Validating Age Estimates from Pectoral Fin Spines and Length-Frequency Analysis of Known-Age Shortnose Sturgeon

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Abstract: The pectoral fin spine is the most accepted hard structure used for estimating ages of sturgeons. However, sturgeon age validation studies indicate that age estimation using fin spines typically underestimate sturgeon ages, particularly of older fish. Underestimating the ages of these long-lived species can result in inaccurate findings in population dynamics studies, such as overestimation of growth and mortality parameters. The shortnose sturgeon (*Acipenser brevirostrum*) is a long-lived, critically endangered fish for which population declines are attributed to anthropogenic effects. One method for evaluating recovery of shortnose sturgeon is through assessments of recruitment and population age structure, which are evaluated via age estimation with pectoral spines and modal assignments from length frequency (L-F) histograms. However, the accuracy of these estimation techniques is unknown, and inaccuracies could hinder conservation decision-making. Therefore, we collected pectoral fin spines from known and unknown age shortnose sturgeon in the Savannah, Ogeechee, and Altamaha Rivers, Georgia, from 2004–2023 to assess accuracy of age estimation procedures. Both the coefficient of variation and average percent error calculated from between-reader age estimates derived from pectoral fin spines were low. Mean consensus age estimates from known-age fin spines typically overestimated ages of younger fish and underestimated ages of fish older than 5 years. Age estimates from fin spines and back-calculated length-at-age estimates both supported the age-1 assignment from a length-frequency histogram. However, age assignments from pectoral fin spines suggest multiple ages present in the age-2+ size bin, indicating that age assignments from length-frequency histograms alone would lead to inaccuracies in demographic-based analyses.

Key words: age validation, age verification, fin spines, sturgeon

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Age estimation is a fundamental aspect of fisheries science, providing crucial data that underpin effective management, conservation, and ecological understanding. Age data are frequently obtained from the interpretation of growth marks consistently deposited on fish hard structures (e.g., otoliths, fin rays, vertebrae). Growth marks typically form from the annual oscillation of growth rates corresponding to environmental influences such as temperature. Therefore, visual growth marks on a fish hard part are interpreted as annular marks (i.e., annuli) and are counted to estimate age. An integral component of age estimation from hard parts is the validation and verification process (Beamish and McFarlane 1983, Casselman 1983). Age validation confirms accurate age estimates are attainable for a given structure, whereas age verification is the process of confirming accuracy and precision in age estimates from readers (Campana 2001). It is important to validate specific structures for each species of interest across the full breadth of ages in the population (Campana 2001, Spurgeon et al. 2015). Collectively, validating and verifying age estimates ensure the greatest accuracy for inference and the highest probability of making informed decisions.

Validating age estimates from long-lived species pose challenges. For a species that may live more than 100 years and exhibit variable growth patterns throughout its life, obtaining known-age individuals throughout the fish's lifespan for validation procedures may be difficult or impossible. Furthermore, many long-lived species are in imperiled and in need of conservation actions. The potential low abundance, protection status, and fragmentary distributions may pose additional challenges for acquiring known-age individuals. Such challenges are directly relevant to age validation for long-lived sturgeon species of high conservation concern.

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To conduct age validation studies on sturgeon species, much research has involved the initial use of smaller, juvenile fish, for which age can be inferred based on size or is known through hatchery rearing and release (Bruch et al. 2009, Koch et al. 2011, Hamel et al. 2014,). Juvenile fish are marked and released before being recaptured a known number of years later, when a hard structure is removed for validation purposes. Challenges to this age validation process are the potential difficulty in recapturing fish and the extensive time and cost that mark-recapture efforts can take to conduct over long periods of time (Hamel et al. 2014). Therefore, this approach may be more applicable to validate ages in younger fish of these long-lived species. Hurley et al. (2004) used hatchery reared juveniles of pallid sturgeon (*Scaphirynchus albus*) to validate fin spines; however, fish were raised in captivity for the duration of the study before having fin spine sections removed for aging. This approach poses potential biases as a captive environment could influence the growth of individuals, which directly affects growth mark deposition on hard structures. Validation studies have also been conducted on sturgeons by chemically marking (OTC) fish before recapturing those individuals a known number of years later (Rien and Beamesderfer 1994, Rossiter et al. 1995, Baremore and Rosati 2014). This application produces a marking on the growth mark being deposited at tagging and can be viewed under fluorescent light. The OTC process can be used to validate growth mark formation in fin spine structures by comparing growth marks formed after the chemical marking with the known time between capture events (Campana 2001). Although recapturing individual fish may be challenging, the OTC method does not rely on initial tagging and recapture of juvenile fish, as any sized wild fish can be chemically marked.

