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[Management Brief]

Lake Erie Yellow Perch Age Estimation Based on Three Structures: Precision, Processing Times, and Management Implications

CHRISTOPHER S. VANDERGOOT*
Ohio Department of Natural Resources, Division of Wildlife, Sandusky Fisheries Research Station, 305 East Shoreline Drive, Sandusky, Ohio 44870, USA

MICHAEL T. BUR AND KIPP A. POWELL[1]
U.S. Geological Survey, Great Lakes Science Center, Lake Erie Biological Station, 6100 Columbus Avenue, Sandusky, Ohio 44870, USA

Abstract.—Yellow perch *Perca flavescens* support economically important recreational and commercial fisheries in Lake Erie and are intensively managed. Age estimation represents an integral component in the management of Lake Erie yellow perch stocks, as age-structured population models are used to set safe harvest levels on an annual basis. We compared the precision associated with yellow perch (N = 251) age estimates from scales, sagittal otoliths, and anal spine sections and evaluated the time required to process and estimate age from each structure. Three readers of varying experience estimated ages. The precision (mean coefficient of variation) of estimates among readers was 1% for sagittal otoliths, 5–6% for anal spines, and 11–13% for scales. Agreement rates among readers were 94–95% for otoliths, 71–76% for anal spines, and 45–50% for scales. Systematic age estimation differences were evident among scale and anal spine readers; less-experienced readers tended to underestimate ages of yellow perch older than age 4 relative to estimates made by an experienced reader. Mean scale age tended to underestimate ages of age-6 and older fish relative to otolith ages estimated by an experienced reader. Total annual mortality estimates based on scale ages were 20% higher than those based on otolith ages; mortality estimates based on anal spine ages were 4% higher than those based on otolith ages. Otoliths required more removal and preparation time than scales and anal spines, but age estimation time was substantially lower for otoliths than for the other two structures. We suggest the use of otoliths or anal spines for age estimation in yellow perch (regardless of length) from Lake Erie and other systems where precise age estimates are necessary, because age estimation errors resulting from the use of scales could generate incorrect management decisions.

Yellow perch *Perca flavescens* are the most recreationally and commercially sought after species in the Laurentian Great Lakes (Scott and Crossman 1973). Lake Erie currently provides the most economically important yellow perch fishery in North America, supporting a multimillion dollar industry that has resulted in an average annual harvest of 2,981 metric tons by recreational and commercial fishers over the last decade (Lake Erie Yellow Perch Task Group 2005). Consequently, management of yellow perch is a top priority for the fisheries management agencies that border Lake Erie (Michigan, Ohio, New York, Pennsylvania, and Ontario). Yellow perch also support economically important fisheries in Lake Michigan (Bence and Smith 1999) and numerous inland lakes, such as Lake Oneida, New York (Connelly and Brown 1991), Lake Winnibigoshish, Minnesota (Radomski 2003), and numerous South Dakota lakes (Isermann et al. 2005).

Successful management of a particular fishery is dependent upon the ability of a manager to understand the dynamics of a fish population: specifically, the ability to estimate population size, growth rates, and mortality rates (Ricker 1975; Van Den Avyle 1993; Campana 2001). Age estimation is a crucial step in describing population dynamics. While numerous calcified structures have been used for age estimation (e.g., see DeVries and Frie 1996), scales have been the most widely used structure for freshwater fish in North America (Carlander 1983) because they are easy to remove and do not require fish sacrifice. On Lake Erie, scales have been the primary structure used to estimate the age of yellow perch. However, the validity and reproducibility of ages estimated from scales have received considerable scrutiny (yellow perch: Robillard and Marsden 1996; Baker and McComish 1998; Niewinski and Ferreri 1999; other fish species: Erickson 1983; Heidinger and Clodfelter 1987; Welch et al. 1993; Hoxmeier et al. 2001). The major bias attributed to the use of scales as age estimation structures is the tendency toward underestimation of fish ages; despite this bias, several authors have advocated the use of scales for age estimation studies

* Corresponding author: christopher.vandergoot@dnr.state.oh.us
[1] Present address: Devine Tarbell and Associates, Inc., 970 Baxter Boulevard, Portland, Maine 04103, USA.

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(Robillard and Marsden 1996; Niewinski and Ferreri 1999).

