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Precision and Relative Accuracy of Striped Bass Age Estimates from Otoliths, Scales, and Anal Fin Rays and Spines

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Abstract.—We counted annuli on otoliths, scales, anal fin rays, and anal fin spines of striped bass *Morone saxatilis* to determine precision of age estimates from several readers and relative accuracy of the estimates from the different structures. Our principal objective was to determine if estimates from scales, spines, and rays, which can be removed without harming the fish, were similar to those from otoliths. Among-reader variation was similar for spines, scales, and rays, and lowest for otoliths. Variation increased with fish total length (TL) for otoliths and scales. Age estimates from scales, spines, and rays were usually within 1 year of the otolith age estimate for striped bass shorter than 900 mm TL. However, for striped bass longer than 900 mm TL, estimates from spines and scales were lower than estimates from otoliths by averages of 1.6 and 3.0 years, respectively. Scales, spines, and rays can provide relatively accurate and precise age estimates for striped bass up to about 900 mm TL (age 10 from our samples). For longer fish, the choice of a structure for age determinations should depend on whether the improved accuracy and precision expected from otoliths is worth killing the fish.

Although scales have been frequently used to age striped bass *Morone saxatilis* (Scofield 1931; Stevens 1958; Robinson 1960; Axon 1979; Wooley and Crateau 1983), numerous problems have been reported, including false annuli, difficulties with locating the first annulus, and crowding of annuli along the outer scale margin in older specimens (Merriman 1941; Orsi 1970; Collins 1982; Bryce and Shelton 1985). Otoliths can be more accurate than scales for determining ages of striped bass (Heidinger and Clodfelter 1987), but their use requires killing the fish. Orsi (1970) and Humphries and Kornegay (1985) reported good agreement between ages of striped bass determined from scales and otoliths, but they did not report the range of ages of fish evaluated.

Other structures that can be removed for age determination without harming the fish, such as fin spines and rays, have proven as accurate as otoliths for several species of fish (Beamish and Harvey 1969; Beamish 1981; Cass and Beamish 1983; Chilton and Bilton 1986). However, Erickson (1983) found that fin spines were less accurate than otoliths, suggesting that the relative accuracy of these structures varies among species.

Our study was conducted to determine the relative accuracy of age estimates obtained from striped bass otoliths, scales, anal fin spines, and anal fin rays, and to determine the precision of estimates given by different readers. We examined precision of annulus counts by measuring variation among readers for each structure and evaluated relative accuracy by comparing age estimates from scales, spines, and rays with those from otoliths. Our results help define the sizes of striped bass for which relatively accurate age estimates can be obtained without killing the fish.

We used 50 sets of otoliths, scales, and spines, and 34 rays from striped bass that were 244–1,067 mm in total length (TL). Fish were collected during January–December 1987 from J. Strom Thurmond Reservoir, Georgia–South Carolina; during March–April in 1983 and 1988 from the Savannah River, Georgia–South Carolina; and during March–April 1988 from the Ogeechee River, Georgia.

Otoliths were prepared for viewing by grinding them into thin cross sections mounted in thermoplastic cement (Maceina 1988). Sections (0.25–0.35 mm thick) of rays were cut near the base with a diamond-grit blade on a low-speed saw, and sections of spines were cut with two diamond-grit blades with a 0.25-mm-thick plastic spacer. All sections were viewed in transmitted light at 40 or 100× magnification. The translucent bands following opaque growth zones were considered annuli. Scales were mounted between glass slides, examined with a microfiche reader, and aged according to the criteria of Everhart et al. (1975).

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TABLE 1.—Precision of striped bass age estimates given by different readers, as measured by average standard deviation (SD), average coefficient of variation (CV = SD/mean); and average percent agreement among estimates. Each structure was read by three readers.

Structures	Number of fish	Average SD[a] (years)	Average CV[a]	Average percent agreement among readers: Exact	Within 1 year
Otoliths	50	0.427 z	0.144 z	65	91
Scales	50	0.650 y	0.189 y	48	81
Fin spines	50	0.774 y	0.288 y	35	82
Fin rays	34	0.804 y	0.269 y	38	74

[a] Within the column, means followed by different letters are significantly different (Kruskal–Wallis test; $P \leq 0.05$).

Each structure was examined independently by three experienced readers who initially worked together to define criteria for identifying annuli. Before the study, practice materials were examined to help standardize techniques. During the study, readers were unaware of fish size and unable to compare estimates among different structures from the same fish. To help compare the amount of effort required to interpret the structures, reading times were recorded by each reader for about half of the fish examined (N = 51–75 determinations per structure). We used analysis of variance and Tukey–Kramer multiple comparisons on log-transformed data to test for differences among mean reading times. Our accepted level of statistical significance was $P \leq 0.05$.

Precision of age estimates from different readers was measured for each structure by computing the standard deviation among age estimates given by the three readers for individual fish and then computing the mean of the standard deviations for all fish. Relationships between precision and fish size were evaluated with Spearman rank correlation coefficients (Zar 1974). For each structure, we also calculated the average percent agreement for all possible pairwise comparisons of readers and the coefficient of variation (SD/mean) (Chang 1982). Kruskal–Wallis tests (Zar 1974) were used to determine if standard deviations and coefficients of variation varied among structures used for age estimation.