The shortnose sturgeon (*Acipenser brevirostrum*) is a long-lived, amphidromous sturgeon found in coastal rivers of the Atlantic coast of North America. Populations of shortnose sturgeon were historically distributed among 41 rivers, ranging from the Saint John River, Canada, to the St. Johns River, Florida (Dadswell et al. 1984). As amphidromous fish, shortnose sturgeon use all habitats of their natal rivers to complete their migratory life cycle, with the propensity for adults to move into saline environments (Kynard 1997). Exhibiting a broad distribution, life history traits of shortnose sturgeon vary by latitude. Across their range, shortnose sturgeon reach sexual maturity at approximately 500 mm fork length (Dadswell et al. 1984). Fish in southern populations, however, obtain smaller maximum sizes and shorter longevity, reaching age-at-maturity at approximately 6 yr and maximum ages of 20 yr (Marchette and Smiley 1982, Dadswell et al. 1984). Contrastingly, fish in northern populations reach age-at-maturity at 10+ yr and obtain maximum ages of 60+ yr (Dadswell et al. 1984).

The complex life history strategies exhibited by shortnose sturgeon made the species vulnerable to population declines from overfishing and habitat alteration in the 20th century. Population declines across the species range led to shortnose sturgeon being listed as endangered in 1967 under the U.S. Endangered Species Preservation Act (SSSRT 2010). Recovery of the species has since been impeded by numerous anthropogenic factors. The development of dams has obstructed spawning migrations of shortnose sturgeon, preventing fish from reaching suitable spawning habitat (Cooke and Leach 2004). Shortnose sturgeon have also been subjected to bycatch from other commercial fisheries, resulting in increased mortality of adult fish (Collins et al. 2000). Currently, shortnose sturgeon populations are presumably found in 19 river systems and are managed on a river-by-river basis (SSSRT 2010, Wirgin et al. 2010).

Determining age for shortnose sturgeon is an integral component of assessing population viability and responses to management actions. Age determination from shortnose sturgeon has primarily occurred through interpretation of growth marks on sections of the pectoral fin spine (Dadswell 1979), but no work has been conducted to validate accuracy of these structures. Previous attempts to validate age estimates from other sturgeon fin spines and rays have produced variable results. Bruch et al. (2009) assessed the validity of pectoral fin spines from lake sturgeon (*Acipenser fulvescens*) in Wisconsin using a bomb radiocarbon approach and determined fin spine age estimates to be accurate up to age-14. However, error increased with age thereafter, as true ages of lake sturgeon were underestimated from fin spine sections. Therefore, fin spines were not recommended for aging older fish. More recently, Izzo et al. (2021) assessed the validity of both the fin spine and second ray from the pectoral fin of known-age lake sturgeon, with known ages derived from stocked individuals that were marked as fingerlings. Again, age was underestimated with both structures, particularly as fish got older. Multiple studies have shown poor precision and accuracy of fin-spine derived age estimates for all ages of sturgeon from the genus *Scaphirhynchus*. Fin spine sections collected from known-age, hatchery-reared juvenile shovelnose sturgeon (*Scaphirhynchus platorynchus*) were inaccurate (age estimate accuracy = 27.8%) and tended to overestimate known ages in younger fish (≤7 yr) (Koch et al. 2011). Similarly, Hamel et al. (2014) reported that age-estimation accuracy for juvenile pallid sturgeon was only 13%. Furthermore, in validating growth mark formation in pectoral fin spines from adult shovelnose sturgeon with a marginal increment analysis, Rugg et al. (2014) found that growth mark formation varied annually. Variation in yearly growth mark deposition would indicate that fin spine derived age estimates are potentially inaccurate, especially in older aged fish that exhibit minimal somatic growth.

