Utility of Scales and Whole Otoliths for Aging Largemouth Bass in North Carolina

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Abstract: Fishery managers routinely collect scales from black basses (*Micropterus* spp.) for age determination; however, the validity of these ages is often unknown. The objectives of this study were to evaluate the accuracy and precision of scales and whole otoliths relative to sectioned otoliths for determining ages of largemouth bass *(M. salmoides)* in North Carolina. Scales and sagittal otoliths were collected from largemouth bass during spring and summer of 1997 from the Chowan river, Neuse River, B. E. Jordan Reservoir, W. Kerr Scott Reservoir, Hyco Reservoir, Tillery Reservoir, and Santeelah Reservoir. Sample sizes varied between 94 and 149 largemouth bass per water body and were pooled for data analysis. Reader-derived ages, mean total length at age capture (TL, mm), and between reader precision for scales and whole otoliths were compared against otolith sections. For comparative purposes in this study, ages determined from otolith sections were considered to be the correct ages. Overall, only 40% of the largemouth bass scale ages were in agreement with otolith section ages. Errors tended to result in age overestimation, although variation in scale aging errors increased markedly with TL. Scale ages were significantly different ($P \leq 0.05$) from otolith section ages at TL ≥230 mm. Overall, 91% of largemouth bass whole otolith ages were in agreement with otolith section ages. Largemouth bass >300 mm tended to have their ages underestimated when whole otoliths were used. Whole otolith ages were significantly different from otolith section ages at TL ≥357 mm. Differences in largemouth bass mean total lengths at age at capture between scales and otolith sections were found by age 2. No significant differences in largemouth bass mean lengths at age of capture were found between whole otoliths and otolith sections. Average percent error and coefficient of variation were in order of magnitude higher when largemouth bass were aged with scales compared to whole otoliths or otolith sections. Scales were ineffective in aging largemouth bass in this study, had relatively low levels of precision, and failed to provide quality management information. Whole otoliths were found to be relatively accurate and precise age predictors.

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Scales are routinely collected from black basses for the purpose of age determination. Historically, the scale method of aging largemouth bass has been used because it is non-lethal. In most instances, validity of ages from scales are assumed but not confirmed. Difficulties in the interpretation of annular marks on scales has been recognized, but generally given little attention (Carlander 1987). There is evidence that scales are unreliable for aging largemouth bass (Beamish and McFarlane 1987), especially in southern latitudes (Prather 1966, Taubert and Tranquilli 1982). The most common problem encountered using scales is the difficulty in distinguishing annuli with increasing age to increased periods of minimal growth (Beamish and McFarlane 1987). The formation of false checks on scales can also interfere with age determination. Physical characteristics of individual scales and the presence of false annuli have been found to vary among individuals from the same population (Muncy 1965, Al-Rawi 1971). Hammers and Miranda (1991) observed that white crappie *(Pomoxis annularis)* held under crowded conditions and later moved into a less crowded environment formed a false check on their scales.

Other non-lethal sources of aging material, including fin rays and dorsal spines have been used to estimate the age of largemouth bass. Maraldo and McCrimmon (1979) noted, however, that fin ray and dorsal spine cross sections proved unreliable for largemouth bass age estimation.

As indicators of fish age, otoliths have advantages over other anatomical structures. Increment counts from otoliths are often more precise than those obtained from scales (Lowerre-Barbieri et. al. 1994). Unlike scales, the annuli in otoliths continue to be discernable during periods of minimal growth (Marshall and Parker 1982, Beamish and McFarlane 1987). Several studies have verified the use of otoliths to quantify the daily age of age-0 fish (Campana and Nielson 1985, Jones 1992, DiCenzo and Bettoli 1995). Simkiss (1974) noted that growth calculated from otoliths might be more valid than growth calculated from scales because otoliths have a higher physiological priority in the utilization of calcium, which can be resorbed from scales. Marshall and Parker (1982) also noted that otiliths did not appear to be resorbed during periods of food deprivation or stress. As growth slows, however, deposition of calcium occurs predominantly on the inner otolith surface. Consequently, otoliths from older of slower growing fish are thicker and may require sectioning to reveal all annuli (Beamish and McFarlane 1987).

