Comparison of Saugeye Age Estimates and Population Characteristics Using Otoliths and Dorsal Spines

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Abstract: Saugeye are hatchery produced hybrids (female walleye [*Sander vitreus*] and male sauger [*S. canadensis*]) that have been introduced to aquatic systems throughout the United States. The Oklahoma Department of Wildlife Conservation (ODWC) stocks reservoirs throughout Oklahoma with saugeye to control overcrowded, stunted white crappie (*Pomoxis annularis*) populations and to provide recreational fishing opportunities. Because sacrificing fish regularly to remove otoliths for age estimation is often unpopular with anglers, a non-lethal means of obtaining age estimates for saugeye to describe population dynamics is desirable. Therefore, we compared age estimate precision between readers and structures (otoliths and dorsal spines), and compared age-based population parameters (growth, mortality, recruitment) derived from these age estimates. Structures were removed from 47 saugeye collected from Thunderbird Reservoir, Oklahoma via electrofishing. Separate age-length keys were developed using consensus ages estimated from each structure, and ages were applied to an additional 253 unaged saugeye (300 fish total) for comparison of age-based population parameters for each structure. Precision was highest between readers for broken otoliths (100% agreement; CV = 0%) and whole otoliths (98% agreement; CV = 3.2%), whereas precision was poor for dorsal spine ages (55% agreement; CV = 22.3%). When comparing final consensus ages, broken otoliths and whole otoliths were in 100% agreement; however, otolith and spine agreement was 14%. Age bias plots indicate that final consensus spine ages always were higher than the final consensus ages from otoliths. Because age assignments from the two structures were dissimilar, corresponding mortality rates, growth models, and recruitment patterns were vastly different. We concluded that dorsal spines are not an appropriate aging structure for saugeye in Oklahoma, as age estimates lacked precision and produced erroneous population parameters. Fisheries managers should continue to sacrifice saugeye to obtain otoliths for aging for the most reliable data.

Key words: catch curves, von Bertalanffy, aging precision, reservoir, *Sander canadensis*

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Characterizing fish population dynamics requires reliable age information, as this provides the best estimates of the age-driven population parameters (growth, mortality, and reproduction) that are critical for managing fish populations. Several authors have compared aging precision between structures and the resulting population parameters derived from those age estimates. Colombo et al. (2010) concluded that pectoral spine and otolith age estimates from channel catfish (*Ictalurus punctatus)* were similar and population dynamics estimated from those age estimates did not differ. Conversely, Vandergoot et al. (2008) determined that total annual mortality estimates for yellow perch (*Perca flavescens)* were 20% higher when using scales compared to otolith estimates, a difference which could affect the ability of fisheries managers to make informed decisions about yellow perch management on Lake Erie.

Saugeye are cultured hybrid fish (female walleye [*Sander vitreus*] and male sauger [*S. Canadensis*]) that have been introduced to aquatic systems throughout the United States. Saugeye function as apex predators and are able to attain large sizes quickly (Leeds 1988) and tolerate shallow, productive systems (Leeds 1990). Fisheries management agencies have stocked saugeye to provide additional recreational angling opportunities (Leeds 1988, Fiss et al. 1997, Hale et al. 2008), reduce overabundant forage populations (Leeds 1988), and manipulate size structure of crappies (*Pomoxis* spp.; Summers et al. 1994, Boxrucker 2002, Galinet et al. 2002).

The Oklahoma Department of Wildlife Conservation (ODWC) has been stocking reservoirs throughout Oklahoma with saugeye since 1985. Saugeye are stocked annually into most systems, however an alternate year stocking schedule was recently implemented for some reservoirs. The primary stocking goals are to control overcrowded, stunted white crappie (*Pomoxis annularis)* populations (Summers et al. 1994, Boxrucker 2002) and to provide additional sportfishing opportunities (Leeds and Summers 1987). Because saugeye provide a valuable recreational fishery, sacrificing fish for otolith extraction is considered undesirable by most anglers. Furthermore, it is postulated that saugeye have high mortality rates, and they suffer from occasional fish kills during extreme summer conditions (K. Thomas, ODWC, personal communication), so sacrificing additional fish for age estimation purposes is not preferred. Therefore, a non-lethal means of obtaining age estimates for saugeye to describe population dynamics is desired.