Federally protected fishes generally require monitoring to ensure populations do not continue to decline and to track population responses to management actions. Monitoring of populations often involves tagging of individual fish with unique tags (e.g., passive integrated responder [PIT] tags). Mark-recapture techniques are well-suited for monitoring growth through time and are a useful approach for validating age estimates from fish hard structures (Hamel et al. 2014). Shortnose sturgeon have been routinely collected, tagged, and released in coastal rivers of Georgia since 2004, and sporadic recaptures of fish varying in size and time since release or previous recapture provide an opportunity to corroborate age estimates derived from fin spines or assigned from modal peaks in a length frequency (L-F) histogram. Specifically, using known-age shortnose sturgeon assigned from mark-recapture, the objectives of this study were to 1) assess precision of shortnose sturgeon pectoral fin-spine derived age estimates from multiple readers; 2) determine accuracy of pectoral fin-spine derived age estimates from known-age fish; and 3) determine accuracy of L-F derived age assignments to known-age fish.

Methods

Study Area

This study occurred in three adjacent coastal rivers of Georgia: the Savannah, the Ogeechee, and the Altamaha rivers (Figure 1). The Savannah River forms a majority of the Georgia-South Carolina border and flows 484 km from the head waters in the Blue Ridge Mountains to the Atlantic Ocean. The lower Savannah River is tidally influenced up to 80 river kms (rkm) upstream from the mouth, with juvenile and adult shortnose sturgeon inhabiting both freshwater and brackish environments below the head of tide (Hall et al. 1991, Collins et al. 2002). We sampled for shortnose sturgeon in estuarine waters of the Savannah River, ~35–50 rkm from the mouth. The Ogeechee River is a 425-km blackwater system that flows from the Piedmont Province of central Georgia to the Atlantic Ocean. Shortnose sturgeon inhabit the lower ~65 rkm of the Ogeechee River, including the estuary (Farrae et al. 2014). We sampled for shortnose sturgeon in estuarine waters, ~20–55 rkm from the river's mouth. Beginning in the Piedmont Province of Georgia, the Altamaha River system is over 800 km in length, with the Altamaha River being formed at the confluence of the Ocmulgee and Oconee Rivers. The Altamaha River flows 212 rkm from the confluence to the Atlantic Ocean. Shortnose sturgeon typically reside in the lower 44 rkm of the Altamaha River for majority of the year (Ingram and Peterson 2018). We sampled for shortnose sturgeon ~10–30 rkm from the river's mouth in estuarine waters.

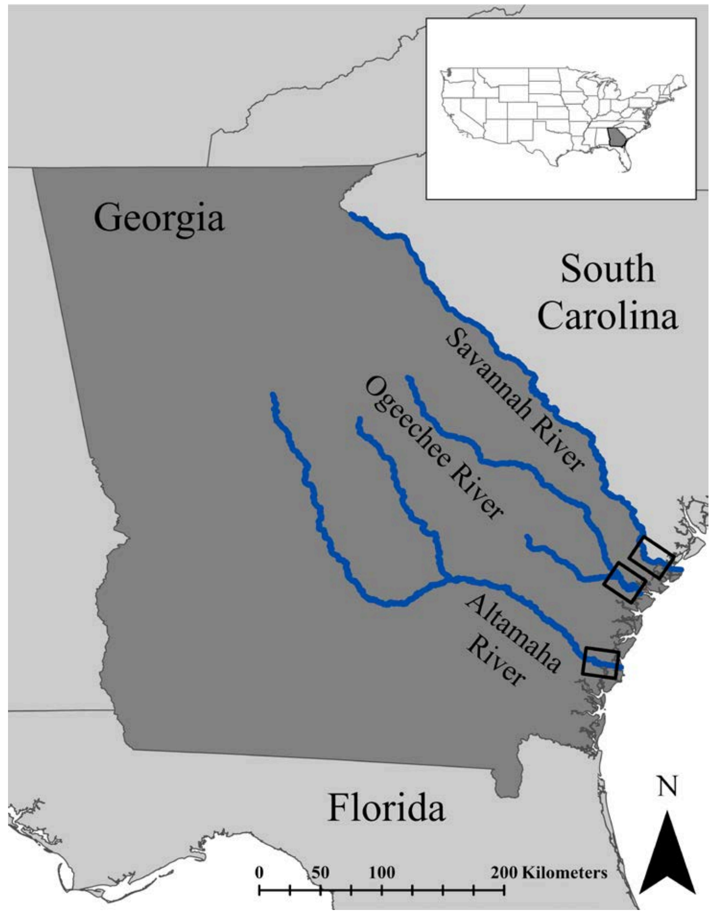

Figure 1. Study rivers where shortnose sturgeon were collected in Georgia during 2004–2023. Black outlined boxes indicate general sampling areas per river system during the summer sampling period.

