Relative Precision among Calcified Structures for White Bass Age and Growth Assessment

Craig A. Soupir, Brian B. Blackwell, and Michael L. Brown
Department of Wildlife and Fisheries Sciences
South Dakota State University
Brookings, South Dakota 57007-1696 USA

Abstract

We assessed the relative precision among scales, sagittal otoliths, and opercles for determining age and estimating the growth of 124 white bass (Morone chrysops). Percent agreement for age among the three structures was 72.1 %. Scale assessments provided the highest percent agreement between readers within structures (89.6 %). Opercles provided the highest agreement with final estimated fish ages (94.8 %). Average percent error values were < 3.0 for all comparsions. It was difficult to detect white bass annuli on scales when estimated ages exceeded six years. Fish ages estimated from otoliths and opercles ranged from 1 to 12 years. Ages determined from scales differed as much as four years from otoliths and opercles for fish older than age 6. Total length to structure radius relations were strongly correlated for scales and opercles. No significant differences were detected between mean back-calculated lengths determined from scales and opercles. Although scales, otoliths, and opercles provided similar precision in determining age and growth of white bass up to age 6, the precision of scales as estimators decreased with fish age after age 6.

Introduction

Most fish age information is collected from scales; however, previous studies have indicated that scales may not provide accurate age determinations. For example, the underestimation of actual fish age from scales was reported for black crappie (Pomoxis nigromaculatus) (Kruse et al. 1993) and walleye (Stizostedion vitreum) (Erickson 1983). Lack of annuli detection is more common in older fishes (Casselman 1983, Beamish and McFarlane 1987). Hard structures, such as otoliths, continue to grow at older ages; however, scales may cease detectable growth at advanced ages or annuli become too compacted, rendering scales unreadable. Also, resorption of scale calcium is likely to occur during periods of calcium deficiency causing loss of annuli (Simkiss 1974).

Most studies reporting white bass age information have used scales (e.g., Forney and Taylor 1963, Priegel 1971). One study on the white bass population in Beaver Reservoir, Arkansas, compared scales, sagittal otoliths, and dorsal spines and indicated that the use of scales may result in misinterpretations of actual fish ages (Kilambi and Prabhakaran 1989). Except for that study, there have been no extensive comparisons of age precision among common aging structures -- scales, otoliths and opercles -- for white bass. Our objectives were to determine which calcified structures from white bass would provide the highest degree of precision across independent readers and to determine if differences exist between back-calculated lengths derived from different structures.

Methods

White bass were collected from Lake Kampeska, South Dakota, by electroshocking, gill netting, and angling. Lake Kampeska is a eutrophic natural lake and has a surface area of approximately 2,000 hectares and a mean depth of 3.0 m (Madison 1994). A total of 124 white bass was collected during April, May, July, and October 1995. All fish were weighed (nearest 1 g) and measured for total length (nearest 1 mm), and scales, opercles, and otoliths (sagittae) were removed.

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Scales were taken from an area directly above the lateral line below the junction of spinous dorsal and soft dorsal fins (Jearld 1983). Scales were pressed onto acetate slides, and the slides were viewed with a microfiche reader (magnification = 24x). The right opercle of each fish was removed and placed in boiling water for approximately one minute to remove extraneous tissues. Opercles were viewed whole with a dissecting microscope (magnification = 11x) equipped with an ocular micrometer. Opercular measurements were made adjacent to the thickened part of the opercle, posterior to the point of articulation. Scale and opercular annuli were counted for age estimation, and the distance from the nucleus center to each annulus edge was measured (nearest mm) for use in determining length at age.

Methodology in otolith age assessment may vary among fish species according to growth rates, otolith thickness, and water quality (Maceina and Betsill 1987). In whole view, our white bass otoliths were extremely cloudy when viewed under microscopy making annuli difficult to detect. Therefore, otoliths were broken into cross sections through the focus to view annuli. Otoliths were placed in white clay with the cross section up, then dabbed with #2 immersion oil and viewed using a dissecting microscope (magnification = 11x) equipped with a incandescent back light. Measurements of annuli from sectioned otoliths are difficult to obtain due to the compactness of annuli and loss of accuracy from otoliths not sectioned directly through the nucleus. Therefore, otolith annuli were counted to only determine age; no attempts were made to measure annuli distances.

