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Movement Patterns of Age-1 and Age-7 Pallid Sturgeon Within the Missouri River During Record 2011 Discharges Downstream of Fort Randall Dam

Robert A. Klumb
U.S. Fish and Wildlife Service, robert_klumb@fws.gov

Dane A. Shuman
U.S. Fish and Wildlife Service, dane_shuman@fws.gov

Daniel A. James
U.S. Fish and Wildlife Service, daniel_james@fws.gov

Kristen L. Grohs
U.S. Fish and Wildlife Service, kristen_grohs@fws.gov

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Progress Report Prepared for Western Area Power Administration, Billings, Montana and the Upper Basin Pallid Sturgeon Workgroup

By:

Robert A. Klumb, Dane A. Shuman, Daniel A. James, and Kristen L. Grohs

United States Fish and Wildlife Service
Great Plains Fish and Wildlife Conservation Office
Pierre, South Dakota

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Project Title: Pallid sturgeon detectability, catchability and post-handling survival with four standardized sampling gears.

Project PIs:

Dr. Robert Klumb, Project Leader, U.S. Fish and Wildlife Service, Great Plains Fish and Wildlife Conservation Office, 420 South Garfield Ave, Suite 400, Pierre, South Dakota 57501; Phone: 605-224-8693 x226; FAX: 605-224-9974; e-mail: robert_klumb@fws.gov

Dane Shuman, Fish and Wildlife Biologist, U.S. Fish and Wildlife Service, Great Plains Fish and Wildlife Conservation Office, 420 South Garfield Ave, Suite 400, Pierre, South Dakota 57501; Phone: 605-224-8693 x233; FAX: 605-224-9974; e-mail: dane_shuman@fws.gov

Dr. Dan James, Fish and Wildlife Biologist, U.S. Fish and Wildlife Service, Great Plains Fish and Wildlife Conservation Office, 420 South Garfield Ave, Suite 400, Pierre, South Dakota 57501; Phone: 605-224-8693 x225; FAX: 605-224-9974; e-mail: daniel_james@fws.gov

Kristen Grohs, Fish and Wildlife Biologist, U.S. Fish and Wildlife Service, Great Plains Fish and Wildlife Conservation Office, 420 South Garfield Ave, Suite 400, Pierre, South Dakota 57501; Phone: 605-224-8693 x228; FAX: 605-224-9974; e-mail: kristen_grohs@fws.gov

Project Summary:

During the summer of 2011, the Missouri River system experienced the largest discharge levels ever recorded from Fort Randall Dam, (> 4,247 m^3s^{-1} sustained from 25 June to 31 July of 2011), which was approximately four fold above normal. Our objective was to determine movement patterns of pallid sturgeon *Scaphirhynchus albus* in the inter-reservoir riverine reach between Fort Randall and Gavins Point dams, South Dakota, during this record discharge period. Fifty-one hatchery reared pallid sturgeon implanted with ultrasonic transmitters from two size classes, large (age-6 at tagging; n = 24) and small (age-1; n = 27), were at large during the flood. Small age-1 fish ranged from 352 – 389 mm fork length (FL; mean = 369 mm) and 165 – 235 g (mean = 193 g), while fish in the large size class ranged from 564 – 723 mm (mean = 652) and 700 – 1,600 g (mean = 1,154 g). After discharge increased in late May, 67% of large pallid sturgeon were relocated at least once with 10 fish relocated multiple times, whereas only 11% of small fish were relocated. Mean net movement between six relocation surveys for both pallid sturgeon size groups pooled was positively correlated with discharge ($r^2 = 0.77$, $p = 0.07$). Mean net movement of the large size class ($r^2 = 0.82$, $p = 0.04$) was positively correlated to changes in net discharge, with two fish moving in the main channel to within 6.5 river km of Fort Randall Dam when flows exceeded 4,000 m^3s^{-1}. Small pallid sturgeon also demonstrated upstream movement with increasing discharge but to a lesser extent. No fish were found on the inundated floodplain or during one survey in late May of Lewis and Clark Lake. Overall, pallid sturgeon remained in the main river channel and generally moved upstream during record discharges out of Fort Randall Dam; however other factors such a temperature and food availability may have also contributed to their movements.

Introduction

The Pallid Sturgeon Population Assessment Program (PSPAP) is designed to track changes and assess trends in the relative abundance of Missouri River fishes downstream of Fort Peck Dam, Montana to the confluence of the Mississippi River, excluding reservoirs (Welker and Drobish 2010a). To assess distribution and abundance of pallid sturgeon and other native fishes, standardized gears are deployed throughout 1,718 river kilometers (rkm) of the Missouri River by the PSPAP. Sampling effort is randomly stratified within 14 river "Segments" delineated by major changes in hydrology, geomorphology, and the presence of mainstem dams or major tributaries. This stratified-random sampling design was chosen because of documented differences in fish communities and abundance downstream of these hydrologic changes (Berry et al. 2004).

Standardization of gear types, specifications, and data collection are requisite to make spatial and temporal comparisons of fish relative abundance, size structure, and condition (Bonar et al. 2009). Since inception of the PSPAP in 2002, member agencies have debated merits of continued standardization, use of various sampling gear, and by consensus have recommended changes to the program after evaluation through an adaptive management approach (Welker and Drobish 2010b). Past evaluations have compared gears of differing specifications (Hammel et al. 2009; Wanner et al. 2010), as well as variation in catch rates, sizes captured, and species diversity among multiple gear types (Schloesser 2008; Doyle et al. 2008) or seasons (Wanner et al. 2007) as well as statistical power (Bryan et al. 2009). These and other unpublished studies have guided the early development of the long-term PSPAP to adopt or discontinue various fish sampling gear, make seasonal changes in deployment of gear, or change sampling effort (Welker and Drobish 2010b). The PSPAP entered its ninth year in 2011 and has settled on a standardized combination of two active gears, benthic otter trawls and drifted trammel nets, which target pallid sturgeon during two seasons: fall through spring, aka "the Sturgeon Season" and summer, aka "the Fish Community Season". Standardized passive gears that collect pallid sturgeon include trotlines deployed river-wide in spring and gill nets set in fall and spring downstream of Fort Randall Dam to St Louis, Missouri.

Relative abundance is comprised of the ratio of numbers of fish captured (*C*) divided by the effort expended (*f*) and is also commonly called catch per unit effort (*C/f*). Relative abundance for the PSPAP (Welker and Drobish 2010a) is reported as numbers of fish per net or hook night for passive, gears (i.e., gill nets and trot lines) and as numbers of fish per 100 m of river bottom sampled for active gears (i.e., otter trawl and trammel net). Mathematically, *C/f* is related to actual population size (*N*) if the probability of capture (*q*) for an individual fish is constant: $C/f = q*N$ (Hubert and Fabrizio 2007). Fundamental to using *C/f* as an index for spatial and temporal comparisons of abundance is constancy of *q*. Lowered catchability in one habitat or season can lower *C/f* independent of the true population's abundance (*N*). Likewise, increased catchability of fish can falsely indicate increases in abundance. However, if *q* for pallid sturgeon is known for different size classes, habitats, or time periods, changes in relative abundance can then be more solidly interpreted to result from specific management actions. A primary objective of the PSPAP is to "evaluate annual and long-term trends in pallid sturgeon population abundance and geographic distribution throughout the Missouri River System". Since the suite of standardized gears used within the PSPAP has become established, improvements should now focus on how each gear fishes different size classes of pallid sturgeon in different habitats and seasons to increase precision of *C/f*. Once variability in catchability is known, increasing confidence in *C/f*, relative abundance can then be scaled by habitat area to provide a measure of population density (Hubert and Fabrizio 2007).