Sturgeon Sampling

We sampled for sturgeon 3–5 days per week, primarily in May–August, from 2004–2023. We deployed anchored monofilament trammel and gill nets during slack high and low tides to catch sturgeon. Nets were set perpendicular to flows in obstruction-free areas with minimum depths of ~3 m, and nets soaked for 30–60 min to minimize both damages to gear and stress to captured fish. Gill nets were 91.4 m long and 3.3 m tall and consisted of three 30.5-m mesh panels in randomized order, with mesh (stretch) measuring 7.6, 10.2, and 12.7 cm. Trammel nets were also 91.4 m long and 3.3 m tall, with the net containing two external panels consisting of 15.2-cm mesh and an internal panel consisting of 7.6 cm-mesh. Upon net retrieval, we immediately placed captured sturgeon in floating net pens alongside the boat for recovery. Once all nets were retrieved, we measured fork length (FL) of each fish, and we scanned fish for a previously inserted PIT tag. If a tag was not detected, we injected a PIT tag under the fourth dorsal scute of the fish for individual identification. Additionally, we used diagonal cutters to remove an ~1 cm portion of the anterior marginal pectoral fin spine from a subsample of fish. We placed fin spine samples in labeled coin envelopes and allowed them to dry for at least 2–3 wk before processing. All sampling for sturgeon were conducted in accordance with the University of Georgia IACUC protocol A2021 09-010-Y3-A3 and NOAA NMFS permit 23096-01.

Known-Age Fish

We assigned fish a known age in this study if they were captured at a FL (mm) in size in which age could be approximated (Campana 2001) using modal distributions from prior L-F analyses on populations residing in Georgia coastal rivers (Peterson and Bednarski 2013, Bahr and Peterson 2017, Cummins 2018, Kleinhans and Fox 2024). Based on prior discrete modal distributions, fish captured in the primary summer sampling period were assigned into one of three demographic groups depending on FL: (1) "age-1 juvenile" if captured at a FL ≤390 mm, (2) "age-2+ juvenile" if captured at a FL 391–499 mm, or (3) "adults" if captured at a FL ≥500 mm. In this study, to assess the accuracy of modal distributions from prior L-F analyses, juvenile fish (i.e., fish <500 mm) that had a fin spine removed for aging analysis were also assigned ages based on fork length at capture. Furthermore, to assess the accuracy of fin spine age estimation techniques, we used fin spines from recaptured fish that were first tagged as juveniles (i.e., based on modal distributions) and could be assigned a known age based off time at large between captures (Table 1).

Fin Spine Processing and Aging

We mounted fin spines in epoxy and allowed samples to cure for ~24 h before being thin sectioned. We used an IsoMet low-speed saw (Buhler Ltd., Lake Bluff, Illinois) with two 127-mm wafering blades separated by ~0.5 mm to produce fin spine thin sections with a single cut. We mounted thin sections to labeled microscope slides with epoxy before lightly sanding the 0.5-mm thick sections with 300-grit sandpaper. We digitally imaged fin spine sections with a camera attachment (Nikon DS-Fi3; Tokyo, Japan) on a stereo microscope (Nikon SMZ1270i). Two readers independently assigned ages to all digital images via annuli counts. Readers had biological information of each fish's fork length to aid in age estimation because of the overall difficulty in annuli interpretation and the presence of presumed false annuli on spines. Once ages were assigned to all spines independently, readers met for a concert reading to resolve potential discrepancies in age assignments and agree on a consensus age for each fin spine. If a consensus age could not be agreed on by readers, then the spine sample was excluded from further analyses.

Data Analysis

We quantified precision as the difference in reader-assigned age estimates of fin spines with the coefficient of variation (CV; Chang 1982) and average percent error (APE; Beamish & Fournier 1981) formulas:

$$\mathrm{CV} = 100\% \times \frac{\sqrt{\sum_{i=1}^{R} \frac{(X_{ij} - X_j)^2}{R-1}}}{X_j},$$

$$\mathrm{APE} = 100\% \times \frac{1}{R} \sum_{i=1}^{R} \frac{|X_{ij} - X_j|}{X_j},$$

