Age, Growth, and Mortality of Shovelnose Sturgeon in Lake Sharpe, South Dakota

Mark Fincel[1*], Cameron Goble[2], Chelsey Pasbrig[3], Dylan Gravenhof[4], and Hilary Morey[5]

Abstract - *Scaphirhynchus platorynchus* Rafinesque (Shovelnose Sturgeon) are recreationally and/or commercially harvested in much of the Mississippi and Missouri Rivers. Currently, South Dakota is considering opening limited angler harvest within its jurisdiction. However, data concerning growth, recruitment, and mortality of South Dakota Shovelnose Sturgeon populations are limited. The objective of this study was to examine growth, recruitment, and mortality of Shovelnose Sturgeon during the springs of 2017–2019 in Lake Sharpe, a Missouri River impoundment in central South Dakota. A total of 1,251 fish were captured by baited trotlines, and pectoral fin rays were collected and aged from 371 fish. Age-estimates were calculated by removing the highest and lowest age estimates from five independent readers and taking the average of the remaining three age-estimates. We collected very few fish < 22 years old and the sampled Lake Sharpe Shovelnose Sturgeon population exhibited older fish than described in other Missouri and Mississippi River populations and had low annual mortality at 5.7% after age 22. Length-at-age was lower than that for populations in the Mississippi River but was like Missouri River basin populations. Recruitment was unapparent in recent years with few fish < 22 years in our estimated ages. It appears 1) either our gear was unable to capture fish < 22 years old or 2) a lack of recruitment is currently being exhibited by the Lake Sharpe Shovelnose Sturgeon population. Additional research is warranted, especially concerning recent recruitment dynamics, before any recreational angler harvest decisions are made by the state of South Dakota.

Introduction

Scaphirhynchus platorynchus Rafinesque (Shovelnose Sturgeon) is one of the most widespread North American sturgeons (Keenlyne 1997). Once abundant throughout the Mississippi and Rio Grande River basins, Shovelnose Sturgeon have been extirpated from the Rio Grande River basin and have experienced range reductions in the Mississippi River basin (Bailey and Cross 1954, Sublette et al. 1990). Shovelnose Sturgeon are similar in appearance to the federally endangered *S. albus* Forbes & Richardson (Pallid Sturgeon). The two species are difficult to differentiate in the wild where they inhabit overlapping portions of the Missouri and Mississippi River basins (Bailey and Cross 1954, Lee et al. 1980). In October 2010, the United States Fish and Wildlife Service (USFWS) listed the Shovelnose Sturgeon as threatened under the similarity of appearance provision of the Endangered Species Act (ESA, USFWS 2010).

Habitat alterations, water pollution, and overharvest have all reduced Shovelnose Sturgeon populations in the United States (Keenlyne 1997), yet Shovelnose Sturgeon are harvested in 13 states (Koch and Quist 2010). Shovelnose Sturgeon are managed differently by individual state

[1]South Dakota Game, Fish, and Parks, Ft. Pierre District Office, 20641 SD HWY 1806, Ft. Pierre, SD, 57532. [2]South Dakota Game, Fish, and Parks, Ft. Pierre District Office, 20641 SD HWY 1806, Ft. Pierre, SD, 57532. [3]South Dakota Game, Fish, and Parks, Pierre Headquarters Office, 523 E. Capitol Ave, Pierre, SD, 57501. [4]South Dakota Game, Fish, and Parks, Ft. Pierre District Office, 20641 SD HWY 1806, Ft. Pierre, SD, 57532. [5]South Dakota Game, Fish, and Parks, Pierre Headquarters Office, 523 E. Capitol Ave, Pierre, SD, 57501. [*]Corresponding author: Mark.Fincel@state.sd.us.

Associate Editor: Brian Blackwell, South Dakota Department of Game, Fish, and Parks.

conservation agencies. Individual states evaluate populations and set fishing and recreational and commercial harvest regulations in accordance with local population characteristics. For instance, Iowa allows a daily bag limit of 10 and possession limit of 20 Shovelnose Sturgeon on the Missouri River (IA DNR 2022), and Montana allows a daily bag limit and possession limit of 5 fish, with no harvest of fish over 40 inches fork length (MT FWP 2022). Both recreational and commercial harvest of Shovelnose Sturgeon in South Dakota are currently prohibited; however, Shovelnose Sturgeon are currently being considered for limited angler harvest.

Six large mainstem high head dams are present on the Missouri River, fragmenting and reducing riverine habitat by an estimated 70% from pre-impoundment conditions (USACE 2001). Four of these dams are in central South Dakota; thus, South Dakota holds the least amount of free-flowing riverine habitat of the Missouri River compared to surrounding states. Little is known about Shovelnose Sturgeon population dynamics in reservoir systems that lack expansive free-flowing riverine sections. Shovelnose Sturgeon are thought to need 58–155 river miles (rmi) as free-floating larvae to successfully complete their early life history (Braaten et al. 2008). Outside the impounded South Dakota sections of the Missouri River, Shovelnose Sturgeon rate functions have been described and most follow similar patterns of growth, recruitment, and mortality (Hamel et al. 2015, Quist et al. 2002).

Shovelnose Sturgeon can be found throughout the impounded Missouri River in South Dakota. South Dakota Department of Game, Fish, and Parks (SDGFP) is considering allowing restrictive angler harvest of Shovelnose Sturgeon in some Missouri River reservoirs. However, little information exists regarding the ecology or population dynamics of this species within these discrete habitats (Keenlyne et al. 1994). Lake Sharpe, in central South Dakota, contains the shortest free-flowing riverine section of all the Missouri River reservoirs (approximately 28 mi, Fincel 2011). The objective of this study was to examine growth, recruitment, and mortality of Shovelnose Sturgeon in Lake Sharpe and discuss the potential for angler harvest of this population.

Methods

This study was conducted in Lake Sharpe, a Missouri River reservoir in central South Dakota. Lake Sharpe covers 61000 acres from Oahe Dam (closure in 1958, filled in 1962) to Big Bend Dam (closure in 1963, filled in 1964), and has a mean depth of 31 ft and maximum depth of 78 ft.

Shovelnose Sturgeon were sampled in the spring using baited trotlines in the upper, flowing portion of Lake Sharpe (15 March 2017–7 May 2019). Trotlines were 105 ft long of 0.35-inch Ashaway Braided Tuna Cord rigged with 20 size 3/0 circle hooks spaced at 5 ft intervals on 1.5 ft dropper lines of 0.11 inch monofilament line. Trotlines were baited with *Lumbricus terrestris* (Night Crawlers), set parallel to the current in depths of 7–26 ft, and fished overnight. Upon capture, fork length (FL, mm) and weight (g) of Shovelnose Sturgeon were recorded. We also inserted a uniquely numbered t-bar anchor tag into the base of the fleshy area between the lateral scutes and dorsal fin on the left side.

