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Precision of Ages Determined from Scales and Opercles for Yellow Perch *Perca flavescens*

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ABSTRACT. *Scales and opercles were used to age yellow perch* Perca flavescens *collected in 1989 from Lake Madison (South Dakota), Dauphin Lake (Manitoba), and southern Lake Michigan (Indiana). Three readers aged fish from Lake Madison and Dauphin Lake once and two readers aged fish from Lake Michigan twice. The coefficient of variation (CV) was calculated to compare precision. Ages determined from opercles were as precise as those from scales for fish from Lake Madison (CV = 0 for both structures), and more precise than ages from scales for fish from Dauphin Lake ($CV_{opercle} = 14.0$, $CV_{scale} = 27.4$, $p < 0.001$) and Lake Michigan ($CV_{opercle} = 10.6$, $CV_{scale} = 13.9$, $p < 0.001$). The high precision of scale and opercle ages for yellow perch from Lake Madison can be attributed to the fast growth rate of fish from that lake and also that only age 1 and 2 fish were aged. The greater precision of opercle ages in comparison to scale ages for Dauphin Lake and Lake Michigan yellow perch can be attributed to ease of recognition of false annuli on opercles as well as to difficulty in distinguishing between false and true annuli crowded on the edge of scales from mature, slower growing fish. Because true annuli are more easily recognized on opercles, ages determined from opercles may be more accurate than ages determined from scales for yellow perch growing at slow or moderate rates.*

INDEX WORDS: *Age determination, opercles, scales, precision, yellow perch, Lake Michigan.*

INTRODUCTION

Accurate age determinations are essential for properly managing fish populations (Carlander 1974, Everhart and Youngs 1981). In North America, scales have been the most widely used structure for assessing the age and growth of freshwater fishes (Carlander 1987). However, numerous studies have shown scales may not be as precise or as accurate as other bony structures for age determination, especially for mature fish and for slow growing fish (Frost and Kipling 1959; Campbell and Babaluk 1979; Beamish and McFarlane 1983, 1987; Carlander 1987; Donald *et al.* 1992). Schmitt and Hubert (1982) questioned the validity of scales for yellow perch *Perca flavescens* age determination and concluded that cleithra were probably better than scales for determining age of yellow perch older than age 4 because cleithra annuli were easier to identify in fish older than age 4. Similarly, Robillard and Marsden (1996) found that ages from otoliths were more precise than scale ages for southern Lake Michigan yellow perch.

The earliest record identified in this study for the opercle method of age determination was Nillson (1921) in a study of the European perch *Perca fluviatilis*, who found it easier to use than the scale method of age determination. Since Nillson's study, several European researchers have used opercles to determine the age and growth history of European perch (Roper 1936; LeCren 1947; Craig 1974 a,b, 1980, 1987; Craig *et al.* 1979) and northern pike *Esox lucius* (Frost and Kipling 1959). In these studies, opercles were found to form annual marks and thus were considered to be a valid structure for determining age and growth history. Furthermore, op-

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ercles were judged easier to read than scales and thus were the preferred aging structure.

Opercles have not been widely used to age fish in North America. Despite the successes of European researchers, scales continue to be the aging structure commonly used by North American investigators (Carlander 1987), perhaps because scale collection is relatively easy and nonlethal. However, opercles have been used in North America for aging common carp *Cyprinus carpio* (McConnell 1951), Utah chub *Gila atraria* (Neuhold 1955), walleye *Stizostedion vitreum* (Campbell and Babaluk 1979, Babaluk and Campbell 1987) and goldeye *Hiodon tergisus* (Donald *et al.* 1992). With the exception of Utah chub, researchers concluded that opercles were preferred over scales for determining fish age mainly because opercle annuli were easier to recognize.

The only identified study that utilized opercles for age determination for yellow perch was completed by Bardach (1955) using fish from Lake Mendota, Wisconsin. He concluded that opercles were valid for determining age and back-calculating length. Bardach also concluded that they may be preferred over scales because the relationship between fish length and opercle length was linear but the relationship between fish length and scale length was neither linear or curvilinear.