where X_{ij} is the *i*th age determination of the *j*th fish, X_j is the mean calculated age of the *j*th fish, and *R* is the number of reads per specimen. Between-reader precision was quantified overall, as well as by demographic groups from modal distributions. We developed an age bias plot with independent reader age assignments to determine potential biases between reader age estimates (Campana et al. 1995). Additionally, we constructed an age bias plot to compare mean consensus age estimates from fin spines with ages of known-age fish for determining accuracy of fin spine aging. We examined the accuracy of modal age assignments from L-F analysis by developing a L-F histogram in which consensus ages from fin spines were corroborated with FL at capture data of individual fish. Finally, we evaluated back-calculated length-at-age estimates from shortnose sturgeon fin spines as this is a commonly used methodology in fish aging studies. We used ImageJ software (Schneider et al. 2012), coupled with the Fraser-Lee method (Francis 1990) to back-calculate size-at-age from juvenile fin spines to further assess modal age distributions:

$$F_i = c + (F_c - c)\left(\frac{S_i}{S_c}\right),$$

where F_i is fish length at the *i*th time, F_c is fish length at time of capture, S_i is the spine length at the *i*th time, S_c is the spine length at capture, and *c* is the intercept of the regression of spine radius (i.e., S_c) and FL (i.e., F_c). We performed analyses using the Simple Fisheries Stock Assessment Methods (FSA) package (Ogle et al. 2023) in R (R Core Team 2023). Mean values are reported ±1 SE.

Results

We aged 128 shortnose sturgeon pectoral fin spines; however, 9 spines were excluded because a consensus age could not be reached, resulting in 119 fin spines being used for further data analyses. We aged 81 fin spines from fish assigned as juveniles based on L-F histograms, with consensus ages ranging from 1 to 6 yr (1.7 ± 0.1). Furthermore, we aged 41 fin spines from known-age fish. The precision (i.e., CV and APE) of between reader age estimates was low overall, with precision of fin spine age estimates being relatively low beyond age-1 fish (Table 2). Additionally, estimated ages between readers increasingly varied as annuli counts increased on spines (Figure 2).

Known-age fish ranged from 3 to 19 yr (6.8 ± 0.6), while estimated consensus ages from known-age fin spines ranged from 3 to 11 yr (5.5 ± 0.3) (Table 1). Mean consensus age estimates from fin spines typically overestimated ages of younger, known-age fish before underestimating known ages of fish older than 5 yr (Figure 3). Differences between estimated age and known age ranged from +2 to -10 yr (-1.2 ± 0.4). Mean length at age from fin spine estimates were in support of the age-1 modal distribution from L-F histograms (Figure 4). The average FL of fish assigned as an age-1

Table 1. Date and fork length (FL) of shortnose sturgeon at initial capture and subsequent recapture from three rivers in Georgia. Fish assigned to demographic groups are based on modal assignments from length frequency (L-F) analysis. Fish assigned to the age 2+ size bin are at least 2 years of age and are not parsed out from older cohorts because of uncertainty in age assignments. Known ages were determined by comparing the FL at initial capture and the time at large between recaptures.

