# HABITAT USE AND MOVEMENTS OF ADULT PALLID STURGEON IN THE MISSOURI RIVER DOWNSTREAM OF FORT RANDALL DAM, SOUTH DAKOTA AND NEBRASKA

Greg A.Wanner, Robert A. Klumb and Wayne J. Stancill
United States Fish and Wildlife Service
Pierre, SD 57501

George R. Jordan
United States Fish and Wildlife Service
Billings, MT 59101

## ABSTRACT

Ultrasonic telemetry was used from 2000 to 2002 to identify habitat use and track seasonal and diel movements of six adult pallid sturgeon (*Scaphirhynchus albus*) released in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska. Extensive sampling occurred at about two week intervals from spring through fall. Two individual fish were intensively tracked for 4 to 12 hours during 2000 to assess diel movements, with one individual tracked on three occasions. A total of 29 relocations were observed from four pallid sturgeon and two fish were only found once after the initial year of stocking suggesting a survival rate of 33%. In all seasons, adult pallid sturgeon were located in the main river channel habitat and at relative depths ranging from 79 to 100% of the maximum channel depth. During the multiple year study, two different movement patterns were observed of the two fish. One of the fish moved throughout the study area while the other fish moved downstream below the Missouri and Niobrara rivers confluence and remained there throughout the study period. In general, both fish moved upstream during late fall through the spring and moved downstream during the summer. Both fish also were relocated in two to three distinct areas of the Missouri River, a potential indication of preference to unknown biotic and abiotic habitat conditions. One fish had a maximum observed range of 8.1 km with low seasonal movement rates compared to the other fish that had a maximum observed range of 45.8 km. The pallid sturgeon that was intensively tracked on three occasions had substantially higher (≥ 40%) movement rates at night compared to dawn, daytime, and dusk. Although the number of tagged fish in this study was small, all field observations for an endangered species are valuable for recovery efforts. Observations from the two fish in this study were consistent with other studies which showed that adult pallid sturgeon are a highly mobile, wide-ranging species.

Keywords

Pallid sturgeon, *Scaphirhynchus albus*, Missouri River, telemetry, movement, habitat use

## INTRODUCTION

Pallid sturgeon (*Scaphirhynchus albus*), a species native to the Missouri River system (Forbes and Richardson 1905), was listed by the U. S. Fish and Wildlife Service (USFWS) as an endangered species in the fall of 1990 (USFWS 1990). Conversion of the free flowing upper Missouri River into a series of impoundments and extensive channelization of the lower Missouri River has resulted in habitat degradation and an altered hydrograph that are suspected for the decline in distribution and abundance of pallid sturgeon (Kallemeyn 1983). Pallid sturgeon are benthic and tend to occupy main channel habitats in the lower Mississippi River (Hurley et al. 2004) and main channel areas associated with islands or sand bars in the upper Missouri River (Bramblett and White 2001). Because all rivers within the historic range of pallid sturgeon are highly modified (Kallemeyn 1983), habitats occupied by the fish likely are not necessarily the species' "preferred" habitat.

An inter-reservoir reach of the Missouri River downstream of Fort Randall Dam, South Dakota (Figure 1) has been listed as one of six recovery priority management areas (RPMA) for pallid sturgeon based on remnant riverine habitat characteristics at the time of listing (USFWS 1993). As part of the recovery efforts for pallid sturgeon, the USFWS initiated a stocking program in RPMA 3 in 2000 and released 416 age-3 hatchery-reared juvenile pallid sturgeon in this reach of the Missouri River. An additional three adult pallid sturgeon used as brood stock were also released with the juveniles.

Biotelemetry studies provide insight on fish movement and habitat use. No telemetry studies using adult pallid sturgeon have been published for the unchannelized Missouri River downstream of Fort Randall Dam. Previous telemetry studies in the Missouri River focused on the unchannelized river in Montana and North Dakota (Bramblett and White 2001) and on a main stem South Dakota reservoir, Lake Sharpe (Erickson 1992). Movements and habitat use of adult pallid sturgeon have also been studied in the middle Mississippi River (Hurley 1999; Hurley et al. 2004).

