0.001)	0	0	0	0	0	0	0	0	0	0	0	0	0.016 (0.016)	0	0
Green sunfish	1	0.001 (0.001)	0	0	0	0	0	0	0	0	0	0	0	0	0.038 (0.038)	0	0
Pallid sturgeon	2	0.003 (0.003)	0	0	0	0	0	0	0	0	0.033 (0.033)	0	0	0	0	0	0
River carpsucker	385	0.453 (0.048)	0.715 (0.296)	0.188 (0.089)	0.730 (0.202)	0.800 (0.338)	0.565 (0.113)	0.243 (0.081)	2.318 (0.491)	0.519 (0.224)	0.235 (0.071)	0.932 (0.404)	0.304 (0.100)	0.118 (0.045)	0.589 (0.257)	0.187 (0.054)	0.093 (0.047)
Sauger	53	0.071 (0.012)	0	0	0.046 (0.032)	0	0.012 (0.012)	0.011 (0.011)	0.205 (0.083)	0.137 (0.062)	0.024 (0.018)	0.342 (0.121)	0.083 (0.032)	0.049 (0.030)	0.109 (0.063)	0.153 (0.063)	0
Saugeye	1	0.002 (0.002)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020 (0.020)	0
Shorthead redhorse	29	0.037 (0.012)	0.071 (0.047)	0	0.084 (0.048)	0	0.012 (0.012)	0.013 (0.013)	0.251 (0.229)	0.020 (0.020)	0	0.087 (0.059)	0.034 (0.034)	0.008 (0.008)	0.201 (0.138)	0	0
Shortnose gar	39	0.055 (0.011)	0	0	0	0.017 (0.017)	0.014 (0.014)	0.062 (0.038)	0.160 (0.114)	0.053 (0.029)	0.071 (0.031)	0.095 (0.095)	0.071 (0.030)	0.176 (0.054)	0	0	0.052 (0.052)
Shovelnose sturgeon	14	0.018 (0.005)	0	0	0	0	0.023 (0.016)	0	0.053 (0.037)	0.026 (0.026)	0	0.066 (0.047)	0.050 (0.024)	0.047 (0.027)	0	0	0
Smallmouth buffalo	1	0.001 (0.001)	0	0	0	0	0	0	0	0	0.010 (0.010)	0	0	0	0	0	0
Walleye	2	0.002 (0.001)	0	0	0	0	0.012 (0.012)	0	0	0	0	0	0	0.011 (0.011)	0	0	0
White bass	2	0.003 (0.002)	0	0	0	0	0	0	0	0.019 (0.019)	0.013 (0.013)	0	0	0	0	0	0
White crappie	1	0.002 (0.002)	0	0	0	0	0	0	0	0	0.019 (0.019)	0	0	0	0	0	0
All fish in 2008	706	0.883 (0.084)	1.044 (0.335)	0.216 (0.095)	1.077 (0.300)	1.340 (0.716)	0.736 (0.138)	0.572 (0.134)	3.515 (0.866)	1.019 (0.242)	0.641 (0.104)	2.372 (1.023)	0.681 (0.128)	0.542 (0.108)	1.740 (0.641)	0.404 (0.116)	0.229 (0.074)
Empty nets (no fish)	104																

Table 3 continued.

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
2009																	
Bigmouth buffalo	1	0.001 (0.001)	0	0	0.024 (0.024)	0	0	0	0	0	0	0	0	0	0	0	0
Bluegill	1	0.001 (0.001)	0	0	0	0	0	0	0	0	0	0	0	0.008 (0.008)	0	0	0
Channel catfish	158	0.235 (0.039)	0.210 (0.091)	0.207 (0.067)	0.190 (0.097)	0.220 (0.104)	0.057 (0.031)	0	0.484 (0.154)	0.215 (0.057)	0.171 (0.077)	0.707 (0.288)	0.150 (0.051)	0.064 (0.033)	1.391 (0.757)	0.208 (0.083)	0.122 (0.070)
Common carp	20	0.036 (0.009)	0.060 (0.060)	0.040 (0.028)	0	0	0.017 (0.017)	0	0	0.029 (0.020)	0.106 (0.061)	0	0.013 (0.013)	0.085 (0.045)	0	0.047 (0.033)	0.084 (0.062)
Pallid sturgeon	1	0.001 (0.001)	0	0	0	0	0	0	0	0	0	0	0	0.008 (0.008)	0	0	0
Quillback	2	0.004 (0.004)	0	0	0	0	0	0	0	0	0	0.104 (0.104)	0	0	0	0	0
River carpsucker	251	0.382 (0.039)	0.362 (0.272)	0.141 (0.050)	0.406 (0.193)	0.590 (0.147)	0.386 (0.101)	0.086 (0.049)	0.614 (0.212)	0.856 (0.181)	0.068 (0.038)	0.191 (0.093)	0.312 (0.098)	0.140 (0.053)	0.638 (0.135)	0.625 (0.135)	0.112 (0.088)
Sauger	72	0.114 (0.016)	0.040 (0.040)	0.020 (0.020)	0	0	0.016 (0.016)	0.026 (0.026)	0.241 (0.101)	0.143 (0.049)	0.096 (0.044)	0.459 (0.122)	0.121 (0.051)	0.069 (0.032)	0.398 (0.150)	0.130 (0.054)	0.134 (0.065)
Shorthead redhorse	29	0.035 (0.012)	0.040 (0.040)	0.030 (0.021)	0.069 (0.049)	0.057 (0.047)	0.021 (0.021)	0	0.094 (0.094)	0	0	0.029 (0.029)	0.032 (0.022)	0	0.342 (0.234)	0.027 (0.027)	0
Shortnose gar	22	0.038 (0.009)	0	0	0	0	0	0	0.093 (0.068)	0.046 (0.023)	0.059 (0.042)	0	0.051 (0.039)	0.083 (0.031)	0	0.083 (0.051)	0.061 (0.043)
Shovelnose sturgeon	3	0.005 (0.004)	0	0	0	0	0.015 (0.015)	0	0	0	0	0	0	0	0	0	0.051 (0.051)
Walleye	1	0.001 (0.001)	0	0	0	0	0	0	0	0	0	0	0.012 (0.012)	0	0	0	0
All fish in 2009	561	0.852 (0.070)	0.713 (0.321)	0.439 (0.112)	0.689 (0.310)	0.867 (0.212)	0.512 (0.111)	0.112 (0.053)	1.526 (0.379)	1.289 (0.250)	0.500 (0.134)	1.490 (0.449)	0.691 (0.156)	0.456 (0.102)	2.769 (0.874)	1.120 (0.200)	0.564 (0.156)
Empty nets (no fish)	114																

Table 4. Pallid sturgeon relative condition (K_n), shovelnose sturgeon relative weight (W_r), and length categories for sturgeon captured in the Niobrara River downstream of Spencer Dam in 2008 and 2009.

Date	PIT or floy tag	Fork length (mm)	Weight (g)	Length category[a]	K_n[b] or W_r[c]
		Pallid sturgeon			
29 Jul 2008	4257124120	514	370	S	0.79
29 Jul 2008	471A30234E	460	280	S	0.86
12 Aug 2009	4719131C0F	388	190	S	1.02
		Shovelnose sturgeon			
24 Jun 2008	C83024	640	1,125	M	99
24 Jun 2008	C83025	645	1,130	M	96
15 Jul 2008	C83018	573	700	P	89
15 Jul 2008	C83011	642	1,005	M	87
15 Jul 2008	C83021	658	1,050	M	84
18 Aug 2008	C83044	568	750	P	98
18 Aug 2008	C83045	576	810	P	101
18 Aug 2008	C83042	619	1,020	P	100
18 Aug 2008	C08644	620	990	P	96
18 Aug 2008	C83048	623	890	P	85
25 Aug 2008	C83528	548	700	P	103
25 Aug 2008	C83526	625	890	P	84
25 Aug 2008	C83530	628	920	P	86
25 Aug 2008	C83535	613	820	P	83
11 Jun 2009	C83520	668	1,190	M	90
9 Sep 2009	C83526	620	950	P	92
9 Sep 2009	C83559	690	940	M	64

a = Pallid sturgeon fork length categories (sub-stock (SS), <330 mm; stock (S), 330 mm; quality (Q), 630 mm; preferred (P), 840 mm; memorable (M), 1040 mm; and trophy (T), 1270 mm) (Shuman et al. 2006). Shovelnose sturgeon fork length groups (SS, <250 mm; S, 250 mm; Q, 380 mm; P, 510 mm; M, 640 mm; and T, 810 mm) (Quist et al. 1998).

b = Relative condition (K_n) was calculated for all pallid sturgeon using the formula K_n = (W/W'), where W is the weight of the individual and W' is the length-specific mean weight for a fish in the population. Shuman et al. (in review) provided a weight-length regression [$\log_{10}W' = -6.2561 + 3.2932 \log_{10}FL$ ($r^2 = 0.98$)].

c = Relative weight (W_r) was calculated as: W_r = W/Ws X 100, where W is the actual weight and Ws is the length-specific standard weight for that species. A standard weight (Ws) equation ($\log_{10}Ws = -6.287 + 3.330 \log_{10}FL$) was developed for shovelnose sturgeon by Quist et al. (1998).