Despite the importance of catchability, it has been rarely measured directly. Calculation of q usually necessitates large-scale mark-recapture studies to estimate N which then enables assessment of relations between actual and relative abundance (Forney 1980). However, telemetry studies result in known locations of individual fish enabling direct determination of "conditional capture probabilities" (Guy et al. 2009). For drifted trammel nets in the riverine section of the Missouri River upstream of Fort Peck Lake, Guy et al. (2009) determined conditional capture probabilities to be 0.37, 0.51, 0.67, and 0.75 for the first through fourth sampling attempts over the known locations of radio-tagged pallid sturgeon and shovelnose sturgeon *Scaphirhynchus platorynchus*. However, variability in length of radio-tagged pallid sturgeon was low and the trammel net outer mesh size used by Guy et al. (2009) was larger (25.4-cm) than that used in the remainder of the Missouri River by the PSPAP (15.2-cm). We propose to expand the study of Guy et al. (2009) to assess conditional capture probability by encompassing two active gears, a wider size range of pallid sturgeon, and wider variation in environmental conditions (i.e., 2 seasons across 3 years). Additionally, we propose to assess detectability of pallid sturgeon by four gears (two passive and two active) using the current stratified random sampling design.

A multi-year telemetry study will also enable initial assessment of post handling survival of pallid sturgeon captured in all standard gears of the PSPAP. A handling protocol exists to protect pallid sturgeon from mortality resulting from capture as part of research and monitoring activities by setting an upper thermal limit for deployment of gill nets (USFWS 2005). However no published data exists to support this seasonal limitation for gill net deployment. Currently no limitations exist for sampling pallid sturgeon with otter trawls, trammel nets, and trot lines while post capture mortality for these three gears is unknown. Additionally, survival rate estimation with Cormack-Jolly-Seber mark-recapture models is reliant on concurrent estimates of detection probability of pallid sturgeon (Hadley and Rotella 2009). Low estimates of detection probability result in low confidence around survival estimates. Direct measurement of capture probability in this study can further refine current survival rate estimates of pallid sturgeon.

Objectives:

(1) Determine the capture/detection probability (i.e. detectability) of pallid sturgeon in active and passive gears currently used in the PSPAP.

(2) Determine the conditional capture probability (i.e. catchability) of pallid sturgeon in active gears currently used in the PSPAP.

(3) Estimate post handling survival of age-1+ hatchery propagated pallid sturgeon captured with currently used PSPAP standardized gear.

Study Area:

Lewis and Clark Lake, the most downstream reservoir of the Missouri River, was formed by the closure of Gavins Point Dam in 1955 and is bounded upstream by Fort Randall Dam (Figure 1). Both dams are operated by the U. S. Army Corps of Engineers (USACE). The primary function of Gavins Point Dam is to level out release fluctuations from Fort Randall Dam to serve downstream purposes such as navigation, flood control, and municipal water supply. The riverine section of Lewis and Clark Lake extends approximately 89 river kilometers (rkm) from Fort Randall Dam to Springfield, South Dakota (Figure 1). Maximum depth of the riverine section of Lewis and Clark Lake is about 12 m and channel width ranges from 45 - 90 m.

Downstream of Springfield, South Dakota, Lewis and Clark Lake becomes more like a reservoir. However, sediment from the Niobrara River has formed a large braided delta, which starts near rkm 1,358 and ends near rkm 1,331. This delta has progressively expanded downriver into the reservoir. The riverine section of Lewis and Clark Lake was selected in the Pallid Sturgeon Recovery Plan (Dryer and Sandoval 1993) as 1 of 4 Recovery Priority Management Areas (RPMA) in the Missouri River for potential recovery of the species and was designated as RPMA 3.

The riverine section of Lewis and Clark Lake retains many natural characteristics such as sandbars, sandbar pools, side channels, backwater areas, islands, old growth riparian forest, and year round flows. However the historical temperature and flow (i.e., the hydrograph) in the riverine section has been altered due to operation of Fort Randall Dam (Pegg et al. 2003). Water levels substantially fluctuate daily and seasonally (Troelstrup and Hergenrader 1990). Diel water levels are subjected to changes of almost 1 m. Lowest daily flows generally occur at 0600 hours with peak flows occurring between 1200 to 1900 hours in support of power generation demands (USACE 1994). The USACE Missouri River Main Stem Reservoirs 2000 - 2001 Annual Operating Plan (http://www.nwd-mr.usace.army.mil/rcc/reports/aop.html) reported highest seasonal releases from Fort Randall Dam during August through November to support navigation on the Missouri River downstream of Sioux City, Iowa. Lowest releases were during December through April to prevent flooding due to ice jams.

Based on the presence of a major tributary, the Niobrara River, the riverine section of Lewis and Clark Lake (RPMA 3) was divided into two sampling segments by the Population Assessment Team. Segment 5 (rkm 1,416 – 1,358, river mile [rm] 880 – 844) encompasses the riverine section downstream of Fort Randall Dam to the Niobrara River confluence. In this segment, water temperatures are depressed by hypolimnetic discharges from Fort Randall Dam and turbidity is low. Segment 6 (rkm 1,358 – 1,331, rm 844 – 827) encompassed the riverine section downstream of the confluence of the Missouri and Niobrara rivers to the headwaters of Lewis and Clark Lake (Figure 1). This segment has increased water temperatures and turbidity due to inflows from the Niobrara River and includes the large braided delta formed in the headwaters of Lewis and Clark Lake.

Methods:

Ultra-sonic tags (Sonotronics Tuscon, Arizona) were used in two size categories (Shuman et al. 2006) of juvenile pallid sturgeon, stock-quality (330 – 629 mm) and quality-preferred (630 – 839 mm), to assess detectability, catchability, and post handling mortality in the unchannelized Missouri River. Sonic tags have worked successfully for pallid sturgeon in the deep (3 - 12 m), high conductivity (50 – 800 µS) waters of the Missouri River downstream of Fort Randall Dam (Jordan et al. 2006; Wanner et al. 2007). Each tag emitted a unique aural code at frequencies that ranged from 70 – 83 kHz. Past detection limits downstream of Fort Randall Dam for similar sonic tags was about 0.4 km using a single unidirectional hydrophone (Jordan et al. 2006). To locate fish in 2011, two omni-directional hydrophones, one on the port and starboard side, were extended about 2 m behind the stern outside the propeller wash. Surveys were conducted moving downstream under power at about 8.5 km/h. A Sonotronics receiver model USR-08 and USR-96 automatically cycled through all tag frequencies and the boat traversed on average (± 1 SE) 172 m (± 6) during each cycle.

Large (> 550 mm fork length [FL]) pallid sturgeon from surplus captive broodstock from the 2004 year class (n = 28) at the U.S Fish and Wildlife Service (USFWS) Gavins Point

National Fish Hatchery (NFH) in Yankton, South Dakota were surgically implanted with transmitters on October 19, 2010. Age-6 pallid sturgeon ranged in length from 564 – 723 mm (mean = 649 mm), while weight ranged from 700 – 1,600 mm (mean = 1,139 mm). Experimental fish were removed from feed 5 d before tagging. All tags were implanted by an experienced surgeon, David Fuller from Montana Fish Wildlife and Parks, Fort Peck, who provided instruction on proper surgical techniques. Implantation surgeries without anesthesia ranged from 128 – 220 s after which fish were treated with a 1% salt treatment (flow through). Tag dimensions were 62 mm length by 16 mm diameter. Tag weight was 10 g in water resulting in a mean (± 1 SE) tag to body weight ratio of 0.93 % (± 0.04). Maximum estimated battery life for tags implanted in large pallid sturgeon is three years. All fish survived the 10-d post surgery holding period in the hatchery. On October 29, 2010, 12 tagged fish each were stocked at the Running Water, South Dakota and Verdel, Nebraska boat ramps (Figure 1). Of these 24 fish, five were of stock – quality length and the remaining 19 were of quality – preferred length (Table 1). Four fish were not stocked because their sutures were ruptured. Large age-6 pallid sturgeon were at liberty 185 d before spillway flows increased above 272 $m^3 s^{-1}$ (9,500 cubic feet per second [CFS]) at Fort Randall Dam on May 2, 2011 (Figure 2). Total discharge through the powerhouse and over the spillway at Fort Randall Dam on May 2, 2011 was 1,252 $m^3 s^{-1}$ (44,200 CFS).