Standard weight (Ws) was calculated for all captured Shovelnose Sturgeon using Quist et al. (1998), using

$$\text{Log}_{10}Ws = -6.287 + 3.330 \log_{10}\text{FL}$$

where FL represents fork length of the Shovelnose Sturgeon and Ws represents the individual standard weight. Standard weight was used to calculate relative weight (Wr) for each fish, using

$$Wr = 100 * W / Ws$$

where *W* is the observed weight of the individual sturgeon and *Ws* is the length specific standard weight.

In 2018, a small section of the anterior ray nearest the basal joint of the left pectoral fin was removed for age estimation from every Shovelnose Sturgeon collected. In 2019, pectoral fin rays were retained only from the largest (> 30 inches) and smallest (< 23 inches) fish. No ageing structures were collected from recaptured Shovelnose Sturgeon throughout the duration of the study. Pectoral fin rays were prepared as described by Koch and Quist (2007). Pectoral fin rays were set in EpoxiCure (Buehler, Lake Bluff, Illinois, USA) resin and hardener and allowed ample time (overnight) for the two-part clear epoxy to harden. Cross sections, 0.02 inches thick, were cut with a low-speed IsoMet saw (Buehler, Lake Bluff, Illinois, USA) and mounted on a microscope slide using cyanoacrylate. Pectoral fin ray sections were viewed with a binocular microscope at 100x magnification. Multiple digital images were taken with an AmScope microscope digital camera (12mP Sony Exmor CMOS sensor, Model # MU1203-FL) of the cross sections under various light angles and intensities for age estimation.

Pectoral fin ray section images were independently aged by five readers without any knowledge of Shovelnose Sturgeon length. Readers were all experienced with estimating sportfish ages using scales, spines, and/or otoliths, but none had estimated ages of Shovelnose Sturgeon prior to this study. The youngest and oldest age estimates were removed and the mean of the three remaining readers was used as an age estimate. Coefficient of variation (CV) was calculated as a measure of variance and exhibits the variability standardized to the mean. We calculated annual Shovelnose Sturgeon mortality using the weighted catch-curve method (Chapman-Robson method, Ricker 1975, Smith et al. 2011). Sampling recruitment was set based on the peak and descending catch limb of the age-frequency graph and the last continuous age class present was used as the age maximum. Counts of fish from each age class were natural log transformed and regressed with the age of the fish. The instantaneous mortality coefficient was converted to total annual mortality of sampled fish using

$$A = 1-e^{(-Z)}$$

where A is the annual mortality and Z is the instantaneous mortality.

Catch-curve residuals (Ricker 1975) were used to describe recruitment variability of the Lake Sharpe Shovelnose Sturgeon population. We assumed 1) equal sampling vulnerability across ages (≥ 22 years) and 2) no angling mortality (Catalano et al. 2009). Catch-curve residual values represented variation in recruitment among years and were used as an index of relative year-class strength (Maceina 1997). Within the sampled population, recruitment to the Shovelnose Sturgeon population was set at 22 years based on peak abundance and subsequent descending limb of the age-frequency relationship.

Shovelnose Sturgeon growth was examined by calculating von Bertalanffy growth functions:

$$Lt = L\infty + (L0-L\infty) * (1-e^{-k(t-t_0)})$$

where Lt = length at time t, L_∞ = the theoretical maximum length, L_0 = length at age 0, K = the growth coefficient (the rate at which fish approach L_∞), and t_0 = the time when length would theoretically equal 0.33 inches. Length at age 0 was bound to 0.33 inches, which corresponds to the length at hatch for Shovelnose Sturgeon (Snyder 2002). Estimated Shovelnose Sturgeon growth characteristics were compared visually to other populations in free-flowing sections of the Missouri River.

Results

We ran 223 trotlines (4,460 baited hook nights) in 2017, 269 trotlines (5,380 baited hook nights) in 2018, and 324 trotlines (6,480 baited hook nights) in 2019. In all, 1,251 Shovelnose Sturgeon were collected during this 3-year timeframe (471, 547, and 233 in 2017, 2018, and 2019, respectively). A total of 113 Shovelnose Sturgeon collected were recaptured individuals previously marked during this study (5, 68, and 40 in 2017, 2018, and 2019, respectively). Mean FL of collected fish was 25 inches (range = 7–43 inches) and mean weight was 2.6 lb (range = 0.3–14 lb, Fig. 1). Mean *Wr* for sampled Shovelnose Sturgeon was 100 (range = 55–213) and generally decreased with fish length (Fig. 2).

Unfortunately, many Shovelnose Sturgeon fin rays cracked and split during the ageing process as the dried fin rays became brittle. Of the 603 fin rays retained for ageing, age estimates were made for 371 Shovelnose Sturgeon (n = 337 in 2018, n = 34 in 2019) ranging in length