To avoid sacrificing fish for aging, many fisheries managers continue to use scales to age walleye (Isermann et al. 2003) despite known underestimation biases when compared to otoliths (Erickson 1983, Kocovsky and Carline 2000, Isermann et al. 2003, Logsdon 2007, Koenigs et al. 2015). Dorsal spines are an alternate non-lethal method for estimating the age of percids (Erickson 1983, Kocovsky and Carline 2000, Isermann et al. 2003, Logsdon 2007, Williamson and Dirnberger 2010, Koenigs et al. 2015), but have produced variable results. Erickson (1983) determined that sectioned dorsal spines provided comparable age estimates to otoliths and scales for walleye in Manitoba. Other studies have found that dorsal spines were a suitable non-lethal aging structure for younger (age 5–7 or less) walleye only (Logsdon 2007, Koenigs et al. 2015). Furthermore, among-reader precision was lower for dorsal spine sections than for otoliths and scales from walleye populations in Pennsylvania (Kocovsky and Carline 2000) and South Dakota (Isermann et al. 2003).

Because ages from dorsal spines and otoliths may be more congruent for younger, faster-growing fish (Logsdon 2007, Koenigs et al. 2015), we felt that dorsal spines could be an acceptable structure to age saugeye in Oklahoma because these fish grow fast throughout their lives and are short lived. Our goal was to determine whether dorsal spines could serve as an acceptable non-lethal method for estimating the age of saugeye in Oklahoma and provide acceptable estimates of growth, mortality, and recruitment patterns. Therefore, the objectives of this study were to 1) evaluate precision of age estimates between two readers and among structures for broken otoliths, whole otoliths, and unsectioned dorsal spines, and 2) compare age-based population parameters derived from these structures.

Methods

Saugeye were collected from Thunderbird Reservoir, Oklahoma, during November and December 2016, using boat electrofishing (pulsed DC, high voltage, 7.5 GPP, Smith Root, Vancouver, Washington). Electrofishing sites were randomly selected to ensure that all available habitat types were surveyed to reduce potential bias in saugeye size or age. Furthermore, day and night samples were collected to account for any diel differences in size or age classes sampled. All saugeye encountered were netted and held in a 114-L live well.

Following capture, each fish was measured for total length (TL; mm) and weighed (g). Our goal was to collect five fish per 25-mm TL group for aging to ensure that all age classes of fish were represented in the sample. From each sacrificed fish, the sagittal otoliths and the second dorsal spine were removed for age estimation. Dorsal spines were cut as close to the skin on the back of the fish as possible using diagonal cutting pliers (i.e., side cutters; Logsdon 2007). One otolith from each fish was left whole, the other was broken in the transverse plane and polished using 600-grit wet/dry sandpaper. Both whole (concave side up) and broken (stood polished-side up) otoliths were placed in a dish containing black modeling clay and submerged in water, and viewed with a dissecting microscope (4–45x) using a fiber optic filament attached to a light source to illuminate annuli. Annuli were counted to assign an age estimate to each fish. Dorsal spines were prepared and aged using the methods of Logsdon (2007). Briefly, unsectioned spines were polished, stood in a tray of modeling clay, and a drop of immersion oil was placed on the polished end of spine to improve clarity. Dorsal spine annuli appeared as dark rings on a light background using side illumination with a fiber optic filament attached to a light source.

To evaluate between-reader precision among structures, two readers independently examined broken otoliths, whole otoliths, and dorsal spines from each fish one time in random order to estimate saugeye ages. Both readers had similar experience and had previously aged 4–5 fish species using otoliths and spines. Also, readers did not have knowledge of fish size or years when saugeye had been stocked to ensure age estimates would be "blind." Precision between readers was analyzed between structures using data collected by each reader independently and was calculated by percent reader agreement (Campana et al. 1995), CV (Chang 1982), and paired *t*-tests (Hurley et al. 2004). When readers were not in agreement, both readers re-examined each structure to obtain a final consensus age. Age-bias plots were generated to evaluate consistency among pairs of aging structures using final consensus ages (Campana et al. 1995) and differences between final consensus ages were evaluated using paired *t*-tests.

