Spawning and Associated Movement Patterns of Pallid Sturgeon in the Lower Yellowstone River

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Abstract

Documentation of pallid sturgeon *Scaphirhynchus albus* spawning Recovery Priority Management Area 2 (RPMA2) in the upper Missouri River was previously inconclusive and recruitment in this area has not been documented in 30+ years. The objectives of this study were to: 1) describe movements and habitat selection of pre-spawn and spawning-stage female pallid sturgeon, 2) identify pallid sturgeon spawning reaches within rivers (e.g., Missouri River, Yellowstone River), 3) attempt to document reproduction of pallid sturgeon, and 4) determine spawning periodicity (i.e., years between spawning events) of female pallid sturgeon. In 2007, fifteen adult pallid sturgeon (two gravid females, one non-gravid females, twelve males) were intensively tracked in the lower Yellowstone River. Female pallid sturgeon did not spawn at the most upstream location. Non-spawning migrations were not similar to spawning migrations. Aggregations of males and changes in movement patterns of females appeared to have indicated spawning time and location. Steroid levels and biopsies verified spawning of both gravid females. Spawning most likely occurred approximately three days after maximum discharge and when temperatures were 20^{o}C. D-net sampling for eggs and larvae occurred in areas below aggregations. This sampling resulted in a total of 458 paddlefish larvae, 107 *Scaphirhynchus* larvae, 9 unknown Acipenserform larvae, and 56 Acipenserform eggs and embryos. All *Scaphirhynchus* larvae, unknown larvae, and 42 eggs and embryos were sent to the USFWS Abernathy Fish Technology Center for genetic confirmation as pallid sturgeon or shovelnose sturgeon (results pending). Female pallid sturgeon appear to spawn every 2-3 years. Results from this study indicate that the Yellowstone River is suitable for pallid sturgeon spawning. Findings of this study will help to identify the bottleneck of pallid sturgeon recruitment in the upper Missouri basin.

Background

The pallid sturgeon *Scaphirhynchus albus* is critically imperiled throughout its native range, and is listed as a federally endangered species (Dryer and Sandvol 1993). In an effort to obtain basic biological information and applications to management and recovery, pallid sturgeon have been the focus of telemetry studies in Recovery Priority Management Area 2 (RPMA2) which includes the Missouri River between Fort Peck Dam and Lake Sakakawea, and the Yellowstone River.

Initial telemetry studies by Clancey (1990) focused on the short-term movements of three adult pallid sturgeon originally tagged in the tailwaters of Fort Peck Dam during March 1989. Sexes were not known for these fish. Two fish moved downstream by mid-June, and the third individual remained in the tailwater. All three of the external tags were shed by August. Minimal information on habitat use characteristics was collected.

Expanding on the 1989 study, Clancey (1991) reported capturing and tagging two pallid sturgeon in the tailwaters of Fort Peck Dam during winter 1990 and four pallid sturgeon below the Yellowstone River confluence. Sex was not determined on the fish. Minimal information on movements and habitat use was collected and reported. Clancey (1992) reported that transmitters were affixed to three pallid sturgeon during 1991. One individual was collected in the tailwaters of Fort Peck Dam between January and March, and the other two were collected below the Yellowstone River confluence in May and October. Sex was not determined for these fish. Relocations on these fish were infrequent, thus minimal habitat use information was collected.

In 1992, nine pallid sturgeon collected from the Yellowstone River and Missouri River downstream from the Yellowstone River were tagged (Tews and Clancey 1993). Sex of these fish was not determined. This study marked the initiation of obtaining more detailed information on habitat characteristics associated with pallid sturgeon relocations. A summary of initial pallid sturgeon studies conducted below Fort Peck was summarized in Tews (1994).

More intensive telemetry studies of pallid sturgeon movements and habitat use in RPMA2 were conducted during 1992 – 1994 (Bramblett and White 2001). In this study, 24 pallid sturgeon were tagged with transmitters and seasonally relocated in the Yellowstone River and Missouri River upstream and downstream from the Yellowstone River confluence. One of the fish was a known female, but sex of the remaining fish was unknown. Important information on seasonal movements and habitat use characteristics was determined from this study. Pallid sturgeon primarily migrated into and used the Yellowstone River during spring and summer, and used the Missouri River downstream from the Yellowstone River during fall and winter. Results from this study also led to the speculation that pallid sturgeon spawn in the lower 6 – 12 km of the Yellowstone River based on the recapture of the known female in this area, and based on the finding that most aggregations of pallid sturgeon occurred in this area. However, there was no conclusive evidence presented to support this hypothesis. In addition to information on movements and aggregations, the study of Bramblett and White (2001) provided important information on habitat use characteristics (depth, velocity, substrate, channel configurations) of pallid sturgeon, and differences that exist between pallid sturgeon and shovelnose sturgeon.

More recently, the U. S. Fish and Wildlife Service (USFWS) initiated a study to examine movements and habitat preferences of adult post-spawn pallid sturgeon of known gender in RPMA2 (USFWS 2001). In this study variable numbers of male and female pallid sturgeon spawned in hatcheries were tagged with combined radio/acoustic transmitters (CART tags), released back into the Missouri River after recovery from hatchery spawning and surgery, and seasonally relocated. Specific objectives of the 2001 study were to: 1) identify and monitor migrational behavior and spawning habitat of post-spawn adult male and female pallid sturgeon, 2) determine pallid sturgeon response to "spring flows" from Fort peck Dam and Yellowstone River, and assess potential spawning behavior and movement, 3) utilize congregations of pallid sturgeon to assist with collection of broodstock pallid sturgeon for propagation efforts, and 4) recapture known post-spawn telemetered pallid sturgeon to assess degrees of maturation of eggs, gestation periods, and times between spawns (USFWS 2001). Information has been gained on seasonal movement patterns of "post-spawn" pallid sturgeon since inception of this project (see King and Wilson 2002, 2003, 2004; USFWS 2005); however, similar to Bramblett and White (2001), information specific to individuals in spawning condition has been limited because ready-to-spawn individuals have not been studied. Furthermore, information on intervals between spawning (e.g., how many years?) has been limited due to the limited availability of females used in the project and tag loss of implanted females. To date, information on spawning intervals is restricted to a single female pallid sturgeon and this information is inconclusive (King and Wilson 2003). One of the primary objectives of the USFWS (2001) pallid sturgeon telemetry study was to determine pallid sturgeon responses to spring flows from the Fort Peck Dam spillway. Unfortunately, releases from the spillway have not occurred, and it is unclear as to when reservoir levels will be sufficient enough to perform a release. Thus, although the present study has a few years of baseline information on movement patterns and river selection (e.g., Missouri River vs. Yellowstone River) of post-spawn pallid sturgeon prior to implementation of spillway releases, additional information is needed prior to, during, and after flow changes are implemented.