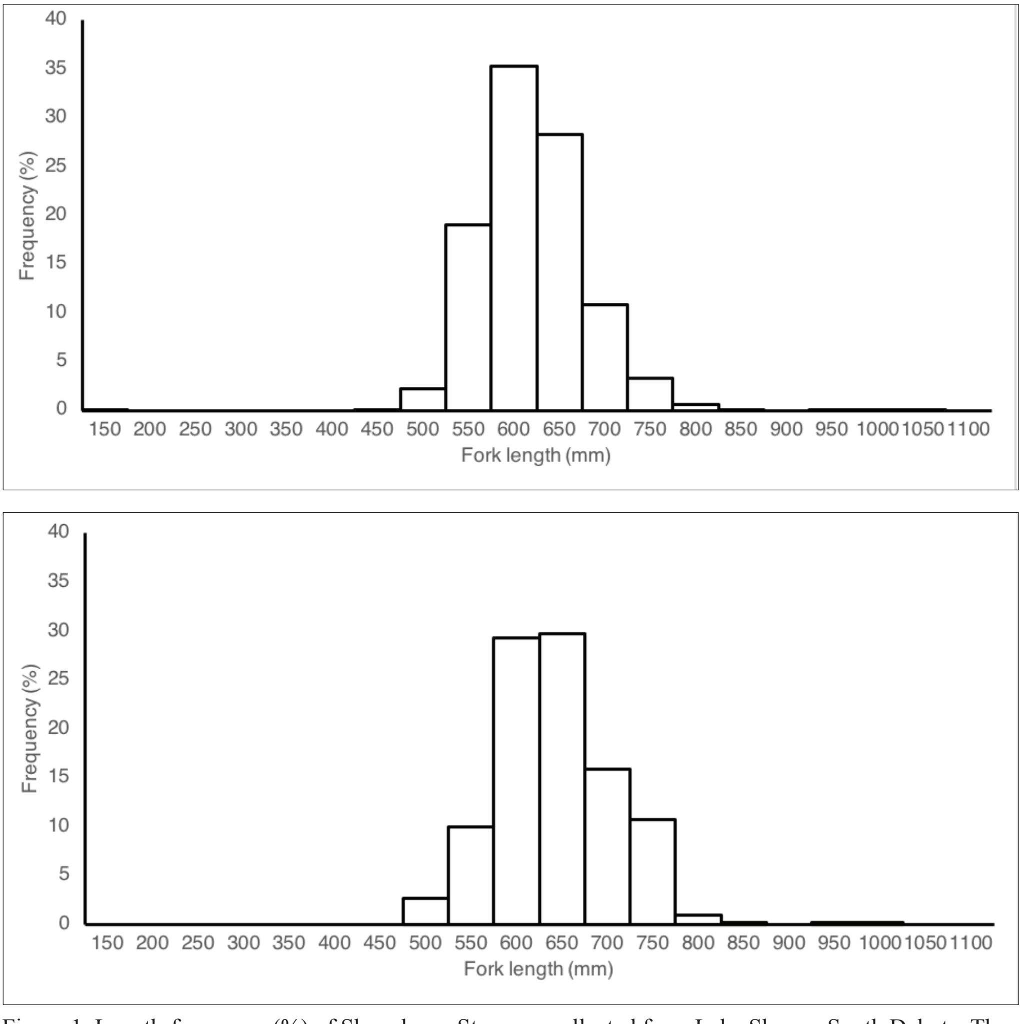


Figure 1. Length-frequency (%) of Shovelnose Sturgeon collected from Lake Sharpe, South Dakota. The upper panel represents the length-frequency of all Shovelnose Sturgeon collected from 2017 to 2019 (n = 1,271). The lower panel represents the length-frequency of aged Shovelnose Sturgeon in 2018 (n = 337) and 2019 (n = 34).

from 20 to 40 inches FL, though most fish were 24 to 30 inches FL (Fig. 1). Overall, reader agreement for pectoral rays was poor, with a CV 13.7% (0.43 SE). Catch-curve relationships for aged Shovelnose Sturgeon was significant ($r^2 = 0.83$, Fig. 3). In general, Shovelnose Sturgeon collected on the trotlines were at least 22 years old (range = 10 to 50). Instantaneous mortality for our sampled fish was 0.059, resulting in an annual mortality estimate of 0.057 (5.7%, Fig. 4).

Of the aged Lake Sharpe Shovelnose Sturgeon, we found 25 year-classes present with only four missing year-classes (ages 22–50, Fig. 5). However, the missing year-classes were all over 45 years of age. The CV for recruitment variability was 11.1% for the aged specimens. Although still present, a very weak year-class was identified at age 40. No strong year-classes

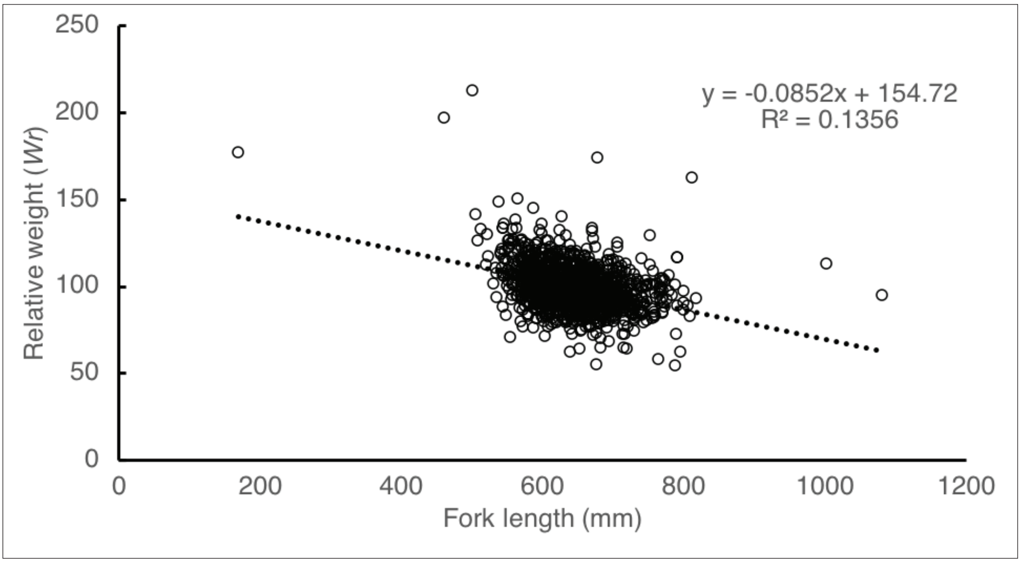


Figure 2. Relative Weight (*Wr*) of 1,271 Shovelnose Sturgeon collected from Lake Sharpe, South Dakota, from 2017 to 2019. Dotted lined represents the linear relationship between *Wr* and fork length (mm).

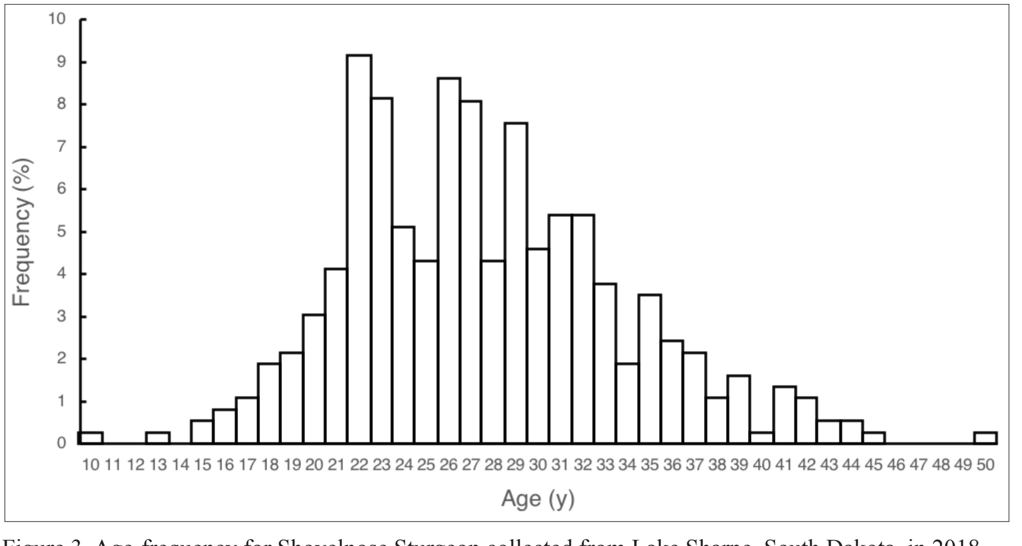


Figure 3. Age-frequency for Shovelnose Sturgeon collected from Lake Sharpe, South Dakota, in 2018 (n = 337) and 2019 (n = 34).

