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[Article]

Habitat Use of Juvenile Pallid Sturgeon and Shovelnose Sturgeon with Implications for Water-Level Management in a Downstream Reservoir

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Abstract.—Natural recruitment of pallid sturgeon *Scaphirhynchus albus* has not been observed in the Missouri River above Fort Peck Reservoir, Montana, for at least 20 years. To augment the population, age-1 hatchery-reared juvenile pallid sturgeon were released in 1998. The objective of this study was to evaluate the habitat use of these fish and compare it with that of indigenous shovelnose sturgeon *S. platorynchus*. Twenty-nine juvenile pallid sturgeon and 21 indigenous shovelnose sturgeon were implanted with radio transmitters in 2003 and 2004. The two species showed no differences in habitat use in terms of mean depth, cross-sectional relative depth, longitudinal relative depth, column velocity, bottom velocity, and channel width. However, there were seasonal differences within both species for cross-sectional relative depth, column velocity, and channel width. Both shovelnose sturgeon and juvenile pallid sturgeon were primarily associated with silt and sand substrate. However, shovelnose sturgeon were associated with gravel and cobble substrate more than juvenile pallid sturgeon. Shovelnose sturgeon and juvenile pallid sturgeon both selected reaches without islands and avoided reaches with islands; the two species also selected main-channel habitat and avoided secondary channels. Mean home range was similar between juvenile pallid sturgeon (15 km; 90% confidence interval, ±5.0 km) and shovelnose sturgeon (16.5 km; ±4.7 km). Spatial distribution differed between the two species, with shovelnose sturgeon using upstream areas more often than juvenile pallid sturgeon. Twenty-eight percent of juvenile pallid sturgeon frequented 60 km of lotic habitat that would be inundated by Fort Peck Reservoir at maximum pool. Stocking juvenile pallid sturgeon can successfully augment the wild pallid sturgeon population in the Missouri River above Fort Peck Reservoir, which is crucial to the long-term recovery of the species. However, water-level management in downstream reservoirs such as Fort Peck can influence the amount of habitat available for pallid sturgeon.

Pallid sturgeon *Scaphirhynchus albus* and shovelnose sturgeon *S. platorynchus* are sympatric throughout the large, turbid rivers of the Missouri and Mississippi River systems (Kallemeyn 1983). Historically, the Missouri and Mississippi River systems provided a diverse array of environments (e.g., islands, alluvial bars, secondary channels, backwaters) that were in a constant state of fluctuation. Today, however, most of the original habitat available to pallid sturgeon has been altered through anthropogenic activities. Fifty-one percent (2,913 km) of the traditional range of pallid sturgeon has been channelized, 28% (1,593 km) has been impounded, and the remaining 21% is below dams where habitat variables (e.g., temperature, turbidity, and discharge) have been altered (Keenlyne 1989). As a result, pallid sturgeon were listed as endangered in 1990 (Dryer and Sandvol 1993), and shovelnose sturgeon abundances have declined over the past 100 years (Keenlyne 1997). The Missouri River above Fort Peck Reservoir, Montana, was estimated to contain only 30–144 pallid sturgeon (Gardner 1995).

The U.S. Fish and Wildlife Service implemented the Pallid Sturgeon Recovery Plan in 1993 (Dryer and Sandvol 1993). One objective of the recovery plan is to capture and spawn wild pallid sturgeon because pallid sturgeon recruitment is limited throughout their range. The resulting progeny would be raised in hatcheries until released at age 1. For example, 732 age-1 hatchery-reared juvenile pallid sturgeon (hereafter referred to as juvenile pallid sturgeon) were released into the Missouri River above Fort Peck Reservoir in 1998. These juvenile pallid sturgeon were the progeny of wild pallid sturgeon sampled near the confluence of the Missouri and Yellowstone rivers in North Dakota

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and subsequently reared at the Gavins Point Dam National Fish Hatchery in Yankton, South Dakota. These fish provided a unique opportunity to study juvenile pallid sturgeon ecology in the least hydrologically altered section of the Missouri River (Scott et al. 1997; Pegg et al. 2003). Unlike other studies that examined habitat use of juvenile pallid sturgeon during the same year in which they were released from a hatchery (e.g., Snook et al. 2002; Jordan et al. 2006), this study examined juvenile pallid sturgeon that had been living in the Missouri River above Fort Peck Reservoir for 5 and 6 years in 2003 and 2004, respectively. Thus, we believe that the juvenile pallid sturgeon in this study were acclimated to their natural lotic environment. Additionally, this study was unique in that both habitat use and diet (see Gerrity et al. 2006) were quantified for the same cohort of juvenile pallid sturgeon over the same time period. A paucity of information exists on the ecology of juvenile pallid sturgeon in their natural environment. Thus, research on the habitat use of juvenile pallid sturgeon in the Missouri River is considered important for providing insight into recovery requirements for the species (Quist et al. 2004).

Evaluation of juvenile pallid sturgeon was also necessary to determine their performance in a natural lotic environment, because stocking fish unable to acclimate to their natural environment would be an ineffective way to recover the species. Survival and growth estimates from the time of stocking were not possible for this study because few 1997 year-class juvenile pallid sturgeon have been captured since their release. However, the observed similarities and differences in habitat use and home range between juvenile pallid sturgeon and indigenous shovelnose sturgeon may provide insight into how hatchery-reared pallid sturgeon are performing in the wild. Therefore, the objective of this study was to evaluate the habitat use of juvenile pallid sturgeon and contrast the habitat use between these fish and indigenous shovelnose sturgeon of similar sizes in the Missouri River above Fort Peck Reservoir, Montana. To allow comparisons with adult pallid sturgeon as well, this study was also designed to be similar to that of Bramblett and White (2001).

