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MANAGEMENT BRIEF

Evaluation of Anal Spines, Dorsal Spines, and Scales as Potential Nonlethal Surrogates to Otoliths for Estimating Ages of Largemouth Bass and Smallmouth Bass

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Abstract
We compared the precision of age estimates from anal spines, dorsal spines, otoliths, and scales and evaluated the agreement of age estimates from nonlethal structures (i.e., anal spines, dorsal spines, and scales) to estimates obtained from otoliths for Largemouth Bass *Micropterus salmoides* and Smallmouth Bass *Micropterus dolomieu* collected in northeastern South Dakota glacial lakes. Reader agreement and coefficient of variation (CV) significantly differed across structures for both species. Otoliths had the highest complete and partial (i.e., at least two of three agree) reader agreement rates, while scales had the lowest for both species along with dorsal spines for Smallmouth Bass. Mean CV for otolith age estimates was 2.0% for Largemouth Bass and 2.3% for Smallmouth Bass; CV means for the nonlethal structures ranged from 8.0% to 15.2% for Largemouth Bass and from 10.0% to 10.7% for Smallmouth Bass. Age estimates derived from anal spines and dorsal spines underestimated ages of both species relative to otoliths. Otolith and scale age estimates were similar through age 9 for Largemouth Bass and through age 7 for Smallmouth Bass. Scale ages generally coincided with otolith ages for Largemouth Bass < 35 cm TL and for Smallmouth Bass < 31 cm TL. Neither anal spines nor dorsal spines proved to be a good nonlethal alternative for estimating ages, while scales may have utility for younger cohorts of both species. We recommend that otoliths be the standard structure for estimating Largemouth Bass and Smallmouth Bass ages when sacrificing fish is acceptable. If sacrificing fish is a concern, then scales may be used as a surrogate for estimating ages of Largemouth Bass < 35 cm TL and Smallmouth Bass < 34 cm TL.

Estimation of fish ages is an important aspect of fisheries management. Knowledge of fish ages is used to estimate growth, mortality, and recruitment, all of which are fundamental to assessing fish population dynamics. Largemouth Bass *Micropterus salmoides* and Smallmouth Bass *Micropterus dolomieu* are important sport fish, and fisheries personnel commonly estimate their ages as part of management and research activities. A multitude of structures have been used to estimate ages of black bass *Micropterus* spp., including but not limited to scales, otoliths, pectoral fin rays, anal fin spines, and dorsal fin spines (Maraldo and MacCrimmon 1979; Long and Fisher 2001; Rude et al. 2012; Morehouse et al. 2013; Klein et al. 2017). In a 2006 survey of U.S. and Canadian fisheries agencies, scales were identified as the most common structure for black bass age estimation, followed by otoliths (Maceina et al. 2007).

Although scales have commonly been used for age estimation of black bass, they are known to underestimate the ages of older fish (Kerns and Lombardi-Carlson 2017). To overcome the inherent bias in scale age estimates, many fisheries agencies currently use otoliths for age estimation. Sagittal otoliths are thought to produce the most precise and accurate age estimates for centrarchids (Phelps et al. 2017). In 2006, approximately 70% of U.S. and Canadian fisheries agencies believed that otoliths provided more accurate ages than scales (Maceina et al. 2007). Otoliths have been validated for both Largemouth Bass (Prather 1967; Taubert and Tranquilli 1982; Buckmeier and Howells 2003) and Smallmouth Bass (Heidinger and Clodfelter 1987; Klumb et al. 1999) and have been recommended for estimating the ages of these two species (Long and Fisher 2001). Despite this, otoliths are not always a structure of choice because of the frequently identified limitation that fish must be sacrificed. Harvesting black bass has fallen out of favor with many anglers, and often regulations do not allow for their harvest. Thus, it becomes difficult for agencies to justify sacrificing black bass for age and growth analysis.

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A nonlethal age-estimating structure that provides accurate and precise age estimates would be advantageous in situations where sacrificing fish is undesirable. The use of nonlethal methods to estimate fish ages is a good idea from a public relations perspective or when releasing fish is necessary to meet research objectives (Isermann et al. 2011). Unfortunately, many evaluations of nonlethal structures for estimating black bass ages have produced mixed to poor results. In North Carolina, scales were found to be ineffective at estimating ages of Largemouth Bass (Besler 1999). Agreement in Largemouth Bass age estimates across three readers was low at 2% for scales, 23% for pectoral fin rays, and 27% for dorsal spines in an Indiana study (Morehouse et al. 2013). In addition, both anal spine and dorsal spine age estimates were found to have poor accuracy when compared with known ages of Largemouth Bass from a Georgia reservoir (Klein et al. 2017) and growth zone patterns of pectoral fin rays and dorsal fin spines were thought to be too variable for age determination of Largemouth Bass in northern latitudes (Maraldo and MacCrimmon 1979).