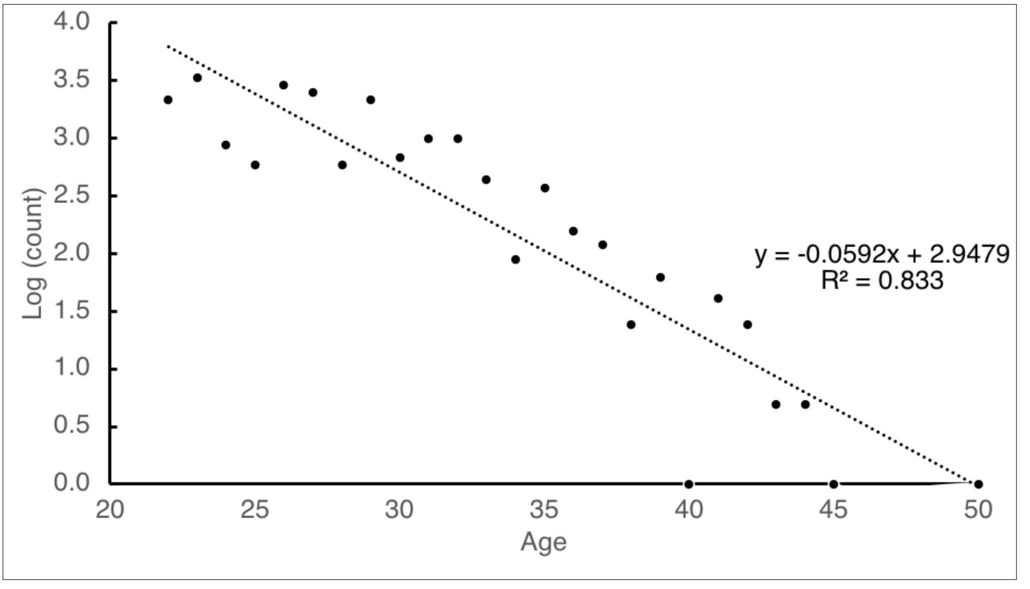


Figure 4. Instantaneous mortality for Shovelnose Sturgeon (estimated ages 22–50) collected from Lake Sharpe, South Dakota, in 2018 (n = 337) and 2019 (n = 34).

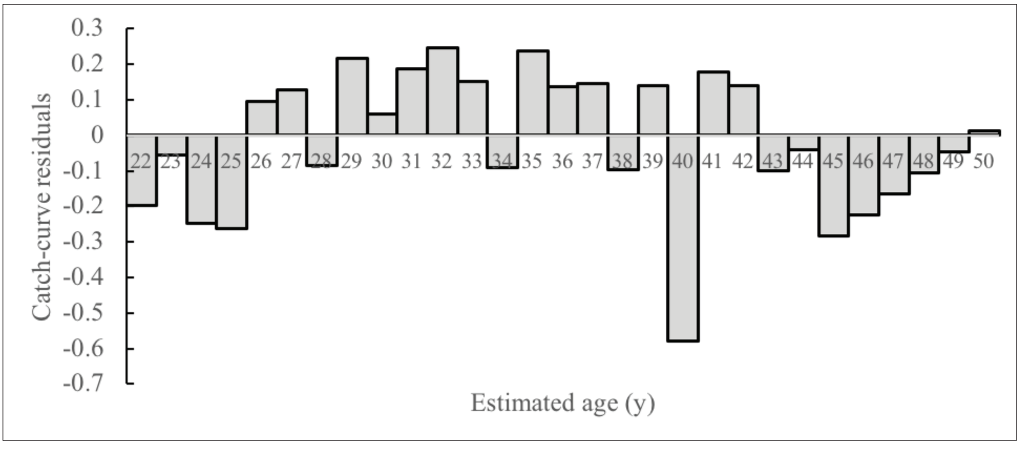


Figure 5. Catch-curve residuals for Shovelnose Sturgeon (estimated ages 22–50) collected from Lake Sharpe, South Dakota, in 2018 (n = 337) and 2019 (n = 34).

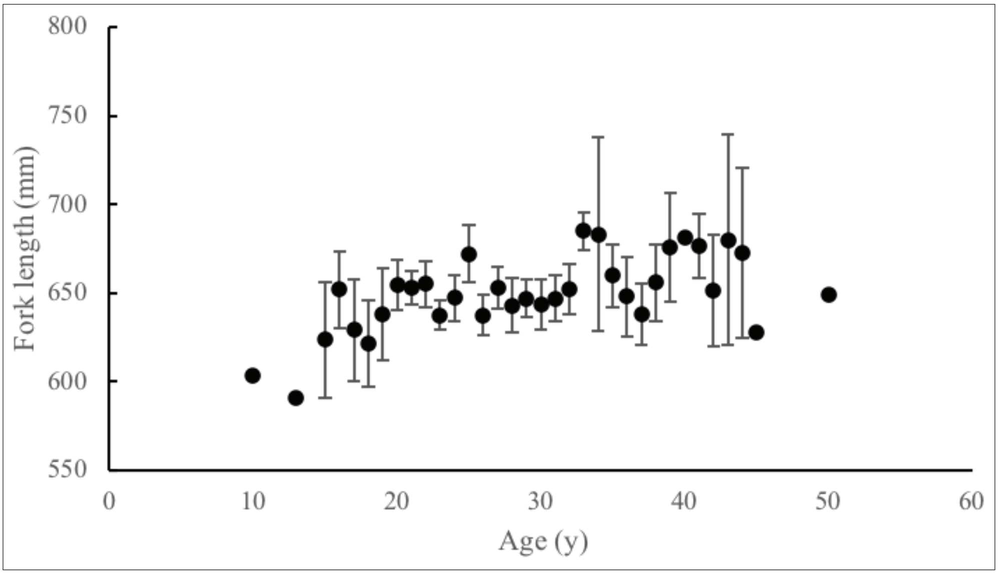
were readily apparent in our collected fish. Shovelnose Sturgeon length-at-age was positive and significantly related to age. The von Bertalanffy growth equation was TL = 657.5 $(1\text{-}e^{-0.209(age+0.07)})$. Von Bertalanffy growth model of the sampled Lake Sharpe Shovelnose Sturgeon exhibited a growth trajectory similar to those reported from other Missouri River populations (Hamel et al. 2015, Quist et al. 2002, Figs. 6, 7).

Discussion

A robust Shovelnose Sturgeon population is currently present in Lake Sharpe, South Dakota, albeit we estimated very few fish < 22 years of age. The observed Shovelnose Sturgeon abundance in Lake Sharpe is interesting given Shovelnose Sturgeon are believed to need 58–155 rmi as free-floating larvae to successfully complete their early life history (Braaten et al. 2008).

Lake Sharpe is 80 rmi in length (Oahe Dam to Big Bend Dam), with only 28 rmi of riverine habitat and the remaining 52 rmi is considered open water, lake-like habitat (Fincel 2011). It is surprising that this population has persisted with such a truncated drift distance available to young Shovelnose Sturgeon.

