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[Management Brief]

Estimating Black Crappie Age: An Assessment of Dorsal Spines and Scales as Nonlethal Alternatives to Otoliths

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Abstract.—Otoliths generally provide more accurate and precise age estimates for crappies *Pomoxis* spp. than do scales, but sacrificing crappies for otolith removal may not be desirable in all situations. We evaluated the use of dorsal spines and scales as nonlethal alternatives to otoliths for estimating the ages of black crappies *P. nigromaculatus* using 111 fish collected from two Minnesota lakes. Among-reader precision was similar for ages estimated from scales and dorsal spines (coefficients of variation [CVs] = 10–14%), but the precision associated with both structures was substantially lower than that observed for otoliths (CVs = 0.12–1.3%). Complete reader agreement (i.e., all three readers agreed on age) for dorsal spines (44–51%) and scales (33–36%) was substantially lower than that observed for otoliths (87–98%). Partial agreement (i.e., at least two of three readers agreed on age) was 100% for both otoliths and dorsal spines and between 79% and 89% for scales. Scale ages assigned by individual readers agreed with consensus otolith ages less than 70% of the time; agreement of individual spine ages with consensus otolith ages was 33% or less. Mean scale ages were usually similar to consensus otolith ages for crappies between the ages of 2 and 6 years, while mean spine ages were consistently lower than consensus otolith ages. Thin-sectioning dorsal spines did not significantly change the number of annuli detected by individual readers. Our results suggest that dorsal spines are not a useful alternative to scales for estimating black crappie age in a nonlethal manner. A conspicuous lumen located in the center of each dorsal spine partially or fully obscures at least one annulus. When otolith removal is not desirable, use of scales and multiple readers may provide mean age estimates that are similar to consensus otolith ages, but we suggest that otolith analysis remains the most reliable method for estimating black crappie age, regardless of latitude.

With the exception of the results of Kruse et al. (1993), otoliths have been shown to provide more accurate (Ross et al. 2005) and precise (Boxrucker 1986; Hammers and Miranda 1991) age estimates than scales for crappies *Pomoxis* spp. However, removal of otoliths requires fish sacrifice. In many exploited fish populations, it is likely that the number of fish sacrificed for otolith-based age estimation represents a negligible source of mortality when compared with the total number of fish harvested by anglers (e.g., Isermann et al. 2003), but the use of nonlethal methods for estimating age remains attractive from a public relations standpoint and is necessary in situations where releasing fish is essential in meeting research objectives (e.g., mark–recapture experiments). Spines have been commonly used as a nonlethal means to estimate age for a variety of fish species, but have yielded mixed results with regards to accuracy and precision (e.g., Erickson 1983; Buckmeier et al. 2002; Isermann et al. 2003; Vandergoot et al. 2008).

Several previous studies have used various sectioning techniques to prepare dorsal spines for age estimation. Some of these sectioning techniques are time-consuming and can require specialized equipment (Isermann et al. 2003; Logsdon 2007; Williamson and Dirnberger 2010). A recent evaluation with sauger *Sander canadensis* (Williamson and Dirnberger 2010) suggested that illuminating the polished base of whole dorsal spines with a fiber optic light generally exposes a similar viewing surface as sectioning techniques and may provide a better method for detecting outer annuli. Similar illumination techniques have been used for estimating ages from the dorsal spines of walleyes *S. vitreus* (Logsdon 2007) and the pectoral spines of channel catfish *Ictalurus punctatus* (Buckmeier et al. 2002).

We found no study evaluating the use of dorsal spines for estimating the age of any centrarchid species, including black crappies *Pomoxis nigromaculatus*. Consequently, we evaluated dorsal spines as an alternative to using scales and otoliths for estimating the age of black crappies. We also determined whether thin-sectioning and fiber optic illumination of whole dorsal spines yielded similar age estimates for black crappies.