Table 5. Pallid and shovelnose sturgeon captures in the Niobrara River downstream of Spencer Dam in 2008 and 2009. GPS location coordinates using WGS84 datum are the start and stop points of the trammel net drift.

Net Unique ID	Date	Fork length (mm)	Weight (g)	PIT or floy tag	Start Latitude	Start Longitude	Stop Latitude	Stop Longitude	Drift distance (m)	Water temp. (°C)	Turb. (NTU)	Max. depth (m)	Min. depth (m)	Vel. bottom (m/s)	Vel. at 0.6 depth (m/s)
Pallid sturgeon															
80699	29 Jul 2008	514	370	4257124120	42.75841	-98.04976	42.75997	-98.04877	192	29.0	81	1.5	0.6	-	-
80699	29 Jul 2008	460	280	471A30234E	42.75841	-98.04976	42.75997	-98.04877	192	29.0	81	1.5	0.6	-	-
90789	12 Aug 2009	388	190	4719131C0F	42.68841	-98.07063	42.68884	-98.06491	473	31.3	69	1.4	0.2	0.88	0.98
Shovelnose sturgeon															
80378	24 Jun 2008	640	1,125	C83024	42.77913	-98.52933	42.78013	-98.52483	380	28.3	91	1.2	0.4	0.90	0.90
80376	24 Jun 2008	645	1,130	C83025	42.77921	-98.53729	42.77864	-98.53316	343	28.0	91	2.0	0.3	-	-
80563	15 Jul 2008	573	700	C83018	42.78916	-98.60497	42.78836	-98.60245	250	27.7	48	2.0	0.3	0.84	0.84
80571	15 Jul 2008	642	1,005	C83011	42.78208	-98.54759	42.78225	-98.54546	180	32.5	-	1.0	0.3	-	-
80559	15 Jul 2008	658	1,050	C83021	42.80314	-98.63809	42.80119	-98.63364	422	25.6	39	1.2	0.3	0.67	0.67
80816	18 Aug 2008	568	750	C83044	42.78364	-98.55176	42.78331	-98.54939	197	26.7	-	1.2	0.3	0.67	0.72
80817	18 Aug 2008	576	810	C83045	42.78333	-98.54942	42.78239	-98.54671	242	26.7	87	1.1	0.3	-	-
80814	18 Aug 2008	619	1,020	C83042	42.78895	-98.60433	42.78835	-98.60111	195	26.0	-	1.8	0.4	-	-
80812	18 Aug 2008	620	990	C08644[a]	42.79157	-98.61038	42.78990	-98.60677	353	25.5	79	2.0	1.0	0.38	0.44
80826	18 Aug 2008	623	890	C83048	42.77526	-98.50974	42.77457	-98.50758	194	28.4	83	1.6	0.2	-	-
80894	25 Aug 2008	548	700	C83528	42.76047	-98.04834	42.76309	-98.04857	295	25.6	77	1.8	0.2	-	-
80888	25 Aug 2008	625	890	C83526[b]	42.72749	-98.05020	42.73018	-98.05079	301	24.6	69	2.0	0.5	-	-
80900	25 Aug 2008	628	920	C83530	42.70255	-98.14080	42.70203	-98.13824	215	25.5	68	1.4	0.3	-	-
80924	25 Aug 2008	613	820	C83535	42.75443	-98.26660	42.75291	-98.26403	272	26.4	81	2.2	0.4	-	-
90687	11 Jun 2009	668	1,190	C83520	42.76643	-98.32912	42.76648	-98.32574	276	17.9	83	1.2	0.8	0.31	0.83
90861	9 Sep 2009	620	950	C83526[b]	42.68698	-98.10065	42.68737	-98.09868	170	26.1	-	1.5	0.2	0.64	0.64
90861	9 Sep 2009	690	940	C83559	42.68698	-98.10065	42.68737	-98.09868	170	26.1	-	1.5	0.2	0.64	0.64

a = Fish originally tagged in the Missouri River.
b = Fish originally tagged in the Niobrara River and recaptured.

Table 6. Mean habitat variables measured with standard error (±1SE) in parentheses where pallid sturgeon and shovelnose sturgeon were captured compared to all trammel net drift samples in the Niobrara River downstream of Spencer Dam in 2008 and 2009.

Species	Water temperature (°C)	Turbidity (NTU)	Max. depth (m)	Min. depth (m)	Average depth (m)	Vel. bottom (m/s)	Vel. at 0.6 depth (m/s)	Conductivity (uS/cm)	DO (mg/L)
				2008					
All samples	23.5 (0.3)	81 (1.7)	1.4 (0.0)	0.4 (0.0)	0.9 (0.0)	0.8 (0.0)	0.8 (0.0)	238 (2.3)	9.6 (0.0)
Pallid sturgeon	29.0	81	1.5	0.6	1.0	-	-	-	-
Shovelnose sturgeon	27.0 (0.5)	74 (5.1)	1.6 (0.1)	0.4 (0.1)	1.0 (0.1)	0.7 (0.1)	0.7 (0.1)	256 (3.6)	9.8 (0.2)
				2009					
All samples	23.7 (0.3)	93 (4.5)	1.1 (0.0)	0.3 (0.0)	0.6 (0.0)	0.7 (0.0)	0.7 (0.0)	270 (3.0)	9.5 (0.1)
Pallid sturgeon	31.3	69	1.4	0.2	0.8	0.88	0.98	293	9.4
Shovelnose sturgeon	22.0 (4.1)	83 (0.0)	1.4 (0.2)	0.5 (0.3)	0.9 (0.1)	0.5 (0.2)	0.7 (0.1)	251 (19.0)	9.6 (0.0)

Table 7. Relative weight (W_r) with standard error (±1SE) in parenthesis, proportional size distribution (PSD[a]), and incremental relative size distribution (RSD[b]) for shovelnose sturgeon in the Niobrara River downstream of Spencer Dam, Nebraska in 2008 and 2009.

Year	Mean W_r	PSD	S-Q RSD	S-Q W_r	Q-P RSD	Q-P W_r	P-M RSD	P-M W_r	M-T RSD	M-T W_r	T RSD	T W_r
2008	92 (2)	100	0		0		71	92 (3)	29	92 (4)	0	
2009	82 (9)	100	0		0		33	92	67	77 (13)	0	

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

Table 8. Larval fish sampling effort including total number of subsamples, time (seconds), and volume of water filtered (m^3) during each diel period and sampling period at the mouth and downstream of Spencer Dam in the Niobrara River during 2008 and 2009.

Sampling dates (sampling week)	Mouth						Spencer Dam					
	Morning			Afternoon			Morning			Afternoon		
	Samples	Time	Volume	Samples	Time	Volume	Samples	Time	Volume	Samples	Time	Volume
2008												
23-24 April (17)	10	720	196	10	600	151	3	900	260	17	5,100	985
5-8 May (19)	21	2,520	534	28	3,480	550	16	3,780	1,284	32	8,700	2,765
12-13 May (20)	10	600	185	10	600	187	10	3,000	866	10	3,000	784
19-22 May (21)	18	1,140	229	0	0	0	19	5,700	1,232	10	3,660	833
3-5 June (23)	8	480	181	10	600	223	8	1,860	281	8	1,440	228
9-10 June (24)	10	600	381	10	600	331	8	600	366	8	6,00	378
23-27 June (26)	16	960	609	8	480	158	18	5,400	1,024	10	3,000	553
30 June - 1 July (27)	8	480	162	8	480	56	8	2,400	322	8	2,400	344
7-8 July (28)	8	480	141	8	540	166	8	2,400	349	8	2,400	361
14-16 July (29)	8	480	123	8	480	134	8	2,400	271	8	2,400	251
21-22 July (30)	8	480	67	8	480	142	8	2,400	480	8	2,400	377
28-29 July (31)	8	480	129	8	480	230	8	2,460	95	7	2,160	170
5-6 August (32)	8	1,320	419	8	1,440	337	8	2,400	103	8	2,400	103
12-13 August (33)	8	480	200	8	480	101	8	2,400	227	7	2,100	316
18-20 August (34)	8	480	153	8	480	134	8	2,400	164	8	2,400	133
Totals	157	11,700	3,707	140	11,220	2,900	146	40,500	7,322	157	44,160	8,580
2009												
5-6 May (19)	5	180	98	6	360	163	8	2,340	720	7	2,100	662
12-13 May (20)	8	480	178	8	480	143	8	2,400	592	8	2,400	436
20-21 May (21)	8	480	169	8	480	135	7	2,100	214	8	2,400	201
27-28 May (22)	8	480	151	8	480	157	8	2,400	415	8	2,400	533
2-3 June (23)	8	480	172	8	480	160	7	2,100	346	8	2,400	212
8-9 June (24)	8	480	154	8	480	164	8	4,800	751	8	4,800	728
16-17 June (25)	8	480	129	8	480	135	8	4,800	1244	7	4,200	746
22-23 June (26)	6	360	111	7	420	126	6	3,600	892	8	4,800	536
29-30 June (27)	8	480	90	8	480	109	8	4,800	619	6	3,600	600
7-8 July (28)	8	480	52	8	480	56	8	4,800	978	8	4,800	850
14-15 July (29)	7	420	65	8	480	84	8	2,400	678	6	3,600	692
20-21 July (30)	8	480	112	8	480	127	6	3,600	504	6	3,600	740
27-28 July (31)	8	480	48	8	480	54	6	3,600	1180	6	3,600	890
3-4 August (32)	8	480	171	8	480	62	5	3,000	865	6	3,600	956
10-11 August (33)	8	480	86	8	480	26	6	3,600	808	6	3,600	948
17-18 August (34)	8	420	124	8	480	127	5	3,000	616	4	2,400	258
Totals	121	7,140	1,907	125	7,500	1,829	112	53,340	11,424	110	54,300	9,986