Separate age-length keys were developed using final consensus ages estimated from otoliths and spines. Using age-length keys for each structure, ages were assigned to an additional 253 saugeye captured by electrofishing that were not directly assigned ages using calcified structures. Therefore, a total of 300 fish (47 with direct age estimates, 253 assigned to specific age groups; Figure 1) were used to compare population parameters calculated from age esti-

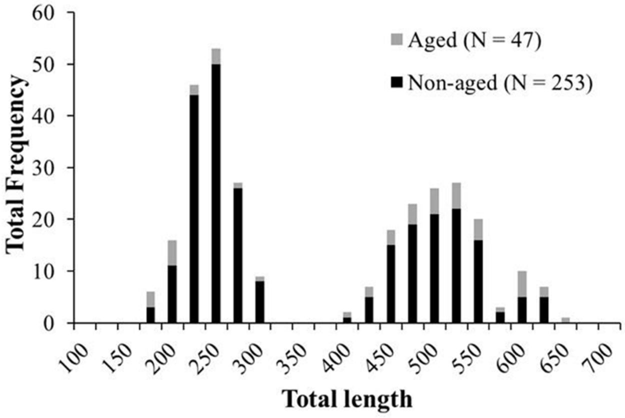

Figure 1. Length-frequency diagram (25-mm bins) showing aged and non-aged saugeye collected from Thunderbird Reservoir, Oklahoma, during November and December 2016.

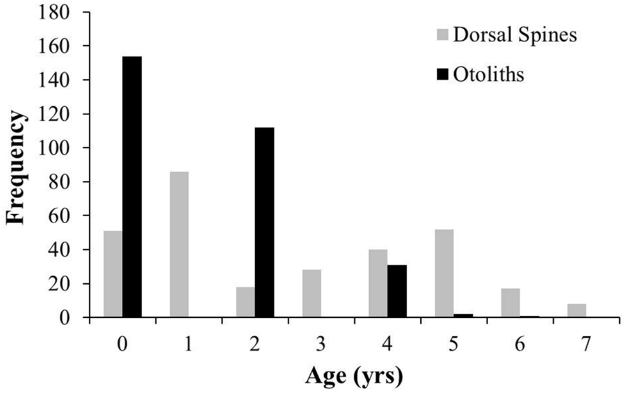

Figure 2. Age-frequency diagram using ages derived from otoliths and dorsal spines of saugeye collected from Thunderbird Reservoir, Oklahoma, during November and December 2016.

mates for each structure. Catch curves (Ricker 1975) were used to estimate instantaneous total mortality (Z) of saugeye based on ages estimated from the two structures. Total annual mortality (A) was then calculated as $1–e^{-z}$. Age-0 saugeye were not fully recruited to the sampling gear, so they were omitted from the catch-curve analysis for both aging structures (Miranda and Bettoli 2007). We compared Z (the slope of the catch curves) between structures with analysis of covariance (ANCOVA) using the lm function of R version 3.2 (R Core Team 2016). Saugeye growth was described with von Bertalanffy growth models fit using PROC NLIN in SAS 9.3 (SAS Institute 2011), and models were then compared using a likelihood ratio test (Kimura 1980, Cerrato 1990, Ogle 2016). A likelihood ratio test was used because it is the most accurate method for comparing von Bertalanffy models (Cerrato 1990). Recruitment patterns were assessed visually from age-frequency distributions produced for each structure. All statistical results were considered significant at $P < 0.05$.