Methods

Black crappies were collected by boat electrofishing and trap nets during April and May 2005 from Lake Hubert (524 ha) and Upper Mission Lake (331 ha), two mesotrophic natural lakes located in Crow Wing

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County near Brainerd, Minnesota. All crappies were measured to the nearest millimeter total length (TL). Scales were removed from just below the lateral line near the point where the distal end of the left pectoral fin touched the body. Scales were placed into coin envelopes prior to examination. Sagittal otoliths were removed, wiped clean, and stored in plastic vials. Similar to the methods used by Borkholder and Edwards (2001) and Logsdon (2007), a pair of side cutters was used to remove the third full dorsal spine at a point just above the flesh; spines were also stored in coin envelopes.

Scale annuli were enumerated using a microfiche projector. Otoliths were initially viewed whole using a dissecting microscope. Whole otoliths were submerged underwater in a black dish and were examined using reflected light. Otoliths displaying four or more potential annuli, or any otolith that was considered difficult to read in whole view, was subsequently cracked in half and annuli were illuminated using a fiber optic light source (Heidinger and Clodfelter 1987). Polishing with 1,000-grit sandpaper and immersion oil were used on some cracked otoliths to improve clarity. Dorsal spines were examined using a side-illumination technique (Logsdon 2007; Williamson and Dirnberger 2010). The proximal end of each dorsal spine (i.e., where it had been cut with the side cutters) was polished using wetted 1,000-grit sandpaper and the spine was placed distal end down (i.e., point down) in a dish lined with plumber's putty, so that the polished base was facing up. The polished base was illuminated by holding a fiber optic light against the side of the spine near the edge of the polished surface while being viewed under a dissecting microscope. Immersion oil was applied to the polished surface of some spines to improve image clarity.

All structures were independently examined by three readers. With the exception of lake names, biological information (i.e., length or sex) regarding each fish was not provided to readers. Due to time of collection, annuli associated with the previous year of growth were not yet visible on structures; hence, we added a value of 1 to all age designations (i.e., age = visible annuli + 1).

Coefficients of variation (CV = [SD/mean] $\times$ 100), complete agreement (i.e., all three readers assigned the same age), and partial agreement (i.e., at least two of three readers assigned the same age) were used to compare the precision of age estimates derived from each structure. Age bias plots similar to those suggested by Campana et al. (1995) were used to examine potential age estimation biases associated with using scales and dorsal spines when compared with consensus otolith ages. Because known-age fish were not available for this study, we assumed that consensus otolith ages (i.e., at least two of three readers agreed on an age) represented accurate estimates of black crappie ages based on a previous evaluation incorporating crappies of known age (Ross et al. 2005). Mean scale and dorsal spine ages were calculated for each fish based on reader age assignments. These mean age assignments were then averaged for all fish of the same consensus otolith age and were used in age bias plots. Age bias plots were constructed by plotting mean scale or dorsal-spine ages and associated 95% confidence intervals (CIs) against consensus otolith age; linear regressions were used to determine whether the slopes of these relationships were significantly different than 1 ($\alpha = 0.05$). Additionally, we used 95% CIs to assess whether mean scale and spine ages were significantly different than consensus otolith ages (i.e., consensus otolith age was not within the 95% CI for mean scale or spine age). We also calculated percent agreement between scale and dorsal spine ages reported by individual readers and the consensus otolith ages. Sex-specific mean lengths at ages 4 and 5 were substantially higher for black crappies in Lake Hubert compared with Upper Mission Lake (23–35 mm higher; Isermann et al. 2010) and relatively large ($\geq$300 mm TL) and presumably older crappies were more prevalent in our sample from Lake Hubert (Figure 1). Because differences in growth rates and age structure could influence precision and potential biases associated with age estimates, individual analyses were conducted for each lake.

To determine whether side illumination and thin-sectioning of dorsal spines yielded similar age estimates for black crappies, we thin-sectioned a subsample of dorsal spines from 30 black crappies (N = 15 from each lake). The subsample was selected to represent the range of consensus otolith ages observed for black crappies collected from both lakes. Dorsal spines were mounted in a two-part epoxy resin (Buehler Epo-Kwick) and a 1-mm cross section was obtained from the base of each spine using a Buehler Isomet 1000 Precision saw mounted with 0.5-mm diamond wafering blade (Buehler Series 15LC). Thin sections were mounted on glass microscope slides with cyanoacrylic cement and examined using a dissecting microscope and transmitted light. Annuli visible on whole and thin-sectioned spines were enumerated independently by two readers. To determine whether age estimates were similar between the two techniques, whole dorsal spine age estimates were plotted against ages estimated from thin sections for each reader. Linear regressions were used to determine whether the slopes of these relationships significantly differed from 1 ($\alpha = 0.05$).