The timing of this study (2003 and 2004) also provided us with a unique opportunity to study juvenile pallid sturgeon habitat use during a drought in the upper Missouri River system in Montana. Mean annual inflow to Fort Peck Reservoir averaged 986,179 ha-m/year from 1968 to 1997 (U.S. Army Corps of Engineers 2007). However, average annual inflow decreased to 622,354 ha-m/year from 1998 to 2004 (U.S. Army Corps of Engineers 2007). This decrease in inflow caused the elevation of Fort Peck Reservoir to

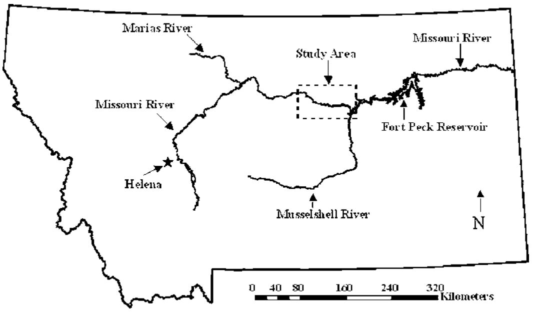

FIGURE 1.—Map showing the location of the study area on the Missouri River above Fort Peck Reservoir, Montana.

decline from 685 m above mean sea level in June 1997 to 672 m above mean sea level in June 2004 (U.S. Army Corps of Engineers 2007). The decrease in reservoir elevation created approximately 46 km of new lotic habitat that had not been available to pallid sturgeon in 1997. Overall, 60 km of lotic habitat available to juvenile pallid sturgeon in 2004 would have been inundated in Fort Peck Reservoir at maximum pool (686 m above mean sea level). Thus, evaluating the habitat use of "newly" created lotic habitat by juvenile pallid sturgeon was an a posteriori objective.

Study Area

The Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,000–3,302, measuring from the confluence with the Mississippi River; Figure 1), is one of six recovery priority management areas in the U.S. Fish and Wildlife Service's Pallid Sturgeon Recovery Plan based on recent records of pallid sturgeon occurrence and the probability that the area still provides suitable habitat for the restoration and recovery of the species (Dryer and Sandvol 1993). River kilometers 3,004–3,138 were chosen for this study, based on the high occurrence of juvenile pallid sturgeon here relative to that in other areas of the Missouri River above Fort Peck Reservoir. The higher number of juvenile pallid sturgeon in this area occurs despite the stocking of many juvenile pallid sturgeon in upstream areas as far as the Marias River confluence (river kilometer 3,302). Average monthly discharge (1934–2005) varied from 183 m^3/s in October to 541 m^3/s in June. Sand is the primary substrate in river kilometers 3,004–3,098, whereas gravel and cobble are more common in river kilometers 3,098–3,138 (Gardner 1994). The area upstream from river kilometer 3,092 was designated as part of the National Wild and Scenic River Systems to protect the last free-flowing portion of the Missouri River (U.S. Congress 1975a).

The "wild and scenic" designation prohibits construction of any dams on protected waters and imposes protective regulations on any new development in areas surrounding the protected area (U.S. Congress 1975b). Water diversions and pumping of water from the protected area for agricultural purposes are still permitted, as are row crop farming and cattle grazing within the immediate watershed (Gardner and Berg 1980). Limited storage of upstream dams, lack of channelization, and unregulated tributaries make the Missouri River above Fort Peck Reservoir the least hydrologically altered portion of the Missouri River (Scott et al. 1997; Pegg et al. 2003). As a result, this reach maintains many of the normal characteristics of a free-flowing river (e.g., islands, alluvial bars, secondary channels, backwaters).

Methods

Juvenile pallid sturgeon and shovelnose sturgeon (we believe that all of the shovelnose sturgeon used in this study were juveniles, but this was not confirmed during the radio-tagging surgery) were sampled for radio-tagging from May through August in 2003 and March through July in 2004 by using a benthic trawl, set lines, rod and reel, and trammel nets. See Gerrity (2005) for sampling gear specifics. Surgeries for transmitter implantation were performed using methods modified from Ross and Kleiner (1982) and Schmetterling (2001) and are described in Gerrity (2005). All radio transmitters used in this study avoided body weight ratios in excess of 2% (Winter 1996). Advanced Telemetry Systems (ATS) radio transmitters measuring 23 mm in length and weighing 2 g were used in 2003. The transmitters had a battery life of 36–72 d; they were programmed to have an 8-h-on, 16-h-off cycle for 3 d, followed by an off period for 4 d. Fish were implanted so that the transmitter was on consecutively for 3 d anytime from Tuesday through Saturday each week. In addition, the transmitters were on from 0900 to 1700. Both 7-g (40 mm in length) and 2-g ATS radio transmitters were used in 2004. The 7-g transmitters, which had a battery life of 134–268 d, were programmed to have a 10-h-on, 14-h-off cycle for 5 d, followed by an off period for 2 d. Fish were implanted so that the transmitter was on consecutively for 5 d anytime from Monday through Saturday each week. In addition, the 7-g transmitters were on from 0800 to 1800. All transmitters used in this study were on unique frequencies at 40 MHz. Tracking of radio-tagged fish commenced the day after surgery so that fish were not lost; however, habitat use data were not collected until after a 1-week acclimation period (Guy et al. 1992).

We attempted to locate radio-tagged fish at least once per week from May through August in 2003 and from April through October in 2004. Each week before tracking commenced, we randomly selected whether to begin tracking in the river reach upstream or downstream from James A. Kipp Recreation Area boat launch (river kilometer 3,091), and whether to track from upstream to downstream or downstream to upstream in the selected river reach. After all fish were located in a river reach, tracking proceeded to the other reach. Daily tracking each week began where tracking ceased on the previous day and continued until transmitters turned off or all fish had been located. Radio-tagged fish were detected by using a Lotek Suretrack STR1000 scanning receiver and an omnidirectional whip antenna. After detection, each fish was located with an ATS directional loop antenna. A buoy was deployed to mark the fish location, and the boat was anchored next to the buoy. Blind tests with both 2-g and 7-g transmitters placed in the river showed mean accuracy of this technique to be 2.5 m (90% confidence interval, ±0.9 m).

