2017 SOUTHEASTERN NATURALIST 16(2):225–234

Precision and Accuracy of Age Estimates Obtained from Anal Fin Spines, Dorsal Fin Spines, and Sagittal Otoliths for Known-Age Largemouth Bass

Zachary B. Klein[1,*], Timothy F. Bonvechio[2], Bryant R. Bowen[2], and Michael C. Quist[3]

Abstract - Sagittal otoliths are the preferred aging structure for *Micropterus* spp. (black basses) in North America because of the accurate and precise results produced. Typically, fisheries managers are hesitant to use lethal aging techniques (e.g., otoliths) to age rare species, trophy-size fish, or when sampling in small impoundments where populations are small. Therefore, we sought to evaluate the precision and accuracy of 2 non-lethal aging structures (i.e., anal fin spines, dorsal fin spines) in comparison to that of sagittal otoliths from known-age *Micropterus salmoides* (Largemouth Bass; n = 87) collected from the Ocmulgee Public Fishing Area, GA. Sagittal otoliths exhibited the highest concordance with true ages of all structures evaluated (coefficient of variation = 1.2; percent agreement = 91.9). Similarly, the low coefficient of variation (0.0) and high between-reader agreement (100%) indicate that age estimates obtained from sagittal otoliths were the most precise. Relatively high agreement between readers for anal fin spines (84%) and dorsal fin spines (81%) suggested the structures were relatively precise. However, age estimates from anal fin spines and dorsal fin spines exhibited low concordance with true ages. Although use of sagittal otoliths is a lethal technique, this method will likely remain the standard for aging Largemouth Bass and other similar black bass species.

Introduction

Effective fisheries management requires an understanding of population demographics (e.g., age structure) and dynamics (i.e., recruitment, growth, mortality) (Ricker 1975). The ability to confidently and accurately estimate the age of fishes is critical for understanding how fish populations function and respond to management actions (Quist et al. 2012). Traditionally, scales were the preferred structure used to age *Micropterus* spp. (black basses), but recent studies have shown them to be inaccurate (Boxrucker 1986, Erikson 1983, Maceina and Sammons 2006, Welch et al. 1993). Sagittal otoliths have become the preferred aging structure for black basses in North America because they have been shown to provide accurate and precise age estimates (Buckmeier and Howells 2003, Heidinger and Clodfelter 1987, Hoyer et al. 1985, Maceina et al. 2007, Taubert and Tranquilli 1982). However, otoliths require sacrificing fish, a practice that may not be permissible

[1]Idaho Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife Sciences, University of Idaho, Moscow, ID 83844. [2]Georgia Department of Natural Resources, PO Box 2089, Waycross, GA 31052. [3]US Geological Survey, Idaho Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife Sciences, University of Idaho, Moscow, ID 83844. [*]Corresponding author - klei7686@vandals.uidaho.edu.

Manuscript Editor: Benjamin Keck

in certain studies (e.g., mark–recapture; Morehouse et al. 2013) or situations (e.g., small population, trophy fisheries; Allen et al. 2003). Furthermore, depending on the species and preparation technique (e.g., whole otoliths, sectioned otoliths), otoliths can take more time to process than scales (Quist et al. 2012). Estimation of rate functions is an important component of fisheries management; thus, a non-lethal aging technique is necessary in situations where fish cannot be sacrificed.