Alternatives to estimating fish age with scales include the use of sagittal otoliths and fin spines, both of which tend to provide more precise and accurate age estimates than scales (Erickson 1983; Heidinger and Clodfelter 1987; Robillard and Marsden 1996; Hoxmeier et al. 2001). However, Niewinski and Ferreri (1999) reported high precision in age estimates for yellow perch aged with otoliths, scales, and dorsal spines, and they stated that scales and dorsal spines can be used to adequately describe the age composition of yellow perch populations. The findings of Niewinski and Ferreri (1999) conflict with those of Robillard and Marsden (1996), who found that otoliths and scales yielded significantly different age frequency distributions and that scales were unable to precisely estimate ages for older individuals (>age 7). Because the management agencies responsible for managing the yellow perch fishery on Lake Erie currently use anal spines, scales, and otoliths in their age determination studies, we conducted this study to investigate the potential age estimation biases associated with each structure. The primary objective was to assess the precision of yellow perch age estimates obtained from anal spines, otoliths, and scales and to calculate estimates of annual mortality derived from each structure to measure the potential impact of age estimation errors (Mills and Beamish 1980). A secondary objective of our study was to evaluate the time required to process and estimate age from each structure, as suggested by Welch et al. (1993) and similar to the work of Isermann et al. (2003). Although Robillard and Marsden (1996) advocated the use of otoliths for fish larger than 150 mm, our study is needed because the length distribution of yellow perch typically harvested in Lake Erie exceeds the yellow perch length range (163–264 mm) used in the Robillard and Marsden (1996) study. For example, in 2006, 8% of the Ohio recreational harvest exceeded 264 mm, and fish larger than 325 mm are routinely harvested (ODNR 2007).

Methods

Sample collection.—By use of a stratified design, yellow perch were sampled from the Ohio waters of Lake Erie via commercial trap nets and bottom trawls between April and June 2003 (i.e., 15 males and 15 females per 10-mm length-group). Age estimation structures (otoliths, anal spines, and scales) were removed shortly after capture, and total length (TL; mm), weight (g), and sex were recorded for each fish. Scales were taken posterior to the pectoral fin (DeVries and Frie 1996), placed in a coin envelope, and allowed to dry for several weeks before being read with a microfiche reader. Sagittal otoliths were taken from the ventral side of the vestibular apparatus, as described by Secor et al. (1991). Otoliths were cracked through the focus and viewed under a dissecting scope (2.5–7.0× magnification), as described by Heidinger and Clodfelter (1987). Anal spines (i.e., the anterior two or three) were pulled out at the joint with a pair of pliers, allowed to dry for several weeks, and cross-sectioned with a Dremel saw, similar to the process described by MacKay et al. (1990). Between three and six cross sections (~1 mm thick) were cut from each spine. Cross sections of each anal spine were read under a compound scope (60× magnification). The second or third cross sections closest to the origin of the second anal spine were determined to offer the clearest (i.e., discernable annuli) images.

Five different readers were used to estimate the ages of yellow perch in our study; each age estimation structure was aged by three individuals with different skill levels (experienced, intermediate, and novice) for that structure. Experienced readers had routinely estimated ages from a particular structure, intermediate readers had not routinely aged fish with the structure but had some experience, and novice readers had little or no age estimation experience with the structure. Random numbers were assigned to each fish and all associated structures to prevent any reader from identifying age estimation structures from the same fish. Each reader estimated age separately without any knowledge of the size or sex of the individual fish or the other readers' age assignments.

To assess the time required to remove and age each structure, 28 yellow perch were collected during July 2004 with a bottom trawl. To estimate processing times, each fish was measured and weighed and an age estimation structure was removed by three individuals familiar with the removal process for all structures. This process was repeated three times (i.e., once per structure) for each fish. Reading times were based on the time required to prepare the structure (i.e., sectioning sagittal otoliths or anal spines) and assign an age to each fish. Processing and reading times were recorded for individuals that were experienced with each age estimation structure.

Data analysis.—Reader bias (i.e., tendency to under- or overestimate age) was assessed graphically using age bias plots (Campana et al. 1995). Mean ages estimated by novice and intermediate readers were plotted against ages determined by an experienced reader for each structure. Age estimation bias among structures was evaluated by plotting the mean ages estimated by the experienced anal spine or scale reader versus ages determined by the experienced otolith reader. Otolith ages estimated by the experienced reader were assumed to represent the true age of an individual fish. Although we did not conduct an age validation study, otoliths have been validated for other percids (e.g., walleyes *Sander vitreus*; Erickson 1983; Heidinger and Clodfelter 1987) and other freshwater fish species (Maceina and Betsill 1987; Welch et al. 1993). Age bias plots are not a statistical comparison of ages derived by one reader relative to another reader; rather, they are a method of determining whether bias exists between the two readers. We determined whether a bias existed by evaluating the proximity of mean age with 95% confidence intervals at each age-group to the equivalence line, which indicates a 1:1 relationship between ages estimated by two readers (Campana et al. 1995). The probability of an experienced anal spine reader, experienced scale reader, and an intermediate otolith reader assigning the same age as an experienced otolith reader was modeled through logistic regression (Agresti 2007). A Hosmer–Lemeshow goodness-of-fit test was used to determine the probability of agreement at length among the structures. Total length was used as the predictor variable, and the probability of agreement with the experienced otolith reader's age estimate was the response variable.