Objectives

1) Describe movements and habitat selection of pre-spawn and spawning-stage female pallid sturgeon

2) Identify pallid sturgeon spawning reaches within rivers (e.g., Missouri River, Yellowstone River)

3) Attempt to document reproduction of pallid sturgeon

4) Determine spawning periodicity (i.e., years between spawning events) of female pallid sturgeon.

Study Area

The spatial extent of the study area in Montana and North Dakota included 350 km of the Missouri River from Fort Peck Dam downstream to near the headwaters of Lake Sakakawea and the lower 114 km of the Yellowstone River (Figure 1). Fort Peck Dam was closed in 1937, and discharge releases are regulated year-round (Bowen et al. 2003). Mean annual discharge under existing operations is 281 m^3/s (gage number 06177000; USGS 2006a). Hypolimnetic withdrawls from Fort Peck Reservoir routed through Fort Peck Dam suppress water temperatures in the Missouri River; mean and maximum water temperatures between late-April and mid-October are 5.2^oC and 8.9^oC cooler, respectively, in the river below Fort Peck Dam than in the free-flowing river upstream from Fort Peck Dam (Braaten and Fuller 2006). Extensive patches of gravel and cobble occur primarily in the upper 100 km of the Missouri River downstream from Fort Peck Dam and to a lesser extent in the lower portions of the river. The closure of Garrison Dam in 1953 created Lake Sakakawea, and the headwater of the reservoir establishes the terminus of free-flowing conditions in Missouri River downstream from Fort Peck Dam. The transition zone from free-flowing river to reservoir headwaters varies annually in association with changes in reservoir water levels.

The Yellowstone River was the primary focus of the study and is a large (mean annual discharge = 353 m^3/s; gage number (06329500, USGS 2006b) free-flowing river that enters the Missouri River upstream from the headwaters of Lake Sakakawea (Figure 1). Although there are six mainstem low-head irrigation structures on the Yellowstone River, it maintains a relatively natural hydrograph and thermal regime (Bowen et al. 2003). Substrate is primarily gravel and cobble upstream of river kilometer (rkm) 50 and is primarily fines and sands below (Bramblett and White 2001). Precipitation and snow-melt events contribute to large discharge pulses in spring and early summer. Intake Diversion Dam spans the river 115 km upstream from the mouth and delimits the upstream extent of the Yellowstone River study area in this study.

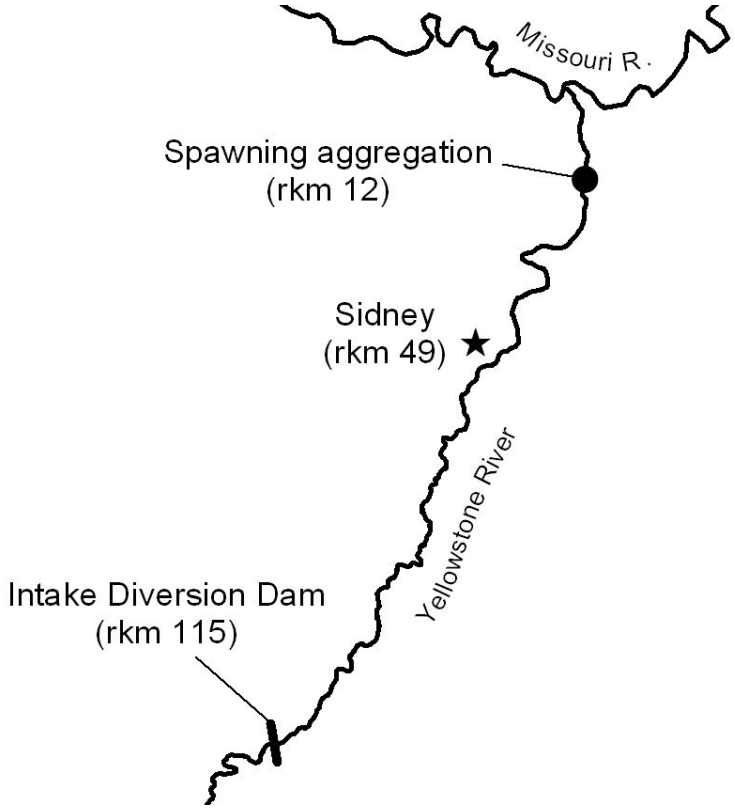

Figure 1. Map of study area

Methods

Capture and implantation

In 2007, the goal for this study was to implant two stage 5 post-vitellogenic female pallid sturgeon. Pallid sturgeon were sampled using 45.7m X 2.4 m drifted trammel nets, that consisted of a 15.2 cm mesh panel and a 25.4 cm mesh panel. After capture, fork length (FL; mm) and weight (kg) were measured by placing the pallid sturgeon in a mesh sling. Each sturgeon was tagged with a passive integrated transponder (PIT) tag placed in the muscle at the base of the dorsal fin, if a tag was not already present. A tissue sample from a pectoral fin was taken for genetic analysis and preserved in 90% non-denatured ethanol. A biopsy was performed to determine sex and stage of the fish and a blood sample was taken. Individuals were partially submerged and water was continually flushed over the gills using a bilge pump apparatus. Using the same incision from the biopsy, a shielded needle technique (Ross and Kleiner, 1982) was used to extrude the antennae through the body wall. The transmitter was inserted in the body cavity and the incision was closed with individually knotted vicryl sutures. Pallid sturgeon were implanted with Lotek (Lotek Wireless Incorporated, New Market, Ontario) coded transmitters (MCFT 3L, 16 mm x 73 mm, 26 g, 1462-day longevity). After processing, pallid sturgeon were released near the point of capture. All pallid sturgeon captured were handled in accordance with the handling protocol developed by the U.S. Fish and Wildlife Service (2007).

Telemetry

Implanted pallid sturgeon were relocated by boat at least once per week from the time of implanting until the oocyte polarization index from either female was estimated to have reached 0.05. Wild sturgeon females have been captured with mean oocyte polarization indices of 0.0367 (Webb and Erickson, In Press; Van Eenennaam et al., 2006). Oocyte polarization index in the telemetered pallid sturgeon was determined by estimating the rate of germinal vesicle migration in pre-spawning pallid sturgeon females maintained at Miles City State Fish Hatchery. Germinal vesicle migration is temperature-dependent. Therefore, the water temperature profile at Miles City State Fish Hatchery was compared to the temperature profile in the Yellowstone River and appropriate rates of germinal vesicle migration were applied to the wild pallid sturgeon female. Once the polarization index reached 0.05, fish were relocated daily until being recaptured to verify spawning. Pallid sturgeon relocation sites were quantified using GPS coordinates and river km. The existing series of automated telemetry ground stations in the study area were also used to detect fish movement events.