Several studies have shown that non-lethal aging structures (e.g., scales, fin rays, fin spines) provide accurate and precise age estimates for several species of fish (Beamish 1981, Beamish and Harvey 1969, Cass and Beamish 1983; Chilton and Bilton 1986, Michaletz et al. 2009). However, the precision and accuracy of some non-lethal aging structures can vary by size, age, and (or) species. For instance, Welch et al. (1993) reported that anal fin spines and scales provided relatively accurate and precise age estimates for *Morone saxatilis* (Walbaum) (Striped Bass) up to about 900 mm total length (TL) and 10 years of age. Erikson (1983) reported that dorsal fin spines were less accurate than otoliths for *Sander vitreus* (Mitchill) (Walleye). Niewinski and Ferreri (1999), reported higher between-reader agreement in age estimates from otoliths (96%) than from scales (83%) or spines (80%) for *Perca flavescens* (Mitchill) (Yellow Perch). Similarly, Maceina and Sammons (2006) reported that between-reader agreement was highest for otoliths (91–98%) compared with scales (57–67%) for *Micropterus salmoides* (Lacepède) (Largemouth Bass), *Micropterus dolomieu* Lacepède (Smallmouth Bass), and Yellow Perch. The purpose of this study was to compare the accuracy and precision of 2 non-lethal structures (anal fin spines, dorsal fin spines) to that of sagittal otoliths of known-age Largemouth Bass collected from Ocmulgee Public Fishing Area, GA.

Methods

Ocmulgee Public Fishing Area (OPFA) is a 42.9-ha reservoir located in central Georgia near the town of Cochran. In an effort to create a trophy bass fishery, female Largemouth Bass were stocked into OPFA to minimize recruitment and maintain a low density of Largemouth Bass (Bonvechio and Rydell 2016). Managers chose female Largemouth Bass because they typically grow faster and reach larger maximum sizes than males (Allen et al. 2002, Carlander 1977, Schramm and Smith 1987). From 2004 to 2012, age-1 female Largemouth Bass were recovered from hatchery ponds, individually tagged with passive integrated transponder tags (Biomark, Boise, ID), and stocked into OPFA. In the summer of 2011, water levels in OPFA began to steadily decline resulting in the closure of OPFA for repairs in November 2012. Prior to closure of OPFA, the Georgia Department of Natural Resources collected and relocated 405 Largemouth Bass from OPFA to Paradise Public Fishing Area, GA. All known-age Largemouth Bass (n = 87) that died during transfer, as a result of lake-wide restoration, or from catch-and-release angling were collected and frozen for later processing.

We measured the total length (TL) of the preserved Largemouth Bass to the nearest mm and removed sagittal otoliths. We also removed the anterior-most anal fin spines and dorsal fin spines at the base of the structure immediately distal to the fish's body. We processed sagittal otoliths and estimated ages according to methods described in Bonvechio and Allen (2005). Briefly, all otolith samples were mounted on glass microscope slides, sectioned transversely along the dorsoventral plane, and examined under a dissecting microscope. Following methods described by Koch and Quist (2007), we mounted anal fin spines and dorsal fin spines in epoxy and used a low-speed Isomet saw (Buehler, Inc., Lake Bluff, IL) to make 1.0-mm–thick sections. We examined the cross-sections under a dissecting microscope with transmitted light and an image-analysis system (Image-Pro Plus; Media Cybernetics, Silver Springs, MD). Two readers estimated the age of otoliths and 2 other readers estimated the age of anal fin spines and dorsal fin spines (Maceina and Sammons 2006). None of the readers had knowledge of the length of the fish and all readers had extensive experience enumerating annuli of various structures prior to the study. After each reader assigned an age, we compared age estimates between readers. If discrepancies existed between age estimates, both readers re-examined the structure and discussed the age during a mutual reading.

In addition to age estimates, readers assigned a confidence rating to their age estimate for each structure to evaluate the readability of each structure (Speigel et al. 2010). Confidence ratings were integers between 0 and 3, where a rating of 0 corresponded to no confidence in the age estimate and a rating of 3 denoted complete confidence in the age estimate (Fitzgerald et al. 1997, Koch et al. 2008). We further evaluated the precision of each structure by calculating the percent agreement (PA) between readers for each structure. We calculated a coefficient of variation (CV = 100 × SD / mean) to measure the variation in age estimates between readers for each structure (Campana et al. 1995). We evaluated the accuracy of age estimates from otoliths, anal fin spines, and dorsal fin spines by comparing the consensus age-estimates from each structure to the known age using age-bias plots. We also calculated a CV for the consensus age-estimates for anal fin spines, dorsal fin spines, and otoliths paired with the true age to further evaluate the accuracy of a given structure.