Because there is considerable disagreement about the statistical procedures that are appropriate for assessing precision (Campana 2001; Hoxmeier et al. 2001), age estimation precision was assessed using both percent agreement (Hoenig et al. 1995) and mean coefficient of variation (CV; Chang 1982). Percent agreement graphs were constructed by plotting novice and intermediate reader age assignments (separate plots) against experienced reader age assignments for each structure. A test of symmetry developed by Bowker (1948) was used to determine whether there were any systematic (i.e., positive or negative bias) age estimation differences between readers and among age estimation structures or whether the differences observed were a result of random error (Hoenig et al. 1995). Bowker's (1948) method uses a chi-square (χ^2) distribution to test the hypothesis that ages determined by two readers are symmetric around a 1:1 relationship; a thorough description of this test is described by Hoenig et al. (1995). Age estimation precision was also assessed by calculating percent agreement and CV metrics for age-3 and younger yellow perch and for age-4 and older fish. These metrics were chosen to allow comparison of our results with those of Niewinski and Ferreri (1999). To further investigate the factors influencing precision, CVs were calculated by sex and length-group (<150, 150–199, 200–249, 250–299, and >300 mm); mean CV between males and females within a structure and length-group were compared with *t*-tests. Differences in precision (CV) among age estimation structures within a length-group were tested with analysis of variance (ANOVA). If ANOVA indicated that a significant difference existed, we used a least-significant-difference test to determine which means were significantly different. Mean processing times were compared through use of ANOVA and least-significant-difference procedures. All statistical tests were considered significant at *P*-values less than 0.05.

To investigate the magnitude of potential age estimation errors associated with reader ability and age estimation structure, we estimated total annual mortality (*A*) via catch-curve analysis (Ricker 1975). Sex-specific age–length keys were constructed for each reader ability and structure combination using the Statistical Analysis System (Isermann and Knight 2005). The sex-specific age–length keys were then applied to the commercial trap-net data set ($n = 360$) from which the fish were taken, and *A* was estimated using the combined (i.e., male and female) catch-at-age data. Yellow perch were assumed to be fully recruited to the commercial trap-net gear at age 4 based on catch-curve data analysis, where the descending limb of catch at age for Ohio commercially harvested fish begins (T. Hartman, Ohio Department of Natural Resources [ODNR], personal communication). To corroborate the ages determined by the individual readers, we graphed the relative abundance of yellow perch year-classes observed in ODNR bottom trawls between 2002 and 1994, which encompasses the age-classes observed in our study (ODNR 2007).

Results

Ages were determined for 251 yellow perch ranging in size from 96 to 340 mm TL. Males ($n = 118$) ranged from 96 to 265 mm; females ($n = 133$) ranged from 110 to 340 mm (Figure 1). Reader bias and precision varied among readers and age structures. Based on the age bias plots (Figure 2), there were no discernable age estimation biases associated with reader experience for otoliths, a slight underestimation bias was associated with anal spines, and a systematic underestimation bias was associated with scales. An underestimation bias was evident for intermediate and novice anal spine readers relative to the ages determined by an experienced anal spine reader for fish older than age 6. Underestimation was evident for novice scale readers beginning at age 3 and for intermediate readers beginning at age 4. For the intermediate scale reader, there was 100% agreement with the experienced scale reader for age-8 yellow perch; however, only one fish was assigned to age 8. Based on 95% confidence intervals, the variability in reader age assignments

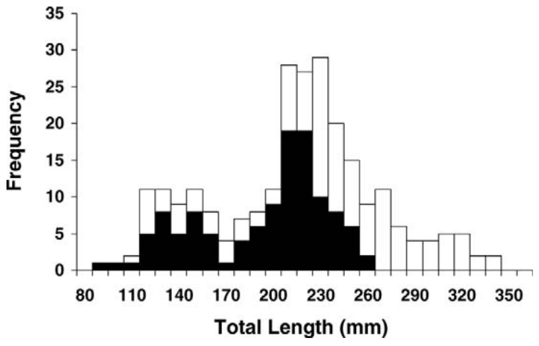

FIGURE 1.—Length frequency distribution of male (darkened bars) and female (open bars) yellow perch aged with anal spines, scales, and sagittal otoliths after collection from Ohio waters of western basin Lake Erie during spring 2003.