In this study, the youngest and oldest Shovelnose Sturgeon aged were estimated at 10 and 50 years, respectively. We had very few fish estimated at < 22 years and we estimated 4 fish > 43 years. Moreover, the Lake Sharpe Shovelnose Sturgeon we collected were older than that recorded for other populations, with most aged individuals being > 22 years. Regrettably, we were unable to age the largest Shovelnose Sturgeon (43 inches) caught in Lake Sharpe due



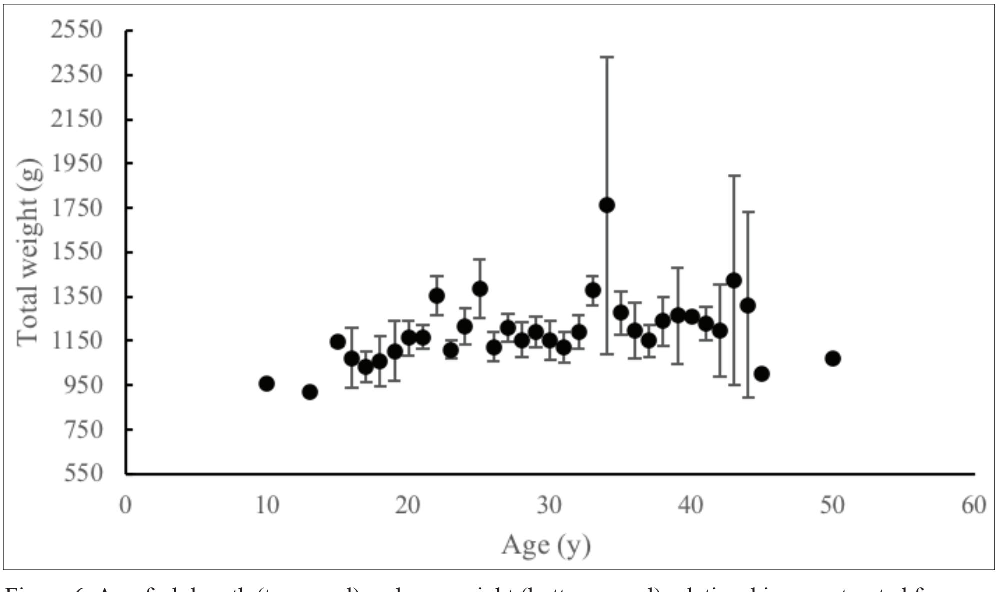


Figure 6. Age-fork length (top panel) and age-weight (bottom panel) relationships constructed for Shovelnose Sturgeon collected from Lake Sharpe, South Dakota, in 2018 (n = 337) and 2019 (n = 34).

to broken and fractured fin ray sections. Shovelnose Sturgeon ages have been estimated at a maximum of 43 years with much lower maximum ages observed in most populations (Everett et al. 2003, Quist and Guy 1999, Quist et al. 2002).

Shovelnose Sturgeon pectoral fin rays are used for age estimation because they are easily collected with minimal long-lasting damage to the fish (Currier 1951) and produce more reliable age estimates compared with other hard structures (Brennan and Cailliet 1989, Jackson et al. 2007). Unfortunately, Shovelnose Sturgeon pectoral fin ray sections are difficult to age with precision (Morrow et al. 1998, Whiteman et al. 2004), and caution must be taken when examining Lake Sharpe Shovelnose Sturgeon ages. Although our age estimate CVs were higher than minimum target levels previously published (Campana 2001), our ageing variability was within the range of previous Sturgeon spp. ageing studies (Koch et al. 2011). Some age estimates of Pallid Sturgeon have shown low accuracy (13%), but this was improved when looking at age estimates within two years of known ages (72%, Hamel et al. 2014). Additionally, Whiteman et al. (2004) found opaque annuli bands were deposited during the summer for most Shovelnose Sturgeon in the lower Missouri River but noted second or false annulus deposition outside of summer months in some fish. It is possible we overestimated some of Lake Sharpe's Shovelnose Sturgeon population given the difficulty in ageing this long-lived species. Conversely, age estimates from fin rays of *Acipenser transmontanus* Richardson (White Sturgeon) and *Acipenser fulvescens* Rafinesque (Lake Sturgeon) have been shown to underestimate true fish ages (Bruch et al. 2009, Paragamian and Beamesderfer 2003). Thus, it is also possible that Lake Sharpe's Shovelnose Sturgeon population could be older than that estimated in the current study.

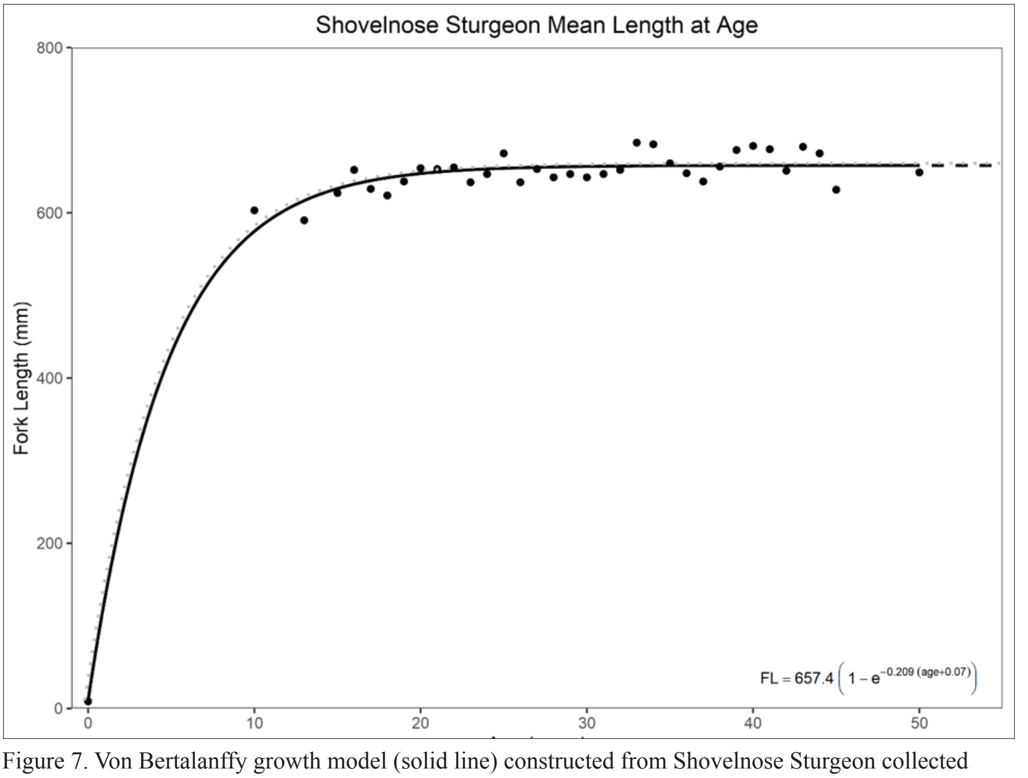


Figure 7. Von Bertalanffy growth model (solid line) constructed from Shovelnose Sturgeon collected from Lake Sharpe, South Dakota, with estimated ages between 22 and 50, in 2018 (n = 337) and 2019 (n = 34). We also present an estimated Shovelnose Sturgeon growth model from fish collected from the free-flowing Missouri River downstream of the last Missouri River Dam (dotted line, Quist et al. 2002).