Larval sampling

The rectangle net for larval sampling consisted of a 3-m long net (1,000 micron mesh) attached to a 0.75 m X 0.5 m frame with an intake area of 0.375 m^2. Two lead weights (4.5 kg) were attached to the frame to ensure bottom contact and to prevent spinning. A velocity meter (General Oceanics Model 2030 R) was mounted in the frame opening, which was used to determine the total volume of water sampled in each set. Since pallid and shovelnose sturgeon larvae drift for an extended period of time (Kynard et al., 2002, Bratten and Fuller, 2004, Kynard et al., 2007, Braaten et al., 2008) and primarily near the river bed (Bratten and Fuller, 2004, Braaten et al., 2008) paired rectangle nets were fished on the bottom at river kilometer 6 of the Yellowstone River, below all suspected spawning areas. The site consisted of three replicates across the river channel at the inside bend (ISB), mid-channnel (MID), and outside bend (OSB) and each replicate consisted of 2-10 subsamples. Set durations ranged from 2-10 min depending on detrital loads. Net contents were then thoroughly inspected for Acipenserform eggs and larvae immediately after retrieval by emptying contents in a large tray and placing specimens in vials containing 90% denatured alcohol. Larvae were later identified as Polyodontidae or Acipenseridae in the lab. Eggs were preserved in the same manner.

Larval sturgeon were sent to the USFWS Abernathy Fish Technology Center for genetic confirmation as pallid sturgeon or shovelnose sturgeon. If identified as a pallid sturgeon, larvae were screened against parental genetic lines to determine if the larvae originated from the implanted female(s), in a similar manner as used by DeHaan and Ardren (2007). Acipenserform eggs were also sent to the lab in Abernathy, although methods have yet to be determined to distinguish differences of *Scaphirhynchus* species and parental linkage.

Recollection of Females

Females were recaptured after they exhibited a change in movement pattern or when temperatures exceeded 24^{o}C. When recaptured, the fish was weighed, and a gonadal examination was conducted via biopsy to determine if the fish had spawned and the incision was closed with silk sutures. The gonad sample was preserved in 10% buffered formalin and examined via histology by the USFWS Bozeman Fish Technology Center. If the post-ovulatory follicles had not collapsed, this provided evidence that the fish had spawned within the last two weeks of obtaining the sample (Molly Webb, personal communication). If they had collapsed, it was indicative that the fish spawned greater than two weeks prior to collecting the sample; therefore, larvae and egg samples were used to determine when the fish had spawned. A blood sample was also taken to compare pre and post spawn steroid levels (Webb et al., 2002).

River discharge and temperature

River discharge data were obtained from the USGS Sidney, MT station (gage number 06329500). Water temperature loggers (Optic StowAway, -5°C – +37°C, 4 min response time, accuracy + 0.2°C from 0 - 21°C) deployed near the larval sampling location recorded water temperature at 1-hr intervals.

Results

At the onset of the project in April 2007, we assumed to have two gravid females already implanted for the study. Code 114 and code 79 were used in the propagation program in 2004 and both contributed to progeny to RPMA2 via hatchery spawning and juvenile stockong events. These females were implanted prior to their release in the fall 2004. Code 114 had a biopsy performed in fall 2006. A biopsy was performed on code 79 in spring 2007. Histological results from both samples indicated that they would be gravid in 2007. Therefore, both females had a spawning periodicity of three years. Interestingly, blood work from code 114 indicated that this fish had very low steroid levels and was exhibiting the initial stages of atresia. These fish were tracked at weekly intervals during on-going telemetry studies by Braaten and Fuller (2006, 2007) which resulted in non-spawning movement patterns for these fish in 2005 and 2006 (Figures 2 and 3).

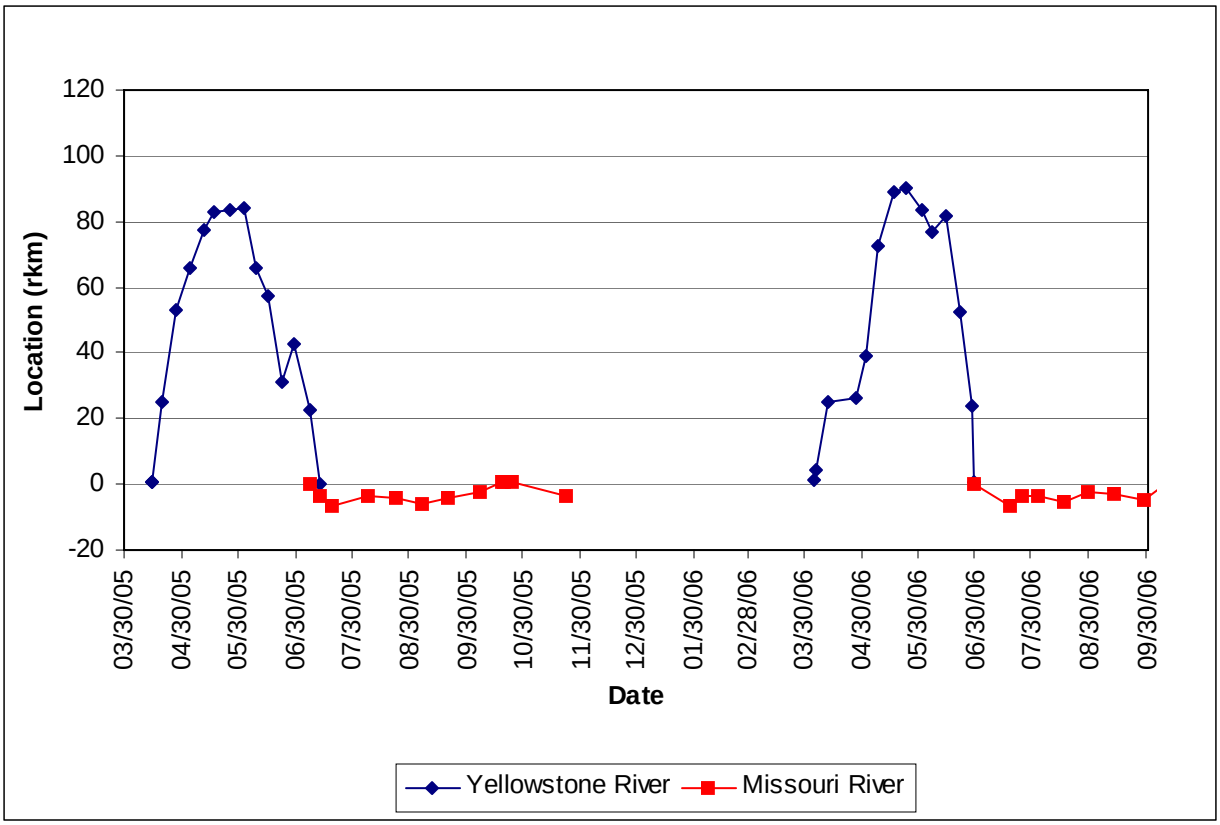

Figure 2. Movement patterns of non-gravid female pallid sturgeon – code 114 in 2005 and 2006. (River kilometer "0" is the confluence of the Yellowstone and Missouri rivers, "-" values are the in the Missouri River downstream of the confluence.

