Comparison of Otolith and Scale Ages for Yellow Perch from Lake Michigan

Article *in* Journal of Great Lakes Research · December 1996

DOI: 10.1016/S0380-1330(96)70967-X

J. Ellen Marsden
University of Vermont

J. Great Lakes Res. 22(2):429–435
Internat. Assoc. Great Lakes Res., 1996

Comparison of Otolith and Scale Ages for Yellow Perch from Lake Michigan

Steven R. Robillard and J. Ellen Marsden
Illinois Natural History Survey—Lake Michigan Biological Station
400 17th Street
Zion, Illinois 60099

ABSTRACT. *The age composition of the yellow perch* (Perca flavescens) *population in Lake Michigan is assessed annually by five management agencies, but all agencies do not use the same structure to estimate ages. The reliability of the most commonly used structure, scales, has not been formally evaluated for this population. We compared ages estimated by three readers from scales and sagittal otoliths for 150 yellow perch from southwestern Lake Michigan. The maximum age of yellow perch determined from scales and otoliths was 12. Otoliths had better precision (reproducibility) and usually had more annuli than scales for all three readers. Scale ages were usually younger than otolith ages when otolith ages were ≥ 7. Chi-square tests revealed significant differences ($P < 0.05$) between the age distributions determined from scales and otoliths for two of the three readers. We recommend use of otoliths for aging Lake Michigan yellow perch greater than 150 mm in length because of greater precision, easier readability, and detection of more annuli.*

INDEX WORDS: *Yellow perch, age, otolith, scale, Lake Michigan.*

INTRODUCTION

Yellow perch (*Perca flavescens*) support multi-million dollar fisheries in Lake Michigan. Because of their recreational and commercial importance, management agencies from the four states bordering the lake and the Chippewa\Ottawa Treaty Fisheries Management Authority continually monitor the harvest (Francis *et al.* 1996). Estimates of year-class strength and annual mortality rates are used to determine harvest quotas and predict future yields. Thus, calculation of these indices requires reliable fish-aging methodologies.

Lake Michigan yellow perch are aged from scales, otoliths, operculae, or a combination of these structures; most agencies use ages determined from scales directly or as a verification (backup) to ages estimated from another structure. However, different scales from the same yellow perch may yield different age estimates (Joeris 1956). Scales have been the preferred aging structure for all fish because they are relatively easy to collect without sacrificing the fish (Everhart and Youngs 1981), but the accuracy of the scale method is questionable, as it has seldom been successfully validated (Casselman 1983; Beamish and McFarlane 1983, 1987).

Some studies have shown that there is a strong correlation between scale ages and ages determined from other bony structures in small, eutrophic systems where growth rates and exploitation rates are high or species are short lived, though this does not hold true for the oldest individuals (Belanger and Hogler 1982, Erickson 1983, Frie *et al.* 1989, Laine *et al.* 1991). However, in large oligotrophic systems such as Lake Michigan, ages determined from scales and otoliths may begin to diverge at earlier fish ages. O'Gorman *et al.* (1987) found that ages determined from otoliths with four or more annuli agreed only 56% of the time, and differed by as much as 3 years, with scale ages for Lake Michigan alewives (*Alosa pseudoharengus*).

Consistent underaging of fish results in overinflation of abundance, growth, and production estimates, and underestimation of mortality rates (Powers 1983, Beamish and McFarlane 1987). These estimates are required to determine commercial and sport-harvest targets and prevent overfishing of naturally reproducing species. Management decisions based on erroneous ages can have serious impacts on heavily exploited fish populations such as Lake Michigan yellow perch.

Validation of an aging technique is necessary to insure the accuracy of age composition data. However, validation of ages from species that inhabit large aquatic systems and migrate long distances is often difficult and may require years of intensive study (Beamish and McFarlane 1995). In light of this fact, technique precision may provide a short-term, easily obtained comparison of the available techniques until validation can be accomplished. We therefore concentrated our investigation on the precision and distribution of scale and otolith age estimates for yellow perch from Lake Michigan.