To assess catchability and detectability of small pallid sturgeon (< 400 mm FL), 31 yearlings from the 2010 year class were implanted with transmitters on May 3, 2011 at the USFWS Gavins Point NFH. These yearlings were produced on heated water to achieve sizes large enough for implantation at the USFWS Garrison Dam NFH in Riverdale, North Dakota. Age-1 pallid sturgeon implanted with transmitters ranged in length from 352 – 389 mm with a mean of 369 mm, while weight ranged from 165 – 235 mm (mean = 193 mm). Surgeries were performed by Dane Shuman, USFWS, Pierre, South Dakota; implantation times ranged from 91 – 272 s. After surgery without anesthesia, fish were treated with a 1% salt treatment (flow through). Tag dimensions were 26 mm length by 9 mm diameter. Mean tag weight in water was 2.1 g resulting in mean (± 1 SE) tag weight to body weight ratio of 1.20 % (± 0.02). Four fish died at the hatchery before being stocked. The maximum battery life of tags implanted in spring yearling pallid sturgeon was five months. Tagged yearlings (n = 27) were stocked at the Verdel, Nebraska boat ramp on May 13, 2011 (Figure 1). All 27 fish were of stock – quality length (Table 1). Flows at Fort Randall Dam on May 13, 2011 were 1,560 $m^3 s^{-1}$ (55,100 CFS) which was 210% higher than the 10-year (2000 – 2010) mean flow on that date (Figure 2).

Capture/detection probability (i.e. detectability) will be defined as the presence of ultra-sonic tagged pallid sturgeon captured blindly through standard stratified-random sampling methods (Welker and Drobish 2010a). Presence of pallid sturgeon is identified by a telemetry crew, but unknown to the fish sampling crew. Conditional capture probability (i.e. catchability) will be defined as the susceptibility of ultra-sonic tagged pallid sturgeon to targeted recapture attempts with drifted trammel nets and otter trawls (Guy et al. 2009; Welker and Drobish 2010a).

Although high flows precluded assessment of catchability due to safety concerns of sampling in the main channel with active gear, pallid sturgeon were relocated river wide on six occasions from April 28 to November 16, 2011. Attempts to assess detectability were only conducted twice, during our fall 2010 gill net survey and spring 2011 trammel net survey. Two river wide telemetry surveys were conducted when discharge exceeded 4,000 $m^3 s^{-1}$ (141,000 CFS) in late July and mid-August. Two surveys were also completed on the ascending (late April and mid-May) and descending (mid-September and mid-November) limbs of the hydrograph. To assess potential emigration, Lewis and Clark Lake was searched on May 27 – 29, 2011. The Missouri River below Gavins Point Dam to 1.6 rkm downstream of the Vermillion River was searched on September 22, 2011. At each fish location latitude and longitude (decimal degrees) and depth (m) were recorded with a WAAS enabled Garmin GPSMAP 168 sounder (Garmin Corporation, Olathe, Kansas). The macrohabitats for each fish location was recorded as: inside bend, outside bend, channel cross-over, secondary connected channel, braided channel, main channel, island tip, and confluence area.

Two types of movement, gross and net, were calculated for all relocated fish. Gross distance traveled was the maximum distance in rkm observed between locations for an individual fish. Net movement was the distance in rkm traveled between successive relocations. Delineation of pre- and post-peak flood event were defined as the period of time prior to 4,500 m^3s^{-1} (Pre: May 15, 2011 – July 22, 2011) to the remainder of the year (Post: 23 July 2011 – 18 November 2011). Gross and net distance traveled and discharge was analyzed with Spearman rank correlation. Spearman rank correlation was also used to assess the relation of net distance traveled between successive relocations and the net change in discharge over that time period. Statistical significance was set to $\alpha = 0.10$ for all tests.

Project Status/Anticipated/Expected Date of Completion:

This project is ongoing but one year behind schedule due to the unprecedented flooding during 2011 and will be reinitiated during 2012. To increase sample size, an additional 30 large-sized pallid sturgeon will be implanted with 3-year tags and stocked in spring 2012. Space at Gavins Point NFH for maintenance of captive pallid sturgeon held for brood stock has become limited. Large fish for use in this telemetry project are anticipated to become available as the pallid sturgeon genetics management plan (Heist et al. 2010) is developed and implemented. This genetics plan will likely recommend targeted thinning of surplus captive brood stock at Gavins Point NFH; whereby this research project can take advantage of the multi-year investment to rear large-sized pallid sturgeon in captivity. Due to poor spawning success for the 2011 year class at all hatcheries in the upper basin of the Missouri River, small sized age-1 pallid sturgeon will not be available for implantation until 2013. Field work for this project will be completed in fall of 2014. Final reports and publications will be compiled in spring of 2015.

The initial proposal for this project entailed three years of field sampling (2011 – 2013) to assess capture and detection probabilities of pallid sturgeon under varying conditions of flow, temperature, and season. Increased flow conditions prevented sampling with active gear in the main channel after May 18, 2011, so no assessments of capture probability were attempted. Therefore 2012 will be the first full year of catchability and detectability assessment. Initial attempts to assess detection probabilities of tagged fish were completed during the fall gill net survey in 2010 (Nov 1-2) and spring trammel net survey in 2011 (May 16 – 18).

Each spring and fall, a river-wide search for all fish will be conducted for assessment of overwinter mortality. River wide surveys to assess overwinter mortality of large pallid sturgeon were completed in April 27-29, 2011 and Nov 16-17, 2011. A river wide survey to relocate as many fish as possible will commence in early April and late fall (Oct or Nov) of 2012. In 2012, our tagged large pallid sturgeon will be 8 years of age.

Accomplishments/Recommendations/Results:

After discharge increased in late May, 67% of large age-7 pallid sturgeon were relocated at least once with 10 fish relocated multiple times (Table 1), whereas only 11% of small age-1 fish were relocated (Table 2). No fish were found on the inundated floodplain. Age-7 pallid sturgeon were relocated in outside bends (33%), channel crossovers (19%), secondary channels (14%), braided channels (12%), inside bends (10%), island tips (5%), and at the Niobrara River confluence (2%). Both age-1 fish relocated in August were in an outside bend. Age-7 and age-1 fish generally occupied deep depths (> 4 m) as discharge increased (Figure 3).

The majority of age-1 pallid sturgeon were relocated only on May 16, 2011, which was three days after stocking at the Verdel Nebraska boat ramp (Table 2). Average distance between relocations (± 1 SE) was 1.6 km (± 0.3) and 12 of 13 fish moved downstream. Maximum distance between locations was 4.4 km, which corresponds to a maximum movement rate of 1.5 km/d. Average (± 1 SE) movement rate of all 13 age-1 pallid sturgeon was 0.5 km/d (± 0.1). Two fish were relocated in essentially the same location on successive days (May 16^{th} and 17^{th}), having moved < 40 m and 9 of the 13 relocated fish had moved < 0.5 km three days after stocking.

Before flows began to dramatically increase out of Fort Randall Dam in late May, tagged pallid sturgeon were distributed throughout the river; however, after flows peaked to 4,500 m^3s^{-1}, 80% of relocated pallid sturgeon had moved upstream (Figure 4). The spatial distribution of relocated fish shifted upstream of the most upstream stocking site at Verdel, Nebraska in July and August (Figure 5). After flows receded about 50% from the peak, pallid sturgeon moved up and downstream in equal proportions with fish increasingly relocated downstream of Verdel, Nebraska in September (Figure 5). During peak flows in July and August eight age-7 pallid sturgeon were relocated within 6.5 km of Fort Randall Dam (Figure 5), which was adjacent to a flooded island complex that is part of the Karl E. Mundt National Wildlife Refuge. The average distance (± 1 SE) from the dam for 10 fish relocated during peak discharge was 21.4 km (± 4.8).

Gross movement of both age groups of pallid sturgeon increased with increasing discharge out of Fort Randall Dam (Figures 4 and 6). However, average gross movement by each survey date (n = 6) for both age groups pooled was not significantly correlated to discharge ($r^2 = 0.03$, $P = 1.00$). The mean gross distance traveled for age-7 pallid sturgeon during peak discharge in July and after discharge declined and stabilized in September was 27 and 25 km, respectively. Largest mean gross movement for age-1 pallid sturgeon was in July.

