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A Comparison of Three Structures for Estimating the Age of Yellow Perch

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Abstract.—The ability to determine the age of fish precisely is essential to understanding the structure and dynamics of fish populations. The goal of this study was to compare three hard structures (scales, otoliths, and dorsal fin spines) for estimating the ages of yellow perch *Perca flavescens* in an unexploited population in a sanctuary of Pymatuning Reservoir, Pennsylvania. Scales, dorsal fin spines, and sagittal otoliths were removed from 107 yellow perch, prepared, and examined by two independent readers. Ages assigned by the two independent readers agreed 96% of the time when using otoliths, 83% when using scales, and 80% when using spines. Pairwise comparisons (paired *t*-tests, $\alpha = 0.05$) indicated no significant differences among the ages assigned using the three methods. Otoliths were the best structure to use for estimating yellow perch age based on high reader agreement and low coefficient of variation (CV). However, we found that scales and dorsal fin spines can be used to adequately describe the age structure of yellow perch populations (CV < 10% for each structure), although dorsal fin spines were slightly more precise than scales for fish assigned to age 4 or older by using otoliths. Thus, use of both dorsal fin spines and scales for yellow perch age and growth studies may improve the precision of population age structure estimates.

Yellow perch *Perca flavescens* are one of the most popular sport and commercial fishes in North America, largely because of their abundance and excellent food quality (Cooper 1979). Because they inhabit a wide variety of habitats, school, and congregate near shore in the spring, yellow perch are readily available to commercial and recreational fishermen (Scott and Crossman 1973). For example, in the Great Lakes, 39% of the more than 2 million anglers who fished in 1991 targeted yellow perch (USDOI et al. 1993). In the Chesapeake Bay, the importance of yellow perch to commercial harvesters has been amplified in light of the moratoria on the harvest of American shad *Alosa sapidissima* and striped bass *Morone saxatilis* (Piavis 1991). To sustain healthy populations of yellow perch, fishery managers must have a clear understanding of the structure and dynamics of these populations. Thus, determining the age of yellow perch accurately and consistently is an important aspect of managing these populations.

Scales are the most commonly used structure for determining ages of freshwater teleosts (Everhart et al. 1975) because they can be easily collected without killing the fish (IAHEES 1982). However, accumulating evidence that scales can provide unreliable estimates of age has forced fishery scientists to use other calcified structures, especially otoliths (Hammers and Miranda 1991) to estimate age. Otoliths are often the preferred structure for age determination because many studies have shown them to reflect the age of the fish more accurately than other structures. For example, Erickson (1983) found that otolith sections were more accurate for estimating ages of older walleyes *Stizostedion vitreum* than scales or dorsal fin spines. The primary disadvantage of using otoliths is that the fish must be killed to extract the otoliths. Other structures that can be removed for age determination without harming the fish, such as fin spines and rays, have proven as accurate a structure for age estimation as otoliths for several species of fish (Welch et al. 1993).

The goal of this study was to evaluate the use of scales, otoliths, and dorsal fin spines to estimate the age of yellow perch. Specific objectives were to determine the precision of ages estimated using these structures and to determine for each structure the agreement between ages assigned by two readers.

Study Site

The Pymatuning Reservoir is a 5,638-ha artificial impoundment located on the Pennsylvania–Ohio state boundary approximately 60 km south of Lake Erie; it is divided by a causeway into two parts: the Pymatuning Sanctuary and the main lake. The sanctuary, located in Crawford County, Pennsylvania, is 1,012 ha and supports a wide diversity of fish species. The sanctuary is shallow, turbid, and nutrient-rich and contains several

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small, dispersed islands. Because the Pennsylvania Fish and Boat Commission manages the sanctuary primarily as a source of walleye broodstock, the sanctuary is closed to all fishing activities.

Methods

Four Pennsylvania-style trap nets (25.4-mm-bar mesh, 30-m leads) were used to collect yellow perch from the Pymatuning Sanctuary in spring 1997. Trap nets were checked daily and periodically relocated to sample all areas of the sanctuary. During fall 1997 we used an electrofishing boat to collect yellow perch in the nearshore areas of the sanctuary. During both the spring and fall sample periods, yellow perch were enumerated, measured (total length; mm), and weighed (g).

Approximately 10 scales were removed from the posterolateral area of each fish behind the pectoral fin and below the lateral line. Impressions of several scales from each fish were made on acetate slides using a scale press, and the impressions were examined with a microfiche reader at 44× magnification (DeVries and Frie 1996). We used the criteria described by DeVries and Frie (1996), including circuli crowding and the crossing over of circuli, to distinguish annuli on scales.

The third dorsal fin spine was removed from each fish at the point of insertion using a pair of wire cutters. The third spine was chosen because the first two spines were generally smaller and more worn. Dorsal fin spines were prepared following the protocol of Margenau (1982) with the exception that a Dremel tool equipped with a cutting disk was used rather than a hand drill. The spine sections were sanded with fine (400-grit) sandpaper. A drop of immersion oil was placed on each section that was then read using a compound microscope (Belanger and Hogler 1982). Annuli were distinguished on the spine sections as a darkened band (Beamish and McFarlane 1985).