In southern Lake Michigan, the yellow perch is an important sport fish and until recently supported a commercial fishery. Consequently, accurate age composition data are important to fishery managers for setting harvest regulations. In the 1980s, yellow perch density in the Indiana waters of Lake Michigan increased with a corresponding decrease in growth rates (Gallinat 1987, Stettner 1989). As a result, scale age determination for these slow growing fish became increasingly difficult and ages determined from scales were probably less reliable than in previous years (Ball State University, unpublished data). Because of the difficulties encountered assigning ages to yellow perch from Lake Michigan using scales and because of the successes of assigning ages to European perch using opercles, this study was undertaken to assess the precision of ages determined from opercles and scales for yellow perch.

METHODS

Yellow perch were collected from Lake Madison, South Dakota, with hook and line on 6 and 15 September 1989 and from Dauphin Lake, Manitoba, with graded mesh gillnets during 9 to 11 September 1989. Yellow perch were collected from Lake Michigan with a 4.9 m headrope semi-balloon otter trawl and graded mesh gillnets during June to August 1989.

Lake Madison in southeastern South Dakota is a eutrophic lake with a maximum depth of 6.1 m and a surface area of 1,133 ha (Guy and Willis 1995). Dauphin Lake in central Manitoba is also shallow (maximum depth of 3.5 m) and eutrophic with a surface area of 52,200 ha (Craig and Babaluk 1989). The Indiana waters of Lake Michigan are oligotrophic (Beeton 1965), comprise most of the extreme southern part of the lake, and have an area of approximately 62,300 ha and a maximum depth of 20 m.

The gender of all fish was determined and total length was measured to the nearest mm, except total lengths of fish from Lake Madison were measured to the nearest 1/8 in and converted to mm. Scales were removed from the left side of fish, below the lateral line, at the distal end of the appressed pectoral fin, by scraping the scales out of their sockets with a knife. The knife was wiped clean after taking scale samples to prevent mixing of scales from different fish. Scales were stored in envelopes labeled with lake, fish length, fish gender, date of capture, and a unique number. Opercles were collected (LeCren 1947), placed in labeled envelopes, and stored in a freezer to prevent decomposition of soft tissue and bone. Opercles were cleaned by immersion in ice water for about 1 min followed by immersion in boiling water for about 3 min (LeCren 1947). When opercles were removed from the boiling water, they were easily cleaned with a paper towel by rubbing them between finger and thumb. Cleaned opercles were stored in a new envelope stapled to the original envelope for later identification. Opercles were allowed to dry for several days prior to aging as suggested by LeCren (1947).

Impressions of several scales from each fish were made in acetate and the scale annuli recognition criteria outlined by Jearld (1983) were used to distinguish annuli on scales. Scales were not cleaned prior to making impressions. Scale aging was completed using a tri-simplex microprojector with 40x magnification.

Opercle age was assigned only after the opercle was examined with both a binocular dissecting microscope and a microprojector. In most instances, the left opercle was used for aging. However, the entire Dauphin Lake population sample was aged from the right opercle. Fish age was determined from opercles using the methods, including the annuli recognition criteria, outlined by LeCren (1947). As described by LeCren, true annuli in opercles were characterized by a gradual change from the broad, opaque summer growth zone to a narrow, transparent winter growth zone followed by an abrupt change from the narrow, transparent zone of winter growth to the next broad, opaque zone of summer growth. The annulus was taken to be the sharp line of demarcation between the narrow transparent zone and the next broad opaque zone. False annuli were characterized by an abrupt change from the opaque summer growth zone to a narrow transparent zone and back to an opaque zone.

Three readers independently determined ages from scales and opercles. Reader A was an experienced opercle reader with some scale aging experience and readers B and C were experienced scale readers with no opercle aging experience. Scales and opercles from Lake Madison and Dauphin Lake yellow perch were aged once by each reader. Readers A and B aged Lake Michigan yellow perch from scales and opercles and after several months aged the same fish again for comparison with the original age assignments. In an effort to minimize bias, the fish were aged without knowledge of length or gender. Fish were aged by lake and in order from the smallest to largest fish, and fish from Lake Michigan were aged separately by month starting with August, then July, and finishing with June. All ages and annuli locations were marked on strips of paper that were kept confidential until all aging was complete. Scales were aged independently from opercles and readers did not discuss age determinations until all aging was complete.