METHODS

Yellow perch were captured in 1.2 × 1.8 m double-ended fyke nets between mid-May and the end of June, 1994, in the Illinois waters of southwestern Lake Michigan, near Lake Bluff. The stretched measure of the nets was 38 mm (1.5″) and all yellow perch over 150 mm were equally susceptible to capture. A random subsample of 25 fish was collected from each net for aging; if the total catch in the net was less than 25, all fish were collected. A total of 715 fish was collected over the entire season. Specimens were usually frozen and stored for up to 1 month before scales and sagittal otoliths were removed; some specimens had the structures removed shortly after capture. For this study, we analyzed 150 randomly selected pairs of scales and otoliths; these 150 fish were between 163 and 264 mm (mean = 207 mm) in total length.

Scales were collected posterior to the left pectoral fin as suggested by Jearld (1983), cleaned for 60 seconds in a 10% bleach solution to remove slime residue, rinsed, and viewed anterior end up with a microfiche reader at 42× magnification. Between readings, scales were stored in numbered scale envelopes with a paper insert to facilitate removal.

Otoliths were extracted and stored in 95% ethanol for a minimum of 24 hours. Forceps were used to remove the membrane surrounding each otolith. Otoliths were manually broken through the nucleus, perpendicular to the anterior-posterior axis, using thumbnail pressure. Usually the posterior half was examined, but when the anterior half contained the entire nucleus, that half was ground on 400 grit sandpaper to expose the nucleus. The broken surface of each otolith was burned briefly in the flame of an alcohol lamp to enhance the distinction between reflective and absorptive zones. Each otolith was mounted in clay, charred surface up, on a numbered microscope slide. The charred surface was wetted with immersion oil before viewing with reflected light under a dissecting microscope at 30-60× magnification. All otoliths remained mounted on their respective slides during the study.

Scales and otoliths were each aged twice by three readers. Readers 1 and 3 were experienced in aging Lake Michigan yellow perch from both scales and otoliths. Reader 2 had no experience aging fish with either structure prior to the study. Random numbers were assigned to all structures during the first reading to preclude the readers from identifying otoliths and scales from the same fish. Otoliths from all 150 fish were aged by all three readers first, then scales were aged. Scale and otolith order was then changed by random number generation before the second reading. Each reader aged fish independently without the knowledge of the other readers' age assignments. Readers were only aware of year and season of capture of the fish. Discrepancies in ages assigned to fish were not discussed or reconciled.

A minimum of five non-regenerated, readable scales from each fish were examined. Age agreement among three scales was required to assign an age to that fish. The term "age" refers to the number of markings interpreted to be annuli on a given structure. Criteria for identifying annuli on scales included the crowding of circuli, cutting over of the annulus across previously deposited circuli, and changes in circuli thickness (Jearld 1983). Spacing between scale annuli was assumed to be regular, i.e., the reader assumed that a year of little growth was not followed by a year of markedly increased growth. On otoliths, the absorptive zones that appeared as dark bands on the charred surface of the otolith were counted as annuli if they were conspicuous in the ventral field and if they were apparent somewhere in the dorsal field (Fig. 1). Usually, the otolith and scale margin was counted as an annulus, but when there appeared to be "new" growth at the margin, the margin was not counted as an annulus.

Precision is the measure of repeatability of age determinations (Wilson *et al.* 1987). We assessed precision with the index of average percent error (APE) rather than the often used percent agreement, because APE is not independent of fish age (Beamish and Fournier 1981). The average percent error in aging the *j*th fish is defined in Beamish and Fournier (1981) as

$$\mathrm{APE}_j = 100 \times \frac{1}{R} \sum_{i=1}^{R} \frac{|X_{ij} - X_j|}{X_j},$$