Table 9. Mean values and standard error (±1SE) in parentheses of environmental variables measured at the mouth of the Niobrara River and downstream of Spencer Dam during 2008 and 2009.

Sampling dates (sampling week)	Mouth					Spencer Dam				
	Temperature (°C)	Turbidity (NTU)	Conductivity (µS/cm)	DO (mg/L)	Velocity (m/s)	Temperature (°C)	Turbidity (NTU)	Conductivity (µS/cm)	DO (mg/L)	Velocity (m/s)
2008										
23-24 April (17)	14.1 (0.0)	120.6 (1.7)			0.53 (0.02)	12.8 (0.3)	58.1 (1.3)			0.41 (0.03)
5-8 May (19)	15.7 (0.2)	138.8 (3.3)	257.7 (1.3)	9.3 (0.0)	0.45 (0.03)	15.3 (0.3)	68.0 (2.4)	242.0 (3.8)	10.0 (0.1)	0.65 (0.01)
12-13 May (20)	15.1 (0.1)	108.0 (0.0)	256.5 (2.0)	8.8 (0.0)	0.62 (0.02)	14.2 (0.7)	51.3 (1.0)	228.5 (3.9)	9.9 (0.1)	0.55 (0.01)
19-22 May (21)	15.0 (0.1)	77.3 (1.2)	232.1 (6.9)	8.9 (0.1)	0.41 (0.03)	17.1 (0.1)	27.7 (1.0)	233.2 (0.5)	9.3 (0.1)	0.44 (0.01)
3-5 June (23)	22.1 (0.4)	181.7 (10.4)	290.7 (5.1)	7.9 (0.0)	0.75 (0.03)	22.6 (0.6)	88.5 (3.1)	258.9 (3.7)	8.1 (0.2)	0.31 (0.01)
9-10 June (24)	22.2 (0.5)	598.0 (29.9)	326.6 (6.4)	7.7 (0.1)	1.19 (0.04)	20.4 (0.7)	469.1 (17.0)	289.1 (2.8)	8.4 (0.1)	1.27 (0.03)
23-27 June (26)		112.2 (5.7)			1.07 (0.07)	20.3 (0.1)	60.0 (1.9)	247.6 (0.4)	8.4 (0.1)	0.38 (0.01)
30 June - 1 July (27)	24.8 (0.7)	93.9 (5.1)	311.5 (5.7)	8.9 (0.1)	0.45 (0.06)	25.1 (0.6)	48.6 (1.8)	282.5 (5.0)	7.6 (0.1)	0.28 (0.01)
7-8 July (28)	27.0 (0.7)	85.9 (1.6)	315.9 (3.7)	8.1 (0.6)	0.62 (0.04)	26.7 (0.7)	45.6 (1.7)	273.9 (3.9)	7.2 (0.1)	0.30 (0.01)
14-16 July (29)		80.6 (2.7)			0.54 (0.02)	26.0 (0.4)	36.6 (0.7)	265.9 (1.3)	7.1 (0.1)	0.22 (0.01)
21-22 July (30)		102.1 (4.6)			0.44 (0.04)		71.6 (5.1)			0.36 (0.02)
28-29 July (31)		78.8 (3.1)			0.75 (0.06)		39.0 (1.9)			0.11 (0.01)
5-6 August (32)		62.9 (2.9)			0.60 (0.08)		38.4 (2.9)			0.09 (0.01)
12-13 August (33)		138.1 (7.7)			0.63 (0.12)		64.5 (7.2)			0.24 (0.02)
18-20 August (34)	24.1 (0.7)	83.1 (1.9)	243.0 (4.0)	8.5 (0.2)	0.60 (0.02)	25.7 (0.6)	49.5 (2.0)	250.8 (1.9)	8.8 (0.1)	0.12 (0.01)
2009										
5-6 May (19)	18.5 (0.9)	98.2 (3.3)	260.6 (11.9)	9.1 (0.1)	1.01 (0.08)	18.2 (0.6)	47.3 (1.2)	250.4 (3.3)	9.0 (0.1)	0.62 (0.01)
12-13 May (20)	17.6 (0.1)	86.0 (6.5)	257.0 (4.0)	9.4 (0.0)	0.67 (0.02)	17.1 (0.2)	38.1 (1.1)	243.2 (1.7)	9.5 (0.0)	0.43 (0.02)
20-21 May (21)		73.3 (7.0)			0.63 (0.02)		25.8 (1.2)			0.18 (0.01)
27-28 May (22)	15.8 (0.2)	118.7 (4.3)	247.3 (3.3)	9.5 (0.0)	0.64 (0.03)	16.6 (0.6)	91.7 (4.0)	248.5 (4.3)	9.6 (0.1)	0.39 (0.01)
2-3 June (23)	18.3 (1.2)	62.3 (2.1)	250.0 (6.3)	9.7 (0.2)	0.69 (0.03)	17.8 (1.1)	28.5 (1.2)	231.5 (5.1)	10.1 (0.1)	0.25 (0.02)
8-9 June (24)	15.9 (0.7)	77.2 (3.1)	209.9 (23.7)	9.0 (0.0)	0.66 (0.01)	15.9 (0.4)	36.5 (1.1)	214.8 (1.2)	9.7 (0.0)	0.31 (0.02)
16-17 June (25)		113.0 (4.8)	284.0 (7.2)	7.6 (0.1)	0.55 (0.02)		97.0 (13.0)	264.8 (6.1)	8.3 (0.1)	0.44 (0.03)
22-23 June (26)					0.61 (0.02)					0.34 (0.06)
29-30 June (27)	26.7 (1.3)	125.0 (3.8)	297.8 (6.9)	7.7 (0.1)	0.41 (0.01)	25.1 (1.2)	59.0 (4.0)	272.2 (6.7)	8.6 (0.1)	0.29 (0.03)
7-8 July (28)	26.8 (1.3)	103.2 (2.4)	274.0 (6.4)	7.5 (0.1)	0.22 (0.01)	26.6 (1.4)	83.7 (1.9)	263.3 (6.9)	8.4 (0.0)	0.38 (0.02)
14-15 July (29)	25.7 (0.7)	148.3 (14.4)	276.2 (4.3)	8.0 (0.3)	0.33 (0.04)	24.9 (1.2)	350.8 (31.9)	249.0 (4.9)	8.5 (0.1)	0.49 (0.05)
20-21 July (30)	22.1 (0.5)	122.7 (1.7)	276.7 (1.5)	8.2 (0.1)	0.50 (0.01)	24.0 (0.9)	105.0 (11.8)	269.3 (6.4)	8.9 (0.1)	0.35 (0.03)
27-28 July (31)	25.9 (1.3)	67.0 (1.7)	292.8 (6.2)	8.3 (0.1)	0.21 (0.03)	25.0 (1.1)	44.2 (2.1)	266.0 (5.7)	8.7 (0.1)	0.58 (0.05)
3-4 August (32)	26.6 (1.4)	70.7 (2.5)	258.2 (6.2)	9.5 (0.1)	0.49 (0.06)	25.6 (1.2)	37.0 (0.0)	260.8 (6.0)	8.8 (0.2)	0.55 (0.05)
10-11 August (33)	25.6 (1.2)	88.0 (1.8)	276.5 (7.4)	8.2 (0.2)	0.23 (0.03)	25.6 (1.1)	53.7 (5.5)	266.0 (4.8)	8.7 (0.1)	0.49 (0.02)
17-18 August (34)	24.9 (1.2)	121.0 (4.8)	255.0 (6.1)	9.3 (0.2)	0.56 (0.06)	23.3 (1.8)	88.0 (2.0)	238.0 (6.9)	8.9 (0.1)	0.32 (0.05)

Table 10. Monthly mean catch per unit effort (CPUE; number of larval fish/100 m^3 of water filtered) and standard error (±1SE) in parentheses of larval fish collected at the mouth of the Niobrara River from April to August 2008 and May to August 2009.