Chang's (1982) coefficient of variation (*CV*) was used to evaluate precision (reproducibility) of age determinations. For comparing agreement and precision of a set of age determinations, the *CV* is a better method than either percent agreement or index of average percent error (Beamish and Fournier 1981) because it is statistically more rigorous and, therefore, more flexible (Campana *et al.* 1995). The *CV* for a fish is defined as:

$$CV_j = \frac{\sqrt{\sum_{i=1}^{R} \frac{(X_{ij} - X_j)^2}{R-1}}}{x_j} \times 100 \qquad (1)$$

where R = number of age estimates for fish j, X_{ij} = the ith age determination for the jth fish, and X_j is the average age for the jth fish (Chang 1982, Campana *et al.* 1995). The *CV* for a population is the average of the values for all fish aged. Mean scale age (R = 3) and mean opercle age (R = 3) were calculated for each fish from Lake Madison and Dauphin Lake and these mean ages were used to calculate *CV* for each aging structure. Similarly, mean scale age and mean opercle age were calculated for fish from Lake Michigan from duplicate age assignments of readers A and B (R = 4). The *CV* for opercle age determinations were compared to the *CV* for scale age determinations for all three populations by use of the nonparametric Wilcoxon matched-pairs signed rank test (Zar 1984).

Because the objective of this study was to determine if one aging structure was consistently over- or under-aged in relation to the other, symmetry was tested between the scale and opercle ages within readers and lakes by use of a Bowker type χ^2 test of symmetry (Hoenig *et al.* 1995). When agreement between aging methodologies (or readers) is poor, the symmetry test can be used to determine if discrepancies are systematic or random. Finally, age-bias plots (Campana *et al.* 1995) were constructed for each reader using the opercle age as the abscissa. Age-bias plots are a graphical method used to detect systematic differences between age assignments of readers or, in this case, between structures aged. The scale age assignments were graphed as the mean and 95% confidence intervals for each opercle age category.

RESULTS

Precision

Age was determined for 64 fish from Lake Madison; 40 females and 24 males. The fish were between 171 and 276 mm long and all were age 1 except three females which were age 2. Age determinations among readers and between structures were in 100% agreement and so *CV* was 0 for both scale and opercle age determinations (Table 1). The mean total length of Lake Madison yellow perch at age 2 was 275 mm.

265 yellow perch were aged from Dauphin Lake; 176 females and 89 males. The fish were between 95 and 293 mm long and ranged in age from 0 to 8 years. The *CV* values indicated opercle ages were significantly more precise than scale ages (Table 1, $p < 0.001$). Percent agreement between scale and opercle ages was nearly three-fold higher for readers A and B than for reader C (Table 2). The test of symmetry demonstrated that all three readers were

TABLE 1. ***Mean coefficient of variation values (standard errors in parentheses) for ages assigned to yellow perch from three lakes aged from scales and opercles. Coefficient of variation values for Lake Madison and Dauphin Lake were calculated from age assignments of three readers whereas coefficient of variation values for Lake Michigan were calculated from the duplicate age assignments of two readers. Significant differences ($p < 0.001$) between scale and opercle coefficient of variation scores within a population are indicated by an asterisk.***

Structure	Lake Madison	Dauphin Lake*	Lake Michigan*
Scale	0 (0)	27.4 (1.4)	13.9 (1.2)
Opercle	0 (0)	14.0 (1.2)	10.6 (1.2)

biased in their age assignments (Table 2). However, readers A and C assigned older ages from scales than from opercles, whereas reader B assigned older ages from opercles (Fig. 1). The mean total length at age 2 of Dauphin Lake yellow perch was 130 mm.

Readers A and B aged 208 yellow perch from Lake Michigan. The fish were 60 to 366 mm long and from 0 to 10 years old. The combined, duplicate age assignments of readers A and B indicated that ages from opercles were significantly more precise than ages from scales (Table 1). Percent agreement between initial scale and opercle age assignments was similar for readers A and B (Table 2). However, reader A assigned older ages from scales than from opercles, as indicated by the test of symmetry, whereas there was no systematic difference between the initial age assignments of reader B (Fig. 2). The mean total length at age 2 of Lake Michigan yellow perch was 115 mm.