The presence of annual growth rings in largemouth bass otolith sections, including the Florida largemouth bass subspecies *(M. salmoides floridanus),* has been validated with known-age fish (Taubert and Tranquilli 1982, Hoyer et al. 1985). The use of sagittal otoliths has also been validated for many other centrarchids including smallmouth bass *(M. dolomieu)* (Heidinger and Clodfelter 1987), black crappie *(P. nigromacultaus)* (Schramm and Doezbacher 1982), white crappie (Maceina and Betsill 1987), bluegill *(Lepomis macrochirus)* (Schramm 1989, Hales and Belk 1992, Mantini et al. 1992), redbreast sunfish *(L. auritus)* (Mantini et al. 1992), and redear sunfish *(L. microlophus)* (Mantini et al. 1992).

Largemouth bass are the most sought after game fish in North Carolina (Van Horn and Birchfield 1987). The North Carolina Wildlife Resources Commission (NCWRC) has developed goals for the conservation, enhancement, and management of black bass populations within the state (N.C. Black Bass Manage. Plan 1993). In order to achieve these goals, information on fish population characteristics such as age structure, growth, and mortality are needed. Accurate age estimators are required to predict these basic population parameters. Historically, the NCWRC has used scales to estimate the ages of largemouth bass. The objectives of this study were to evaluate the accuracy and precision of scales and whole otoliths relative to sectioned otoliths for determining ages of largemouth bass in North Carolina.

Methods

Scales and otoliths were collected in spring and summer 1997 during scheduled electrofishing surveys of the Chowan River, Neuse River, B. E. Jordan Reservoir, Tillery Reservoir, Hyco Reservoir, W. Kerr Scott Reservoir, and Santeetlah Reservoir, North Carolina (Table 1). Total length (TL, mm) and sex were determined for each fish. Largemouth bass were considered immature if the gonads were undeveloped. Scales and sagittal otoliths were removed from up to 10 largemouth bass in each 25-mm length group. At least 10 scales from each fish were removed from below the lateral line at the tip of the pectoral fin and stored in coin envelopes. Otoliths were removed, stored in vials, and dried for a minimum of 14 days. All structures were coded but stored without reference to TL.

Scales were pressed onto 0.5-mm cellulose acetate strips using a roller press. Scale impressions were read using a microfiche reader. Otoliths were placed in a black dish containing water and viewed whole under reflected light using a dissecting microscope (10×). Otoliths exhibiting 2 or more annuli (Hoyer et al. 1985) were broken perpendicular to the longest axis through the nucleus. The broken otolith was polished using 400 grit wet sandpaper, embedded in clay, and immersed in water. Annular marks were illuminated with transmitted light using fiber-optic filament placed along the side of the otolith. Scales, whole otoliths, and otolith sections were each read by 2 readers. If the ages from the 2 readers were not in agreement, aging structures were jointly read in an attempt to rectify the differences between readers on the same aging structure. For comparative purposes in this study, ages assigned from otolith sections were considered to be the correct ages.

Ages estimated from whole otoliths and scales were compared to the ages derived from otolith sections using repeated measures analysis of variance (ANOVA, $P \leq 0.05$). The agreed upon age determined from each structure (scale, whole otolith, and otolith section) of each fish was considered 1 measure within the repeated measures ANOVA design (SYSTAT 1996). Precision of the ages estimated by the scale and otolith methods were calculated using the average percent error method (Beamish and Fournier 1981). An alternative index of precision, coefficient of variation, was also used to test the reproducibility of age determinations among readers (Boxrucker 1986). Student's 2-sample *t*-tests were used to compare mean lengths at age at capture by structure. Mean lengths at age at capture determined from scales and

Table 1. Sample sites, size (ha), relative location, trophic status (chlorophyll-a), and largemouth bass sample size breakdown.

