HABITAT USE, DIET, AND GROWTH OF HATCHERY-REARED JUVENILE PALLID STURGEON AND INDIGENOUS SHOVELNOSE STURGEON IN THE MISSOURI RIVER ABOVE FORT PECK RESERVOIR

by

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APPROVAL

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Natural recruitment of pallid sturgeon *Scaphirhynchus albus* has not been observed in the Missouri River above Fort Peck Reservoir, Montana, for at least 20 years. To augment the population, 732 hatchery-reared juvenile pallid sturgeon (HRJPS) were released as yearlings in 1998. Evaluation of these HRJPS was necessary to determine their performance in a natural lotic environment. Habitat variables were measured at 666 locations obtained from 29 HRJPS (mean length = 511 mm, 90% confidence interval $\pm$ 17 mm; mean weight = 434 $\pm$ 37 g) and 21 indigenous shovelnose sturgeon *Scaphirhynchus platorynchus* (mean length = 497 $\pm$ 29 mm; mean weight = 566 $\pm$ 97 g) implanted with radio transmitters in 2003 and 2004. Mean home range was similar between HRJPS and shovelnose sturgeon. Mean river kilometer was different between the two species, with shovelnose sturgeon using upstream areas of the study reach more than HRJPS. Hatchery-reared juvenile pallid sturgeon frequented lotic habitat created by receding reservoir water levels, indicating that Fort Peck Reservoir influences the amount of available habitat for HRJPS. No differences existed in mean depth, cross-section relative depth, longitudinal relative depth, column velocity, bottom velocity, and channel width between HRJPS and shovelnose sturgeon. Shovelnose sturgeon and HRJPS were primarily associated with fines and sand substrate. However, shovelnose sturgeon associated with gravel and cobble substrate more than HRJPS. Shovelnose sturgeon and HRJPS selected reaches without islands and avoided reaches with islands. Additionally, HRJPS and shovelnose sturgeon selected main channel habitat and avoided secondary channels. The diets of 50 HRJPS and 155 shovelnose sturgeon were examined. Shovelnose sturgeon primarily consumed Chironomidae (percent occurrence = 70%; percent composition by weight = 67%), whereas HRJPS primarily consumed fish (percent occurrence = 54%; percent composition by weight = 90%). There was no difference in relative growth rate between recaptured HRJPS (N = 18) and shovelnose sturgeon (N = 11) from May through October in 2003 and 2004. It appears that HRJPS in the Missouri River above Fort Peck Reservoir are capable of living in a natural lotic environment. Therefore, stocking HRJPS can be used to successfully augment wild pallid sturgeon populations.

INTRODUCTION

Pallid sturgeon *Scaphirhynchus albus* inhabit the large, turbid rivers of the Missouri and Mississippi river systems (Kallemeyn 1983). Historically, these rivers provided a diverse array of environments (e.g., islands, alluvial bars, secondary channels, backwaters) that were in a constant state of fluctuation. However, today most of the original habitat available to pallid sturgeon has been altered through anthropogenic activities. Fifty-one percent (2,913 km) of the traditional range of pallid sturgeon has been channelized, 28% (1,593 km) has been impounded, and the remaining 21% is below dams where habitat variables (e.g., temperature, turbidity, discharge) have been altered (Keenlyne 1989). In addition, commercial fishing has probably reduced pallid sturgeon population levels in the Missouri and Mississippi River systems (Barnickol and Starret 1951; Keenlyne 1989), and high concentrations of contaminants found in pallid sturgeon may interfere with reproduction (Ruelle and Keenlyne 1993). As a result, Keenlyne (1995) estimated that there were only 6,000 to 21,000 pallid sturgeon left in the wild in 1994, with the Missouri River above Fort Peck Reservoir, Montana, estimated to contain only 30 to 144 fish (Gardner 1995). As a consequence of habitat alterations and low numbers of fish, pallid sturgeon were listed as endangered in 1990 under the Endangered Species Act of 1973 (Dryer and Sandvol 1993).

Loss of spawning habitat has contributed to the decline of pallid sturgeon, as dams built on the Missouri River block movements to traditional spawning grounds and fragment the population. Impoundment of the Missouri River has also reduced sediment loads, changed temperature regimes, and altered the timing and amount of discharge that may have triggered pallid sturgeon spawning in the past (Keenlyne 1989; Dryer and Sandvol 1993). Prior to impoundment of the Missouri River in 1926, high discharges usually occurred in April, and a larger peak discharge occurred in June (Pflieger and Grace 1987). Currently, flows throughout most of the Missouri River are reduced from April to July for flood control, and increased from July to April for hydroelectric power, water supply, and navigation (Pflieger and Grace 1987).

Although many factors have contributed to the decline of pallid sturgeon throughout their range, loss of rearing habitat is probably the most significant factor in the upper Missouri River (i.e., Montana, North Dakota, and South Dakota). Larval pallid sturgeon were captured in the Missouri River between Fort Peck Reservoir and Lake Sakakawea (North Dakota) during two consecutive years of sampling (Braaten and Fuller 2003; P. Braaten, U.S. Geological Survey, personal communication), confirming that pallid sturgeon are spawning in at least one reach of the upper Missouri River. However, recruitment has not been observed for at least 20 years, suggesting that altered temperature and discharge causes pallid sturgeon to spawn at the wrong time, or that rearing habitat for larval pallid sturgeon is limiting. The lack of recruitment of pallid sturgeon in the upper Missouri River is likely related to dams that have altered natural river morphology and blocked long distance larval drift. Reservoirs created by these dams have inundated many traditional spawning and rearing areas for lotic fishes (Dryer and Sandvol 1993). Many of the lotic species in the Missouri River may never adapt to the relatively rapid changes in habitat that have occurred since the first main-stem dams were built in the 1930s. In addition, abundances of non-native, sight-feeding pelagic planktivores such as cisco *Coregonus artedi*, and carnivores such as northern pike *Esox* *lucius*, smallmouth bass *Micropterus dolomieui*, and walleye *Sander vitreus* have increased since main-stem reservoirs were created (Dryer and Sandvol 1993). Adaptations suited to turbid, lotic systems (e.g., light body-black tail phenotype and tendency to swim at the surface in aggregations) along with diurnal activity are conspicuous in clear, lentic systems, and may make larval pallid sturgeon more susceptible to predation (Kynard et al. 2002).

Pallid sturgeon are sympatric with the closely related shovelnose sturgeon *Scaphirhynchus platorynchus* throughout their range. Shovelnose sturgeon are more common than pallid sturgeon; however, their numbers have also declined throughout most of their range during the past 100 years because of anthropogenic activities (Keenlyne 1997). No data are available to compare the abundance of shovelnose sturgeon in Montana before and after the construction of Fort Peck Dam. However, the Missouri River above Fort Peck Reservoir may have the best conditions for shovelnose sturgeon throughout the range of the species. Shovelnose sturgeon in the Missouri River above Fort Peck Reservoir have larger average size, faster growth, longer life, and lower annual mortality than shovelnose sturgeon in other areas of the Missouri River (Quist et al. 2002). In addition, shovelnose sturgeon from the Missouri River above Fort Peck Reservoir have higher relative weight (W_r) values than other shovelnose sturgeon throughout the Missouri and Mississippi river systems (Quist et al. 1998). Pallid sturgeon and shovelnose sturgeon demonstrate dietary overlap (Carlson et al. 1985), interbreed (Carlson et al. 1985; Keenlyne et al. 1994), and have been captured in the same habitats (Carlson et al. 1985; Tews 1994). Whereas these observations suggest both species likely occupy similar ecological niches, some aspects of their ecology differ. For example, a greater proportion of fish occurred in the diets of adult pallid sturgeon than in those of shovelnose sturgeon in the Missouri and Mississippi rivers (Carlson et al. 1985). In addition, Bramblett and White (2001) concluded that shovelnose sturgeon are not good surrogates for pallid sturgeon because of differences in movements and habitat use in the lower Yellowstone River and Missouri River above Lake Sakakawea.

The Pallid Sturgeon Recovery Plan was implemented by the U.S. Fish and Wildlife Service in 1993 (Dryer and Sandvol 1993). The recovery plan designates seven recovery priority management areas (RPMAs) along the Missouri and Mississippi rivers based on recent records of pallid sturgeon occurrence and probability that the areas still provide suitable habitat for the restoration and recovery of the species (Dryer and Sandvol 1993). One objective of the recovery plan is to capture and spawn wild pallid sturgeon, with the resulting progeny raised in hatcheries until they are released at age-1 in the RPMAs. For example, 732 age-1 hatchery-reared juvenile pallid sturgeon (HRJPS) were released into the Missouri River above Fort Peck Reservoir (RPMA 1) in 1998. Anecdotal data suggest that the 1997 year class of HRJPS may be growing slower than indigenous shovelnose sturgeon of similar ages (W.M. Gardner, Montana Department of Fish, Wildlife and Parks (MTFWP), personal communication). Reduced growth of hatchery-reared fish may indicate they are not well adapted to the natural lotic environment, habitat is limiting, or is a result of a combination of environmental and behavioral factors. Alternatively, pallid sturgeon may naturally have a slower growth rate relative to shovelnose sturgeon.

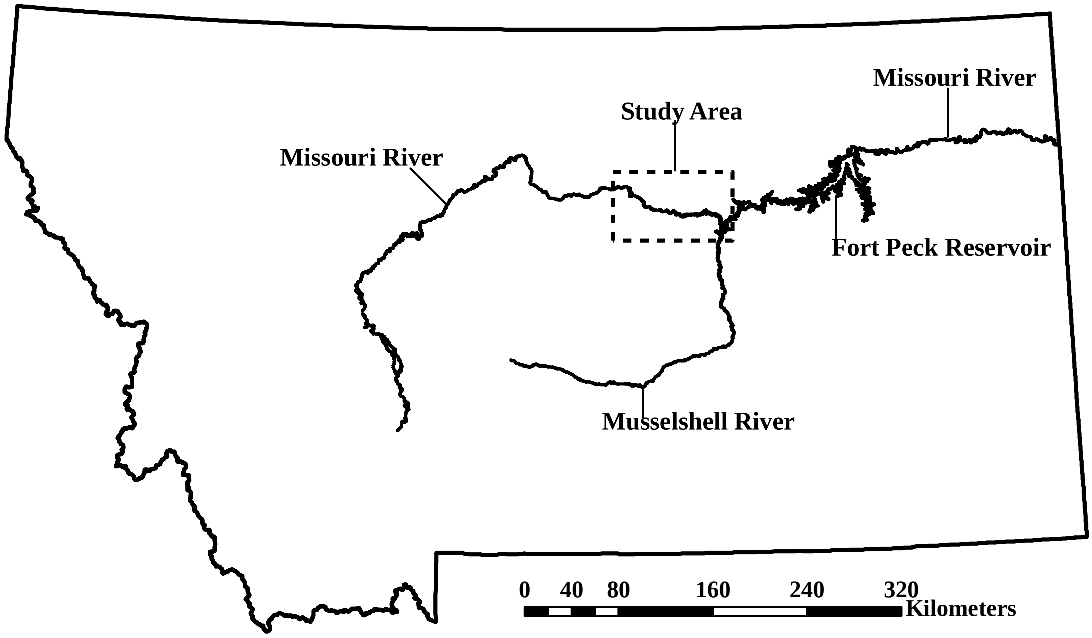
Although additional steps will be necessary to reverse the decline of pallid sturgeon (e.g., habitat restoration), stocking HRJPS into the wild is an essential step in increasing recruitment. Propagation has been used to augment populations of other sturgeon species throughout the world, including North American species lake sturgeon *Acipenser fulvescens,* shortnose sturgeon *Acipenser brevirostrum*, and white sturgeon *Acipenser transmontanus*. Jackson et al. (2002) concluded that the restoration of lake sturgeon into Onieda Lake, New York, was successful based on high catch rates, fast growth, and abundant food resources. Shortnose sturgeon stocked as juveniles from 1985 to 1992 made up approximately 39% of the adult population in the Savannah River from 1997 to 2000 (Smith et al. 2002). Propagation of white sturgeon has also been successful in the Kootenai River, where 60% of hatchery-reared juveniles survived in the first year after stocking and 90% survived in subsequent years (Ireland et al. 2002).

