Distribution, Habitat Use, and Population Persistence of Shovelnose Sturgeon in Lake Sharpe, South Dakota

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Abstract - Located on the Missouri River in central South Dakota, Lake Sharpe holds an isolated population of *Scaphirhynchus platorynchus* Rafinesque (Shovelnose Sturgeon). During the spring seasons of 2017–2019, 1,251 adult Shovelnose Sturgeon were collected and marked with uniquely numbered floy tags. Of these, 55 were implanted with acoustic telemetry tags and monitored over the course of two years. A mark-recapture estimate of population size suggests approximately 7,000 (LCI = 5,836, UCI = 8,444) adult Shovelnose Sturgeon inhabit Lake Sharpe, and annual survival of adult Shovelnose Sturgeon was estimated at 83.4%. As expected, most Shovelnose Sturgeon telemetry detections occurred in the riverine portion of Lake Sharpe with fewer detections in the lotic/lentic transition zone and none in the lentic zone of the reservoir. Tagged Shovelnose Sturgeon were found to occupy habitats with a mean depth of 4.37 m (SD = 1.07 m) and moderate bottom water velocity of 0.47 m/s (SD = 0.16 m/s). It is believed that Shovelnose Sturgeon are successfully recruiting in Lake Sharpe as other potential explanations for post-impoundment population persistence (i.e., entrainment from upstream or pre-impoundment holdovers) appear unlikely. Thus, the Shovelnose Sturgeon in Lake Sharpe represent a unique reservoir-bound population of a species adapted to large, complex river habitats.

Introduction

Sturgeons in the genus *Scaphirhynchus* evolved to live in large, complex riverine environments such as the Mississippi, Missouri, and Mobile Rivers (Bailey and Cross 1954, Campton et al. 2000). However, anthropogenic alterations, such as channelization and impoundment of these systems, have threatened the population viability of all three extant species (Bajer and Wildhaber 2007, Campton et al. 2000, Keenlyne 1997). Two members of the genus—*Scaphirhynchus albus* Forbes and Richardson (Pallid Sturgeon) and *Scaphirhynchus suttkusi* Williams and Clemmer (Alabama Sturgeon) are listed as Federally endangered throughout their ranges (Campton et al. 2000). While apparently more secure than either the Pallid or Alabama Sturgeon, the third member of the genus, *Scaphirhynchus platorynchus* Rafinesque (Shovelnose Sturgeon) is listed as threatened due to similarity of appearance to Pallid Sturgeon where the two species co-occur (Hann and Schramm 2019).

Both the Pallid Sturgeon and Shovelnose Sturgeon were historically found throughout the Missouri River and its larger tributaries in South Dakota (Bailey and Cross 1954, Keenlyne 1997). However, following the construction of four mainstem dams in South Dakota (Oahe, Big Bend, Ft. Randall, and Gavin's Point) between 1956 and 1963 under the Pick-Sloan Act, Pallid Sturgeon numbers declined, and it is believed that they are now restricted to portions of the river below Ft. Randall and Gavin's Point Dams. While not as precipitous as the decline of Pallid Sturgeon, Shovelnose Sturgeon numbers also decreased since reservoir impoundment (Keenlyne 1997). However, populations are still found below Oahe, Big Bend, and Fort Randall Dams in South Dakota (Held 1969, Keenlyne 1997).