Recovery of pallid sturgeon and assessment of RPMA 3 as a recovery area necessitates studies encompassing all life stages. Jordan et al. (2006) reported that hatchery-reared juvenile pallid sturgeon used the entire reach of RPMA 3 and had a high survival rate (> 65%). However, it is not known whether this inter-reservoir reach of the Missouri River will support an adult pallid sturgeon population. A self-sustaining population is the ultimate determinate of recovery success identified in the pallid sturgeon recovery plan (USFWS 1993). Thus, the objectives of this study were to document seasonal and diel movement patterns and general habitat use of adult pallid sturgeon in this inter-reservoir reach of the Missouri River (RPMA 3).

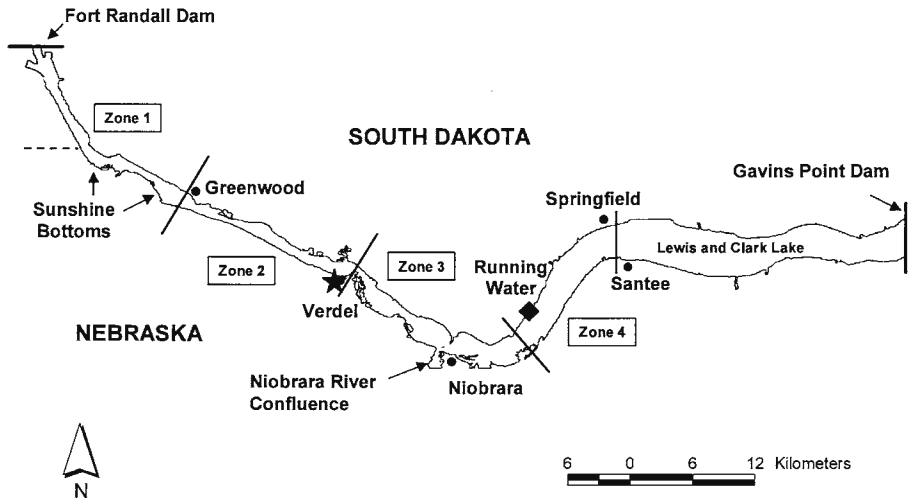


***Figure 1. Map showing the Missouri River downstream of Fort Randall Dam where four sonic-tagged adult pallid sturgeon were released near Verdel, Nebraska on 6 July 2000 (star) and where two adult pallid sturgeon were released near Running Water, South Dakota on 20 September 2000 (diamond) and tracked from 2000 to 2002. The Missouri River was divided into four zones for randomization of tracking effort.***

## STUDY AREA

Gavins Point Dam on the Missouri River was closed in 1955 which formed Lewis and Clark Lake (Figure 1). This reservoir forms a boundary between the states of South Dakota and Nebraska and can be subdivided into two distinct habitats. The upper reach extends for approximately 76 river km (rkm) from Fort Randall Dam (rkm 1,416) to near Springfield, South Dakota (rkm 1,340) and still retains many natural riverine characteristics including: sand bars, old growth riparian forest, side channels, and year round flows. Because of these remaining riverine characteristics, this upper reach was chosen for stocking juvenile hatchery-reared pallid sturgeon as part of the recovery plan (USFWS 1993; Jordan 2006). However, discharge is regulated by Fort Randall Dam resulting in unnatural daily fluctuations (> 0.75 m) and seasonal discharge patterns. The second habitat, downstream of Springfield, South Dakota to Gavins Point Dam (rkm 1,305), is comprised of the reservoir, Lewis and Clark Lake.

## METHODS

Six adult pallid sturgeon (mean fork length [FL] = 1,321 mm [SE = 55] and mean weight = 15.1 kg [SE = 1.9]) were surgically implanted with sonic transmitters (Sonotronics, Tuscon, Arizona) on 2 June 2000. These six fish were captured in Lake Sharpe, South Dakota in 1992 and maintained for eight years at Gavins Point Dam National Fish Hatchery (NFH) in Yankton, South Dakota. Water temperatures at the hatchery at the time of tagging were

19 - 20 ºC. No anesthesia was used during surgery and the fish were held after surgery in the hatchery for five weeks to assess tag expulsion and mortality. Antibiotics were administered following surgery to reduce bacterial infection. Following this holding period, the surviving fish were released into the Missouri River near Verdel, Nebraska (rkm 1,377) on 6 July 2000. Another two adult pallid sturgeon (mean FL = 1,403 mm [SE = 33] and mean weight 15.4 kg [SE = 5.7]) had sonic transmitters surgically implanted on 15 August 2000 and were released in the Missouri River near Running Water, South Dakota (rkm 1,360) on 20 September 2000. These two fish were originally captured in the Missouri River downstream of the Yellowstone River Confluence in North Dakota in 1997 and maintained at Gavins Point NFH for three years.