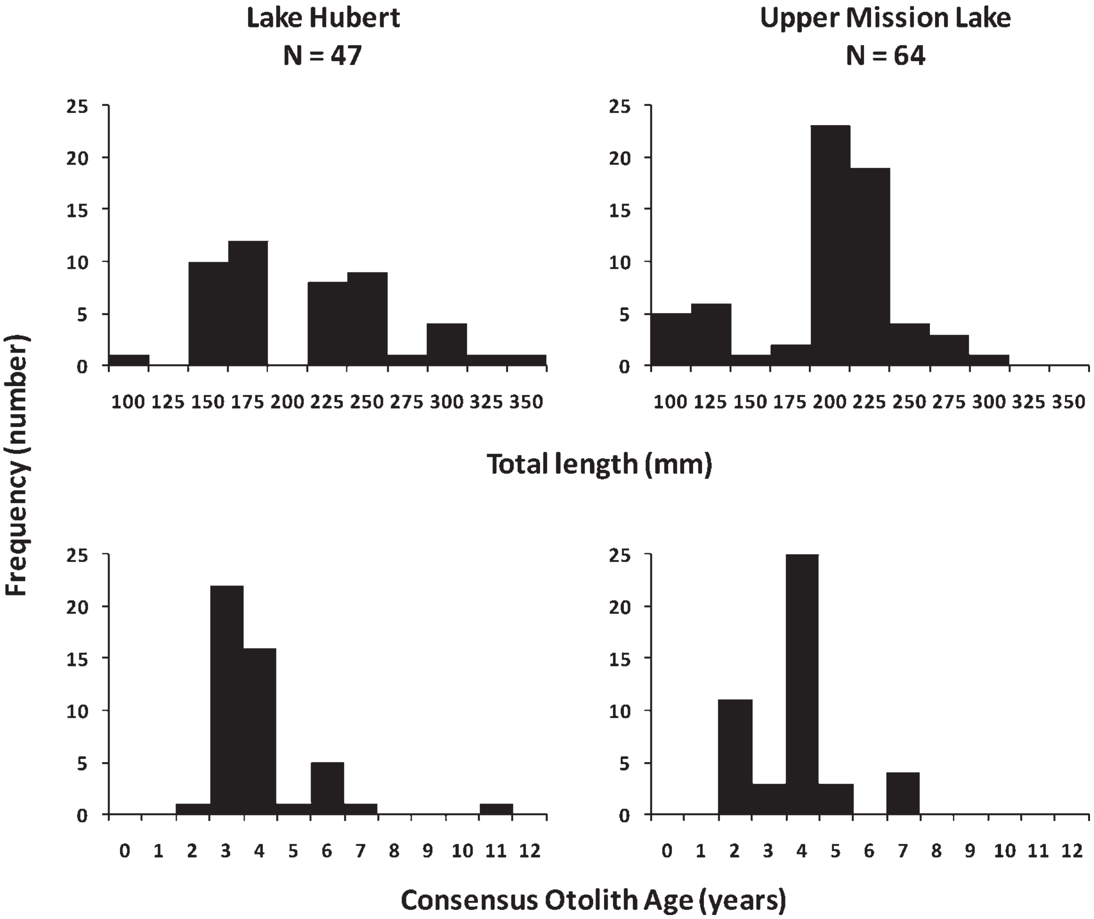

FIGURE 1.—Total length (mm) and age frequencies based on consensus otolith ages for black crappies collected from Lake Hubert and Upper Mission Lake during April–May 2005.