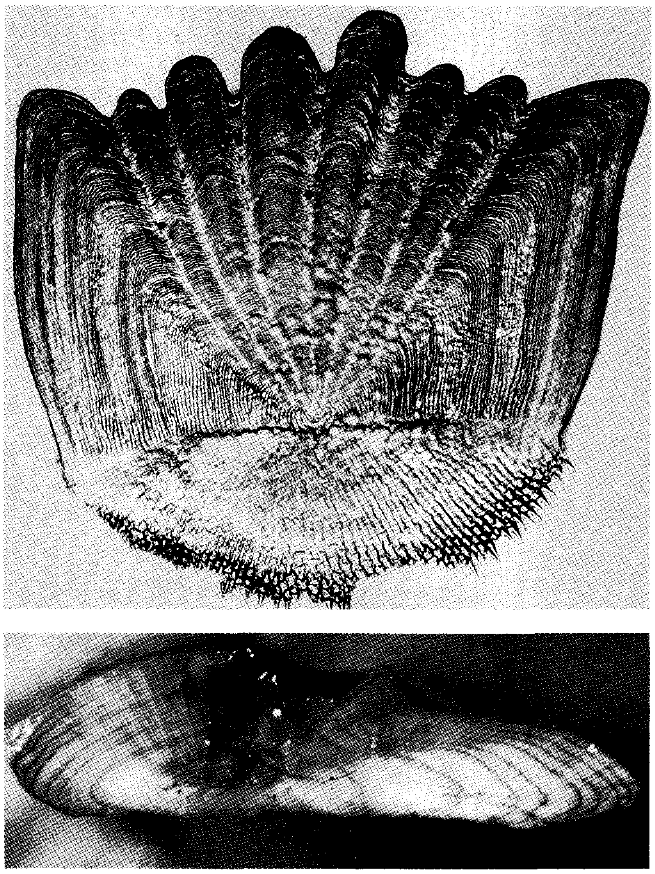

FIG. 1. Scale (top) and sectioned sagittal otolith (bottom) from a Lake Michigan yellow perch. The ages assigned to the fish from this scale by the three readers were 7, 8, 5, 9, 8, and 9; the ages from the otolith were 9, 9, 9, 9, 9, and 9.

where X_{ij} is the ith age determination of the jth fish, X_j is the average age calculated for the jth fish, and R is the number of times each fish is aged. When APEj is averaged across many fish it becomes the index of average percent error.

Two other measures of precision were calculated: the coefficient of variation (CV), which is based on variances that are considered to be unbiased, and the index of precision (D), which expresses the percent error contributed by each observation to the average age-class (Chang 1982). The coefficient of variation is written as

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

The index of precision was only calculated for comparison among the three readers, because D = APE when R = 2. The index of precision, which is similar to CV, is calculated as

$$D_j = \frac{CV_j}{\sqrt{R}}.$$

Otolith- and scale-age frequency distributions were compared by Peterson Chi-square (Zar 1984). We assessed disagreement between ages with age-bias plots (Campana *et al.* 1995). Age-bias plots can be used to compare one age reading versus another with reference to an equivalence line. Systematic differences are illustrated by the difference between the observed average ages and the equivalence line.

RESULTS

The three readers did not assign ages to some of the fish from scales because three scales with the same number of annuli were not found or because there was an insufficient number of non-regenerated scales. However, each reader assigned an age to all 150 fish from otoliths. Mean ages of the sample using scales were 6.0, 5.9, and 7.0 for readers 1, 2, and 3, respectively, compared to 6.6, 6.2, and 6.5 for mean ages estimated using otoliths. All ages from scales and otoliths were between 3 and 12. There was a poor correlation of length with age. Of the 715 subsampled fish aged using otoliths, 6-year-old fish (n = 243) were between 179 and 277 mm in total length, while 12-year-old fish (n = 13) were between 178 and 251 mm.

Precision in age assignments for both structures was directly proportional to each reader's level of experience. Of the two experienced readers (1 and 3), the precision of age assignments reflected their relative levels of experience, i.e., reader 1 was more experienced than reader 3. The inexperienced reader (2) was the least precise of the three readers. Otolith ages were more precise than ages determined from scales for all readers (Table 1). Similarly, precision of otolith ages among the three readers was also better than precision of scale ages. In both comparisons, i.e., agreement within and among readers, ages assigned to otoliths never varied by more than 2 years whereas ages assigned to scales varied by 5 years.

The difference in precision between scale and otolith ages did not, for the most part, appear to affect age-frequency distributions (Fig. 2). Peterson

TABLE 1. Three measures of the precision of three readers' age determinations from otoliths and scales for Lake Michigan yellow perch (n = number of comparisons, APE = Average Percent Error [a], CV = Coefficient of Variation [b], D = Index of Precision [b], age 1 = age assignment at first reading, age 2 = age assignment at second reading).