The smallest Shovelnose Sturgeon collected during the present study was 7 inches and only 3 fish were ≤ 20 inches. This is different from other Shovelnose Sturgeon age and growth studies, which were able to capture smaller individuals. In the Mississippi River near Bellevue, IA, Shovelnose Sturgeon were collected and aged between 0 and 4 years (Helms 1974). However, the largest fish captured by Helms (1974) was smaller than the smallest fish aged in the present study. Additionally, Morrow et al. (1998) collected many Shovelnose Sturgeon near Rosedale and Vicksburg, Mississippi, < 20 inches (our shortest Shovelnose Sturgeon aged), with younger relative corresponding ages compared to Lake Sharpe's age distribution. In the Wabash River, Indiana, Shovelnose Sturgeon between 11 and 34 inches were collected, but very few individuals were < 20 inches (Kennedy et al. 2007). In the Platte River, Nebraska, most of the Shovelnose Sturgeon collected were between 20 and 24 inches and aged between 8 and 11 years, again smaller than most of the fish in the current ageing study (Rugg et al. 2014). Thus, older age estimates of Shovelnose Sturgeon in the current study are expected as aged Shovelnose Sturgeon were substantially larger than many previous age and growth studies.

Based on the sample collected, recruitment to the Lake Sharpe Shovelnose Sturgeon fishery appears to be lacking. Unfortunately, we are unable to determine if this is true recruitment failure where few small fish are present in the system, or whether it is a gear bias, and our methods were only able to catch relatively larger (older) Shovelnose Sturgeon. If recruitment failure is occurring, escapement from Oahe Dam (immediately upstream of Lake Sharpe) could be populating the downstream reach as escapement through this hydro-electric dam is common for many species (Carlson et al. 2016a, b, 2017; Fincel et al. 2016). However, this is unlikely as the intakes for Oahe Dam are mid-water column intakes with water entering the intakes from approximately 50 ft below the lake surface but 83 ft from the bottom of the lake. Moreover, Lake Oahe is the second largest mainstem impoundment on the Missouri River, and Shovelnose Sturgeon produced in the free-flowing stretch in North Dakota would need to traverse approximately 155 rmi of lake habitat downstream before reaching the intakes on Oahe Dam. Hence, it is unlikely that escapement of Shovelnose Sturgeon from Lake Oahe is populating the downstream reservoir of Lake Sharpe.

Another plausible explanation for the lack of smaller Shovelnose Sturgeon collected is a bias to collecting larger Shovelnose Sturgeon when using the baited trot lines. For instance, near Rosedale and Vicksburg, Mississippi, Shovelnose Sturgeon became fully vulnerable to the trotlines at 25 inches (n = 295, Morrow et al. 1998). However, near St Louis, Missouri, Shovelnose Sturgeon recruited to the trotlines at 11 inches (Kilgore et al. 2007), and in the middle Mississippi River near Cairo, Illinois, smaller (range 15–37 inches) Shovelnose Sturgeon were collected using trotlines compared to 3-in-bar mesh gillnets (range 19–41 inches, Phelps et al. 2009). In the lower Platte River, Nebraska, trotlines collected Shovelnose Sturgeon that ranged in length from 14–28 inches (Hammen et al. 2018). Thus, other research has shown that trotlines can collect smaller Shovelnose Sturgeon compared to the current study where only three fish were collected < 20 inches.

Our aged sample of the Lake Sharpe Shovelnose Sturgeon population exhibits low annual mortality (A = 5.7% annual mortality), but aged fish were generally older and low natural mortality is likely given their size. Additionally, mortality estimates derived from an ongoing acoustic-telemetry study corroborates the low annual mortality imparted on this population (Goble et al. 2022). This is expected, as currently no sport or commercial harvest is permitted for Shovelnose Sturgeon in South Dakota. The observed Lake Sharpe annual mortality in aged Shovelnose Sturgeon is much lower than mortality estimates documented for other sections of the Missouri and Mississippi Rivers where limited recreational and commercial harvest is allowed. Commercially harvested Shovelnose Sturgeon showed annual mortality estimates ranging from 37–44% in the middle Mississippi River by Cairo and St. Louis, Illinois, though those fish were younger than fish collected in the present study (range 12–18 years, Tripp et al. 2009). In the lower Wabash River, Illinois, estimated Shovelnose Sturgeon annual mortality was 20.6% for fish up to 25 years (Nepal et al. 2015). However, the Lake Sharpe population exhibited similar mortality to the unexploited Yellowstone River population that included estimated ages of Shovelnose Sturgeon to 43 years (A = 8.6%, Everett et al. 2003). Thus, it appears as if the Lake Sharpe Shovelnose Sturgeon population shows similar mortality trends to other populations that contain relatively long-lived individuals.

Compared to Mississippi River populations, our Lake Sharpe Shovelnose Sturgeon sample exhibited slower growth (Hamel et al. 2015). Moreover, fish condition generally declined as fish got larger. In other Missouri River impoundments, changing water elevations can decrease benthic invertebrate abundance (Benson and Hudson 1975), which is the primary diet for Shovelnose Sturgeon (Hoover et al. 2007). Thus, it is possible that prey resources may be limiting growth on the Lake Sharpe population and preventing growth witnessed in other systems. In most populations, Shovelnose Sturgeon rarely exceed 3 ft fork length and 10 lb (Carlander 1969, Keenlyne 1997). Some studies using mark-recapture methods have documented very slow and even negative growth, especially for Missouri River populations (Hamel et al. 2015, Kennedy et al. 2007). The Lake Sharpe Shovelnose Sturgeon population exhibits slow individual growth like other Missouri River populations (Keenlyne 1997), but greatly reduced compared to populations in the Yellowstone River (Everett et al. 2003). We also documented high variability in Shovelnose Sturgeon length-at-age, which was expected given their erratic growth record. Although significant sexual dimorphism is not known to occur in Shovelnose Sturgeon (Colombo et al. 2004, Wildhaber et al. 2007), it is possible that differences between sexes in age at maturity and spawning periodicity (Keenlyne 1997, Tripp et al. 2009) could account for the high growth variability observed. However, since we did not determine sex of individuals collected, this remains a question for future research.