All habitat use measurements were recorded from an anchored boat position next to the fish location. Current velocity at 50% depth and within 15 cm of the bottom (hereafter referred to as bottom velocity) was measured with a Marsh-McBirney Model 201 flowmeter, channel width was measured with a Bushnell Lytespeed 400 rangefinder, and depth profiles were recorded by a Garmin GPSMAP 168 Sounder. Cross-sectional depth profiles were obtained by recording depth in 5-m increments while driving the boat from one riverbank to the other along a transect perpendicular to the current. Longitudinal depth profiles were produced by recording depth in 5-m increments while driving the boat from 50-m downstream to 50-m upstream of the fish location along a transect parallel with the current. The depth at the fish location and maximum depth were marked in each profile, and relative depth was calculated by dividing the depth at the fish location by the maximum depth. Each year of the study (2003 and 2004) was divided into three seasons, based on mean daily discharge (obtained from a U.S. Geological Survey gauging station) and water temperature (obtained from a Montana Department of Fish, Wildlife and Parks [MTFWP] temperature logger) recorded at James A. Kipp Recreation Area to determine whether changing river conditions affected habitat use of juvenile pallid sturgeon and shovelnose sturgeon (see Gerrity [2005] for more detail on season delineations).

Substrate composition at each fish location was determined by "feeling" the river bottom with a metal conduit probe (Bramblett and White 2001). Substrate was classified as (1) silt and sand (soft, smooth texture); (2) gravel and cobble (rough texture); or (3) boulder and bedrock (hard, smooth texture). Blind tests over areas of known substrate composition indicated this technique was 100% accurate.

Use and availability of river reaches with islands was measured by using the same methods as Bramblett and White (2001) and is considered a measure of habitat complexity because islands create multiple flow channels and a diversity of depths and current velocities. A river reach consisted of a 0.5-km upstream and downstream section from a fish location. Use of river reaches with islands was calculated by classifying the reach of each fish location into one of four island density categories: (1) no islands; (2) occasional islands—a single island with no overlapping of other islands; (3) frequent islands—more than one island with no or infrequent overlapping of islands; or (4) split channel—frequent or continuous overlapping of islands, causing two or three channels (Kellerhals et al. 1976). U.S. Geological Survey Landsat Enhanced Thematic Mapper satellite imagery from 2004 was used to calculate the availability of each island category by quantifying how many 0.5-km sections of the 134-km study reach contained each island category.

The use and availability of main- and secondary-channel habitat were also used as measures of habitat complexity. Main-channel habitat was defined as the main course of the Missouri River that contained the thalweg throughout the 134-km study area. Secondary channels were defined as flow (around islands) connected to the main channel but not containing the thalweg. Use of these habitats was calculated by classifying each fish location as occurring in either the main channel or a secondary channel. Again, satellite imagery from 2004 was used to calculate proportional availability of main- and secondary-channel habitat by quantifying how many 0.5-km sections of the 134-km study reach contained each habitat type. If a 0.5-km section contained more than one secondary channel, then secondary channel availability for that section was classified as the number of secondary channels present.

Mean river kilometer (calculated for each radio-tagged fish from the river kilometers recorded at each fish location by a Garmin GPSMAP 168 Sounder) was used as a measure of the most frequented areas of the study site by radio-tagged fish. Home range, defined as the number of river kilometers used by a radio-tagged fish, was calculated by subtracting the river kilometer at the furthest downstream location from the river kilometer at the furthest upstream location (Hurley et al. 1987; Bramblett 1996; Curtis et al. 1997). Telemetry data from 2003 and 2004 were supplemented by MTFWP capture locations of juvenile pallid sturgeon (obtained through MTFWP monitoring of the study area) in "newly" created lotic habitat from 2003 to 2006 to further evaluate our a posteriori objective. All 1997 year-class juvenile pallid sturgeon were implanted with unique passive integrated transponder tags before stocking; thus the fish captured by MTFWP were not multiple recaptures of a few individuals and did not include the radio-tagged fish.

Normality was assessed for all analyzed variables by using residual and normal probability plots. Two-tailed t-tests were used to test the hypotheses that there were no differences in mean home range and mean river kilometer between juvenile pallid sturgeon and shovelnose sturgeon. Different analyses were used in 2003 and 2004 for mean column velocity, bottom velocity, fish depth, channel cross-sectional relative depth, longitudinal section relative depth, and channel width because in the first case, data were collected only in summer during 2003, whereas data were collected in three seasons during 2004. Two-tailed t-tests were used to test the hypotheses that there were no differences in mean column velocity, bottom velocity, fish depth, channel cross-sectional relative depth, longitudinal section relative depth, and channel width between juvenile pallid sturgeon and shovelnose sturgeon during the summer of 2003. A Bonferroni approach was used to adjust α in order to reduce the likelihood of making a type I error in the main effect of species ($\alpha = 0.1$; adjusted $\alpha = 0.1/6 = 0.02$, where 6 = the number of different habitat variables). Repeated-measures (with individual fish as the repeated variable) analysis of variance (ANOVA) was used to test the hypotheses that there were no differences in mean column velocity, bottom velocity, fish depth, channel cross-sectional relative depth, longitudinal section relative depth, and channel width between juvenile pallid sturgeon and shovelnose sturgeon among seasons in 2004. As in the 2003 analysis, a Bonferroni approach was used to reduce the likelihood of committing a type I error in the main effects of species and season. When there was a significant difference in the main effects, a Bonferroni multiple comparison procedure was used to test for pairwise differences between species and seasons for each habitat variable, and alpha was reduced to 0.01 (0.1/9) as presented by Sheskin (1997). No significant species $\times$ season interactions existed in the analyses.

The substrate types at fish locations were converted to proportions for each radio-tagged fish (e.g., radio-tagged shovelnose sturgeon 40.121 was associated with silt and sand in 92.9% of locations, gravel and cobble in 7.1% of locations, and boulder and bedrock in 0% of locations). Because these data were not normally distributed, a Mann–Whitney U-test was used to test the hypotheses that there were no differences between juvenile pallid sturgeon and shovelnose sturgeon for association with silt and sand substrate, gravel and cobble substrate, and boulder and bedrock substrate (Bramblett and White 2001). Although the assumption of equal variances was violated in some instances (Levene's test for homogeneity of variance <0.1), the Mann–Whitney U-test is not as affected by a violation of the equal-variance assumption (Sheskin 1997). An $\alpha = 0.1$ was established a priori, and radio-tagged fish were the experimental unit for all statistical tests. All statistical tests were conducted by using Statistical Analysis Systems (SAS) version 8.2 (SAS Institute, Cary, North Carolina).