Evaluation of HRJPS is necessary to determine their performance in a natural lotic environment, because stocking hatchery-reared fish that cannot adapt to their natural environment would be an ineffective way to recover the species. Survival and growth estimates from the time of stocking were not possible for this study because of a low number of recaptured 1997 year-class HRJPS since their release. However, observed similarities and differences in ecology among HRJPS, indigenous shovelnose sturgeon, and wild adult pallid sturgeon may help determine if HRJPS are performing similarly to wild individuals, and may also explain the differences in growth observed between HRJPS and indigenous shovelnose sturgeon. Additionally, a paucity of information exists on the ecology of juvenile pallid sturgeon in their natural environment. Assuming behavior similar to wild pallid sturgeon, these hatchery-reared fish provided a unique opportunity to study the ecology of juvenile pallid sturgeon. Currently, research on the habitat use and diet of juvenile pallid sturgeon in the Missouri River is considered important for providing insight into recovery requirements for the species (Quist et al. 2004). Therefore, the objectives of this study were to contrast the habitat use, diets, and growth rates of the 1997 year class of HRJPS and indigenous shovelnose sturgeon in the Missouri River above Fort Peck Reservoir, Montana, and also to make qualitative comparisons between HRJPS and wild pallid sturgeon in other areas. Additionally, knowledge gained about the ecology of HRJPS may be used to assist recovery efforts of pallid sturgeon throughout the range of the species.

STUDY AREA

The Missouri River above Fort Peck Reservoir, Montana, (river kilometers 3,004 to 3,138) (Figure 1) is located within the Charles M. Russell National Wildlife Refuge. River kilometers 3,004 to 3,138 were chosen based on the high occurrence of HRJPS relative to other areas of the Missouri River above Fort Peck Reservoir, according to MTFWP biologists who had extensive experience in the study area. The higher number of HRJPS in this area occurs despite the stocking of many fish in upstream areas as far as the Marias River confluence (river kilometer 3,302). Average monthly discharge (1934 – 2003) varies from 187 m^3/s in January to 549 m^3/s in June. Sand is the primary substrate from river kilometers 3,004 to 3,098, while gravel and cobble are more common from river kilometers 3,098 to 3,138 (Gardner 1994). The area upstream from river kilometer 3,092 was designated as part of the National Wild and Scenic River Systems to protect the last free-flowing portion of the Missouri River (U.S. Congress 1975a). The “Wild and Scenic” designation prohibits construction of any dams on protected waters and imposes protective regulations on any new development in areas surrounding the protected area (U.S. Congress 1975b). Water diversions and pumping of water from the protected area for agricultural purposes are still permitted, as are row-crop farming and cattle grazing within the immediate watershed (Gardner and Berg 1980). Limited storage of upstream dams and unregulated tributaries make the Missouri River above Fort Peck Reservoir the least hydrologically altered portion of the Missouri River (Scott et al. 1997). As a result, this reach maintains many of the normal characteristics of a free-flowing river (e.g., islands, alluvial bars, secondary channels, backwaters).

Figure 1. Map of the study area, the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138).



METHODS

Fish Capture

Hatchery-reared juvenile pallid sturgeon and shovelnose sturgeon were sampled for radio-tagging from May through August in 2003 and March through August in 2004. Both species were sampled for diet analysis from May through September in 2003 and March through October in 2004. Fish were sampled using rod and reel, set lines, benthic trawl, and trammel nets. Rod and reel gear consisted of 1.8-m rods, 2.7 – 5.4-kg test monofilament or multifilament fishing line, and number-two circle hooks. Set lines were 8-m long with six to eight number-two circle hooks spaced 91-cm apart. Both gears were baited with earthworms *Lumbricus terrestris*. The benthic trawl was a 1.8-m wide by 0.46-m high rectangular metal frame with skids and a 5.5-m long outer chafing net with a 3.4-m long, 3.2-mm mesh inner liner attached to the frame. Trammel nets were 45.8-m long and 1.8-m deep, with a 2.5-cm mesh inner panel and 25.4-cm mesh outer panels. Fork length (mm) and weight (g) of all fish sampled were measured. All gears were deployed throughout the 134-km study area. However, most sampling effort was focused on areas where HRJPS and shovelnose sturgeon were known to commonly occur, according to MTFWP biologists who had extensive experience in the study area. Thus, the HRJPS and shovelnose sturgeon captured for this study represented the sturgeon assemblage in this reach.

Surgery

Transmitter implantation surgeries were performed using methods modified from Ross and Kleiner (1982) and Schmetterling (2001). All surgical tools and radio transmitters were soaked in Betadine disinfectant before a surgery. Each HRJPS and shovelnose sturgeon was placed in a V-shaped wooden cradle, ventral side up. A 25-mm incision was made midway along the body posterior to the pectoral fin, and a groove director was pushed posteriorly into the incision. A catheter was inserted into the fish immediately anterior to the pelvic girdle, towards the incision, and the groove director was used to guide the catheter towards the incision. The antenna was directed through the catheter at the incision until it protruded from the opposite end. The catheter and antenna were pulled posteriorly while simultaneously inserting the transmitter into the incision. About 200 mm of antenna protruded from the fish. The incision was then closed with three or four surgical staples. After surgery, radio-tagged fish were placed in a holding tank for 10 min to allow recovery, and then released at the capture location. Tracking of radio-tagged fish commenced the day after surgery so that fish were not lost; however, habitat use data were not collected until after a one week acclimation period (Guy et al. 1992).

Transmitters

All radio transmitters used in this study avoided body weight ratios in excess of 2% (Winter 1996). Advanced Telemetry Systems (ATS) radio transmitters weighing about 2 g were used in 2003. The transmitters had a battery life of 36 to 72 d, and were programmed to have an 8-h on and 16-h off cycle for 3 d, followed by an off period for 4 d. Fish were implanted so that the transmitter was on consecutively for 3 d anytime from Tuesday through Saturday each week. In addition, the transmitters were on from 0900-1700.

Both 7-g and 2-g ATS radio transmitters were used in 2004. The 7-g transmitters had a battery life of 134 to 268 d, and were programmed to have a 10-h on and 14-h off cycle for 5 d, followed by an off period for 2 d. Fish were implanted so that the transmitter was on consecutively for 5 d anytime from Monday through Saturday each week. In addition, the 7-g transmitters were on from 0800-1800. All transmitters used in this study were on unique frequencies at 40 MHz.

Tracking Schedule

I attempted to locate radio-tagged fish at least once per week from May through August in 2003 and April through October in 2004. Each week before tracking commenced, I randomly selected whether to begin tracking in the river reach upstream or downstream from James A. Kipp Recreation Area boat launch (river kilometer 3,091), and whether to track from upstream to downstream or downstream to upstream in the selected river reach. After all fish were located in a river reach, tracking proceeded to the other reach. Daily tracking each week began where tracking ceased on the previous day and continued until transmitters turned off or all fish had been located.

Radio-tagged fish were detected using a Lotek Suretrack STR1000 scanning receiver and an omnidirectional whip antenna. Following detection, each fish was located with an ATS directional loop antenna. A buoy was deployed to mark the fish location, and coordinates (i.e., latitude and longitude) and river kilometer were recorded from a Garmin GPSMAP 168 Sounder. Blind tests with both 2-g and 7-g transmitters placed in the river showed mean accuracy of this technique to be 2.5 m (90% confidence interval $\pm$ 0.9 m).

Mean River Kilometer and Home Range

Mean river kilometer (calculated for each radio-tagged fish using river kilometers recorded at each fish location) was used as a measure of the most frequented areas of the study site by radio-tagged fish. Home range was defined as the number of river kilometers used by a radio-tagged fish, and was calculated by subtracting the river kilometer at the furthest downstream location from the river kilometer at the furthest upstream location (Hurley et al. 1987; Bramblett 1996; Curtis et al. 1997) (e.g., if the furthest downstream location was river kilometer 3,090, and the furthest upstream location was river kilometer 3,100, then the home range of that fish was 10 km).

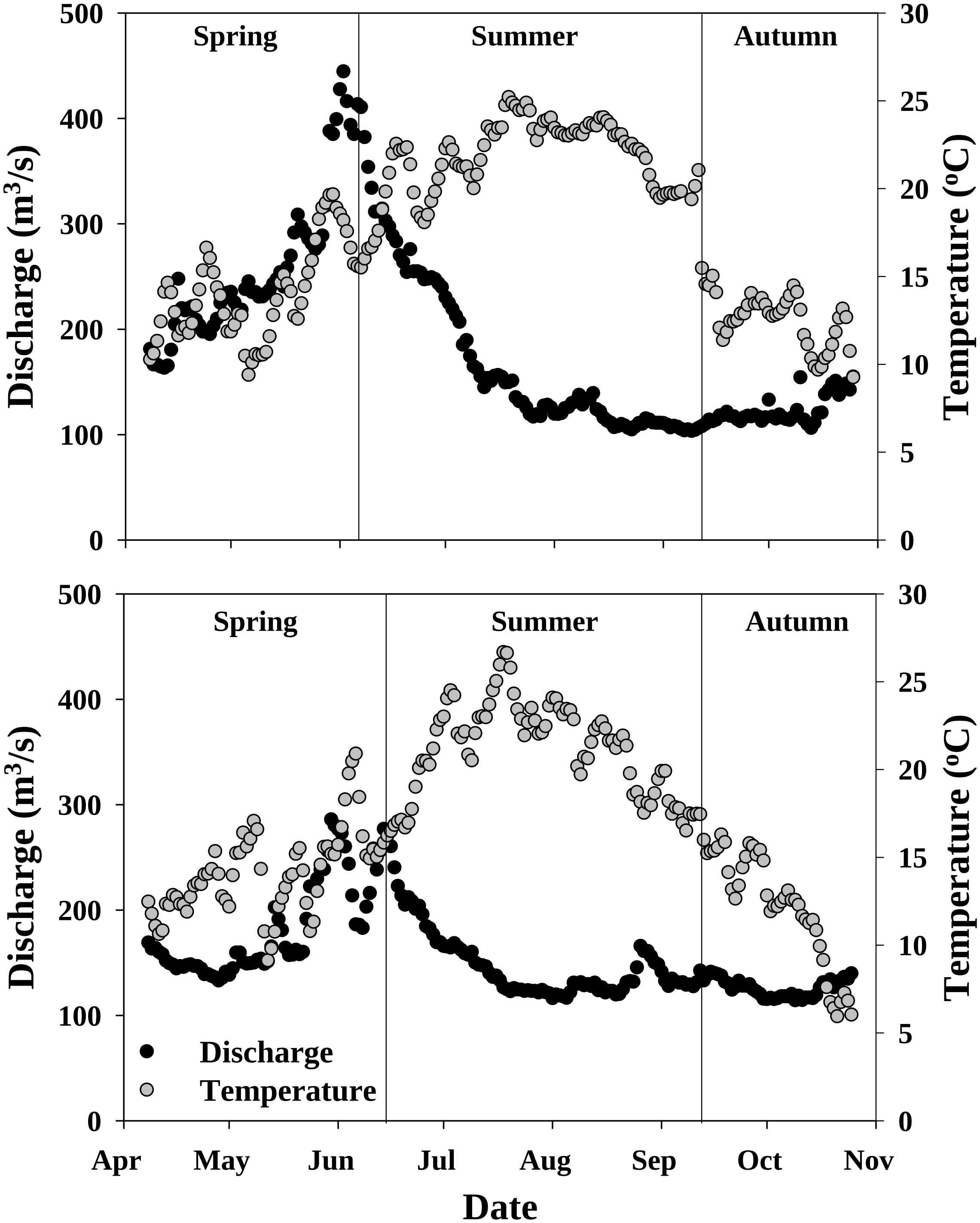
Water Temperature and Discharge

The years 2003 and 2004 were divided into three seasons based on mean daily discharge and water temperature recorded at James A. Kipp Recreation Area (Figure 2) to determine if changing river conditions affected habitat use of HRJPS and shovelnose sturgeon. Mean daily water temperature data were obtained from a MTFWP temperature logger, and mean daily discharge data were obtained from a U.S. Geological Survey stream flow gauging station. Mean daily discharge was used to classify the beginning of summer. However, discharge varied little after peak spring flows, so mean daily water temperature was used to classify the beginning of autumn. The time between ice-off and the final high discharge was classified as spring. The first day mean daily discharge declined after the final high discharge was classified as the first day of summer (June 7, 2003 and June 15, 2004). The first day mean daily water temperature declined consistently from 15.5°C in 2003 and 16.2°C in 2004 (the mean daily water temperatures on the first day of summer in 2003 and 2004, respectively) was classified as the first day of autumn. The last day of autumn was classified as the last day radio-tagged fish were tracked (September 12, 2003 and October 15, 2004).