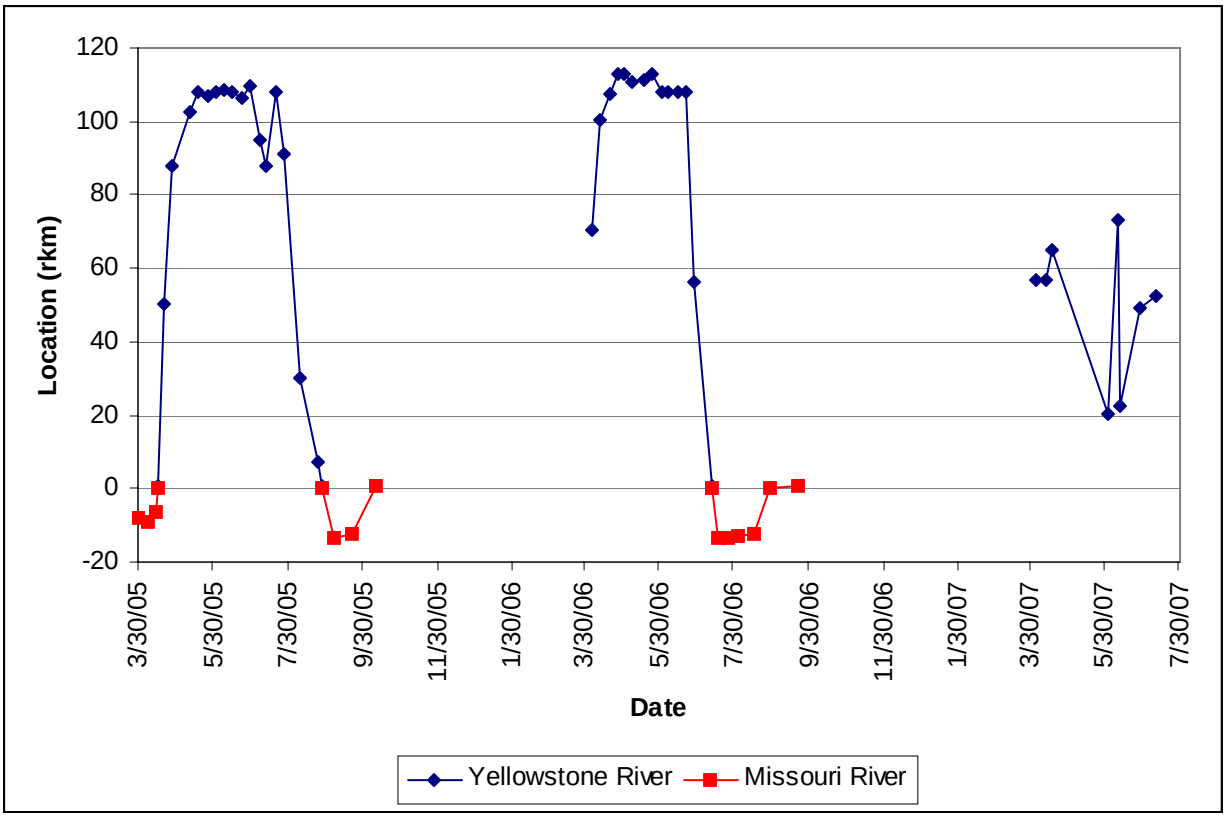

Figure 3. Movement patterns of non-gravid female pallid sturgeon – code 79 in 2005, 2006, and 2007. (River kilometer "0" is the confluence of the Yellowstone and Missouri rivers, "-" values are in the Missouri River downstream of the confluence).

Both of these fish began their migrations up the Yellowstone River in early April before a major flow event, resided at their most upstream point for 2-7 weeks and exited the Yellowstone River after flows receded. These fish also exhibited site-fidelity, returning to the same area in 2005 and 2006 (river kilometer 85 for code 114, rkm 110 for code 79). During these years, these fish only selected the Yellowstone River and were never relocated in the Missouri River above the confluence.

After several tracking events in spring 2007, code 114 had not moved and was assumed to have died or have expelled its transmitter. Therefore, another gravid female was implanted on April 18, 2007 in the Yellowstone River above Fairview, MT – code 155. This fish was last captured in 2002, had not been used in the propagation program, and its sex was undetermined at that time. In addition to these two gravid females, there was also one non-gravid female and 12 males used in the study. An additional four-telemetered pallid sturgeon were taken to hatcheries in 2007 and one individual has been at liberty since July 2006. All of these fish were originally implanted from 2000 to 2007 (Table 1).

Table 1. Telemetered pallid sturgeon used in the 2007 spawning characteristics study. A "+" following number stocked indicates yearlings have not been stocked yet and number stocked are fall fingerling and/or fry stockings.

Code	PIT #	Sex	Weight	Implant Year	Used for Propagation, # ,Yrs at hatchery	Notes
Females						
155	220E7E3A38	F	16 kg	2007	No	Gravid 2007 - for study
79	454910202B	F		2004	Yes (4,685 + 75k fry), 2004	Gravid 2007 - for study
140	115716093A	F	17 kg	2007	No 2002 & 2004	White eggs/stage 3 in 2007
Males						
96	43105C602B	M	11.2 kg	2003	No	
27	1F47606357	M	16 kg	2004	Yes (43,401), 2004 + cryo	
28	220F0F7677	M	16 kg	2004	Yes (1,588), 2004 + cryo	
32	220F0E6207	M	19 kg	2004	No 2004 + cryo	
97	7F7F065834	M	16 kg	2004	Yes (906), 2004 + cryo	
67	1F4A33194B	M	20 kg	2000	No 2000 & 2006 +cryo	
70	4718447879	M	13.5 kg	2006	No	
80	7F7B082C10	M	21.5 kg	2006	No	
71	220F107A6F	M	15 kg	2006	Yes (2,173), 2002 + cryo	
144	115679523A	M	21.5 kg	2007	No	
145	1F4A312640	M	23.5 kg	2007	Yes (22,078), 1995 & 2004 + cryo	
154	220E5F6E26	M	30 kg	2007	No 2003	
Other telemetered pallid sturgeon not present during the study						
14	115631222A	M	13.5 kg	2001	Yes (300+3,846 +), 2001 & 2007 + cryo	Taken to hatchery in 2007
31	115553544A	F	19 kg	2004	Yes (21,219 +) 1999, 2002 & 2007	Taken to hatchery in 2007
129	220E5F4928	M	17.2 kg	2004	Yes (11,335 +) 2004 & 2007 + cryo	Taken to hatchery in 2007
68	115525534A	M	15 kg	2000	Yes (1798 +), 2000, 2006 & 2007+ cryo	Taken to hatchery in 2007
121	1F4B246E04	F	24 kg	2005	Yes (876), 1997	At large / Lake Sakakawea