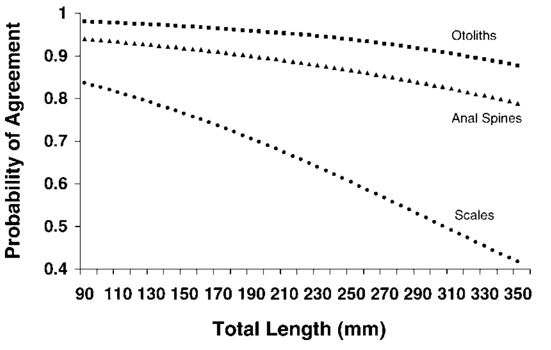

FIGURE 3.—Probability of agreement between western basin Lake Erie yellow perch age assigned by an experienced otolith reader and that estimated by an experienced anal spine reader (black triangles), an experienced scale reader (black circles), or an intermediate otolith reader (black squares). Agreement probability is presented in relation to fish total length.

increased for fish older than age 6 when anal spines were used and for fish older than age 5 when scales were used. For a 200-mm yellow perch, the probability of age agreement between reader pairs was 90% for an experienced anal spine reader and an experienced otolith reader, 69% for an experienced scale reader and an experienced otolith reader, and 96% for intermediate and experienced otolith readers (Figure 3). Reader precision in percent agreement was highest for otoliths (mean = 94.5%, SE = 0.5%), intermediate for anal spines (mean = 73.5%, SE = 2.5%), and lowest for scales (mean = 47.5%, SE = 2.5%; Table 1). Similarly, CVs were lowest (i.e., precision was highest) for otoliths and highest for scales (Table 1). Results of symmetry tests indicated that systematic differences existed ($P < 0.05$) between the ages determined by novice or intermediate readers and those estimated by experienced readers using anal spines or scales but not otoliths (Table 1). Age bias plots indicated that there was no apparent age estimation bias between anal spine and otolith readers (Figure 4). However, underestimation bias was observed for age-6 and older fish in

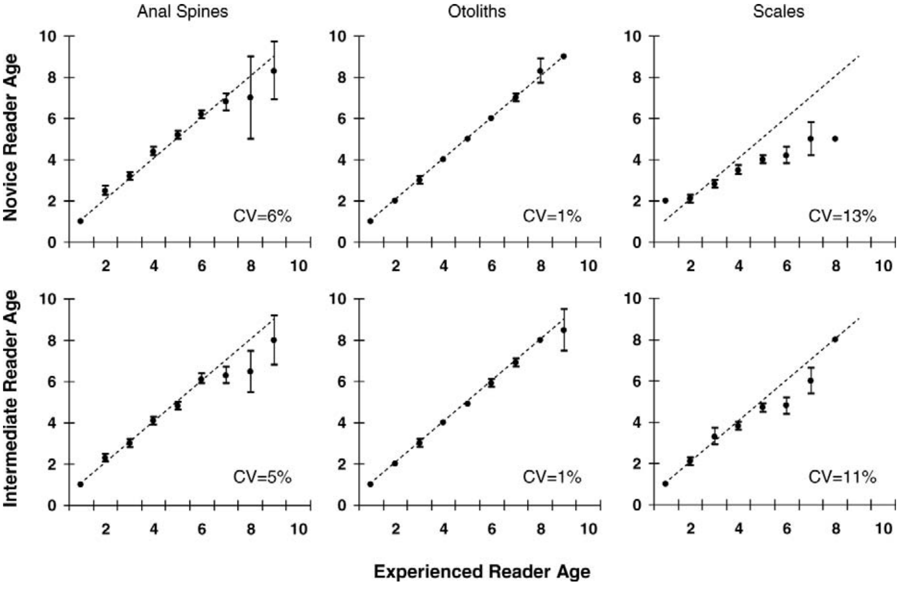

FIGURE 2.—Age bias plots comparing agreement between western basin Lake Erie yellow perch ages assigned by a reader experienced in estimating age from anal spines, otoliths, or scales and a novice or intermediate reader of the same structure (mean coefficient of variation [CV] is given for each plot). Diagonal lines represent full agreement between readers.

