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MANAGEMENT BRIEF

Latitudinal Influence on Age Estimates Derived from Scales and Otoliths for Bluegills

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Abstract

Scales are perceived to give reliable estimates of age of fish in northern latitudes and unreliable estimates of age in southern latitudes, whereas otoliths are perceived to give reliable estimates of age regardless of latitude. The objective of our study was to assess the influence of latitude on the estimates of ages derived from scales and otoliths for bluegill *Lepomis macrochirus*. Our hypothesis was that a south-to-north gradient exists for precision between scales and otoliths with partial agreement between age estimates derived from scales and otoliths for fish in southern latitudes and nearly complete agreement between age estimates derived from scales and otoliths for fish in northern latitudes. Fish were sampled from Louisiana (latitude = 30°43′48″N) to North Dakota (latitude = 47°05′49″N). Contrary to a priori expectations, we did not find greater agreement in age estimates between structures in northern bluegill stocks than in those in the southern USA. The low agreement between structures increases uncertainty in the source of aging error, given that both scales and otoliths are valid structures (i.e., age estimates validated as accurate) for estimating ages of bluegills. Biologists should not compare age-dependent parameters for bluegill populations derived from different aging structures.

Scales and otoliths, two calcified structures in which annual marks (i.e., annuli) are formed, are widely used for estimating the age of fish (DeVries and Frie 1996; Campana and Thorrold 2001). Annuli are formed in calcified structures during periods of slow growth, generally associated with cold weather in temperate climates (DeVries and Frie 1996). Age estimates derived from scales have been validated for bluegill *Lepomis macrochirus* using known-age fish in New York (Regier 1962), and age estimates derived from otoliths have been validated for bluegills using marginal-increment analysis in South Carolina (Hales and Belk 1992). Lucchesi and Johnson (2006) compared the amount of time for removal and processing of scales and otoliths to estimate ages for walleye *Sander vitreus* and yellow perch *Perca flavescens*; they reported a similar amount of time to read and process each structure. Collection of scales is frequently preferred to collection of otoliths because fish from which only scales have been taken can be released alive.

Accurate age estimates are vital for quantifying population dynamics (e.g., recruitment, growth, and mortality) and assessing age structure of a population. Furthermore, a recent emphasis has been placed on standardization of methods to compare data gathered across large geographic areas (Bonar and Hubert 2002; Bonar et al. 2009). Inaccuracy in age estimation of fishes is caused by error associated with interpretation of annuli (Campana 2001), which is compounded by variability in the quality of annuli. Quality of annuli can differ among populations and years due to environmental factors that influence physiological mechanisms controlling formation of annuli; quality can also differ between the calcified structures being examined. Not all calcified structures in fish form a complete growth sequence throughout the lifetime of the animal (Casselman 1990). Therefore, aging techniques that produce accurate estimates are essential for analysis of population dynamics (Summerfelt and Hall 1987; Campana 2001).

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Quantification of the accuracy of age estimates is typically determined when estimating age of known-age fish or through marginal-increment analysis—information that typically is not available when sampling wild populations. In contrast, quantification of the precision of age estimates derived from two different calcified structures from the same fish (e.g., scales and otoliths) can be easily obtained. Although an estimate of precision and associated error does not provide an estimate of the true value of the quantity being measured, it does provide a distribution from which the probability of the existence of an independent random variable can be determined. Given that both age estimation methods we evaluated have been validated, we considered precision of estimates between structures as a measure of uncertainty that is introduced in age estimation.