Sexes were pooled for all analyses. All aging structures were independently viewed by two readers. In the event of a disagreement between the two readers, a third reader viewed the aging structure. Estimated ages were compared and each fish was assigned the age selected by at least two readers. When three different ages were derived for a particular structure, independent reassessment of the structure by all readers was conducted until a final assumed age could be assigned. White bass for which an age could not be agreed upon were considered for overall percent disagreement, but removed from all further analysis (Erickson 1983). Scale and opercular focus to annuli measurements were digitized and the back calculated length-at-age estimates were made using DisBcal (Frie 1982).

The average percent error (APE) index was calculated to determine the repeatability of a particular assigned age (Beamish and Fournier 1981). Percent agreement and APE were determined between readers within structures, within readers between structures, and between final assigned structure ages. Contingency tests (2x2) were used to detect significant differences in the frequency of assigned ages among structures, as well as to determine biases in overestimating or underestimating ages between readers. Statistical analyses were conducted with SAS.JMP version 3.1.5 (SAS Institute 1995).

Results and Discussion

The sample was dominated by three age groups (ages 1, 4, and 5), representing 93 % of the sample. It was difficult to detect white bass annuli from scales when estimated ages exceeded six years. For example, the oldest white bass captured was estimated to be age 8 by scales and age 12 by otolith and opercle. We attributed differences between maximum ages of structures to underestimation of scale age. The maximum age reported in the literature for other white bass populations was nine years (Forney and Taylor 1963, Sigler 1949). Based on our observations, the difference between maximum ages of white bass from Lake Kampeska compared to other populations is likely due to the different structures used for age determination.

Table 1. Percent agreement and average percent error (APE) values within structures between readers (e.g. S1:S2), between structures (scales [S], otoliths [O], opercles [P]), and between final assumed fish ages combining all structures (A). Second character numbers (e.g. S1 and S2) represent reader number, and the second A represents assumed ages.

	Percent			
	Agreement	Over	Under	APE
Within structure				
S1:S2	89.6	4.4	6.1	1.09
O1:O2	88.7	7.9	3.5	1.45
P1:P2	85.2	5.3	9.6	1.63
Between structure [a]				
SA:OA	80.0	12.3	7.9	2.67
SA:PA	84.3	13.2	2.6	2.00
OA:PA	85.2	10.5	4.4	1.80
Final assumed ages				
SA:AA	89.6	2.6	7.9	1.44
OA:AA	90.4	4.4	5.3	1.24
PA:AA	94.8	5.3	0.0	0.56
Overall agreement				
SA:OA:PA	72.1			2.86

[a]Percent over and percent under represent the mean number of times structure two was different from structure one.

The overall percent agreement of the assigned ages among the three aging structures was 72.1 % (Table 1). Percent agreement within structures was 89.6, 88.7 and 85.2 % for scales, otoliths and opercles, respectively (Figure 1). Agreement between final estimated structure age with the assumed fish age (all structures) showed that opercles had the highest agreement (94.8%), while scales had the lowest agreement (89.6%). The level of agreement was likely influenced by the age composition of the sample. Age 6 or older white bass composed about 4% of our sample. We believe that agreement on scale ages would decrease with an increase shift in the age structure due to difficulty in detecting scale annuli toward the edges of scales.

The APE is a good indicator of the repeatability of age determinations because it is independent of the actual fish ages (Beamish and Fournier 1981). The APE values were < 3.0 for all comparisons (Table 1); therefore, we believe that ages determined from scales, otoliths, and opercles are equally repeatable and precise for white bass under age 6.