Results

In total, 87 known-age Largemouth Bass were collected from OPFA in November 2012. We aged all otoliths, but only 82 anal fin spines and 85 dorsal fin spines were aged because we were unable to identify any annuli in 5 and 2 samples, respectively (Table 1). Largemouth Bass had an average TL of 536 mm (variation =

Table 1. Precision in age estimates for anal fin spines, dorsal fin spines, and sagittal otoliths from Largemouth Bass collected from Ocmulgee Public Fishing Area, GA, in November 2012. Sample sizes (*n*), coefficient of variations (CV), and percent agreement (PA) are included.

	n	CV	PA
Anal fin spine	82	2.0	84
Dorsal fin spine	85	2.1	81
Otolith	87	0.0	100

340–635 mm; Fig. 1). The true-age distribution varied from 1 to 9 years, and 85% of the fish were older than age 7 (Fig. 2). Age estimates for anal fin spines and dorsal fin spines varied from 1 to 10 years; whereas, ages estimated from otoliths varied from 1 to 9 years.

Compared with anal fin spines and dorsal fin spines, otoliths provided the most accurate and precise age estimates. Consensus age estimates from otoliths exhibited the highest concordance (CV = 1.2; PA = 91.9) with true ages when compared to anal fin spines (CV = 19.0; PA = 12.2) and dorsal fin spines (CV = 12.0; PA = 34.1) (Fig. 3). Precision was highest for otoliths (CV = 0.0 and 100% agreement between readers; Table 1). Consensus age estimates for anal fin spines and dorsal fin spines demonstrated little concordance with true ages. Dorsal fin spines exhibited the highest variability in age estimates (CV = 19.0) followed by anal fin spines (CV = 12.0). Age estimates obtained from anal fin spines and dorsal fin spines were less precise than from otoliths. Dorsal spines were the least precise aging structure as evidenced by a high CV (2.1) and low between-reader agreement (81%). Anal fin spines yielded only slightly more-precise age estimates than dorsal spines (Table 1). Reader confidence ratings reinforced our finding that sagittal otoliths provided the most precise estimates of all the aging structures examined (Table 2). For example, readers 1 and 2 applied a confidence rating of 3 to 96.5% of their otolith age estimates. Conversely, readers assigned a confidence rating of 3 to <5% the anal fin spine age estimates and <2% of the dorsal fin spine-age estimates.