Latitude of origin has a potential impact on the precision of age estimates of fish. The lack of a definitive cold season in southern latitudes affects physiological mechanisms that control annuli formation. In contrast, fish populations from northern latitudes typically experience definitive periods of fast growth associated with warm temperatures and slow growth associated with cool temperatures. Decreased precision between age estimates derived from scales and otoliths has been documented in fish from southern latitudes (Schramm and Doerzbacher 1985; Boxrucker 1986; Hammers and Miranda 1991). The loss of precision in age estimates between structures has been attributed to a reader's inability to distinguish annuli formation on scales because of the effects of climate on the seasonal growth and metabolic activity of fish (Schramm and Doerzbacher 1985; Boxrucker 1986; Hoxmeier et al. 2001). Thus, fish from southern latitudes, with shorter or intermittent cold seasons, may have indistinguishable annuli on scales. In contrast, otoliths have been used to accurately age fish from both southern and northern latitudes (Schramm and Doerzbacher 1985; Boxrucker 1986; Kruse et al. 1993; Hoxmeier et al. 2001). A reader's ability to accurately estimate age with scales and otoliths has been studied at relatively small spatial ranges (Boxrucker 1986; Hammers and Miranda 1991; Kruse et al. 1993; Hoxmeier et al. 2001; Edwards et al. 2005) but has not been thoroughly evaluated across a large latitudinal gradient. Therefore, we evaluated the influence of latitude (30°43′48″N through47°05′49″N) on the precision of age estimates derived from scales and otoliths for bluegills. Our hypothesis was that a south-to-north gradient exists for precision between scales and otoliths, that is, partial agreement between age estimates derived from scales and from otoliths for fish in southern latitudes and nearly complete agreement between age estimates derived from scales and otoliths for fish in northern latitudes. If correct, then a latitudinal threshold should exist for interchangeable utility between scales and otoliths for age estimation.

METHODS

Collection of bluegills.—We analyzed scales and otoliths of bluegills from populations centered along a line (longitude = 93°42′48″W to 97°07′09″W) from the Texas–Louisiana border north to the North Dakota–Minnesota border (latitudes = 30°43′48″N through 47°05′49″N). Bluegill samples were provided by biologists representing state agencies along the latitudinal gradient. Each biologist was asked to collect bluegills from all age groups present during sampling and to weight the sampling toward older age groups because we assumed discrepancies in age estimates would be more prevalent in older fish. Fish were frozen and shipped to University of Nebraska–Lincoln Fishery Science Laboratory for processing. In the laboratory, each fish was thawed and individually numbered. Scales (collected from under the tip of the pectoral fin when pressed against the body) and otoliths were removed for age analyses following procedures described by DeVries and Frie (1996).

Structure aging.—Scales were pressed onto acetate slides and viewed through a microfiche reader. Scale annuli were identified by close spacing of the circuli and cross-over points (Jerald 1983; Kruse et al. 1993). Whole otoliths were submerged in a black petri dish filled with water and viewed through a dissecting microscope with reflected light. Otolith annuli were identified as lighter colored, opaque bands (representing reduced growth increments) separated by darker colored, translucent bands (representing increased growth increments). All scales and otoliths were read separately by two independent readers to estimate fish age. To reduce reader bias, we resolved all discrepancies in age estimates between readers with a concert read (Campana 2001; Buckmeier et al. 2002). Age bias plots with linear regression were constructed for each population to examine the precision of age estimates derived from scales and otoliths (Phelps et al. 2007). Analysis of variance (ANOVA) was used to determine whether the slope of the regression line differed from 1, and in cases in which it did not differ from 1, to determine whether the *y*-intercept differed from 0. We estimated growth parameters (asymptotic average length [L_∞] and growth rate coefficient [K]) and instantaneous mortality (Z) using our study fish to illustrate potential influences of discrepancies in age estimates; we caution readers that the bluegill samples provided for this study were not representative of actual populations because we requested samples weighted toward older (i.e., larger) fish.

RESULTS AND DISCUSSION

We expected to find significant differences between regression lines and the 1:1 line in southern populations and no differences in northern populations. Contrary to a priori expectations, however, we found no evidence of a latitudinal gradient in any agreement of age estimates derived from scales and otoliths of bluegill. Age estimates derived from scales and otoliths were significantly different in 14 of 15 populations assessed (Figure 1). We found five populations in which the slope of the regression line did not differ from 1, but only one population in which slope did not differ from 1 *and* the *y*-intercept