	2008						2009				
Taxon	Total catch	April	May	June	July	August	Total catch	May	June	July	August
All larval fish	720	0	1.707 (0.612)	16.450 (2.305)	26.831 (2.688)	6.138 (1.933)	528	4.243 (0.813)	22.950 (4.268)	33.021 (8.726)	5.810 (3.271)
Shortnose gar	0	0	0	0	0	0	3	0.187 (0.131)	0.071 (0.071)	0	0
Cyprinidae	282	0	0.241 (0.241)	2.265 (0.728)	16.550 (1.878)	4.631 (1.666)	384	2.507 (0.558)	16.609 (3.670)	24.040 (7.376)	4.982 (2.759)
Flathead chub	2	0	0	0	0.089 (0.089)	0.117 (0.117)	11	0.101 (0.101)	0.530 (0.201)	0.335 (0.335)	0
Red shiner	23	0	0	0	0.156 (0.156)	1.972 (1.134)	24	0	0.332 (0.165)	1.781 (1.069)	1.509 (0.899)
Sand shiner	252	0	0	1.973 (0.635)	16.304 (1.866)	2.543 (0.861)	284	0.702 (0.316)	12.814 (3.492)	21.824 (7.179)	3.241 (2.135)
Common carp	5	0	0.241 (0.241)	0.292 (0.213)	0	0	64	1.704 (0.395	2.871 (0.584)	0.101 (0.101)	0.231 (0.231)
Unknown cyprinid	0	0	0	0	0	0	1	0	0.062 (0.062)	0	0
River carpsucker	352	0	1.296 (0.561)	12.948 (1.963)	6.143 (1.395)	0.803 (0.614)	42	0.293 (0.166)	1.524 (0.347)	3.003 (0.939)	0
Shorthead redhorse	1	0	0	0.065 (0.065)	0	0	3	0	0.243 (0.139)	0	0
Channel catfish	5	0	0	0.080 (0.056)	0.118 (0.086)	0.091 (0.091)	7	0	0.309 (0.178)	0.538 (0.331)	0
Grass pickerel	0	0	0	0	0	0	1	0.074 (0.074)	0	0	0
Centrarchidae	55	0	0.105 (0.105)	0.682 (0.421)	2.977 (0.518)	0.613 (0.263)	78	0.910 (0.386)	3.782 (0.807)	5.273 (1.390)	0.533 (0.375)
Unknown centrarchid	11	0	0	0.119 (0.068)	0.546 (0.246)	0.091 (0.064)	18	0.656 (0.347)	0.556 (0.229)	0.563 (0.402)	0
All *Lepomis* spp.	40	0	0	0.485 (0.411)	2.171 (0.459)	0.521 (0.261)	48	0	2.486 (0.671)	4.710 (1.362)	0.533 (0.375)
Green sunfish	8	0	0	0	0.360 (0.160)	0.358 (0.245)	4	0	0	0.499 (0.284)	0.237 (0.237)
Bluegill	1	0	0	0	0	0.040 (0.040)	0	0	0	0	0
Unknown *Lepomis* spp.	31	0	0	0.486 (0.412)	1.829 (0.451)	0.123 (0.093)	44	0	2.486 (0.671)	4.211 (1.319)	0.296 (0.296)
Largemouth bass	1	0	0	0.078 (0.078)	0	0	4	0	0.314 (0.188)	0	0
White crappie	3	0	0.105 (0.105)	0	0.241 (0.177)	0	8	0.254 (0.184)	0.426 (0.245)	0	0
Sauger	0	0	0	0	0	0	1	0.077 (0.077)	0	0	0
Unidentified larval fish	25	0	0.065 (0.065)	0.409 (0.0263)	1.044 (0.377)	0	9	0.196 (0.141)	0.411 (0.225)	0.167 (0.167)	0.296 (0.296)
Fish eggs	210	0	0.474 (0.292)	6.976 (0.899)	6.059 (1.448)	0.091 (0.091)	68	1.452 (0.317)	3.071 (0.407)	2.754 (0.670)	0.296 (0.296)

Table 11. Monthly mean catch per unit effort (CPUE; number of larval fish/100 m^3 of water filtered) and standard error (±1SE) in parentheses of larval fish collected immediately downstream of Spencer Dam on the Niobrara River from April to August 2008 and May to August 2009.

	2008						2009				
Taxon	Total catch	April	May	June	July	August	Total catch	May	June	July	August
All larval fish	1,797	0	0.112 (0.043)	27.100 (2.647)	23.005 (1.564)	39.241 (7.983)	2,103	3.197 (0.728)	26.902 (6.300)	14.235 (1.885)	4.876 (1.046)
Shortnose gar	0	0	0	0	0	0	0	0	0	0	0
Cyprinidae	1,183	0	0.049 (0.028)	10.438 (1.563)	19.014 (1.445)	38.877 (7.985)	1,573	2.653 (0.614)	18.075 (5.160)	11.273 (1.706)	4.474 (1.026)
Flathead chub	24	0	0.019 (0.019)	0.525 (0.122)	0.081 (0.057)	0	40	0.326 (0.117)	0.881 (0.304)	0.089 (0.040)	0
Red shiner	275	0	0	0	0.599 (0.271)	26.039 (5.549)	226	0	0.511 (0.186)	1.896 (0.385)	2.336 (0.692)
Sand shiner	877	0	0	9.786 (1.510)	18.272 (1.392)	12.838 (4.632)	1,249	1.846 (0.527)	15.469 (5.121)	9.185 (1.655)	2.138 (0.480)
Common carp	7	0	0.030 (0.021)	0.127 (076)	0.062 (0.044)	0	53	0.481 (0.144)	1.173 (0.532)	0.089 (0.062)	0
Unknown cyprinid	0	0	0	0	0	0	5	0	0.040 (0.020)	0.013 (0.013)	0
River carpsucker	550	0	0.013 (0.013)	15.631 (1.840)	3.347 (0.525)	0	268	0.134 (0.059)	5.379 (1.007)	1.400 (0.207)	0.052 (0.036)
Shorthead redhorse	1	0	0.012 (0.012)	0	0	0	1	0	0.010 (0.010)	0	0
Channel catfish	0	0	0	0	0	0	5	0	0.069 (0.069)	0.053 (0.038)	0.023 (0.023)
Grass pickerel	1	0	0	0	0.043 (0.043)	0	0	0	0	0	0
Centrarchidae	23	0	0.028 (0.019)	0.312 (0.111)	0.254 (0.087)	0.199 (0.140)	221	0.387 (0.107)	2.909 (1.063)	1.297 (0.250)	0.260 (0.101)
Unknown centrarchid	4	0	0	0.053 (0.053)	0.066 (0.047)	0.102 (0.102)	79	0.099 (0.059)	1.155 (0.656)	0.518 (0.167)	0.025 (0.025)
All *Lepomis* spp.	18	0	0.015 (0.015)	0.259 (0.099)	0.189 (0.076)	0.097 (0.097)	110	0.031 (0.031)	1.175 (0.322)	0.765 (0.205)	0.210 (0.092)
Green sunfish	0	0	0	0	0	0	8	0	0	0.108 (0.048)	0.053 (0.038)
Bluegill	0	0	0	0	0	0	0	0	0	0	0
Unknown *Lepomis* spp.	18	0	0.015 (0.015)	0.259 (0.099)	0.189 (0.076)	0.097 (0.097)	102	0.031 (0.031)	1.175 (0.322)	0.657 (0.196)	0.157 (0.087)
Largemouth bass	0	0	0	0	0	0	5	0	0.062 (0.029)	0	0
White crappie	1	0	0.013 (0.013)	0	0	0	27	0.256 (0.090)	0.517 (0.384)	0.014 (0.014)	0.025 (0.025)
Sauger	1	0	0.010 (0.010)	0	0	0	0	0	0	0	0
Unidentified larval fish	38	0	0	0.719 (0.301)	0.348 (0.127)	0.165 (0.165)	35	0.024 (0.024)	0.460 (0.161)	0.213 (0.058)	0.068 (0.038)
Fish eggs	710	0	1.234 (0.244)	12.256 (1.349)	9.750 (0.997)	0.092 (0.065)	129	0.748 (0.148)	1.119 (0.218)	0.806 (0.062)	0.218 (0.060)