Management Implications

Sturgeon spp. research studies within the impounded section of the Missouri River in South Dakota are rare though needed, given these species have remained in an altered system well after dam closure (Erickson 1992, Keenlyne et al. 1994). This study provides the first evaluation of Shovelnose Sturgeon rate functions from a reservoir with limited riverine habitat. Nonetheless, Shovelnose Sturgeon are present, and reproduction has likely taken place since the closing of the upstream and downstream dams in the 1960s. Few fish < 22 years and no fish less than 10 years were aged during this study, which is somewhat expected given the large size of the aged fish relative to other ageing studies. Care must be taken when interpreting these results as accurate age estimates for Shovelnose Sturgeon with known age wild Shovelnose Sturgeon are lacking. Using current age estimates, it appears Lake Sharpe exhibits an old population with limited reproduction and/or recruitment in the last 20 years. If age estimates underestimated the true age of Lake Sharpe's Shovelnose Sturgeon, it is possible that at least some of these fish remain in the system from pre-impoundment (1960s).

We believe the information presented herein should support further research on the Lake Sharpe Shovelnose Sturgeon fishery. The low mortality of large fish can likely provide a restricted sport fishery like the *Polyodon spathula* Walbaum (Paddlefish) seasons in South Dakota where a small number of tags are allocated to anglers through a limited draw system. Using this structure, SDGFP can set harvest of large individuals (minimum length restriction), which exhibit very low natural mortality, at a level that could be sustained for several years. However, further recruitment assessments are needed before subjecting the Lake Sharpe Shovelnose Sturgeon population to open angler harvest. With the perceived limited recruitment, open harvest has the potential to quickly reduce the adult population, and with little recruitment identified in the sampled population, stock collapse could occur.

Acknowledgements

We thank Marty Hamel, Jeremy Hammen, Jeff Koch, and Mathew Rugg for age estimation validation and insights on a subset of Shovelnose Sturgeon pectoral fin rays. We also thank the biologists, seasonals, and interns of the South Dakota Game, Fish, and Parks for their help collecting and ageing Shovelnose Sturgeon.

Literature Cited

Bailey, R.M., and F.B. Cross. 1954. River sturgeons of the American genus *Scaphirhynchus*: Characters, distribution, and synonymy. Papers of the Michigan Academy of Science, Arts, and Letters 39:169–208.

Braaten, P.J., D.B. Fuller, L.D. Holte, R.D. Lott, W. Viste, T.F. Brandt, and R.G. Legare. 2008. Drift dynamics of larval Pallid Sturgeon and Shovelnose Sturgeon in a natural side channel of the upper Missouri River, Montana. North American Journal of Fisheries Management 28:808–826.

Benson, N.G., and P.L. Hudson. 1975. Effects of a reduced fall drawdown on benthos abundance in Lake Francis Case. Transactions of the American Fisheries Society 3:526–528.

Brennan, J.S., and G.M. Cailliet. 1989. Comparative age determination techniques for White Sturgeon in California. Transactions of the American Fisheries Society 118:296–310.

Bruch, R.M., S.E. Campana, S.L. Davis-Faust, M.J. Hansen, and J. Janssen. 2009. Lake Sturgeon age validation using bomb radiocarbon and known-aged fish. Transactions of the American Fisheries Society 138:361–372.

Campana, S.E. 2001. Accuracy, precision, and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology 59:197–242.

Carlander, K.D. 1969. Handbook of Freshwater Fishery Biology. Iowa University Press, Ames, IA, USA. 752 pp.

Carlson, A.K., M.J. Fincel, and B.D.S. Graeb. 2016a. Otolith microchemistry reveals natal origins of Walleyes in Missouri River reservoirs. North American Journal of Fisheries Management 36:341–350.

Carlson, A.K., P.E. Bailey, M.J. Fincel, and B.D.S. Graeb. 2016b. Otoliths as elemental tracers of Walleye environmental history: Insights for interjurisdictional fisheries management. Lake and Reservoir Management 32:329–340.

Carlson, A.K., M.J. Fincel, and B.D.S. Graeb. 2017. Otolith chemistry indicates Walleye movement and entrainment in a large serial reservoir system. Fisheries Management and Ecology 24:217–229.

Catalano, M.J., A.C. Dutterer, W.E. Pine III, and M.A. Allen. 2009. Effects of variable mortality and recruitment on performance of catch-curve residuals as indicators of fish year-class strength. North American Journal of Fisheries Management 29:295–305.

Colombo, R.E., P.S. Willis, and J.E. Garvey. 2004. Use of ultrasound imaging to determine sex of Shovelnose Sturgeon. North American Journal of Fisheries Management 24:322–326.

Currier, J. 1951. The use of pectoral fin rays for determining age of sturgeon and other species of fish. The Canadian Fish Culturist 11:1–8.

Erickson, J.D. 1992. Habitat selection and movement of Pallid Sturgeon in Lake Sharpe, South Dakota. M.Sc. Thesis. South Dakota State University, Brookings, SD, USA. 70 pp.

Everett, S.R., D.L. Scarnecchia, G.J. Power, and C.J. Williams. 2003. Comparison of age and growth of Shovelnose Sturgeon in the Missouri and Yellowstone Rivers. North American Journal of Fisheries Management 23:230–240.

Fincel, M.J. 2011. Productivity and trophic interactions in the Missouri River impoundments. PhD Dissertation. South Dakota State University, Brookings, SD, USA. 219 pp.

Fincel, M.J., W.J. Radigan, and C.M. Longhenry. 2016. Entrainment of Rainbow Smelt through Oahe Dam during the 2011 Missouri River flood. North American Journal of Fisheries Management 36:844–851.

Goble, C., M. Fincel, C. Pasbrig, D. Gravenhof, and H. Morey. 2022. Distribution, habitat use, and population persistence of Shovelnose Sturgeon in Lake Sharpe, South Dakota. The Prairie Naturalist *This Issue*.

Hamel, M.J., J.D. Koch, K.D. Steffensen, M.A. Pegg, J.J. Hammen, and M.L. Rugg. 2014. Using mark-recapture information to validate and assess age and growth of long-lived fish species. Canadian Journal of Fisheries and Aquatic Sciences 71:559–566.

Hamel, M.J., M.A. Pegg, R.R. Goforth, Q.E. Phelps, K.D. Steffensen, J.J. Hammen, and M.L. Rugg. 2015. Range-wide age and growth characteristics of Shovelnose Sturgeon from mark-recapture data: Implications for conservation and management. Canadian Journal of Fisheries and Aquatic Sciences 72:1–12.

Hammen, J.J., M.J. Hamel, M.L. Rugg, E.J. Peters, and M.A. Pegg. 2018. Population characteristics of Shovelnose Sturgeon during low- and high-water conditions in the lower Platte River, Nebraska. North American Journal of Fisheries Management 38:308–315.

Helms, D.R. 1974. Age and growth of Shovelnose Sturgeon *Scaphirhynchus platorynchus* in the Mississippi River. Proceedings of the Iowa Academy of Science 81:73–75.