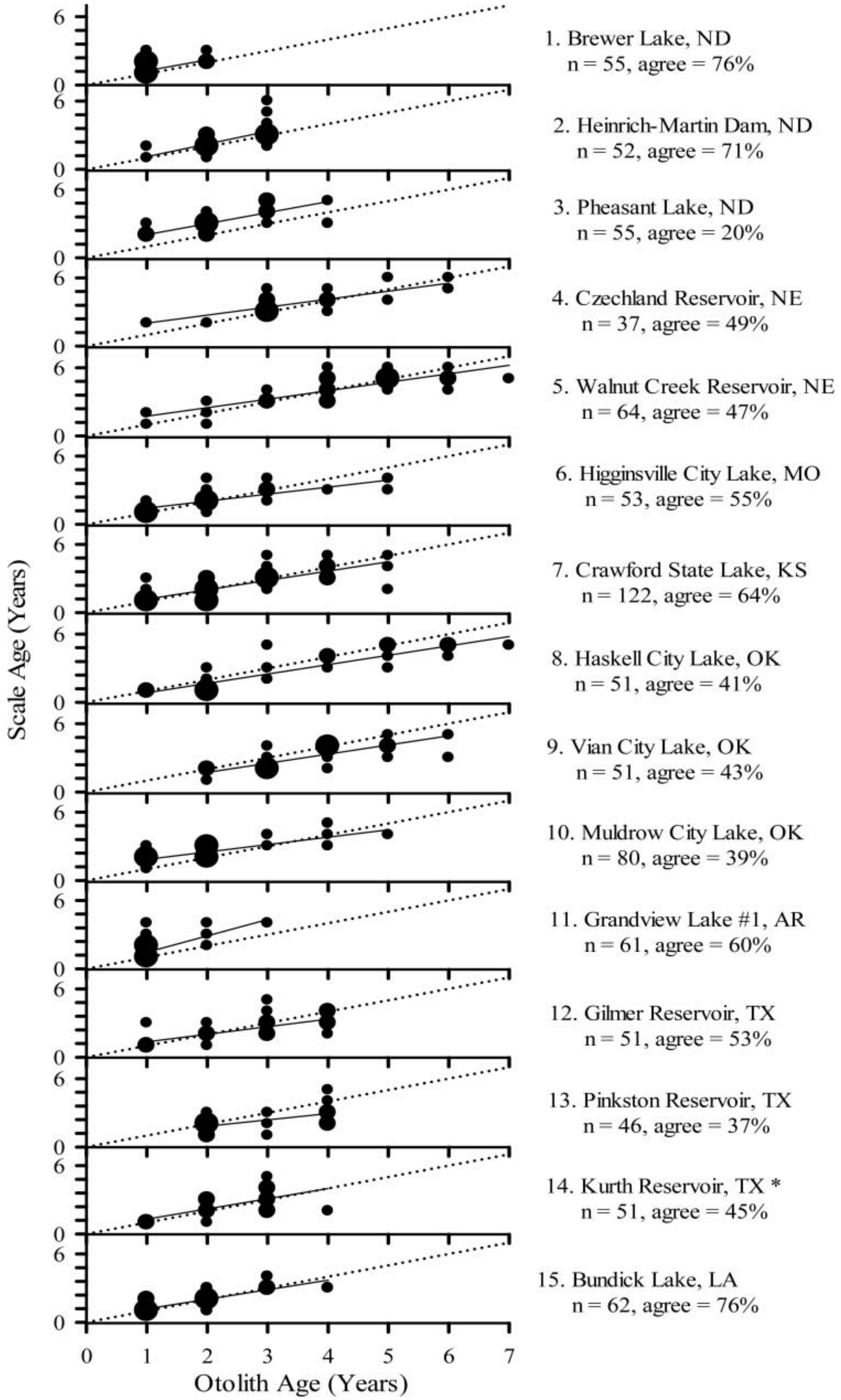

FIGURE 1. Age bias plots for 15 bluegill populations. Linear regression indicated by solid black line. All regressions were significant ($P < 0.001$). The 1:1 dotted line (age estimates derived from scales = age estimates derived from otoliths) is provided for reference. The number of bluegills represented by each data point is indicated by size of data point: 1–4 bluegills for small points, 5–9 bluegills for medium points, and 10 or more bluegills for large points. Asterisk denotes regression slope = 1, and y-intercept = 0. Sample size (n) and structure agreement (agree; %) are provided for each population.

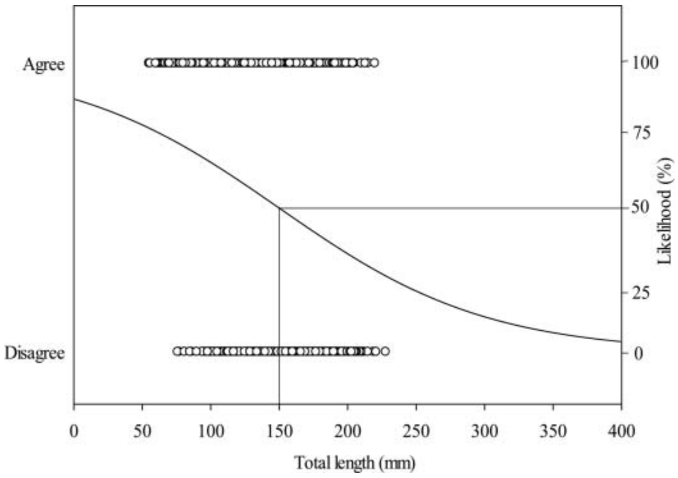

FIGURE 2. Logistic regression of agreement of age estimates derived from scales and from otoliths plotted as a function of total length (mm) for bluegills ($n = 891$). A 50% likelihood of agreement occurred at a total length of 150 mm.