Correlations between net movement of pallid sturgeon between relocation dates and discharge were stronger than for overall gross movement. Mean net movement between seven sampling occasions during 2011 for both age groups pooled was positively correlated with discharge ($r^2 = 0.77$, $p = 0.07$; Figure 7). However, mean net movement of age-7 pallid sturgeon alone was not significantly correlated with discharge ($r^2 = 0.59$, $P = 0.22$). Net movement of age-7 pallid sturgeon and the change in discharge (i.e. net discharge) over the same time period was positively correlated ($r^2 = 0.82$, $p = 0.04$; Figure 8) and remained significant when age-1 fish were included ($r^2 = 0.78$, $P = 0.07$). Net movement of age-7 fish was directed upstream as discharge increased and activity decreased as discharge declined. Age-1 pallid sturgeon also demonstrated net upstream movement with increasing discharge but to a lesser extent than for age-7 fish. For both age groups, highest net movement rate was observed in July after discharge increased 177% since mid May (Figure 7). Two age-7 pallid sturgeon moved in the main channel to within 6.5 river km of Fort Randall Dam in July and August when discharge exceeded 4,000 $m^3 s^{-1}$ (Figure 5).

To assess if pallid sturgeon emigrated from the Fort Randall riverine reach, searches were made in Lewis and Clark Lake in late May and downstream of Gavins Point Dam in September. No ultra-sonic tagged pallid sturgeon were relocated in Lewis and Clark Lake or downstream of Gavins Point Dam.

Survey attempts to assess detectability with active and passive gears were conducted during fall of 2010 and spring of 2011 with gill nets and trammel nets, respectively. Unknown equipment malfunctions with the receiver or hydrophone prevented determination of detectability during these two surveys.

Discussion

During the high discharge of 2011, we relocated 67% of age-7 pallid sturgeon stocked downstream of Fort Randall Dam. In the same area, similar numbers of older fish (ages 3 – 6) were relocated by Jordan et al (2006) during more "normal" regulated discharges during 2000 - 2002. Low numbers of relocations after stocking for age-1 fish suggests potential high mortality for these young fish, tag failure, detection issues within large flooded areas, or emigration from the study area. The lake wide survey of Lewis and Clark Lake in late May, two weeks after stocking, failed to relocate any fish. However, the small-sized transmitters used in age-1 fish required extended intervals between signal transmissions to prolong battery life which may have limited their detectability in the lake and on the floodplain. Our survey in late September downstream of Gavins Point Dam, which also failed to relocate any fish, occurred near the time that the 5-month tags were about to expire. Pallid sturgeon stocked downstream of Fort Randall Dam have been recaptured by all survey crews downstream of Gavins Point Dam from South Dakota and Nebraska to Missouri (Pallid Sturgeon Population Assessment team, unpublished data), therefore, we cannot eliminate the possibility that fish emigrated from our study area.

Movement rates from the stocking site of age-1 pallid sturgeon after 3 days were similar to age-3 and 4 fish intensively tracked by Jordan et al. (2006). Maximum movement rate calculated for the three days since stocking for age-1 fish in this study was 1.5 km/d (0.06 km/h) whereas the older fish in Jordan et al. (2006) had median movement rates of 0.03 – 0.08 km/h during spring and summer. With the exception of two fish, short term dispersal distances of yearlings from the stocking site were low and generally directed downstream.

Historically, the spatial distribution of pallid sturgeon captured as part of the Pallid Sturgeon Population Assessment Program was generally highest downstream of the Niobrara River (Shuman et al. 2010). However, 2011 gill net, trammel net, and trot line surveys completed before large increases in discharge during May found a majority of pallid sturgeon captured upstream of the Niobrara River (USFW unpublished data). Reasons for this shift in distribution are unknown but most of April 2011 had discharges greater than the maximum values observed from 2000 – 2010 (Figure 2). In 2011, rainbow smelt *Osmerus mordax* catches were the highest recorded downstream of Fort Randall Dam (USFWS unpublished data). Increased rainbow smelt abundance from entrainment out of upstream reservoirs may have provided a novel food source for pallid sturgeon during the flood of 2011. Flooding may also have enhanced macroinvertebrate production from the inundated floodplain in the Missouri River upstream of the Niobrara River. During years with more “normal” discharge in this reach of the Missouri River (2005 and 2006), macroinvertebrate abundance was generally higher downstream of the Niobrara River confluence compared to upstream sites (Grohs 2008). Downstream of Fort Randall Dam, abundance of Diptera and Ephemeroptera were the strongest predictors for juvenile and early adult pallid sturgeon occurrence among the habitat and prey availability variables studied (Spindler et al. 2012). Food availability may have contributed to the shift in pallid sturgeon distribution observed in early fish collections in spring of 2011 for the Pallid Sturgeon Population Assessment Program as well as with our ultra-sonic tagged fish during summer of 2011. Results of this study showed that movement by age-7 pallid sturgeon, and to a lesser extent age-1 juveniles, responded to and were often correlated with increasing flows out of Fort Randall Dam; flows which may have facilitated increased availability of food resources upstream of the Niobrara River.

Deliverables:

Updates to the original schedule (below) include the final completion report and submission for publication will occur in 2015. Initial data collected in 2011 will be presented at the 2012 Missouri River Natural Resources Conference (MRNRC) in Pierre (March 13 – 16) and at the parent society meeting of American Fisheries Society (AFS) in Minneapolis (Aug 19 – 23). Annual progress presentations and reports to the Upper Basin Workgroup summarizing field seasons in 2012 – 2014 will occur at the spring meeting.

Deliverables	Schedule
Annual progress reports	January 31, 2012*, and 2013
Annual presentations: Dakota &/or Nebraska Chapters AFS	February 2012* and February 2013
Annual presentations: MRNRC-BioOP conference	March 2012* and March 2013
Completion report	May 2014
Submission for Peer Reviewed Publication	July 2014

***indicates requirements completed**

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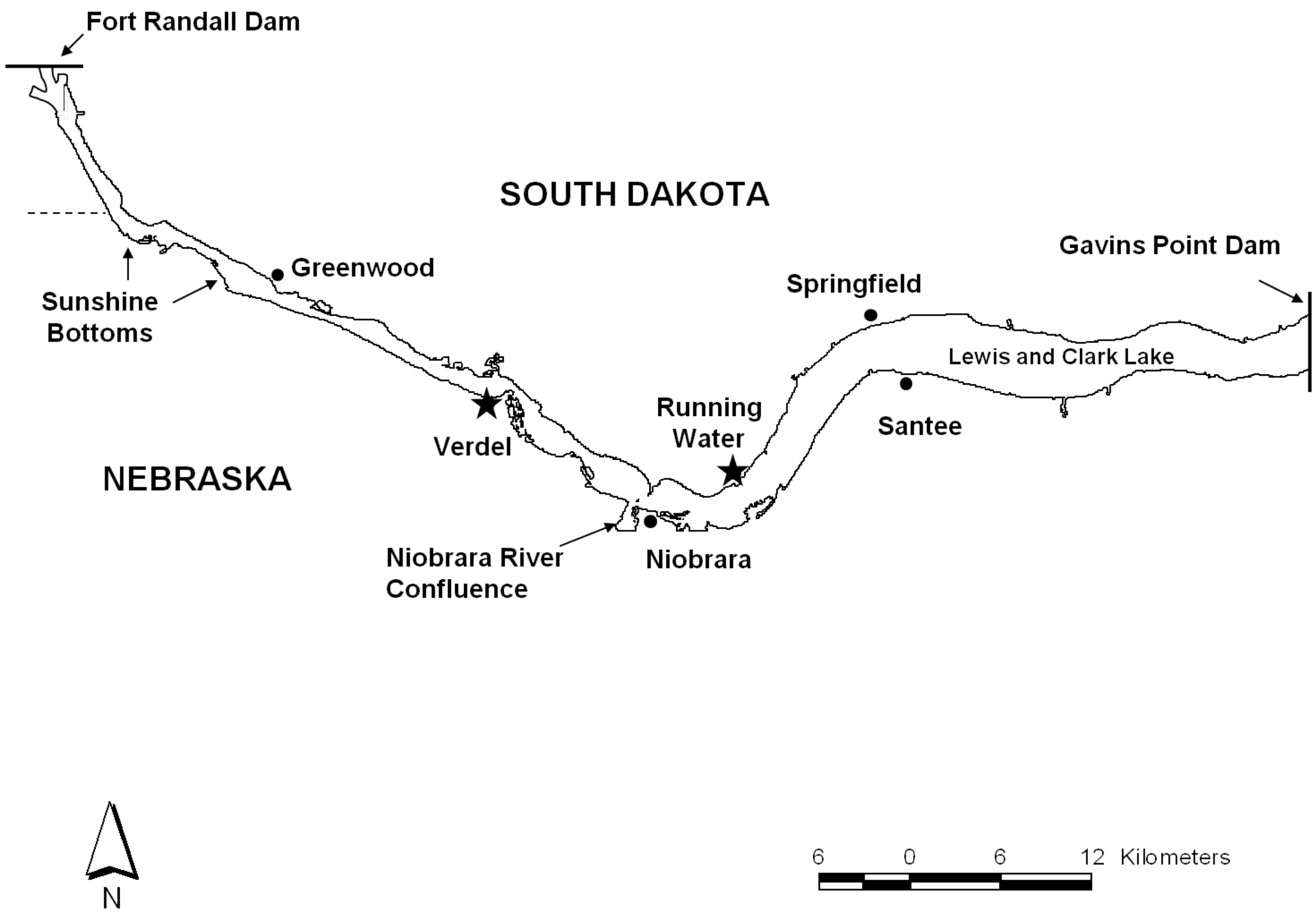