Movement patterns

Code 79 - The transmitter for code 79 was not functioning properly and only a few relocations were obtained (Figures 3 and 4). However, it was evident that the non-spawning migrations were not similar to its spawning migration (Figure 3). The Yellowstone River from Intake diversion to the confluence was tracked at least weekly in 2007, all relocations obtained were below rkm 75 with two relocations at rkm 20. In contrast, code 79 was relocated weekly throughout the months of May and June above rkm 100 in 2005 and 2006.

Code 155 - We were able to relocate code 155 almost daily (Figure 4). This fish was initially implanted in the Yellowstone River at rkm 20. Code 155 made a 90 kilometer upstream migration to Intake Diversion Dam, spent three days there, and then abruptly migrated back downstream. Over the next two weeks this fish exhibited a roaming behavior, migrating up and down the Yellowstone River from the confluence to rkm 20. After June 15, it did not move for two weeks. This fish exited the Yellowstone River on July 11.

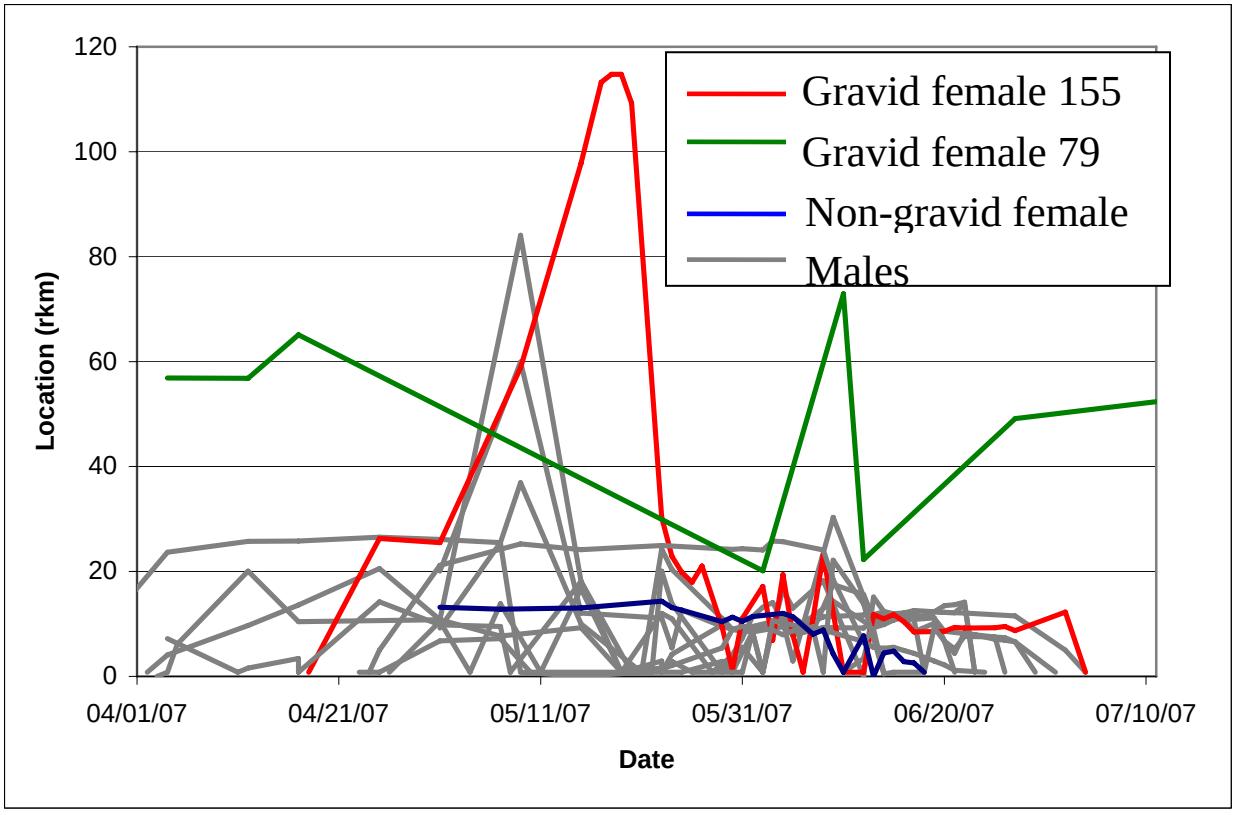

Figure 4. Movement patterns of pallid sturgeon in 2007.

Males - Most males migrated into the Yellowstone River from the Missouri River below the confluence by early April (Figure 4). One exception was code 96, which was residing in the tailrace below Fort Peck Dam. This fish migrated nearly 300 kilometers downstream, entered the Yellowstone River on June 9 and remained there until June 26. This fish then migrated back up the Missouri River to the tailrace below Fort Peck Dam. One male did not ascend above the Yellowstone/Missouri confluence. One fish (code 70) was relocated near Intake Diversion Dam on April 25, and was not found again until mid-September near the confluence of the Missouri River. Fish were very active throughout April and May, constantly moving upstream and downstream up to 20 km/day. On June 13, seven males and female code 155 formed an aggregation at rkm 12 of the Yellowstone River (Figure 5). The remaining three males were in the area but not part of this aggregation. This aggregation formed shortly after the hydrograph began declining (Figure 6). Fish remained in this area for a median of 3 days (range 2-15 days). Afterwards, the roaming behavior ceased and they began emigrating out of the Yellowstone River to areas below the confluence. Blood assays were conducted on three telemetered males;
codes 70, 144, and 154, steroid levels indicated that all of these fish were in spawning condition in 2007. Two of these fish were part of the aggregation.

