ASSESSMENT OF THE YELLOWSTONE RIVER FOR PALLID STURGEON RESTORATION EFFORTS

Annual Report for 2005

Matthew Jaeger and Mark Nelson
Montana Department of Fish, Wildlife and Parks

George Jordan
U.S. Fish and Wildlife Service

Sue Camp
U.S. Bureau of Reclamation

ABSTRACT

Although there is evidence that pallid sturgeon may successfully spawn in the Yellowstone River below Intake Diversion (river kilometer 115), long downstream drift times following hatching preclude recruitment; larval pallid sturgeon likely drift into Sakakawea Reservoir and die. Therefore, establishing spawning populations far upstream of reservoirs is necessary if natural recruitment is to occur. However, no stocking has occurred above Intake Diversion partly because these habitats were considered unsuitable; pallid sturgeon are thought to prefer habitats downstream of the diversion with lower gradients, wider valleys, and sand substrates. To assess suitability of the Yellowstone River above Intake Diversion, post-stocking dispersal patterns of telemetered juvenile hatchery-reared pallid sturgeon released below Cartersville Diversion (rkm 379) were compared to those of fish released below Intake Diversion. Cartersville pallid sturgeon dispersed longer distances downstream than Intake pallid sturgeon, although half of the Cartersville fish remained above Intake Diversion. Irrespective of release site, pallid sturgeon dispersed into reaches in River Breaks ecoregions characterized by high complexity and dynamic channel processes. Fish were evenly distributed between higher gradient cobble-gravel reaches and lower gradient fines-sand reaches. Initial results suggest that parts of the Yellowstone River upstream of Intake Diversion are suitable for pallid sturgeon stocking.

INTRODUCTION

Pallid sturgeon, a species native to the Yellowstone River, was listed as endangered in 1990. Declines in pallid sturgeon distribution and abundances are attributed to alteration of a natural flow regime and habitat degradation caused by impoundments and channelization throughout the upper Missouri River (Kallemeyn 1983). No recruitment has occurred in Recovery Priority Management Area (RPMA) 2 in at least 30 years and this species will likely be extirpated by 2024 (Klungle and Baxter 2004). Accordingly, recovery efforts have focused on preserving the pallid sturgeon genetic pool through a captive breeding program until habitat restoration permits the re-establishment of self-sustaining populations. Because limited time remains before extant populations senesce, identification of areas that provide the best opportunity for survival to maturity and successful spawning and recruitment by hatchery-reared pallid sturgeon is essential for continued existence of this species.

Because of its relatively pristine character, including a near-natural hydrograph and associated temperature and sediment regimes, the Yellowstone River provides an excellent opportunity for pallid sturgeon recovery. The importance of natural riverine function is emphasized by the movements and behavior of extant pallid sturgeon; the Yellowstone River may be the only location in RPMA 2 that is used for and supports successful spawning (Bramblett and White 2001; Kapuscinski and Baxter 2004). However, inadequate larval drift distances between putative spawning areas downstream of Intake Diversion and the headwaters of Sakakawea Reservoir preclude recruitment; larval pallid sturgeon likely drift into the reservoir and die (P. Braaten, U.S. Geological Survey, Fort Peck, Montana, personal communication). Although establishment of spawning populations further upstream is necessary to facilitate successful recruitment, stocking has not occurred in the 265 kilometers between Cartersville and Intake diversions because of concerns that habitats in this reach are unsuitable. Pallid sturgeon are thought to prefer habitats downstream of Intake Diversion with lower gradients, wider valleys, and sand substrates (Bramblett and White 2001). Although wild adult pallid sturgeon historically occupied the reach above Intake Diversion, its suitability for hatchery-reared juvenile pallid sturgeon has not been empirically determined. However, recent sampling efforts suggest relatively high survival of hatchery-reared juvenile pallid sturgeon downstream of Intake Diversion. Therefore, the objective of this study is to assess the suitability of the Yellowstone River upstream of Intake Diversion for pallid sturgeon restoration efforts by comparing post-stocking behavior of fish released below Cartersville Diversion to that of fish released below Intake Diversion