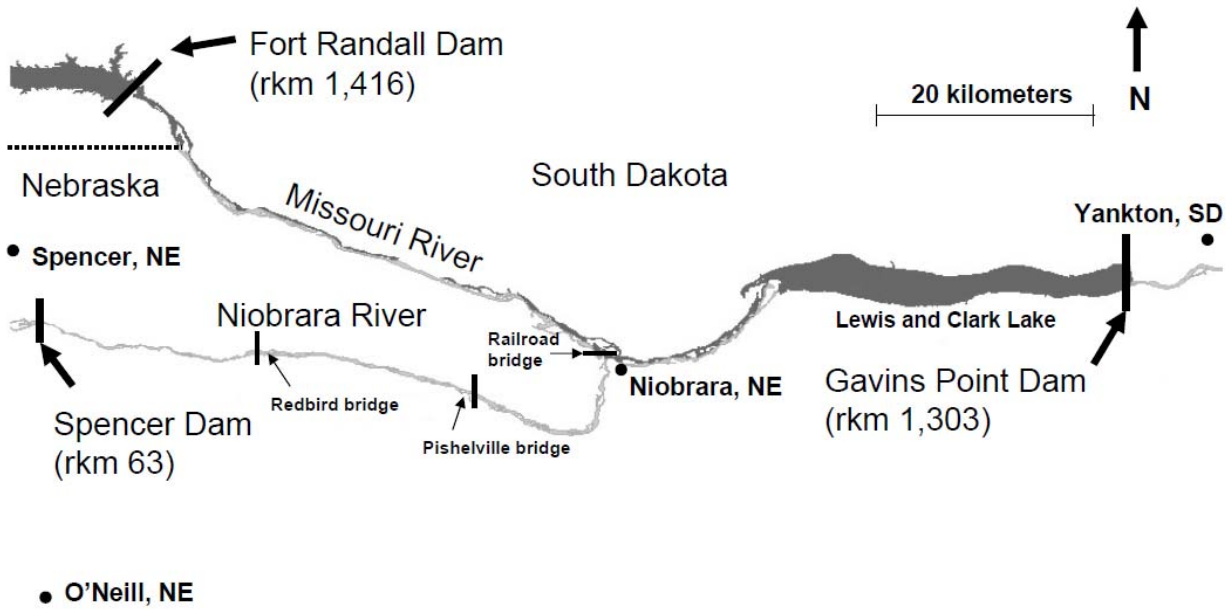

Figure 1. Niobrara River downstream of Spencer Dam, Nebraska and the Missouri River downstream of Fort Randall Dam to Gavins Point Dam, South Dakota and Nebraska.

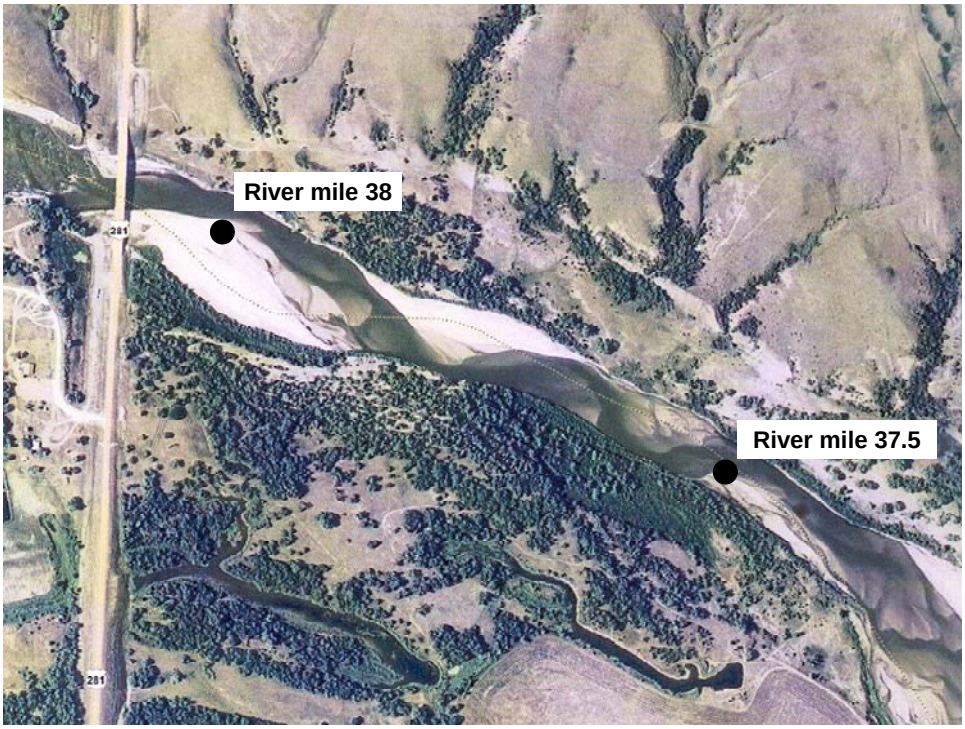

Figure 2. Example of the single thread reach in the Niobrara River downstream of Spencer Dam, Nebraska.

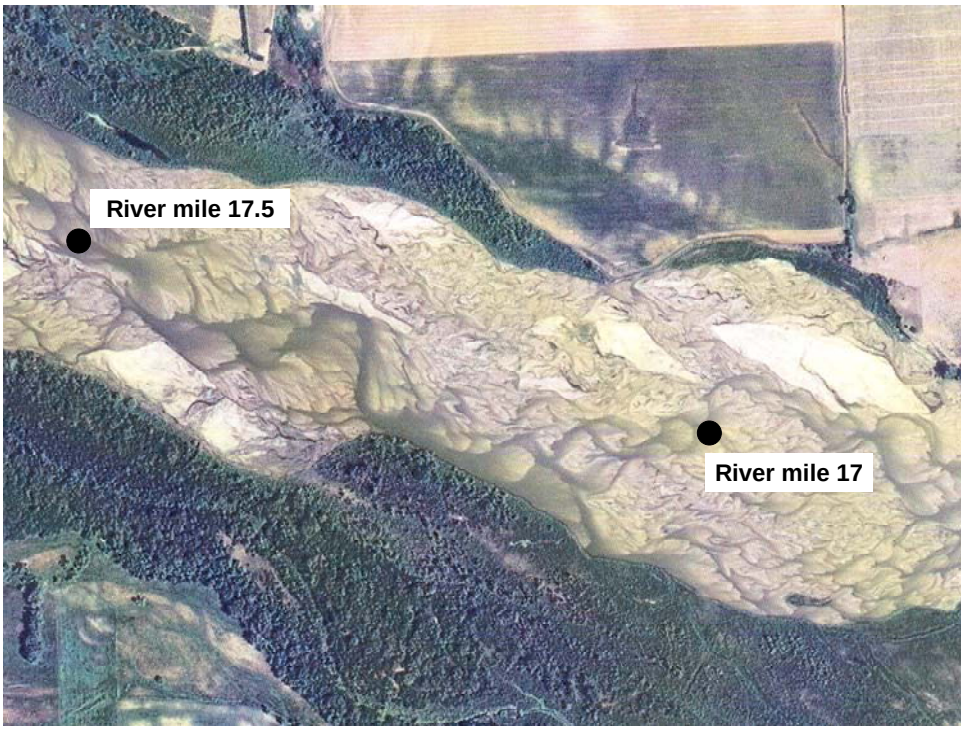

Figure 3. Example of the braided reach in the Niobrara River downstream of Spencer Dam, Nebraska.