Current Velocity, Channel Width, Depth Profiles, and Relative Depth

Current velocity, channel width, and water depth profiles were measured at each fish location. Current velocity at 50% depth and within 15 cm of the bottom (hereafter bottom velocity) was measured with a Marsh-McBirney Model 201 flow meter, channel width was measured using a Bushnell Lytespeed 400™ rangefinder, and depth profiles were recorded from a Garmin GPSMAP 168 Sounder. Cross section depth profiles were obtained by recording depth in 5-m increments while driving the boat from one river bank to the other along a transect perpendicular to the current. I chose the riverbank (river-bank right or left) to begin the cross section based on feasibility of boat navigation. Longitudinal depth profiles were produced by recording depth in 5-m increments while driving the boat from 50-m downstream to 50-m upstream of the fish location along a transect parallel with the current. Depth at the fish location and maximum depth were marked in each profile, and relative depth was calculated by dividing the depth at the fish location by the maximum depth.

Figure 2. Mean daily temperature and discharge recorded at river km 3,091 in the Missouri River above Fort Peck Reservoir, Montana, in 2003 (top) and 2004 (bottom).



Substrate

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

Islands and Alluvial Bars

Distances to islands and alluvial bars within 350 m of fish locations were measured with a Bushnell Lytespeed 400™ rangefinder using methods modified from Bramblett and White (2001). Islands were defined as stable, vegetated land surrounded by water, at or near the same elevation as the valley floor (Kellerhals et al. 1976). Alluvial bars were defined as land at a lower elevation than the valley floor with little or no vegetation (Kellerhals and Church 1989). Each fish location was classified as having: 1) an island; 2) an alluvial bar; or 3) neither islands nor an alluvial bars present. Locations were classified as both island and alluvial bar if both were present. Additionally, alluvial bars were classified as either: 1) midchannel bars – bars formed in the midchannel; 2) channel side bars – bars on the side of a channel, usually associated with slight curves in the channel; or 3) point bars – bars formed on the inside of well-developed bends in the channel (Kellerhals et al. 1976). Locations were classified with more than one bar type if more than one bar was present.

Use and Availability of Islands

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

Use and Availability of Main and Secondary Channel Habitat

Use and availability of main and secondary channel habitat was also used as a measure of habitat complexity. Secondary channels are a normal characteristic of free-flowing rivers that are present in the Missouri River above Fort Peck Reservoir, but this habitat has been reduced throughout most of the channelized lower Missouri River (Funk and Robinson 1974). Main channel habitat was defined as the main course of the Missouri River that contained the thalweg throughout the 134-km study area. Secondary channels were defined as flow around islands that is connected to the main channel, but does not contain the thalweg. Use of these habitats was calculated by classifying each fish location as occurring in either the main channel or a secondary channel. United States Geological Survey Landsat Enhanced Thematic Mapper satellite imagery from 2004 was used to calculate proportional availability of main and secondary channel habitat by quantifying how many 0.5-km sections of the 134-km study reach contained each habitat type. If a 0.5-km section contained more than one secondary channel, then secondary channel availability for that section was classified as the number of secondary channels present.

Diet

Stomach contents of HRJPS and shovelnose sturgeon were obtained by gastric lavage modified from Brosse et al. (2002). Fish were held ventral side up, and an intramedic polyethylene tube (1.57-mm inner diameter, 2.08-mm outer diameter) was inserted through the mouth until it reached the stomach. Tubing was attached to a 7.58-L pressurized garden sprayer filled with water. After the tubing reached the stomach, the fish was placed dorsal side up, and water from the garden sprayer was slowly pumped into the stomach to flush out food items. The lavage process lasted no longer than 15 - 20 s for each fish to prevent water from entering the swim bladder. Stomach contents were washed into a 500-µm mesh sieve and then placed in a plastic bag and frozen. After the lavage process was complete, fish were placed in a holding tank for 10 min to allow recovery, and then released in the vicinity of capture.

Stomach contents were examined in the laboratory under a dissecting microscope. Fish were identified to species and insects to order except Diptera, which were all chironomids. Wet weight of each taxonomic group from each sample was measured to the nearest milligram. Frequency of occurrence and percent composition by wet weight were calculated for each taxon (Bowen 1996). Individual fish were the experimental unit. However, some individuals in the sample (fish that were radio-tagged for another study) were captured and lavaged two or three times during the study, and it is possible that other untagged fish were captured and lavaged more than once. If we knew the diet of an individual had been examined more than once (i.e., recaptured radio-tagged fish only), the total wet weight of each prey taxon was averaged for all samples collected from that individual to preclude pseudoreplication.

Pianka's index of niche overlap was calculated to determine the amount of diet overlap between HRJPS and shovelnose sturgeon:

$$O_{jk} = \frac{\sum_{i}^{n} p_{ij} p_{ik}}{\sqrt{\sum_{i}^{n} p_{ij}^{2} \sum_{i}^{n} p_{ik}^{2}}}$$

where O_{jk} is Pianka's measure of overlap, p_{ij} is the proportion diet item i is of the total resources used by species j, p_{ik} is the proportion diet item i is of the total resources used by species k, and n is the total number of diet items (Pianka 1973). Complete diet overlap is indicated by a value of 1.0, and no diet overlap is indicated by a value of 0 (Pianka and Pianka 1976). The index value was then bootstrapped 5,000 times (Efron and Tibshirani 1993) to reduce bias and provide an estimate of variability (Mueller and Altenberg 1985; Smith 1985). To facilitate this process, bootstrapping was conducted using R-software version 1.8.

Description of Potential Fish Prey at HRJPS and Shovelnose Sturgeon Locations

I attempted to estimate the abundance of potential prey fish (i.e., fish $\leq$ 12 cm) at a location for each radio-tagged HRJPS and shovelnose sturgeon in May, July, and September in 2004. After a fish was located, a benthic trawl was deployed 50-m upstream and retrieved 50-m downstream of the fish location, and the time of each trawl was recorded. Catch per unit effort (C/f; number of fish/min trawled) of potential prey fish was calculated for each radio-tagged HRJPS and shovelnose sturgeon for which a trawl sample was collected. All trawl samples were pooled by individual fish because of low sample size within months. Potential prey fish were quantified and identified to species except for *Hybognathus* spp., which were identified to genus because of the difficulty in species identification in the field.

Growth Rate

Radio-tagged fish were recaptured to estimate growth rate by drifting trammel nets over known fish locations from July through August in 2003 and May through October in 2004. Growth rate of HRJPS and shovelnose sturgeon (calculated for both length and weight) was determined from the time a transmitter was implanted until a fish was recaptured using relative growth rate (Busacker et al. 1990):

$$\text{relative growth rate} = (Y_2 - Y_1)/[Y_1(t_2 - t_1)] \times 100$$

where Y_1 = length or weight of the fish at first capture; Y_2 = length or weight of the fish at final recapture; and $(t_2 - t_1)$ = number of days elapsed between first capture and final recapture.

DATA ANALYSES

Habitat Use and Growth

Two-tailed *t*-tests were used to test the hypotheses that there were no differences in mean home range and mean river kilometer between HRJPS and shovelnose sturgeon. Different analyses were used in 2003 and 2004 for mean column velocity, bottom velocity, fish depth, channel cross section relative depth, longitudinal section relative depth, and channel width because data were only collected in summer during 2003, whereas data were collected in three seasons during 2004. Two-tailed *t*-tests were used to test the hypotheses that there were no differences in mean column velocity, bottom velocity, fish depth, channel cross section relative depth, longitudinal section relative depth, and channel width between HRJPS and shovelnose sturgeon during the summer of 2003. A Bonferroni approach to adjust alpha was used to reduce the likelihood of making a Type I error in the main effects (alpha = 0.1; adjusted alpha = 0.1/6 = 0.02). Repeated-measures (with individual fish as the repeated variable) analysis of variance (ANOVA) was used to test the hypotheses that there were no differences in mean column velocity, bottom velocity, fish depth, channel cross section relative depth, longitudinal section relative depth, and channel width between HRJPS and shovelnose sturgeon among seasons in 2004. As in the 2003 analysis, a Bonferroni approach was used to reduce the likelihood of committing a Type I error in the main effects. When there was a significant difference in the main effects, a Bonferroni multiple comparison procedure was used to test for pairwise differences between species and seasons for each habitat variable (Sheskin 1997).

Observations of association with substrates, islands, and alluvial bars at each fish location were converted to proportions for each radio-tagged fish. Because these data were not normally distributed, a Mann-Whitney *U*-test was used to test the hypotheses that there were no differences between HRJPS and shovelnose sturgeon for association with: 1) fines and sand substrate; 2) gravel and cobble substrate; 3) boulder and bedrock substrate; 4) islands within 350 m; 5) alluvial bars within 350 m; and 6) neither islands nor alluvial bars within 350 m (Bramblett and White 2001). A Mann-Whitney U-test was also used to test the hypotheses that there were no differences between HRJPS and shovelnose sturgeon for association with: 1) midchannel bars; 2) channel side bars; and 3) point bars. Although the assumption of equal variances was violated in some instances (Levene's test for homogeneity of variance < 0.1), the Mann-Whitney *U*-test is not as affected by a violation of the equal variance assumption (Sheskin 1997). One-tailed *t*-tests were used to test the hypotheses that: 1) catch per unit effort of potential prey fish was higher at HRJPS locations than shovelnose sturgeon locations; and 2) shovelnose sturgeon displayed a faster relative growth rate than HRJPS from April through October. Individual fish were the sampling unit for all statistical tests. Alpha = 0.1 was established *a priori* for all statistical tests. All statistical tests were conducted using Statistical Analysis Systems (SAS) version 8.2 (SAS Institute Inc. 2001, Cary, NC).

Use and Availability of Islands and Main and Secondary Channel Habitat

The following chi-square log likelihood test statistic was used to test the hypotheses that animals in each population as a whole (i.e., HRJPS and shovelnose sturgeon) were selecting for: 1) river reaches of different island categories in proportion to availability; and 2) main and secondary channel habitat in proportion to availability:

$$\chi^2_{L2} = 2\sum_{j=1}^{n}\sum_{i=1}^{I} u_{ij} \log_e\left(u_{ij} \big/ E(u_{ij}) \right)$$

where $E(u_{ij}) = \pi_i u_{+j}$; $\pi_i =$ the proportion of type i habitat available to the population throughout the study area; u_{+j} = total amount of habitat units used by fish j; u_{ij} = amount of habitat i used by fish j; I = number of habitat categories; and n = number of fish (Manly et al. 2002). A log-likelihood test statistic larger than the critical value of the chi-squared distribution with $n(I-1)$ degrees of freedom indicates selection by at least some animals in the population (Manly et al. 2002). Although some of the expected values were less than the recommended minimum of five (Devore and Peck 2001), chi-square tests are robust to smaller expected values (Roscoe and Byars 1971; Lawal and Upton 1984).