STUDY AREA

The study area consists of the 379 km of the Yellowstone River below Cartersville Diversion (Figure 1). Mean annual discharge at the USGS gauging station in Miles City, Montana, is 323 m^3/s and mean annual peak discharge is 1480 m^3/s. River geomorphology varies throughout the study area in direct response to valley geology; straight, sinuous, braided, and irregular-meander channel patterns occur (Silverman and Tomlinsen 1984). The channel is often braided or split and long side channels are common. Islands and bars range from large vegetated islands to unvegetated point and mid-channel bars (White and Bramblett 1993). Substrate is primarily gravel and cobble upstream of river kilometer 50 and is primarily fines and sand below (Bramblett and White 2001). The fish assemblage is comprised of 49 species from 15 families, including eight state-listed Species of Special Concern and one federally listed endangered species (White and Bramblett 1993; Carlson 2003). The primary deleterious anthropogenic effect on the fish assemblage is water withdrawal for agriculture (White and Bramblett 1993). About 90% of all water use on the Yellowstone River is for irrigation, which corresponds to annual use of 1.5 million acre-feet (White and Bramblett 1993). Six mainstem low-head irrigation diversions dams occur in the study area. The largest and downstream-most of these, Intake Diversion, diverts about 38 m^3/s during the mid-May to mid-September irrigation season (Hiebert et al. 2000).

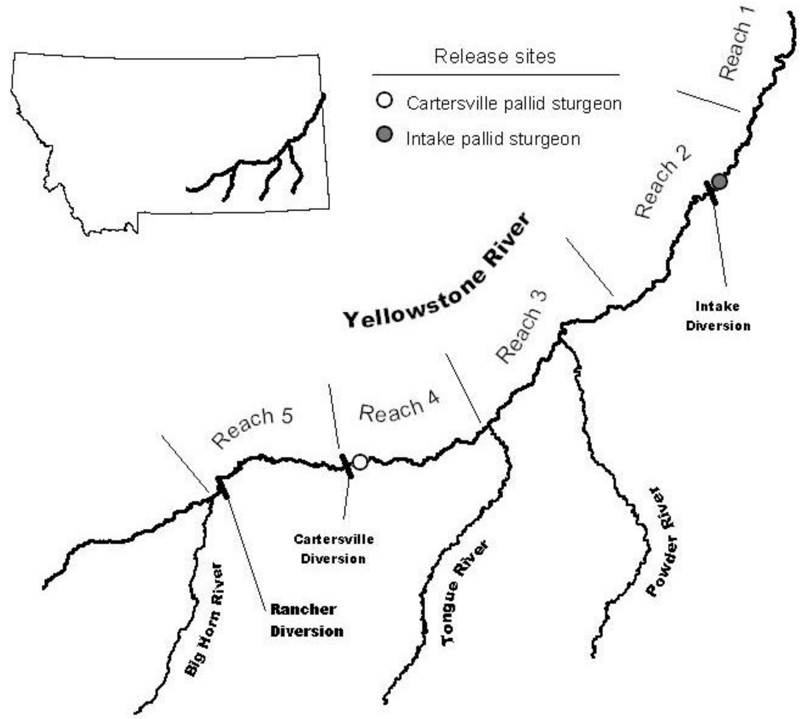

Figure 1. The lower Yellowstone River, its major tributaries, diversion dams, reaches, and release locations of telemetered juvenile pallid sturgeon.

METHODS

One hundred hatchery-reared 2004 year-class pallid sturgeon weighing 102 to 250 g were telemetered at the Miles City State Fish Hatchery (MCSFH) September 12, 2005. Transmitters were 15.1 mm long and 7.6 mm in diameter, weighed 1.4 g, and had a battery life of 38 to 87 days. Each transmitter emitted a unique code detectable with radio antennae at 148.640 MHz. Transmitters were surgically implanted using procedures modified from Hart and Summerfelt (1975). Incisions were closed using surgical staples. The 450-mm long whip antennae trailed externally (Ross and Kleiner 1982).

Telemetered pallid sturgeon were released at two sites in the Yellowstone River September 13, 2005; Fifty fish (Cartersville pallid sturgeon) were released about 5 kilometers downstream of Cartersville Diversion and fifty fish (Intake pallid sturgeon) were released about 6 kilometers downstream of Intake Diversion (Figure 1). Fish were relocated by boat about once per week between September 13 and November 8, 2005. Following detection, coordinates of each pallid sturgeon location were determined using a hand-held global positioning unit. Location was converted to river kilometer using geographic information system software. Fixed receiving stations were placed near Cartersville and Intake diversions and the confluence with the Big Horn, Tongue, Powder, and Missouri rivers to assess movements over diversion dams and emigration out of the Yellowstone River.