South Dakota, like other northern states and provinces, has historically used scales to estimate the ages of Largemouth Bass and Smallmouth Bass. Concern with identified biases associated with scales and difficulty with reading scales led us to evaluate other structures in hopes of finding an alternative for age estimation. Otoliths have been recommended for estimating ages of these species (Long and Fisher 2001), but their utility has not been evaluated in South Dakota. A single study was found that used anal spines for age estimation of Largemouth Bass (Klein et al. 2017) and none were found for Smallmouth Bass. Evaluations of dorsal spines for age estimation of Largemouth Bass have exhibited variable results (Morehouse et al. 2013; Klein et al. 2017), and we did not find any studies evaluating dorsal spines for estimating ages of Smallmouth Bass. Because of the paucity of research evaluating otoliths, anal spines, and dorsal spines for estimating ages of Largemouth Bass and Smallmouth Bass, we evaluated the precision and agreement of anal spines, dorsal spines, otoliths, and scales for estimating the ages of these two species. Scales were included in this evaluation because they represented our current method and that of many other northern agencies for estimating the ages of these species. Our objectives were to (1) compare the precision of age estimates obtained from anal spines, dorsal spines, otoliths, and scales and (2) evaluate the agreement of age estimates from nonlethal structures (i.e., anal spines, dorsal spines, and scales) to estimates obtained from otoliths.

METHODS

Largemouth Bass were collected from Lake Cochrane (Deuel County; 148 ha), Lake Enemy Swim (Day County; 871 ha), and Roy Lake (Marshall County; 689 ha). Smallmouth Bass were collected from Lake Enemy Swim, Lake Kampeska (Codington County; 1,952 ha), and Roy Lake. All lakes are located in northeastern South Dakota and are typical of glacial lakes found in the area (Willis et al. 2007). Fish were collected by boat electrofishing during the spring of 2014. Collected fish were euthanized, placed on ice, and transported to our laboratory, where they were measured for TL (mm) and structures (i.e., anal spines, dorsal spines, otoliths, and scales) were removed.

Scales were collected from below the lateral line at the tip of the depressed pectoral fin (McInerny 2017) and stored in uniquely numbered coin envelopes. Sagittal otoliths were removed, wiped clean of tissue, and stored in individually numbered plastic vials. The second dorsal and anal spines were collected from each fish with side cutters by clipping each spine as close to the fish as possible. Fischer and Koch (2017) noted that the second or third spine is often used for age estimation as they tend to be longer and more robust than anterior-located spines. Spines were placed in individual coin envelopes and frozen. Thawed spines were cleaned of any residual tissue and stored dry in individual coin envelopes. Spines that were difficult to clean were immersed in warm water for a short period (i.e., < 1 min) to hydrate residual tissue, aiding in its removal.

Scales were pressed onto acetate slides with a roller press (Wildco, Yulee, Florida), and resulting impressions were viewed with a microfiche reader (Micron 780; Iron Ridge, Wisconsin). Sagittal otoliths were cracked in half at the nucleus and viewed on end with a stereomicroscope (UNITRON Z850; Commack, New York) using reflected light and a fiber-optic filament (Long and Grabowski 2017). The second anal and second dorsal spines were embedded in two-part epoxy (EpoxiCure; Buehler, Lake Bluff, Illinois) and several sections (0.6 mm) were cut close to the spine base with an Isomet low-speed saw (Buehler, Lake Bluff, Illinois). Spine sections were viewed with a stereomicroscope using transmitted light through a dark-field attachment, and a digital image of a section from each spine type was recorded with a Motic 5.0 MP camera (Richmond, British Columbia) mounted on the trinocular body of the stereomicroscope. Age estimates for spines were made from the digital images while viewed on a flat computer screen. Wegleitner and Isermann (2017) found that age estimates of Walleye *Sander vitreus* dorsal spines made from digital images were similar to those made by direct viewing.