Contingency tests indicated no difference (n=114, $\underline{P}$<0.001) between the number of agreements to disagreements both between readers, and between structure age assignments. Comparisons of age determinations calculated between readers within structures (Figure 1) indicated that no biases existed in age estimates (Fisher's exact values = 1.0, 0.2, and 1.0 for scales, otoliths, and opercles, respectively). However, no agreement occurred between readers for scale estimates of age 6 and older white bass. Conversely, greater than 80% agreement occurred between readers for otoliths and

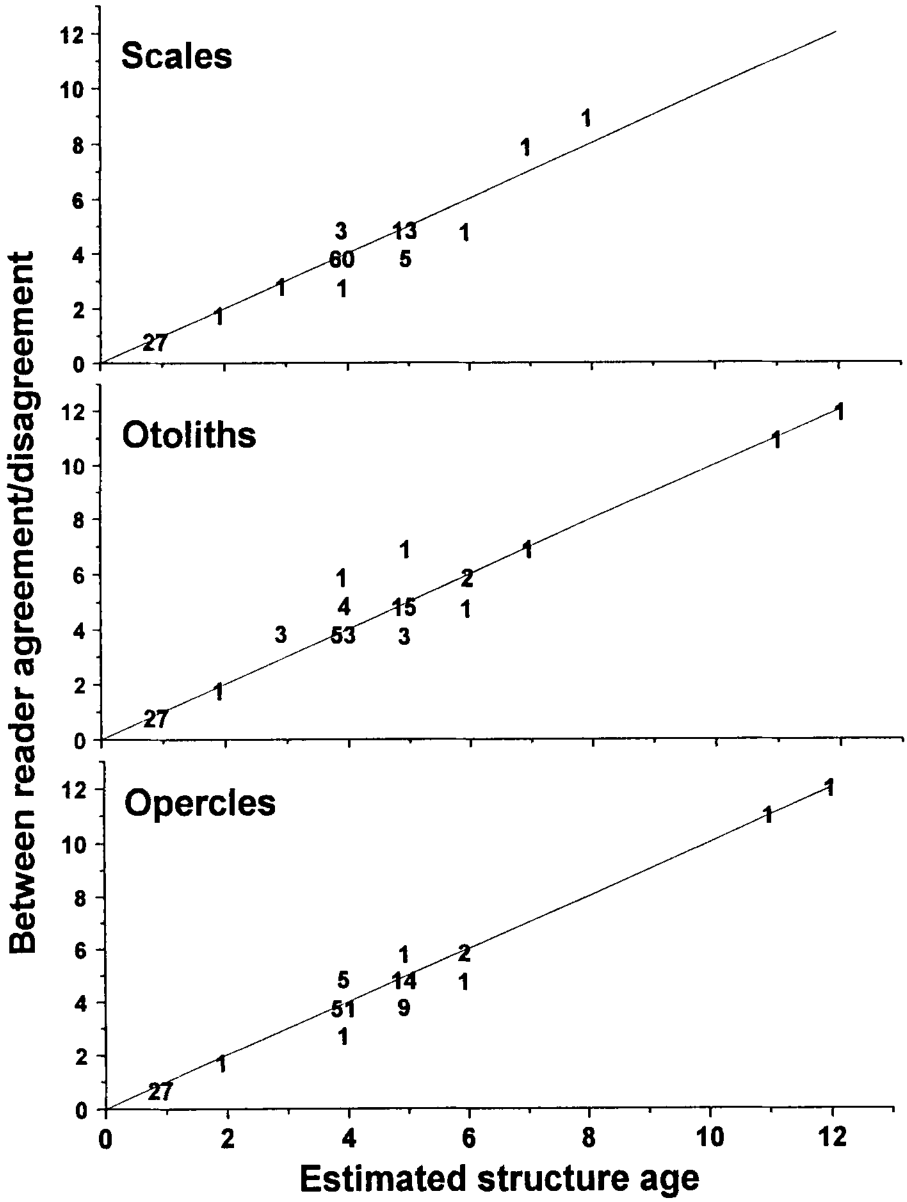

Figure 1. Agreement/disagreement between readers within scales, otoliths, and opercles. Estimated structure ages are those in which at least 2/3 of the readers agreed. Diagonal lines represent 100% agreement. Numbers (N = 114) represent the number of times when an agreement or disagreement occurred for an individual fish. Deviations from the diagonal line show the differing number of years that readers assigned as the age for a particular structure.