Figure 1. Map showing the Missouri River, South Dakota and Nebraska where sonic-tagged hatchery-reared pallid sturgeon were released (stars) and tracked during 2011. Age-6 pallid sturgeon were released on October 29, 2010 at Running Water and Verdel. Age-1 pallid sturgeon were released on May 13, 2011 at Verdel.

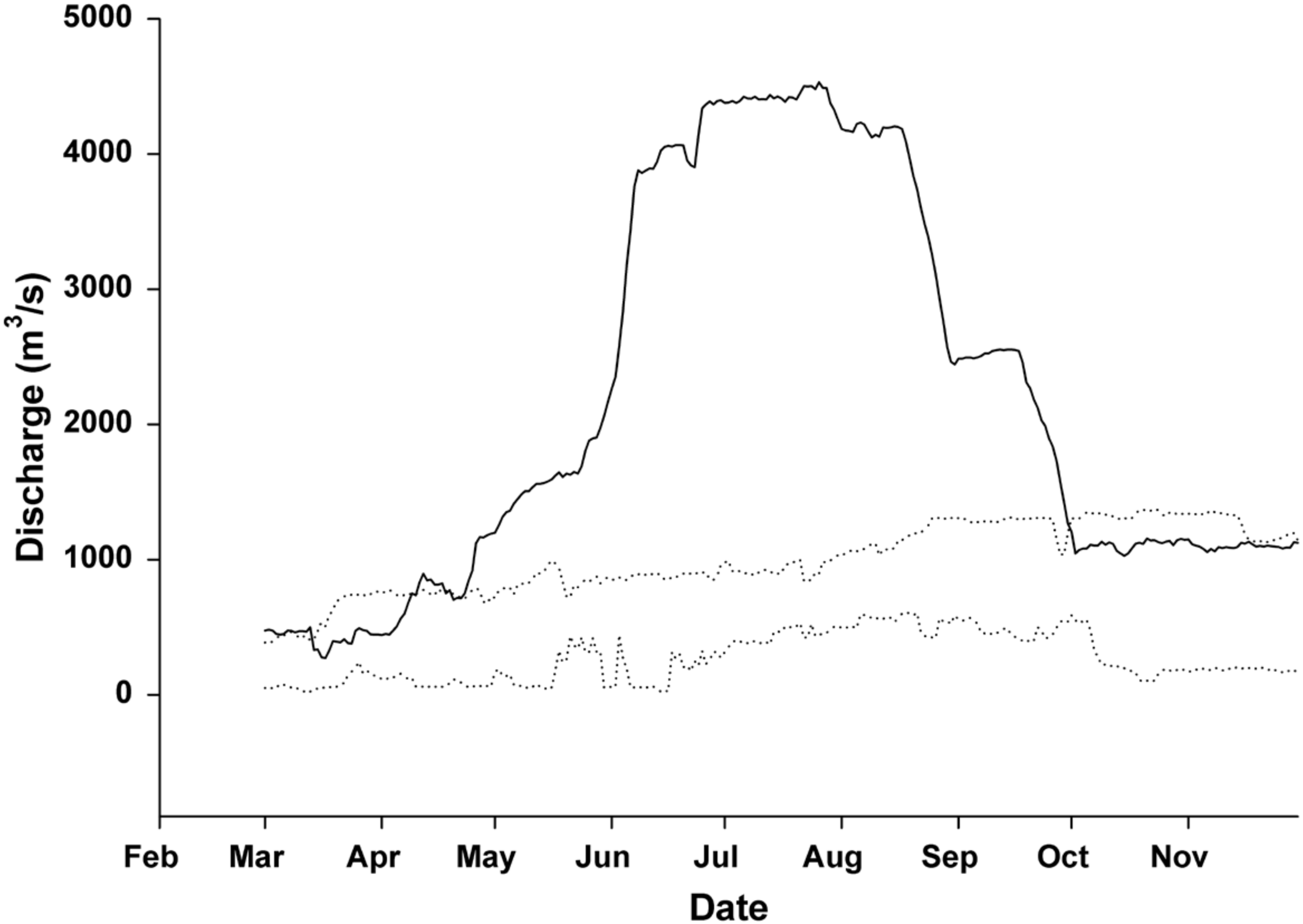

Figure 2. Mean daily discharge at Fort Randall Dam during March 1 through November 30, 2011 (solid line) and the maximum and minimum discharges observed from 2000 – 2010.