Twenty-five hatchery-reared 2004 year-class pallid sturgeon weighing 78 to 128 g were surgically implanted with dummy transmitters at the Bozeman Fish Technology Center

(BFTC) on September 16, 2005 to estimate transmitter expulsion and mortality rates of telemetered pallid sturgeon released in the Yellowstone River. Transmitter sizes and surgical methods used at the BFTC were the same as those used at the MCSFH. Pallid sturgeon implanted with dummy transmitters were held at the BFTC and monitored for transmitter expulsion and mortality throughout the period that telemetered fish were being relocated in the Yellowstone River.

Dispersal patterns of Cartersville and Intake pallid sturgeon were assessed by calculating movement rates (km/d) during each 10-day interval following release. Movement rate was calculated by dividing the change in river kilometer between successive relocations by the number of days that had elapsed between relocations such that a positive rate indicated upstream movement and a negative rate indicated downstream movement (Bramblett 1996). Because additional movement may have occurred between relocations, calculated movement rates represent the minimum movement for the time period between relocations. Median movement rates of Cartersville and Intake pallid sturgeon at each 10-day interval following release were compared using Mann-Whitney tests (Zar 1999). Median movement rates at each 10-day interval within both groups of fish were compared using Kruskal-Wallis tests (Zar 1999). When significant differences were detected, Dunn's multiple comparisons test was used to determine which rates differed (Zar 1999). Directionality of movements was determined for each group at each 10-day interval following release using Wilcoxon signed-rank tests (Zar 1999).

Pallid sturgeon association with reach-scale habitat features was assessed by comparing distributions of telemetered fish and geomorphically distinct reaches. Reaches were delineated based on underlying geologic type (Montana Bureau of Mines and Geology 1979-2001b) and level IV ecorgeion (Woods et al. 1999). Geologic types and ecoregions and were required to exist continuously for a minimum of 20 channel widths (about 4 km) to be considered a separate reach (Frissell et al. 1986; Leopold et al. 1992). Reaches were characterized by channel pattern (Silverman and Tomlinsen 1984; Boyd and Thatcher 2004), valley width (Boyd and Thatcher 2004), channel slope (Boyd and Thatcher 2004), braiding parameter (Boyd and Thatcher 2004), and dominant substrate (Koch et al. 1977; Bramblett and White 2001).

RESULTS

Transmitter retention was high. No expulsion of dummy transmitters occurred during the study period (60 days). Fish implanted with dummy transmitters were the same length (*t* test; $P = 0.603$) but weighed less (*t* test; $P < 0.001$) than fish telemetered for the field study. All transmitter weight-to-fish weight ratios were less than 1.8%.

Cartersville pallid sturgeon moved more than Intake pallid sturgeon (Figure 2). Movement rates of Cartersville pallid sturgeon were greater than those of Intake pallid sturgeon at each 10-day interval following release ($P < 0.001$). Movement rates varied among 10-day intervals within both groups of fish ($P < 0.01$); however, movement rates from 30 to 60 days post release were the same within each group ($P \geq 0.05$). More Intake pallid sturgeon (46%) made upstream movements than Cartersville pallid sturgeon (4%) although both groups of fish moved predominantly downstream; distributions of movement rates were less than zero at each 10-day interval ($P < 0.001$) with the exception of Intake fish 30 days post-release. About half of the Cartersville pallid sturgeon (48%) remained above Intake Dam and most fish (92%) remained in the Yellowstone River. No upstream-moving pallid sturgeon that encountered Intake Dam (20%) successfully passed, although Cartersville pallid sturgeon (52%) migrated downstream over the dam.

