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Evaluation of Three Different Structures Used for Walleye Age Estimation with Emphasis on Removal and Processing Times

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Abstract.—We compared the removal and processing times required when scales, sagittal otoliths, and dorsal spines were used as age estimation structures for 160 walleyes *Stizostedion vitreum* collected from six water bodies in South Dakota. Removal and processing times were calculated by 10 fish groups. Dorsal spines required the least amount of time for removal, followed by scales and otoliths. Whole-view otoliths required no further manipulation prior to estimating age, while the sectioning of dorsal spines and scale pressing required 12.5 and 16.6 min of additional processing time, respectively. Dorsal spines and scales also required significantly more time to read than otoliths. In terms of total processing time, whole-view otoliths proved the most time-efficient approach for estimating the age of walleyes. Scales were slightly more time-efficient than dorsal-spine sections, and sectioning otoliths would add additional processing time. Sectioning may not have been necessary in this evaluation because ages estimated by an experienced viewer from the sectioned otoliths agreed with ages estimated from whole-view otoliths 98% of the time (although reader inexperience could result in lower rates of agreement). The relative precision between readers was approximately five times greater with whole-view otoliths than with scales or spines. Reader agreement rates associated with whole-view otoliths were also significantly higher than rates for scales or spines. Based on our findings, otoliths provide the most time-efficient and precise approach for estimating the age of walleyes.

Sagittal otoliths provide a more accurate (Erickson 1983; Heidinger and Clodfelter 1987) and precise (Campbell and Babaluk 1979; Belanger and Hogler 1982; Marwitz and Hubert 1995; Kocovsky and Carline 2000) approach to walleye *Stizostedion vitreum* age estimation than scales, especially when dealing with older individuals. Conversely, many agencies continue to use scales for estimating the age of walleyes during routine management surveys; they frequently state that scales require less time to remove and process and do not require fish sacrifice. Dorsal-spine sections also provide a nonlethal means of estimating the age of walleyes and may offer similar or improved precision when compared with scales (Erickson 1983; Marwitz and Hubert 1995). However, reader agreement rates associated with walleye dorsal-spine sections can be lower than those reported for scales (Kocovsky and Carline 2000).

Although many studies have analyzed the precision and accuracy of using otoliths, scales, and dorsal-spine sections as structures for estimating the age of a variety of freshwater fishes, only a few have offered anecdotal insights into the time required to remove and process these structures (e.g., Boxrucker 1986; Welch et al. 1993; Kocovsky and Carline 2000). Welch et al. (1993) recommended that future studies into the use of structures for estimating the age of striped bass *Morone saxatilis* incorporate an assessment of the amount of time required to remove, prepare, and read each structure. Our primary objectives were to estimate and compare the processing times associated with the use of scales, sagittal otoliths, and dorsal spines as structures for estimating walleye age, and to discuss the potential implications for routine sampling for each method. We also compared the relative precision and reader agreement rates among structures.

Methods

Walleyes ($n = 160$) were collected via electrofishing and gill netting during August–September 2001 from five natural lakes in eastern South Dakota and one large Missouri River impoundment. Removal and processing times associated with each structure were estimated by using groups of 10 fish ($N = 16$ groups of 10 fish). The time required to measure total lengths and weights for each group of walleyes was recorded. Structures were removed by two different individuals to simulate variability in removal times due to differences in skill level among personnel. Scales were collected from just below the lateral line imme-

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TABLE 1.—Mean removal, processing (pressing or sectioning), viewing, and total processing times (min) per 10-fish group associated with the use of dorsal-spine sections, scales, and whole-view otoliths to estimate the age of walleyes collected from six South Dakota water bodies during August–September 2001. Standard errors are reported in parentheses. Means within a column denoted by different letters represent significant differences in least-squares means (Bonferroni procedure, $P < 0.02$). Sectioned otoliths were not included in statistical comparisons. Processing time for sectioned otoliths includes both sectioning and viewing times that could not be separated into distinct periods.