Date of initial capture	FL at capture (mm)	Size bin	Date of recapture	FL at recapture (mm)	Time at large (yr)	Known age	Fin spine age
18 March 2004	495	Age 2+	21 June 2006	573	2.3	4	6
7 April 2004	480	Age 2+	22 May 2007	644	3.1	5	6
7 June 2004	333	Age 1	29 July 2008	668	4.1	5	6
28 July 2004	342	Age 1	25 June 2008	637	3.9	5	5
14 July 2005	475	Age 2+	2 July 2020	981	15.0	17	11
19 July 2005	476	Age 2+	1 July 2008	644	3.0	5	6
5 August 2005	450	Age 2+	18 June 2007	541	1.9	4	4
31 August 2005	432	Age 2+	5 June 2007	526	1.8	4	3
7 December 2005	360	Age 1	11 July 2023	980	17.6	19	9
28 April 2006	328	Age 1	29 July 2009	580	3.3	4	5
30 June 2006	356	Age 1	30 July 2008	542	2.1	3	5
21 July 2006	485	Age 2+	25 July 2008	625	2.0	4	6
11 June 2007	484	Age 2+	29 June 2023	737	16.1	18	6
28 April 2008	459	Age 2+	12 May 2008	546	2.0	4	4
17 May 2013	477	Age 2+	28 June 2023	724	10.1	12	8
17 June 2013	465	Age 2+	22 June 2020	748	7.0	9	8
12 May 2014	491	Age 2+	12 July 2023	786	9.2	11	4
28 May 2015	352	Age 1	10 June 2020	618	5.0	6	5
28 May 2015	375	Age 1	26 July 2023	747	8.2	9	7
9 June 2015	445	Age 2+	21 July 2023	728	8.1	10	4
18 June 2015	391	Age 2+	22 May 2023	723	8.0	10	7
23 July 2015	364	Age 1	26 July 2023	662	8.0	9	6
1 August 2016	388	Age 1	16 May 2023	717	6.8	8	7
25 May 2017	424	Age 2+	26 June 2023	714	6.1	8	5
31 May 2017	396	Age 2+	11 July 2023	732	6.1	8	7
23 June 2017	340	Age 1	31 July 2023	643	6.1	7	6
5 July 2017	348	Age 1	11 July 2023	784	6.0	7	6
9 May 2018	354	Age 1	21 July 2023	585	5.2	6	6
9 May 2018	465	Age 2+	9 June 2020	578	2.1	4	5
16 May 2018	401	Age 2+	31 July 2023	608	5.2	7	5
1 June 2018	449	Age 2+	16 May 2023	776	5.0	7	6
6 June 2018	452	Age 2+	26 July 2023	713	5.1	6	4
18 June 2018	420	Age 2+	27 June 2023	653	5.0	7	6
24 June 2019	482	Age 2+	24 July 2023	685	4.1	6	6
10 July 2019	450	Age 2+	23 July 2023	495	1.0	3	4
28 May 2020	359	Age 1	24 July 2023	497	3.2	4	3
23 July 2020	405	Age 2+	26 June 2023	594	3.0	5	6
31 July 2020	332	Age 1	24 July 2023	548	3.0	4	3
25 May 2021	489	Age 2+	28 June 2023	597	2.1	4	4
1 June 2021	376	Age 1	24 June 2023	523	2.1	3	4
19 July 2022	459	Age 2+	31 July 2023	491	1.0	3	3

from fin spine aging procedures was 358 ± 5 mm, although some age-1 fish >390 mm FL were observed. Back-calculated lengths from juvenile fin spines further supported the classification of the age-1 size bin, as the mean back-calculated FL for age-1 fish was 287 ± 7 mm (Figure 5). Length-at-age data derived from fin spine estimates, however, were much more variable in older cohorts and did not corroborate with the age 2+ modal distribution obtained from L-F analysis (Figure 4). Consensus age assignments ranged

Table 2. Precision (coefficient of variation, CV; average percent error, APE) of between reader age estimates obtained from shortnose sturgeon fin spines, broken down by demographic groups from age modal distributions of length-frequency analysis.

Demographic group	Spine count	CV (%)	APE (%)
Age-1	38	3.72	2.63
Age-2+	44	13.88	9.82
Adult	38	11.71	8.28
Total	119	10.06	7.11

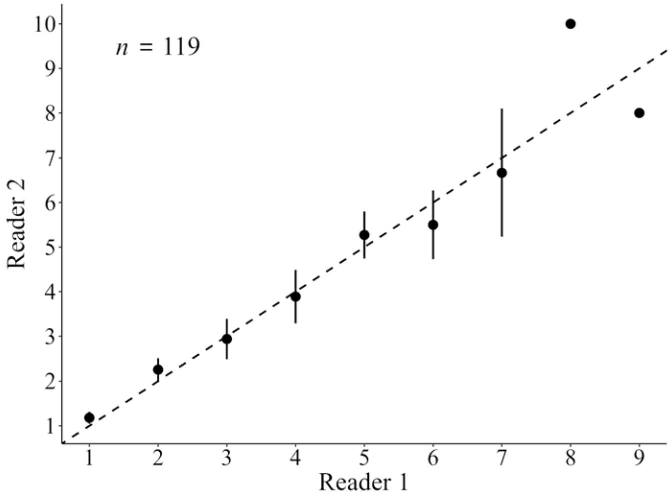

Figure 2. Age bias plot of between reader age estimates from shortnose sturgeon fin spines. The dotted line represents the 1:1 equivalence line between readers. The error bars represent the 95% confidence intervals around the mean age estimates of reader 2 for age estimates of reader 1 with more than one sample.