Three readers independently estimated ages for each structure without knowledge of capture location, biological information (e.g., size or sex), or estimated ages from other structures. Readers were experienced at estimating fish ages using scales and otoliths, but experience with estimating ages from anal spines and dorsal spines was limited. Prior to estimating ages, readers familiarized themselves with each structure and came to an agreement on what would be considered an annulus. An annulus was assigned to the outer edge of each structure because all fish were collected in the spring before new annulus formation would have been apparent. Readers estimated ages for all structures of one type and species before estimating ages from a different structure type or species.

We quantified reader agreement for each structure and species as percent complete agreement (i.e., all three readers agreed on age estimate) and percent partial agreement (i.e., at least two of three readers agreed on age estimate). Percent complete agreement and percent partial agreement were tested across structures for each species using a chi-square test. A Bonferroni correction was used to maintain an experimentwise error rate of $\alpha = 0.05$ for chi-square tests; the significance level for each comparison was determined by dividing 0.05 by the number of comparisons (Neumann and Allen 2007). A coefficient of variation ($CV = 100 \times SD/mean$; Chang 1982) was used to measure the precision of age estimates for each structure of each species. The CVs were tested across structures for each species with a Kruskal–Wallis test, and the Dwass–Steel–Chritchlow–Fligner test (Systat Software, Richmond, California) was used for pairwise comparisons.

Possible bias between structures was assessed by constructing structure age-bias plots (Campana et al. 1995). Mean partial-agreement age estimates ($n \geq 3$) for anal spines, dorsal spines, and scales combined with 95% confidence intervals were plotted against otolith partial-agreement ages for both Largemouth Bass and Smallmouth Bass. Otoliths were used as the independent variable because they have previously been validated for Largemouth Bass (Taubert and Tranquilli 1982; Buckmeier and Howells 2003) and Smallmouth Bass (Heidinger and Clodfelter 1987) and we were evaluating nonlethal structures as possible surrogates to otoliths. Structure ages were considered significantly different from otolith ages if the 95% confidence intervals did not include the specified otolith age.

To explore if structure agreement with otoliths was length related we generated age-difference plots (Campana et al. 1995) for the difference between nonlethal structure ages (i.e., anal spines, dorsal spines, and scales) and otolith ages by centimeter length-groups. Mean age differences between nonlethal structure ages and otolith ages with 95% confidence intervals were plotted by length-groups for each species. Significant differences between age assignments were identified when the 95% confidence intervals did not include zero. Positive differences show that a structure overestimates ages compared with otoliths, and negative values indicate underestimation of ages by the structures relative to otoliths. All statistical tests were completed with Systat 13.0 (Systat Software, Richmond, California), with a significance level of ≤ 0.05.

RESULTS

Age estimates were obtained for anal spines, dorsal spines, otoliths, and scales from 170 Largemouth Bass and 147 Smallmouth Bass (Table 1). Largemouth Bass ranged from 217 to 485 mm TL and Smallmouth Bass from 179 to 453 mm TL. Partial-agreement age estimates for Largemouth Bass ranged from 1 to 11 years for anal spines, 1 to 12 years for dorsal spines, 2 to 20 years for otoliths, and 2 to 13 years for scales. Smallmouth Bass partial-agreement age estimates ranged from 1 to 9 years for anal spines, 1 to 10 years for dorsal spines, 2 to 13 years for otoliths, and 2 to 11 years for scales.

The percent complete agreement of age estimates for the three readers ranged from 22.9% (scales) to 77.1% (otoliths) for Largemouth Bass and from 35.4% (dorsal spines and scales) to 84.4% (otoliths) for Smallmouth Bass (Table 1). Otoliths had the highest rate of complete agreement for both species, while scales were lowest for Largemouth Bass and scales and dorsal spines were lowest for Smallmouth Bass. Significant differences in complete agreement across structures were identified for Largemouth Bass ($\chi^2 = 103.23$, df = 3, $P < 0.001$) and Smallmouth Bass ($\chi^2 = 99.31$, df = 3, $P < 0.001$). Partial-agreement rates for all structures and both species were substantially higher than complete-agreement rates. Similar to complete-agreement rates, partial-agreement rates also differed significantly across structures for Largemouth Bass ($\chi^2 = 49.57$, df = 3, $P < 0.001$; Table 1) and Smallmouth Bass ($\chi^2 = 48.78$, df = 3, $P < 0.001$). Otoliths had the highest rate of partial agreement, exceeding 97% for both species. Scales were found to have the lowest rate of partial agreement for Largemouth Bass (72.6%) and Smallmouth Bass (77.6%).