Reader	Comparison	n	APE	CV	D
1	Otolith age 1: age 2	150	0.81	1.14	= APE
	Scale age 1: age 2	140	4.69	6.63	= APE
2	Otolith age 1: age 2 to otolith 2	150	2.09	2.96	= APE
	Scale age 1: age 2	136	8.24	11.65	= APE
3	Otolith age 1: age 2	150	1.35	1.91	= APE
	Scale age 1: age 2	134	6.51	9.21	= APE
1, 2, 3	Otolith age 1	150	2.76	3.63	2.10
1, 2, 3	Scale age 1	138	9.33	12.68	7.32

[a] Beamish and Fournier 1981
[b] Chang 1982

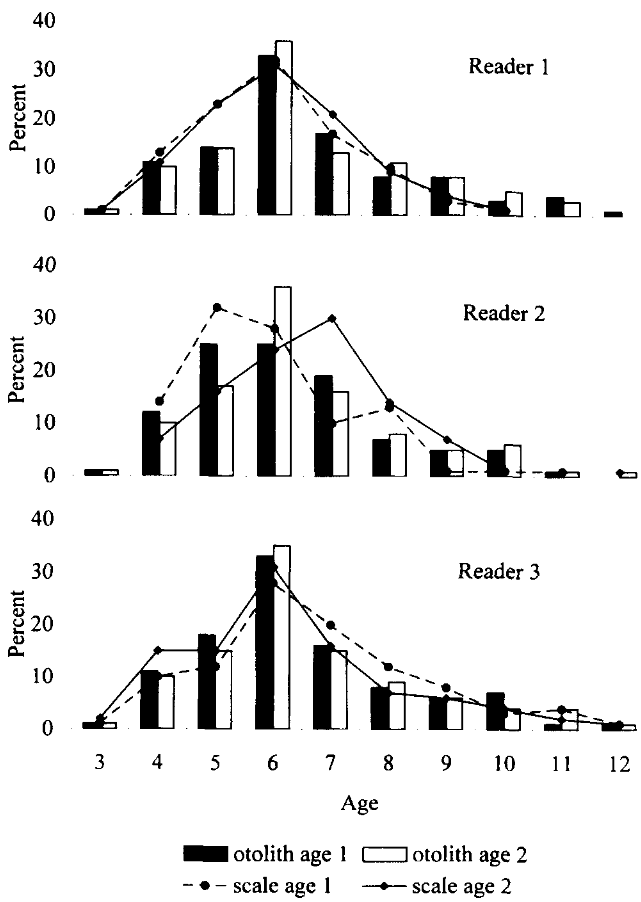

FIG. 2. Age-frequency distributions of Lake Michigan yellow perch determined by three readers from two readings of scales and otoliths.

chi-square tests revealed no significant difference between each reader's age-frequency distributions from the same structure, except for reader 2's scale-age distributions ($P \geq 0.05$). Otolith-age distributions differed significantly ($P < 0.05$) from scale-age distributions for readers 1 and 2.

No consistent disagreement could be visually detected from the age-distribution plots for repeated scale or otolith age determinations (Figs. 3a, b). Regression analysis of data from the age-distribution plots yielded correlation coefficients of 0.77, 0.65, and 0.79 for scale age determinations for readers 1, 2, and 3, respectively, compared to 0.98, 0.95, and 0.97 for otolith age determinations (Figs. 3a, b). Age-bias plots revealed that repeated scale readings (Fig. 4a) agreed less than repeated otolith readings (Fig. 4b). Regression of the otolith-scale comparison data from Figure 3c yielded correlation coefficients of 0.62, 0.57, and 0.55, respectively, for the three readers. However, the age-distribution plot is not as rigorous as the age-bias plot for comparison between structures when fish ages disagree at both ends of the distribution (Campana *et al.* 1995). The age-bias plots comparing ages determined from otoliths and scales for all three readers revealed a systematic error; fish were usually underaged by scales relative to otoliths when otolith age exceeded 7 (Fig. 4c).