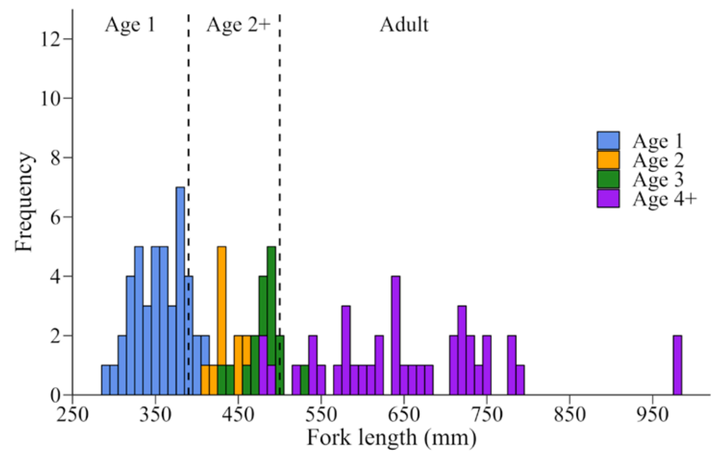

Figure 4. Length-frequency histogram (L-F; 10 mm bins) displaying shortnose sturgeon fork length (FL) at capture data corroborated with consensus age assignments from fin spines. The dotted lines separate theoretical size bins from age modal distributions, such that: (1) age-1 juveniles <390 mm FL, (2) age-2+ juveniles 390–499 mm FL, and (3) adults ≥500 mm FL. Colors (legend) indicate consensus age groups.

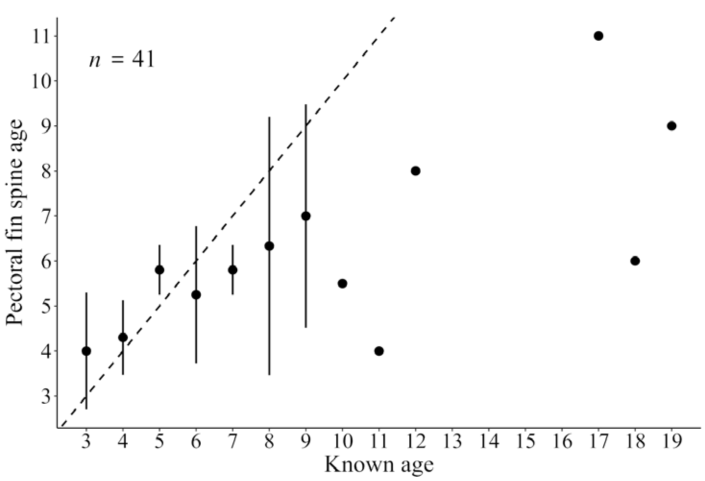

Figure 3. Age bias plot comparing mean consensus age estimates from fin spines with known-age shortnose sturgeon. The dotted line represents the 1:1 equivalence line between mean age estimates and ages of known-age fish. The error bars represent the 95% confidence intervals around mean age estimates for known ages with more than one sample.

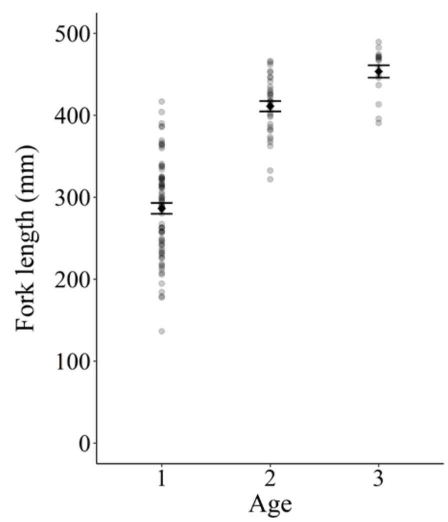

Figure 5. Mean (± SE) fork length at age estimated from back-calculation of juvenile shortnose sturgeon fin spines. The transparent points represent individual size at ages per juvenile age.

from 1 to 4+ years in the age 2+ juvenile size bin, indicating that FL at capture data alone would lead to inaccuracies in demographic group assignments.

Discussion

Age estimation from shortnose sturgeon pectoral fin spines proved challenging. Presumed annular marks were not easily distinguishable or consistent across the structure. Consequently, these structures did not provide precise or accurate age assignments for ages observed in this study. Pectoral fin spines consistently over-estimated ages until age-6, usually by 1 year. After age-5, age estimates from fin spines exceedingly underestimated age compared to known-age fish. There may be utility in using pectoral fin spines to age shortnose sturgeon less than age-6, particularly if readers studied the discrepancies between age estimates and known-age information.