We found the CV across structures to significantly differ for both Largemouth Bass (Kruskal–Wallis test statistic = 125.48, df = 3, $P < 0.001$) and Smallmouth Bass (Kruskal–Wallis test statistic = 92.12, df = 3, $P < 0.001$; Table 1). Otoliths had the lowest CV for both Largemouth Bass (CV = 2.0%, SE = 0.3) and Smallmouth Bass (CV = 2.3%, SE = 0.5), and in each case the otolith CV was significantly different from that of the nonlethal structures. Scales were found to have the highest CV for Largemouth Bass (CV = 15.2%, SE = 1.1), while anal spines had the highest CV for Smallmouth Bass (CV = 10.7%, SE = 0.9).

Largemouth Bass anal spines, dorsal spines, and scales tended to underestimate ages at older ages when compared with otolith age estimates (Figure 1). Anal spines agreed with otoliths for ages 2–4 and also at age 7. Dorsal

TABLE 1. Percent complete agreement (all three readers agree), percent partial agreement (at least two of three readers agree), and mean coefficient of variation (CV) for each age estimation structure for Largemouth Bass (collected from Lake Cochrane, Lake Enemy Swim, and Roy Lake, South Dakota) and Smallmouth Bass (collected from Lake Enemy Swim, Lake Kampeska, and Roy Lake, South Dakota) collected in 2014. Standard errors are in parentheses for the mean CV. Values followed by different letters within a column for each species are significantly different ($P \leq 0.05$).

Species	Structure	*N*	Complete agreement (%)	Partial agreement (%)	Mean CV (%)
Largemouth Bass	Otoliths	170	77.1 x	97.6 x	2.0 (0.3) z
	Anal spines	170	45.9 y	89.4 y	9.0 (0.9) y
	Dorsal spines	170	45.9 y	89.4 y	8.0 (0.7) y
	Scales	170	22.9 z	72.6 z	15.2 (1.1) x
Smallmouth Bass	Otoliths	147	84.4 y	99.3 x	2.3 (0.5) z
	Anal spines	147	40.8 z	93.2 y	10.7 (0.9) y
	Dorsal spines	147	35.4 z	94.6 y	10.4 (0.8) y
	Scales	147	35.4 z	77.6 z	10.0 (0.7) y

spines followed a similar pattern as anal spines. Although a significant difference in ages was identified at ages 3 and 4, the actual difference at these ages was minimal. Largemouth Bass scale age estimates generally were in agreement through age 9 before underestimation by scales was apparent.

Smallmouth Bass anal and dorsal spine age estimates followed a similar pattern as those of Largemouth Bass (Figure 1). Ages assigned for anal and dorsal spines were significantly lower than for otoliths at ages 3 through 9. Visual inspection of the age-bias plot revealed little difference between the estimated ages of scales and otoliths for ages 2 through 7. Significant differences between scale and otolith ages were identified at age 3 and 9, but the identified difference at age 3 was minimal.

Age differences between structures by length-groups generally suggest that anal spines, dorsal spines, and scales underestimated Largemouth Bass ages when compared with otoliths, particularly at larger sizes (Figure 2). Differences in age estimates between otoliths and anal spines, dorsal spines, and scales were minimal (≤1 year) through 35–36 cm TL (Figure 2). However, at approximately 35–36 cm TL the magnitude of the underestimation increased. In addition to underestimating ages at TL ≥ 35 cm, the larger confidence intervals suggest increased variability.

Anal and dorsal spines of Smallmouth Bass tended to underestimate ages relative to otoliths across length-groups (Figure 3). The differences in age estimates for anal spines and otoliths were fairly constant through 31 cm TL before a decreasing trend and underestimation of ages by anal spines was observed. Dorsal spines followed a similar pattern as anal spines, but the decreasing trend did not occur, rather only variability in differences increased at 31 cm TL. No significant differences in age estimates at individual length-groups were identified between scales and otoliths. Although no significant differences were identified, an increase in variability in the differences between scale and otolith age estimates occurred for larger Smallmouth Bass length-groups (i.e., ≥34 cm TL).