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There is a large body of work describing movement patterns and habitat use of adult Pallid and Shovelnose Sturgeon throughout much of their range (e.g., Bramblett and White 2001, Lyons et al. 2016, Quist et al. 1999). Most of this research has occurred in free-flowing stretches of river with fewer published studies of Shovelnose Sturgeon habitat use in impoundments/navigation pools or inter-reservoir systems (e.g., Curtis et al. 1997, Held 1969, Hurley et al. 1987). With the exception of Held (1969), most of these studies have been conducted nearer the core of the Shovelnose Sturgeon range with less known about population persistence or habitat use in impounded systems near the geographical fringe of their range. One such population occurs in Lake Sharpe, which is a mid-sized, flow-through reservoir on the Missouri River in central South Dakota. While there has been some research conducted on Shovelnose Sturgeon in Lake Sharpe (e.g., Keenlyne et al. 1994), little is known about their current distribution, habitat use, dynamic rate functions (i.e., recruitment, growth, mortality), and/or population size. Thus, our objectives were to use acoustic telemetry and mark recapture methods to 1) provide a population estimate of Shovelnose Sturgeon in Lake Sharpe, 2) estimate annual survival of adult Shovelnose Sturgeon in Lake Sharpe, and 3) describe in-reservoir distribution and habitat use of adult Shovelnose Sturgeon in Lake Sharpe.

Methods

Study Area

This study was conducted in Lake Sharpe, a mainstem Missouri River reservoir located in central South Dakota, USA (Figure 1). The second smallest Missouri River mainstem reservoir, Lake Sharpe has a surface area of 24,686 ha at normal operating pool and is closed upstream by Oahe Dam (rkm 1725) and downstream by Big Bend Dam (rkm 1589). The lake is shallow compared to the other Missouri River reservoirs with mean and maximum depths of 9.5 m and 23.7 m. Lake Sharpe has one major tributary, the Bad River (confluence at rkm 1714) and several smaller tributaries. The riverine segment of the reservoir extends from Oahe Dam downstream roughly 45 rkm where a transition zone occurs downstream to rkm 1649 at which point the habitat is considered lentic extending to Big Bend Dam (Fincel 2011). Water depth, temperature, and velocity in the upper riverine portions of the reservoir are heavily influenced by releases from Oahe Dam, and to a lesser extent, the Bad River.

Fish Sampling

From March through May of 2017, 2018, and 2019, Shovelnose Sturgeon were captured using baited trotlines. Sampling locations were distributed from below Oahe Dam, downstream approximately 30 km (Figure 1). Trotlines were deployed 4 days per week (barring inclement weather) at randomly selected sites in the riverine zone of Lake Sharpe (Figure 1). Trotline design followed the specifications of Welker and Drobish (2012) with 20 individual 3/0 hooks baited with *Lumbricus terrestris* Linnaeus (nightcrawlers) spaced evenly along a 32-m mainline. Each trotline was set near mid-day and was allowed to fish overnight for approximately 20 hours before retrieval. Water temperatures during the sampling timeframe ranged from 1.1 to 14.0° C. Shovelnose Sturgeon were marked with a T-bar anchor tag (Floy Tag and Mfg Inc., Seattle WA) with a unique identifier. All fish collected were weighed (g), measured to fork length (FL; mm), and a fin-clip (a small section of the anterior ray nearest the basal joint of the left pectoral fin) was removed as a secondary mark to identify tag loss and retained for later age and growth classification (Fincel et al. 2022a).

Acoustic Telemetry

In May 2017, 25 Shovelnose Sturgeon were captured on trotlines and surgically implanted with Vemco® (Innovasea, Bedford NS) V13 acoustic transmitters (roughly 2.5-year life span). In May 2018, an additional 30 Shovelnose Sturgeon were surgically implanted with acoustic transmitters for a total of 55 tagged fish. In order to accommodate the size of tag used and adhere to the recommended maximum of 2% of a fish's body weight for tag burden only fish, >500mm FL and >700g were tagged (Brownscombe et al. 2019, Winter 1983). Surgical procedures followed standard operating protocols, and surgeries were performed by individuals with extensive experience in telemetry tag implantation. During surgery, the head/dorsal side of each fish was oriented down so that