Transmitters were 60 mm in length and 18 mm in diameter. Transmitter dry weight was 25 g and the transmitter weight to fish body weight ratio ranged from 0.1 to 0.3%. Each transmitter emitted a unique aural code which identified an individual fish and had a life expectancy (battery life) of 36 months. Frequencies emitted by the sonic tags ranged from 71 to 78 kHz. The six adult pallid sturgeon in this study were relocated in conjunction with a post-stocking movements study of 22 hatchery-reared juvenile pallid sturgeon (Jordan et al. 2006).

The riverine reach was divided into four sample zones of approximately equal length (Figure 1). The upper site extended from Fort Randall Dam (rkm 1,416) to downstream of Greenwood, South Dakota (rkm 1,392). The upper-middle site extended from Greenwood to near Verdel, Nebraska (rkm 1,377), the lower-middle site extended from Verdel to Running Water, South Dakota (rkm 1,360). The most downriver site encompassed the remainder of the river from Running Water to near Springfield, South Dakota (rkm 1,340). Extensive surveys of the Missouri River in all four zones occurred on four dates in 2000, 13 dates in 2001, and 10 dates in 2002. One survey date in 2002 occurred during the winter (January). The reservoir, Lewis and Clark Lake, was also searched once in 2000 and once in 2001. One final survey of the riverine reach was done in 2003 near the end of the battery life for the transmitters.

Two tracking methods, extensive and intensive, were employed during each sample period in 2000. Extensive tracking was also conducted throughout 2001 and 2002. Extensive tracking ascertained the locations of as many fish as possible in each zone by stopping and listening for fish about every 0.4 km. Then a randomly selected individual fish was intensively followed for 24 h. Intensive tracking encompassed the day, night, and both crepuscular periods, dawn and dusk. These diel tracking periods were defined as: dawn (1 h before to 1 h after sunrise), day (2 h after sunrise to 2 h before sunset), dusk (1 h before to 1 h after sunset), and night (2 h after sunset to 2 h before sunrise). Tracking began immediately after release and occurred approximately every other week, until weather conditions prohibited tracking during late fall and resumed as early as feasible each spring. One tracking survey occurred in winter (January 2002).

An ultrasonic receiver and directional hydrophone were used to detect fish locations and a fish was considered located when the coded impulses from the sonic transmitter were equally audible with a 360º rotation of the hydrophone. Once a fish location was determined, latitude and longitude coordinates were recorded with a PLGR+96 Global Positioning System (GPS) receiver (Rockwell

International, Milwaukee, Wisconsin). The mean error reading (N = 67) for GPS locations of adult pallid sturgeon from both extensive and intensive surveys was 5.2 m (SE = 0.2). The habitat type for each located fish was classified as: main channel, side channel, backwater, island tip, reservoir, tributary mouths, and dam tailrace. Habitat characteristics measured at each fish location included surface water temperature (°C), water depth (m) occupied by the fish, maximum water depth (m) of the channel cross-section, bottom water velocity (m/s), and turbidity (nephalometric turbidity units, [NTU]). The relative depth for each fish was calculated as the ratio of the water depth at the fish's location to the maximum water depth of the channel cross-section.