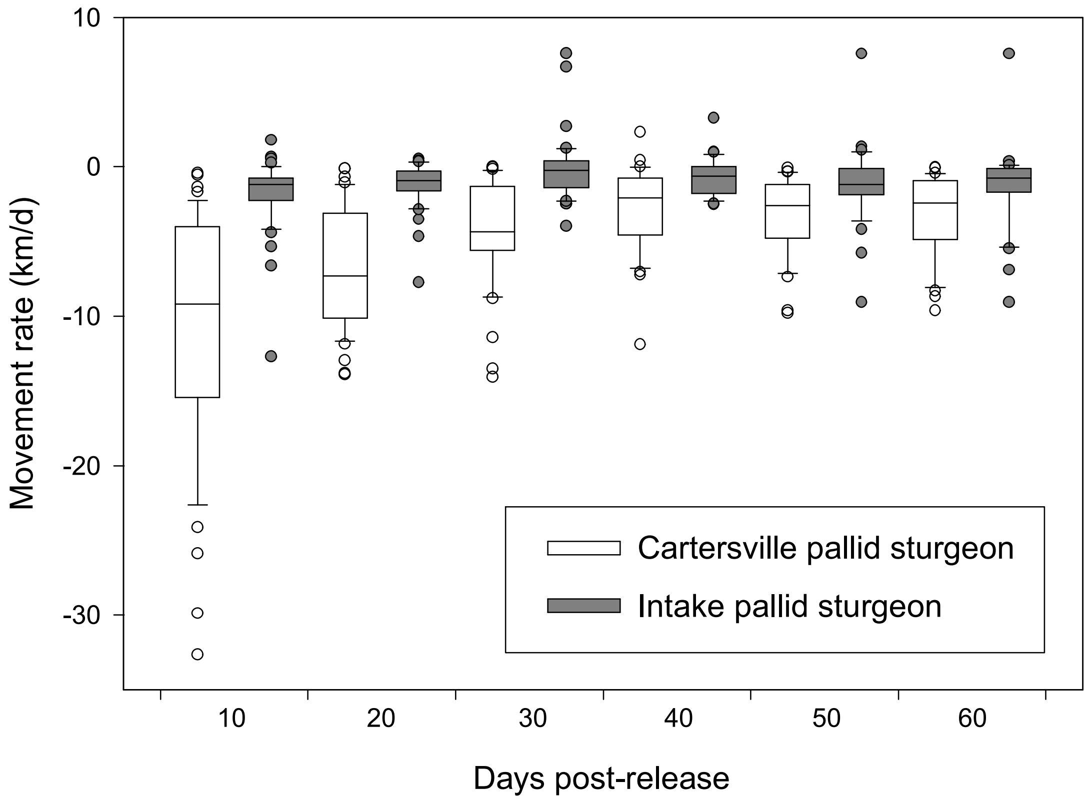

Figure 2. Movement rates by post release 10-day intervals of telemetered juvenile pallid sturgeon in the Yellowstone River, September to November 2005. Lines within boxes represent medians, boxes represent 25th and 75th percentiles, whiskers represent 10th and 90th percentiles, and circles represent outliers beyond the 10th and 90th percentiles. Negative values indicate predominantly downstream movement, positive values indicate predominantly upstream movement, and values near zero indicate no predominant directionality of movement.

Pallid sturgeon dispersed into the same reaches irrespective of release site. Five geomorphically distinct reaches occurred between the confluence with the Big Horn River and the confluence with the Missouri River (Figure 1). Intake pallid sturgeon remained in Reach 2 or dispersed downstream into Reach 1 (Figure 3). Cartersville pallid sturgeon dispersed out of Reach 4, through Reach 3, and into Reaches 2 and 1 (Figure 3). Distributions of the two groups were not significantly different at 60 days post-release (*t* test, $P = 0.07$). Occupied reaches (2 and 1) occurred in River Breaks ecoregions underlain by the Tongue River member of the Fort Union formation (Table 1). Lower channel slopes (*t* test, $P < 0.001$), wider valleys (*t* test, $P < 0.001$), and smaller substrate sizes (Koch et al. 1977; Bramblett and White 2001) occurred in Reach 1 than in Reach 2 (Table 1).