TABLE 1.—Percent agreement (%) and coefficient of variation (CV; ±SE) for western basin Lake Erie yellow perch ages estimate from anal spines, otoliths, or scales by a novice or intermediate reader and those assigned by an experienced reader (fish were collected in 2003). Bowker's (1948) symmetry test statistics (df, chi-square [χ^2], and P) describe percent agreement comparisons (*$P < 0.05$).

Structure	Reader	Agreement with experienced reader %	df	χ^2	P	CV (%)
Anal spine	Novice	71	14	56.0	0.00*	6 (0.7)
	Intermediate	76	13	32.3	0.00*	5 (0.6)
Otolith	Novice	94	7	8.0	0.33	1 (0.2)
	Intermediate	95	7	13.0	0.07	1 (0.2)
Scale	Novice	45	14	109.4	0.00*	13 (0.9)
	Intermediate	50	10	22.4	0.01*	11 (0.8)

comparisons of scale age and otolith age (Figure 4). Overall, otoliths (mean CV = 1.6%) were more precise than anal spines (mean CV = 7.1%) or scales (mean CV = 16.3%). Age estimation from otoliths and anal spines resulted in similar CV estimates for fish smaller than 150 mm and larger than 250 mm (Table 2). Precision was higher for anal spines than for scales, except in fish smaller than 150 mm. For age-group comparisons (ages ≤ 3 versus ages ≥ 4), the percent agreement with an experienced otolith reader exceeded 86% for experienced anal spine and intermediate otolith readers (Table 3). Percent agreement between an experienced scale reader and an experienced otolith reader was 65% and 68% for the same two age-groups. For each age estimation structure, there was no detectable difference in precision between males and females or among individual length-groups (Table 4).

Values of A calculated from anal spine, otolith, and scale ages varied between 50.3% and 81.3% (Figure 5). Mean A was 73.9% for scales, 55.9% for anal spines, and 53.6% for otoliths. Precision (CV) of A estimates were higher for otoliths (4%) than anal spines (10%) or scales (9%). In general, yellow perch age distributions were similar among otolith readers regardless of experience level. Age distributions were almost identical between the experienced anal spine and otolith readers; however, age distributions differed substantially among scale readers. Ages assigned by the intermediate and experienced otolith readers and the experienced anal spine reader suggested that ages 4, 5, and 7 were common in the sample (Figure 5); these ages coincide with strong to moderately strong year-classes (1998, 1999, and 1996) observed in bottom trawl surveys conducted by ODNR in the western basin of Lake Erie (Figure 6). In comparison with experienced anal spine and otolith readers, the experienced scale reader failed to detect older fish (i.e., ages > 7).

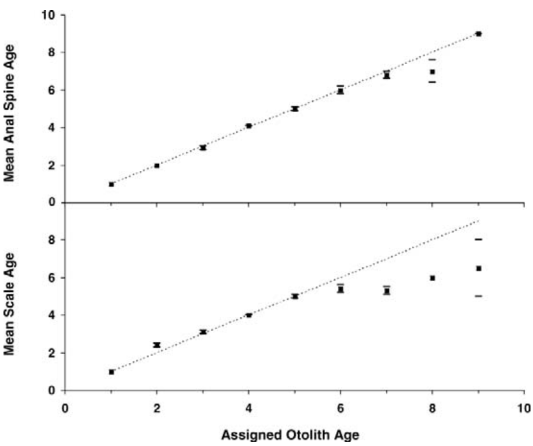

FIGURE 4.—Age bias plots comparing average ages assigned to western basin Lake Erie yellow perch by an experienced otolith reader with those assigned by an experienced anal spine reader (upper panel) or an experienced scale reader (lower panel). Diagonal line represents 1:1 correspondence between age estimates.

The total amount of time needed to process and read a structure was shorter for otoliths and scales than for anal spines (Table 5). Mean processing times for anal spines and scales were similar and shorter than the mean otolith processing time; however, reading time was significantly less for otoliths than for the other two structures. Practically speaking, processing (i.e., measuring and weighing the fish and removing the structure) a sample of 200 yellow perch requires approximately 56 min if scales are used, 63 min if anal spines are used, and 117 min if otoliths are used. For the same 200-fish sample, reading a structure to determine age requires 3.4 h when using otoliths, 5.1 h when using anal spines, and 10.4 h when using scales. Although it takes almost twice as long to remove otoliths than anal spines or scales, reading time is twice as long for anal spines than for otoliths and three times as long for scales than for otoliths.