Sample sites	Size (ha)	Location	Trophic status	Total	Sample size		
					Male	Female	Immature
Neuse River		Coast	Eutrophic	127	45	45	39
Chowan River		Coast	Eutrophic	121	49	45	27
B. E. Jordan Reservoir	5,270	Piedmont	Eutrophic	149	56	58	36
Tillery Reservoir	2,130	Piedmont	Eutrophic	130	42	48	42
Hyco Reservoir	1,760	Piedmont	Oligotrophic	103			
W. Kerr Scott Reservoir	590	Mountain	Oligotrophic	94	25	32	37
Santeetlah Reservoir	1,525	Mountain	Oligotrophic	99	38	26	37

whole otoliths were tested for differences ($P \leq 0.05$) with mean lengths at age at capture determined from otolith sections (SYSTAT 1996).

Results and Discussions

General Catch Information

A total of 871 largemouth bass were collected and 823 were successfully aged. The remaining 48 were not aged due to missing scales, missing otoliths, regenerated scales, or unresolvable aging differences. A total of 659 largemouth bass were aged ≥ age 2 (sectioned otolith age), and were used in this study. Sample sizes varied between 94 and 149 fish per water body (Table 1). Approximately equal numbers of male, female, and immature largemouth bass were sampled from each water body (Table 1). Due to the relatively low numbers of largemouth bass collected in each 25-mm size class per water body, data for all water bodies was pooled.

Aging Comparisons

Scales were generally ineffective as aging structures for largemouth bass. Overall, only 40% of the largemouth bass scale ages were in agreement with otolith section ages. Ages assigned using scales differed from otolith section ages at TL ≥ 230 mm (Table 2). Carlander (1974) noted some largemouth bass failed to form a detectable first year annulus on scales, but concluded this would not interfere with growth studies. In this study, only 52% of the largemouth bass ≤332 mm aged using scales were in agreement with otolith section ages. When scales were used, largemouth bass under 300 mm were overaged by approximately 1 year (Fig. 1). The variation in scale ages from otolith section ages increased markedly in largemouth bass over 300 mm, however, no aging error trends were evident (Fig. 1). Similar results have been found

Table 2. Repeated measures analysis of variance results and sample sizes by 25-mm size class. Repeated measures analysis of variance comparisons were declared different at $P \leq 0.05$.

Size class (mm)	Scales vs. otolith sections	Whole otoliths vs. otolith sections	Samples size
204–229	0.103	0.326	29
230–254	0.001	0.661	43
255–279	0.001	0.322	57
280–305	0.001	0.995	65
306–330	0.001	0.995	65
331–356	0.021	0.398	67
357–381	0.012	0.024	60
382–406	0.044	0.011	65
407–432	0.023	0.013	51
433–457	0.388	0.019	50
458–483	0.903	0.044	36
484–508	0.015	0.083	27
≥509	0.168	0.383	44
All fish	0.001	0.001	659