Results

Lake Hubert

Ages were estimated for 47 Lake Hubert black crappies ranging from 111 to 352 mm TL (Figure 1). Complete agreement among otolith readers was 87% (41 of 47 crappies aged; Table 1); five of the six disagreements occurred for crappies estimated to be age 5 or older by at least two readers. Partial agreement for otolith ages was 100%. The mean CV for otolith age estimates was 1.3% (SE, 1.4). Based on consensus otolith ages, black crappies in the Lake Hubert

TABLE 1.—Complete (all three readers agreed on an age) and partial (at least two of three readers agreed on an age) agreement, mean coefficients of variation (CV = [SD/mean] × 100; SEs in parentheses), and percentage of ages assigned by individual readers from scales and dorsal spines that agreed with consensus otolith ages for black crappies collected from Lake Hubert and Upper Mission Lake during April–May 2005.

Lake	*N*	Structure	Complete agreement (%)	Partial agreement (%)	Mean CV (%)	Agreement with otolith age (%)
Hubert	47	Otoliths	87	100	1.3 (1.4)	
		Scales	30	79	14 (1.6)	62
		Dorsal spines	51	100	10 (1.6)	21
Upper Mission	64	Otoliths	98	100	0.12 (0.1)	
		Scales	36	89	11 (1.1)	69
		Dorsal spines	44	100	11 (1.4)	33

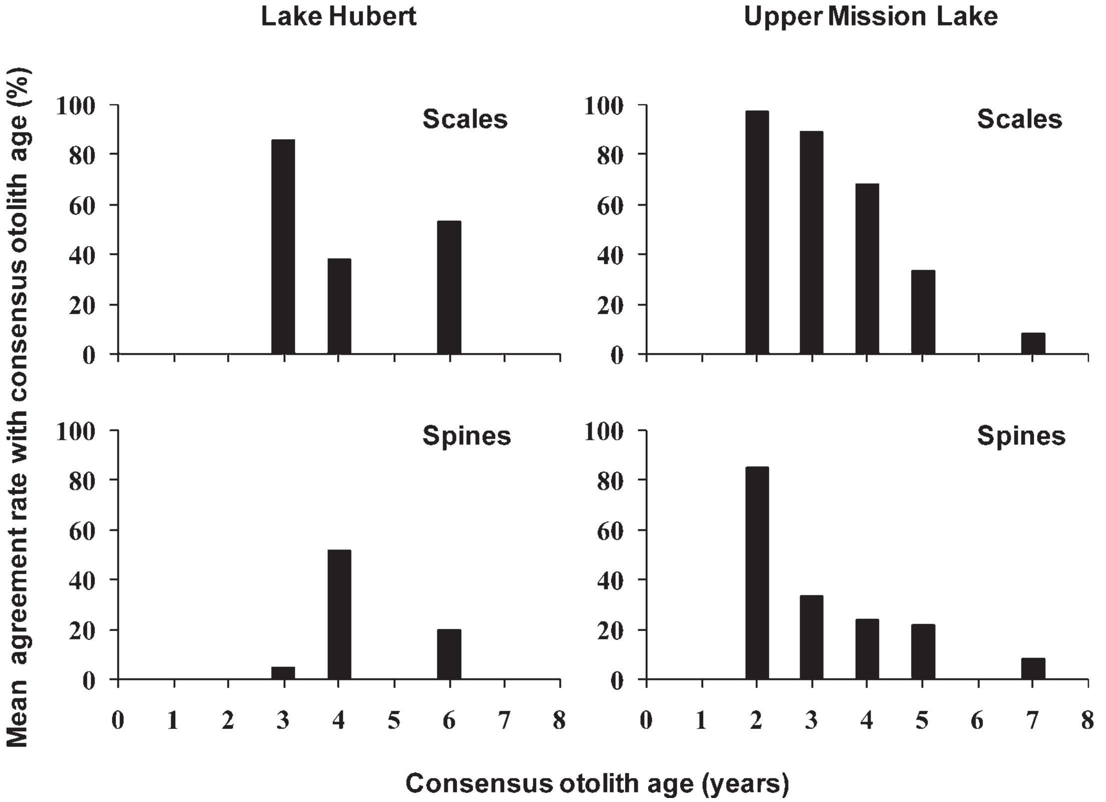

FIGURE 2.—Mean agreement between individual ages estimated by three different readers from scales and dorsal spines in relation to consensus otolith ages for black crappies collected in Lake Hubert and Upper Mission Lake during April–May 2005.

sample were 2–11 years of age and, with the exception of four fish, the sample consisted of 3-, 4-, and 6-year-old crappies (Figure 1); hence, only these three age-classes were used in age bias plots and when calculating agreement among scale, spine, and otolith ages.