If selection was established, the following selection ratio was used to determine which habitat types each population of fish was selecting:

$$\hat{w}_i = \frac{u_{i+}}{(\pi_i u_{++})}$$

where u_{i+} = amount of type i habitat used by all fish and u_{++} = total number of habitat units used by all fish (Manly et al. 2002). Two analyses were conducted for each species for the island category analysis: 1) comparisons of all island categories separately; and 2) comparison of island category one (no islands) versus categories two (occasional islands), three (frequent islands), and four (split channel) combined. Selection is indicated with a value > 1, avoidance is indicated with a value < 1, and use in proportion to availability is indicated with a value = 1 (Manly et al. 2002). In addition, simultaneous 90% Bonferroni confidence intervals were calculated for all population selection ratios using the formula:

$$w_i \pm z_{\alpha/2I}\, se(\hat{w}_i)$$

where $z_{\alpha/(2I)}$ = the variable of the standard normal distribution corresponding to the upper tail probability of $\alpha/(2I)$, and:

$$se(\hat{w}_i) = \sqrt{\left\{\frac{n}{(u_{++})^2}\right\}\left\{\sum_{j=1}^{n}\frac{\left(\dfrac{u_{ij}}{\pi_i - \hat{w}_i u_{+j}}\right)^2}{(n-1)}\right\}}$$

(Manly et al. 2002). All chi-square log-likelihood statistics and selection ratios were calculated using FishTel 1.4 software.

RESULTS

Thirty HRJPS and 23 shovelnose sturgeon were captured and implanted with radio-transmitters (Tables 1 and 2). Six HRJPS and 23 shovelnose sturgeon were captured with trammel nets, 1 HRJPS was captured in a benthic trawl, 12 HRJPS were captured with setlines, and 11 HRJPS were captured by angling. Two radio-tagged fish were never located (one HRJPS and one shovelnose sturgeon) and another shovelnose sturgeon was located only once after being implanted with a radio-transmitter, thus they were excluded from all analyses (Tables 1 and 2). A total of 666 locations obtained from 29 HRJPS (mean fork length = 511 mm, 90% confidence interval $\pm$ 17 mm; mean weight = 434 $\pm$ 37 g) and 21 shovelnose sturgeon (mean fork length = 497 $\pm$ 29 mm; mean weight = 566 $\pm$ 97 g) were used for all habitat analyses.

Home range varied from 1.1 to 73.9 km for HRJPS (Table 3) and 0.7 to 41.5 km for shovelnose sturgeon (Table 4). No difference in mean home range existed between HRJPS (15.0 $\pm$ 5.0 km) and shovelnose sturgeon (16.5 $\pm$ 4.7 km) (t_{48} = -0.34, P = 0.73). However, mean river kilometer differed between species (3,072.9 $\pm$ 4.6 for HRJPS; 3,089.7 $\pm$ 6.3 for shovelnose sturgeon; t_{48} = -3.79, P < 0.001), with shovelnose sturgeon using upstream areas more than HRJPS.

Table 1. Descriptive statistics of hatchery-reared juvenile pallid sturgeon captured and radio-tagged in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004.

Radio frequency	Transmitter weight (g)	Date of capture	Capture location (river km)	Fork length (mm)	Weight (g)
40.011	7	3/31/04	3,060.0	526	445
40.031	2	5/06/04	3,087.5	462	317
40.041	2	5/06/04	3,086.7	473	353
40.051	2	8/14/03	3,070.3	557	552
40.061	2	6/05/03	3,078.6	512	462
40.061	7	5/04/04	3,086.7	495	320
40.071	7	4/22/04	3,069.0	503	365
40.091	2	6/19/03	3,082.6	491	489
40.091	7	5/06/04	3,087.5	496	415
40.101[a]	2	7/03/03	3,078.7	549	538
40.101	7	4/22/04	3,069.0	518	429
40.111	7	3/31/04	3,060.0	559	531
40.131	7	4/01/04	3,060.0	521	404
40.141	2	6/10/03	3,069.0	493	450
40.141	7	4/15/04	3,074.2	523	465
40.600	7	4/15/04	3,059.4	526	430
40.601	2	7/10/03	3,079.0	522	462
40.611	7	4/15/04	3,052.9	554	540
40.621	2	8/05/04	3,076.1	489	378
40.641	7	4/15/04	3,090.7	510	404
40.651	7	4/23/04	3,098.3	615	755
40.671	7	4/15/04	3,065.8	493	357
40.681	7	4/15/04	3,059.4	510	408
40.691	2	6/05/03	3,078.7	503	396
40.751	7	4/01/04	3,071.8	495	361
40.761	7	5/04/04	3,086.7	587	607
40.791	7	7/27/04	3,047.6	556	588
40.811	2	6/09/03	3,083.5	554	504
40.820	2	5/29/03	3,090.9	491	355
40.830	2	5/29/03	3,085.8	506	419

[a] Never located after transmitter implantation.

Table 2. Descriptive statistics of shovelnose sturgeon captured and radio-tagged in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004.

Radio frequency	Transmitter weight (g)	Date of capture	Capture location (river km)	Fork length (mm)	Weight (g)
40.021	2	5/15/03	3,087.5	321	128
40.021	7	5/25/04	3,085.9	559	898
40.071	2	6/05/03	3,091.5	570	682
40.081	7	6/01/04	3,091.9	544	593
40.110	2	7/03/03	3,091.5	567	768
40.121	2	7/03/03	3,091.5	528	810
40.131[a]	2	7/03/03	3,091.5	568	836
40.151	2	7/09/04	3,072.2	445	352
40.631	2	8/07/03	3,075.5	432	251
40.631	7	5/25/04	3,098.3	486	599
40.641	2	8/07/03	3,063.1	317	100
40.651	2	8/08/03	3,091.5	537	865
40.661	2	6/04/03	3,091.5	398	208
40.661	7	5/25/04	3,085.9	574	915
40.671	2	6/05/03	3,091.5	561	708
40.691	7	6/18/04	3,072.4	481	417
40.731	7	5/06/04	3,098.8	458	428
40.771	2	7/31/03	3,082.9	508	428
40.771	7	5/06/04	3,096.1	556	751
40.781	7	4/26/04	3,092.5	505	449
40.782	2	5/29/03	3,091.2	560	812
40.791	2	6/20/03	3,091.5	535	732
40.841[b]	2	7/12/04	3,080.6	448	342

[a] Never located after transmitter implantation.
[b] Located only once after transmitter implantation.

Habitat Use

Mean depth varied from 2.31 m to 2.48 m at HRJPS locations and 1.93 m to 2.36 m at shovelnose sturgeon locations by season. Variation in mean depth at HRJPS and shovelnose sturgeon locations was less than 0.5 m (90% confidence interval). No differences in mean depth existed between species in 2003 (t_{19} = 1.57, P = 0.13) or 2004 ($F_{1,28}$ = 1.52, P = 0.23), and no differences existed among seasons within species in 2004

Table 3. Area used and home range size for radio-tagged hatchery-reared juvenile pallid sturgeon (HRJPS) in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004.

Radio frequency	Locations	Days at large	Mean river km	90% CI	Minimum river km	Maximum river km	Home range (km)
40.011	24	189	3,061.3	0.6	3,056.8	3,063.4	6.6
40.031	9	72	3,088.3	3.3	3,078.5	3,095.1	16.6
40.041	6	71	3,087.2	0.9	3,085.1	3,088.3	3.2
40.051	6	16	3,070.0	0.6	3,069.3	3,071.4	2.1
40.061 (2003)	18	86	3,076.6	1.0	3,069.2	3,080.8	11.6
40.061 (2004)	6	35	3,074.0	5.1	3,062.9	3,080.0	17.1
40.071	21	160	3,076.5	3.1	3,067.4	3093.2	25.8
40.091 (2003)	13	70	3,067.3	4.7	3,056.6	3,086.1	29.5
40.091 (2004)	18	146	3,086.5	0.5	3,084.5	3,088.3	3.8
40.101	21	154	3,081.9	4.8	3,068.5	3,099.0	30.5
40.111	24	198	3,066.1	0.7	3,064.2	3,069.0	4.8
40.131	20	198	3,057.8	0.8	3,054.4	3,061.0	6.6
40.141 (2003)	14	65	3,070.7	0.7	3,068.2	3,072.2	4.0
40.141 (2004)	22	183	3,071.8	1.4	3,065.0	3,078.0	13.0
40.600	20	174	3,044.5	3.0	3,033.6	3,056.8	23.2
40.601	16	63	3,078.3	2.1	3,072.6	3,089.3	16.7
40.611	21	174	3,051.7	1.2	3,043.8	3,055.3	11.5
40.621	3	41	3,074.8	0.9	3,074.2	3,075.3	1.1
40.641	21	167	3,088.4	0.5	3,084.6	3,090.1	5.5
40.651	13	130	3,106.3	9.2	3,074.2	3,125.3	51.1
40.671	24	168	3,072.3	0.3	3,069.0	3,073.5	4.5
40.681	22	174	3,061.8	4.2	3,044.7	3,073.2	28.5
40.691	8	16	3,078.4	0.3	3,077.5	3,078.8	1.3
40.751	24	207	3,078.1	1.0	3,065.8	3,079.8	14.0
40.761	6	51	3,046.5	22.3	3,005.1	3,079.0	73.9
40.791	7	71	3,044.0	2.2	3,037.5	3,046.6	9.1
40.811	5	19	3,087.2	0.6	3,086.7	3,088.3	1.6
40.820	8	44	3,080.2	3.2	3,075.3	3,090.3	15.0
40.830	6	44	3,085.1	1.2	3,083.2	3,086.6	3.4

($F_{2, 43}$ = 2.02, P = 0.15) (Table 5). Hatchery-reared juvenile pallid sturgeon were in 73% to 83% of the maximum cross section depth and 89% to 91% of the maximum longitudinal depth, whereas shovelnose sturgeon were in 77% to 86% of the maximum cross section depth and 90% to 94% of the maximum longitudinal depth by season. Similar to depth, no differences existed between species in mean cross-section relative depth (t_9 = -0.68, P = 0.51 in 2003; $F_{1, 33}$ = 0.12, P = 0.73 in 2004) and longitudinal relative depth (t_{19} = 0.4, P = 0.69 in 2003; $F_{1, 31}$ = 2.42, P = 0.13 in 2004) (Table 5). No differences existed in mean longitudinal relative depth among seasons within species ($F_{2,}$

$_{46}$ = 0.35, P = 0.70); however, seasonal differences existed within species for HRJPS in mean cross-section relative depth ($F_{2,\,47}$ = 5.11, P = 0.0098) (Table 5).

Table 4. Area used and home range size for radio-tagged shovelnose sturgeon in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004.

Radio frequency	Locations	Days at large	Mean river km	90% CI	Minimum river km	Maximum river km	Home range (km)
40.021 (2003)	10	71	3,097.7	2.6	3,092.4	3,102.8	10.4
40.021 (2004)	16	129	3,091.7	3.6	3,078.2	3,098.6	20.4
40.071	4	22	3,110.5	12.4	3,098.0	3,121.6	23.6
40.081	15	122	3,082.9	6.3	3,059.8	3,097.8	38.0
40.110	4	23	3,098.9	3.2	3,093.5	3,103.6	10.1
40.121	16	71	3,088.3	1.3	3,082.1	3,091.5	9.4
40.151	3	27	3,071.1	0.7	3,070.6	3,071.3	0.7
40.631 (2003)	9	23	3,076.3	0.3	3,075.5	3,076.7	1.2
40.631 (2004)	15	142	3,102.1	4.1	3,088.5	3,110.2	21.7
40.641	8	22	3,064.9	0.5	3,063.9	3,066.4	2.5
40.651	2	14	3,104.9	11.4	3,103.1	3,106.7	3.6
40.661 (2003)	5	30	3,125.8	12.5	3,106.4	3,147.9	41.5
40.661 (2004)	15	143	3,082.0	2.1	3,073.0	3,091.5	18.5
40.671	15	63	3,079.0	2.2	3,075.0	3,088.5	13.5
40.691	11	111	3,075.7	6.9	3,060.3	3,096.5	36.2
40.731	20	161	3,109.2	1.6	3,100.7	3,116.3	15.6
40.771 (2003)	3	9	3,055.0	28.0	3,039.7	3,072.6	32.9
40.771 (2004)	17	146	3,088.9	2.4	3,077.9	3,099.0	21.1
40.781	19	157	3,085.2	1.8	3,079.0	3,093.5	14.5
40.782	19	76	3,094.9	0.8	3,092.4	3,098.1	5.7
40.791	14	70	3,098.1	0.7	3,095.6	3,100.2	4.6