Relative accuracy of age estimates was evaluated by comparing annulus counts from scales, spines, and rays with those from otoliths. First, the three readers discussed their findings for each structure and agreed on one age estimate—hereafter called the consensus age. We then compared consensus estimates for scales, spines, and rays with those from otoliths by calculating the mean arithmetic difference (years), the percent exact agreement, and the percent agreement within 1 year. We collected no rays from striped bass longer than 900 mm TL; therefore, comparisons of consensus estimates for the longest fish were limited to otoliths, spines, and scales.

Reader precision was better for otoliths than scales, spines, or rays, as indicated by the significantly lower mean standard deviation and coefficient of variation among readers (Table 1). We found that 65% of estimates from otoliths agreed exactly among readers, and 91% of the estimates were within 1 year (Table 1). The percent exact agreement among readers for scales, spines, and rays was less than 50%, but 74–82% of the estimates agreed within 1 year.

Among-reader agreement for estimates from scales and otoliths varied with fish size (Figure 1). Precision was lowest for striped bass larger than 800 mm TL. In contrast, precision of estimates from rays and spines was not greatly affected by fish size (Figure 1).

The amount of time required to make age determinations differed among structures. Mean reading times per structure were 0.7 min for otoliths, 1.1–1.4 min for spines and rays, and 2.9 min for scales.

Accuracy of ages estimated from scales, spines, and rays relative to estimated otolith ages varied with striped bass length (Figure 2). For striped bass larger than 900 mm TL, consensus age estimates for spines and scales were less than the otolith consensus ages by an average of 1.6 and 3.0 years, respectively (Table 2). Overall, only 57% of spine estimates and 28% of scale estimates were in agreement (±1 year) with otolith estimates. From otoliths, fish longer than 900 mm TL were estimated to be age 10 or older. For striped bass smaller than 900 mm TL, however, scales, spines, and rays provided age estimates similar to those obtained from otoliths. In fact, 93–95% of the consensus ages from these structures were within 1 year of the otolith consensus ages (Table 2).

The results of our precision evaluation were similar to those from previous studies involving species other than striped bass. We found that among-reader agreement was better for estimates from otoliths than for estimates from scales, spines, or rays, and that precision decreased with increasing fish length. Likewise, Erickson (1983) reported levels of exact agreement of age estimates for walleyes *Stizostedion vitreum* ranging from 78 to 93% among otolith readers, from 52 to 90% among

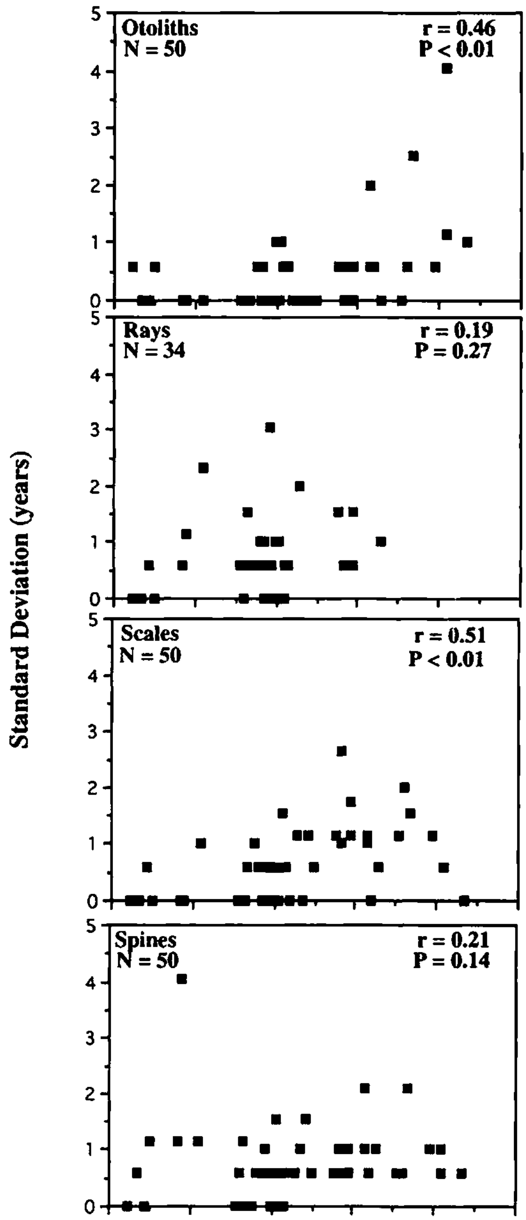

FIGURE 1.—Standard deviation of age estimates given by three readers from anal fin spines, scales, anal fin rays, and otoliths, as correlated with total length for striped bass (Spearman rank correlation).