Complete agreement among scale readers was 30% (14 of 47; Table 1); partial agreement was only 79% (37 of 47). Mean CV for scale age estimates was 14% (SE, 1.6). Scale ages estimated by individual readers agreed with consensus otolith ages only 62% of the time (88 of 141 age assignments; Table 1); discrepancies of 1 year accounted for 66% (35 of 53) of the disagreements. On average, scale ages estimated by individual readers agreed with consensus otolith age 86% of the time at consensus otolith age 3, but were less than 60% at consensus otolith ages 4 and 6 (Figure 2). Based on age bias plots, mean scale age was similar to consensus otolith age for black crappies assigned a consensus otolith age of 3. Mean scale ages were higher than consensus otolith age at ages 4 and 6, but were not significantly different based on 95% CIs (Figure 3). Furthermore, the slope of the relationship between mean scale age and consensus otolith age was not significantly different than 1 ($F = 0.10$; df $= 1,2$; $P = 0.10$; Figure 3).

Complete agreement among the three readers for dorsal spines was 51% (24 of 47); partial agreement was 100%. Mean CV for dorsal spine age estimates was 10% (SE, 1.6). Dorsal spine ages estimated by individual readers agreed with consensus otolith ages only 21% of the time (31 of 141 age assignments; Table 1); discrepancies of 1 year accounted for 58% (64 of 110) of the disagreements. On average, dorsal-spine ages estimated by individual readers agreed with consensus otolith ages less than 60% of the time at consensus otolith ages 3, 4, and 6 (Figure 2). Based on 95% CIs, mean ages derived from dorsal spines were significantly lower than consensus otolith ages for all age-groups (Figure 3). The slope of the relationship between mean spine age and consensus otolith age was significantly lower than 1 ($F = 4.51 \times 10^{15}$; df $= 1, 2$; $P < 0.01$; Figure 3).