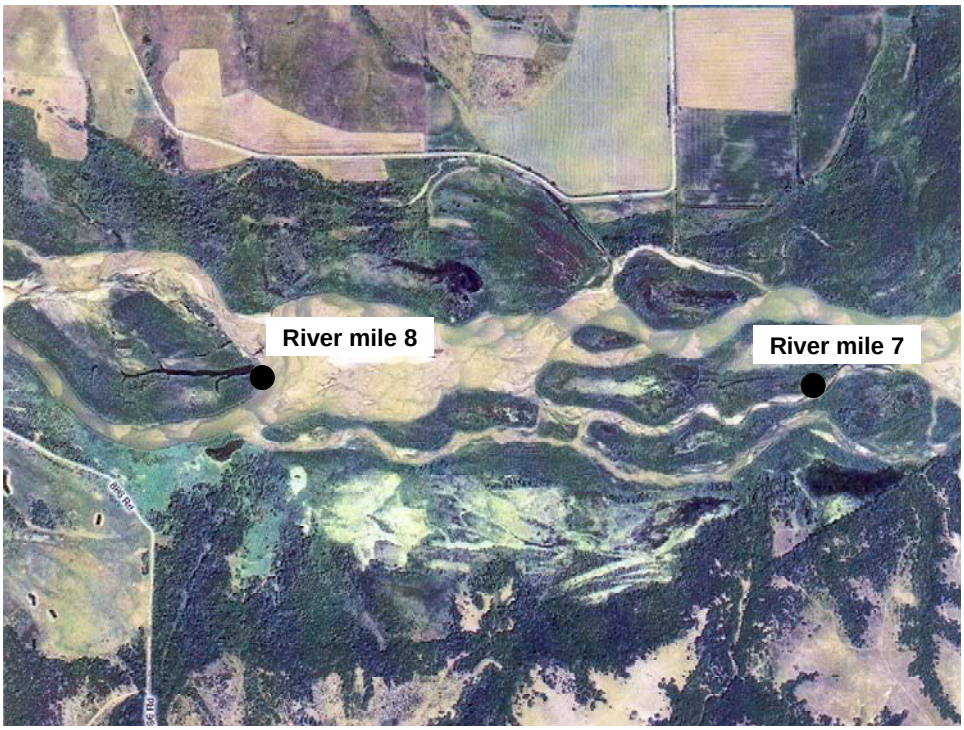

Figure 4. Example of the delta reach in the Niobrara River downstream of Spencer Dam, Nebraska.

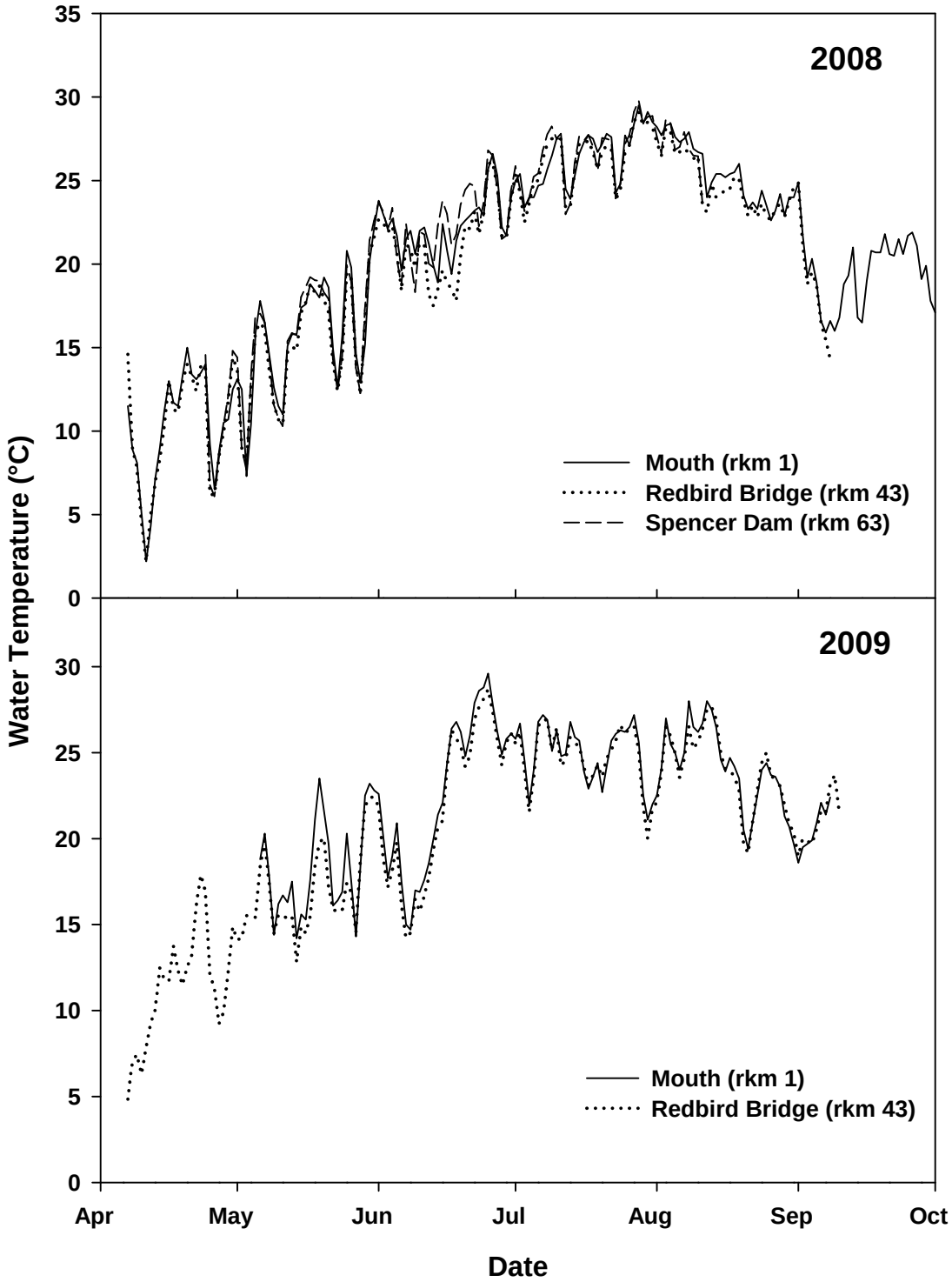

Figure 5. Niobrara daily mean water temperatures measured at three locations in 2008 and two locations in 2009 from April through September 2008 downstream of Spencer Dam, Nebraska.

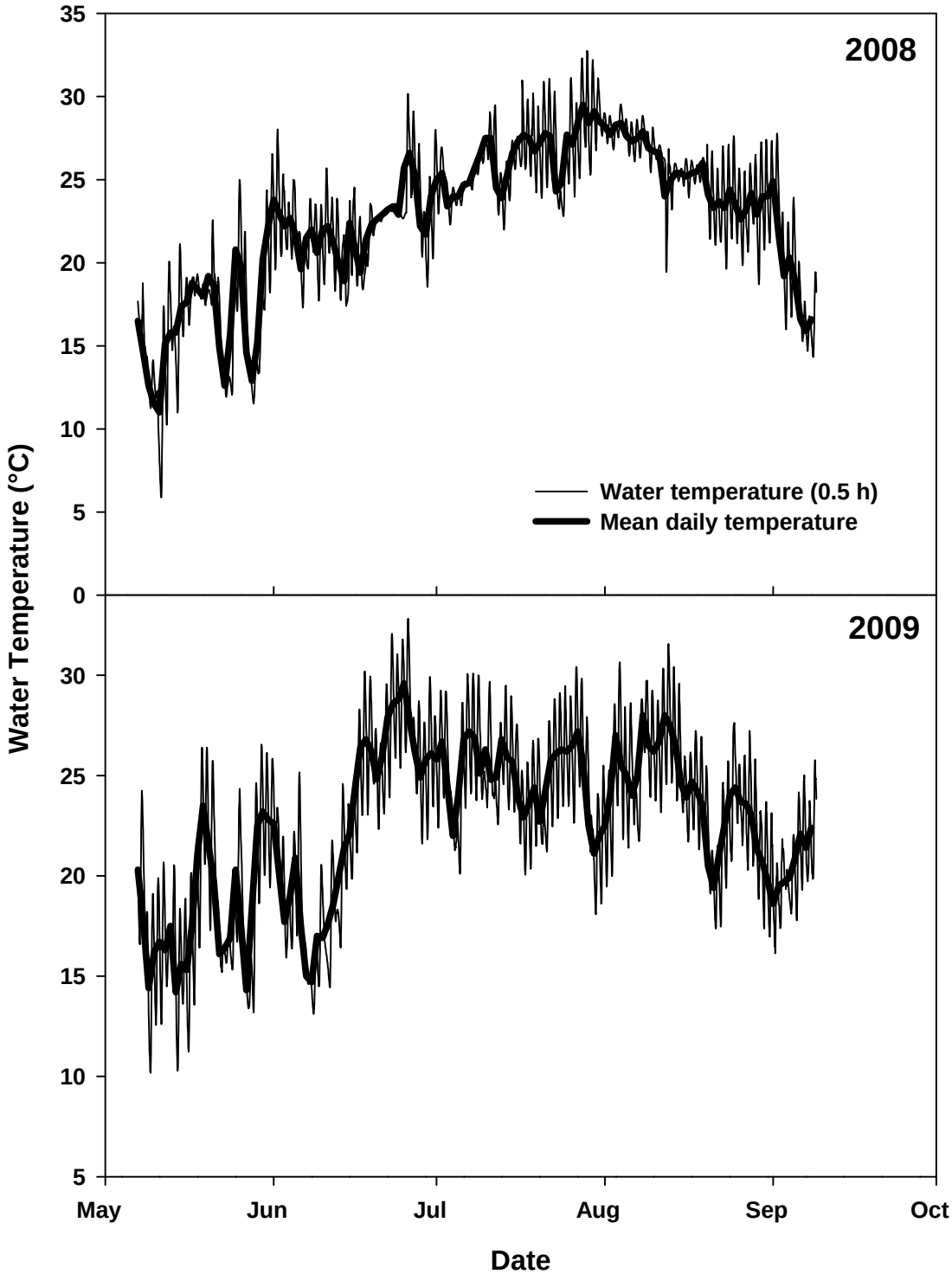

Figure 6. Water temperature measured every 0.5 h at the mouth of the Niobrara River (rkm 1) from May to September 2008 and 2009.