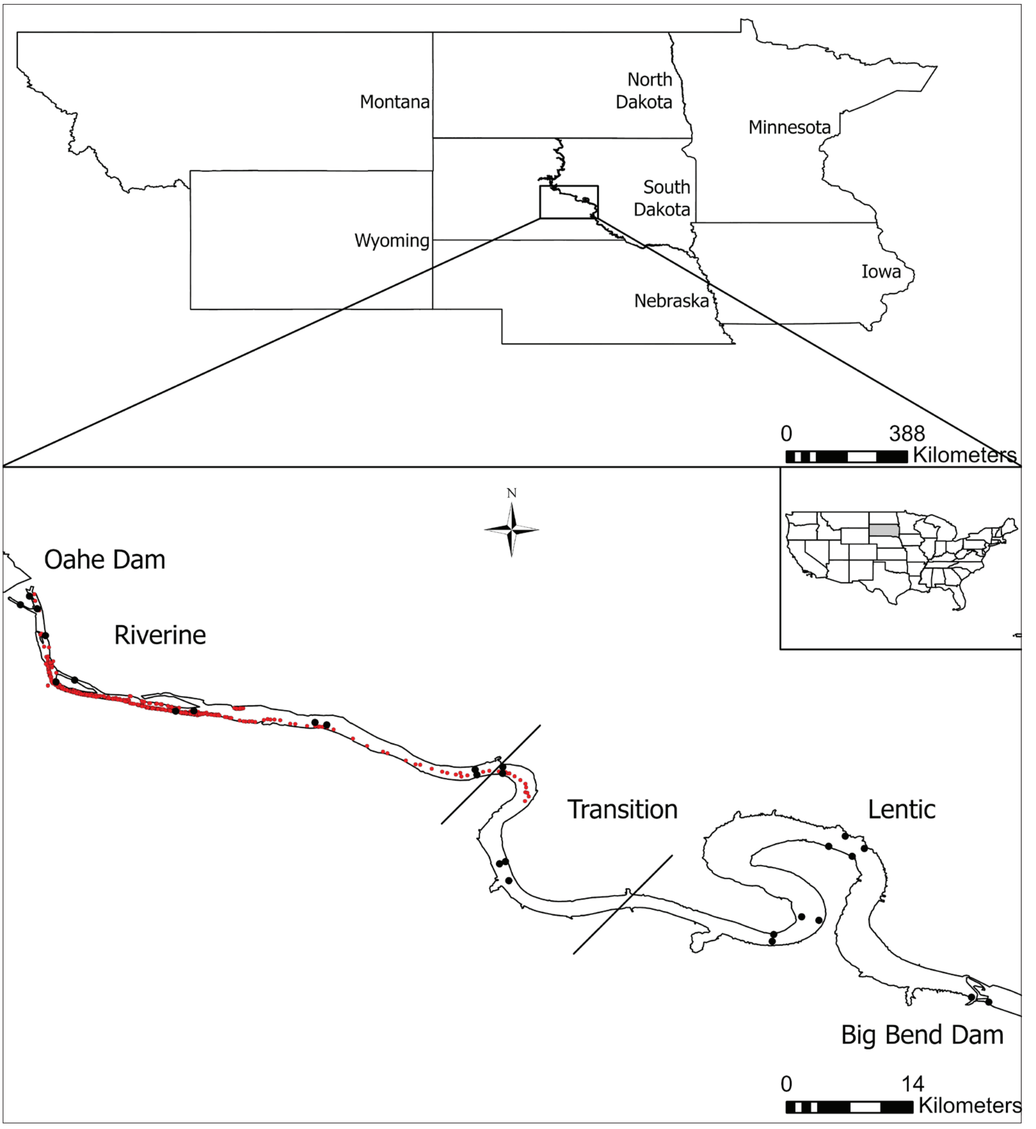

Figure 1. Location of Lake Sharpe, South Dakota and approximate reservoir zonation (i.e., riverine, transition, and lentic zones). Black circles indicate locations of acoustic telemetry receivers, red circles indicate locations of individual trotline deployments.