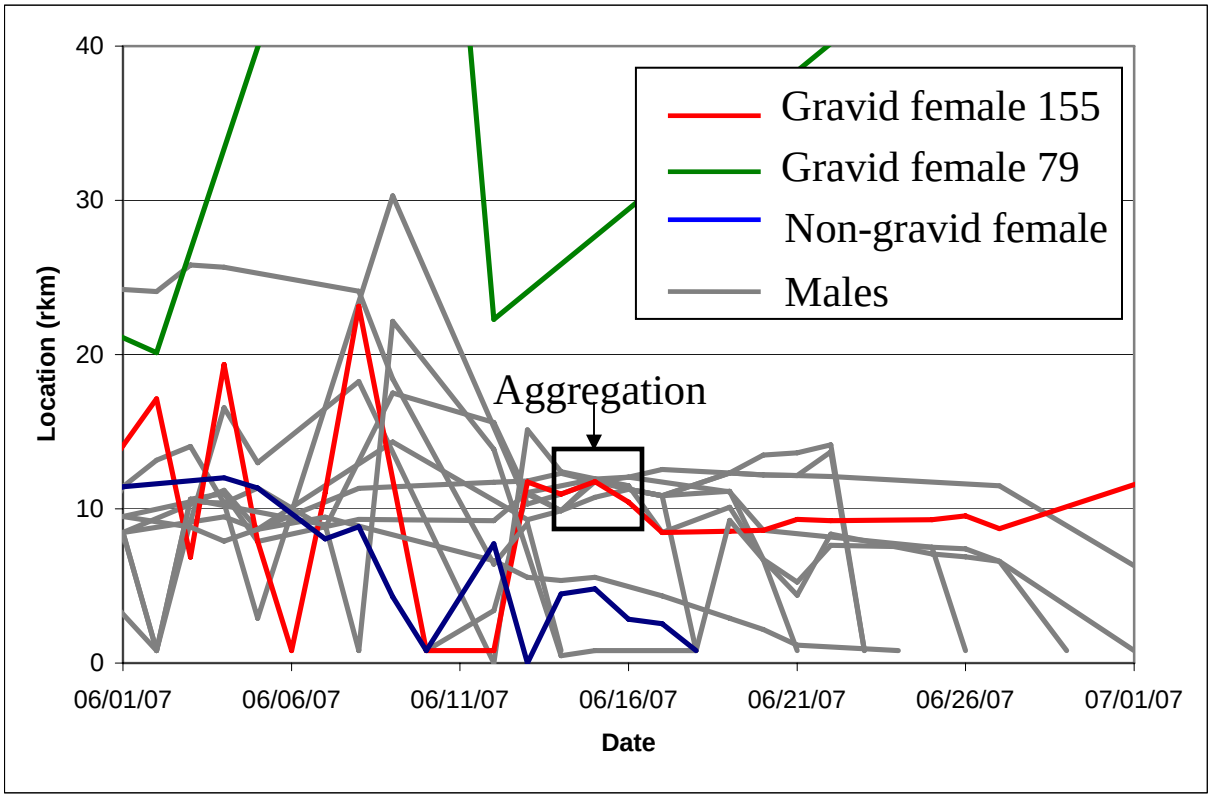

Figure 5. Aggregation of seven males and code 155.

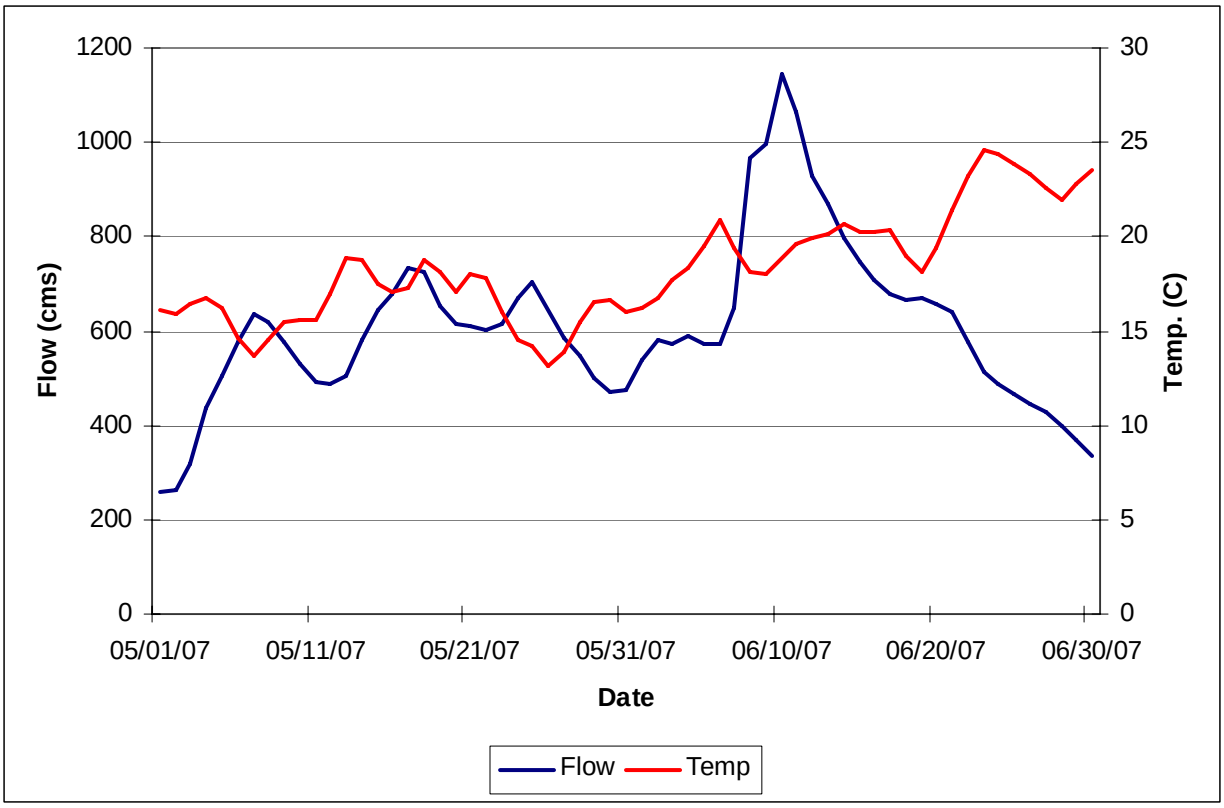

Figure 6. Temperature and flow of the Yellowstone River near Sidney, MT – 2007

Recollection/Spawning verification

Code 79 was recollected on June 25 near Sidney, MT (rkm 50). This fish lost 22% of its body weight since April 15 and appeared to have spawned based upon a gonadal examination. Steroid levels were also a positive indication that it had spawned (Table 2).

Code 155 was recollected twice. On May 24, after a long downstream migration Figure 4), this fish was recollected but had not spawned based on a gonadal examination. One month later, June 26, after converging with the aggregation of males and a exhibiting a change in movement pattern, it was recollected and was determined to have spawned. Code 155 lost 12.5% of its body weight, the body was devoid of eggs, and steroid levels indicated that this fish had spawned (Table 2). The post-spawn gonad sample has not yet been examined to determine if the post-ovulatory follicles have collapsed.