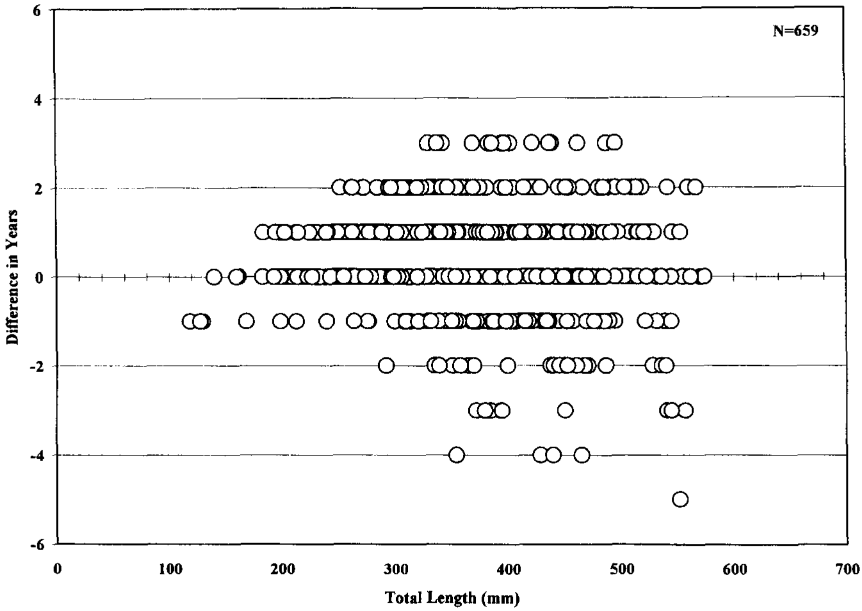

Figure 1. Difference in years that individual largemouth bass scale ages varied from otolith section ages by total length (mm).

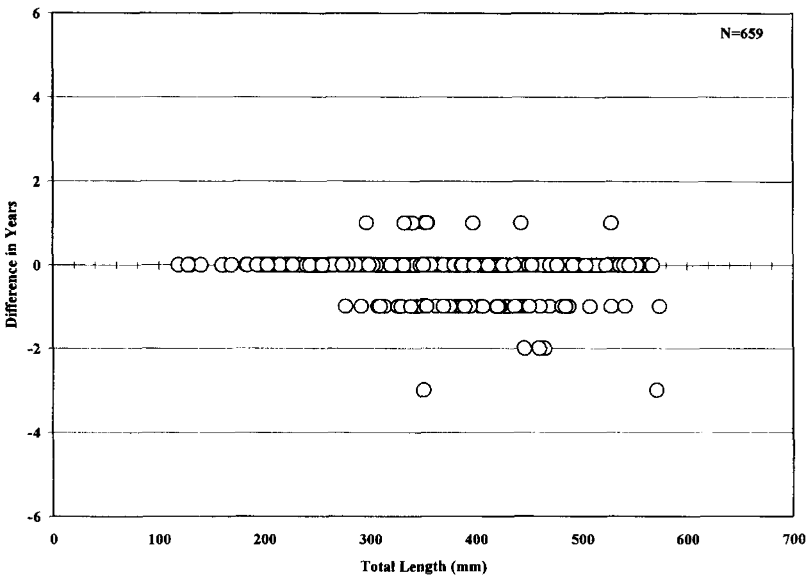

Figure 2. Difference in years that individual largemouth bass whole otolith ages varied from otolith section ages by total length (mm)

Table 3. Summary of 2-sample Student's *t*-test comparisons of mean length at age at capture (TL, mm) between scales and whole otoliths versus otolith sections by largemouth bass age class. Student's *t*-test differences declared at $P \leq 0.05$. Scale, whole otoliths, and otolith section sample sizes *(N)*, mean total length at age at capture, and standard deviation (SD) are listed by age class.

			Scales			Whole otoliths			Otolith sections		
Age	Scales vs. otolith sections	whole otoliths vs. otolith sections	*N*	Mean TL(mm)	SD	*N*	Mean TL(mm)	SD	*N*	Mean TL(mm)	SD
2	0.001	0.909	119	210.8	47.1	176	252.7	42.2	174	253.2	42.1
3	0.001	0.905	149	282.2	44.1	159	332.1	41.7	146	331.6	42.4
4	0.001	0.335	173	346.2	45.1	132	380.1	46.5	139	374.7	46.7
5	0.001	0.937	114	396.9	43.3	75	420.8	50.7	69	420.1	50.8
6	0.866	0.665	84	434.8	46.5	48	440.3	48.7	56	436.1	48.4
7	0.578	0.904	35	472.7	51.9	38	474.9	48.2	39	473.6	50.5
8	0.062	0.896	25	500.1	34.2	26	474.1	71.9	26	471.5	66.7
9	0.354	0.661	18	515.7	34.7	15	499.1	55.4	13	508.2	52.2
10	0.046	0.097	4	548.5	20.1	5	537.4	42.6	6	473.8	69.2
11	0.945	0.304	4	556.5	28.5	3	544.3	8.1	6	553.2	15.9

for other centrarchids aged with scales (Carlander 1974, Schramm and Doerzbacher 1982, Heidinger and Clodfelter1987).