DISCUSSION

Otoliths were the most precise age estimation structure evaluated in our study; our results are similar to what others have found when investigating otoliths relative to nonlethal structures for age estimation of black bass. Otoliths had the highest reader agreement and the lowest CVs of the structures we evaluated for both Largemouth Bass and Smallmouth Bass. Campana (2001) suggested that a CV of 5% serve as an aging precision reference point for fishes of moderate longevity and reading complexity. Otoliths were the only structure we examined that had a CV < 5%. Likewise, Largemouth Bass ages estimated from sectioned otoliths had a CV of 1.2% for fish collected from a Georgia public fishing area (Klein et al. 2017) and Wegleitner and Isermann (2017) reported a mean CV of approximately 4% for Largemouth Bass sectioned otoliths. Otoliths may be superior to other structures in their ability to document fish ages because, unlike skeletal bones and scales, they continue to grow and generally are not subject to resorption (Casselman 1990; Campana and Thorrold 2001).

Neither anal spines nor dorsal spines proved to be a good nonlethal alternative for estimating ages of either Largemouth Bass or Smallmouth Bass. Estimated ages from anal and dorsal spines tended to underestimate ages, even at young ages, when compared to otoliths, and the CV for each spine type exceeded the suggested 5% threshold (Campana 2001). For these reasons we believe that age estimates from anal spines and dorsal spines were biased and should not be used for estimating ages of these species. Klein et al. (2017) reported that Largemouth Bass dorsal spine and anal spine age estimates did not agree