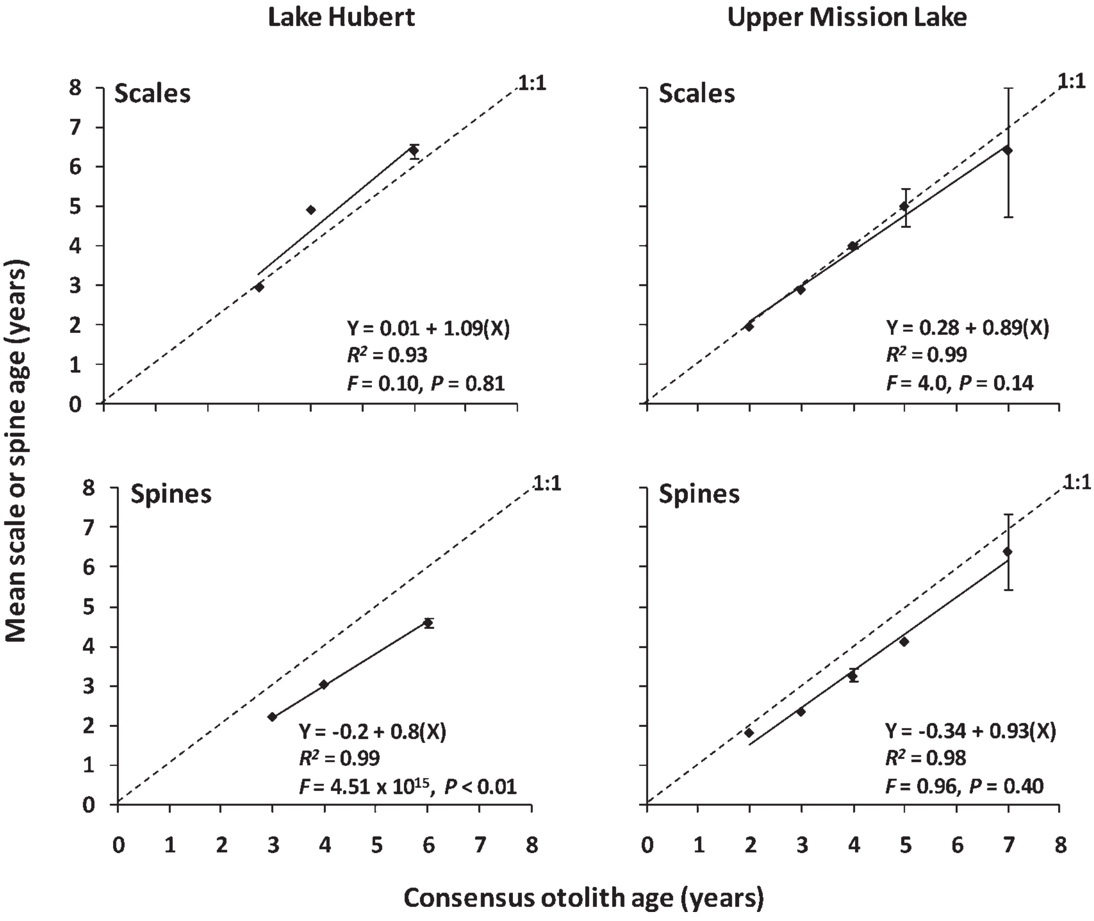

FIGURE 3.—Plots of mean ages estimated from scales and dorsal spines in relation to consensus otolith ages for black crappies collected in Lake Hubert and Upper Mission Lake during April–May 2005, assuming that the consensus otolith ages represented the true ages of fish. Mean scale and dorsal spine ages are averages of the mean age assignments ($N = 3$ independent assignments per fish) for fish of a specified consensus otolith age. Error bars represent 95% confidence intervals. Linear regressions (solid lines) were used to determine whether the slopes of the relationships between mean scale or spine age and consensus otolith age differed significantly from 1; dashed lines represent a 1:1 relationship between ages. The sample sizes of black crappies at each consensus otolith age are reported in Figure 1.

Upper Mission Lake

Ages were estimated for 64 black crappies from Upper Mission Lake ranging from 107 to 300 mm TL (Figure 1). Complete agreement among the three otolith readers was 98% (63 of 64 crappies), the single discrepancy occurring for a crappie estimated to be age 7 by two of three readers. Partial agreement among otolith readers was 100%. The mean CV for otolith age estimates was 0.12% (SE, 0.1). Based on consensus otolith ages, black crappies in the Upper Mission Lake sample were 2–7 years of age and, with the exception of 10 fish, the sample consisted of 2- and 4-year-old crappies.

Complete reader agreement associated with scales was 36% (23 of 64 black crappies), partial agreement was 89%, and the mean CV in reader age estimates for scales was 11% (SE, 1.1). Overall, scale readers replicated consensus otolith ages for 69% (132 of 192) of the black crappies (Table 1); discrepancies of 1 year accounted for 93% (56 of 60) of the disagreements between scale age and consensus otolith age. Mean agreement between scale ages and consensus otolith age was 89% or greater among readers for crappies assigned consensus otolith ages of 2 and 3, but were less than 70% at consensus otolith ages 4, 5, and 7 (Figure 2). On average, mean scale ages were similar to consensus otolith ages at ages 2–6 (Figure 3). At a