Discussion

Lake Erie yellow perch ages estimated with otoliths were more precise than ages estimated with scales. Our

TABLE 2.—Mean coefficients of variation (±SE) for western basin Lake Erie yellow perch ages estimated from anal spines, otoliths, and scales (fish were collected in 2003). Within a column, means with differing letters are significantly different ($P < 0.05$).

		Length group (mm)					
Structure	*N*	<150	150–199	200–249	250–299	>300	All
Anal spine	250	8.6 (2.2) zy	11.9 (2.0) y	5.3 (0.7) y	6.6 (1.4) z	6.6 (3.2) z	7.1 (0.6) y
Otolith	248	2.0 (1.1) z	0.2 (0.2) z	1.7 (0.5) z	2.0 (0.9) z	1.4 (0.8) z	1.6 (0.3) z
Scale	250	9.6 (2.8) y	21.3 (2.0) x	15.7 (1.2) x	18.8 (1.9) y	17.1 (2.1) y	16.3 (0.9) x

results were similar to the results observed in Lake Michigan (Robillard and Marsden 1996) and Pymatuning Reservoir, Pennsylvania (Niewinski and Ferreri 1999). In our study, anal spine ages were less precise than otolith ages but more precise than scale ages. Niewinski and Ferreri (1999) found that otoliths, dorsal spines, and scales were highly precise for estimating yellow perch age, but dorsal spines were more precise than scales in estimating ages for age-4 and older fish. Thus, they recommended the combined use of scales for smaller (younger) fish and dorsal spines for longer (older) fish to adequately describe the age structure of yellow perch populations. Similarly, Robillard and Marsden (1996) suggested using otoliths for yellow perch longer than 150 mm in Lake Michigan. Our findings suggest that regardless of yellow perch length, scales were relatively imprecise aging structures and were inadequate for describing the age composition of the Lake Erie population. Agreement between experienced scale and otolith readers was 88% in the Niewinski and Ferreri (1999) study and 68% in our study for age-3 and younger fish. The discrepancy between their results and ours may be attributable to the age distributions in the respective studies. In our study, 1% of age-3 and younger fish (based on otoliths) were estimated as age 1 by an experienced otolith reader compared with 84% in the Niewinski and Ferreri (1999) study. The higher proportion of age-1 fish in their study probably resulted in the higher agreement rates between scale and otolith ages. Likewise, in their study, age 1 was the most numerous otolith age category (60%), whereas in our study, age 4 was the most numerous otolith age (35%). The disparity in age distributions between the two studies may also explain why agreement among scale readers was 83% in the Niewinski and Ferreri (1999) study and only 50% in our study. Between 2001 and 2004, 42–63% of the Ohio yellow perch harvest in Lake Erie was age 3 and younger (ODNR 2006). Because a substantial proportion of the Ohio harvest is typically age 3 and younger, considerable errors in catch-at-age and *A* estimates can occur if scales are used in estimating age, even for the smaller (younger) fish. Furthermore, we suspect that the findings of our study (i.e., a tendency for scales to underestimate age) and those of Robillard and Marsden (1996) and Niewinski and Ferreri (1999) are not limited to the populations where the studies were conducted but are common to other yellow perch populations in North America.

The Lake Erie Yellow Perch Task Group uses harvest-at-age data from the commercial and recreational fisheries to estimate *A*. The *A* estimates were similar between experienced anal spine and otolith readers (<1% difference), whereas *A* estimated by the experienced scale reader was almost 30% higher than estimates from anal spines and otoliths. The tendency to underestimate yellow perch age in Lake Erie prevents fishery managers from tracking cohorts as they progress through the fishery. Such errors in estimating harvest at age and *A* may prevent managers from making informed decisions about population dynamics and abundance of Lake Erie yellow perch.

Reader experience was a factor in age estimation biases associated with this study, especially when scales or anal spines were used. Age estimation precision varied among readers; for each structure, precision was higher (i.e., higher % agreement and lower CV) for the intermediate reader than for the

TABLE 3.—Percent agreement (%) and coefficients of variation (CV = 100 × SD/mean) for western basin Lake Erie yellow perch ages determined by an experienced anal spine reader, an experienced scale reader, or an intermediate otolith reader and ages assigned by an experienced otolith reader for three age-groups (≤age 3, ≥4 age, and combined). Fish were collected in 2003.