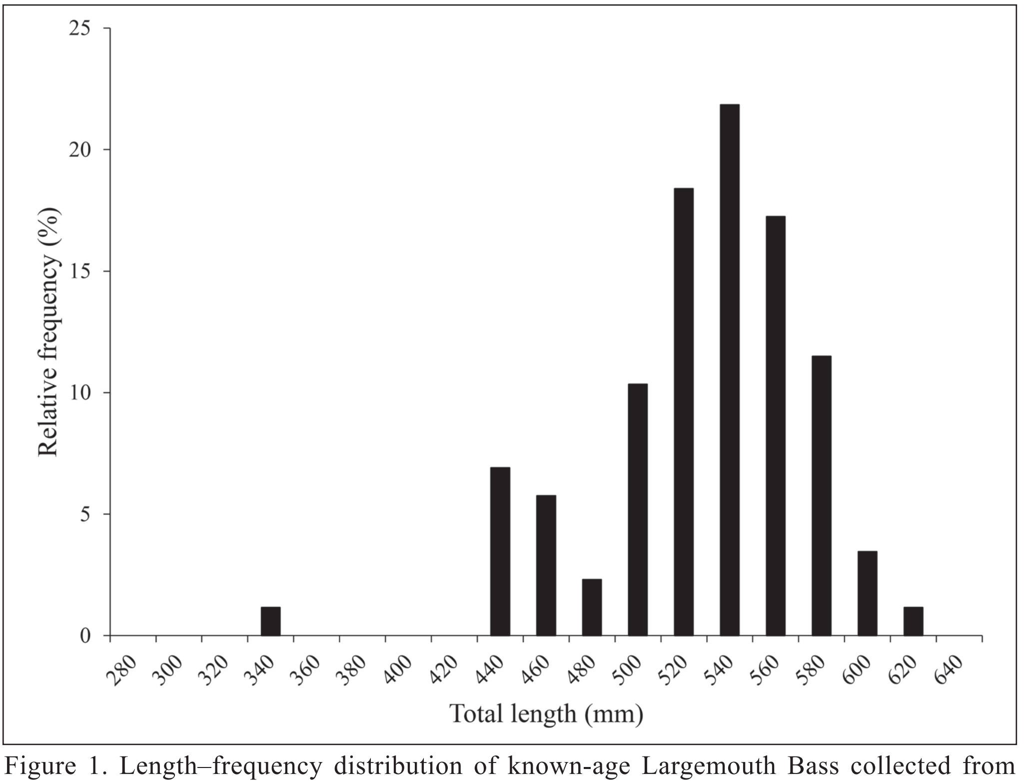

Figure 1. Length–frequency distribution of known-age Largemouth Bass collected from Ocmulgee Public Fishing Area, GA, in November 2012.

Discussion

Sagittal otoliths are the preferred aging structure for black basses because they yield accurate and precise results. For example, Besler (1999) reported 91% agreement between age estimates obtained from whole sagittal otoliths and sectioned sagittal otoliths from Largemouth Bass collected from various rivers and

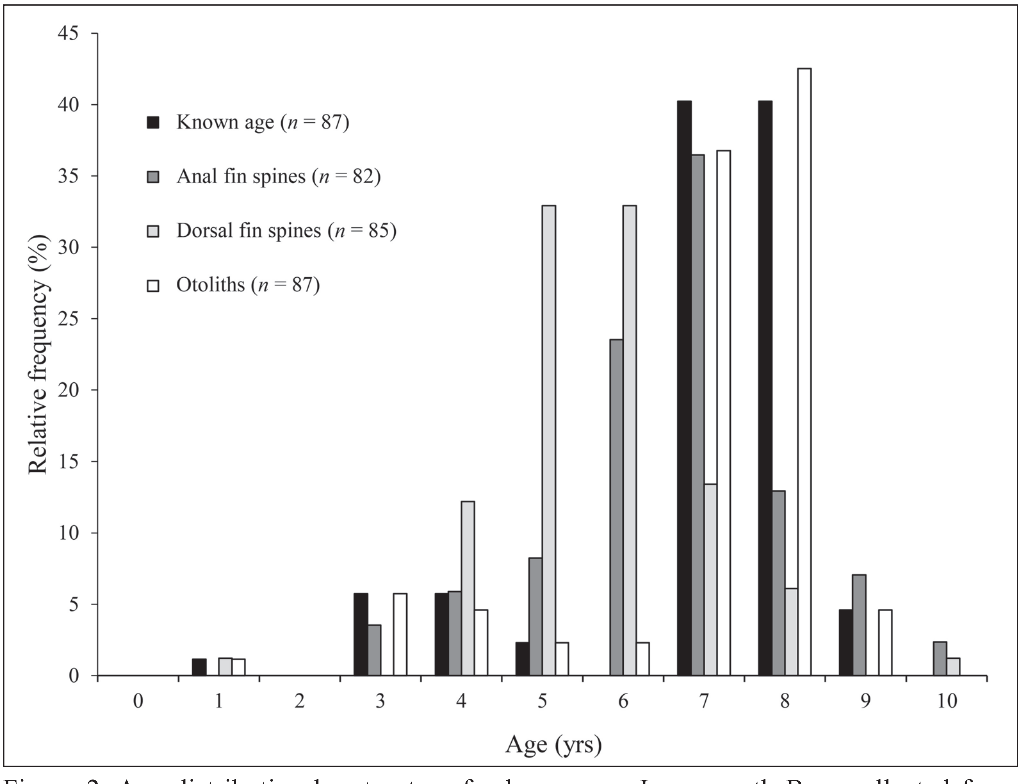

Figure 2. Age distribution by structure for known-age Largemouth Bass collected from Ocmulgee Public Fishing Area, GA, in November 2012.