the fish exhibited tonic immobility. Fish were placed in a sling/cradle and the gills were flushed with water for the duration of the surgery. An incision slightly larger than the tag (25–35 mm) was made in the ventral body wall approximately 2.5 cm off the midline and anterior to the pelvic fins using a scalpel with a size 10 blade. Following insertion of the acoustic tag into the body cavity, the incision was closed with two individually knotted sutures of ETHICON 3.0 metric perma-hand silk black braided sutures with a 3/8c x 26 mm reverse cutting needle. Before and after surgery, the incision site was flushed with sterile water and all surgical tools were soaked in betadine to prevent infection. Surgical times for this study averaged approximately 3.5 minutes, and all fish were held in a recovery tank until they regained equilibrium prior to release back to Lake Sharpe. These fish were monitored continuously beginning in May 2017 using an array of approximately 20 Vemco® (Innovasea, Bedford NS) VR2W-69kHz coded acoustic passive receivers affixed on metal stands which held the receivers approximately 0.75 m above the sediment. Range testing indicated that the detection efficiency of the receivers was between 70 and 100% at 200 m (Fincel et al. 2022b). Additionally, from June through October of 2017 and 2018, telemetry crews used VR-100 active tracking system to get bi-weekly locations of Shovelnose Sturgeon. An omnidirectional hydrophone was used to roughly locate tagged Shovelnose Sturgeon at which point crews switched to a directional hydrophone to pinpoint the fish's location for habitat assessment. Upon encounter, active tracking crews recorded the specific latitude and longitude position of individual fish and once directly overtop the tagged fish, crews would anchor, measure water depth, and take a measure of the water velocity at the bottom. Mean water depth and mean bottom water velocity at Shovelnose Sturgeon detection locations were calculated from all active tracking detection events. Passive receivers were downloaded twice a year (spring and fall), and receivers that were damaged or lost were replaced throughout the study.

Data Analyses

Shovelnose Sturgeon population size was estimated from the T-bar tag capture and recapture data for 52 unique sampling occasions across 3 years. While the assumption of full population closure was likely violated, a closed-captures model was selected based upon the presumption (based on catch-curve analysis; Fincel et al. 2022a) that mortality was low over the three-year study timeframe. Additionally, the lack of juvenile Shovelnose Sturgeon in Lake Sharpe sampling suggests that recruitment of new individuals into the adult population was likely limited (Keenlyne 1997, M. Fincel, South Dakota Game, Fish and Parks, Ft. Pierre, SD, 2022 unpubl. data). All population size analyses were conducted in Program MARK version 9.0 (White and Burnham 1999). Four fish were deemed to have shed their tags (i.e., identified by the presence of a fin clip but no tag) and were excluded from population size analyses.

Mortality of adult Shovelnose Sturgeon was estimated using monthly detection histories from both active and passive acoustic telemetry. A standard Cormack-Jolly-Seber live recapture model (Cormack 1964, Jolly 1965, Seber 1965) was run in Program MARK (White and Burnham 1999) using monthly detections. Fish were assumed alive if they were detected by stationary or active tracking in each month. Akaike information criterion (AIC) model selection procedures were used to determine the best fit model (i.e., fixed or varying detection probability and survival). Annual (i.e., 12 months from the time the fish were tagged and released) survival estimates were calculated by expanding the monthly survival estimates (e.g., if monthly survival was constant at 99% annual survival was estimated at 99% raised to the 12^{th} power; Krebs 1999).