Structure	Removal time	Processing time	Viewing time	Total processing time
Scales	2.5 (0.07) y	16.6 (0.73) z	8.4 (0.31) y	29.6 (0.80) y
Dorsal spines	1.5 (0.07) x	12.5 (0.28) y	11.7 (0.43) z	34.6 (1.75) z
Whole-view otoliths	9.0 (0.33) z		5.3 (0.16) x	16.0 (0.29) x
Sectioned otoliths	9.0 (0.33)	24 (1.87)		34.7 (0.96)

diately posterior to the pectoral fin and were placed in coin envelopes prior to pressing and age estimation. Ten scales from each fish were pressed (standard roller press) on acetate slides for viewing purposes, and scale images were viewed with a microfiche projector (25× magnification). Sagittal otoliths were submersed in water contained within a black dish and viewed in whole view under a dissecting microscope (15–25× magnification). Ages were estimated for otoliths displaying three or more annuli in whole view ($N = 60$) by sectioning otoliths into halves by hand following the procedures described by Heidinger and Clodfelter (1987). Otolith sectioning was conducted to estimate the additional time that may be required if older fish were commonly encountered in a sample. Dorsal spines were cross-sectioned with a Dremel tool fitted with a dental saw blade. Two sections were taken from the second or third dorsal spine of each walleye; sections were placed on a microscope slide and viewed under a dissecting microscope (63× magnification) with transmitted light.

Total processing times associated with whole-view otoliths, scales, and spine sections were derived for each 10-fish group by adding the times required to record lengths and weights, process each structure (sectioning or pressing), and estimate the age from each structure. Mean times associated with scale pressing and spine sectioning were compared with a *t*-test for unequal variances (Schlotzhauer and Littell 1997). Sectioned otoliths were considered separately from whole otoliths in comparisons of total processing times. Because walleye groupings based on the 60 otoliths ($N =$ six groups of 10 walleyes) that were sectioned differed from those groups used for whole-view otolith analysis, and because the otolith sectioning and viewing process could not be separated into distinct periods, the total processing time for sectioned otoliths was obtained for each 10-fish group by adding the average times required for recording lengths and weights, removing otoliths, and sectioning and estimating the age from otolith sections. Each structure was read by two individuals; individuals varied across structures to accommodate different experience levels. Due to heterogeneous variances, removal, reading, and total processing times were compared among whole-view otoliths, scales, and dorsal spines with mixed-model procedures available in SAS (Littell et al. 1996); multiple comparisons were made with least-squares means and Bonferroni procedures.

The coefficient of variation ($CV = 100 \times SD/\text{mean}$) was used as a measure of the relative precision between readers (Chang 1982); mean CV was compared among structures with the use of a block design (with each fish representing a block) and mixed-model procedures; multiple comparisons were made with the use of least-square means and Bonferroni procedures. We also calculated reader agreement rates (exact agreement and agreement within ±1 year) for each structure as an additional measure of structural readability, under the assumption that structures exhibiting easily discernible annuli would result in high agreement rates. Reader agreement rates were compared among structures with chi-square analysis. Pairwise plots of mean ages and simple linear regression were used to determine whether age estimates differed among structures by testing whether slopes differed significantly from one.

Results

Total lengths (TL) of walleyes used in the study ranged from 130 to 501 mm (mean TL = 350 mm, SE = 5.08). On average, recording length and weight for a 10-fish group required 1.7 min (SE = 0.03). Removal times were significantly different among all structures (Table 1; $F = 269$, df = 2, 21, $P < 0.001$). Dorsal spines required the least amount of time for removal, followed by scales

TABLE 2.—Mean coefficient of variation (CV = 100 × SD/mean) between reader age assignments and reader agreement rates associated with the use of dorsal-spine sections, scales, whole-view otoliths, and sectioned otoliths to age walleyes collected from six South Dakota water bodies during August–September 2001. Mean CVs denoted by different letters represent significant differences in least-squares means (Bonferroni procedure, $P \leq 0.01$). Reader agreement rates within a column denoted by different letters denote significant differences (chi-square, $P < 0.01$). Sectioned otoliths were not included in statistical analyses.