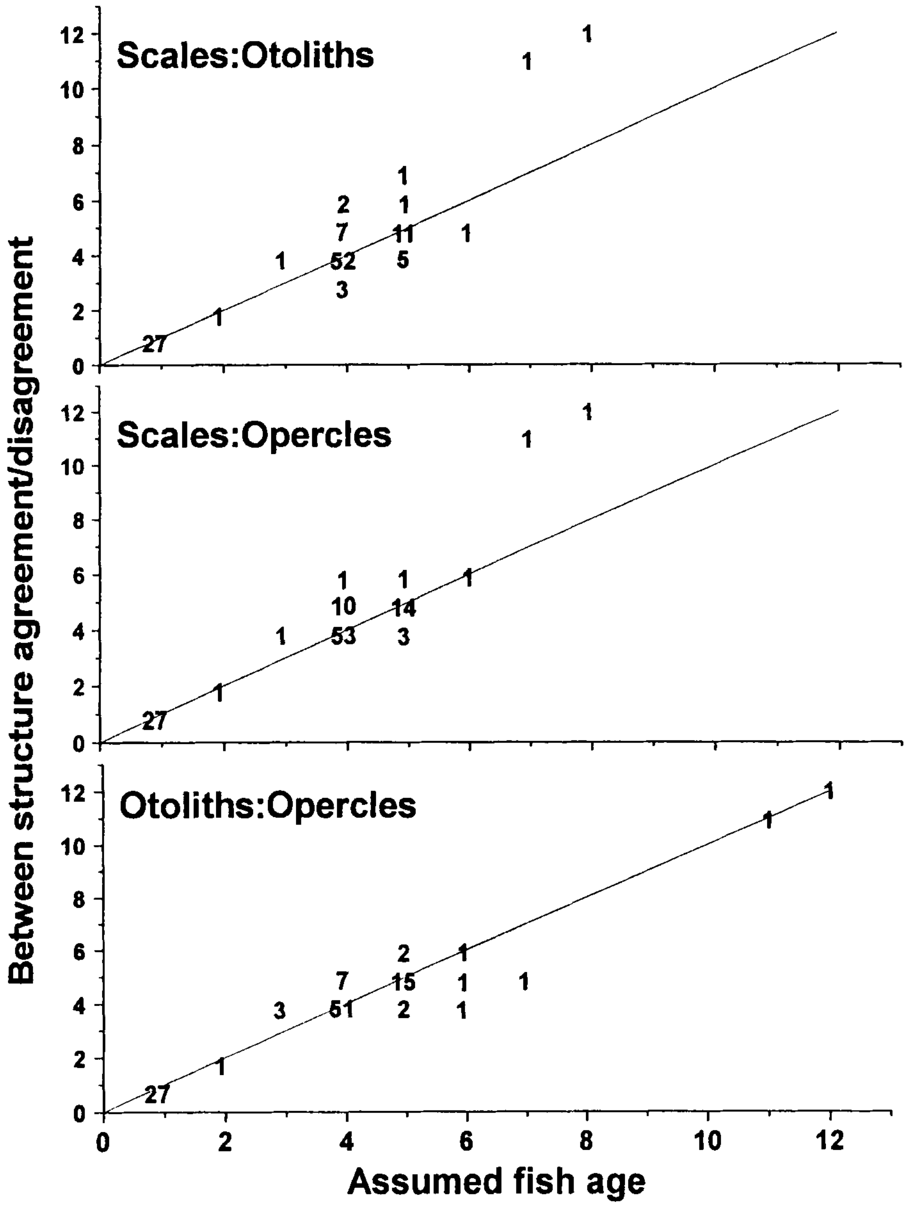

Figure 2. Agreement/disagreement of opercles to scales, otoliths to scales, and opercles to otoliths. Assumed fish ages are those in which 2/3 of readers agreed. Diagonal lines represent 100% agreement. Numbers represent the number of fish (N = 114) in which a particular agreement or disagreement occurred. Deviations from the diagonal line show the number of years different a particular structure was assessed.