DISCUSSION

We conclude that otoliths of adult yellow perch from Lake Michigan provide better age estimates

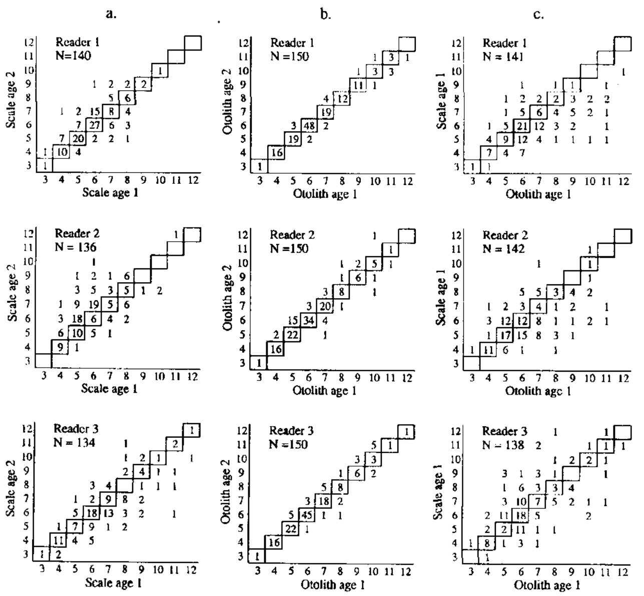

FIG. 3. Age-distribution plots summarizing pairwise comparisons: (a) repeated scale readings, (b) repeated otolith readings, and (c) scale and otolith readings; of three readers' yellow perch age estimates.

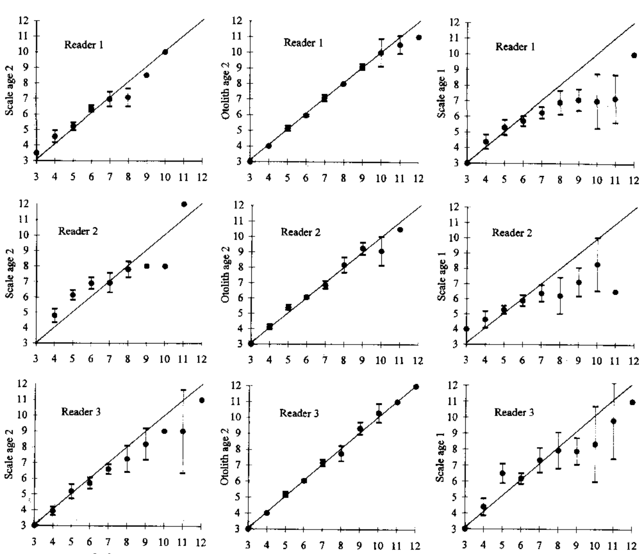

FIG. 4. Three readers' age-bias plots comparing (a) two reading of the same scales, (b) two readings of the same otoliths, and (c) one reading of scales and otoliths. Errors bars represent 95% confidence intervals around the mean. The diagonal line is the 1:1 equivalence line.

than scales because otoliths are more precise than scales. These findings are similar to other studies in which otolith ages were found to be more precise and thus were believed to be more accurate than scales (Erickson 1983, Goeman *et al.* 1984, Boxrucker 1986). Other structures such as cleithra (Le Cren 1947, Laine *et al.* 1991), operculae (Donald *et al.* 1992), and fin rays and spines (Mills and Beamish 1980, Frie *et al.* 1989) have also been shown to have greater precision than scales, especially at older ages.

The poor precision of the scale method may stem from accessory checks or false annuli on scales and crowding of annuli at the scale margin. Joeris (1956) could not age some yellow perch from Green Bay using scales because of the confusion of these marks with true annuli. Accessory checks and crowding of annuli at the scale margin can be caused by food limitations, seasonal cold-water upwellings, behavioral changes, or sexual maturation (Beamish and McFarlane 1983). False annuli were produced on bluegill scales by subjecting the fish to stress by handling and by deprivation of food (Coble 1970).