Structure	CV	Exact reader agreement (%)	Reader agreement (±1 year)
Scales	18.3 (1.89) z	51 y	81 y
Dorsal spines	17.0 (2.21) z	55 y	96 z
Whole-view otoliths	3.0 (0.68) y	88 z	99 z
Sectioned otoliths	2.54 (0.85)	87	100

and otoliths. Whole-view otoliths required no further manipulation prior to viewing, and the sectioning of dorsal spines took significantly less time than scale pressing. On average, otolith sectioning and the reading of sections required 24 min (SE = 1.87) per group. Ages estimated by an experienced reader from otolith sections agreed with the ages estimated from whole-view otoliths 98% of the time; however, agreement was lower with an inexperienced reader (77%). Mean viewing times were significantly different among all structures (Table 1; $F = 99.71$, df = 2, 93, $P = 0.0001$); otoliths required the least amount of viewing time, followed by scales and dorsal-spine sections. Based on comparisons of total processing times ($F = 174$, df = 2, 19, $P = 0.0001$), whole-view otoliths were the most time-efficient structure for estimating walleye ages, followed by scales and dorsal-spine sections. The average total processing time required when sectioned otoliths were used was 34.7 min (SE = 0.96) per 10-fish group.

The mean CV in reader age estimates differed significantly among structures (Table 2; $F = 38.74$, df = 2, 267, $P = 0.0001$). Whole-view otoliths showed approximately five times greater precision than both scales and dorsal-spine sections; mean CV did not significantly differ between scales and spines. The exact reader agreement rate was significantly higher with whole-view otoliths than with scales or dorsal-spine sections; exact reader agreement was not significantly different between scales and dorsal spine sections (Table 2). The rate of reader agreement (within ±1 year) for scales was significantly lower than the rates for whole-view otoliths and dorsal spines; rates did not differ significantly between whole-view otoliths and spines (Table 2). The regression slope between mean otolith age and mean scale age was not significantly different from one (Figure 1; $F = 0.47$, df = 1, 158, $P = 0.49$); however, the relationship between mean ages estimated from these structures was relatively weak (Figure 1; $r^2 = 0.70$, $P = 0.0001$). The linear relationship between mean dorsal spine age and mean otolith age was weaker still (Figure 1; $r^2 = 0.60$, $P = 0.0001$), and the slope was significantly different than one (Figure 1; $F = 20.6$, df = 1, 157, $P = 0.0001$). The relationship between mean scale age and mean spine age was also weak (Figure 1; $r^2 = 0.62$, $P = 0.0001$), and the slope of the relationship was not significantly different than one (Figure 1; $F = 0.12$, df = 1, 157, $P = 0.73$).

Discussion

Variation in the techniques and individuals used to process the structures used for age estimation would obviously result in different outcomes than those reported here. Other studies have offered anecdotal evidence that the use of whole otoliths for estimating the age of fish was less time consuming than the use of scales (Boxrucker 1986; Kruse et al. 1993). Based on our results and the results of other studies concerning accuracy (Erickson 1983; Heidinger and Clodfelter 1987) and precision (Campbell and Babaluk 1979; Belanger and Hogler 1982; Marwitz and Hubert 1995; Kocovsky and Carline 2000), we recommend that to obtain relatively accurate and precise estimates of walleye ages in the most time-efficient manner, sagittal otoliths should be used to estimate walleye ages, regardless of the walleye ages encountered within a sample. We also recommend that sagittal otoliths be incorporated to estimate ages for walleye populations that are sampled via overnight gill-net sets, where fish sacrifice is not an issue.

We did not include sectioned otoliths in comparisons of total processing time because the sectioning of otoliths would likely not be required for an entire random sample of walleyes. Samples of exploited walleye populations are often dominated by younger fish (ages 1–5; Erickson 1983; Mero 1992; Marwitz and Hubert 1995), and, based on the agreement between ages estimated from whole-view and sectioned otoliths by an experienced viewer, the use of whole-view otoliths would yield nearly the same age structure results as the use of otolith sections for walleyes age 5