Results

Saugeye captured for this study ranged from 182 to 650 mm TL (Figure 1). Of the 47 fish used for age estimation, 33 (70%) were female and 14 (30%) were male. Estimated ages from broken otoliths and whole otoliths ranged from 0 to 6 years, whereas age estimates from dorsal spines ranged from 0 to 7 years (Figure 2). Between-reader precision was highest for broken otoliths (CV = 0%), followed closely by whole otoliths (CV = 3.2%), and lowest for dorsal spines (CV = 22.3%). Agreement between readers was highest for broken otoliths (100%) and whole otoliths (97.7%), and lowest for dorsal spines (55%). Age estimates between the two readers were similar for whole otoliths ($t = –1.00$, df = 46, $P = 0.32$) and dorsal spines ($t = –0.46$, df = 46, $P = 0.64$), but were identical between readers using broken otoliths for all fish. The few differences in otolith age assignments were always ±1 year, whereas dorsal spine ages differed by as much as 2 years between readers. Final consensus ages were in full agreement between broken and whole otoliths, but final consensus ages from dorsal spines always overestimated the final consensus ages of broken or whole otoliths (Figure 3). Final consensus ages of dorsal spines were significantly different than those assigned to otoliths ($t = 4.22$, df = 46, $P < 0.01$), and identical between broken otoliths and whole otoliths.

Estimated mortality varied among aging structures; A was estimated to be 71% using otoliths and 21% using spines (Figure 4), and the associated estimates of Z differed among these datasets (ANCOVA; $F = 13.85$, $P < 0.01$). The von Bertalanffy growth parameters for otolith ages indicated that initial saugeye growth was rapid ($k = 0.49$), with individuals in the population growing to 77% of their expected TL ($L_\infty = 655$) by age 2 (Figure 5). Conversely, estimated von Bertalanffy growth parameters calculated using dorsal spine ages indicated that saugeye grew slower ($k = 0.14$), but attained much larger sizes ($L_\infty = 859$). Growth estimates derived from von Bertalanffy models were all different between structures ($X^2 = 471.73$, df = 3, $P < 0.01$), with all three von Bertalanffy model parameters differing (for all comparisons $P < 0.01$).

The otolith age-frequency distribution (Figure 2) showed strong year classes in alternating years (i.e., age 0, age 2, and age 4), with few individuals remaining in older year classes (ages 5 and 6), all of which correspond to stocked year classes (2016, 2014, 2012, 2011, and 2010). In contrast, age-frequencies calculated from dorsal spine ages showed variable abundance among year classes ranging from age 0 to age 7 (Figure 2), including a strong cohort from 2015 when fish were not stocked.