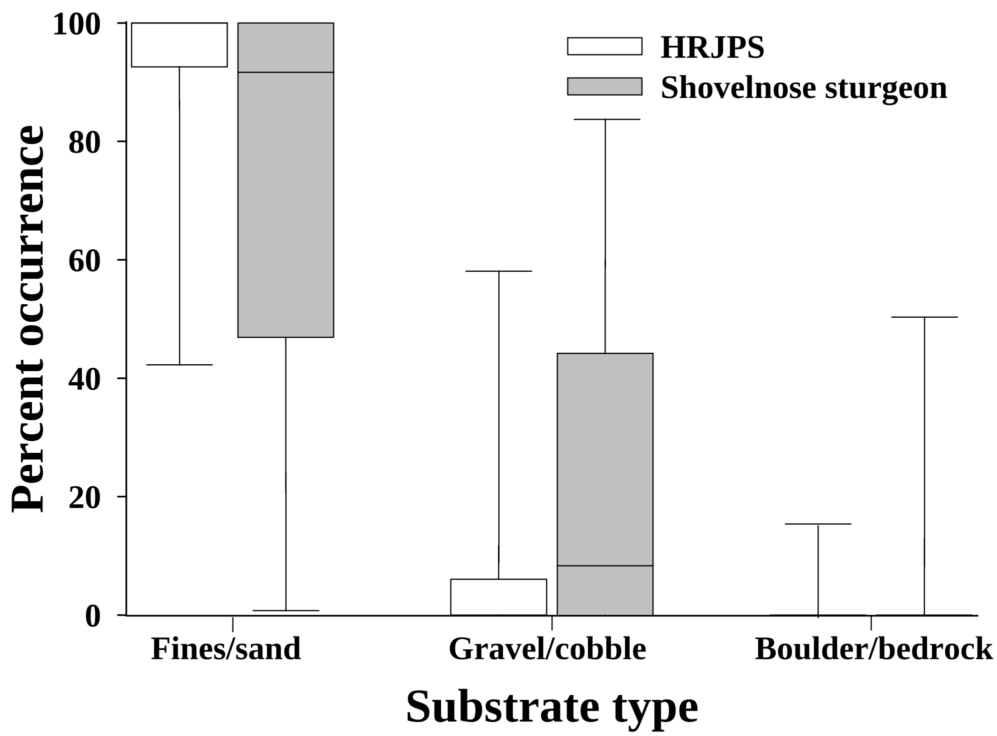
Mean column velocity varied from 0.65 m/s to 0.78 m/s at HRJPS locations and 0.67 m/s to 0.87 m/s at shovelnose sturgeon locations by season. No differences existed in mean column velocity between species (t_{19} = 1.92, P = 0.07 in 2003; $F_{1,\,27}$ = 2.67, P = 0.11 in 2004); however, differences among seasons within species existed in 2004 ($F_{2,\,42}$ = 16.88, P < 0.0001) (Table 5). Mean bottom velocity was relatively constant between species and among seasons in 2004, varying from 0.45 m/s to 0.50 m/s for HRJPS and 0.48 m/s to 0.55 m/s for shovelnose sturgeon by season. No differences in mean bottom velocity existed between species (t_{16} = 0.55, P = 0.59 in 2003; $F_{1,\,25}$ = 3.51, P = 0.07 in 2004) or among seasons within species ($F_{2,\,40}$ = 1.88, P = 0.17) (Table 5). Mean channel width varied from 137 m to 153 m at HRJPS locations and 142 m to 162 m at shovelnose sturgeon locations by season. No differences in mean channel width existed between species (t_{19} = 0.43, P = 0.67 in 2003; $F_{1, 27}$ = 0.68, P = 0.42 in 2004); however, differences existed among seasons within species for HRJPS in 2004 ($F_{2, 42}$ = 4.43, P = 0.02) (Table 5).

Table 5. Means and 90% confidence intervals of measured habitat variables at radio-tagged hatchery-reared juvenile pallid sturgeon (HRJPS) and shovelnose sturgeon locations by season in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004. No significant differences were found between species by season for any habitat variable. For each habitat variable, different letters indicate a difference among seasons within species in 2004 (alpha = 0.1). No data were collected in spring and autumn 2003, thus no seasonal analysis was conducted.

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

Hatchery-reared juvenile pallid sturgeon and shovelnose sturgeon were primarily associated with fines and sand substrate (Figure 3). However, HRJPS associated with fines and sand more than shovelnose sturgeon ($\chi^2_1 = 7.32$, $P = 0.0068$), while shovelnose sturgeon associated with gravel and cobble more than HRJPS ($\chi^2_1 = 8.49$, $P = 0.0036$). No differences existed in the association with boulder and bedrock substrate between species ($\chi^2_1 = 0.82$, $P = 0.36$).

Figure 3. Percent occurrence by substrate type for radio-tagged hatchery-reared juvenile pallid sturgeon (HRJPS) ($N = 29$) and shovelnose sturgeon ($N = 21$) in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004. Line delineates the median, box is 25% and 75% percentiles, and whiskers are minimum and maximum values.



Hatchery-reared juvenile pallid sturgeon and shovelnose sturgeon primarily associated with areas that were classified as “neither islands nor alluvial bars present”

(Figure 4). No differences existed between species in the association with islands (χ^2_1 = 0.01, P = 0.93) or areas classified as "neither islands nor alluvial bars present" (χ^2_1 = 1.64, P = 0.2); however, HRJPS were associated with alluvial bars slightly more than shovelnose sturgeon (χ^2_1 = 3.07, P = 0.08) (Figure 4). When alluvial bars occurred at fish locations, midchannel bars were most common for both species, followed by point bars and channel side bars (Figure 5). No differences existed between HRJPS and shovelnose sturgeon in the association with midchannel bars (χ^2_1 = 0.04, P = 0.84), channel side bars (χ^2_1 = 0.05, P = 0.83), or point bars (χ^2_1 = 0.11, P = 0.74).

Figure 4. Percent occurrence of islands and alluvial bars within 350 m of radio-tagged hatchery-reared juvenile pallid sturgeon (HRJPS) (N = 29) and shovelnose sturgeon (N = 21) in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004. Locations were classified as both island and alluvial bar if both were present and neither present if both were absent. Line delineates the median, box is 25% and 75% percentiles, and whiskers are minimum and maximum values.

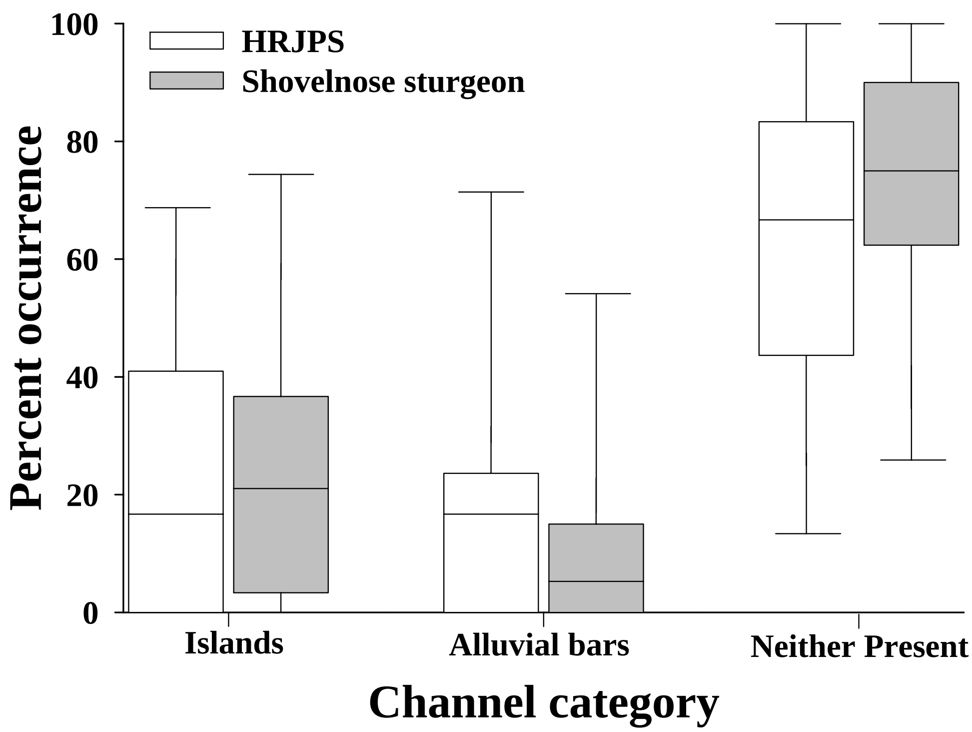
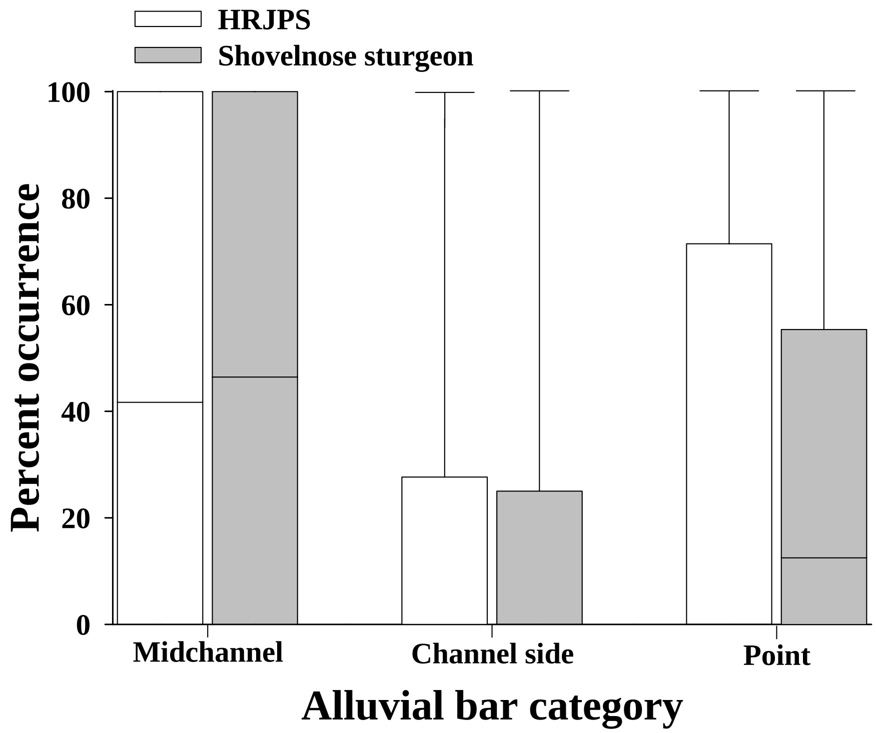


Figure 5. Percent occurrence of three alluvial bar categories at radio-tagged hatchery-reared juvenile pallid sturgeon (HRJPS) (*N* = 29) and shovelnose sturgeon (*N* = 21) locations when fish were located within 350 m of an alluvial bar in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004. Locations were classified with more than one bar category if more than one bar was present. Line delineates the median, box is 25% and 75% percentiles, and whiskers are minimum and maximum values.



<u>Use and Availability of Islands</u>

Fifty-one percent of the study area had no islands, followed by occasional islands (26%), frequent islands (13%), and split channel (10%). Hatchery-reared juvenile pallid sturgeon and shovelnose sturgeon did not select island habitat categories in proportion to availability, whether all island density categories were considered separately (χ^2_{87} = 429.95, $P < 0.0001$ for HRJPS; χ^2_{63} = 193.99, $P < 0.0001$ for shovelnose sturgeon) or when island categories two (occasional islands), three (frequent islands), and four (split channel) were combined (χ^2_{29} = 237.88, $P < 0.0001$ for HRJPS; χ^2_{21} = 96.55, $P < 0.0001$

for shovelnose sturgeon). When island categories were analyzed separately, HRJPS avoided reaches with frequent islands, while shovelnose sturgeon selected reaches without islands and avoided reaches with frequent islands and split channels (Figure 6). Both HRJPS and shovelnose sturgeon selected reaches without islands and avoided reaches with islands when considering island categories two (occasional islands), three (frequent islands), and four (split channel) combined (Figure 7).

Figure 6. Selection ratios and simultaneous 90% Bonferroni confidence intervals of river reaches by island category for radio-tagged hatchery-reared juvenile pallid sturgeon (HRJPS) (N = 29) and shovelnose sturgeon (N = 21) in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004. Selection is indicated with a value > 1, avoidance is indicated with a value < 1, and use in proportion to availability is indicated with a value = 1.