Chi-square log-likelihood test statistics (Manly et al. 2002) were used to test the null hypotheses that the animals in each population as a whole (i.e., juvenile pallid sturgeon and shovelnose sturgeon) were selecting river reaches of different island categories and main- and secondary-channel habitat in proportion to availability. Two analyses were conducted for each species for the island category analysis: comparisons of all island categories separately; and comparison of island category one (no islands) versus categories two (occasional islands), three (frequent islands), and four (split channel) combined. Although some of the expected values were less than the recommended minimum of five (Devore and Peck 2001), chi-square tests are robust to smaller expected values (Roscoe and Byars 1971; Lawal and Upton 1984). If selection was established in the chi-square log-likelihood tests, we calculated selection ratios with simultaneous 90% Bonferroni confidence intervals to determine which habitat types each population of fish was selecting (Manly et al. 2002). Selection is indicated by a value greater than 1, avoidance by a value less than 1, and use in proportion to availability by a value of exactly 1 (Manly et al. 2002). All chi-square log-likelihood statistics and selection ratios were calculated by using FishTel 1.4 software (Rogers and White 2007).

Results

One juvenile pallid sturgeon was captured in a benthic trawl, 12 with setlines, and 10 by angling, and 6 juvenile pallid sturgeon and 21 shovelnose sturgeon were captured with trammel nets. Nine juvenile pallid sturgeon and 12 shovelnose sturgeon were implanted with radio transmitters in 2003; in 2004, 20 juvenile pallid sturgeon and 9 shovelnose sturgeon were implanted with radio transmitters. For all habitat analyses we used a total of 666 locations obtained from 29 juvenile pallid sturgeon (fork length = 511 ± 17 mm [90% confidence interval around the mean; range = 295–615 mm]; weight = 434 ± 37 g [range = 90–755 g]) and 21 shovelnose sturgeon (fork length = 497 ± 29 mm [range = 317–574 mm]; weight = 566 ± 97 g [range = 100–915 g]).

Mean column velocity varied from 0.65 to 0.78 m/s at juvenile pallid sturgeon locations and from 0.67 to 0.87 m/s at shovelnose sturgeon locations, depending on the season. Mean column velocity occupied by the fish did not differ between species ($t = 1.92$, df = 19, $P = 0.07$ in 2003; $F_{1,27} = 2.67$, $P = 0.11$ in 2004); however, column velocity at sturgeon locations did differ among seasons within species in 2004 ($F_{2,42} = 16.88$, $P < 0.0001$; Table 1). Mean bottom velocity was relatively constant between species and among seasons in 2004, varying from 0.45 to 0.50 m/s for juvenile pallid sturgeon and from 0.48 to 0.55 m/s for shovelnose sturgeon by season. Mean bottom velocity did not differ between species ($t = 0.55$, df = 16, $P = 0.59$ in 2003; $F_{1,25} = 3.51$, $P = 0.07$ in 2004) or among seasons within species ($F_{2,40} = 1.88$, $P = 0.17$; Table 1). Mean channel width varied from 137 to 153 m at juvenile pallid sturgeon locations and from 142 to 162 m at shovelnose sturgeon locations by season. Mean channel width did not differ between species ($t = 0.43$, df = 19, $P = 0.67$ in 2003; $F_{1,27} = 0.68$, $P = 0.42$ in 2004); however, mean channel width did differ among seasons within species for juvenile pallid sturgeon in 2004 ($F_{2,42} = 4.43$, df = 2,42, $P = 0.02$; Table 1).

Mean depth varied from 2.31 to 2.48 m at juvenile pallid sturgeon locations and from 1.93 to 2.36 m at shovelnose sturgeon locations, depending on the season. Variation in mean depth at juvenile pallid sturgeon and shovelnose sturgeon locations was less than 0.5 m (90% confidence interval). Mean depth at a location did not differ between species in 2003 ($t = 1.57$, df = 19, $P = 0.13$) or 2004 ($F_{1,28} = 1.52$, df = $P = 0.23$) or among seasons within species in 2004 ($F_{2,43} = 2.02$, $P = 0.15$; Table 1). Juvenile pallid sturgeon were in 73–83% of the maximum cross-sectional depth and 89–91% of the maximum longitudinal depth, whereas shovelnose sturgeon were in 77–86% of the maximum cross-sectional depth and 90–94% of the maximum longitudinal depth by season. Similar to depth, mean cross-sectional relative depth ($t = -0.68$, df = 9, $P = 0.51$ in 2003; $F_{1,33} = 0.12$, $P = 0.73$ in 2004) and longitudinal relative depth ($t = 0.4$, df = 19, $P = 0.69$ in 2003; $F_{1,31} = 2.42$, $P = 0.13$ in 2004) did not differ between species (Table 1). Mean longitudinal relative depth did not differ among seasons within species ($F_{2,46} = 0.35$, df = $P = 0.70$); however, mean cross-sectional relative depth did differ among seasons for juvenile pallid sturgeon ($F_{2,47} = 5.11$, $P = 0.009$; Table 1).

Juvenile pallid and shovelnose sturgeon were primarily found in areas with silt and sand substrate (Figure 2). However, juvenile pallid sturgeon were

TABLE 1.—Means and 90% confidence intervals (CIs) of measured habitat variables at radio-tagged juvenile pallid sturgeon and shovelnose sturgeon locations by season in the Missouri River above Fort Peck Reservoir, Montana in 2003 and 2004. No significant differences were found between species by season for any habitat variable. For each habitat variable and species, different letters indicate significant ($\alpha \leq 0.10$) differences among seasons in 2004. No data were collected in spring and autumn 2003.