Results

A total of 223 trotlines (4,460 baited hooks) were run overnight in 2017, 268 (5,360 baited hooks) in 2018, and 174 (3,480 baited hooks) in 2019. Crews captured 1,251 Shovelnose Sturgeon (including recaptures) during the 3-year timeframe of this study (2017 = 471, 2018 = 547, 2019 = 233). The catch per unit effort (CPUE) of Shovelnose Sturgeon was 0.11, 0.10, and 0.07 fish per hook night in 2017, 2018, and 2019, respectively. Most fish captured were large individuals with a mean fork length of 644 mm (range = 368–1,030 mm, SD = 56.3 mm; Figure 2) and an average weight of 1,188 g (range = 500–6,230 g, SD = 372.1 g). Of the 1,251 Shovelnose Sturgeon captured over the three-year study, 113 individuals were caught multiple times (i.e., recaptures: 2017 = 5, 2018 = 68, 2019 = 40). Tag retention was estimated at > 99% for the duration of the study. The estimated number of adult Shovelnose Sturgeon in Lake Sharpe was 6,997 individuals (LCI = 5,836, UCI = 8,444).

A model with constant capture probability (p) and time-varying monthly survival (Phi) showed the most support (AIC weight = 96.8%). Probability of detecting transmittered Shovelnose Sturgeon on the passive array was approximately 82% (LCI = 78.4%, UCI = 85.7%) over the course of the study. Monthly survival ranged from 90.3% to 100% with an average of 98.5% (SD = 3.2%). When expanded to an annual estimate, adult Shovelnose Sturgeon survival was 83.4% (LCI = 71.8%, UCI = 95.6%), which is relatively high and expected for an unexploited population.

Most Shovelnose Sturgeon telemetry detections occurred in the riverine zone of Lake Sharpe. Active tracking crews were able to get habitat use information on 95 unique fish observations from 42 individuals through the 2017 and 2018 tracking periods. Transmit-

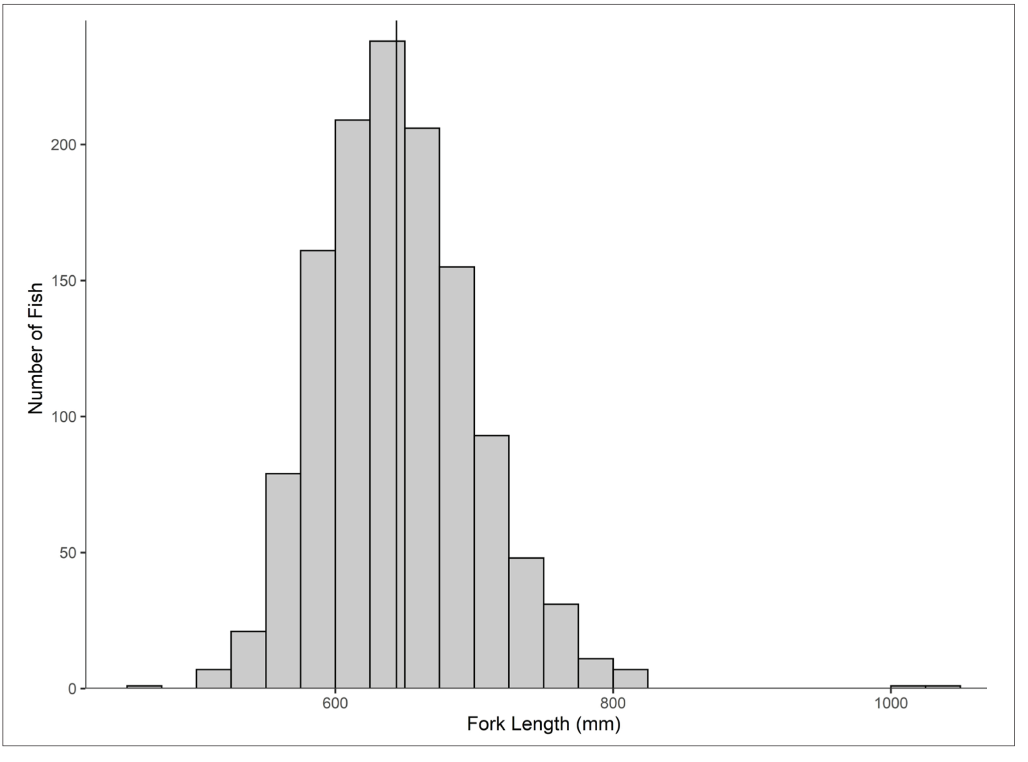

Figure 2. Length frequency of Shovelnose Sturgeon captured in Lake Sharpe, South Dakota, 2017–2019. Vertical line indicates the mean fork length (644 mm) of Shovelnose Sturgeon captured.