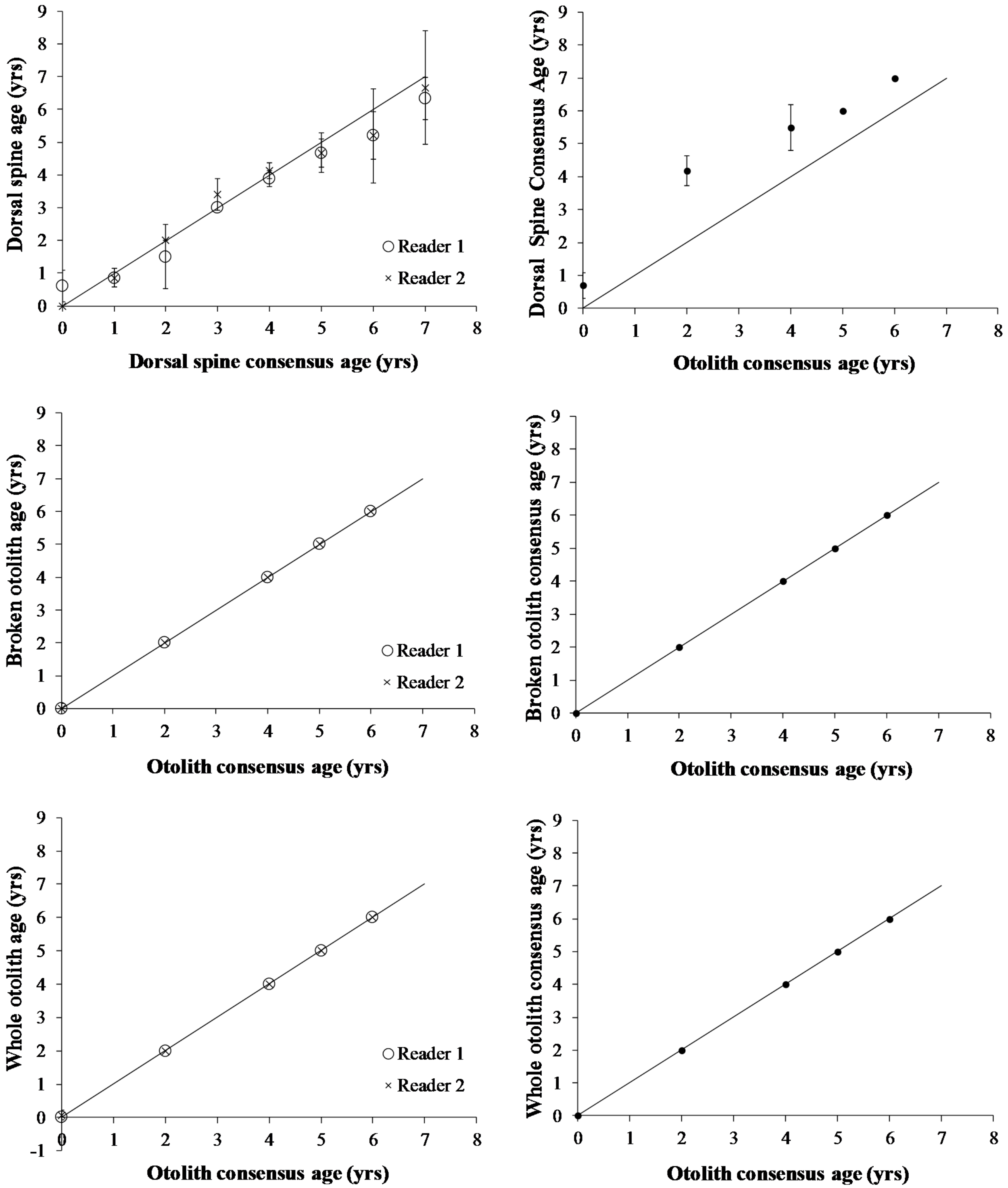

Figure 3. Age-bias plots comparing reader 1 and reader 2 age estimates from dorsal spines (top left), broken otoliths (middle left), and whole otoliths (bottom left) to final consensus age estimates for each structure and comparison of final consensus age estimates from dorsal spines (top right), broken otoliths (middle right), and whole otoliths (bottom right) from saugeye collected from Thunderbird Reservoir, Oklahoma. Error bars represent the 95% confidence interval. The diagonal line represents 100% agreement between structures.

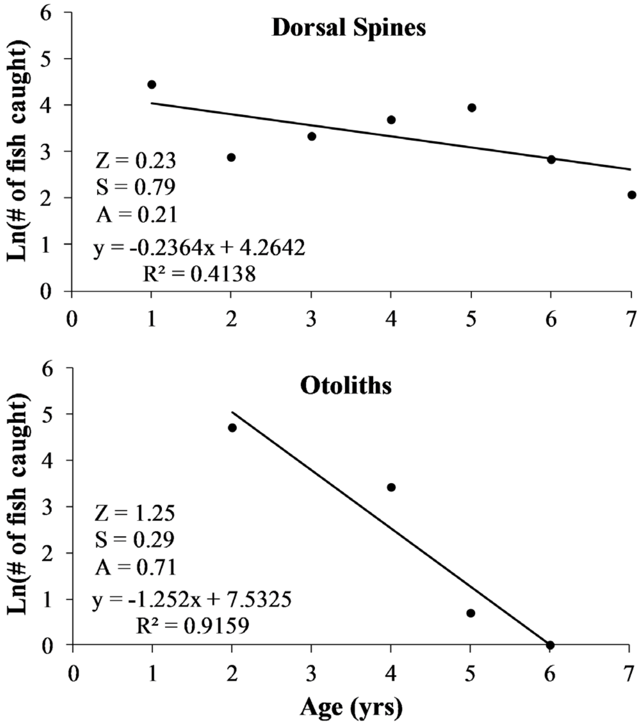

Figure 4. Catch-curve regression and total annual mortality (*A*) calculated from dorsal spine age estimates (top) and otolith age estimates (bottom) for saugeye collected from Thunderbird Reservoir, Oklahoma, during November and December 2016.