Sagittal otoliths were extracted from yellow perch in the laboratory. Otolith pairs were sectioned by cutting through the focus of the otolith with a scalpel. The sections were mounted, sectioned side down, onto an acetate slide using Super Glue and allowed to dry overnight. The otolith sections were first sanded using the Dremel tool with a sanding wheel attachment, and then again with fine (400-grit) sandpaper. The sections were examined under a dissecting microscope with a dark background underneath to add contrast to the opaque otolith sections (Belanger and Hogler 1982). Otolith annuli were distinguished as opaque rings with regular spacing between each annulus.

Two readers independently read all the scales, dorsal fin spines, and otoliths to estimate the yellow perch ages. Prior to making these estimates, both readers familiarized themselves with the literature describing the criteria for distinguishing annuli on each structure. Then, both readers jointly examined a small subsample of yellow perch to become comfortable with using the three structures to estimate ages. Finally, readers independently estimated ages for the entire sample using scales first, then dorsal fin spines, and lastly otoliths. To minimize bias, until all aging was completed the readers were not privy to information regarding the sex or length of the fish being aged nor to the ages they assigned using the other structures; the other reader's results were also withheld.

Several measures were used to determine the precision (reproducibility) of ages assigned using the three structures. Percent agreement, paired *t*-tests ($\alpha = 0.05$), age bias plots (Campana et al. 1995), and coefficients of variation (CV = 100 × SD/mean; Chang 1982) were used to compare the two readers use of each structure to assign ages. To compare precision between structures, for each structure we averaged the ages assigned by both readers and constructed age bias plots using otolith ages on the abcissa. Because we used otolith ages as our benchmark for comparison, we removed the four fish to which the readers assigned different otolith ages. We calculated CVs for the scale–otolith and the spine–otolith comparisons to evaluate the precision of ages assigned using scales and spines in comparison to ages assigned using otoliths.

Results

We collected 107 yellow perch during the spring and fall of 1997 for age analysis. The size structure of this sample was characterized by many smaller fish, between 120 and 180 mm (Figure 1).

Of the three structures evaluated for estimating ages of yellow perch in the Pymatuning Sanctuary, we found otoliths to be the most precise. Ages assigned by two independent readers using otoliths agreed 96% of the time (Table 1), leading to little variation in age bias plots (Figure 1). In addition, the calculated CV for two readers using otoliths was very low (0.84%), indicating high precision. Ages assigned using scales were slightly less precise, with ages assigned by the two readers agreeing 83% of the time. Reader agreement was the lowest (80%) for ages estimated using spines, indicating that spines were the most difficult structure to interpret. Paired *t*-tests indicated no sig-

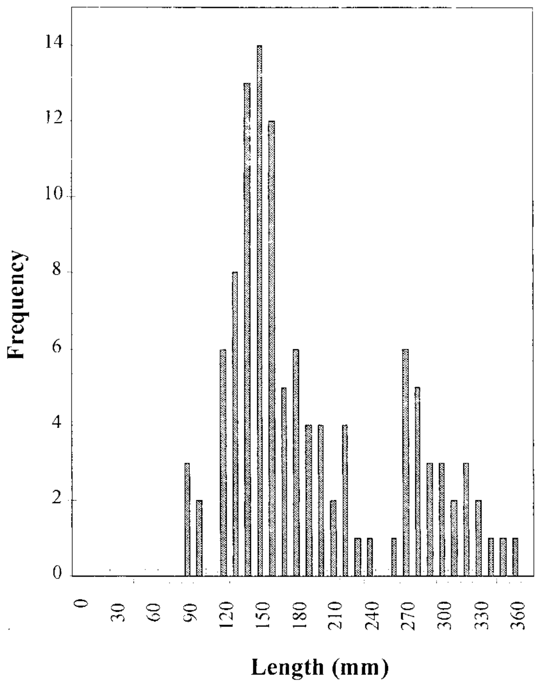

FIGURE 1.—Size frequency of yellow perch collected for age estimation in the spring and fall 1997 in the Pymatuning Sanctuary (N = 107).

nificant differences between the ages assigned by two readers using each structure (P = 0.08–0.32, Table 1). Although ages assigned using all three structures exhibited a high level of precision (CV <10% in all cases), age bias plots and CV for ages assigned by two the readers using scales and spines indicate that these structures are slightly less precise than otoliths (Figure 2).

Using otolith ages as a benchmark, ages assigned using dorsal fin spines were more precise (CV = 5.21%) than ages assigned using scales (CV = 9.91%; Figure 3). In general, when ages assigned using spines and otoliths disagreed, spines tended to overestimate the age by 1 year, particularly at younger ages. On the other hand, disagreements between ages assigned using scales and otoliths were not consistent; ages assigned using scales both underestimated and overestimated otolith ages throughout the range of ages analyzed (Figure 3).