did not differ from 0. A logistic regression of agreement of age estimates derived from scales and otoliths plotted as a function of total length (mm) for sampled bluegills indicated a likelihood of agreement of 50% at a total length of 150 mm (Figure 2). Apparently, the disagreement between aging structures of bluegills is prevalent for large ($\geq$150 mm) bluegill throughout the latitudinal range that we assessed. This low agreement between age estimates derived from scales and from otoliths across the latitudinal gradient examined was unexpected, given that both scales and otoliths are considered valid structures (i.e., age estimates are validated as accurate) for estimating ages of bluegills.

The low agreement increases uncertainty in the source of aging error, which creates difficulty for biologists when comparing bluegill population dynamics that had been generated from age data estimated with a combination of scales and otoliths. Relative use of scales to age sunfish increased with latitude (Maceina et al. 2007); accordingly, use of scales to age sunfish is limited for state agencies located south of the 40th parallel (Kansas–Nebraska border; Maceina et al. 2007). Given our hypothesis, we anticipated that age estimates derived from scales and from otoliths should not be used interchangeably in the southern portion of the latitudinal gradient examined, but our data suggest this issue exists across the entire geographic range. Our results suggest that conclusions drawn from age-based assessments obtained using these two structures (Table 1) could result in different, possibly conflicting, management recommendations. Thus, biologists should not compare age-based assessments of bluegill populations when the age estimates were derived from a combination of both kinds of aging structures. Furthermore, we recommend that validation studies for age estimates of both scales and otoliths be completed across a wide range of latitudes for bluegills of at least 150 mm total length to better understand error in precision between structures.

TABLE 1. Comparison of asymptotic average length (L_∞) and growth rate coefficient (K) from the Von Bertalanffy growth equation and instantaneous mortality rate (Z) between models by using ages derived from scales and from otoliths for each bluegill population. Percent difference was calculated for parameter estimates according to the formula $((|(X_{\text{scale}} - X_{\text{otolith}})| / (0.5(X_{\text{scale}} + X_{\text{otolith}})) * 100)$.

	L_∞(mm)			K			Z		
	Age derived from			Age derived from			Age derived from		
Reservoir	Scales	Otoliths	% Diff.	Scales	Otoliths	% Diff.	Scales	Otoliths	% Diff.
Brewer Lake, ND	*	*	*	*	*	*	1.228	1.631	28
Heinrich Martin Dam, ND	238	*	*	0.359	*	*	0.880	−0.214[a]	329
Pheasant Lake, ND	270	*	*	0.173	*	*	0.257	1.134	126
Czechland Reservoir, NE	211	228	8	0.540	0.317	52	0.607	0.775	24
Walnut Creek Reservoir, NE	200	194	3	0.471	0.534	13	0.092	0.409	127
Higginsville City Lake, MO	168	156	7	0.437	0.633	37	0.232	0.374	47
Crawford State Lake, KS	191	196	3	0.725	0.725	0	0.572	0.548	4
Haskell City Lake, OK	241	260	8	0.370	0.281	27	−0.040[a]	0.358	250
Vian City Lake, OK	225	280	22	0.373	0.190	65	0.914	0.304	100
Muldrow City Lake, OK	298	188	45	0.142	0.576	121	1.017	0.631	47
Grandview Lake #1, AR	218	178	20	0.275	2.092	154	0.798	1.994	86
Gilmer Reservoir, TX	196	226	14	0.785	0.435	57	0.919	−0.187[a]	302
Pinkston Reservoir, TX	154	155	1	0.821	1.000	20	0.914	−0.027[a]	212
Kurth Reservoir, TX	171	231	30	1.259	0.399	104	0.588	0.420	33
Bundick Lake, LA	574	344	50	0.077	0.156	68	0.664	0.795	18

[a] We recognize Z cannot be negative; values are reported only for comparison purposes, to illustrate differences in estimates.

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