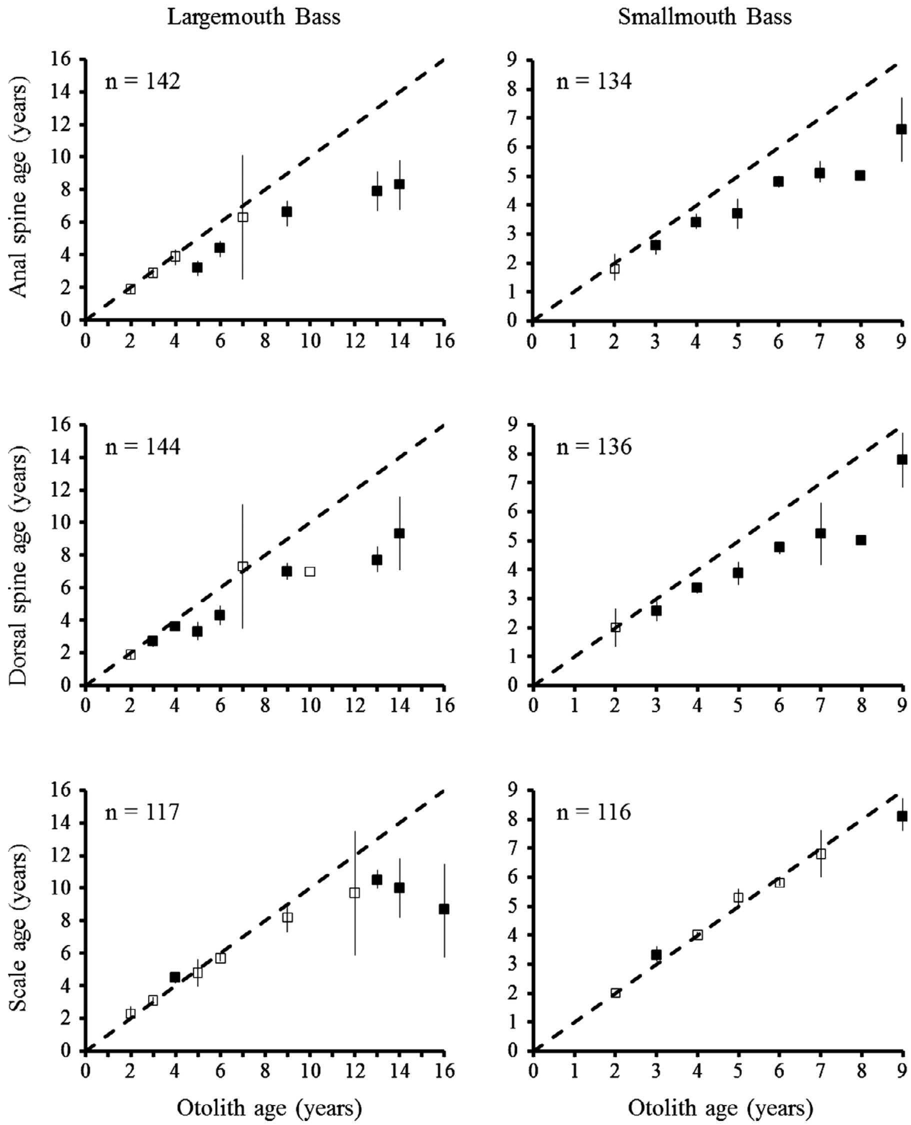

FIGURE 1. Age-bias plots of mean ages estimated from anal spines, dorsal spines, and scales in relation to otolith age estimates for partial-agreement (at least two of three readers agree) age estimates for Largemouth Bass collected from Lake Cochrane, Lake Enemy Swim, and Roy Lake, South Dakota, and Smallmouth Bass collected from Lake Enemy Swim, Lake Kampeska, and Roy Lake, South Dakota, during 2014. Mean ages for anal spines, dorsal spines, and scales are the average of the age estimates ($n \geq 3$). Significant differences in ages are represented with filled squares, and open squares indicate no significant difference. In each graph, the error bars represent 95% confidence intervals and the dashed line indicates a 1:1 agreement line between structures.

with the known ages. Estimating ages from anal spines and dorsal spines should be avoided as biased growth parameter estimates can lead to mismanagement of fisheries because calculated rate functions will not be accurate. Underestimating the ages of older, larger fish can lead to higher growth estimates and catch-curve regression survival estimates will be lower (Maceina and Sammons 2006). Modeling of potential bias in age-estimating structures for Largemouth Bass in Ohio reservoirs indicated that underestimation of ages by scales would result in an underestimation of fishing mortality by up to five times at low levels of natural and fishing mortality (Tyszko and Pritt 2017).

Several possibilities may come into play as to why anal spines and dorsal spines performed poorly as nonlethal age-estimating structures in our study. One possible reason may be the presence of lumen in the center of anal and dorsal spines, making it difficult to discern early annuli (Mayhew 1969). Lumen was observed in the center of many of the spines we examined, and it likely contributed to our lower age estimates for both anal spines and dorsal spines when compared with age estimates derived from

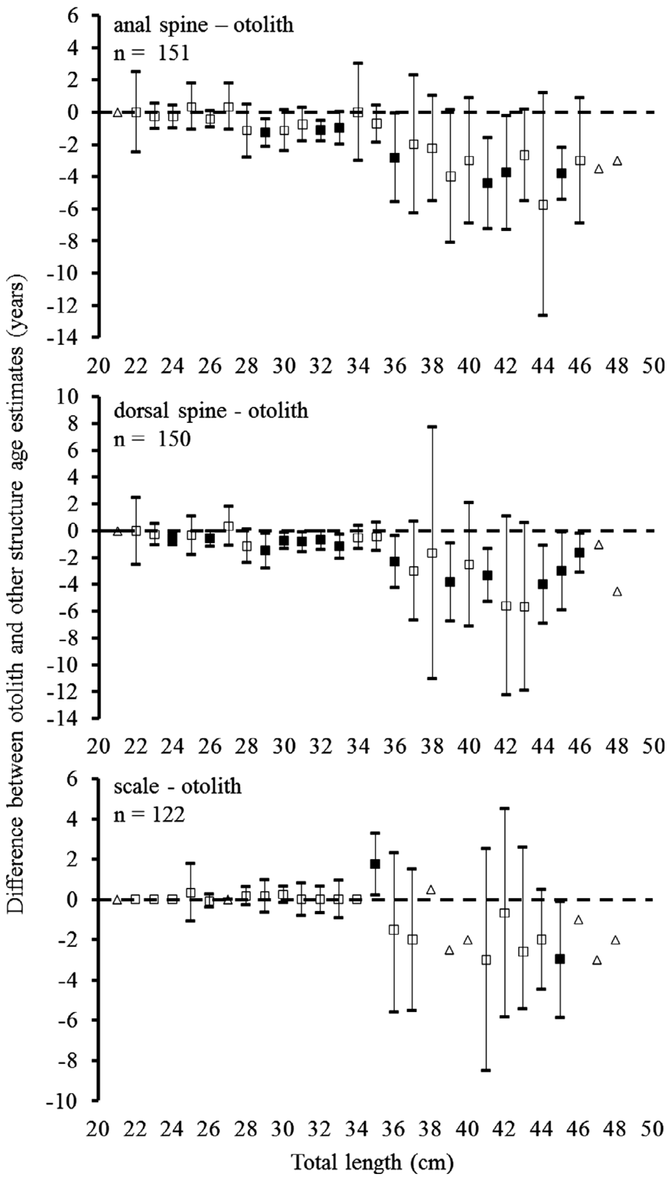

FIGURE 2. Age-difference plots showing the mean difference between partial-agreement (at least two of three readers agree) age estimates by centimeter length-groups for anal spines and otoliths, dorsal spines and otoliths, and scales and otoliths of Largemouth Bass collected from Lake Cochrane, Lake Enemy Swim, and Roy Lake in 2014. Significant differences in ages are represented with filled squares; open squares indicate no significant difference, and open triangles represent length-groups with less than three observations. In each graph, the error bars represent 95% confidence intervals and the dashed line indicates no difference between structures.