			Juvenile pallid sturgeon		Shovelnose sturgeon	
Variable	Year	Season	Mean (90% CI)	*N*	Mean (90% CI)	*N*
Depth (m)	2003	Summer	2.31 ± 0.34	9	1.97 ± 0.23	12
	2004	Spring	2.44 ± 0.23 z	18	2.36 ± 0.44 z	6
		Summer	2.48 ± 0.29 z	18	2.03 ± 0.31 z	9
		Autumn	2.34 ± 0.42 z	14	1.93 ± 0.24 z	8
Cross-sectional relative depth	2003	Summer	0.73 ± 0.10	9	0.77 ± 0.04	12
	2004	Spring	0.76 ± 0.03 y	18	0.79 ± 0.07 z	6
		Summer	0.81 ± 0.03 zy	18	0.77 ± 0.04 z	9
		Autumn	0.83 ± 0.04 z	14	0.86 ± 0.04 z	8
Longitudinal relative depth	2003	Summer	0.90 ± 0.02	9	0.90 ± 0.02	12
	2004	Spring	0.91 ± 0.02 z	18	0.92 ± 0.04 z	6
		Summer	0.91 ± 0.02 z	18	0.90 ± 0.03 z	9
		Autumn	0.89 ± 0.02 z	14	0.94 ± 0.03 z	8
Column velocity (m/s)	2003	Summer	0.78 ± 0.04	9	0.72 ± 0.04	12
	2004	Spring	0.77 ± 0.04 z	18	0.87 ± 0.05 z	6
		Summer	0.73 ± 0.05 z	18	0.78 ± 0.06 z	9
		Autumn	0.65 ± 0.05 y	14	0.67 ± 0.07 y	8
Bottom velocity (m/s)	2003	Summer	0.50 ± 0.04	9	0.48 ± 0.06	12
	2004	Spring	0.49 ± 0.04 z	18	0.55 ± 0.05 z	6
		Summer	0.47 ± 0.03 z	18	0.49 ± 0.04 z	9
		Autumn	0.45 ± 0.06 z	14	0.51 ± 0.05 z	8
Channel width (m)	2003	Summer	147.34 ± 22.72	9	141.75 ± 11.97	12
	2004	Spring	153.52 ± 12.72 z	18	154.95 ± 14.18 z	6
		Summer	137.37 ± 13.03 y	18	141.77 ± 10.74 z	9
		Autumn	138.87 ± 14.78 zy	14	161.73 ± 15.03 z	8

found in areas with silt and sand more often than shovelnose sturgeon were ($\chi^2 = 7.32$, df = 1, $P = 0.007$), whereas shovelnose sturgeon were found in areas with gravel and cobble more often than juvenile pallid sturgeon ($\chi^2 = 8.49$, df = 1, $P = 0.004$). Association with boulder and bedrock substrate did not differ between species ($\chi^2 = 0.82$, df = 1, $P = 0.36$).

Fifty-one percent of the study area had no islands, whereas 26% was classified as having occasional islands, 13% as having frequent islands, and 10% as having split channels. Juvenile pallid sturgeon and shovelnose sturgeon did not select island habitat categories in proportion to availability, whether all four island density categories were considered separately ($\chi^2 = 429.95$, df = 87, $P < 0.0001$ for juvenile pallid sturgeon; $\chi^2 = 193.99$, df = 63, $P < 0.0001$ for shovelnose sturgeon) or the three island categories (occasional islands, frequent islands, and split channels) were combined ($\chi^2 = 237.88$, df = 29, $P < 0.0001$ for juvenile pallid sturgeon; $\chi^2 = 96.55$, df = 21, $P < 0.0001$ for shovelnose sturgeon; Figure 3). When island categories were analyzed separately, juvenile pallid sturgeon avoided reaches with frequent islands, whereas shovelnose sturgeon selected reaches without islands and avoided reaches with frequent islands and split channels (Figure 3). If we consider the three island categories combined, both juvenile pallid sturgeon and shovelnose sturgeon selected reaches without islands and avoided reaches with islands (Figure 3).

Sixty-one percent of the study area was main

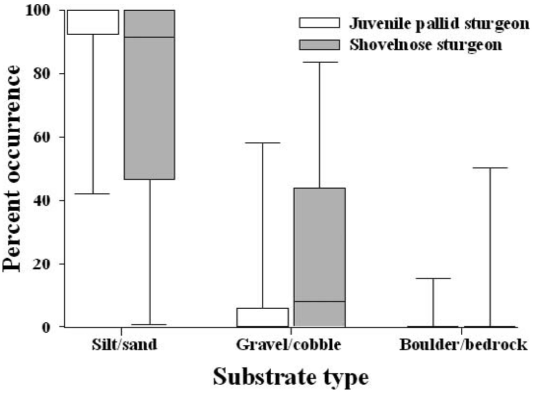

FIGURE 2.—Percent occurrence of radio-tagged juvenile pallid sturgeon ($N = 29$) and shovelnose sturgeon ($N = 21$) in the Missouri River above Fort Peck Reservoir, Montana, by substrate type in 2003 and 2004. The horizontal lines within the boxes denote the medians, the lower and upper boundaries of the boxes represent the 25% and 75% percentiles, respectively, and the whiskers represent the minimum and maximum values.

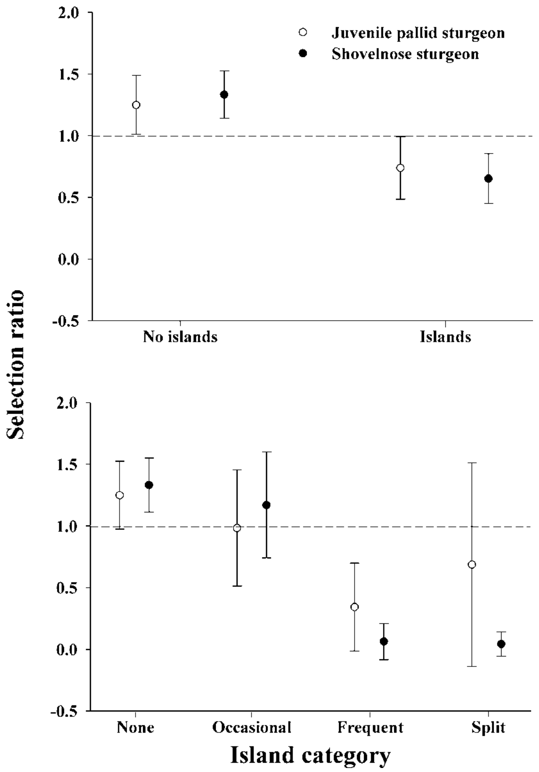

FIGURE 3.—Selection ratios and simultaneous 90% Bonferroni confidence intervals for river reaches with and without islands (top panel) and by island category (bottom panel) for radio-tagged juvenile pallid sturgeon ($N = 29$) and shovelnose sturgeon ($N = 21$) in the Missouri River above Fort Peck Reservoir, Montana, in 2003 and 2004. Selection is indicated with values greater than 1, avoidance by values less than 1, and use in proportion to availability by values of exactly 1.