Table 2. Mean observed and back-calculated total lengths (mm) of white bass collected from Lake Kampeska, South Dakota, 1995. Mean annual growth increments determined from back-calculated lengths were determined using a body:structure intercept of 40 mm for scales and of 9.23 for opercles. Numbers in parentheses following total lengths are numbers of fish that were used to determine each back-calculated total length.

	Age											
	1	2	3	4	5	6	7	8	9	10	11	12
Total length	189.1 (27)	236.0 (1)	-- (0)	321.7 (62)	340.9 (20)	338.5 (2)	-- (0)	-- (0)	-- (0)	-- (0)	375.0 (1)	395.0 (1)
Back calculated length												
Scales	128.0 (114)	208.0 (87)	273.0 (86)	317.2 (84)	341.5 (19)	361.2 (2)	378.2 (2)	395.0 (1)				
Increment	128.0	79.4	65.0	45.0	19.4	18.0	17.0	13.5				
Opercles	125.8 (109)	201.7 (82)	265.6 (81)	310.4 (81)	335.8 (26)	337.8 (6)	353.8 (3)	363.9 (3)	369.7 (3)	378.0 (3)	386.4 (3)	395.0 (1)
Increment	125.8	76.0	64.0	44.8	27.7	21.9	17.3	10.1	5.8	8.3	8.38	14.9

opercles when white bass were age 6 and older. Comparisons of the number of agreements to the number of disagreements between structures (Figure 2) also showed no significant difference in all structure comparisons (n=114, Pearson's chi square values = 0.8, 0.3, and 0.4 for scales:otoliths, scales:opercles, and otoliths:opercles, respectively). However, scale age estimates underestimated white bass ages as much as four years when compared to estimated ages of otoliths and opercles.

The fish length to scale radius relation was linear (total length = 43.09 + 60.83 scale radius; r=0.98, P<0.001). Forney and Taylor (1963) found a curvilinear relationship between fish length and scale radius of white bass collected from Oneida Lake, New York. However, our results concur with the linear relationship determined for white bass collected from Spirit Lake, Iowa (Sigler 1949). The fish total length to opercle radius relation was also positively correlated (total length = 9.23 + 15.25 opercle radius; r=0.98, P<0.001).

For comparisons to be made between mean back-calculated length-at-age estimates for different white bass populations, it is important to use a standard total length:scale radius constant (Carlander 1981). The recommended body length:scale constant for white bass is 40 mm (Beck et al. In press). Consequently, this value was similar to the actual intercept value found for white bass from Lake Kampeska (43.09 mm); therefore a body length-scale constant of 40 mm was used for all back-calculated lengths (Table 2). No data exist on the determination of age and measurement of growth of white bass from opercles; therefore, the intercept value (9.23 mm) determined for Lake Kampeska white bass was used for determining back-calculated lengths from opercles (Table 2). No differences were detected between scales and opercles in the mean annual growth increment; therefore, both structures appear to result in precise determinations of back-calculated length-at-age estimates. However, fish ages were underestimated using scales, which could result in higher back-calculated than actual growth increments in older ($\geq$ age 6) white bass. Therefore we recommend the use of otoliths or opercles for length-at-age estimates for whitebass populations with older age distributions. Furthermore, when sectioning of otoliths is necessary, it may save effort if opercles are utilized for length-at-age estimates due to difficulty in obtaining annuli measurements from sectioned otoliths.

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