Discussion

Before ages of fish from a particular waterbody are used as the basis for prescribing management actions, it is important to validate the accuracy of the ages. However, this important step is often ignored or difficult to accomplish (Beamish and McFarlane 1983, Robillard and Marsden 1996). In this study it was not possible to validate the annual nature of the marks on the scales and opercles of the fish. However, other investigators have validated the annual marks on opercles. Babaluk and Campbell (1987) marked walleye with tetracycline and released them back to the waterbody where captured. The released fish were recaptured up to 2 years later and in each case ($n = 10$) there was complete agreement between the number of annuli distal to the tetracycline mark and the number of years since a fish was marked. Further, marginal increment analysis results presented by Craig (1974b) conclusively demonstrated that the marks on the opercles of European perch were annual and could be used to determine fish age.

Previous investigators have found that precision of age determinations can depend on several factors including reader experience, reader bias, fish growth rates, and structures aged (Frost and Kipling 1959, Campbell and Babaluk 1979, Donald *et al.* 1992, Hoenig *et al.* 1995, Robillard and Marsden 1996). The results of this study indicate that opercles provide more precise, and potentially more accurate, ages than scales for fish that are growing at slow or moderate rates. Although results varied among lakes and between aging structures within lakes, opercle ages were more precise than scale

TABLE 2. ***Percent agreement between ages assigned to yellow perch from scales and opercles by various readers and results of X^2 tests of symmetry. Significant departures from symmetry ($p < 0.01$) are indicated with an asterisk.***

	Reader								
	A			B			C		
Lake	% Agreement	X^2	df	% Agreement	X^2	df	% Agreement	X^2	df
Madison	100	—		100	—		100	—	
Dauphin	68	69.1^*	13	69	51.0^*	15	24	194.0^*	16
Michigan**	48	51.8^*	24	55	17.6	16	—	—	

** Percent agreement and test of symmetry evaluated only for initial age assignments of two readers.

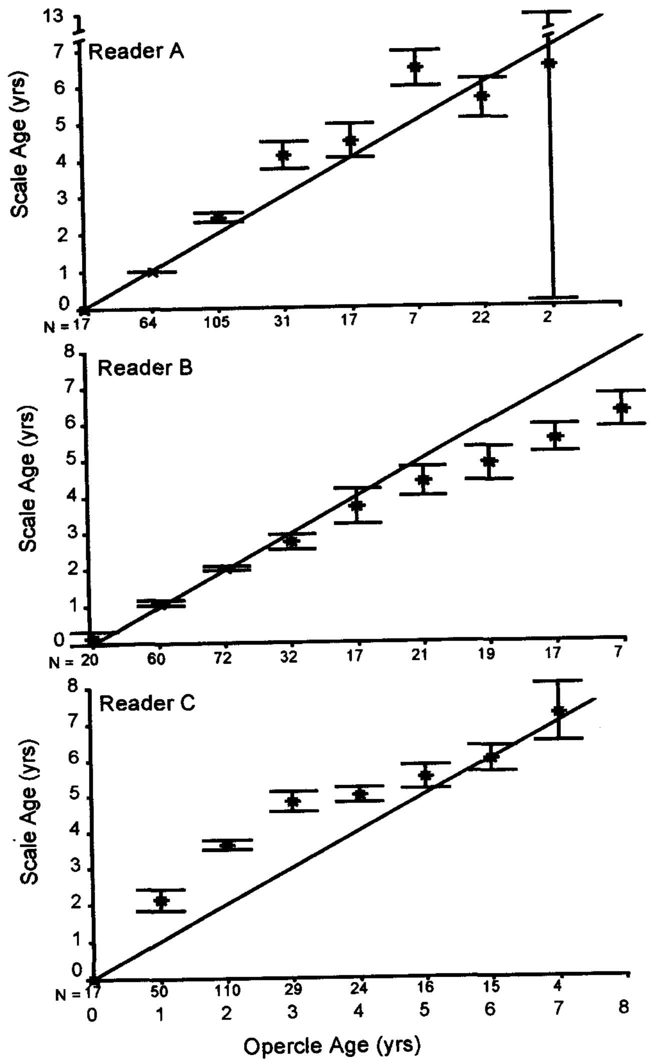

FIG. 1. Age bias plots for yellow perch from Dauphin Lake for each of three readers comparing ages assigned from opercles with ages assigned from scales. Error bars represent 95% confidence interval about the mean scale age for fish of each opercle age. Diagonal lines represent mean scale age equal to opercle age.