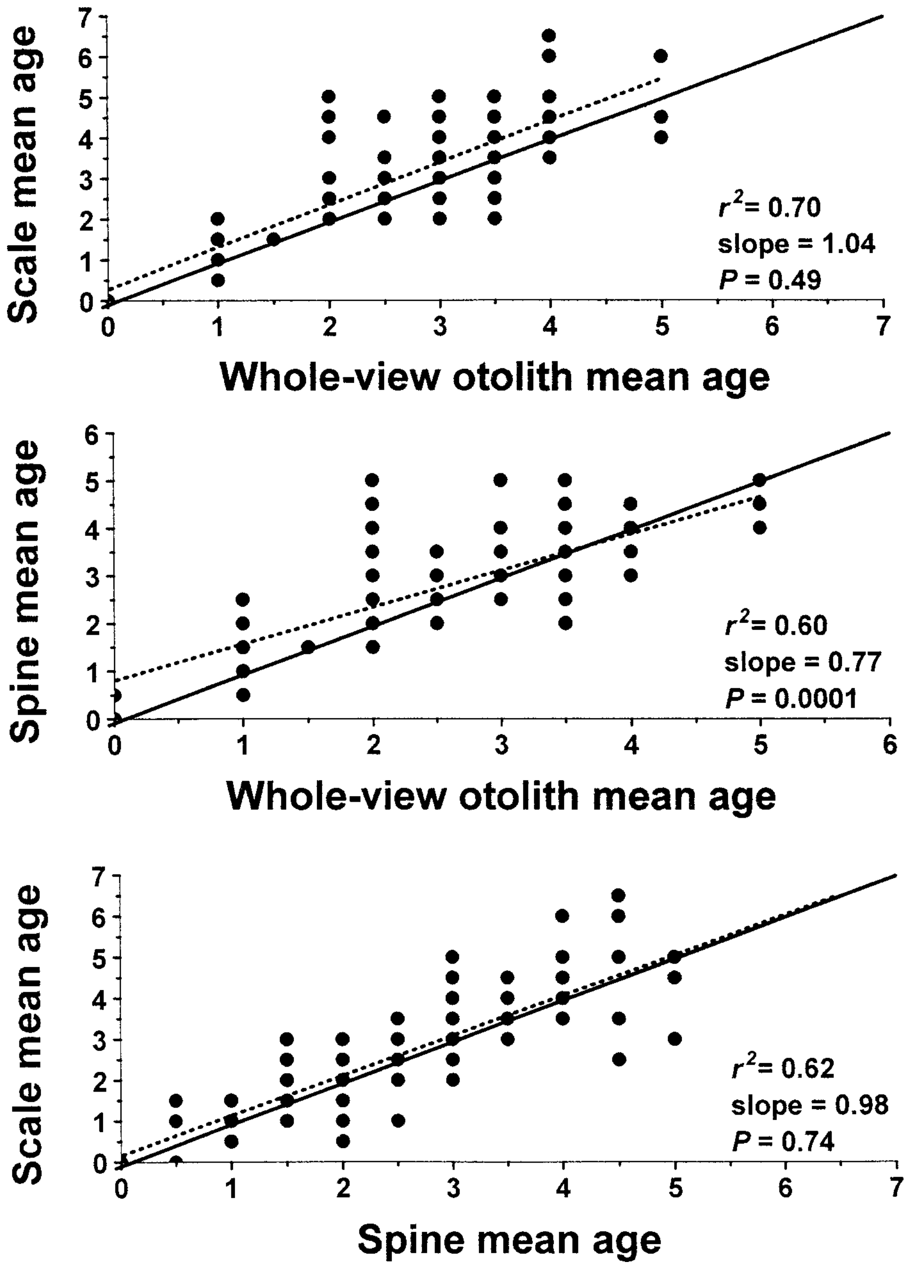

FIGURE 1.—Pairwise, mean age plots for ages estimated by two readers from dorsal-spine sections, scales, and whole-view otoliths removed from 160 walleyes collected from six South Dakota water bodies during August–September 2001. Solid black lines represent a 1:1 relationship; dashed lines represent simple linear regressions. Coefficients of determination (r^2) and slopes for each regression are reported. Probability values (P) associated with the test of slopes (slope = 1) are reported for each plot.

and younger. However, reader inexperience could result in reduced levels of agreement. In some cases, higher agreement rates between whole-view and sectioned otoliths may be desired, hence sectioning may be required for ages less than age 5. Sectioned otoliths (with the use of a different sectioning technique) required the least amount of viewing time for estimating the age of striped bass when compared with scales and sectioned anal fin rays and spines (Welch et al. 1993). Welch