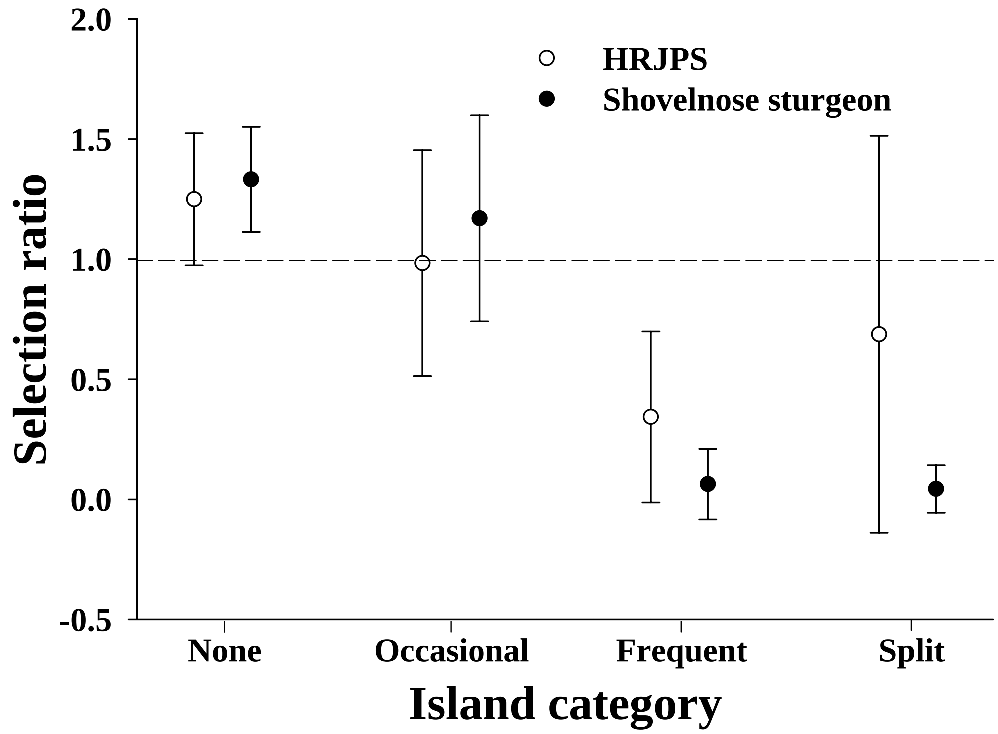
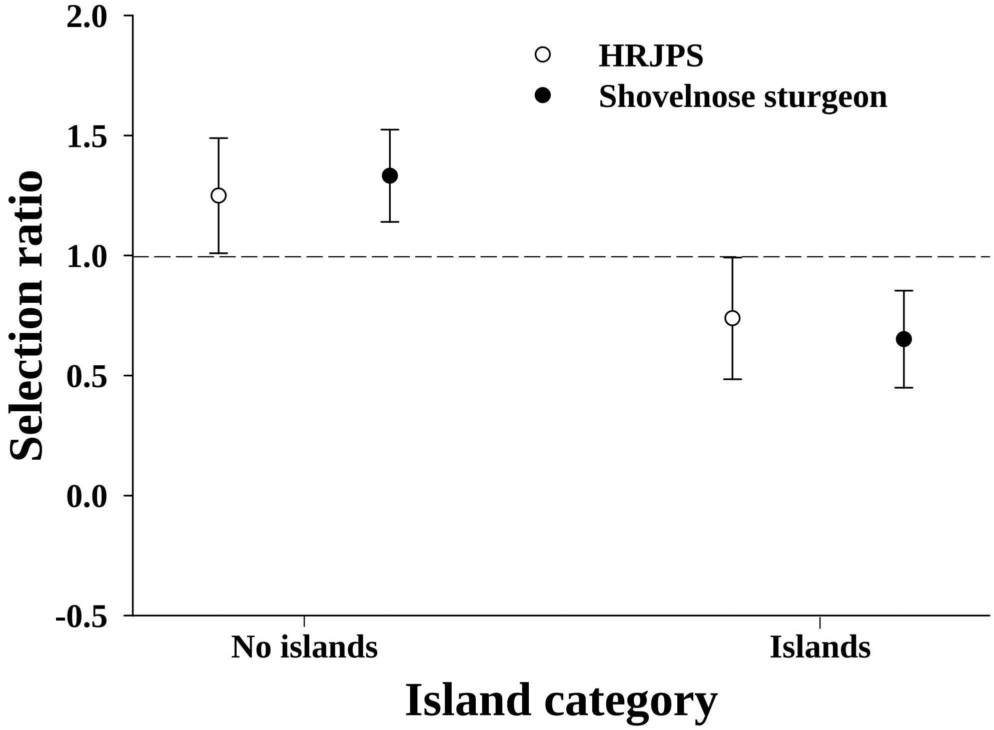


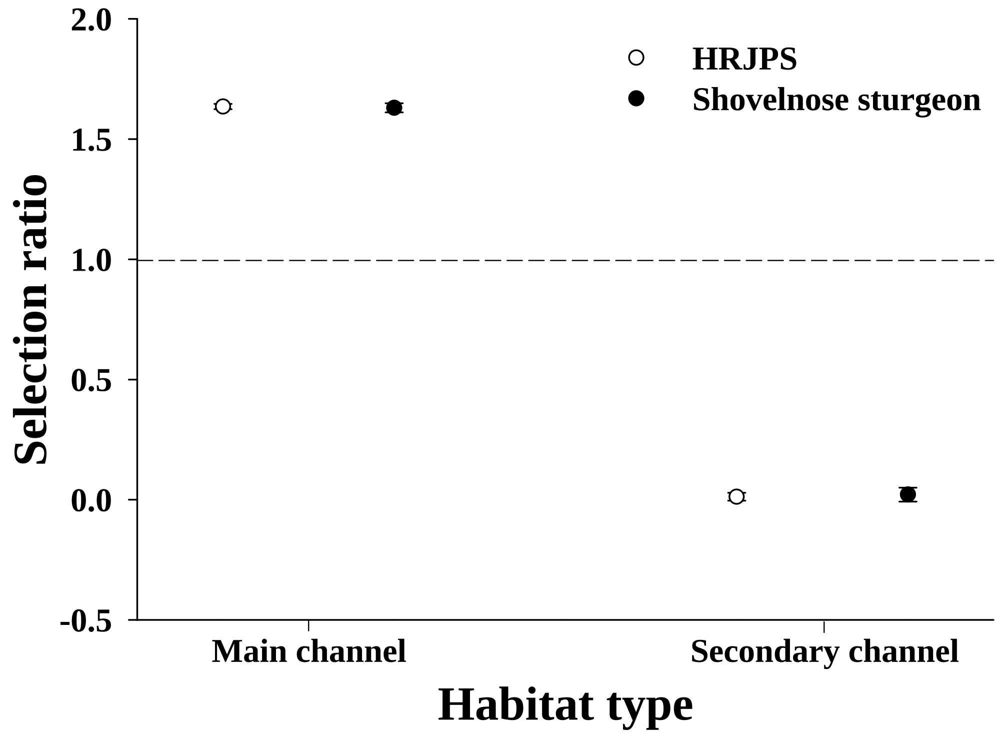
Figure 7. Selection ratios and simultaneous 90% Bonferroni confidence intervals of reaches with and without islands for radio-tagged hatchery-reared juvenile pallid sturgeon (HRJPS) (N = 29) and shovelnose sturgeon (N = 21) in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004. Selection is indicated with a value > 1, avoidance is indicated with a value < 1, and use in proportion to availability is indicated with a value = 1.



Use and Availability of Main and Secondary Channel Habitat

Sixty-one percent of the study area was main channel and 39% contained secondary channel habitat. Hatchery-reared juvenile pallid sturgeon and shovelnose sturgeon did not select main and secondary channel habitat in proportion to availability (χ^2_{29} = 409.78, P < 0.0001 for HRJPS; χ^2_{21} = 231.49, P < 0.0001 for shovelnose sturgeon). Both species selected main channel habitat and avoided secondary channels (Figure 8). Only 4 out of 666 locations (two HRJPS locations and two shovelnose sturgeon locations) obtained on 50 radio-tagged fish were in secondary channel habitat.

Figure 8. Selection ratios and simultaneous 90% Bonferroni confidence intervals of main and secondary channel habitat for radio-tagged hatchery-reared juvenile pallid sturgeon (HRJPS) (N = 29) and shovelnose sturgeon (N = 21) in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004. Selection is indicated with a value > 1, avoidance is indicated with a value < 1, and use in proportion to availability is indicated with a value = 1.



Diet

In 2003 and 2004, 50 HRJPS (mean FL = 538 ± 13 mm; mean weight = 518 ± 49 g) and 155 shovelnose sturgeon (mean FL = 525 ± 12 mm; mean weight = 683 ± 41) diets were sampled. Twenty-nine HRJPS and 154 shovelnose sturgeon were captured with trammel nets, 13 HRJPS and 1 shovelnose sturgeon were captured with setlines, and eight HRJPS were captured by angling. No stomach contents were obtained from 30% of the HRJPS and 26% of the shovelnose sturgeon that were lavaged. Diet overlap between HRJPS and shovelnose sturgeon was low (mean Pianka's overlap index value = 0.0269 ±

0.0003). Fish (percent occurrence = 54%; percent composition by weight = 90%) composed the majority of the HRJPS diet, whereas Chironomidae larvae (percent occurrence = 70%; percent composition by weight = 67%) were the primary prey of shovelnose sturgeon (Figures 9 and 10). Fish remains were found in 1% of the shovelnose sturgeon diets, whereas 30% of the HRJPS ate Chironomidae (Figure 9). Sturgeon chub and sicklefin chub composed 79% of the of the identifiable fish remains (N = 19) in HRJPS stomach contents, while channel catfish *Ictalurus punctatus*, flathead chub *Platygobio gracilis*, sand shiner *Notropis stramineus*, and shorthead redhorse *Moxostoma macrolepidotum* composed the other 21%. Ephemeroptera, Trichoptera, Chironomidae, and detritus each occurred in at least 10% of the HRJPS diets (Figure 9); however, no prey other than fish composed more than 10% of the diet by weight (Figure 10). Ephmeroptera and detritus occurred in at least 10% of the shovelnose sturgeon diets (Figure 9), while fish eggs and Ephemeroptera each made up more than 10% of the diet by weight (Figure 10).

Potential prey fish abundance did not reflect the differences in diet, as mean C/f of potential prey fish at HRJPS locations (3.15 $\pm$ 1.13 fish/min) did not differ from shovelnose sturgeon locations (2.25 $\pm$ 1.89 fish/min) (t_{22} = 0.76; P = 0.23). Sturgeon chubs were the most abundant prey fish sampled at the locations of both species (1.43 $\pm$ 0.59 fish/min for HRJPS; 1.63 $\pm$ 1.35 fish/min for shovelnose sturgeon) (Table 6).

Figure 9. Mean percent occurrence of fish (Fis.), fish eggs (Egg.), Ephemeroptera (Eph.), Trichoptera (Tri.), Chironomidae (Chi.), detritus (Det.), and other prey (Oth.) in the diets of hatchery-reared juvenile pallid sturgeon (HRJPS) (*N* = 50; 30% empty) and shovelnose sturgeon (*N* = 155; 26% empty) sampled in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004.