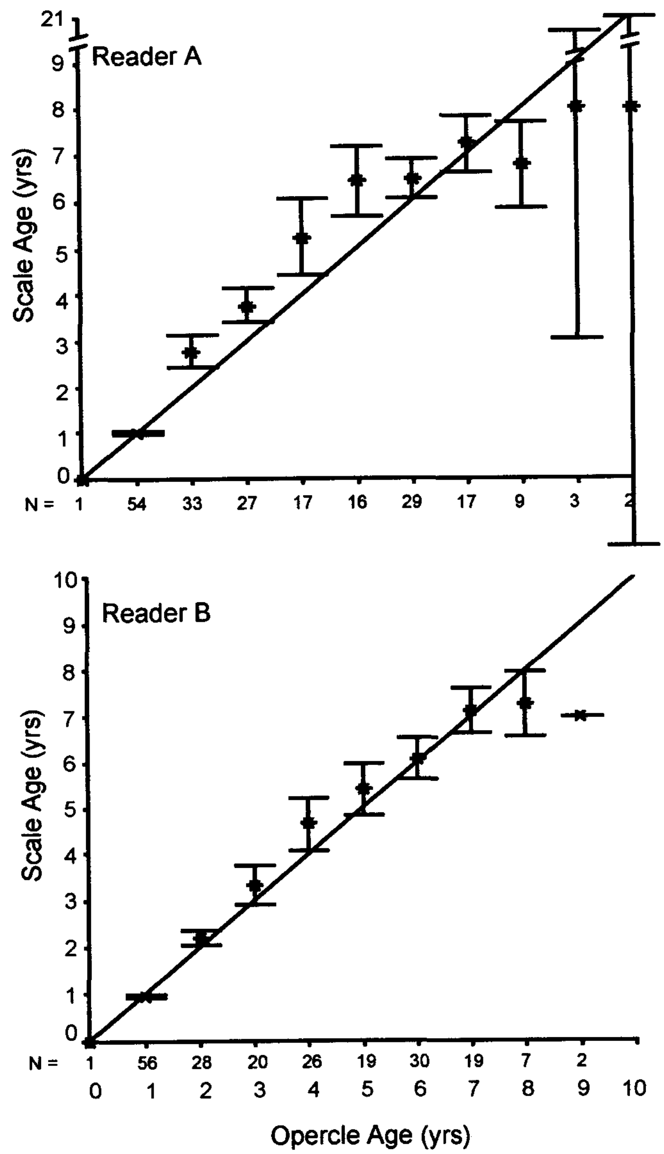

FIG. 2. Age bias plots for yellow perch from Lake Michigan for two readers comparing initial ages assigned from opercles with initial ages assigned from scales. Error bars represent 95% confidence interval about mean scales ages for fish of each opercle age. Diagonal lines represent mean scale age equal to opercle age.

ages for yellow perch from Lake Michigan and Dauphin Lake. Based on the mean length of age 2 fish from each population, the fish from Lake Michigan and Dauphin Lake were growing slower than fish from Lake Madison and ages from scales and opercles of Lake Madison fish were identical. These results suggest that growth rate and age can affect the results of an age determination study. Others have noted that accuracy and precision of age determinations are affected by the fish's growth history (Beamish and MacFarlane 1983, Carlander 1987). Because the true growth rates of the fish investigated in this study are not known (each fish had multiple length-at-annulus estimates from the multiple age assignments), it was not possible to statistically test for a growth effect on age determinations. However, it is possible to make qualitative statements about the impacts of growth rate on the precision of age assignments.

The results suggest that yellow perch that grew rapidly were easy to age from scales and opercles. The yellow perch from Lake Madison were the fastest growing fish (2-year-old fish were up to 276 mm long) and the age assignments of the three readers and from both aging structures were in complete agreement. Annuli were easy to recognize on scales and opercles of Lake Madison yellow perch and false annuli were not present on either structure. Kruse *et al.* (1993) also found high age agreement among three readers and between scales and otoliths for fast growing black crappie *Pomoxis nigromaculatus* from South Dakota. Hammers and Miranda (1991) aged fast growing white crappie (*Pomoxis annularis*) from Mississippi and found that the rate of agreement between scale ages was 79% and was 91% for otolith ages.