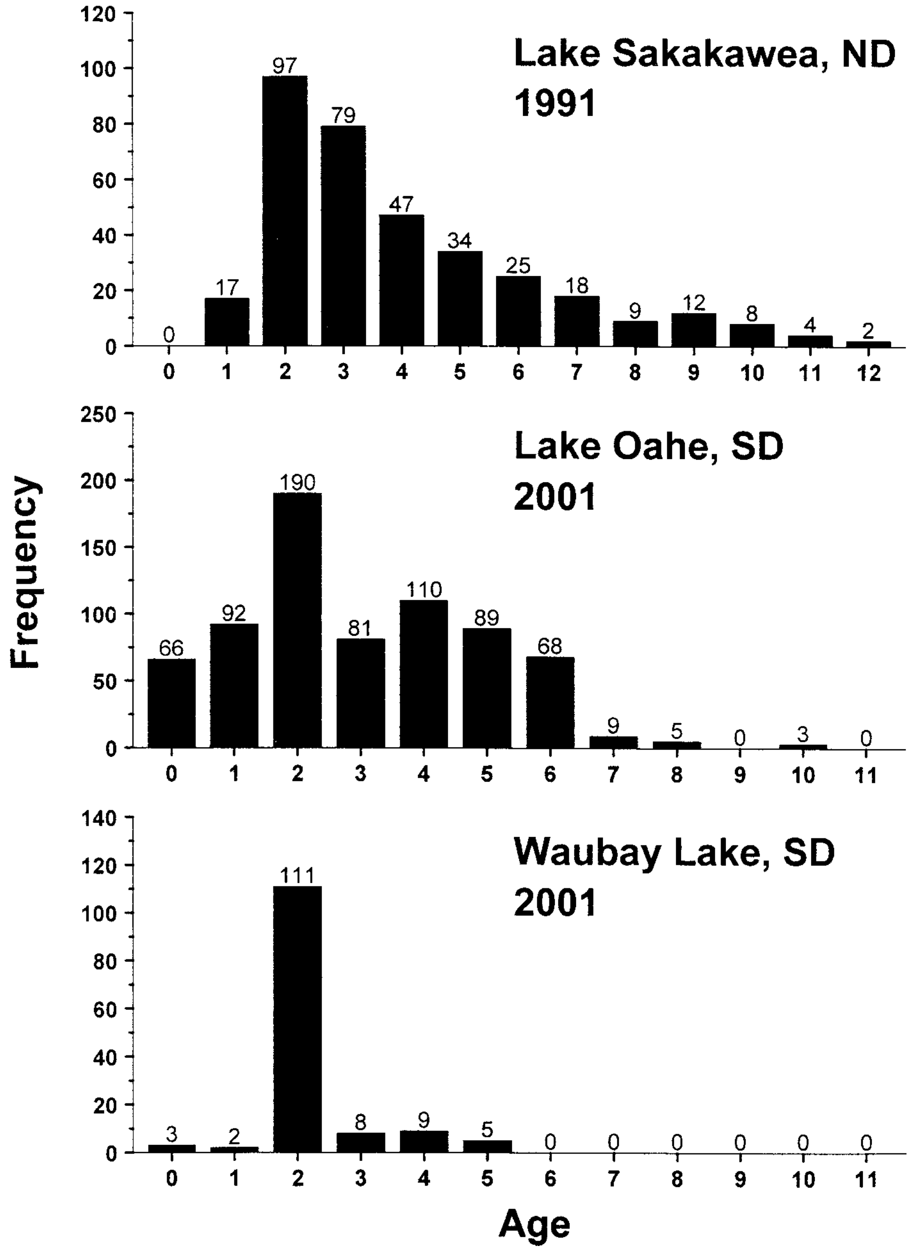

FIGURE 2.—Age-frequency histograms of walleyes used to determine the age structure for three walleye populations. Age-frequency data for Lake Sakakawea, North Dakota, were reported by Mero (1992); data for Waubay Lake and Lake Oahe represent data collected during summer 2001 (M. Hubers and J. Lott, South Dakota Department of Game, Fish, and Parks, unpublished data). All walleyes were collected via experimental gill nets.

et al. (1993) observed that sectioned otoliths required the most time for preparation, and otoliths from all striped bass were sectioned prior to estimating ages.