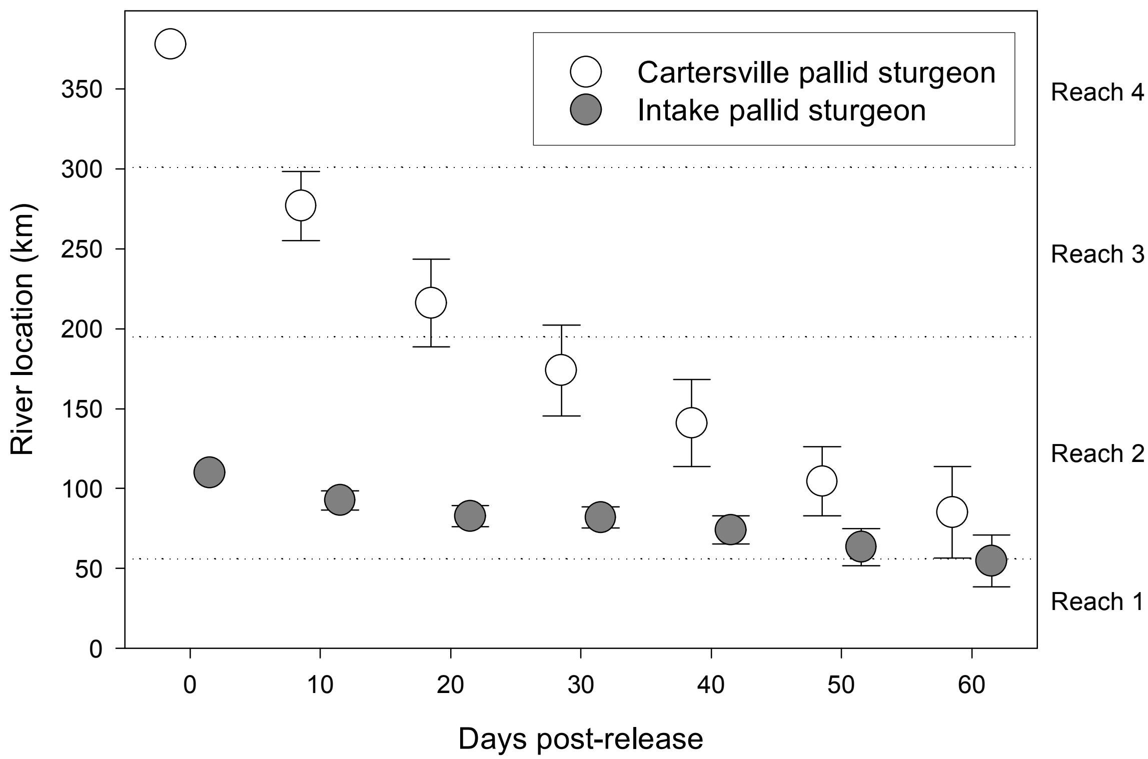

Figure 3. Distributions by post-release 10-day intervals of telemetered juvenile pallid sturgeon in the Yellowstone River, September to November 2005. Circles represent mean river location and whiskers represent 95% confidence intervals. River location describes the distance from the confluence with the Missouri River.

Table 1. Description and characteristics of Yellowstone River reaches.

Reach (river km)	Ecoregion	Formation: Lithology Dominant (secondary)	Channel pattern Dominant (secondary)	Mean valley width (km)	Mean channel slope (%)	Mean braiding parameter	Dominant substrate
5 (473-378)	Sagebrush Steppe	Bearpaw: shale (Lance: sandstone, shale, coal) (Judith River: shale/sandstone)	Unconfined anabranching (Partially confined braided, strait, meandering)	4.2	0.08	3.5	Gravel - cobble
4 (378-301)	Central Grassland	Tullock: sandstone/shale/coal (Lance: sandstone/shale/coal)	Partially confined meandering/islands (Partially confined strait)	3.7	0.06	2.9	Gravel - cobble
3 (301-195)	River Breaks	Tullock: sandstone/shale/coal (Lebo member: shale)	Confined meandering (Confined strait)	4.0	0.07	1.8	Gravel - cobble
2 (195-56)	River Breaks	Tongue R: sandstone/shale/coal Ludlow: sandstone/shale/coal (Lance: sandstone/shale/coal) (Pierre: shale)	Partially confined anabranching (Partially confined meandering/islands)	4.7	0.05	3.6	Gravel - cobble
1 (56-0)	River Breaks	Tongue R: sandstone/shale/coal	Partially confined meandering/islands (Unconfined strait/islands)	7.4	0.02	2.7	Fines - sand