In contrast to the results from Lake Madison, precision of ages assigned to yellow perch from Dauphin Lake and Lake Michigan was considerably lower from scales and opercles. The fish from Dauphin Lake and Lake Michigan were relatively slow growing (the mean length of age 2 Lake Michigan yellow perch was 115 mm and was 130 mm for Dauphin Lake yellow perch) in comparison to the Lake Madison fish which probably contributed to lower precision estimates for Dauphin Lake and Lake Michigan. The scales and opercles of age 4 and older fish from these two lakes had annuli crowded near the margins. In addition, many of the opercles of fishes from Dauphin Lake and Lake Michigan had recognizable false annuli whereas the crowded annuli near the scale margins were difficult to distinguish as true or false annuli. LeCren (1947) also found that opercles of the European perch had false annuli that were easier to recognize than false annuli on scales.

Reader bias contributed to poor precision. When there was a discrepancy between scale and opercle age assignments for yellow perch from Dauphin Lake and Lake Michigan, reader A consistently assigned older ages from scales than from opercles (Table 2, Figs. 1 and 2). The other two readers did not consistently assign a higher age from one structure. Reader B consistently assigned older ages from opercles of fish from Dauphin Lake but did not consistently assign older ages from either structure for fish from Lake Michigan. Reader C assigned older ages from scales to Dauphin Lake yellow perch, a bias opposite to that of reader B but similar to that of reader A. The different biases of readers B and C cannot be explained. However, the lack of experience aging scales may have contributed to reader A systematically over-aging scales in relation to opercles. These results are in partial agreement with those presented by Robillard and Marsden (1996). In their study, scales were also less precise than the alternate aging structure (otoliths) for yellow perch from Lake Michigan. However, they found that scale ages were younger than otolith ages for fish older than otolith age 7 whereas here it was found that scale ages were most often older than opercle ages. A likely explanation for the older scale ages assigned by readers A and C is they counted false annuli as true annuli on scales but not on opercles.

The results also suggest that precision of age determinations is greater if readers have had prior experience aging fish from the lake. Investigators at Ball State University have been monitoring the yellow perch population in Indiana waters of southern Lake Michigan since the middle 1970s (Gallinat 1987, Baker 1989, Stettner 1989, Shroyer and McComish 1998). As a result, each reader had at least 2 years' experience aging yellow perch from Lake Michigan prior to this study. It is possible that familiarity with growth patterns on scales of Lake Michigan yellow perch contributed to the high degree of precision in assigning ages to Lake Michigan fish. In contrast, the readers had no prior experience aging fish from either of the other two lakes.

Although all aging was completed blind, there may still be a question about bias introduced by aging the fish in order from smallest to largest. It seems likely that there was little or no bias introduced by this aspect of the procedure because it is possible to judge the relative size of a fish based on the size of the bone, irrespective of the order that fish were aged. Furthermore, any potential bias that might have been introduced was constant because all readers followed the same protocol.

Finally, because there was no way of knowing the true age of the fishes, it was not possible to determine if opercle ages are more accurate than scale ages. However, because annuli do not become as crowded at the edge of the opercle as they do at the edge of the scales in older fish, it seems likely that opercle ages may be more accurate than scale ages when yellow perch are growing at moderate or slow rates.

Scales will likely continue to be commonly used for determining age and back-calculating length at annulus for yellow perch in North America because of tradition and ease of collection. However, the only true advantage of using scales is they can be collected without sacrificing the fish. Here it was demonstrated that opercles can be more precise than scales for determining the age of yellow perch. Robillard and Marsden (1996) demonstrated that otoliths were also more precise than scales for yellow perch from Lake Michigan. Therefore opercles or otoliths should be used in lieu of scales, particularly if the yellow perch are mature or growing slowly. Finally, opercles can be easily used for back-calculating length at annulus (Bardach 1955, Baker 1989). In contrast, length at annulus can not be calculated from sectioned otoliths because of the difficulty in splitting the otolith directly through the nucleus (Jearld 1983).

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