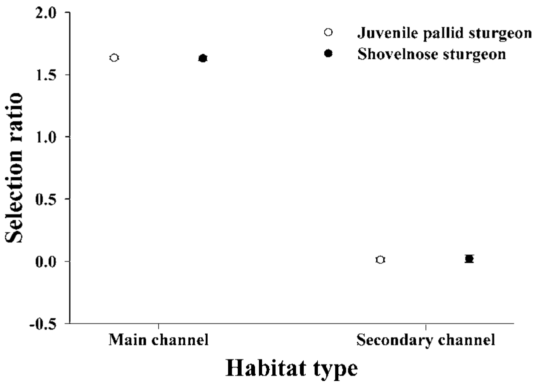

FIGURE 4.—Selection ratios and simultaneous 90% Bonferroni confidence intervals for main- and secondary-channel habitats for radio-tagged juvenile pallid sturgeon and shovelnose sturgeon in the Missouri River above Fort Peck Reservoir, Montana, in 2003 and 2004. See Figure 3 for additional details.

channel and 39% secondary channel. Juvenile pallid sturgeon and shovelnose sturgeon did not select main and secondary-channel habitat in proportion to availability ($\chi^2 = 409.78$, df = 29, $P < 0.0001$ for juvenile pallid sturgeon; $\chi^2 = 231.49$, df = 21, $P < 0.0001$ for shovelnose sturgeon). Rather, both species selected main-channel habitat and avoided secondary channels (Figure 4). Only 4 of 666 locations (two juvenile pallid sturgeon locations and two shovelnose sturgeon locations) determined for 50 radio-tagged fish were in secondary-channel habitat.

Mean river kilometer differed between species (3,072.9 ± 4.6 for juvenile pallid sturgeon; 3,089.7 ± 6.3 for shovelnose sturgeon; $t = -3.79$, df = 48, $P < 0.001$), with shovelnose sturgeon using upstream areas more than juvenile pallid sturgeon. Home range varied from 1.1 to 73.9 km for juvenile pallid sturgeon and from 0.7 to 41.5 km for shovelnose sturgeon. The two species exhibited no difference in mean home range; that for juvenile pallid sturgeon was 15.0 ± 5.0 km and that for shovelnose sturgeon was 16.5 ± 4.7 km ($t = -0.34$, df = 48, $P = 0.73$).

The home ranges of five radio-tagged juvenile pallid sturgeon (17.2% of radio-tagged juvenile pallid sturgeon) and one radio-tagged shovelnose sturgeon (4.7% of radio-tagged shovelnose sturgeon) included lotic habitat that had been inundated by Fort Peck Reservoir in 1997 (Figure 5). The home ranges of eight radio-tagged juvenile pallid sturgeon (27.6% of radio-tagged juvenile pallid sturgeon) and three radio-tagged shovelnose sturgeon (14.3% of radio-tagged shovelnose sturgeon) included lotic habitat that would be inundated by Fort Peck Reservoir at maximum pool (Figure 5). Radio-tagged juvenile pallid sturgeon were located as far downstream as river kilometer 3,005 near the headwaters of Fort Peck Reservoir in 2004 (Figure 5); radio-tagged shovelnose sturgeon were located as far downstream as river kilometer 3,040. Eighteen additional 1997 year-class juvenile pallid sturgeon were captured by MTFWP from 2003 to 2006 in lotic habitat that had been inundated by Fort Peck Reservoir in 1997 and 34 were captured during that period in lotic habitat that would be inundated by Fort Peck Reservoir at maximum pool (Figure 5).

Discussion

The habitat use of juvenile pallid sturgeon and shovelnose sturgeon in the Missouri River above Fort Peck Reservoir was similar in many aspects to that of adult pallid sturgeon and adult shovelnose sturgeon in the lower Yellowstone River and the Missouri River

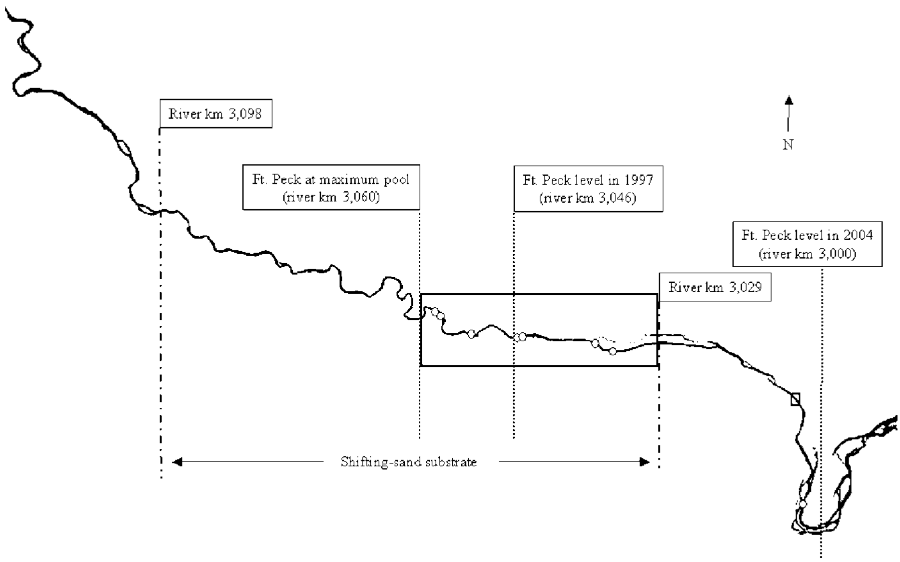

FIGURE 5.—Grayscale satellite image of the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004–3,138) in 2004. The boxes denote the areas where 34 juvenile pallid sturgeon were sampled by Montana Fish, Wildlife and Parks from 2003 to 2006. The circles denote the most downstream locations of eight radio-tagged juvenile pallid sturgeon. Sampling and relocations of juvenile pallid sturgeon above river kilometer 3,060 are not depicted on this figure.