DISCUSSION

Behavior of telemetered fish released in the Yellowstone River was likely minimally affected by surgical implantation of transmitters. Methods used in this study resulted in no transmitter expulsion or mortality of fish held in captivity. High rates of transmitter expulsion (45% to 50%) and mortality (56%) of pallid sturgeon held in hatcheries following surgery have been reported (Jaeger et al. 2005; G. Jordan, U.S. Fish and Wildlife Service, Billings, Montana, personal communication). Expulsion and mortality may have been influenced by larger transmitter weight-to-fish weight ratios in previous studies (1.6% to 3.5%) than in this study (0.6% to 1.8%). Likelihood of transmitter expulsion increases as transmitter weight-to-fish weight ratios increase (Summerfelt and Mosier 1984). Incision closure with surgical staples instead of suture material may also have contributed to lower rates of expulsion; faster surgeries, less infection, better tag retention, and reduced signs of systemic stress occur when surgical staples are used instead of suture material to close incisions (Swanberg et al. 1999).

Intake Diversion restricted pallid sturgeon movements. Juvenile fish moved upstream to Intake Diversion but were not able to move above the dam. Similarly, telemetered adult pallid sturgeon have been documented moving up to but not beyond Intake Diversion (Bramblett and White 2001). Observations of adult and juvenile pallid sturgeon are common below the diversion but rare above (Watson and Stewart 1991; Backes et al. 1994). Laboratory trials suggest that sturgeon have difficulty negotiating turbulent flow and high velocities over large substrates (White and Mefford 2002), which characterize Intake Diversion. Entrainment was not estimated by this study (Intake Diversion headgates were closed for the season before fish were released) but previous research and angler reports indicate that entrainment of juvenile (14.3%; Jaeger et al. 2005) and adult pallid sturgeon occurs. About 576,629 fish of 36 species are annually entrained at Intake Diversion, of which as many as 8% are sturgeon (Hiebert et al. 2000). Improved passage and reduced entrainment at Intake Diversion is needed to allow pallid sturgeon access to suitable and formerly occupied upstream habitats.

Suitable habitats were characterized by a combination of factors. Occupied reaches (2 and 1) occurred in a common ecoregion, geologic type, and degree of bedrock confinement, which resulted in similar channel patterns (anabranching or meandering/islands) characterized by relatively high complexity (braiding parameter) and dynamic channel processes (Silverman and Tomlinsen 1984; Boyd and Thatcher 2004). Dynamic reaches that occur in River Breaks ecoregions were also preferentially used by juvenile pallid sturgeon in RPMA 1 (Gerrity 2005) and adult pallid sturgeon in RPMA 1 and 2 (Bramblett and White 2001; Gardner 2005). Although pallid sturgeon primarily occupy low gradients, wide valleys, and sand substrates (Bramblett and White 2001), reaches with relatively high gradients, narrow valleys, and gravel and cobble substrates used by fish in this study were also historically (Reach 3) or currently (Reach 2) occupied by wild pallid sturgeon (Brown 1971; Watson and Stewart 1991; Backes et al. 1994; Bramblett and White 2001). Avoided reaches occurred in different ecoregions (Reach 4), geologic types (Reaches 4 and 3), and degrees of confinement (Reach 3) than preferred reaches. Non-River Breaks ecoregions were similarly avoided by hatchery-reared juvenile pallid sturgeon in RPMA 1 following stocking (Gardner

2005; C. Guy, Montana Cooperative Fisheries Research Unit, Bozeman, Montana, personal communication).

Post-stocking movements were likely dictated by the presence of suitable habitats. Following stocking, Intake pallid sturgeon dispersed relatively short distances upstream and downstream within Reaches 2 and 1. Cartersville pallid sturgeon dispersed only long distances downstream until they entered Reaches 2 and 1, at which point their behavior became similar to that of Intake pallid sturgeon. Downstream dispersal to suitable habitats was also observed for juvenile pallid sturgeon stocked upstream of areas commonly occupied by extant pallid sturgeon in RPMA 1 (Gardner 2005; C. Guy, Montana Cooperative Fisheries Research Unit, Bozeman, Montana, personal communication). Although adult pallid sturgeon historically occupied Reach 3 (Brown 1971; Watson and Stewart 1991), it may not provide suitable rearing habitat for juvenile pallid sturgeon or was only seasonally occupied; adult pallid sturgeon annually migrate long distances (Bramblett and White 2001). Conversely, impoundment and flow management of the Tongue and Big Horn rivers resulting in altered discharge, temperature, and sediment regimes may have degraded habitats to the extent that this reach is no longer suitable (Koch et al. 1977). Establishing pallid sturgeon populations in desirable locations further upstream of reservoirs is unlikely to be successful simply by stocking fish unless suitable habitat also exists.