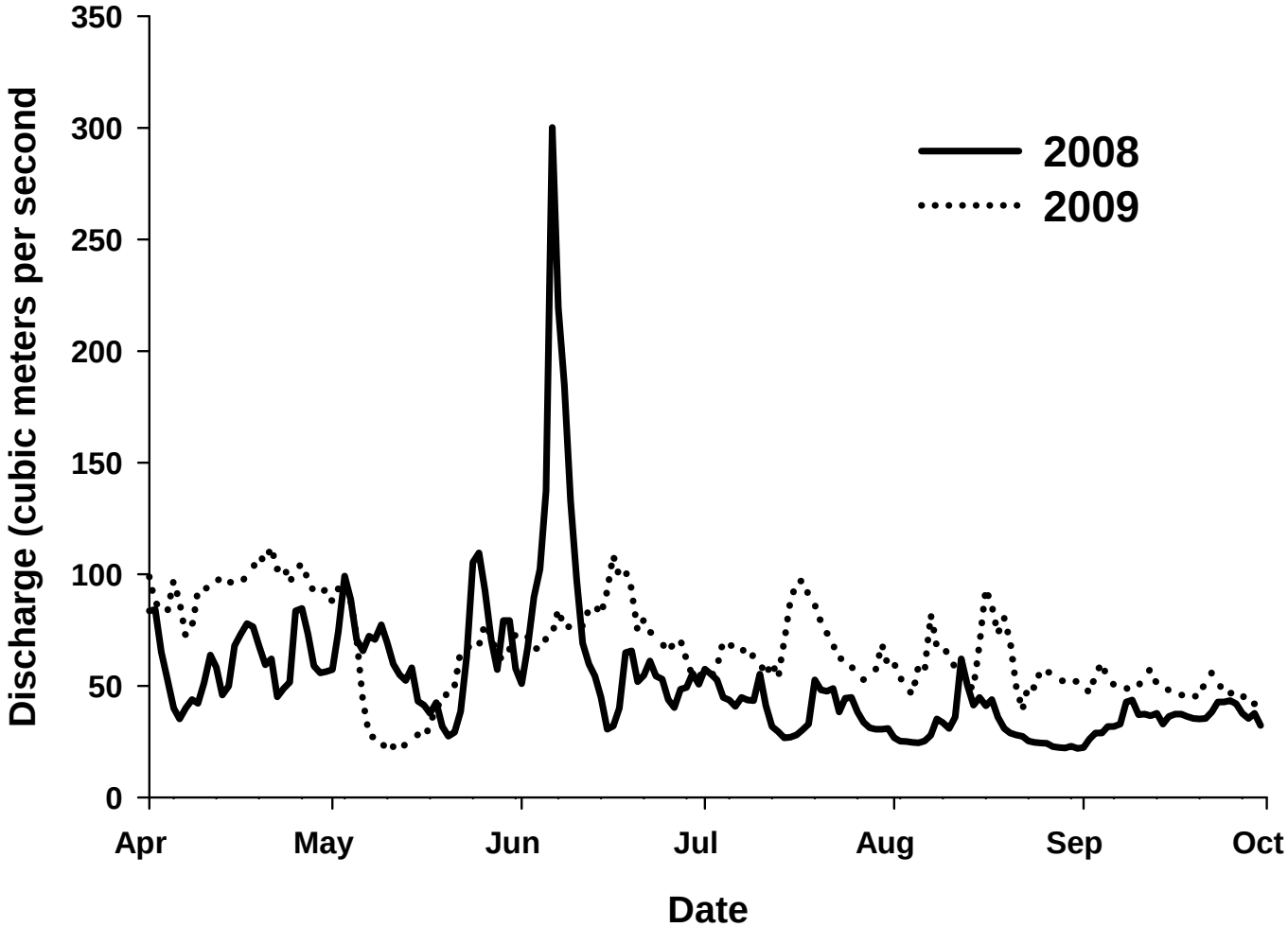

Figure 7. Niobrara River daily mean discharge measured in cubic meters per second at the Pischelville Bridge from April to October 2008 and 2009 (http://waterdata.usgs.gov/usa/nwis/uv?site_no=06465500).

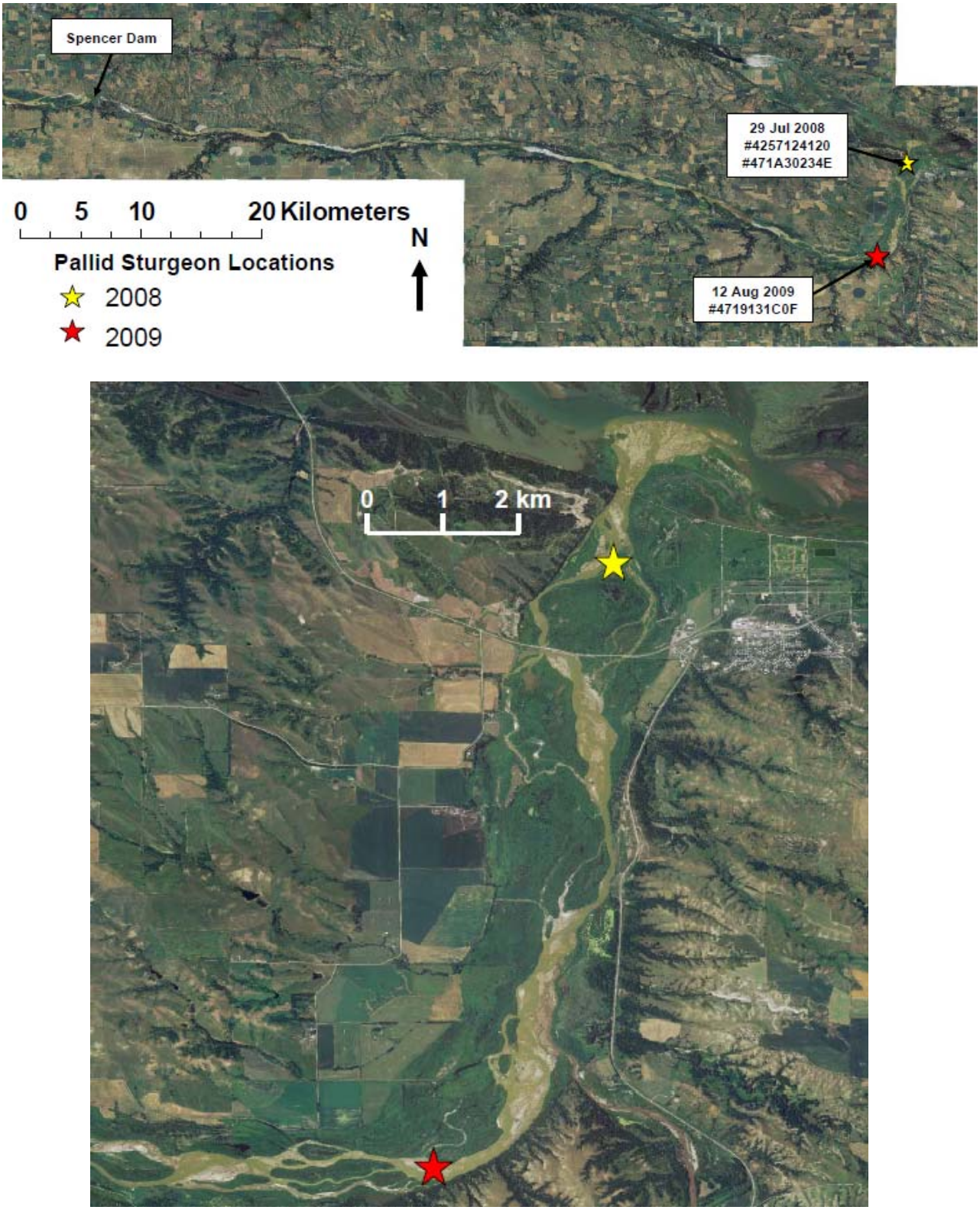

Figure 8. Pallid sturgeon capture locations in the Niobrara River downstream of Spencer Dam in 2008 and 2009. Top figure is the entire study area downstream of Spencer Dam to the mouth and the bottom figure is a close up of the last 13 rkm of the Niobrara River.