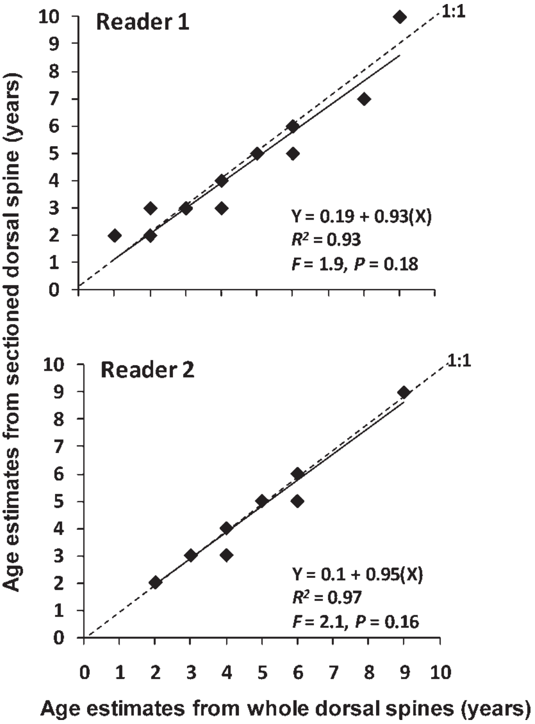

FIGURE 4.—Comparison of ages estimated from whole dorsal spines illuminated with a fiber optic light and ages estimated from thin sections obtained from the same dorsal spines for 30 black crappies collected from Lake Hubert and Upper Mission Lake during April–May 2005. Black diamonds may represent age pairings for more than one fish. Ages were estimated independently by two readers. Dashed lines represent a 1:1 relationship between age estimates. Slopes for linear regressions (solid lines) between age estimates did not differ significantly from 1 (F-tests: $P > 0.05$).

consensus otolith age of 7 mean scale age was 6.4, but this was not considered significantly lower based on the 95% CI. The slope of the relationship between mean scale age and consensus otolith age was not significantly different than 1 ($F = 4.0$; df = 1, 4; $P = 0.14$; Figure 3).

For Upper Mission Lake black crappies, complete agreement among dorsal spine readers was only 44% (28 of 64), partial agreement was 100%, and the mean CV in reader age estimates for spines was 11% (SE, 1.4). Overall, spine readers replicated consensus otolith ages for only 33% (64 of 192 age designations) of black crappies (Table 1); discrepancies of 1 year accounted for 98% (125 of 128) of the disagreements. Mean agreement between spine ages and consensus otolith age was 82% among readers for black crappies assigned a consensus otolith age of 2, but mean agreement was less than 35% for fish assigned consensus otolith ages 3 and older (Figure 2). With the exception of black crappies assigned a consensus otolith age of 2, mean ages estimated from dorsal spines were consistently lower than consensus otolith ages and were significantly lower at ages 3, 4, and 7 based on 95% CIs; however, the slope of the relationship between mean spine age and consensus otolith age was not significantly different than 1 ($F = 0.96$; df = 1, 4; $P = 0.40$; Figure 3).

Comparison of Ages Estimated from Whole and Sectioned Dorsal Spines

Ages estimated from dorsal spine thin sections and whole dorsal spines illuminated with a fiber optic light were similar 83% of the time (50 of 60 age pairings) between the two readers. In all cases disagreements between age estimates were ± 1 year. In 7 of 10 cases, ages estimated from thin sections were 1 year less than ages estimated from whole dorsal spines. Slopes for the relationships between ages estimated using the two techniques did not significantly differ from 1 ($F = 1.9$ and 2.1, df = 1, 29; $P > 0.05$; Figure 4).

Discussion

Although among-reader precision was similar between scales and dorsal spines and reader agreements were higher for dorsal spines, we suggest that dorsal spines do not offer a useful nonlethal alternative to scales for estimating black crappie age. Comparisons with consensus otolith ages suggest that not all annuli were clearly visible on dorsal spines. A conspicuous lumen was located in the center of each dorsal spine (Figure 5); the expansion of this lumen over time partially or fully obscures annuli, a pattern previously reported when using spines to estimate the age of catfish *Ictalurus* spp. (Buckmeier et al. 2002). For example, while at least five potential annuli are visible on the otolith cross section for a 302-mm (TL) black crappie collected from Lake Hubert (Figure 5, top photo), only the last three annuli are clearly visible on the spine; another probable annulus is partially obscured by the lumen (denoted by the number 2) and the fifth and presumably innermost annulus is not visible (Figure 5, bottom photo). Missing annuli pose an obvious problem for age estimation and annuli that are partially obscured by the lumen may not be consistently detected by individual readers. Furthermore, thin-sectioning of dorsal spines did not significantly change the number of annuli detected by readers. Although known-age black crappies were not included in our evaluation, we suggest that ages estimated from dorsal spines were probably inaccurate