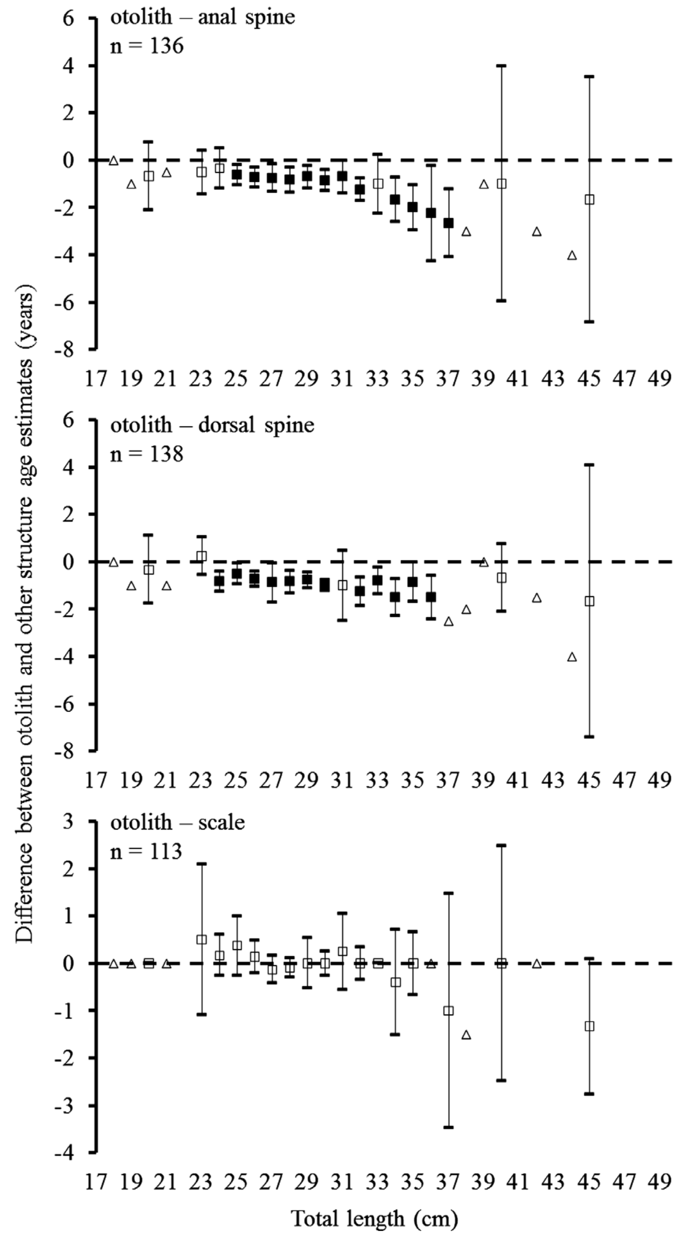

FIGURE 3. Age-difference plots showing the mean difference between partial-agreement (at least two of three readers agree) age estimates by centimeter length-groups for anal spines and otoliths, dorsal spines and otoliths, and scales and otoliths of Smallmouth Bass collected from Lake Cochrane, Lake Enemy Swim, and Roy Lake in 2014. Significant differences in ages are represented with filled squares; open squares indicate no significant difference, and open triangles represent length-groups with less than three observations. In each graph, the error bars represent 95% confidence intervals and the dashed line indicates no difference between structures.

otoliths. The presence of lumen was believed to obscure annuli on Largemouth Bass dorsal spines in the study completed by Morehouse et al. (2013). Lumen was also found to obscure one or more annuli, causing dorsal spines to underestimate ages of Black Crappie *Pomoxis nigromaculatus* in two Minnesota lakes (Isermann et al. 2011). The underestimation of ages obtained from anal spines and dorsal spines may also occur because of annuli crowding on the edge of the spines of old and slow-growing fish, making it difficult to discern the annuli (Kocovsky and Carline 2000). The increasing magnitude of age underestimation with age and TL of both Largemouth