Although collection of scales is relatively inexpensive in terms of time and money, the precision of aging fish by otoliths outweighs the relative ease of collecting fish scales. The otolith method requires sacrificing the fish, but requires smaller sample sizes to achieve the same level of accuracy. Several scales from each fish may be collected for aging, although scales collected from different areas of the same yellow perch body have been shown to yield different age estimates (Joeris 1956). Any of the three pairs of otoliths may be used to age fish (Blacker 1974); the sagittus is generally preferred because of its relatively large size compared to the lapillus and astericus (Brothers 1987). Yellow perch otoliths require more time to extract and process, but less time to read than scales as otolith annuli are more obvious and false annuli are easily distinguished. The greater precision obtained by the otolith method also justifies the relatively expensive processing equipment (i.e., a microscope).

It is important to include some type of validation, or at the very least verification, in all aging studies (Beamish and McFarlane 1983). Accuracy errors can be addressed by age validation strategies such as mark and recapture studies, and identification of known-age fish in a population (Beamish and McFarlane 1983). Although these strategies are ideal, they are not always feasible. Direct validation of the ages of yellow perch from Lake Michigan would be a costly and time consuming undertaking due to the large area of the lake and low recapture rates of tagged yellow perch (Marsden *et al.* 1993). In light of this fact, we concentrated our efforts on investigating the precision associated with determining fish ages from scales and otoliths and cannot discount the accuracy of either method. When technique reliability is assessed by precision alone, systematic aging errors may be undetected, and systematic errors are more serious than random errors (Powers 1983).

Discrepancies between ages obtained from different structures can be affected by growth rates (Erickson 1983). High levels of exploitation can lead to increased growth rates. We note that fish for this study were only sampled from 1 year, at a time when the yellow perch population was in decline (Francis *et al.* 1996). Thus, the frequency of discrepancies could change in subsequent years, but is likely to be conservative for this study.

Age-frequency distributions from yellow perch scales in this study were significantly different than those from otoliths, but scale ages can nevertheless fulfill a manager's need for information about population age composition if the oldest age-groups are lumped. However, the scale method is not sufficiently precise to assess ages of individuals in a population, and does not, for the most part, recognize yellow perch older than age-7 in Lake Michigan.

ACKNOWLEDGMENTS

We thank W. Brofka, C. Meeks, and K. Shillinglaw for processing the structures. We especially thank W. Brofka and C. Meeks for determining ages, and M. Chotkowski provided statistical advice. We thank R. Frie and R. Hess for their review of the manuscript and helpful comments. We particularly appreciate R. O'Gorman's comments and suggestions on an earlier draft. This study was funded in part by the Illinois Department of Conservation.

REFERENCES

Beamish, R. J., and Fournier, D. A. 1981. A method for comparing the precision of a set of age determinations. *Can. J. Fish. Aquat. Sci.* 38:982-983.

_______, and McFarlane, G. A. 1983. The forgotten requirement for age validation in fisheries biology. *Trans. Am. Fish. Soc.* 112:735-743.

_______, and McFarlane, G. A. 1987. Current trends in age determination methodology. In *Age and Growth of Fish*, eds. R. C. Summerfelt and G. E. Hall, pp. 15-24. Iowa State University Press, Ames.

_______, and McFarlane, G. A. 1995. A discussion of the importance of aging errors, and an application to walleye pollock: the world's largest fishery. In *Recent Developments in Fish Otolith Research*, eds. D. H. Secor, J. M. Dean, and S. E. Campana; A. B. Miller, assoc. ed., pp. 545-565. University of South Carolina Press, Columbia.

Belanger, S. E., and Hogler, S. R. 1982. Comparison of five aging methodologies applied to walleye (*Stizostedion vitreum*) in Burt Lake, Michigan. *J. Great Lakes Res.* 8:666-671.

Blacker, R. W. 1974. Recent advances in otolith studies. In *Sea Fisheries Research*, eds. S. B. Saila and P. M. Roedel, pp. 67-90. Paul Elek (Sci. Books) Ltd., London.

Boxrucker, J. 1986. A comparison of the otolith and scale methods for aging white crappies in Oklahoma. *N. Am. J. Fish. Manage.* 6:122-125.