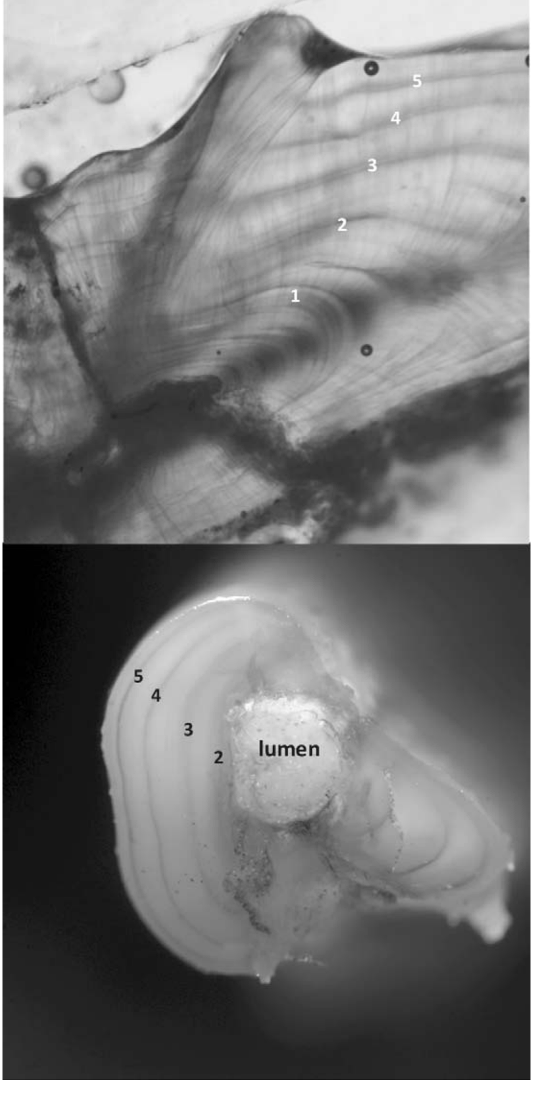

FIGURE 5.—Digital images of a sagittal otolith section (top photograph) and the polished base of a dorsal spine (bottom photograph) removed from a 302-mm (TL) black crappie collected from Lake Hubert during May 2005. Potential annuli are denoted by numerals.

and typically underestimated the true age of black crappies.

Scale readers were generally ineffective in replicating consensus otolith ages, and precision among scale readers was low. All of the readers estimated fish ages from scales as part of their duties with the Minnesota Department of Natural Resources (i.e., 2–5 years of experience). Kruse et al. (1993) and Hoxmeier et al. (2001) suggested that the precision of ages estimated from scales might follow a latitudinal gradient. This suggestion is based on the underlying theory that at northern latitudes scales could be easier to interpret because annuli are more pronounced as a result of extended slow growth during winter. Conversely, at northern latitudes black crappies are likely to grow slower and live longer than their southern counterparts, two factors that are known to increase the relative difficulty of estimating fish age with any structure, but particularly when using scales (Hoxmeier et al. 2001; Ross et al. 2005; DeCicco and Brown 2006; Maceina and Sammons 2006). Our results demonstrate that among-reader precision for black crappie ages estimated from scales can be low regardless of latitude.

Our findings did suggest that using multiple readers to examine black crappie scales can result in mean scale ages that are similar to consensus otolith ages. Based on the results of Maceina et al. (2007), we infer that multiple readers are rarely used in most agency settings. Incorporating multiple scale readers and using consensus scale ages might prove a more reasonable approach for estimating the age of black crappies from scales; however, this process will increase the time and cost needed to estimate ages and, based on our comparisons with otoliths, will not be effective for black crappies age 5 and older. Based on our results and the age-validation work conducted by Ross et al. (2005), we suggest that otoliths remain the most reliable method for estimating black crappie age, regardless of latitude.

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