## RESULTS

### Post-surgery survival

During the five-week holding period, two mortalities (mean FL = 1,320 mm [SE = 50] and mean weight = 15.7 kg [SE = 2.8]) from the Lake Sharpe adult pallid sturgeon occurred within 24 h of tag implantation. Lengths and weights of dead fish were similar to those that survived for five weeks after surgery. No expulsions of tags were observed, but inflammation at the incision was noted. Four of the pallid sturgeon (mean FL = 1,322 mm [SE = 84] and mean weight = 14.8 kg [SE = 2.6]) stocked at Verdel, NE were relocated at least once during the first year, but only two fish (Fish 375 and Fish 446) were found in both 2001 and 2002, suggesting a minimum survival rate of 33% of the stocked fish (Table 1). Fish 446 was a male and the sex of Fish 375 was unknown. The two pallid sturgeon stocked at Running Water, SD were never relocated during the study.

### Habitat

In all seasons, adult pallid sturgeon were located in the main channel habitat (mean depth = 4.1 m [SE = 0.3]), except on one occasion where a fish was found in a deep (4.1 m) secondary channel in the delta formed at the headwaters of Lewis and Clark Lake. However, the Missouri River below the Niobrara River Confluence (rkm 1,358) is dynamic, with continuously shifting channels and differentiation between secondary channels and the main channel was often difficult. Fish 375 was located in this dynamic area below the confluence during the entire study, whereas, over 53 % of the relocations for Fish 446 were found above the confluence where there is a distinct main river channel habitat. No fish were found in the tailrace, island tips, backwaters, reservoir, or in tributaries. Relative depths where the two pallid sturgeon were relocated ranged from 79 to 100% of the maximum depth of the river. Turbidity in all years, seasons, and habitats was uniformly low (< 34 NTU). Bottom water velocities associated with pallid sturgeon locations ranged from 0.1 to 0.9 m/s. No substantial differences in depth, percent maximum depth, or turbidity were apparent among seasons (Table 2).

***Table 1. Size at tagging, number of relocations, and days at large for adult pallid sturgeon implanted with ultrasonic transmitters and released in the Missouri River downstream of Fort Randall Dam on 6 July and 20 September 2000.***

| Transmitter number[a] | PIT tag number | Fork length (cm) | Weight (kg) | Date last seen | Days at large | Total relocations | Relocations by year | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 2000 | 2001 | 2002 | 2003[b] |
| 244 | 7F7D291C3D | 141 | 17.1 | 12 July 2000 | 36 | 1 | 1 | 0 | 0 | 0 |
| 375 | 7F7D396837 | 107 | 7.2 | 1 April 2003 | 1029 | 10 | 3 | 4 | 2 | 1 |
| 248 | 7F7D441774 | 144 | 21.1 | 20 Sept 2000 | 0 | 0 | 0 | 0 | 0 | 0 |
| 258 | 113719262A | 137 | 9.8 | 20 Sept 2000 | 0 | 0 | 0 | 0 | 0 | 0 |
| 446 | 7F7D352F24 | 142 | 17.8 | 23 Sept 2002 | 839 | 17 | 2 | 7 | 8 | 0 |
| 2246 | 7F7D267960 | 139 | 17.4 | 13 July 2000 | 37 | 1 | 1 | 0 | 0 | 0 |

[a] Two fish were never relocated after release.
[b] Relocations in 2003 resulted from ad hoc sampling, near end of battery life for the transmitters.

***Table 2. Mean seasonal habitat characteristics with standard error (SE) in parenthesis where two adult pallid sturgeons implanted with ultrasonic transmitters and stocked in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska were relocated from 2000 – 2003. N indicates combined relocations for both fish.***

| Season | N | Temperature (°C) | Depth (m) | % max depth | Turbidity (NTU) | Bottom Velocity (m/s) |
|---|---|---|---|---|---|---|
| Spring | 6 | 6.7 (1.0) | 4.1 (1.0) | 92.0 (2.5) | 14.7 (9.7) | No data |
| Summer | 12 | 22.4 (0.7) | 4.0 (0.4) | 82.5 (4.7) | 14.1 (2.7) | 0.6 (0.2) |
| Fall | 5 | 17.3 (1.6) | 4.1 (0.3) | 87.8 (6.2) | 16.7 (10.0) | No data |
| Winter | 2 | 1.3 (0.1) | 3.7 (0.4) | 94.6 (3.0) | No data | No data |