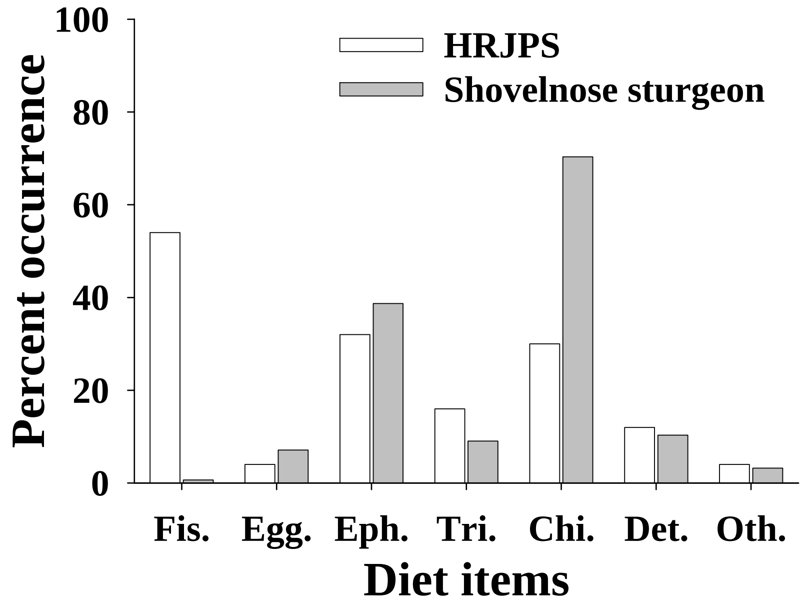


Figure 10. Mean percent composition by weight of fish (Fis.), fish eggs (Egg.), Ephemeroptera (Eph.), Trichoptera (Tri.), Chironomidae (Chi.), detritus (Det.), and other prey (Oth.) in the diets of hatchery-reared juvenile pallid sturgeon (HRJPS) (*N* = 50) and shovelnose sturgeon (*N* = 155) sampled in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004.

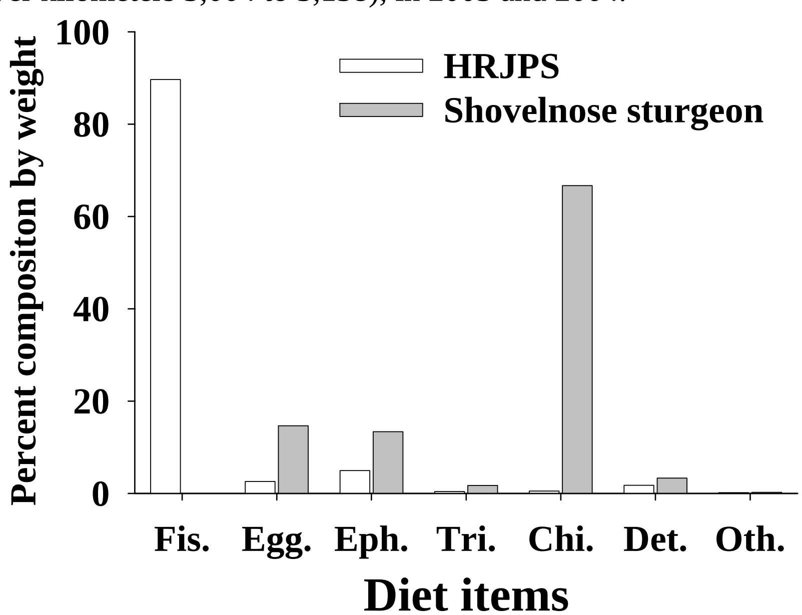


Table 6. Mean catch per unit effort (fish/min) and 90% confidence intervals of potential prey fish at radio-tagged hatchery-reared juvenile pallid sturgeon (HRJPS) and shovelnose sturgeon locations in May, July, and September 2004 in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138).

Radio-tagged species	*N*	Sturgeon chub	Ictalurids	Sicklefin chub	Flathead chub	*Hybognathus* spp.	Longnose dace	Total
HRJPS	17	1.43	1.05	0.62	0.02	0.02	0.01	3.15
		(0.59)	(1.03)	(0.30)	(0.03)	(0.03)	(0.02)	(1.13)
Shovelnose sturgeon	7	1.63	0.13	0.44	0.05	0.00	0.00	2.25
		(1.35)	(0.26)	(0.46)	(0.09)	(0.00)	(0.00)	(1.89)

Growth Rate

The number of days between radio-tagging and recapturing of fish varied from 50 to 198 d for HRJPS (mean = 123 $\pm$ 23 d) (Table 7) and 63 to 290 d for shovelnose sturgen (mean = 128 $\pm$ 35 d) (Table 8). Hatchery-reared juvenile pallid sturgeon 40.091 from 2003 lost weight at 0.39 %/day, and was considered an outlier [> 3 times the interquartile range of the sample (Devore and Peck 2001)], and not included in the analyses. Relative growth rate of length varied from -0.016 to 0.062 %/d for HRJPS (Table 7) and -0.017 to 0.1 %/d for shovelnose sturgeon (Table 8). Relative growth rate of weight varied from -0.172 to 0.174 %/d for HRJPS (Table 7) and -0.025 to 0.194 %/d for shovelnose sturgeon (Table 8). Variability in relative growth rate for length (HRJPS coefficient of variation (CV) = 266 %; shovelnose sturgeon CV = 239 %) and weight (HRJPS CV = 276 %; shovelnose sturgeon CV = 120 %) was high for both species. There were no differences in mean relative growth rate of length (t_{13} = 0.7, P = 0.25) or weight (t_{26} = 0.88, P = 0.19) between HRJPS (0.01 $\pm$ 0.01 %/d for length; 0.03 $\pm$ 0.04 %/d for weight) and shovelnose sturgeon (0.02 $\pm$ 0.02 %/d for length; 0.06 $\pm$ 0.04 %/d for weight).

Table 7. Relative growth rate calculations in fork length (FL) and weight for radio-tagged hatchery-reared juvenile pallid sturgeon (HRJPS) in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004.

Radio frequency	Transmitter weight (g)	Date of capture	Capture FL (mm)	Capture weight (g)	Date of recapture	Recapture FL (mm)	Recapture weight (g)	Number of days between recaptures	Relative growth rate for FL (%/day)	Relative growth rate for weight (%/day)
40.011	7	3/31/04	526	445	6/16/04	527	431	77	0.002	-0.041
40.061	2	6/05/03	512	462	8/15/03	512	440	71	0.0	-0.067
40.071	7	4/22/04	503	365	9/29/04	503	374	130	0.0	0.019
40.091	2	6/19/03	491	484	8/28/03	498	352	70	0.02	-0.39
40.091	7	5/06/04	496	415	9/29/04	508	478	145	0.017	0.105
40.101	7	4/22/04	518	429	8/24/04	535	488	124	0.026	0.111
40.111	7	3/31/04	559	531	10/15/04	563	621	198	0.004	0.086
40.131	7	4/01/04	521	404	5/21/04	521	430	50	0.0	0.129
40.141	2	6/10/03	493	450	8/14/03	513	445	65	0.062	-0.017
40.141	7	4/15/04	523	465	10/15/04	539	556	183	0.017	0.107
40.600	7	4/15/04	526	430	10/06/04	521	430	174	-0.005	0.0
40.611	7	4/15/04	554	540	10/06/04	563	576	174	0.009	0.038
40.641	7	4/15/04	510	404	9/29/04	510	403	167	0.0	-0.001
40.651	7	4/23/04	615	755	7/09/04	625	856	77	0.021	0.174
40.671	7	4/15/04	493	357	9/30/04	490	355	168	-0.004	-0.003
40.681	7	4/15/04	510	408	10/06/04	502	431	174	-0.009	0.032
40.751	7	4/01/04	495	361	5/21/04	491	330	50	-0.016	-0.172
40.791	7	7/27/04	556	588	10/06/04	553	595	71	-0.008	0.017

Table 8. Relative growth rate calculations in fork length (FL) and weight for radio-tagged shovelnose sturgeon in the Missouri River above Fort Peck Reservoir, Montana (river kilometers 3,004 to 3,138), in 2003 and 2004.

Radio frequency	Transmitter weight (g)	Date of capture	Capture FL (mm)	Capture weight (g)	Date of recapture	Recapture FL (mm)	Recapture weight (g)	Number of days between recaptures	Relative growth rate for FL (%/day)	Relative growth rate for weight (%/day)
40.021	7	5/25/04	559	898	8/24/04	552	918	91	-0.014	0.024
40.081	7	6/01/04	544	593	10/01/04	556	613	122	0.018	0.028
40.121	2	7/03/03	528	810	6/16/04	534	899	290	0.004	0.038
40.661	7	5/25/04	574	915	10/15/04	565	929	143	-0.011	0.011
40.671	2	6/05/03	561	708	8/07/03	555	697	63	-0.017	-0.025
40.691	7	6/18/04	481	417	10/07/04	508	440	111	0.051	0.050
40.731	7	5/06/04	458	428	10/14/04	532	562	161	0.100	0.194
40.771	7	5/06/04	556	751	8/30/04	552	810	116	-0.006	0.068
40.781	7	4/26/04	505	449	10/07/04	540	580	164	0.042	0.178
40.782	2	5/29/03	560	812	8/14/03	563	820	77	0.007	0.013
40.791	2	6/20/03	535	732	8/29/03	532	756	70	-0.008	0.047

DISCUSSION

Habitat

The habitat use of HRJPS and shovelnose sturgeon in the Missouri River above Fort Peck Reservoir was similar in many aspects to adult pallid sturgeon and adult shovelnose sturgeon in the lower Yellowstone River and the Missouri River above Lake Sakakawea (Bramblett and White 2001). The similarities and differences between the two closely related species in this study and similarities with adults found in other studies indicate that HRJPS behave naturally in lotic environments. The similarities between the species were probably related to similar morphological adaptations. *Scaphirhynchus* spp. are more derived than any other genus in Acipenseridae, with many characteristics especially adapted for living in large, turbid lotic systems (Findeis 1997). For example, *Scaphirhynchus* spp. have adaptations suited to benthic feeding in turbid systems, including small eyes, sensitive barbels, flattened heads that contain many sensory organs, and mouths that open ventrally (Findeis 1997). These specialized adaptations make *Scaphirhynchus* spp. ideal predators for benthic inhabitants such as aquatic invertebrates, sicklefin chubs, and sturgeon chubs. Additionally, a flattened ventral surface, extensive scalation, and curved leading pectoral fin rays that can be used as “legs” for shuffling along the bottom are all adaptations for extensive contact with substrate (Findeis 1997), which may be necessary for station holding in swift currents (Adams et al. 1999).

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

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

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

Large-scale differences in where HRJPS and shovelnose sturgeon were located (i.e., mean river km) are likely related to the differences in diet and substrate use. The highest catch rates of sturgeon chubs and sicklefin chubs in the Missouri River above Fort Peck Reservoir in 2001 and 2002 occurred in the study area from river km 3,030 to

3,092 (Gardner 2004). Additionally, sand is the most common substrate at river km 3,004 to 3,098, whereas gravel and cobble is the primary substrate at river km 3,098 to 3,138 (Gardner 1994). Thus, the reach between river km 3,004 and 3,098 has many of the characteristics of a large warm-water river such as shifting sand substrate. Subsequently, this area appears important for HRJPS and their prey.

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

The home ranges of six radio-tagged HRJPS and one radio-tagged shovelnose sturgeon included lotic habitat that was historically inundated by Fort Peck Reservoir. Higher reservoir water levels in the mid 1990s inundated a large portion of the study reach. However, the recent drought has caused Fort Peck Reservoir water levels to drop and about 56 km (river kilometers 3,000 to 3,056) are now lotic habitat. Shovelnose sturgeon in the upper Mississippi River (Curtis et al. 1997) and pallid sturgeon and shovelnose sturgeon in the Missouri River above Lake Sakakawea (Bramblett and White 2001) appeared to avoid impounded areas, indicating that reservoirs are unsuitable habitat for both species. The use of previously inundated lotic habitat by HRJPS in this study indicates that reservoir level affects available habitat for pallid sturgeon. Therefore, the management of reservoir water levels is important to the pallid sturgeon population upstream of Fort Peck Reservoir.

Hatchery-reared juvenile pallid sturgeon and shovelnose sturgeon in this study did not use areas with islands and alluvial bars as often as pallid sturgeon and shovelnose sturgeon in other studies. For example, HRJPS (Snook et al. 2002) and shovelnose sturgeon (Swigle 2003) were often located at the downstream tips of alluvial bars in the lower Platte River, whereas pallid sturgeon in the middle Mississippi River selected for downstream island tips (Hurley et al. 2004). Additionally, pallid sturgeon selected for river reaches with frequent islands and avoided reaches with no islands, occasional islands, and split channels in the lower Yellowstone River and the Missouri River above Lake Sakakawea (Bramblett and White 2001). A possibility for the low number of locations near alluvial bars in this study is that only alluvial bars visible above the surface of the water were quantified. Alluvial bars below the surface (especially near inside bends of the river channel) were sometimes encountered when recording depth profiles; however, their presence was not recorded because of the difficulty in observing all submerged alluvial bars near a fish location. Additionally, some alluvial bars normally visible above the surface were submerged during periods of high discharge, and thus not recorded to remain consistent with the data collection methods.