Hoover, J.J., S.G. George, and K.J. Kilgore. 2007. Diet of Shovelnose Sturgeon and Pallid Sturgeon in the free-flowing Mississippi River. Journal of Applied Ichthyology 23:494–499.

Iowa Department of Natural Resources (IA DNR). 2022. 2022 Iowa Fishing Regulations. Available online at https://www.iowadnr.gov/Portals/idnr/uploads/fish/regs_fish2022.pdf. Accessed 1 September 2022.

Jackson, N.D., J.E. Garvey, and R.E. Colombo. 2007. Comparing aging precision of calcified structures in Shovelnose Sturgeon. Journal of Applied Ichthyology 23:525–528.

Keenlyne, K.D., C.J. Henry, A. Tews, and P. Clancy. 1994. Morphometric comparisons of upper Missouri River sturgeons. Transactions of the American Fisheries Society 123:779–785.

Keenlyne, K.D. 1997. Life history and status of the Shovelnose Sturgeon *Scaphirhynchus platorynchus*. Environmental Biology of Fishes 48:291–298.

Kennedy, A.J., D.J. Daugherty, T.M. Sutton, and B.E. Fisher. 2007. Population characteristics of Shovelnose Sturgeon in the Upper Wabash River, Indiana. North American Journal of Fisheries Management 27:52–62.

Kilgore, K.J., J.J. Hoover, S.G. George, B.R. Lewis, C.E. Murphy, and W.E. Lancaster. 2007. Distribution, relative abundance and movements of Pallid Sturgeon in the free-flowing Mississippi River. Journal of Applied Ichthyology 23:476–483.

Koch, J.D., and M.C. Quist. 2007. A technique for preparing fin rays and spines for age and growth analysis. North American Journal of Fisheries Management 27:782–784.

Koch, J.D., and M.C. Quist. 2010. Current status and trends in Shovelnose Sturgeon *Scaphirhynchus platorynchus* management and conservation. Journal of Applied Ichthyology 26:491–498.

Koch, J.D., K.D. Steffensen, and M.A. Pegg. 2011. Validation of age estimates obtained from juvenile Pallid Sturgeon *Scaphirhynchus albus* pectoral fin spines. Journal of Applied Ichthyology 27:209–212.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer. 1980. Atlas of North American Freshwater Fishes. North Carolina Museum of Natural History, Raleigh, NC, USA. 73 pp.

Maceina, M.J. 1997. Simple application of using residuals from catch-curve regressions to assess year-class strength in fish. Fisheries Research 32:115–121.

Montana Fish, Wildlife & Parks (MT FWP). 2022. 2022 Montana Fishing Regulations. Available online at https://fwp.mt.gov/binaries/content/assets/fwp/fish/regulations/2022-fishing-regulations-final-for-web.pdf. Accessed 1 September 2022.

Morrow Jr., J.V., J.P. Kirk, K.J. Killgore, and S.G. George. 1998. Age, growth, and mortality of Shovelnose Sturgeon in the Lower Mississippi River. North American Journal of Fisheries Management 18:725–730.

Nepal, V.K.C., R.E. Colombo, and L.D. Frankland. 2015. Demographics of Shovelnose Sturgeon in the lower Wabash River, Illinois. North American Journal of Fisheries Management 35:835–844.

Paragamian, V.L., and R.C.P. Beamesderfer. 2003. Growth estimates from tagged White Sturgeon suggest that ages from fin rays underestimate true age in the Kootenai River, USA and Canada. Transactions of the American Fisheries Society 132:895–903.

Phelps, Q.E., D.P. Herzog, R.C. Brooks, V.A. Barko, D.E. Ostendorf, J.W. Ridings, S.J. Tripp, R.E. Colombo, J.E. Garvey, and R.A. Hrabik. 2009. Seasonal comparison of catch rates and size structure using three gear types to sample sturgeon in the middle Mississippi River. North American Journal of Fisheries Management 29:1487–1495.

Quist, M.C., C.S. Guy, and P.J. Braaten. 1998. Standard weight (*Ws*) equation and length categories for Shovelnose Sturgeon. North American Journal of Fisheries Management 18:992–997.

Quist, M.C., and C.S. Guy. 1999. Spatial variation in population characteristics of Shovelnose Sturgeon in the Kansas River. The Prairie Naturalist 31:65–74.

Quist, M.C., C.S. Guy, M.A. Pegg, P.J. Braaten, C.L. Pierce, and V.H. Travnichek. 2002. Potential influence of harvest on Shovelnose Sturgeon populations in the Missouri River system. North American Journal of Fisheries Management 22:537–549.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Ottawa, Canada. 382 pp.

Rugg, M.L., M.J. Hamel, M.A. Pegg, and J.J. Hammen. 2014. Validation of annuli formation in pectoral fin rays from Shovelnose Sturgeon in the lower Platte River, Nebraska. North American Journal of Fisheries Management 34:1028–1032.

Smith, M.W., A.Y Then, C. Wor, G. Ralph, K.H. Pollock and J.M. Hoenig. 2011. Recommendations for catch-curve analysis. North American Journal of Fisheries Management 32:956–967.

Snyder, D.E. 2002. Pallid and Shovelnose Sturgeon larvae — morphological description and identification. Journal of Applied Ichthyology 18:240–265.

Sublette, J.E., M.D. Hatch, and M. Sublette. 1990. The Fishes of New Mexico. University of New Mexico Press, Albuquerque, NM, USA. 393 pp.

Tripp, S.J., R.E. Colombo, and J.E. Garvey. 2009. Declining recruitment and growth of Shovelnose Sturgeon in the middle Mississippi River: Implications for conservation. Transactions of the American Fisheries Society 138:416–422.

US Army Corps of Engineers (USACE). 2001. Missouri River master water control manual: review and update. Available online at https://www.nwd-mr.usace.army.mil/mmanual/feis/Index.htm. Accessed 1 September 2022.

US Fish and Wildlife Service (USFWS). 2010. Endangered and Threatened Wildlife and Plants; Threatened Status for Shovelnose Sturgeon Under the Similarity of Appearance Provisions of the Endangered Species Act. Federal Register 74 (169): 53598-53606. Available online at https://www.federalregister.gov/documents/2010/09/01/2010-21861/endangered-and-threatened-wildlife-and-plants-threatened-status-for-shovelnose-sturgeon-under-the. Accessed 1 September 2022.

Whiteman, K.W., V.H. Travnichek, M.L. Wildhaber, A. Delonay, D. Papoulias, and D.D. Tillett. 2004. Age estimation for Shovelnose Sturgeon: A cautionary note based on annulus formation in pectoral fin rays. North American Journal of Fisheries Management 24:731–734.

Wildhaber, M.L., D.M. Papoulias, A.J. Delonay, D.E. Tillitt, J.L. Bryan, and M.L. Annis. 2007. Physical and hormonal examination of Missouri River Shovelnose Sturgeon reproductive stage: A reference guide. Journal of Applied Ichthyology 23:382–401.