For most walleye populations, the use of a combination of whole-view and sectioned otoliths will likely be necessary to estimate walleye age structure. For example, based on ages estimated from scales taken from walleyes (N = 352; Figure 2, top graph) collected in gill-net samples at Lake Sakakawea, North Dakota (156,000-ha Missouri River impoundment) during May–June 1991

(Mero 1992), otoliths from approximately 22% (78 of 353 >age 5) of the walleyes used to estimate the age in the sample would require sectioning according to our criterion. Based on our results (and assuming scale ages were accurate), 11.8 h would be required to process and estimate the ages for the Lake Sakakawea sample with a combination of whole and sectioned otoliths, while 17.3 h would be required to process and estimate the ages for the sample with scales and 20.2 h with dorsal-spine sections. Similarly, based on walleyes used to estimate age structure in the South Dakota portion of Lake Oahe, South Dakota (126,000-ha Missouri River impoundment) during 2001 (Figure 2, middle graph), 12% of walleyes were older than age 5 (85 of 713 were >age 5). This indicates that estimating the ages for the sample with whole and sectioned otoliths would require 20.1 h; the use of scales would require 35.2 h, and dorsal-spine sections would require 41.1 h. Conversely, in younger walleye populations (such as the population of Waubay Lake, South Dakota; Figure 2, bottom graph), the sectioning of otoliths would be required less frequently. In 2001, scales were removed from 139 walleyes to estimate the age structure of the Waubay population in standard summer gill-net assessments; only one of the 139 fish in the sample was designated as being older than age 5. Hence, the sample of walleyes taken from Waubay would require approximately 3.7 h to process and estimate ages with the use of otoliths, 6.9 h with scales, and 8.0 h with dorsal-spine sections. Additionally, high levels of agreement between whole-view otolith age estimates and ages estimated from otolith sections may extend beyond age 5 in some populations, further reducing the time required when otoliths are used to estimate the ages for a sample of walleyes.

The use of scales for estimating walleye age is a relatively inaccurate approach for describing walleye population patterns, especially where older walleyes are commonly encountered (Erickson 1983; Heidinger and Clodfelter 1987). Additionally, despite the fact that most walleyes used in our evaluation were relatively young, low reader agreement, low precision, and the weak relationship between mean scale age and mean otolith age indicated that scales might not provide accurate walleye age estimates. Dorsal-spine sections also offer a nonlethal means of estimating walleye ages, but results from our analysis and from other studies indicate that the use of spine sections did not consistently improve reader agreement rates (Erickson 1983; Kocovsky and Carline 2000) or precision when compared with the use of scales, and low agreement among ages obtained from walleye dorsal spines and otoliths has been reported in other evaluations (Erickson 1983; Marwitz and Hubert 1995). Mean age plots indicated that scale ages more closely reflected ages estimated from whole-view otoliths than spines. After discussions among readers used in this study and based on correspondence with other readers allowed to view the dorsal-spine sections used in our evaluation, much of the observed bias among readers and lack of reader agreement associated with dorsal-spine sections likely stems from the identification of the first annulus. Although the precision of age estimates did not differ significantly between spines and scales in our evaluation, Campbell and Babaluk (1979) demonstrated that spines had higher reader agreement than scales in aging walleyes.

In some populations, the sacrifice of fish for age estimation is not feasible (e.g., endangered stocks, privately owned waters, or low-density populations), whereas for many exploited walleye populations, the sacrifice of age-structured subsamples of fish for otolith removal (e.g., 10 walleyes per 25-mm length-group) would represent very small proportions of the total number of walleyes harvested by anglers during a given year. Based on annual creel surveys, the 139 walleyes used to estimate age structure in Waubay Lake during 2001 represented less than 1% of the estimated number of walleyes harvested annually by anglers from May to August during 1998–2000 (B. Blackwell, South Dakota Department of Game, Fish, and Parks [SDGFP], unpublished data). In Lake Oahe, the 713 walleyes used for age analysis in 2001 represented only 0.1% of the total estimated number of walleyes harvested from the lake during that year (J. Lott, SDGFP, unpublished data).

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