The most likely explanation for HRJPS and shovelnose sturgeon rarely associating with islands and alluvial bars in this study is because other habitat needs (e.g., depth and prey availability) were not met in these areas. Although I did not measure availability, the depths occupied by HRJPS and shovelnose sturgeon in this study were rarely associated with alluvial bars. Perhaps ideal depths for HRJPS and shovelnose sturgeon were not present near islands and alluvial bars in the Missouri River above Fort Peck Reservoir. Mean maximum depth in channel cross section profiles (averaged across all seasons) was 3.1 m for HRJPS and 2.6 m for shovelnose sturgeon in this study, whereas maximum depths averaged 4.4 m for pallid sturgeon and 3.1 m for shovelnose sturgeon in the lower Yellowstone River and Missouri River above Lake Sakakawea (Bramblett and White 2001). Pallid sturgeon in the middle Mississippi River were never found in water shallower than 1.8 m, and usually used depths from 6 to 12 m (Hurley 1999). Additionally, the lower Platte River is shallow in comparison to the Missouri, Mississippi, and lower Yellowstone rivers, with less than 10% of the river > 0.6 m deep (Peters et al 1989). Mean depths in the lower Platte River were 0.9 m for shovelnose sturgeon (Swigle 2003) and 0.76 m and 0.98 m for HRJPS (Snook et al. 2002), suggesting both species use depths not in proportion to availability. It has been hypothesized that downstream island and alluvial bar tips provided abundant prey for pallid sturgeon (Bramblett and White 2001; Snook et al. 2002; Hurley et al. 2004). However, deep water in the main channel is the primary habitat for sicklefin chubs and sturgeon chubs (Grisak 1996; Everett 1999; Welker and Scarnecchia 2004), which were the primary prey of HRJPS in this study. Additionally, chironomid densities were highest in deep water main channel habitat in the Missouri River above Fort Peck Reservoir (Megargle 1996). Thus, pallid sturgeon and shovelnose sturgeon in other studies were probably not selecting for islands and alluvial bars, but for the depths where prey are abundant. The variation in river morphology makes comparison among rivers difficult. Nevertheless, it is evident that pallid sturgeon are selecting deep water habitat that contain main-channel cyprinid species.

The avoidance of secondary channels by HRJPS and shovelnose sturgeon was also probably influenced by a lack of suitable habitat and prey availability. Secondary channels in this area are typically shallow (< 2 m) and do not provide ideal habitat for HRJPS and shovelnose sturgeon. Although chironomids were sampled in secondary channels in the Missouri River above Fort Peck Reservoir, densities were higher in deeper main channel habitat (Megargle 1996). Additionally, sicklefin chubs and sturgeon chubs use water depths between 2 and 7 m in main channel habitat and are rarely captured in secondary channels (Grisak 1996; Everett 1999; Welker and Scarnecchia 2004). Although HRJPS and shovelnose sturgeon were almost exclusively located in main channel habitat, secondary channels are important for other native Missouri River fishes, and may be important to other *Scaphirhynchus* spp. life stages. Loss of shallow, low velocity secondary channel and backwater habitat in the channelized lower Missouri River has been attributed to the decline of many native fishes (Funk and Robinson 1974; Pflieger and Grace 1987; Hesse and Sheets 1993; Hesse 1994). Shallow, low-velocity habitat found along the main channel border and alluvial bars is a nursery area for many lotic fishes (Scheidegger and Bain 1995; Freeman et al. 2001). The low-flow recruitment hypothesis states that shallow, low-velocity habitat provides high densities of small prey necessary for the survival of larval fishes (Humphries et al. 1999). Low flows in the summer provide this habitat in the main channel of unchannelized rivers, which may be more beneficial to *Scaphirhynchus* spp. than secondary channels. For example, low August flows create shallow water habitat in the main channel (e.g., alluvial bars) that is critical nursery habitat for sicklefin chubs (Dieterman and Galat 2004). More importantly, these habitats are juxtaposed to the main channel habitat used by pallid sturgeon. However, low flows do not provide the necessary shallow water habitat for the latter interaction in channelized rivers where habitat is homogenized.

Diet

Fish were an important diet component of HRJPS, and aquatic insects were the primary prey of shovelnose sturgeon. These are the first reported food habits data for juvenile pallid sturgeon in the wild. Low niche overlap values confirmed that HRJPS and shovelnose sturgeon used different food resources. These results are similar to those reported for adult pallid sturgeon (Coker 1930; Cross 1967; Carlson et al. 1985), and for shovelnose sturgeon (Barnickol and Starrett 1951; Hoopes 1960; Held 1969; Helms 1974; Modde and Schmulbach 1977; Gardner and Berg 1980; Carlson et al. 1985; Megargle 1996; Shuman 2003). The distinct differences in diet between HRJPS and shovelnose sturgeon further illustrate that shovelnose sturgeon are not a surrogate for pallid sturgeon.

Although the gastric lavage technique used in this study was probably not 100% efficient, it was the only way to examine stomach contents from a live endangered species such as a pallid sturgeon. Mean gastric lavage recovery rate of known quantities of prey fed to Siberian sturgeon *Acipenser baeri* was only 67.5%, and recovery rate varied by prey type (Brosse et al. 2002). Although I did not quantify recovery rate in this study, it is likely that gastric lavage efficiency for different prey types was not different between two morphologically similar species such as pallid sturgeon and shovelnose sturgeon. Thus, the conclusions that fish composed the majority of the HRJPS diet and aquatic insects composed the majority of the shovelnose sturgeon diet were probably not affected by the use of a gastric lavage. Brosse et al. (2002) recovered stomach contents from all Siberian sturgeon lavaged. Therefore, it is likely that the fish I classified as empty were indeed empty. Interestingly, 94% of the HRJPS lavaged during the spring were empty, whereas only 23% were empty during the summer and autumn. Additionally, 36% of the shovelnose sturgeon stomachs were empty during spring, and 24% were empty during summer and autumn. These results suggest that shovelnose sturgeon are actively feeding more than HRJPS in the spring, or that food is limiting to HRJPS during this period.

The consumption of fish by HRJPS substantiates claims by Bramblett and White (2001) and Snook et al. (2002) that pallid sturgeon habitat use may be influenced by the presence of potential piscine prey. However, no difference existed in the C/f of potential prey fish between the locations of piscivorous HRJPS and insectivorous shovelnose sturgeon. The lack of a difference in the C/f of potential prey fish between the two species may have been because of a small sample size. Additionally, sturgeon chubs and sicklefin chubs had the highest two C/fs at shovelnose sturgeon locations, and two of the top three C/fs at HRJPS locations (young-of-the-year Ictalurids were second highest for HRJPS). Thus, the high C/fs of sicklefin chubs and sturgeon chubs relative to other fishes at HRJPS and shovelnose sturgeon locations may have been the result of similar habitat use among the four species, which are all main channel obligates.

Sicklefin chubs and sturgeon chubs were important prey items for HRJPS in the study area. Populations of both species have declined in the Missouri River in Nebraska

(Hesse 1994), and a review by Galat et al. (in press) concluded that population declines of sturgeon chubs and sicklefin chubs have occurred throughout much of the Missouri River. As a result, both of these cyprinids are listed as imperiled in many states along the Missouri River (Galat et al. in press). Conversely, stable or increasing population levels of sicklefin chubs and sturgeon chubs were reported in the Missouri River in Missouri (Pflieger and Grace 1987; Grady and Milligan 1998). These two species are also fairly abundant in deep main channel habitat of the Missouri River in Montana and North Dakota (Grisak 1996; Young et al. 1997; Everett 1999; Gardner 2004; Welker and Scarnecchia 2004). In the Missouri River between Fort Peck Reservoir and Lake Sakakawea, catches of sicklefin chubs and sturgeon chubs were higher in areas least affected by Fort Peck Dam, suggesting that natural river characteristics (e.g., naturally fluctuating hydrograph and high sediment load) should be preserved to produce sustainable populations of these species (Welker and Scarnecchia 2004).

Growth

The results of this study do not support MTFWP anecdotal data suggesting that 1997 year class HRJPS were growing slower than indigenous shovelnose sturgeon of similar ages. The MTFWP results may have been influenced by the use of pectoral fin ray sections to age shovelnose sturgeon. Although pectoral fin ray sections are considered the most practical way to age shovelnose sturgeon, split annuli, false annuli, spawning bands, imbedded rays, and deteriorating sections can lead to imprecise age estimations (Whiteman et al. 2004). Thus, the shovelnose sturgeon aged by MTFWP may have been older than the HRJPS and growth rates may be similar between the two species. However, the similarities in growth rate between HRJPS and shovelnose sturgeon in this study may be related to when the data were collected. I measured growth rates of HRJPS and shovelnose sturgeon from spring through autumn; growth rate was not measured after winter because expired transmitter batteries prevented the recapture of radio-tagged fish. Based on the high percentage of empty HRJPS stomachs relative to shovelnose sturgeon in the spring, it is possible that HRJPS were feeding less than shovelnose sturgeon in winter. Thus, the slower growth of HRJPS relative to shovelnose sturgeon observed by MTFWP may be related to differences in winter ecology; however, this needs further research. Evidence suggesting that winter is a time of minimal activity for both species does exist. For example, adult pallid sturgeon and shovelnose sturgeon movement in winter was lower than in spring, summer, and autumn in the lower Yellowstone River and the Missouri River above Lake Sakakawea (Bramblett and White 2001), and Quist et al. (1999) hypothesized that shovelnose sturgeon in the Kansas River were not actively feeding in the winter. Additionally, no discernible growth was observed in adult shovelnose sturgeon until mid-May through August in the Mississippi River in Iowa (Helms 1974), indicating that most growth probably occurs during spring, summer, or autumn.

Management Recommendations and Implications for Recovery

Habitat use, diet, and growth of HRJPS and shovelnose sturgeon were similar in many aspects; however, differences also existed. Based on these results and those by Bramblett and White (2001), shovelnose sturgeon should not be used as surrogates for pallid sturgeon in research or management.

This study indicates that HRJPS perform similar to wild pallid sturgeon in a lotic environment. Thus, stocking HRJPS to maintain populations should continue until natural recruitment resumes. However, the HRJPS in this study were not sexually mature. Therefore, the 1997 year-class of HRJPS should be continually evaluated to determine if hatchery-reared fish can successfully reproduce in their natural environment.

Hatchery-reared juvenile pallid sturgeon in this study frequented part of the Missouri River that was unavailable in the past because of inundation by Fort Peck Reservoir. According to Keenlyne (1989), 28% of the traditional range of pallid sturgeon has been lost to impoundment. However, results from this study indicate that low Fort Peck Reservoir water levels increase the amount of lotic habitat used by HRJPS. Thus, lower reservoir water levels throughout the Missouri River system may be necessary for the recovery of pallid sturgeon.

The use of sicklefin chubs and sturgeon chubs by HRJPS as a food resource indicates that recovery and management of native cyprinids in the Missouri River is an important step to the long-term recovery of pallid sturgeon. Sicklefin chub and sturgeon chub survival is dependent on natural flow regimes in the Missouri River (Dieterman and Galat 2004; Welker and Scarnecchia 2004). Areas with the normal characteristics of a free-flowing river (i.e., lower Yellowstone River and the Missouri River below the Yellowstone River confluence) were also more important to pallid sturgeon and shovelnose sturgeon than hydrologically altered areas (i.e., Missouri River below Fort Peck Dam) (Bramblett and White 2001). Thus, conserving the current hydrological characteristics of the Missouri River above Fort Peck Reservoir is important to HRJPS.

Ideally, a more naturally fluctuating hydrograph would likely benefit all native species within the Missouri River.

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