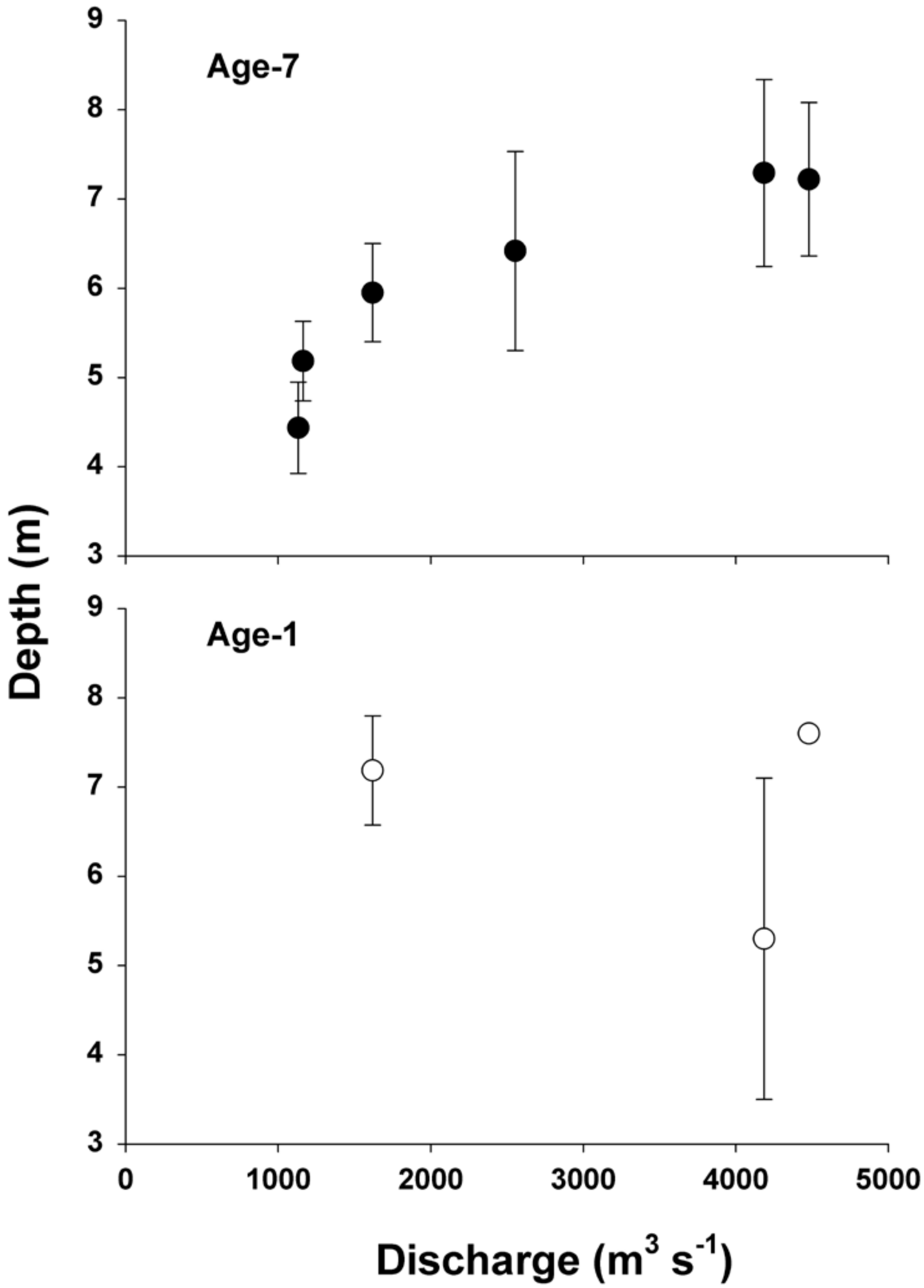

Figure 3. Relation between depths occupied in the Missouri River by age-7 (upper panel) and age-1 (lower panel) ultrasonic tagged pallid sturgeon and discharge out of Fort Randall Dam during 2011.

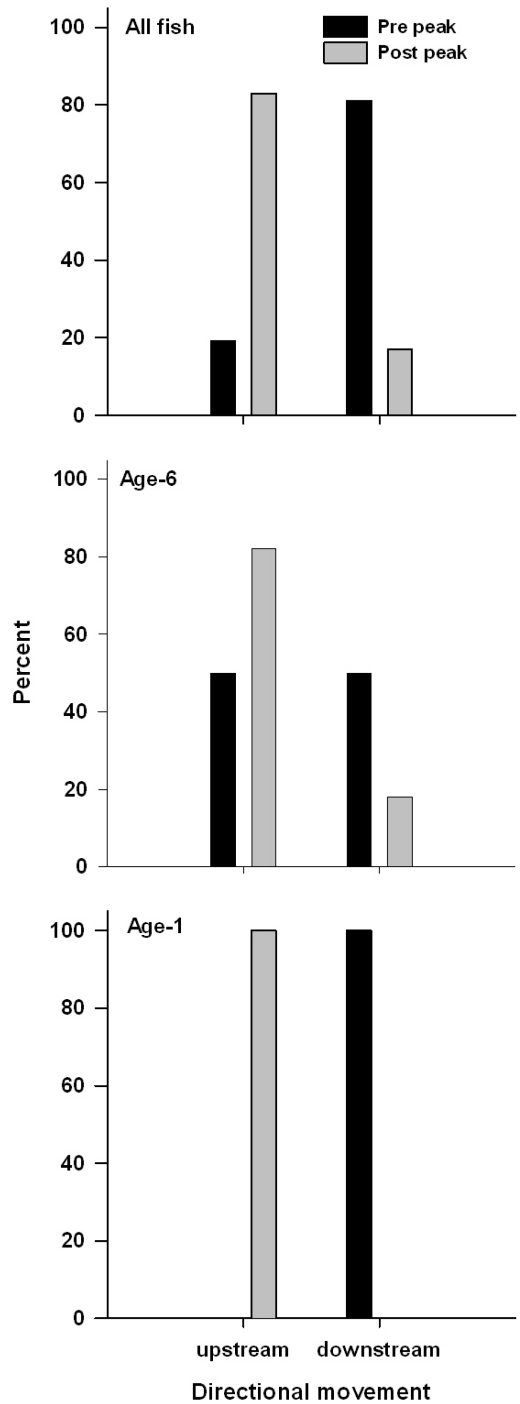

Figure 4. Proportion of ultrasonic tagged pallid sturgeon directionality pre- peak (black bars) and post-peak (gray bars) in the Missouri River during 2011. Peak discharge was initiated at 4,500 m^3s^{-1} on 22 July 2011.

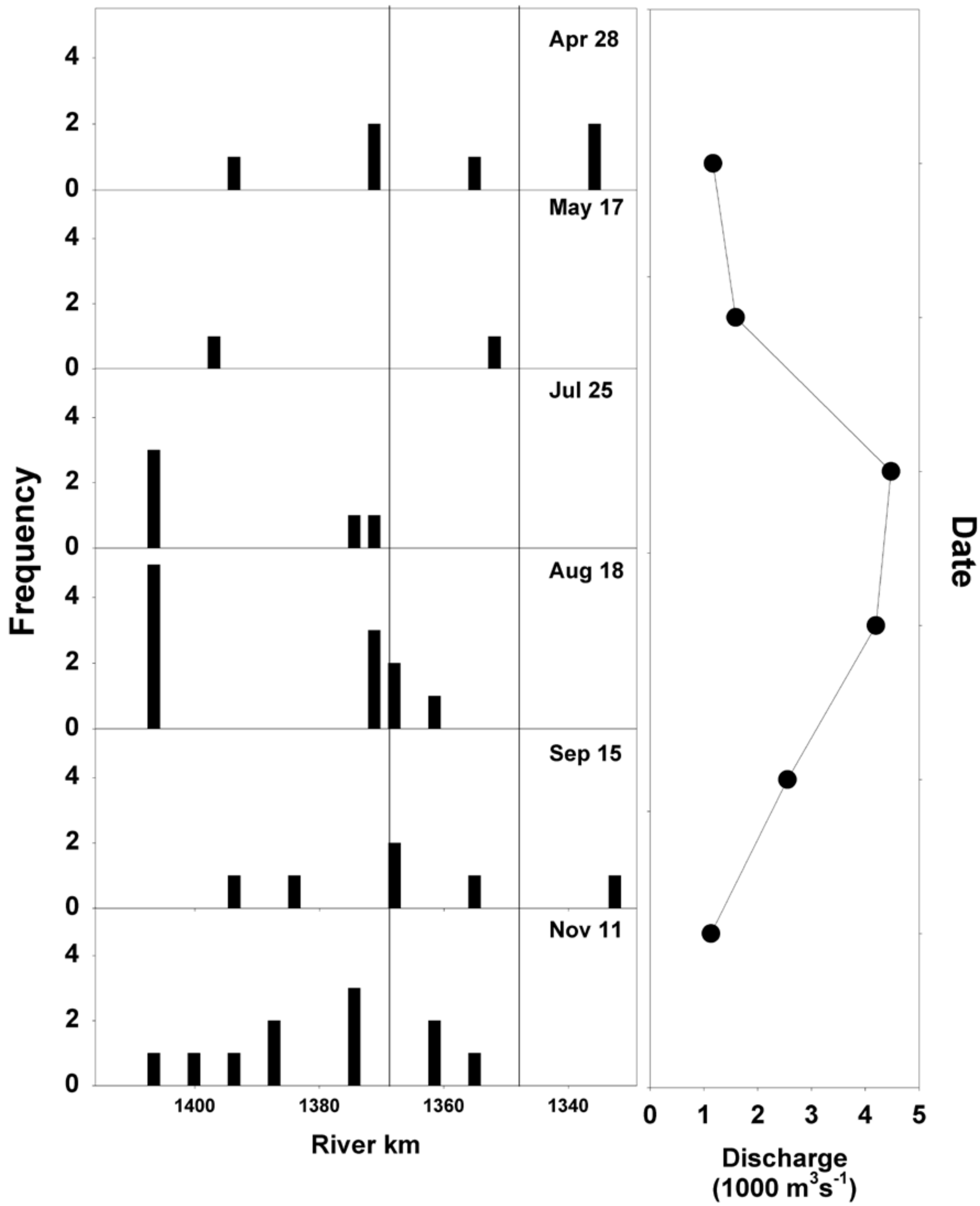

Figure 5. Frequency of ultrasonic tagged pallid sturgeon relocated in the Missouri River downstream of Fort Randall dam by river kilometer for six surveys conducted during 2011. Corresponding discharge out of Fort Randall Dam presented in right panel. Vertical lines at rkm 1370 and 1352 correspond respectively to the Verdel, Nebraska and Running Water, South Dakota stocking locations. Fort Randall Dam is located at rkm 1416.