Table 2. Percent confidence rating for reader 1 and 2 by structure for Largemouth Bass collected from Ocmulgee Public Fishing Area, GA, in November 2012. Sample sizes are included in parenthesis.

	Confidence rating			
Reader	0	1	2	3
Anal fin spine				
Reader 1	39 (32)	38 (31)	19 (16)	4 (3)
Reader 2	48 (39)	30 (25)	17 (14)	5 (4)
Dorsal fin spine				
Reader 1	62 (53)	24 (20)	12 (10)	2 (2)
Reader 2	62 (53)	25 (21)	12 (10)	1 (1)
Otolith				
Reader 1	0 (0)	1 (1)	1 (1)	98 (85)
Reader 2	0 (0)	0 (0)	5 (4)	95 (83)

reservoirs in North Carolina. Similarly, between-reader agreement was 94% for age estimates obtained from sagittal otoliths collected from Smallmouth Bass in the Hudson River, NY (Maceina and Sammons 2006). In addition, sagittal otoliths have been validated by a few authors using known-age fish. Taubert and Tranquilli (1982) reported high concordance between the number of potential growing days and counts of daily growth rings in sectioned sagittal otoliths for age-1 and age-2 Largemouth Bass collected from Lake Sangchris, IL. Buckmeier and Howells (2003) evaluated age estimates obtained from sectioned otoliths for Largemouth Bass that varied in age from 0 to 16 years. The authors reported that 2 readers correctly estimated the age of 97% of known-age Largemouth Bass using transversely sectioned sagittal otoliths. In the current study, 92% of the consensus age-estimates from otoliths agreed with the true age. Our results support the findings of other studies that otoliths are both precise and accurate structures for estimating the age of Largemouth Bass.

Non-lethal aging structures (e.g., fin spines, fin rays) are gaining popularity among researchers who are reluctant to sacrifice fish due to research methods (e.g., mark–recapture) or public perception (e.g., killing trophy-size fish). For some species, non-lethal structures provide reliable estimates of age. Dorsal spines collected from Walleyes from Red Lake, MN, exhibited high between-