above Lake Sakakawea (Bramblett and White 2001). The similarities and differences between the two closely related species in this study and similarities with adults found in other studies indicate that hatchery-reared juvenile pallid sturgeon are acclimating to the Missouri River above Fort Peck Reservoir in Montana. The similarities between the species were probably related to similar morphological adaptations. *Scaphirhynchus* is the most phylogenetically derived genus within Acipenseridae, having many characteristics especially adapted for living in large, turbid lotic systems (Findeis 1997). For example, *Scaphirhynchus* spp. have adaptations suited to benthic feeding in turbid systems, including small eyes, sensitive barbels, flattened heads that contain many sensory organs, and mouths that open ventrally (Findeis 1997). These specialized adaptations make *Scaphirhynchus* spp. ideal predators for benthic inhabitants such as aquatic invertebrates, sicklefin chubs *Macrhybopsis meeki*, and sturgeon chubs *M. gelida* (Gerrity et al. 2006). Additionally, a flattened ventral surface and curved leading pectoral fin rays that can be used as "legs" for shuffling along the bottom are all adaptations for extensive contact with substrate (Findeis 1997)—which may be necessary for station holding in swift currents (Adams et al. 1999).

Juvenile pallid sturgeon and shovelnose sturgeon were often located in the relatively deep, swift water near the thalweg to which they are morphologically adapted. The use by juvenile pallid sturgeon of greater channel cross-sectional relative depths in autumn than in spring may have been related to lower discharge or clearer water. Juvenile pallid sturgeon in the Missouri River below Fort Randall Dam also used relatively deep water (80% to 92%) in main-channel habitat (Jordan et al. 2006). Shovelnose sturgeon and pallid sturgeon used relatively deep water in the lower Yellowstone River and the Missouri River above Lake Sakakawea, but shovelnose sturgeon were at slightly greater relative depths (Bramblett and White 2001). In contrast to fish in this study, mean depth at pallid sturgeon locations was significantly greater than at shovelnose sturgeon locations in the lower Yellowstone River and the Missouri River above Lake Sakakawea (Bramblett and White 2001). Interestingly, juvenile pallid sturgeon and shovelnose sturgeon in this study used shallower depths than *Scaphirhynchus* spp. in other areas of the Missouri and Mississippi rivers (Hurley et al. 1987; Erickson 1992; Curtis et al. 1997; Hurley 1999; Bramblett and White 2001; Jordan et al. 2006), but deeper depths than fish in Missouri River tributaries (Quist et al. 1999; Snook et al. 2002; Swigle 2003). These results support Bramblett and White (2001), who suggested that use of shallower depths by pallid sturgeon and shovelnose sturgeon in upstream areas and tributaries may be because availability of deeper depths increases longitudinally.

The use by both species of lower column velocities in autumn than in spring or summer was probably related to mean daily discharge, which also decreased seasonally. Conversely, mean bottom velocity remained relatively constant from spring through autumn. Mean bottom velocities in all seasons for both species in this study were greater than those reported for juvenile pallid sturgeon (Snook et al. 2002) and shovelnose sturgeon (Hurley et al. 1987; Curtis et al. 1997; Quist et al. 1999; Swigle 2003) in many other studies throughout the Missouri and Mississippi River systems. Conversely, the juvenile pallid sturgeon in the Missouri River below Fort Randall Dam used bottom velocities similar to those we found (Jordan et al. 2006), and pallid sturgeon and shovelnose sturgeon in the lower Yellowstone River and the Missouri River above Lake Sakakawea (Bramblett and White 2001) used greater bottom velocities. Similar to the depth relationship, the differences in bottom velocity among studies may be related to differences in velocity availability among study areas.

The association of juvenile pallid and shovelnose sturgeon with silt and sand substrate in this study is similar to other findings on *Scaphirhynchus* spp. throughout much of the Missouri and Mississippi river systems (Hurley et al. 1987; Curtis et al. 1997; Hurley 1999; Quist et al. 1999; Bramblett and White 2001; Snook et al. 2002; Swigle 2003). However, shovelnose sturgeon were found most often in areas with gravel and cobble substrate in the lower Yellowstone River and in the Missouri River above Lake Sakakawea (Bramblett and White 2001). Although shovelnose sturgeon were primarily found in areas with silt and sand substrate in the Missouri River above Fort Peck Reservoir, they were also found in areas with gravel and cobble and to a greater extent than juvenile pallid sturgeon. As suggested by Bramblett and White (2001), the slight differences in substrate association may be related to the differences in diet between pallid sturgeon and shovelnose sturgeon. Shovelnose sturgeon in the study area primarily consume aquatic insects (Gerrity et al. 2006), which are found in rocky substrates more often than in shifting sand (Ward 1992; Allan 1995). Alternatively, the majority of the juvenile pallid sturgeon diet is composed of sicklefin chubs and sturgeon chubs (Gerrity et al. 2006), which in other studies in the upper Missouri and lower Yellowstone rivers (Grisak 1996; Welker and Scarnecchia 2004) were found primarily in areas with sand substrate.