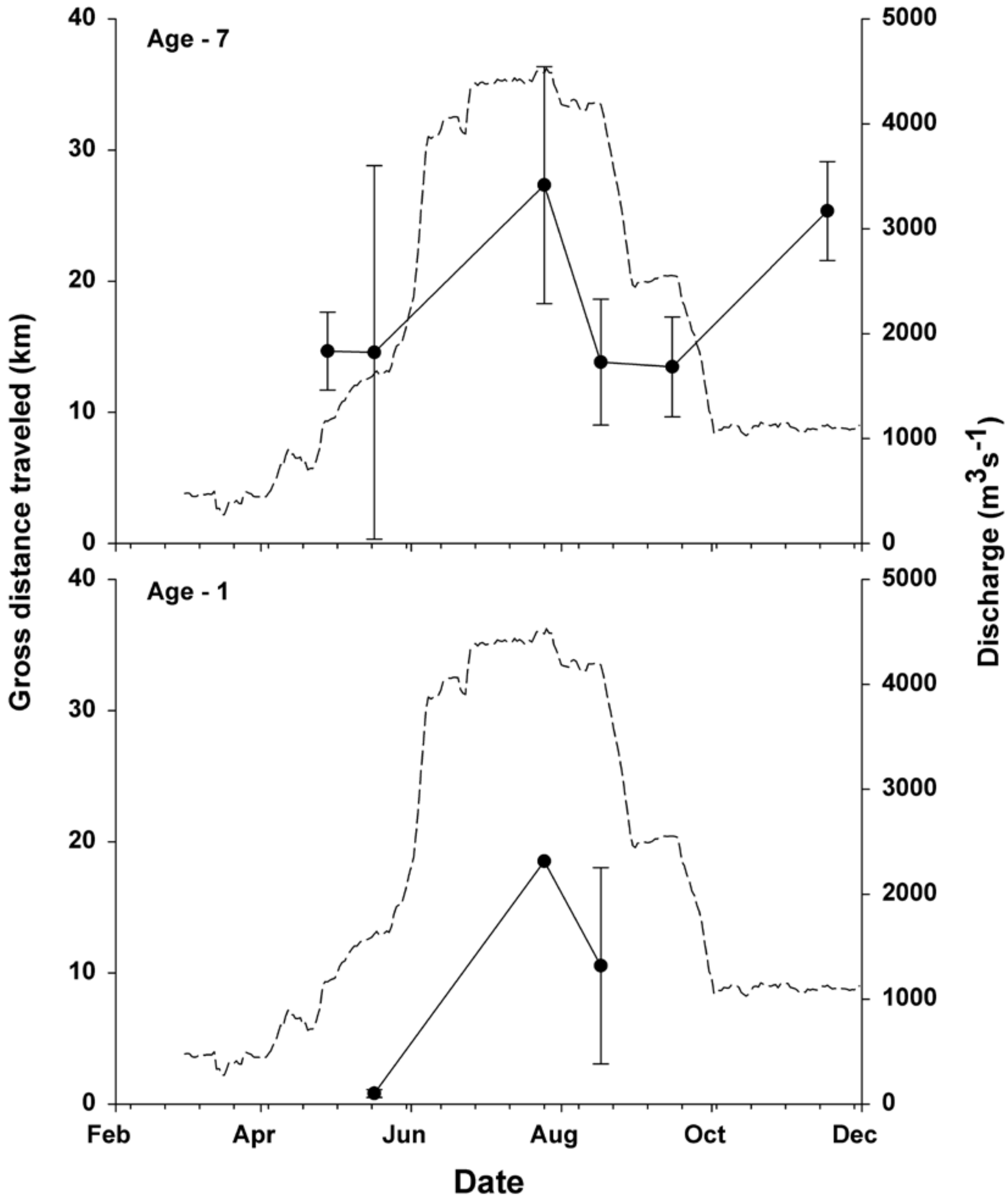

Figure 6. Mean gross distance traveled (± 1 SE) of age-7 (upper panel) and age-1 pallid sturgeon (lower panel) from their stocking location and between relocation dates in the Missouri River downstream of Fort Randall Dam during 2011 in relation to discharge (hatched line).

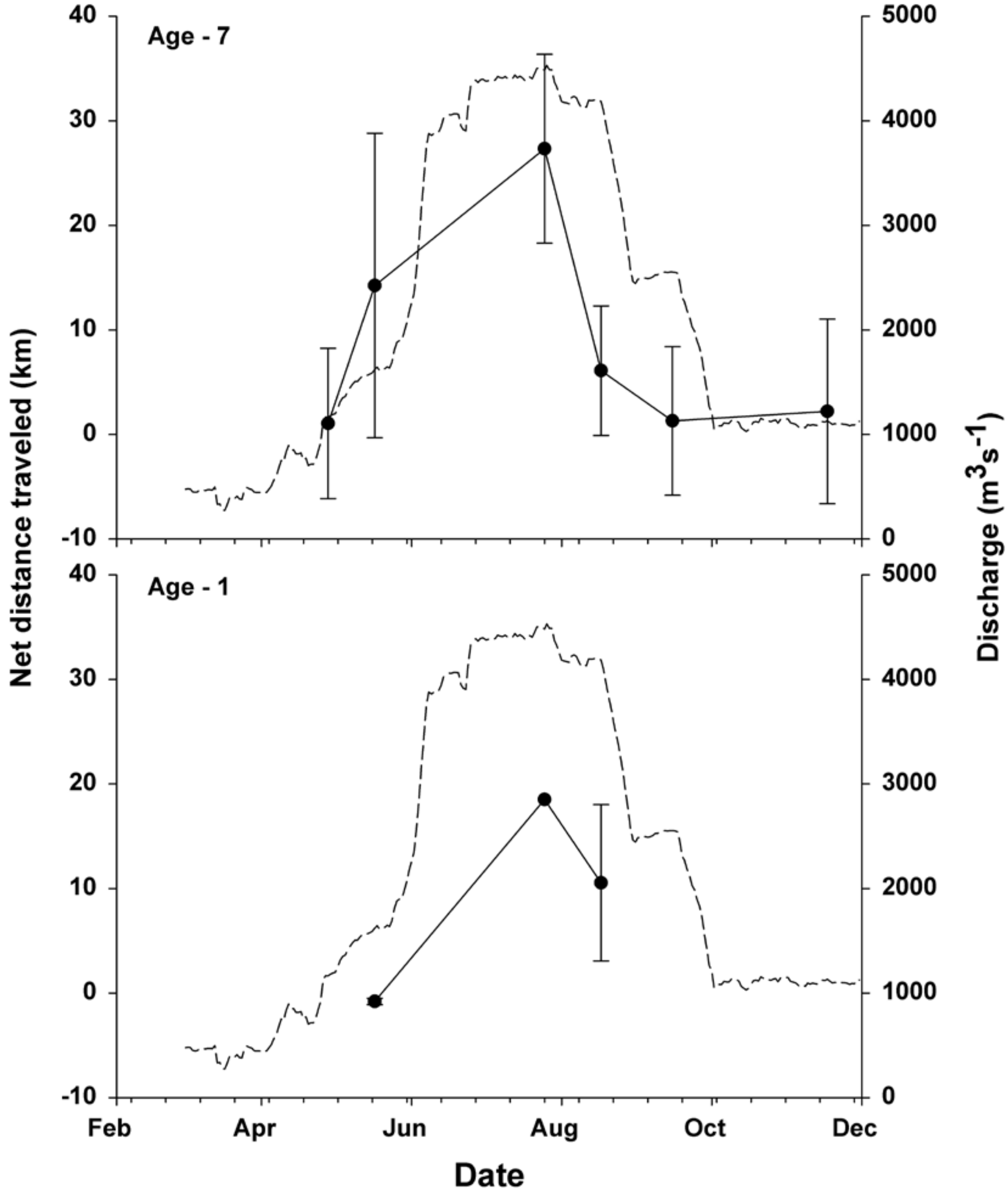

Figure 7. Mean net distance traveled (± 1 SE) of age-7 (upper panel) and age-1 pallid sturgeon (lower panel) from their stocking location and between relocation dates in the Missouri River downstream of Fort Randall Dam during 2011 in relation to discharge (hatched line). Negative net movement indicates downstream movement from previous location.