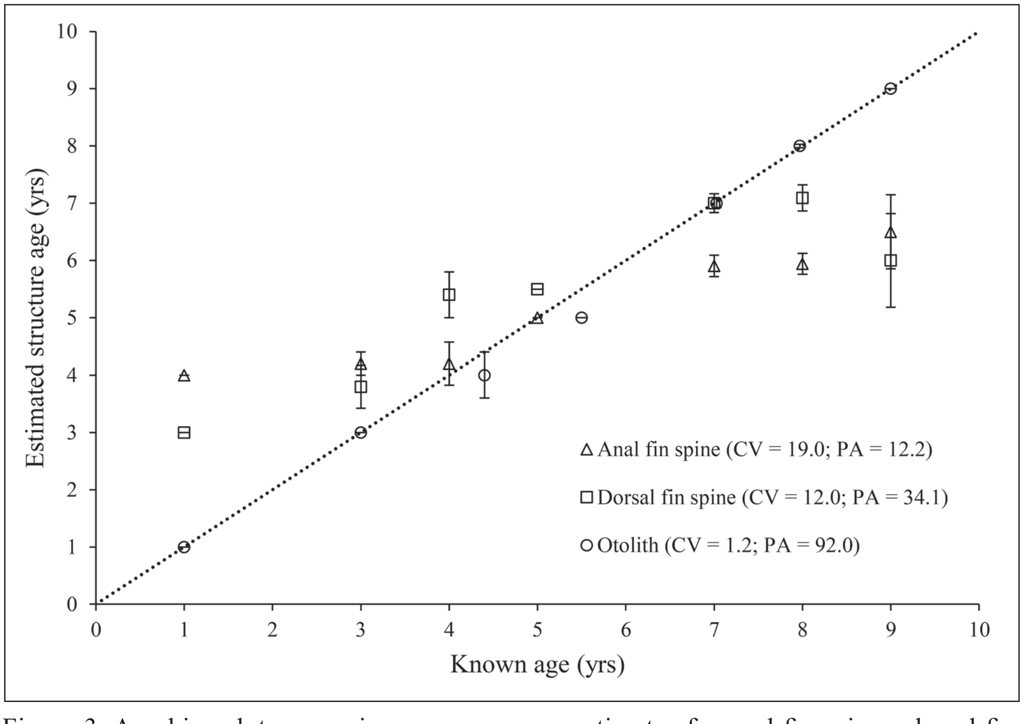

Figure 3. Age-bias plot comparing consensus age estimates for anal fin spines, dorsal fin spines, and sagittal otoliths to the true ages of Largemouth Bass collected from Ocmulgee Public Fishing Area, GA, in November 2012. The dashed line represents exact agreement and error bars denote one standard error. Coefficients of variation (CV) and percent agreement (PA) with known ages are included for each structure.

reader agreement (95%) and high agreement with otolith age estimates (≥95%; Logsdon 2007). Yates et al. (2016) reported higher percent agreement (65.2%) and a relatively low CV (3.0) for dorsal fin spines compared to otoliths (CV = 17.6, PA = 18.4), scales (CV = 15.4, PA = 29.7), and pectoral fin rays (CV = 4.9, PA = 51.7) for *Cyprinus carpio* L. (Common Carp) collected from Crane Creek Reservoir and Lake Lowell, ID. However, results on the reliability of non-lethal methods for estimating the age of black basses have varied. For instance, dorsal fin spines of Smallmouth Bass collected from Lake Champlain, NY, had the 2nd-highest average between-reader CV (9.1) when compared to scales (12.1), sagittal otoliths (7.4), and opercles (5.2) (Sotola et al. 2014). Morehouse et al. (2013) suggested the use of dorsal fin spines to estimate the age of large, adult Largemouth Bass due to high between-reader agreement (99%) for fish collected from 6 lakes in Indiana. Results from the current study suggest that anal fin spines and dorsal fin spines are relatively precise (PA ≥ 81), but do not provide accurate age estimates for Largemouth Bass. Because accurate age estimates are critical for effectively estimating population dynamics and making management decisions, otoliths will likely remain the primary aging method for Largemouth Bass, particularly for populations in southern latitudes.

Our results add to the growing body of literature evaluating the precision and accuracy of non-lethal aging structures. Although a number of studies have reported the accuracy and precision of non-lethal aging structures for various fishes (Beamish 1981, Beamish and Harvey 1969, Cass and Beamish 1983, Chilton and Bilton 1986, Michaletz et al. 2009), the majority of work focused on Largemouth Bass suggests otoliths yield the most accurate and precise age estimates (DeVries and Frie 1996, Heidinger and Clodfelter 1987, Taubert and Tranquilli 1982). In situations where managers are unwilling or unable to sacrifice fish, they can use alternative age-estimation methods such as mark–recapture of known-age fish or length–frequency analysis (Quist et al. 2012). However, mark–recapture methods require repeated sampling events, which may be cost prohibitive for natural resource agencies. Length–frequency analysis can be constructed from a single sampling event, but is typically only effective for estimating the ages of young fish or short-lived species. Given the limitations of these methods, the collection of age data for black basses should rely solely on the use of otoliths. Managers must carefully consider if losing a small proportion of fish from a population outweighs the importance of obtaining accurate and precise age data.