Some habitats upstream of Intake Diversion appeared suitable for pallid sturgeon restoration efforts. Heretofore, stocking had not occurred between Cartersville and Intake diversions because it appeared this reach was unsuitable; few extant pallid sturgeon were captured (Watson and Stewart 1991) and telemetry studies in similar habitats (higher gradient, gravel and cobble substrates) elsewhere suggested that stocked fish would rapidly disperse out of this reach (Gardner 2005). Although Cartersville fish dispersed further downstream than Intake fish, about half remained above Intake Diversion; fish that are stocked or disperse into Reach 2 are likely to remain there. Stocking pallid sturgeon in suitable habitats upstream of Intake Diversion would help bolster extant populations and may increase the likelihood of natural recruitment by allowing longer larval drift distances if spawning occurs.

ACKNOWLEDGEMENTS

This work was made possible by the efforts and assistance of Mike Rhodes (MCSFH) and Matt Toner (BFTC) in raising and holding the fish used in this study at their hatcheries and John Hunziker, Trevor Watson, and Cindy Sampson in telemetering and relocating fish in the field. The Fort Peck Flow Modification Crew provided data recorded at a fixed receiving station at the confluence of the Yellowstone and Missouri rivers. The Western Area Power Administration, U.S. Bureau of Reclamation, and U.S. Fish and Wildlife Service provided the funding necessary to complete this work.

LITERATURE CITED

Backes, K. M., and W. M. Gardner, D. Scarnecchia, P. A. Stewart. 1994. Lower Yellowstone River pallid sturgeon study IV and Missouri River creel survey. Montana Fish, Wildlife and Parks Report, Helena.

Boyd, K. F., and T. Thatcher. 2004. Geomorphic reconnaissance and GIS development Yellowstone River, Montana. Applied Geomorphology, Inc., Bozeman to Custer County Conservation District, Miles City.

Bramblett, R. G. 1996. Habitats and movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri Rivers, Montana and North Dakota. Ph.D. dissertation, Montana State University, Bozeman.

Bramblett, R. G., and R. G. White. 2001. Habitat use and movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri Rivers in Montana and North Dakota. Transactions of the American Fisheries Society 130:1006-1025.

Brown, C. J. D. 1971. Fishes of Montana. Big Sky Books. Bozeman, Montana.

Carlson, J. 2003. Montana animal species of special concern. Montana Natural Heritage Program and Montana Fish, Wildlife and Parks Report, Helena.

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10:199-214.

Hart, L. G., and R. C. Summerfelt. 1975. Surgical procedures for implanting ultrasonic transmitters into flathead catfish (*Pylodictis olivaris*). Transactions of the American Fisheries Society 1:56-59.

Hiebert, S. D., R. Wydoski, and T. J. Parks. 2000. Fish entrainment at the lower Yellowstone diversion dam, Intake Canal, Montana, 1996-1998. USDI Bureau of Reclamation Report, Denver, Colorado.

Gardner, B. 2005. 2004 pallid sturgeon recovery efforts in the upper Missouri River, Montana (RPMA #1). Pages 49-64 *in* Upper Basin Pallid Sturgeon Recovery Workgroup 2004 Annual Report. Upper Basin Workgroup, Montana Department of Fish, Wildlife and Parks, Helena.

Gerrity P. C. 2005. Habitat use, diet, and growth of hatchery-reared juvenile pallid sturgeon and indigenous shovelnose sturgeon in the Missouri River above Fort Peck Reservoir. Master's thesis. Montana State University, Bozeman.

Jaeger, M. E., G. R. Jordan, and S. Camp. 2005. Assessment of the suitability of the Yellowstone River for pallid sturgeon restoration efforts, annual report for 2004.