Bass and Smallmouth Bass in our study may be related to crowding of annuli in these older fish. Another possibility is the northern latitude of South Dakota. Maraldo and MacCrimmon (1979) believed that the annuli pattern on Largemouth Bass dorsal spine cross sections was too variable for accurate age determination at northern latitudes. The variability the authors encountered may have been related to the presence of lumen and crowding of annuli on the spine sections as the inability to identify annuli has often been blamed on the expansion of the central lumen and an inability to separate annuli on the edge of a structure (Buckmeier et al. 2002). A lack of experience in estimating ages with anal spines and dorsal spines may have also resulted in our lower precision and age underestimation relative to otoliths. Less-experienced readers were found to be more apt to underestimate Smallmouth Bass ages derived from pectoral fin rays compared with otolith age estimates (Rude et al. 2012). Similarly, novice readers were found to underestimate the ages of Yellow Perch *Perca flavescens* relative to more experienced readers when estimating ages from anal spines (Vandergoot et al. 2008). However, reader experience was not a good indicator of accuracy when aging Channel Catfish *Ictalurus punctatus* pectoral spines (Buckmeier et al. 2002).

Our identified concern with using scales as a nonlethal aging structure because of difficulty in reading was confirmed by our low complete reader agreement and high CV in scale age estimates. These findings are consistent with other studies that have compared scale age estimates to ages estimated from otoliths for Largemouth Bass and Smallmouth Bass. A CV of 37.2% and an initial agreement rate among readers of only 2% was reported for scale age estimates for Largemouth Bass collected from six lakes in northern Indiana (Morehouse et al. 2013). Additionally, age estimates from scales were found to have the highest CV for both Largemouth Bass (14.6%) and Smallmouth Bass (12.1%) in a study that compared age estimates of dorsal spines, opercles, otoliths, and scales of fish collected from Lake Champlain, New York (Sotola et al. 2014). Furthermore, scales were found to underestimate the ages of Largemouth Bass compared with the use of otoliths in two South Africa impoundments (Taylor and Weyl 2012), and scales were found to be ineffective for estimating ages of Largemouth Bass in North Carolina because of their low precision (Besler 1999). Scale resorption, presence of false annuli, and annuli crowding on the scale edges are often cited as reasons for difficulty in estimating fish ages with scales.

Although scales have generally proven to be a questionable structure at estimating black bass ages, some researchers have advocated their use for estimating ages of young fish. Our results for both Largemouth Bass and Smallmouth Bass lend support to this concept. We found that partial agreement for scale age estimates was similar to otoliths through age 9 and 35 cm TL for Largemouth Bass and through age 7 and 34 cm TL for Smallmouth Bass. Age estimates derived from scales for Largemouth Bass collected from an Ontario lake were thought to be valid through age 7, but after age 7 scales would likely underestimate ages (Maraldo and MacCrimmon 1979). Maceina and Sammons (2006) indicated that age determinations for Largemouth Bass and Smallmouth Bass in Hudson River, New York, from scales would likely lead to underestimation of ages in larger and older fish; however, scales may provide reasonable age estimates for young fish. Scales were recommended as a nonlethal method to estimate ages of young Largemouth Bass in place of estimates made from pectoral fin rays and dorsal fin spines (Morehouse et al. 2013). Additionally, Taylor and Weyl (2012) recommended otoliths for estimating Largemouth Bass ages in South Africa unless strong evidence exists that the population is composed of young fish ($\leq$ age 5).

We agree with previous studies that indicate otoliths should be the standard structure for age estimation of Largemouth Bass (Long and Fisher 2001; Klein et al. 2017; Tyszko and Pritt 2017) and Smallmouth Bass (Long and Fisher 2001) if sacrificing fish is not a concern. Much of the existing literature suggests that otoliths likely provide the most precise and accurate age estimates for centrarchids (Phelps et al. 2017). If age information is needed from Largemouth Bass or Smallmouth Bass and there is no concern with sacrificing fish, we recommend that otoliths be used. However, if sacrificing fish is not an option, we are also in agreement with the body of literature that has suggested scales may be used to estimate ages of young fish (e.g., Maceina and Sammons 2006; Taylor and Weyl 2012; Morehouse et al. 2013). We believe that scales can be surrogate to otoliths for estimating ages of young Largemouth Bass < 35 cm TL and Smallmouth Bass < 34 cm TL, but that scale ages and the TL or age where scale and otolith age estimates do not agree should be periodically confirmed by comparing with otolith age estimates.

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