Acknowledgments

This research was jointly funded by the Georgia Department of Natural Resources Wildlife Resources Division Fisheries Management Section and the Idaho Cooperative Fish and Wildlife Research Unit. The Idaho Cooperative Fish and Wildlife Research Unit is jointly sponsored by the University of Idaho, US Geological Survey, Idaho Department of Fish and Game, and Wildlife Management Institute. We thank past and present fisheries personnel at the Wildlife Resources Division—L. Ager, J. Biagi, B. Baker, B. Deener, D. Harrison, T. Litts, J. Miller, J. Mitchell, S. Robinson, J. Rydell, C. Sexton, S. Schleiger, J. Swearingen,

M. Thomas, J. Woolsey, K. Weaver, T. Will, and E. Zmarzly—for their support regarding the Ocmulgee Public Fishing Area. We thank J. Long, B. Keck and 1 anonymous reviewer for their helpful comments on previous versions of this manuscript. The use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the US Government.

Literature Cited

Allen, M.S., W. Sheaffer, W.F. Porak, and S. Crawford. 2002. Growth and mortality of Largemouth Bass in Florida waters: Implications for use of length limits. Pp. 559–566, *In* D.P. Phillip and M.S. Ridgway (Eds.). Black Bass: Ecology, Conservation, and Management. American Fisheries Society, Symposium 31, Bethesda, MD. 740 pp.

Allen, M.S., K.I., Tugend, and M.J. Mann. 2003. Largemouth Bass abundance and angler catch-rates following a habitat enhancement Project at Lake Kissimmee, Florida. North American Journal of Fisheries Management 23:845–855.

Beamish, R.J. 1981. Use of fin-ray sections to age Walleye Pollock, Pacific Cod, and Albacore, and the importance of this method. Transactions of the American Fisheries Society 110:287–299.

Beamish, R.J., and H.H. Harvey. 1969. Age determination in the White Sucker. Journal of the Fisheries Research Board of Canada 26:633–638.

Besler, D.A. 1999. Utility of scales and whole otoliths for aging Largemouth Bass in North Carolina. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 53:119–129.

Bonvechio, T.F., and M.S. Allen. 2005. Relations between hydrological variables and year-class strength in eight Florida waterbodies. Hydrobiologia 532:193–207.

Bonvechio, T.F., and J.J. Rydell. 2016. Use of a female-only stocking strategy to establish a trophy Largemouth Bass fishery in a Georgia Small Impoundment. Journal of the Southeastern Associated Fish and Wildlife Agencies 3:136–143.

Boxrucker, J. 1986. A comparison of the otolith and scale methods for aging White Crappies in Oklahoma. North American Journal of Fisheries Management 6:122–125.

Buckmeier, D.L., and R.G. Howells. 2003. Validation of otoliths for estimating ages of Largemouth Bass to 16 years. North American Journal of Fisheries Management 23:590–593.

Campana, S.E., M.C. Annand, and J.L. McMillan. 1995. Graphical and statistical methods for determining the consistency of age determinations. Transactions of the American Fisheries Society 124:131–138.

Carlander, K.D. 1977. Handbook of Freshwater Fishery Biology, Vol. 2. Iowa State University Press, Ames, IA. 431 pp.

Cass, A.J., and R.J. Beamish. 1983. First evidence of validity of the fin-ray method of age determination for marine fishes. North American Journal of Fisheries Management 3:182–188.

Chilton, D.E., and H.T. Bilton. 1986. New method for aging Chinook Salmon (*Onchoryhynchus tshawytscha*) using dorsal fin rays, and evidence of its validity. Canadian Journal of Fisheries and Aquatic Sciences 43:1588–1594.

DeVries, D.R., and R.V. Frie. 1996. Determination of age and growth. Pp. 483–508, *In* B.R. Murphy and D.W. Willis (Eds.). Fisheries Techniques, 2nd Edition. American Fisheries Society, Bethesda, MD. 732 pp.

Erickson, C.M. 1983. Age determination of Manitoba Walleyes using otoliths, dorsal spines, and scales. North American Journal of Fisheries Management 3:176–181.

Fitzgerald, T.J., T.L. Margenau, and F.A. Copes. 1997. Muskellunge scale interpretation: The question of aging accuracy. North American Journal of Fisheries Management 17:206–209.