The age-1 modal peak from our L-F analysis appeared to correspond well with age assignments of fin spines. Furthermore, the back-calculated mean length-at-age-1 fish fell within the size range observed in the L-F histogram, despite being less than the length-at-age data derived from fin spine estimates of unknown age. This makes sense, however, as back-calculations relate to the length of the fish at the end of the first year whereas our observed mean length at age-1 corresponds to summer captures when fish were approximately 1.5 years old. Therefore, the use of L-F histograms or fin spines to derive age-1 assignments appears to be a valid tool for age estimation. This may prove useful for quantifying recruitment and linking environmental effects or management actions to specific years. Previous research in Georgia coastal rivers have used L-F analyses to identify ages when calculating abundance estimates of specific year classes of shortnose sturgeon (Peterson and Farrae 2011, Peterson and Bednarski 2013, Bahr and Peterson 2017). However, these studies identified multiple age classes with L-F analysis and our results indicate that the increased uncertainty after the first year of life should preclude the use of fin spines or L-F analysis for age determination of age-2 and older fish.

The precipitous decline of sturgeons around the globe has led researchers to deploy non-lethal techniques to produce age data, particularly from pectoral fin spines. However, there is a growing body of literature evaluating the precision and accuracy of age and growth estimates of various sturgeon species generated from pectoral fin spines and rays. Few studies have provided evidence that age estimates from pectoral fin spines and rays are accurate. Bruch et al. (2009) used known-age fish and bomb radiocarbon analysis to validate both fin spine sections and otoliths of lake sturgeon. The authors found that fin spine sections were mostly accurate up to age-14, but then underestimated true age thereafter; otoliths were found to be accurate for fish aged to 52 years. In gulf sturgeon (*Acipenser oxyrinchus desotoi*), OTC marked fish ($n = 3$) that were recaptured 1 year post-marking showed a fully formed band on a thin section of the second pectoral fin ray (Baremore and Rosati 2014). The authors reported high precision between pectoral fin spines, the second pectoral fin ray, and otoliths, concluding that the second pectoral fin ray is an acceptable and less harmful alternative structure to the fin spine for aging gulf sturgeon.

Several studies have pointed to the inaccuracies of using age data generated from sturgeon pectoral fin spines and rays. Hamel et al. (2014) and Koch et al. (2011) both found that sections of pectoral fin spines produced erroneous age estimates for known-age pallid sturgeon. Similarly, attempts to validate annulus deposition on pectoral fin spines were unsuccessful in shovelnose sturgeon (Whiteman et al. 2004, Rugg et al. 2014). The variability in precision and accuracy among species and systems is largely unknown. Seasonal growth changes occurring in temperate climates are the primary driver for growth mark deposition on fish hard parts. However, sturgeon may exhibit different growth patterns that influence growth mark deposition. For example, Hamel et al. (2015) found that many populations of shovelnose sturgeon grow very little as adults (i.e., a few millimeters per year). Sturgeon also reside in a variety of aquatic environments (e.g., river vs. reservoir) across a wide breadth of latitudes. Shortnose sturgeon in southern Georgia commonly experience summer water temperature exceeding 30 C. It is unknown how high summer temperatures coupled with mild winters impact growth and growth mark deposition on hard parts. Interestingly, Hessenauer et al. (2018) found that pectoral fin spines of lake sturgeon were only accurate for a subset of the population in Lake St. Clair and the St. Clair River, Michigan. Those individuals that grew faster than 30 mm per year provided valid age estimates, whereas slower growing fish did not. Despite the cautionary notes in several publications assessing precision or accuracy of pectoral fin spines for aging sturgeon, researchers continue to use age estimates generated from pectoral fin spines and rays to calculate important fisheries management metrics such as age, growth, mortality, and other life history attributes. While age data generated from these structures may show promise from some species or systems, using erroneous age estimates can lead to mismanagement of a species (Hamel et al. 2016).

Future work is needed to identify potential sources of process and measurement error relevant to shortnose sturgeon age estimation. Age information is a fundamental component for evaluating population dynamics and constructing age-structured population models. Therefore, there is a strong desire to continue using fin spines and rays to generate these data. Additional work to determine the periodicity of growth mark deposition on shortnose sturgeon pectoral fin spines and rays will provide information on whether growth marks correspond to annual growth cycles and help to inform future aging techniques on fin spines. This information coupled with known-age fish will help to further elucidate the applicability of using sturgeon hard parts for age and growth analysis.

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