Pages 92-99 *in* Upper Basin Pallid Sturgeon Recovery Workgroup 2004 Annual Report. Upper Basin Workgroup, Montana Department of Fish, Wildlife and Parks, Helena.

Kallemeyn, L. W. 1983. Status of the pallid sturgeon, *Scaphirhynchus albus*. Fisheries 8:3-9.

Kapuscinski, K. L. and M. W. Baxter. 2004. Lower Missouri and Yellowstone rivers pallid sturgeon study 2003 report. Pages 57-132 *in* Upper Basin Pallid Sturgeon Recovery Workgroup 2003 Annual Report. Upper Basin Workgroup, Montana Department of Fish, Wildlife and Parks, Helena.

Klungle, M. M. and M. W. Baxter. 2005. Lower Missouri and Yellowstone rivers pallid sturgeon study 2004 report. Pages 69-91 *in* Upper Basin Pallid Sturgeon Recovery Workgroup 2004 Annual Report. Upper Basin Workgroup, Montana Department of Fish, Wildlife and Parks, Helena.

Koch, R., R. Curry, and M. Webber. 1977. The effect of altered streamflow on the hydrology and geomorphology of the Yellowstone River basin, Montana. Yellowstone Impact Study, Technical Report No. 2, Montana Department of Natural Resources and Conservation, Helena.

Leopold, L. B., M. G. Wolman, and J. P. Miller. 1992. Fluvial processes in geomorphology. Dover Publications, Mineola.

Montana Bureau of Mines and Geology. 1979. Geologic map of the Hysham 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 371. Butte.

Montana Bureau of Mines and Geology. 1980. Geologic map of the Terry 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 284. Butte.

Montana Bureau of Mines and Geology. 1981a. Geologic map of the Sidney 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 277. Butte.

Montana Bureau of Mines and Geology. 1981b. Geologic map of the Wibaux 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 282. Butte.

Montana Bureau of Mines and Geology. 1998. Geologic map of the Glendive 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 371. Butte.

Montana Bureau of Mines and Geology. 2000. Geologic map of the Billings 30' x 60' quadrangle, Montana. 1:100,000. Geologic map series no. 59. Butte.

Montana Bureau of Mines and Geology. 2001a. Geologic map of the Miles City 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 426. Butte.

Montana Bureau of Mines and Geology. 2001b. Geologic map of the Forsyth 30' x 60' quadrangle, Montana. 1:100,000. Open-file report no. 425. Butte.

Ross, M. J., and C. F. Kleiner. 1982. Shielded-needle technique for surgically implanting radio-frequency transmitters in fish. Progressive Fish-Culturist 44:41-43.

Silverman, A. J., and W. D. Tomlinsen. 1984. Biohydrology of mountain fluvial systems: the Yellowstone (part I). U. S. Geologic Survey, Completion Report G-853-02, Reston.

Summerfelt, R. C. and D. Mosier. 1984. Transintestinal expulsion of surgically implanted dummy transmitters by channel catfish. Transactions of the American Fisheries Society 113:760-766.

Swanberg, T. R., D. A. Schmetterling, and D. H. McEvoy. Comparison of surgical staples and silk sutures for closing incisions in rainbow trout. North American Journal of Fisheries Management 19:215-218.

Watson, J. H. and P. A. Stewart. 1991. Lower Yellowstone pallid sturgeon study. Montana Fish, Wildlife and Parks Repot, Helena.

White, R. G., and R. G. Bramblett. 1993. The Yellowstone River: its fish and fisheries. Pages 396-414 *in* L. W. Hesse, C. B. Stalnaker, N. G. Benson, J. R. Zuboy, editors. Restoration planning for the rivers of the Mississippi River ecosystem. Biological Report 19, National Biological Survey, Washington, D.C.

White, R. G. and B. Mefford. 2002. Assessment of behavior and swimming ability of Yellowstone River sturgeon for design of fish passage devices. Bureau of Reclamation Report, Denver.

Woods, A. J. and J. M. Omernik, J. A. Nesser, J. Shelden, and S. H. Azevedo. 1999. Ecoregions of Montana (color poster with map, descriptive text, summary tables, and photographs). U.S. Geological Survey, Reston, Virgina (map scale 1:1,500,000).

Zar, J. H. 1999. Biostatistical Analysis. Prentice Hall, Upper Saddle River.