The avoidance of islands by shovelnose sturgeon in this study is similar to the findings of Bramblett and White (2001) for shovelnose sturgeon in the lower Yellowstone River and in the Missouri River above Lake Sakakawea. However, juvenile pallid sturgeon in this study did not use areas with islands as often as pallid sturgeon in other studies. For example, pallid sturgeon selected river reaches with frequent islands and avoided reaches with no islands, occasional islands, and split channels in the lower Yellowstone River and in the Missouri River above Lake Sakakawea (Bramblett and White 2001). Additionally, pallid sturgeon in the middle Mississippi River selected downstream island tips (Hurley et al. 2004). Perhaps ideal depths for juvenile pallid sturgeon and shovelnose sturgeon were not present near islands in the Missouri River above Fort Peck Reservoir. Mean maximum depth in channel cross-sectional profiles (averaged across all seasons) was 3.1 m for juvenile pallid sturgeon and 2.6 m for shovelnose sturgeon in this study, whereas maximum depths averaged 4.4 m for pallid sturgeon and 3.1 m for shovelnose sturgeon in the lower Yellowstone River and in the Missouri River above Lake Sakakawea (Bramblett and White 2001). Pallid sturgeon in the middle Mississippi River were never found in water shallower than 1.8 m and usually used depths from 6 to 12 m (Hurley 1999). Downstream island and alluvial bar tips have been thought to provide abundant prey for pallid sturgeon (Bramblett and White 2001; Snook et al. 2002; Hurley et al. 2004). However, deep water in the main channel is the primary habitat for sicklefin chubs and sturgeon chubs (Grisak 1996; Everett 1999; Welker and Scarnecchia 2004), which were the primary prey of juvenile pallid sturgeon in the study area (Gerrity et al. 2006). Additionally, chironomid densities were highest in deep water main-channel habitat in the Missouri River above Fort Peck Reservoir (Megargle 1996). Thus, pallid sturgeon in other studies were probably not selecting islands and alluvial bars but the depths where prey are abundant. The variations in river morphology make comparisons among rivers difficult. Nevertheless, pallid sturgeon in the Missouri River above Fort Peck Reservoir clearly are using deepwater habitat that contain main-channel cyprinid species.

The avoidance of secondary channels by juvenile pallid and shovelnose sturgeon in this study and others was also probably influenced by a lack of suitable habitat and prey availability. Only 4.4% of juvenile pallid sturgeon locations in the Missouri River below Fort Randall Dam were in secondary channels; however, average depth at those locations was 3.0 m (Jordan et al. 2006). Secondary channels in the Missouri River above Fort Peck Reservoir are typically shallow (<2 m) and do not provide ideal habitat for juvenile pallid sturgeon and shovelnose sturgeon. Although chironomids were sampled in secondary channels in the Missouri River above Fort Peck Reservoir, their densities were higher in deeper, main-channel habitat (Megargle 1996). Additionally, sicklefin chubs and sturgeon chubs use water depths between 2 and 7 m in main-channel habitat and are rarely captured in secondary channels (Grisak 1996; Everett 1999; Welker and Scarnecchia 2004).

Large-scale differences in the locations of juvenile pallid and shovelnose sturgeon (i.e., mean river kilometers) are probably related to differences in diet and substrate use. The highest catch rates of sturgeon chubs and sicklefin chubs in the Missouri River above Fort Peck Reservoir in 2004 occurred in the study area from river kilometers 3,030 to 3,092 (Gardner 2006). Additionally, silt and sand is the most common substrate from river kilometers 3,004 to 3,098, whereas gravel and cobble is the primary substrate from river kilometers 3,098 to 3,138 (Gardner 1994). Thus, the reach between river kilometers 3,004 and 3,098 has many of the characteristics of a large warmwater river, such as shifting-sand substrate. Subsequently, this area appears important for juvenile pallid sturgeon and their prey.

The shovelnose sturgeon and juvenile pallid sturgeon in this study did not make the long-range movements that were observed for adult pallid sturgeon and adult shovelnose sturgeon in the lower Yellowstone River and in the Missouri River above Lake Sakakawea (Bramblett and White 2001) and for pallid sturgeon in the middle Mississippi River (Hurley 1999). However, shovelnose sturgeon in the upper Mississippi River (Hurley et al. 1987; Curtis et al. 1997) had mean home ranges similar to those in this study. The differences in home range among studies may be related to differences in the sexual maturity of radio-tagged fish. Pallid sturgeon and shovelnose sturgeon in the lower Yellowstone River and in the Missouri River above Lake Sakakawea were adults; their long movements may have been related to spawning (Bramblett and White 2001).

Juvenile pallid sturgeon were located within the operational pool levels of Fort Peck Reservoir. If Fort Peck Reservoir were to rise to maximum pool level, the lotic habitat with shifting-sand substrate would be reduced by 31 km. In addition, the lotic habitat that would be inundated by Fort Peck Reservoir at maximum pool is that which had the highest catch rates of sicklefin chubs and sturgeon chubs in the Missouri River above Fort Peck Reservoir in 2004 (Gardner 2006). Thus, the lotic habitat near the headwaters of the reservoir may be an important feeding area for juvenile pallid sturgeon (see Gerrity et al. 2006). Shovelnose sturgeon in the upper Mississippi River (Curtis et al. 1997) and pallid sturgeon and shovelnose sturgeon in the Missouri River above Lake Sakakawea (Bramblett and White 2001) appeared to avoid impounded areas, indicating that reservoirs are unsuitable habitat for both species. The use of previously inundated lotic habitat by juvenile pallid sturgeon and their prey indicates that reservoir level can influence available habitat for pallid sturgeon.

Given the limited natural recruitment of pallid sturgeon throughout the Missouri River, survival of hatchery-reared juveniles is essential to the recovery of the species. We suggest that stocking juvenile pallid sturgeon can successfully augment wild pallid sturgeon populations in the Missouri River above Fort Peck Reservoir in Montana, as was found by Jordan et al. (2006) for the Missouri River below Fort Randall Dam in South Dakota and Nebraska. However, the conservation of juvenile pallid sturgeon habitat should also be a high priority for pallid sturgeon recovery until the factors that limit recruitment are discovered and resolved. Therefore, the success of these stockings relies in part on available habitat, which can be altered by water-level management in downstream reservoirs. Contemporary decisions regarding water-level management in Fort Peck Reservoir must consider the upstream pallid sturgeon population.

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