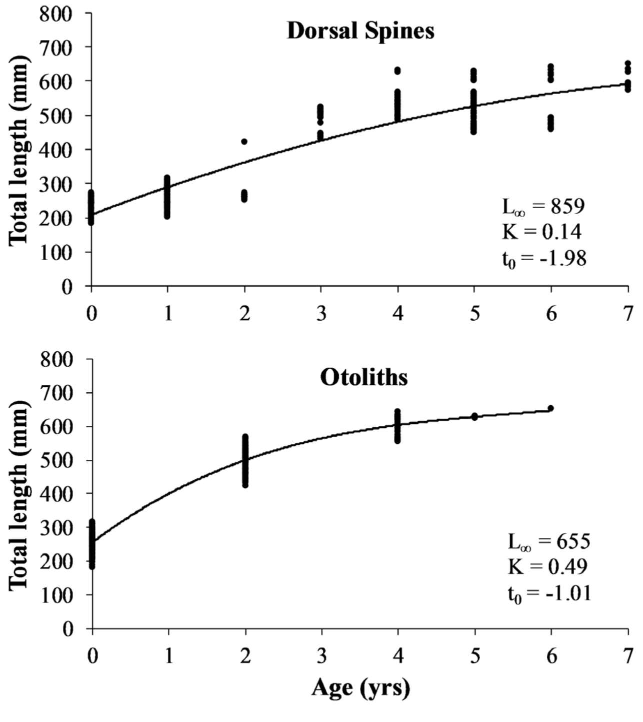

Figure 5. Von Bertalanffy growth curve calculated from dorsal spine age estimates (top) and otolith age estimates (bottom) for saugeye collected from Thunderbird Reservoir, Oklahoma, during November and December 2016.

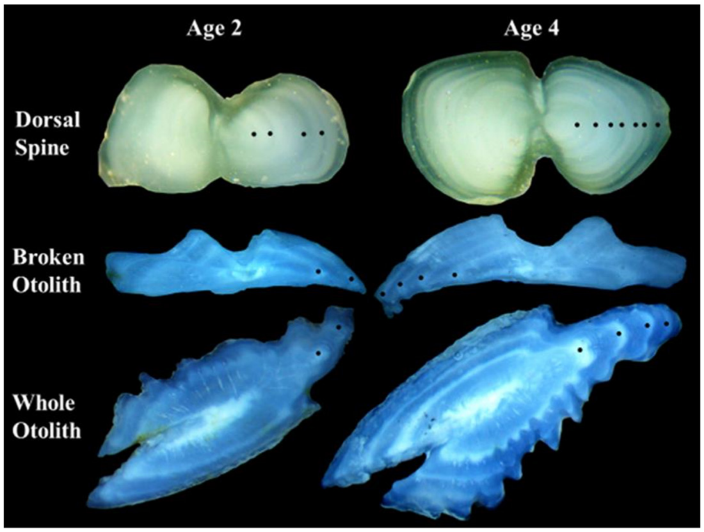

Figure 6. Photographs of the dorsal spine, broken otolith, and whole otolith from an otolith estimated age 2 saugeye (male, 436 mm TL, 825 g) and age 4 saugeye (female, 593 mm TL, 1,975 g) from Thunderbird Reservoir, Oklahoma. Black dots indicate annuli counted for final consensus ages.

Discussion

Our results suggest that otoliths provide the most precise age estimate for saugeye, but contrary to most *Sander* spp. aging studies, dorsal spine aging lacked precision and resulted in more variable age estimates and spine-derived age estimates were at times unrealistically high, suggesting that they also lacked accuracy. Previous work detailing aging precision of walleye suggests that spine ages corresponded with age estimated from otoliths for younger fish (<7 years) but underestimated the age of older fish (Logsdon 2007, Koenigs et al. 2015). Based on our results, the underestimation of age observed in these studies may bias age-based population parameters resulting in misinformed management decisions.