		Anal spine		Scale		Otolith	
Otolith age-group (years)	*N*	%	CV	%	CV	%	CV
≤3	67	96	1.2	68	9.2	99	0.4
≥4	183	86	2.2	65	6.6	93	0.9
Combined	250	88	2.0	66	7.3	95	0.8

TABLE 4.—Mean coefficients of variation (%; ±SE) for western basin Lake Erie yellow perch ages estimated from anal spines, otoliths, and scales for each sex and length-group of fish collected in 2003. Within each length-group, no significant differences among structures were observed ($P > 0.05$).

			Length-group (mm)					
Structure	Sex	N	<150	150–199	200–249	250–299	>300	All
Anal spine	Male	117	9.4 (2.9)	11.0 (2.4)	4.9 (0.9)	4.8 (2.7)		7.0 (9.6)
	Female	133	7.5 (3.3)	13.3 (3.7)	5.7 (1.1)	7.0 (1.7)	6.6 (3.2)	7.2 (10.7)
Otolith	Male	118	2.3 (1.6)	0.4 (0.4)	2.2 (0.7)	1.0 (1.0)		1.8 (5.4)
	Female	130	1.8 (1.8)	0.0 (0.0)	1.1 (0.5)	2.2 (1.1)	1.4 (0.8)	1.4 (4.7)
Scale	Male	118	12.5 (4.2)	22.6 (2.1)	16.2 (1.6)	25.2 (6.0)		17.5 (14.6)
	Female	132	5.3 (2.8)	19.0 (4.0)	15.0 (1.8)	17.4 (1.9)	17.1 (2.1)	12.5 (12.6)

novice reader. Previous age estimation studies concur with our results and suggest that biases are often associated with reader experience (Robillard and Marsden 1996; Baker and McComish 1998; Kocovsky and Carline 2000; Isermann et al. 2003). Precision did not appear to be significantly influenced by fish gender, but scale age precision was lower for males than for females. A similar pattern in precision between sexes was not evident for anal spines or otoliths.

The argument for choosing one aging structure over another is often complex. Aside from precision, Lake Erie fishery management agencies are concerned about the amount of time needed to remove, process, and age fish, particularly yellow perch. From our observations, otoliths required more processing time than either scales or anal spines. A similar observation was reported by Isermann et al. (2003) for walleyes. Although the time required to remove and process