tered Shovelnose Sturgeon used habitats with a mean depth of 4.37 m (SD = 1.07 m, range 1.9–6.7 m) and moderate bottom current (mean = 0.47 m/s, SD = 0.16 m/s, range 0.1–0.8 m/s). Moreover, there were no observable trends in Shovelnose Sturgeon depth or water velocity use over time.

Discussion

Several possible (and non-exclusive) explanations exist for the presence of the Shovelnose Sturgeon population in Lake Sharpe: 1) The Shovelnose Sturgeon in Lake Sharpe are comprised of individuals that have been present since pre-impoundment; 2) Shovelnose Sturgeon are being entrained from areas upstream of Lake Sharpe where more riverine habitat exists; and 3) Shovelnose Sturgeon are successfully reproducing and recruiting into the adult population in Lake Sharpe and/or its tributaries. Concurrent research on the age-structure of Shovelnose Sturgeon in Lake Sharpe indicates that the reservoir may hold some of the oldest documented individuals of the species. However, none of the fish that were aged via fin-ray cross sections appear old enough to have survived from pre-impoundment (age range = 10–50 years; Fincel et al. 2022a). While it is certainly possible that the fin-ray sections underestimate the true ages of Shovelnose Sturgeon (Rugg et al. 2014), the magnitude of underestimation would have to be quite large to account for $20–50^{+}$ years difference. While some of the individuals in this study could have survived from pre-impoundment, we find it an unlikely source for all the approximately 7,000 Shovelnose Sturgeon in Lake Sharpe. Entrainment from upstream sources also seems unlikely. Oahe Dam, which forms the upstream barrier of Lake Sharpe, has water intakes that are approximately 15 m above the bottom of the reservoir. Shovelnose Sturgeon reside in benthic habitats of swift flowing waters (Bramblett and White 2001, Hurley et al. 1987) and would likely not be found in the pelagic zone where they would be susceptible to entrainment. Moreover, Lake Oahe is the second largest mainstem impoundment on the Missouri River, and Shovelnose Sturgeon produced in the free-flowing riverine stretch in North Dakota would need to traverse approximately 250 rkm of lake habitat downstream before reaching the intakes at Oahe Dam. Based on the observation from this study that acoustically tagged Shovelnose Sturgeon were not detected in the lentic portion of Lake Sharpe, it is unlikely that they would be found in great enough numbers in the much larger and deeper lacustrine zone of Lake Oahe to provide a significant source for entrainment into Lake Sharpe.

Thus, we believe that the most likely explanation for Shovelnose Sturgeon persisting in Lake Sharpe is natural reproduction and recruitment, either in the riverine portions of the reservoir or in its tributaries. While the free-flowing potion of Lake Sharpe is less than that noted in the literature as a requirement for Shovelnose Sturgeon larval drift (i.e., 90 km; Braaten et al. 2008), it is possible that the characteristics of this reservoir system allow for successful reproduction and recruitment. Guy et al. (2015) found that a zone of near-sediment anoxia in the transition from lotic to lentic habitats in reservoirs was responsible for the lack of Pallid Sturgeon recruitment in reservoirs. Given the proximity of Lake Sharpe's lotic zone to the outflow of Oahe Dam (a mid-column intake structure) and relatively stable flow conditions it is plausible that the anoxic conditions observed in typical lotic transition habitats have not developed or are not consistently present in this section of Lake Sharpe. More study is needed to test this hypothesis, but if supported, it could assist fisheries managers working to maintain and restore populations of *Scaphirhynchus* in highly altered river/reservoir systems like Lake Sharpe.