Brothers, E. B. 1987. Methodological approaches to the examination of otoliths in aging studies. In *Age and Growth of Fish*, eds. R. C. Summerfelt and G. E. Hall, pp. 319-330. Iowa State University Press, Ames.

Campana, S. E., Annand, M. C., and McMillan, J. I. 1995. Graphical and statistical methods for determining the consistency of age determinations. *Trans. Am. Fish. Soc.* 124:131-138.

Casselman, J. M. 1983. Age and growth assessment of fish from their calcified structures-techniques and tools. *NOAA Technical Report NMFS* 8:1-17.

Chang, W. Y. B. 1982. A statistical method for evaluating the reproducibility of age determination. *Can. J. Fish. Aquat. Sci.* 39:1208-1210.

Coble, D. W. 1970. False annulus formation in bluegill scales. *Trans. Am. Fish. Soc.* 99:363-368.

Donald, D. B., Babaluk, J. A., Craig, J. F., and Musker, W. A. 1992. Evaluation of the scale and operculum methods to determine age of adult goldeyes with special reference to a dominant year-class. *Trans. Am. Fish. Soc.* 121:792-796.

Erickson, C. M. 1983. Age determination of Manitoban walleyes using otoliths, dorsal spines, and scales. *N. Am. J. Fish. Manage.* 3:176-181.

Everhart, W. H., and Youngs, W. D. 1981. *Principles of Fishery Science,* 2nd. ed. Cornell University Press Ltd., New York.

Francis, J. T., Robillard, S. R., and Marsden, J. E. 1996. Yellow perch management in Lake Michigan: a multi-jurisdictional challenge. *Fisheries* 21(2):18-20.

Frie, R. V., Anderson, J. K., and Larson, M. J. 1989. Age verification of walleyes from Lake of the Woods, Minnesota. *J. Great Lakes Res.* 15:298-305.

Goeman, T. J., Helms, D. R., and Heidinger, R. C. 1984. Comparison of otolith and scale age determinations for freshwater drum from the Mississippi River. In

Proceedings of the Iowa Academy of Sciences 91:49-51.
Jearld, A., Jr. 1983. Age determination. In *Fisheries Techniques*, eds. L. A. Nielson and D. L. Johnson, pp. 301-326. American Fisheries Society, Bethesda, Maryland.
Joeris, L. S. 1956. Structure and growth of scales of yellow perch of Green Bay. *Trans. Am. Fish. Soc.* 86:169-194.
Laine, A. O., Momot, W. T., and Ryan, P. A. 1991. Accuracy of using scales and cleithra for aging northern pike from an oligotrophic Ontario lake. *N. Am. J. Fish. Manage.* 11:220-225.
Le Cren, E. D. 1947. The determination of the age and growth of the perch (*Perca fluviatilis*) from the opercular bone. *J. Anim. Ecol.* 16:188-204.
Marsden, J. E., Brofka, W., Machauskas, D., and Horns, W. 1993. *Yellow perch supply and life history.* Final report to the Illinois Department of Conservation. F-95-R-1-4.
Mills, K. H., and Beamish, R. J. 1980. Comparison of fin-ray and scale age determinations for lake whitefish (*Coregonus clupeaformis*) and their implications for estimates of growth and annual survival. *Can. J. Fish. Aquat. Sci.* 37:534-544.
O'Gorman, R., Barwick, D. H., and Bowen, C. A. 1987. Discrepancies between ages determined from scales and otoliths for alewives from the Great Lakes. In *Age and Growth of Fish*, eds. R. C. Summerfelt and G. E. Hall, pp. 203-210. Iowa State University Press, Ames.
Powers, J. E. 1983. Some statistical characteristics of ageing data and their ramifications in population analysis of oceanic pelagic fishes. *NOAA Technical Report NMFS* 8:19-24.
Wilson, C. A., Chairman, and Glossary Committee. 1987. Glossary. In *Age and Growth of Fish*, eds. R. C. Summerfelt and G. E. Hall, pp. 527-530. Iowa State University Press, Ames.
Zar, J. H. 1984. *Biostatistical Analysis,* 2nd ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Submitted: 9 May 1995
Accepted: 15 April 1996