## Fish Movement

The two fish found in all years of the study demonstrated different ranges of movement. After stocking in 2000, Fish 446 moved upstream and Fish 375 moved downstream of the stocking site (Figure 2). The mean range of movement between successive relocations of Fish 446 during the extensive tracking was 11.5 km in 2000 (n = 2 observations), 27.1 km (SE = 9.1) in 2001 (n = 7), and 13.2 km (SE = 5.0) in 2002 (n = 8). The mean range of movement between successive relocations of Fish 375 was 1.3 km (SE =1.1) in 2000 (n = 3), 2.6 km (SE = 2.5) in 2002 (n = 4), and 7.1 km in 2002 (n = 2). Substantial differences

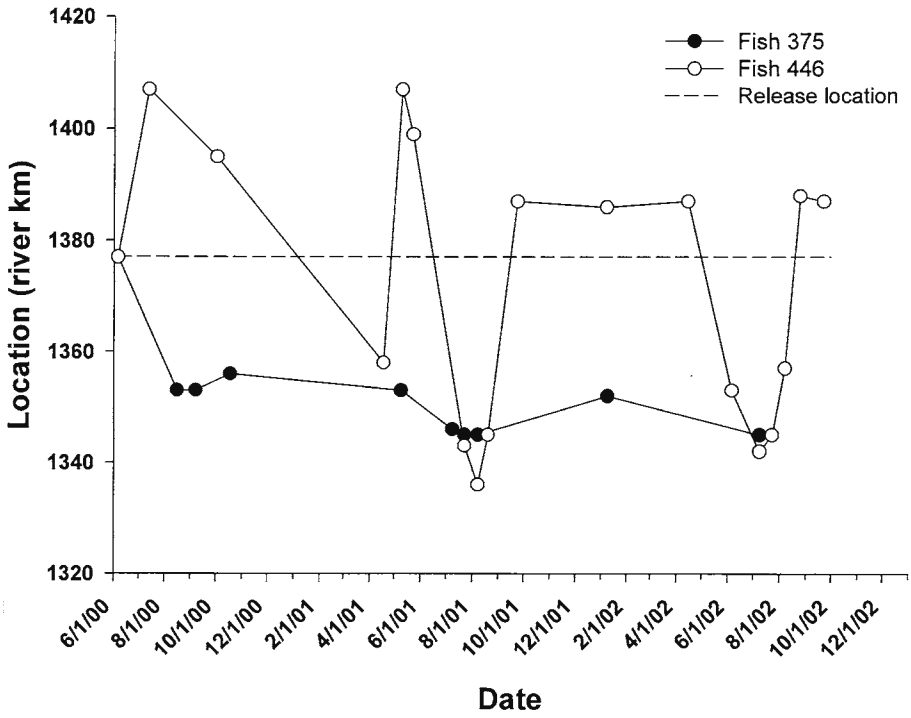


***Figure 2. River kilometer (rkm) and location by date of two sonic-tagged adult pallid sturgeon in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska from 2000 to 2002. Release location for Fish 375 and 446 was near Verdel, Nebraska (rkm 1,377).***

in maximum observed range and seasonal movement rates were found between Fish 446 and Fish 375 (Table 3). Seasonal movement rates should be interpreted cautiously as considerable fish movement likely occurred during the time period between relocations of the fish.

Both fish showed similar seasonal movement patterns of moving upstream either during late fall or in the spring and then downstream during summer; however, the magnitude of these movements differed. Fish 446 was located throughout the study area and showed a pronounced seasonal pattern. In contrast, Fish 375 remained downstream of the stocking site in the delta formed below the Niobrara River Confluence and had a reduced seasonal pattern. Fish 446 moved upstream to main river channel crossover near rkm 1,407 on 13 July 2000 and returned to the same location on 10 May 2001. Within one month during the summer of 2001, this fish then moved 64 km downstream to the Bazille Creek Confluence. The following year, Fish 446 again moved upstream to a main river channel crossover near rkm 1,387, then moved downstream to the Bazille Creek Confluence where it was located the previous summer and subsequently returned to the same upstream location observed in 2001. Fish 375 was commonly relocated at two distinct sites: 1) just upstream of Running Water (rkm 1,353) (16 August 2000 to 9 May 2001), which is characterized by