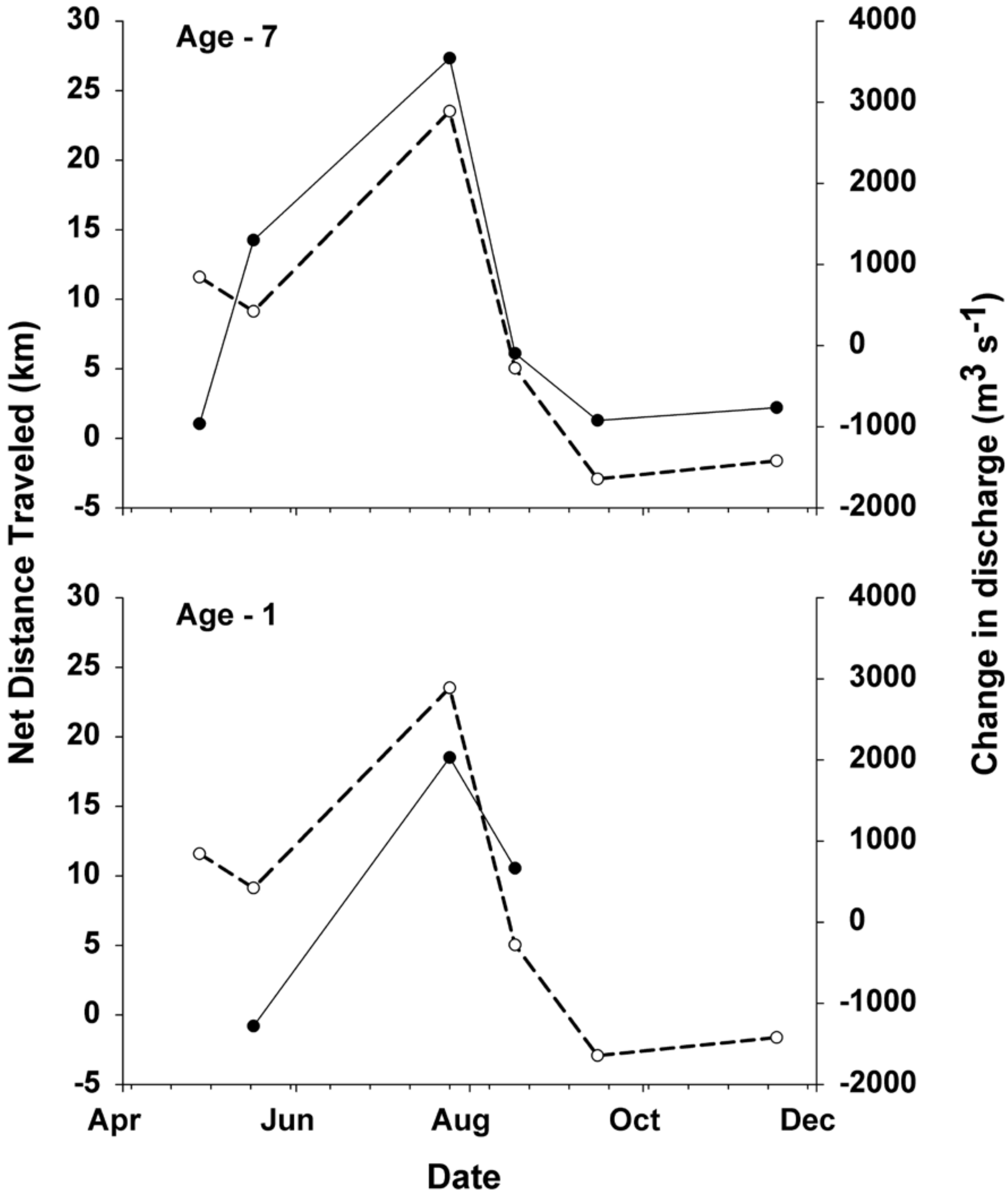

Figure 8. Mean net distance traveled of age-7 (upper panel) and age-1 pallid sturgeon (lower panel) from their stocking location and between relocation sampling dates in the Missouri River downstream of Fort Randall Dam during 2011 in relation to concomitant changes in discharge (hatched line). Negative numbers indicate downstream fish movement from previous location.

Table 1. Sizes, dates relocated (X), and known days at large for 24 age-6 ultrasonic tagged pallid sturgeon released into the Missouri River downstream of Fort Randall Dam on October 29, 2010. Peak discharged defined as sustained flows > 4,000 m^3/s: June 14, to August 18, 2011 (Figure 2).

Fish code	Frequency (kHz)	Fork length (mm)	Weight (g)	Date last relocated (mm/dd/yy)	Known days at large	Total relocations during peak discharge	Survey Date							
							Nov 1, 2010	Apr 11, 2011	Apr 27-29, 2011	May 16-19, 2011	Jul 25-26, 2011	Aug 16-17, 2011	Sep 14-16, 2011	Nov 16-18, 2011
334	70	637	1050	9/26/11	332	0			X				X	
366	72	663	1200	11/17/11	384	2					X	X		X
447	73	695	1400	11/16/11	383	1						X		X
448	74	655	1150	4/29/11	182	0			X					
488	75	663	1200	11/17/11	384	2		X			X	X		X
555	76	655	1150	11/16/11	383	0							X	X
677	77	717	1550	10/29/10	0	0								
678	78	564	700	9/14/11	320	0				X			X	
3354	79	637	1050	9/15/11	321	1				X		X	X	
3355	80	646	1100	11/17/11	384	0			X					X
3386	81	576	750	10/29/10	0	0								
3387	82	646	1100	11/16/11	383	0								X
3545	70	576	750	10/29/10	0	0								
3546	71	576	750	8/17/11	292	1						X		
3578	72	723	1600	11/16/11	383	0								X
3584	73	695	1400	11/1/10	3	0	X							
3666	74	702	1450	10/29/10	0	0								
3774	76	663	1200	11/17/11	384	1			X			X		X
3775	77	717	1550	8/17/11	292	2			X		X	X		
4467	78	702	1450	7/26/11	270	2					X	X		X
4468	79	655	1150	10/29/10	0	0								
4577	81	655	1150	9/15/11	321	2					X	X	X	
4747	82	655	1150	11/17/11	384	1						X	X	X
4748	83	564	700	11/16/11	383	1						X		X

Table 2. Sizes, dates relocated (X), and known days at large for 27 age-1 ultrasonic tagged pallid sturgeon released into the Missouri River downstream of Fort Randall Dam on May 13, 2011. Peak discharged defined as sustained flows > 4,000 m3/s: June 14, to August 18, 2011 (Figure 2).

Fish code	Frequency (kHz)	Fork length (mm)	Weight (g)	Date last relocated (mm/dd/yy)	Known days at large	Total relocations during peak discharge	Survey date			
							May 16-19	Jul 25-26	Aug 16-17	Sep 14-16
334	70	371	201	5/13/11	0	0				
365	71	363	187	5/13/11	0	0				
447	73	378	203	5/16/11	3	0	X			
448	74	366	171	5/17/11	4	0	X			
555	76	368	187	5/13/11	0	0				
677	77	376	184	5/17/11	4	0	X			
678	78	365	210	5/17/11	4	0	X			
3355	80	371	192	8/16/11	95	1			X	
3386	81	360	198	5/13/11	0	0				
3387	82	383	212	8/17/11	96	1	X		X	
3458	83	374	196	5/16/11	3	0	X			
3545	70	359	170	5/13/11	0	0				
3546	71	389	235	5/13/11	0	0				
3584	73	356	175	5/17/11	4	0	X			
3666	74	369	186	5/13/11	0	0				
3667	75	367	183	7/26/11	74	1		X		
3774	76	352	165	5/13/11	0	0				
4467	78	376	199	5/13/11	0	0				
4468	79	375	195	5/13/11	0	0				
4568	80	380	196	5/13/11	0	0				
4747	82	360	183	5/17/11	4	0	X			
3365	70	363	199	5/17/11	4	0	X			
3366	71	381	219	5/17/11	4	0	X			
3437	72	384	215	5/13/11	0	0				
3438	73	363	166	5/17/11	4	0	X			
3678	81	362	196	5/17/11	4	0	X			
4445	83	361	185	5/17/11	4	0	X			