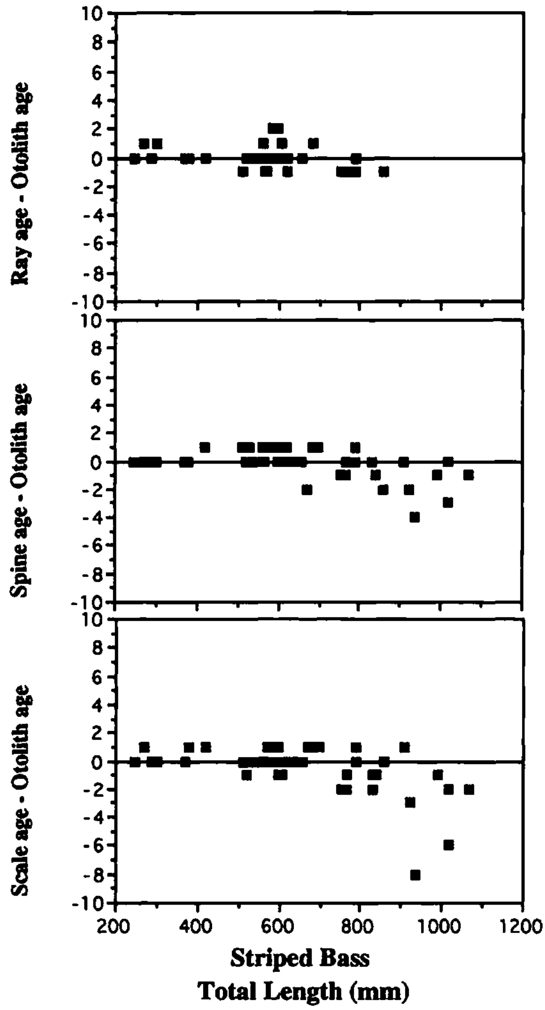

FIGURE 2.—Differences between ages determined from anal fin spines, scales, anal fin rays, and otoliths, in relation to total length of striped bass.

scale readers, and from 55 to 79% among spine readers. Libby (1985) and Boxrucker (1986), who calculated among-reader coefficients of variation for age estimates from alewives *Alosa pseudoharengus* and white crappie *Pomoxis annularis*, respectively, reported that agreement was better among otolith readers than among scale readers. Our results also concur with those of Sharp and Bernard (1988), who noted lower levels of reader precision with increasing fish length in age estimates from otoliths and scales of lake trout *Salvelinus namaycush*.

Exact agreement between scale and otolith consensus ages for striped bass shorter than 900 mm TL was unexpectedly low in our study (53%). Two other published comparisons of scales and otoliths from striped bass reported exact agreement of 86–92% (Orsi 1970; Humphries and Kornegay 1985), but these authors did not indicate the sizes or ages

TABLE 2.—Relative accuracy of striped bass age estimates from scales, anal fin spines, and anal fin rays, expressed as mean arithmetic difference from otolith age estimates and percent agreement with otolith estimates.

Fish size-class and structure examined	Number of fish	Mean difference from otoliths (year)[a]	Percent agreement with otoliths	
			Exact	Within 1 year
Total length <900 mm				
Scales	43	−0.02	53	93
Fin spines	43	−0.23	51	95
Fin rays	34	0.03	56	94
Total length >900 mm				
Scales	7	−3.00*	0	28
Fin spines	7	−1.57*	28	57

[a] An asterisk indicates a value significantly different from 0 (*t*-test; $P \leq 0.05$*).

of fish evaluated. Heidinger and Clodfelter (1987) reported 80% exact agreement between scale and otolith age estimates from striped bass up to age 4 (656 mm TL). The lower percent agreement in our evaluation probably reflects the inclusion of larger, older fish, which are more difficult to interpret. Our results are consistent with Erickson (1983), Barber and McFarlane (1987), and Sharp and Bernard (1988), who reported that age estimates from scales and spines were consistently lower than otolith estimates for older fish. In old fish, otoliths may provide more accurate estimates than other structures because scale growth (and possibly spine growth) slows considerably with age (Beamish and McFarlane 1987). We had difficulty with discerning annuli on scales and spines of larger fish because of crowding near the margins; this did not occur in otoliths.

Our study showed that otoliths required the least amount of reading time. However, we also observed that preparation times were greatest for otoliths and least for scales. Because we did not measure preparation times, we recommend that future studies include a more complete assessment of the amount of time required to remove, prepare, and read each structure.

Our data on precision of estimates from several readers indicate that using otoliths may be more efficient than using scales, spines, and rays to determine ages of striped bass. However, if killing the fish to obtain otoliths is undesirable, scales, spines, or rays may provide sufficiently accurate and precise age estimates for fish smaller than 900 mm TL. For larger fish, estimates from these structures could be substantially lower than the ages that would be obtained from otoliths.

We were unable to determine the true accuracy of any of the structures tested because we did not have known-age specimens. Hence, we compared annulus counts from alternative structures to those of otoliths, which have been shown to provide valid estimates for striped bass up to age 4 (Heidinger and Clodfelter 1987). Use of known-age materials could provide a more definitive evaluation of accuracy than was possible in our study.

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