***Table 3. Range of movement (in river km) and seasonal movement rates (km/d) with standard error (SE) in parenthesis of two sonic-tagged adult pallid sturgeon from 2000 to 2003. Diel movement rates were from Fish 375 that was intensively tracked once in August, September, and October in 2000 in the Missouri River downstream of Fort Randall Dam, South Dakota and Nebraska.***

| Fish number | Maximum range (rkm)[a] | Seasonal movement rate (km/d) | | | Diel movement rate (km/h) | | | |
|---|---|---|---|---|---|---|---|---|
| | | Spring | Summer | Fall | Dawn | Day | Dusk | Night |
| 375 | 8.1 | No data | 0.04 (0.03) | 0.06 [b] | 0.05 (0.04) | 0.05 (0.01) | 0.03 (0.01) | 0.07 (0.01) |
| 446 | 45.8 | 1.11 (0.47) | 0.71 (0.19) | 0.46 (0.36) | No data | No data | No data | No data |
| 244 | No data | No data | Nodata | No data | No data | 0.63 (0.09) | 1.61 (0.43) | No data |

[a] Defined as the difference from the most upstream and downstream locations.
[b] Single observation of movement rate for Fish 375 in Fall 2000.

a dynamic area of shifting sandbars attributable to the influence of the Niobrara River's sediment load and 2) just downstream of the Bazille Creek Confluence (9 July to 8 August 2001).

Diurnal movement rates were measured on four occasions. Fish 244 was intensively tracked only on 3 August 2000 with a mean movement rate of 0.83 ± 0.16 km/h. Fish 244 was never relocated throughout the rest of the study and likely either died or left the study area. Fish 375 was intensively tracked once in August, September, and October in 2000. The data for diel mean movement rates for Fish 375 were pooled. Movement rates were substantially higher (≥ 40%) at night compared to dawn, daytime, and dusk diel periods (Table 3). The maximum movement rate was 0.15 km/h during the day and the minimum was also during the day at 0.002 km/h.

Clusters, defined as ≥ 2 fish within 750 m of each other (Jordan et al. 2006), of an adult and a juvenile pallid sturgeon were observed once on 23 July 2002. Evaluation of extensive tracking data (29 relocations) indicated Fish 375 and 446 were never observed together throughout the study.

## DISCUSSION

Our transmitter weight to fish body weight ratio never exceeded the 2% recommended by Nielsen (1992). However, the two observed mortalities were likely due to the combined stress of surgery and elevated water temperatures. Higher water temperatures have been reported to increase stress and mortality for many fish species (Walsh et al. 2000; Davis 2004; Meka and McCormick 2005). Increased infection was also reported after implantation of a transmitter at elevated water temperatures (Walsh et al. 2000). The six pallid sturgeon healed from the transmitter implantation surgery but had some inflammation around the incision at time of stocking. Warm water temperatures during surgery may have increased stress and infection, but warmer water temperatures also promotes rapid healing in sturgeon (Herb Bollig, U.S. Fish and Wildlife Service, Gavins Point NFH, personal communication; 2005). Ream et al. (2003) also

reported increased wound healing in warmer water temperatures among four teleost fish adapted to widely different thermal environments. Tews et al. (1994) found the incision wound on one adult pallid sturgeon, captured and tagged in the cold waters of the tailrace of Fort Peck Dam in Montana during July, failed to heal completely after five months. Snook et al. (2002) reported 50% of their fish shed tags or presumably died after release in the Platte River, Nebraska in April using radio tags that weighed < 1.2% of the body weight (1.2 – 2.5 kg) of age-6 juvenile pallid sturgeon. Jordan et al. (2006) also reported 56% mortality of age-3 juvenile pallid sturgeon when sonic transmitter weight to fish body weight ratios ranged from 2.1 to 3.5%. Anesthesia during surgery may reduce stress levels and increase post surgery survival. Hurley (1999) anesthetized adult pallid sturgeon with CO2 (85 L/min for 3 - 6 min) before surgery and subsequently relocated 75% of the fish 100 d after release. Fish in this study, Jordan et al. (2006), and that of Snook et al. (2002) were not anaesthetized while the tags were inserted. Based on recent experiments, the USFWS (2006) recommends a safe and effective anesthetic during surgery on pallid sturgeon may be MS-222 in water buffered with sodium bicarbonate.