There were no post-ovulatory follicles present in either tissue samples collected, therefore it was undetermined if these fish had spawned two weeks prior to collection.

Table 2. Pre-spawn and post-spawn weights and steroid levels of Code 79 and Code 155 (KT = ketotestosterone , T = Testosterone, E2 = Estradiol, ND = Non-Detectible)

Fish	Code 79		Code 155	
Date	4-5-07	6-25-07	4-18-07	6-24-07
Body Weight	18 kg	14 kg	16 kg	14 kg
KT	5.78 ng/ml	ND	5.22 ng/ml	ND
T	44.19 ng/ml	ND	49.69 ng/ml	ND
E2	13.81 ng/ml	ND	2.62 ng/ml	ND

Larval collections

A total of 238 larval subsamples were collected from May 30 to June 28, 2007 during 16 sampling events. Mean volume of water sampled per subsample was 93.7 m^3 (total 22,310 m^3). Paddlefish larvae were collected from the first date of sampling through June 22 and peaked at 8.55 larvae/100m^3 on June 6 (Figure 6). Sturgeon larvae were first collected on June 5 and were still being collected on the final date of sampling on June 28. Maximum density of 2.37 larvae/100m^3 occurred on June 26, although no sampling was conducted for three days prior to that date. There was a total of 458 paddlefish larvae, 107 *Scaphirhynchus* larvae, 9 unknown Acipenserform larvae, and 56 Acipenserform eggs collected. All Scaphirhynchus larvae, unknown larvae, and 42 eggs were sent to Abernathy for genetic testing. Initial results from the lab at Abernathy indicated that no pallid sturgeon larvae were collected on June 19, 20, or part of the 21 (n=33). The inside bend (depth = 1.7 m) collected the fewest larvae (cpue 0.114 larvae/100m^3). The mid channel (2.9 m) and outside bend (3.6 m) had much higher catch rates at 0.791 larvae/100m^3 and 0.808 larvae/100m^3 respectively.

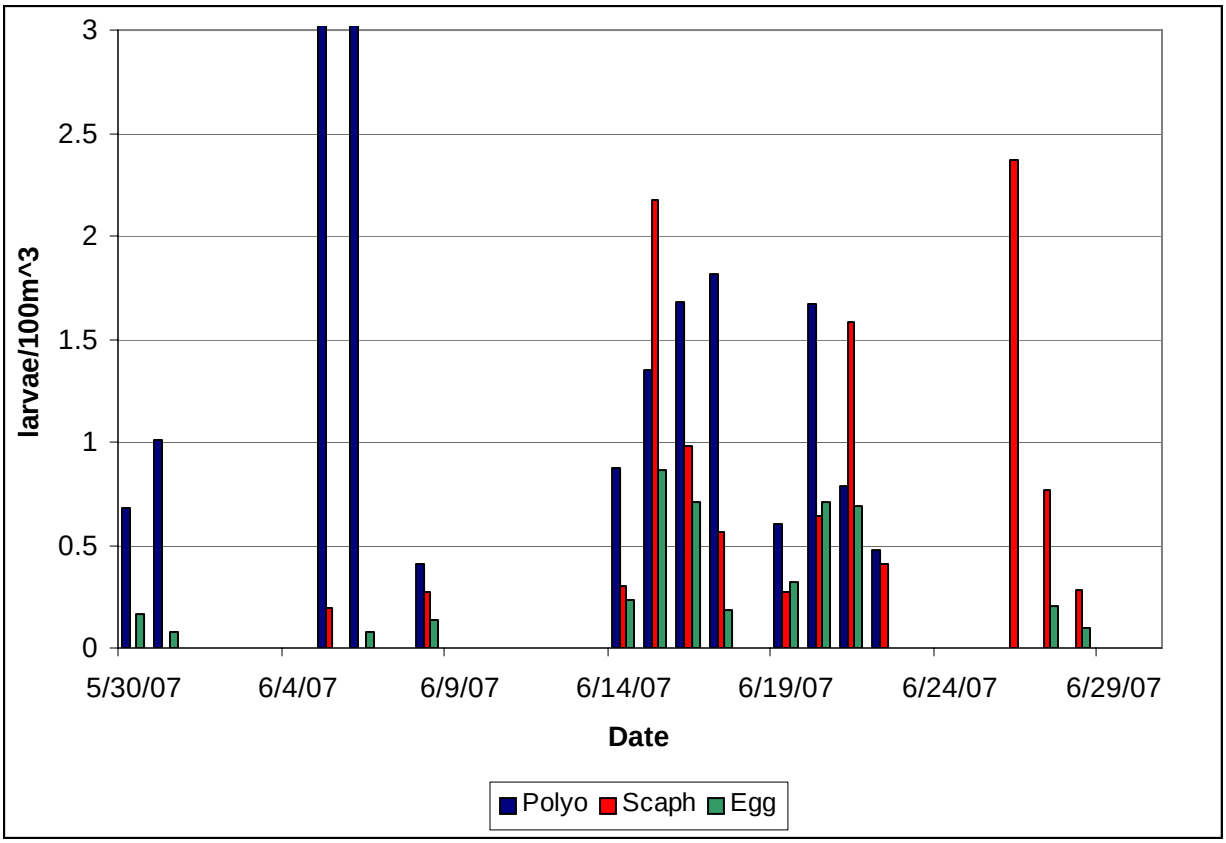

Figure 6. Acipenserform larvae and egg/embryo cpue by date in 2007. (Paddlefish cpue >8.3 larvae/100 m^3 on 6-5-07 and 6-6-07)

Spawning periodicity

Prior to 2007, there were only two female pallid sturgeon that had been taken to the hatchery in consecutive spawning cycles(Table 3). Both of these fish had a spawning periodicity of two years. In 2007, thirteen female pallid sturgeon were taken to hatcheries. Two of these fish were used in 2005 indicating a two-year cycle, and one was used in 2004 indicating a three-year cycle.

As mentioned earlier, the two previously telemetered female pallid sturgeon had a three-year spawning periodicity. One other telemetered female, code 31, was tagged in the spring of 2004 with stage one eggs and was successfully spawned at Gavins Point National Fish Hatchery in 2007. This fish had another gonadal examination in the fall of 2005 and had immature eggs. This may indicate that this fish had a four-year cycle or this fish may have spawned in 2005 and 2007 suggesting two two-year cycles.

Table 3. Spawning periodicity of female pallid sturgeon. An (H) indicates the fish was taken to the hatchery.