Heidinger, R.C., and K. Clodfelter. 1987. Validity of the otolith for determining age and growth of Walleye, Striped Bass, and Smallmouth Bass in power-plant cooling ponds. Pp. 241–251, *In* R.C. Summerfelt and G.E. Hall (Eds.). Age and Growth of Fish. Iowa State University Press, Ames, IA. 544 pp.

Hoyer, M.V., J.V. Shireman, and M.J. Maceina. 1985. Use of otoliths to determine age and growth of Largemouth Bass in Florida. Transactions of the American Fisheries Society 114:307–309.

Koch, J.D., and M.C. Quist. 2007. A technique for preparing fin rays and spines for age and growth analysis. North American Journal of Fisheries Management 27:782–784.

Koch, J.D., W.J. Schreck, and M.C. Quist. 2008. Standardized removal and sectioning locations for Shovelnose Sturgeon fin rays. Fisheries Management and Ecology 15:139–145.

Logsdon, D.E. 2007. Use of unsectioned dorsal spines for estimating Walleye ages. North American Journal of Fisheries Management 27:1112–1118.

Maceina, M.J., and S.M. Sammons. 2006. An evaluation of different structures to age freshwater fish from a northeastern US river. Fisheries Management and Ecology 13:237–242.

Maceina, M.J., J. Boxrucker, D.L. Buckmeier, R.S. Gangl, D.A. Isermann, J.R. Jackson, D.O. Lucchesi, and P.J. Martinez. 2007. Current status and review of freshwater-fish aging procedures used by state and provincial fisheries agencies with recommendations for future directions. Fisheries 32:329–340.

Michaletz, P.H., D.M. Nicks, and E.W. Buckner Jr. 2009. Accuracy and precision of estimates of back-calculated Channel Catfish lengths and growth increments using pectoral spines and otoliths. North American Journal of Fisheries Management 29:1664–1675.

Morehouse, R.L., S.B. Donabauer, and A.C. Grier. 2013. Estimating Largemouth Bass age: precision and comparisons among scales, pectoral fin rays, and dorsal fin spines as non-lethal methods. Fisheries and Aquaculture Journal 2013:1–7.

Niewinski, B.C., and C.P. Ferreri. 1999. A comparison of three structures for estimating the age of Yellow Perch. North American Journal of Fisheries Management 19:872–877.

Quist, M.C., M.A. Pegg, and D.R. DeVries. 2012. Age and growth. Pp. 677–731, *In* A.V. Zale, D.L. Parrish, and T.M. Sutton (Eds.). Fisheries Techniques, 3rd Edition. American Fisheries Society, Bethesda, MD. 1009 pp.

Ricker, W.E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Fisheries Research Board of Canada Bulletin 191, Ottawa, ON, Canada. 400 pp.

Schramm, H.L., Jr., and D.C. Smith. 1987. Differences in growth rate between sexes of Florida Largemouth Bass. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 41:76–84.

Sotola, V.A., G.A. Maynard, E.M. Hayes-Pontius, T.B. Mihuc, M.H. Malchoff, and J.E. Marsden. 2014. Precision and bias of using opercles as compared to otoliths, dorsal spines, and scales to estimate ages of Largemouth and Smallmouth Bass. Northeastern Naturalist 21:565–573.

Spiegel, J.R., M.C. Quist, and J.E. Morris. 2010. Precision of scales and pectoral fin rays for estimating age of Highfin Carpsucker, Quillback Carpsucker, and River Carpsucker. Journal of Freshwater Ecology 25:271–277.

Taubert, B.D., and J.A. Tranquilli. 1982. Verification of the formation of annuli in otoliths of Largemouth Bass. Transactions of the American Fisheries Society 111:531–534.

Welch, T.J., M.J. Van Den Avyle, R.K. Betsill, and E.M. Driebe. 1993. Precision and relative accuracy of Striped Bass age estimates from otoliths, scales, and anal fin rays and spines. North American Journal of Fisheries Management 13:616–620.

Yates, J.R., C.J. Watkins, and M.C. Quist. 2016. Evaluation of hard structures used to estimate age of Common Carp. Northwest Science 90:195–205.