## Habitat

Throughout this study, adult pallid sturgeon were almost exclusively located in the main channel with only one relocation in a deep secondary channel. However, one of the adult pallid sturgeon was located below the Niobrara River Confluence where differentiation between the main river channel and secondary river channels were often difficult due to the dynamic nature of shifting sandbars and numerous river channels. The high sediment load of the Niobrara River is deposited downstream of the confluence in the headwaters of the Lewis and Clark Lake creating a dynamic braided delta. Juvenile pallid sturgeon were also reported to use almost exclusively the main river channel in this reach of the Missouri River (Jordan et al. 2006). In the Middle Mississippi River, Hurley et al. (2004) found that adult pallid sturgeon used the main channel (39% of all relocations) despite negative selection for this habitat, but fish positively selected main channel border habitats (26%). In the Platte River, Snook et al. (2002) relocated juvenile pallid sturgeon adjacent to the main channel characterized by sharp changes in depth, but never found pallid sturgeon directly in the main channel. Bramblett and White (2001) also found that adult pallid sturgeon in the Yellowstone and Missouri rivers in Montana and North Dakota selected sinuous and dynamic river reaches with many islands and secondary channels. Middle Mississippi River adult pallid sturgeon selected for more diverse habitats downstream of island tips and wing dams (Hurley et al. 2004).

Pallid sturgeon are generally associated with deep turbid waters in the main channel of large rivers (Kallemeyn 1983). All adults in this study were predominately found in the main channel at relative depths > 79%. Juvenile pallid sturgeon in this same reach also were reported at relative depths > 80% (Jordan et al. 2006). Adult pallid sturgeon occupied somewhat smaller relative depths in the Upper Missouri River which may be due to low water clarity (Bramblett and White 2001). However, both juvenile and adult pallid sturgeon have been

located in shallow waters < 1 m (Bramblett and White 2001; Snook et al. 2002). Water clarity in the Missouri River below Fort Randall Dam was uniformly high (< 34 NTU) throughout our study which may account for the greater relative depths occupied by adult pallid sturgeon compared to adults in the Missouri and Yellowstone rivers (Bramblett and White 2001). Foraging for prey fish at greater depths and less light may be advantageous for pallid sturgeon in a river with low turbidity. Adult pallid sturgeon in Lake Sharpe, South Dakota were most commonly located in waters with bottom turbidities > 80 NTU (Erickson 1992).

In October 2002, the U. S. Geological Survey collected bathymetric data and used side scan sonar to collect images of habitat features where Fish 446 and 12 sonic-tagged juvenile pallid sturgeon were relocated as well as in unoccupied areas to assess habitat availability and selection (Elliot et al. 2004). They found that Fish 446 and the juvenile pallid sturgeon selected large sand dunes in the main channel over any other habitat available in the Missouri River downstream of Fort Randall Dam (Elliot et al. 2004; Jordan et al. 2006).

## Fish Movement

Interestingly, both adult pallid sturgeon moved up and downstream returning to what may be two or three preferred locations throughout the study reach. These fish were likely finding favorable foraging areas during the different seasons. Returning to known areas of favorable foraging would be bioenergetically profitable, reducing the time needed to search for prey. However, these movements may have been related to spawning migrations. Movements upstream were either in the late fall or early spring while downstream movements occurred in summer. This study and past telemetry studies (Hurley 1999; Bramblett and White 2001; Snook et al. 2002) have described the high mobility of pallid sturgeon. However, one of our adult pallid sturgeon, Fish 446, had a substantially higher movement range and rates among all seasons compared to the other fish. Fish 446 was a known male and may have made a spawning migration during the study. The sex of Fish 375 was unknown and may not have made a spawning migration during the study. Gamete development in pallid sturgeon is extended over several years with an estimated 3 to 5 year interval between spawning for females, compared to only 2 to 3 year intervals for males (Herb Bollig, U.S. Fish and Wildlife Service, Gavins Point NFH, personal communication; 2006). The extent of annual movement by most adult pallid sturgeon in the Missouri and Yellowstone rivers in Montana was 20 – 80 km, but some fish moved distances > 200 km during spring and summer (Bramblett and White 2001). The mean extent of movements by adult pallid sturgeon in the Mississippi River was 34 km but this was considered a minimum estimate because searches for fish generally occurred within a 60 km reach of the river (Hurley 1999). It has also been reported that adult pallid sturgeon below the confluence of the Missouri and Yellowstone rivers had directed upstream movements into the Yellowstone River during spring (Bramblett and White 2001). However, middle Mississippi River adult pallid sturgeon moved both up and downstream during spring (Hurley 1999).