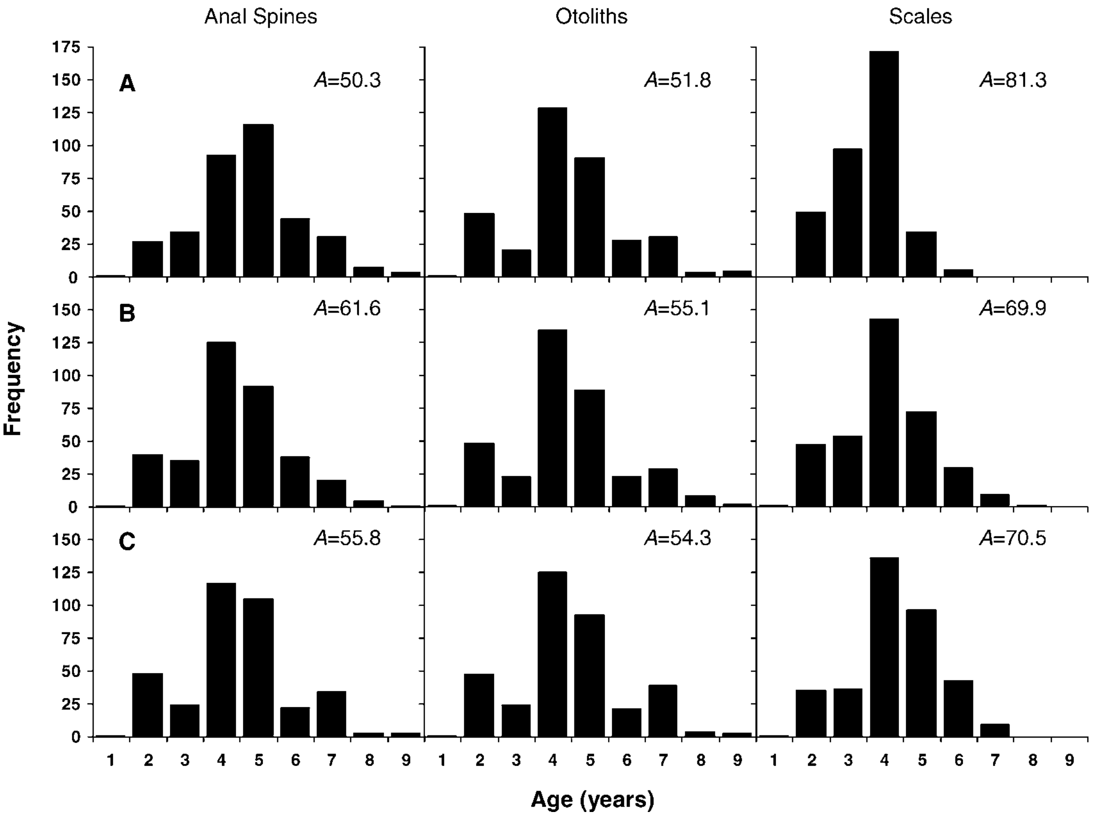

FIGURE 5.—Age frequency distributions of yellow perch from western basin Lake Erie as determined based on anal spine, otolith, and scale age assignments by **(A)** novice readers, **(B)** intermediate readers, and **(C)** experienced readers. The annual mortality (A) estimate is given for each distribution.

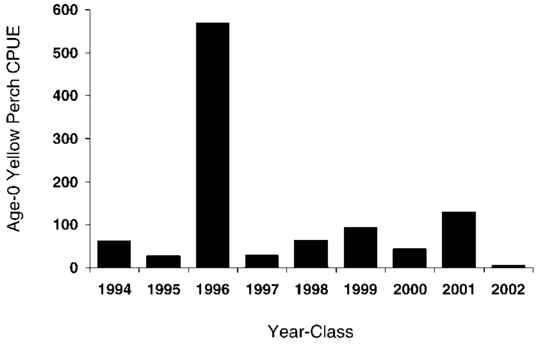

FIGURE 6.—Relative abundance (catch per unit effort [CPUE] in fish/ha) of age-0 yellow perch collected in bottom trawls from the western basin of Lake Erie by the Ohio Department of Natural Resources between 1994 and 2002.

aging structures was calculated differently by Isermann et al. (2003), they found that it took significantly more time to remove otoliths than dorsal spines and scales, similar to our results with yellow perch. In our study, the time required to read otoliths was significantly less than the time required to read scales or anal spines. Isermann et al. (2003) observed that whole-view otoliths required significantly less viewing and aging time than did scales and dorsal spines. Although the results of our study are not directly comparable with those of Isermann et al. (2003; i.e., our otoliths were cracked and polished rather than viewed whole), both studies revealed that percid ages can be estimated with high precision without sectioning the otolith. Robillard and Marsden (1996) noted that readers spent less time estimating yellow perch ages when examining otoliths than when using scales. Although Lake Erie yellow perch otoliths required the least amount of time to read, the total amount of time needed to process and read otoliths was similar to that of scales.

A common reason cited for avoiding the use of otoliths as aging structures is the desire or necessity to avoid sacrificing the fish. In our study, anal spines provided a satisfactory nonlethal age estimation structure. Although less precise than otoliths, anal spine estimates of A were similar to those generated using otoliths; thus, they should be adequate for describing the age composition of yellow perch in Lake Erie. However, anal spines tended to underestimate ages of fish older than age 6; therefore, otoliths should be used for populations in which a large proportion of fish belong to this age-group. Furthermore, in fish that have already been sacrificed due to the nature of the sampling method (e.g., gill nets and harvest surveys), otoliths should be the preferred age estimation structure. Another disadvantage of using anal spines is the difficulty in training individuals to

TABLE 5.—Mean (±SE) processing and reading times for anal spines, otoliths, and scales used to estimate ages of yellow perch collected from the western basin of Lake Erie in 2003. Within a column, means with differing letters are significantly different ($P < 0.05$).

Structure	Processing time (s/fish)	Reading time (s/fish)	Total time (s/fish)
Anal spine	17 (0.4) z	188 (8.7) x	204 (8.7) y
Scale	19 (0.6) z	92 (5.8) y	111 (5.9) z
Otolith	35 (1.9) y	61 (2.6) z	96 (2.8) z

recognize annuli, whereas annuli recognition in otoliths is apparently easier based on the high agreement (>94%) among otolith readers. In exploited yellow perch populations for which harvest-at-age or precise age estimation information is required, structures other than scales should be chosen because of the poor age estimation precision of scales. Anal spines or otoliths should be selected in such cases, because these structures offer a higher level of precision than scales and the amount of expertise required to obtain precise age estimates is minimized. The latter benefit is particularly useful given that the individual(s) responsible for estimating ages of fish often vary over time (e.g., due to employee turnover).

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