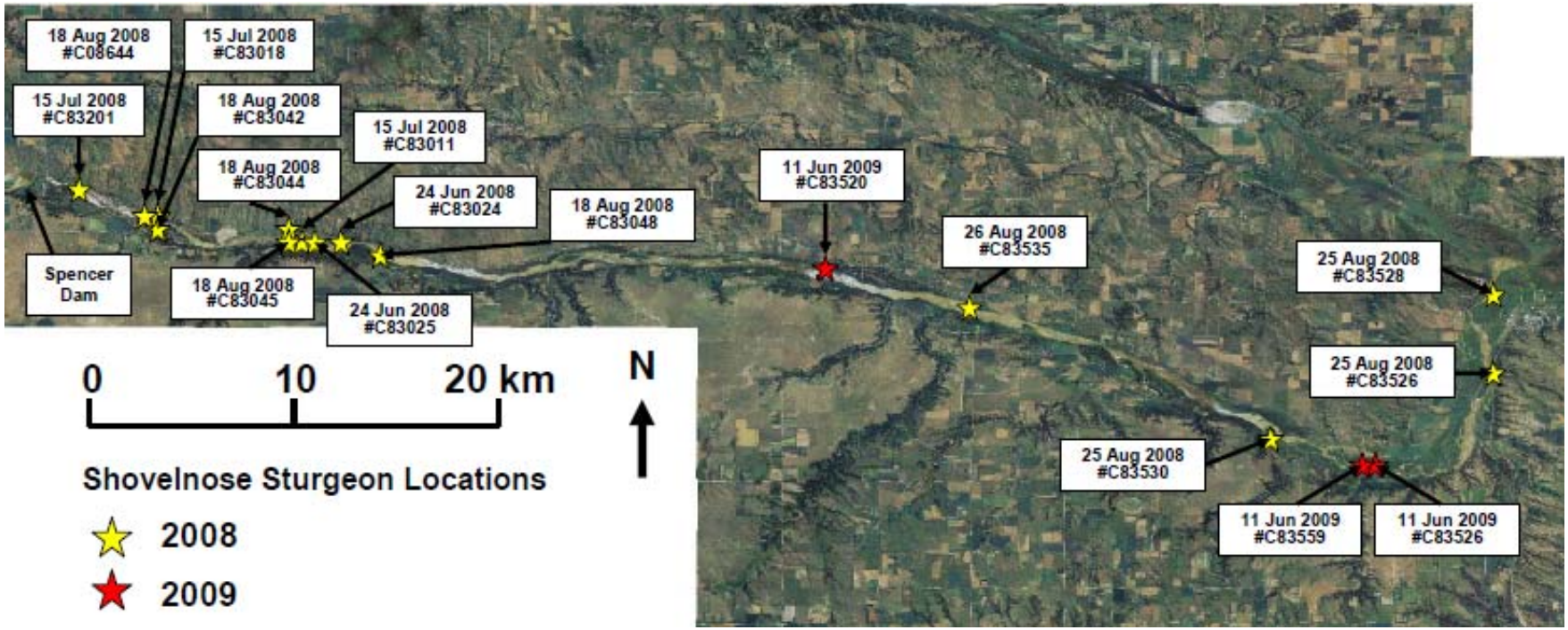

Figure 9. Shovelnose sturgeon capture locations in the Niobrara River downstream of Spencer Dam in 2008 and 2009.

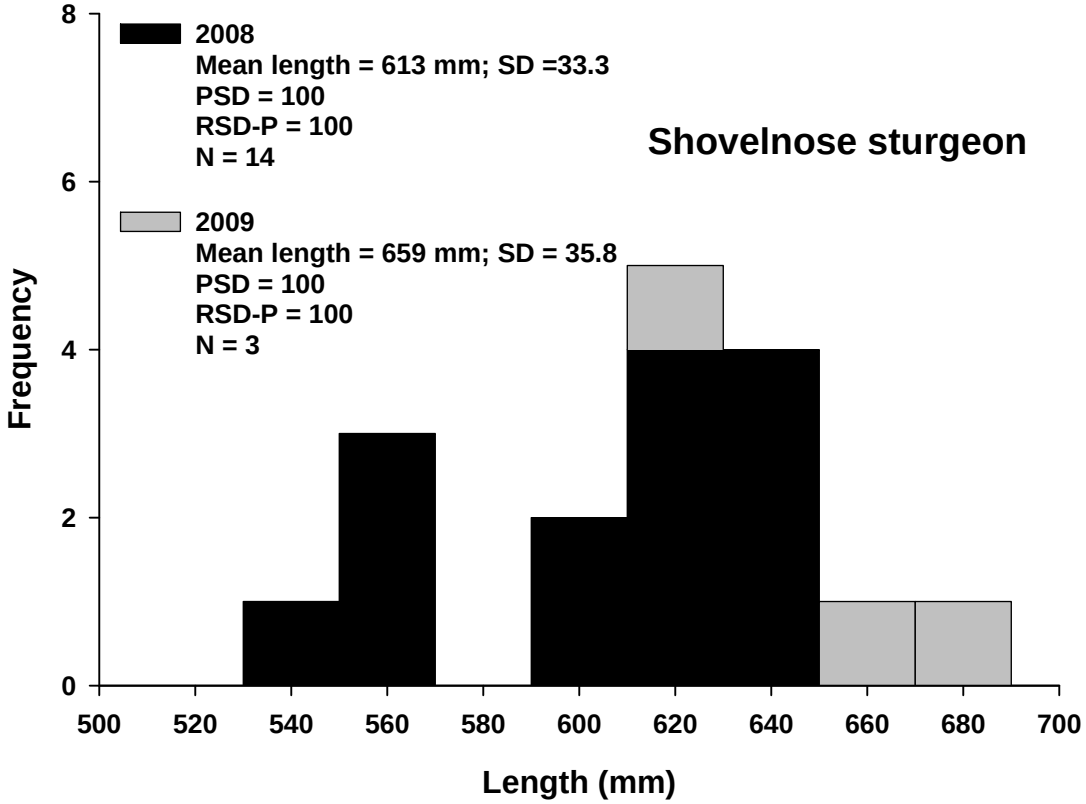

Figure 10. Length frequency distribution (20-mm length groups) of shovelnose sturgeon captured by drifted trammel nets in the Niobrara River downstream of Spencer Dam in 2008 and 2009.

Appendix A. Phylogenetic list of Niobrara River and Missouri River fishes discussed in this report. The phylogeny follows that used by the American Fisheries Society (Nelson et al. 2004).

Common name	Scientific name
Acipenseridae - sturgeons	
Pallid sturgeon	*Scaphirhynchus albus*
Shovelnose sturgeon	*Scaphirhynchus platorynchus*
Polyodontidae - paddlefishes	
Paddlefish	*Polyodon spathula*
Lepistosteidae - gars	
Shortnose gar	*Lepisosteus platostomus*
Cyprinidae - carps and minnows	
Grass carp	*Ctenopharyngodon idella*
Red shiner	*Notropis lutrensis*
Common carp	*Cyprinus carpio*
Silver carp	*Hypophthalmichthys molitrix*
Bighead carp	*Hypophthalmichthys nobilis*
Black carp	*Mylopharyngodon piceus*
Silver chub	*Macrhybopsis storeriana*
Sand shiner	*Notropis stramineus*
Flathead chub	*Platygobio gracilis*
Catostomidae - suckers	
River carpsucker	*Carpiodes carpio*
Quillback	*Carpiodes cyprinus*
Blue sucker	*Cycleptus elongatus*
Smallmouth buffalo	*Ictiobus bubalus*
Bigmouth buffalo	*Ictiobus cyprinellus*
Shorthead redhorse	*Moxostoma macrolepidotum*
Ictaluridae - bullhead catfishes	
Channel catfish	*Ictalurus punctatus*
Esocidae - pikes	
Grass pickerel	*Esox americanus*
Northern pike	*Esox lucius*
Percichthyidae - temperate basses	
white bass	*Morone chrysops*
Centrarchidae - sunfishes	
Green sunfish	*Lepomis cyanellus*
Bluegill	*Lepomis macrochirus*
Largemouth bass	*Micropterus salmoides*
White crappie	*Pomoxis annularis*
Percidae - perches	
Sauger	*Sander canadense*
Walleye	*Sander vitreum*
Sciaenidae -drums	
Freshwater drum	*Aplodinotus grunniens*