We did not find any substantial differences in daily movement rates among seasons for either fish but our sample size was small. However, Bramblett and White (2001) and Erickson (1992) reported adult fish in the Missouri River moved up to 21 km/d and were most active in spring. In Lake Sharpe, mean movement rates of adult pallid sturgeons were > 2 km/d from June through August compared to < 1 km/d during the remainder of the year (Erickson 1992). Hatchery-reared juvenile pallid sturgeon stocked below Fort Randall Dam in 2000 were more active in spring and fall compared to summer (Jordan et al. 2006). Movement rates of hatchery-reared juvenile pallid sturgeon in the Platte River ranged from 0.2 – 3.3 km/d (Swigle 2003). Movement rates in this study from extensively tracked fish surveys at two week intervals would not account for fish movement that occurred between surveys. Adult pallid sturgeon activity was likely underestimated if a fish returned to the same general area it was located previously, which may explain these lower movement rates compared to fish that were intensively followed for 24 h.

We found that Fish 375 moved more at night compared to dawn, daytime, and dusk. However, movement rates of hatchery-reared juvenile pallid sturgeon in this same reach of the Missouri River did not significantly differ among diel periods (Jordan et al. 2006). Bramblett and White (2001) reported a greater proportion of adult pallid sturgeon moved during the day (56%) compared to night (37%) and hypothesized that pallid sturgeon would become more nocturnal in low turbidity habitats. They reported an average secchi depth of 20 cm. This hypothesis may explain the higher movement rates of an adult pallid sturgeon during the night in the low turbidity downstream of Fort Randall Dam. Erickson (1992) also reported significantly higher mean movement rates of adult pallid sturgeon at night (0.49 km/h) compared to during the day (0.23 km/h) with a mean turbidity of 91 NTU and mean secchi disk depth of 46 cm at adult pallid sturgeon relocations. Additionally, Hurley (1999) did not report water clarity, but reported that mean 2-hr movement rates for adult pallid sturgeon in the Middle Mississippi River were significantly greater during the day compared to night where turbidity is substantially higher compared to downstream of Fort Randall Dam.

We did not relocate the two adult pallid sturgeon within 1 km of each other throughout the study. Because of the low sample size and large study area (76 km), we are not suggesting that adult pallid sturgeon do not cluster or aggregate. Jordan et al. (2006) reported that on 15 dates, juvenile pallid sturgeon would cluster (≥ 2 fish within 750 m of each other) and these clusters were found in all seasons. Adult sturgeon also aggregated in spring and summer in the Missouri and Yellowstone rivers (Bramblett and White 2001). Although, Erickson (1992) did not consider pallid sturgeon to aggregate in a Missouri River reservoir, > 2 adult fish were found within 0.8 km of each other on four dates. These observations by Erickson (1992) are notable in context of the large study area (137 km length) and the small number of fish (n = 7) used. Spring and summer aggregations by adult pallid sturgeon may indicate fish congregating in spawning habitat, areas of high prey availability, or areas of refuge from high water velocities.

We recognize that our study was limited by small sample size (n = 2 fish). However, in the case of the pallid sturgeon, an endangered species, all field ob-

servations merit documentation to provide managers as large of a knowledgebase as possible to enhance recovery efforts. Overall this study found adult pallid sturgeon, like hatchery-reared juveniles (Jordan et al. 2006) moved throughout the remnant riverine Missouri River downstream of Fort Randall Dam known as RPMA 3 in the recovery plan (USFWS 1993). Wanner (2006) indicated RPMA 3 is suitable habitat for juvenile pallid sturgeon but whether this area will support adults and provide conditions needed for natural recruitment leading to self sustaining populations remains unknown.

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