The levels of adult survival of Shovelnose Sturgeon in Lake Sharpe are near the highest reported in the literature. Given that the Lake Sharpe population is unexploited by anglers (either recreational or commercial), and is near the northern extent of the species distribution, it can be expected that total annual survival would be at or near the upper end of the range reported in the literature. Studies of commercially-exploited populations of Shovelnose Sturgeon elsewhere have reported annual survival estimates from 65– ~80% (Kennedy et al. 2007, Morrow et al. 1998, Phelps et al. 2013, Thornton et al. 2019). Besides commercial exploitation, these populations were located in lower latitudes than the Lake Sharpe population (e.g., Morrow et al. 1998, Phelps et al. 2013), and ectotherms living at higher latitudes are known to live longer (Munch & Salinas 2009). An additional factor likely related to high survival within this population is lack of large predators (e.g., *Pylodictis olivaris* Rafinesque [Flathead Catfish], *Ictalurus furcatus* Valenciennes [Blue Catfish], etc.) that could consume adult Shovelnose Sturgeon that commonly exceed 500 mm (Keenlyne 1997).

Habitat use of Shovelnose Sturgeon in Lake Sharpe was similar to observations in other altered river systems. As expected, Shovelnose Sturgeon primarily occurred in the riverine portion of Lake Sharpe with few detections in the reservoir's transition zone and none in the lentic zone. Numerous studies have documented similar patterns where Shovelnose Sturgeon are most commonly found in the most upstream (i.e., riverine) portions of river/reservoir systems (e.g., Bramblett and White 2001, Curtis et al. 1997, Held 1969). Similarly, the water depths and velocities where Shovelnose Sturgeon were detected (i.e., range 1.9–6.7 m and 0.1– 0.8 m/s respectively) are near the ranges of depths and velocities reported by Curtis et al. (1997) for Shovelnose Sturgeon in an impounded pool of the Mississippi River. All fish collected during this study were captured in the upper portions of Lake Sharpe during the spring and trotline catches may reflect spawning or pre-spawning habitat selection. However, the lack of telemetry detections throughout the year in the lentic zone suggest that habitat conditions in that portion of the reservoir are likely less preferred by Shovelnose Sturgeon under normal flow conditions, such as were observed in 2017 and 2018, as well as during the flood conditions that occurred in 2019.

In this study, we have provided a population estimate, estimated natural survival rates, and identified the in-reservoir distribution and habitat use for adult Shovelnose Sturgeon in Lake Sharpe, South Dakota. This information provides an extension to the understanding of Shovelnose Sturgeon population dynamics in a novel portion of the Missouri/Mississippi River system. Somewhat surprisingly the Shovelnose Sturgeon population in Lake Sharpe appears to be relatively robust with low natural mortality and a large, estimated population size. Unlike sturgeons of other genera (e.g., *Acipenser*, *Huso*), *Scaphirhynchus* species are not known for their tolerance of lentic environments (Auer 1996, Keenlyne 1997, Zhuang et al. 2003). *Scaphirhynchus* species (like most sturgeons) spawn in flowing water and the larvae drift with the current until developed enough to settle out and actively seek suitable habitats (Auer and Baker 2002, Braaten et al. 2008), so it is surprising that Shovelnose Sturgeon are still present in Lake Sharpe more than 50 years post-impoundment. This is particularly true when considering that the closely related and longer-lived (Braaten et al. 2015) Pallid Sturgeon was last documented in the reservoir in 2006 (L. Pierce, USFWS, Pierre, SD, 2022 unpubl. data). Studies like this one can be key components towards helping managers develop successful management plans for highly altered systems such as the Missouri River in South Dakota that may allow the persistence of this genus throughout its historic range.

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