Whole otoliths were relatively accurate estimators of largemouth bass age. Overall, 91% of the whole otolith ages were in agreement with the sectioned otolith ages. Ages assigned using whole otoliths were significantly different from otolith section ages at TL ≥ 357 mm (Table 2). Largemouth bass >300 mm were usually underaged when whole otoliths were used (Fig. 2). Underestimation of largemouth bass age using whole otoliths is consistent with other studies which cite differential calcium deposition on the otolith surface and slower growth rates as reasons for missing annular marks on whole otoliths, which can be seen on otolith sections (Hoyer et al. 1985, Beamish and McFarlane 1987).

Length at Age at Capture

The aging errors associated with scale-aged largemouth bass directly impacted estimates of mean length at age at capture. Significant differences in mean lengths at age at capture determined from scales and otolith sections were found by age-2 (Table 3). Between age-2 and age-5, mean length at age at capture was underestimated by an average of 36 mm relative to otolith sections (Table 3). These significant underestimations of growth rates in these important age classes can lead to erroneous conclusions about the effectiveness of a regulation, the placement of a size limit, or the time required to reach a size limit.

Whole otoliths were found to be accurate estimators of largemouth bass mean length at age at capture. No differences were found comparing whole otolith and otolith section mean lengths at age at capture for any ages (Table 3). The findings in this study indicate that although significant differences were found between ages determined from whole otoliths and ages determined from sectioned otoliths, these differences did not result in significant differences in mean lengths at age at capture. Other otolith studies, however, concluded that centrarchid otoliths should be sectioned, particularly for older or slower growing populations (Hoyer et al. 1985, Maceina and Betsill 1987). Hoyer et al. (1985) noted that beginning at age-2, at least 1 annulus became obscure in whole otolith mounts and recommended that otolith sectioning become the accepted procedure for Florida largemouth bass.

Precision

Between reader precision in assigning ages to otolith sections and whole otoliths was considerably higher than assigning ages to scales. Average percent error and coefficient of variation were an order of magnitude higher when largemouth bass were aged with scales compared to whole otoliths or otolith sections (Table 4). In addition to greater precision, preparation and reading time was similar among aging structures. Scale samples used in this study showed variation in physical characteristics such as clarity, amount of edge erosion, and the number of regenerated scales per fish. No attempts were made to clean individual scales and this may have influenced between reader precision. Scale washing and sonic cleaning have been attempted to remove physical debris and mucous from scales in other studies (Carlander 1974,

Table 4. Average percent error and coefficient of variation estimates of precision for largemouth bass aged using scales, whole otoliths, and otolith sections.

Aging structure	Average % error	Coefficient of variation
Scales	6.51%	4.61
Whole otoliths	1.41%	0.91
Otolith sections	0.06%	0.04

Prentice and Whiteside 1974); however, these cleaning processes can be time consuming and their effectiveness has not been demonstrated.

Conclusions

Age structure is an important indicator used by the NCWRC in largemouth bass stock assessment. The percentage of a fish population within certain age classes is used to help identify problems associated with recruitment, stockpiling below a size limit, or fishing related mortality. Scales were not accurate estimators of largemouth bass age relative to otolith sections in this study. The errors associated with scale-aging largemouth bass were biologically significant when lengths at age at capture were assigned. The ineffectiveness of scales to accurately age largemouth bass, particularly in the important age 2–5 fish, reduces the NCWRC's ability to identify problems. Whole otoliths were found to be relatively accurate and precise age predictors. The aging errors associated with whole-otolith aged largemouth bass were not biologically significant. Sectioning otoliths, however, requires little additional lab time, provides greater accuracy, and improved the overall sample precision.

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