In our study, ages estimated from spines typically overestimated saugeye age when compared to otoliths using final consensus ages (Figure 6). The likely explanation for this bias is the presence of checks in the spines that were counted as annuli (false annuli). Kocovsky and Carline (2000) likewise found that dorsal spines sometimes overestimated ages of walleye when compared to otolith ages because split rings were counted as separate annuli. These higher age counts in our study resulted in variation of age estimates between readers, resulting in low percent agreement (55%) and decreased precision (CV = 22.3%). Checks are formed in calcified structures when fish are exposed to stressful events (e.g., handling, spawning, low dissolved oxygen levels, starvation, fluctuating or unfavorable water temperature, and water level changes; Jackson et al. 2007). Kocovsky and Carline (2000) suggested that checks in walleye spines may have resulted from a stressful thermal regime. Leeds (1988) found that July and August water temperatures (28–31 °C) in Thunderbird Reservoir reached upper thermal maximum levels for sauger and walleye (28–34 °C, Hokanson 1977). Under these extreme summer conditions, saugeye moved to deeper, offshore areas of the lake where water quality was adequate and may have withstood brief exposure to high temperatures and low oxygen levels (Leeds 1988). These stressful, sub-lethal conditions likely caused check formation in spines of these fish that were interpreted as false annuli by readers in this study, and resulted in age estimation bias.

Because our study did not have known-age fish, we cannot definitely say which aging structure was more accurate. However, otoliths are generally considered to be more accurate than external structures, given they are easier to interpret and material is not reabsorbed by fish (Isely and Grabowski 2007). This is further supported by the higher precision we observed for otoliths (Welch et al. 1993). Furthermore, the age-frequency distribution of otolith ages matched stocking patterns, further supporting that otoliths produced relatively accurate age estimates (Snyder et al. 1983). Saugeye can spawn in reservoirs and could potentially create a year class in years when no stocking occurred (Fiss et al. 1997); however, there is no evidence that saugeye spawn in Thunderbird Reservoir (K. Thomas, ODWC, personal communication), indicating that ages derived using dorsal spines were likely incorrect.

Disparity, and therefore inaccuracies, in saugeye age estimates between otoliths and spines in our study resulted in differences in population metrics that were substantial enough to conceivably prompt changes in management strategy. For example, population parameters calculated from dorsal spines in our study suggested that young age classes had low mortality and poor growth, which could cause fisheries managers to change fishing regulations or reduce stocking rates to improve growth by reducing density-dependent feedbacks. Conversely, population parameters calculated from otoliths suggested the exact opposite, with high *A* and rapid growth of young fish. These results could prompt managers to increase stocking rates to capitalize on the high growth and apparent heavy angler harvest. Clearly these two scenarios are strongly antithetical; the proper management action for one scenario is the worst possible action for the other.

In summary, dorsal spines will not serve as a non-lethal aging structure for saugeye in Oklahoma as age estimates lacked precision and produced erroneous population parameters. Because we were concerned about sacrificing fish, this evaluation was conducted with only 47 saugeye. Fisheries managers and the angling public should not be concerned about sacrificing fish to collect an age sample, because annual harvest rates likely far exceed the sample size needed for a good age sample. For example, the annual harvest estimate for saugeye from a 2010 creel survey conducted at Thunderbird Reservoir was 296 fish (ODWC unpublished data), considerably higher than the number of fish needed every few years for an otolith sample. The results of this study demonstrate the importance of having precise age estimates using otolith age estimates from sacrificed fish. Both broken and whole-viewed otoliths provide precise and similar age estimates for saugeye up to age 6. Fisheries managers should continue to sacrifice saugeye for aging, as otolith age estimates are precise and appear to be more accurate at describing population dynamics. Results of this study can be used by managers to engage stakeholders concerned with sacrificing fish for aging to explain the importance of obtaining accurate data to make informed decisions regarding their fisheries.

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