PIT	Radio	Year 1	Year 2	Periodicity
7F7B026102	-	2003(H)	2005(H)	2
1F497F1801	-	2004(H)	2006(H)	2
4443230458	-	2005(H)	2007(H)	2
115557165A	-	2005(H)	2007(H)	2
454B380D60	-	2004(H)	2007(H)	3
454910202B	79	2004(H)	2007	3
114476216A	114	2004(H)	2007	3
115553544A	31	2003?	2007(H)	2 or 4

Discussion

At this point, we are assuming the aggregation formed on June 13-16 at river kilometer 12 and the change in movement patterns indicated the spawning time and location. Pallid sturgeon began their migrations into the Yellowstone River by early April, prior to a major discharge event, which contrasts white sturgeon (Paragamian and Kruse 2001) migrations. Both females and males were very active migrating several kilometers every day prior to forming the aggregation. Fish remained in the aggregation for approximately three days. This is different than white sturgeon (Paragamian and Kruse 2001, Paragamian and Wakikinen 2002,) and lake sturgeon (Bruch and Binkowski 2002) where males arrive at the spawning grounds first followed by females. It appears that pallid sturgeon spawned on the descending limb of the hydrograph similar to shortnose sturgeon (Kieffer and Kynard, 1996) and white sturgeon (Perrin et al. 2003). After spawning both males and females eventually migrated downstream to areas below the confluence. Downstream movement after spawning is also characteristic of gulf sturgeon (Sulak and Clugston 1998), white sturgeon (Paragamian and Kruse 2001), lake sturgeon (Bruch and Binkowski 2002), and shortnose sturgeon (Buckley 1982) although Buckley and Kynard (1985) reported that fish only moved down about 2 km for about two weeks and then moved down lower to summer feeding areas which was similar to the female pallid sturgeon's pattern. Interestingly, the female was the last fish to emigrate out of the Yellowstone.

Code 155 did not spawn at its most upstream point. This fish was potentially blocked by the diversion structure at Intake but still spawned in a lower portion of the Yellowstone River. Females of some sturgeons, when prevented from reaching spawning areas because of barriers or manipulated water flows, either resorb their eggs and do not spawn or survival of spawned eggs is reduced (Artyukhin et al. 1978; Vescev and Novikova 1983, 1988 from Auer 1996). Certain sturgeon species have shown homing fidelity such as gulf sturgeon (Heiss et al. 2004) and lake sturgeon (Lyons and

Kempinger 1992 in Auer 1996, Bruch and Binkowski 2002), this is still unknown for pallid sturgeon.

Egg collectors (McCabe and Beckman, 1990) and egg tubes (Firehammer et al., 2006) were constructed; however, they were not used in the study in 2007. Preliminary trials of both types of collectors indicated that neither would work well in sand substrate and most relocations were on sand. At the time of the study, pallid sturgeon exhibited a roaming behavior and did not give indication of where to set the mats. Future studies should include egg collectors at the identified site if sturgeon species can be genetically differentiated from eggs.

Since egg collectors were not deployed in 2007, spawning habitat was not identified on a small-scale level. The aggregation of fish occurred in a bluff pool below Fairview, MT at rkm 12. Locations of aggregations in 1993 also suggested that rkm 6-12 of the Yellowstone River may be potential spawning areas for pallid sturgeon (Bramblett 2001). This area is relatively deep (3-4 m) and is the first site that contains a substantial amount of gravel/cobble substrate as fish migrate upstream.

Reproduction of paddlefish and sturgeon species in the Yellowstone River seemed to be relatively high in 2007 based on larval collections from this study and past studies from the Fort Peck Flow Modification field crews (Braaten and Fuller 2003-2007). There were some sturgeon collected as early as June 5 and June 8 however these were large individuals (12-14 mm). Based on Braaten and Fuller (2007), these fish were approximately 6 dph and most likely were produced from areas upstream from Intake and were nearing the end of their drifting life stage (Braaten et al. 2004).

In addition to code 31, three telemetered males were taken to hatcheries in the spring 2007. All of these fish were spawned successfully and made significant contributions to RPMA2. Therefore, it does not appear that there are any detrimental effects on transmitter implantation and spawning/spawning periodicity in pallid sturgeon. These fish were tagged with CART-32-2s (32 mm x 101 mm, air weight 114 g, 1095-day longevity) and (MCFT 3L) tags, which are much smaller (16 mm x 73 mm, 26 g, 1462-day longevity).

An important application of this study was to help identify the bottleneck of pallid sturgeon recruitment in RPMA2 of the Missouri River basin. This was the first documentation of pallid sturgeon spawning in this area. There is still an outstanding information gap that exists between spawning and age 17-day post hatch (dph) larvae that may explain the lack of recruitment in this area. First, the extant population of 158 adults (Klungle 2005) may be too small to have progeny successfully recruit into the population. Nichols et al. (2003) estimated that less than 1% of lake sturgeon eggs deposited during spawning survived to hatch. Secondly, water temperatures may be exceeding lethal temperatures for embryos due to drought and changing environmental conditions. Webb and Kappenman (unpublished data) reported that temperatures between 24 and 26 C were lethal for pallid and shovelnose sturgeon embryos. Maximum temperatures exceeded 26^{o}C by July 1, 2007. Levels of contaminants and their affects on embryo and larval survival are still unknown at this time. Thirdly, if embryos do survive to hatch, larval pallid sturgeon may require 245-530 km of river, depending on water velocity, to complete their ontogenetic development (Braaten et al. 2008). Braaten and Fuller (2003) reported capturing young-of-year pallid sturgeon; however, identification was based on morphometrics and meristics. Unfortunately, results from the genetics and

morphometrics/meristics analyses are somewhat contradictory. In 2004, genetic testing of 29 individuals sent to Dr. Ed Heist and Aaron Schrey (Southern Illinois University) indicated that two individuals sampled from the Highway 85 bridge site in North Dakota (sample date 8/12/03, length = 22 mm; sample date 8/26/03, length = 21 mm) exhibited a pallid sturgeon genotype (Schrey and Heist 2004). The genotype from the first individual was strongly indicative of a pallid sturgeon as this individual was 210 times more likely to have been generated from a pallid sturgeon gene pool than a shovelnose sturgeon gene pool. Conversely, the second individual was only 1.6 times more likely to have been generated from a pallid sturgeon gene pool. Thus, based on genetic testing, it is highly likely that limited pallid sturgeon reproduction occurred during 2003. In this year, no *Scaphirhnchus* larvae were collected from the Yellowstone River after July 15. In contrast, sturgeon larvae were collected from the Missouri River near Wolf Point in late July and early August (Braaten and Fuller 2004). Based on the date collected and the size of these young-of year sturgeon, it is likely these fish were produced from the upper areas of the Missouri River. Several individuals also had genetic characteristics suggestive of hybrids.

If these fish are spawning at river kilometer 12 of the Yellowstone River, this would only allow for approximately 60-100 kilometers of free flowing river before reaching the headwaters of Lake Sakakawea. The issue of larval survival in the headwaters of reservoirs is still unresolved and significant.

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