To further explore the utility of scales and spines for estimating yellow perch ages, we compared their percent agreement with otolith ages, percent agreement between readers, and CVs as assigned ages became older. As we expected, percent reader agreement decreased for all structures at age 4 and

TABLE 1.—Percent agreement between ages assigned to yellow perch (N = 107) by two independent readers using the same hard structure and the results (P) of paired t-tests (α = 0.05) used to compare precision between readers.

Structure	Reader agreement (%)	P
Scales	83	0.28
Spines	80	0.08
Otoliths	96	0.32

older (Table 2). Reader agreement for ages assigned using scales exhibited the greatest decrease, dropping nearly 30 percentage points at age 4. In contrast, reader agreement for spines declined by only 11 percentage points at age 4 and by 10 percentage points for otoliths, indicating that spines and otoliths may be more precise for estimating ages of older yellow perch. In fact, decreasing CVs

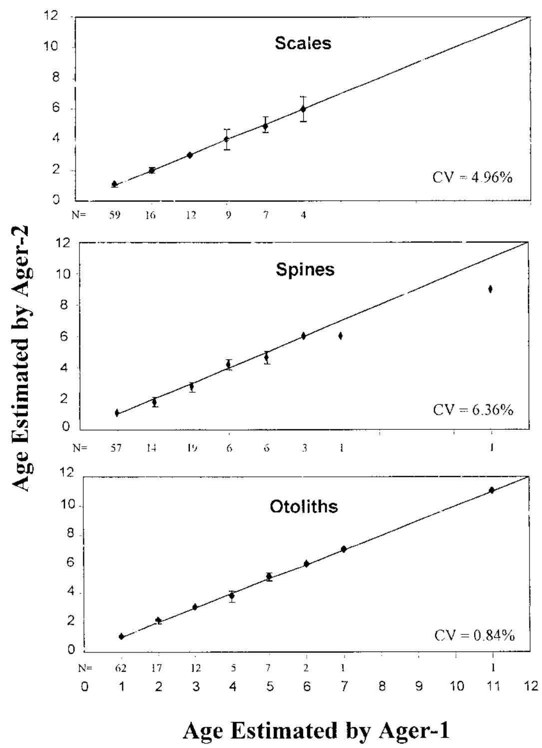

FIGURE 2.—Age bias plots and coefficient of variation (CV = 100 × SD/mean) comparing yellow perch ages assigned by the two independent readers using scales (upper panel), spines (middle), and otoliths (lower). Error bars represent the 95% confidence interval about the mean age assigned by ager 2 for all fish assigned a given age by ager 1. The diagonal lines represent full agreement between readers (i.e., ages assigned by ager 2 = ages assigned by ager 1); N is the number of comparisons for each age.

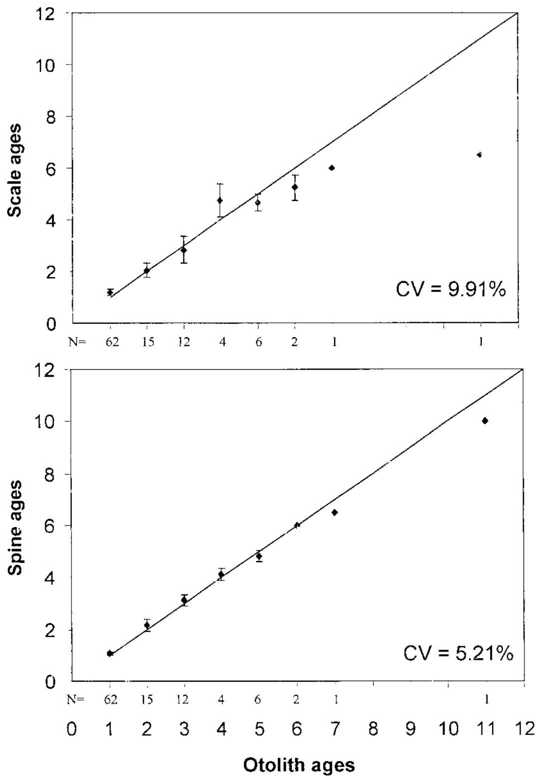

FIGURE 3.—Age bias plots and coefficients of variation (CV = 100 × SD/mean) comparing the average of ages assigned by two independent readers using scales (upper panel) and spines (lower) to ages assigned using otoliths. Using otoliths, four fish were aged differently by the two readers; these fish were removed from the analysis. Error bars represent the 95% confidence interval about the mean scale or spine age for fish of each otolith age. Diagonal lines represent mean scale or spine age equal to otolith age; *N* is the number of comparisons for each age.

indicate that precision between readers using spines improved as assigned ages increased (Table 2). For both scales and otoliths, CVs increased with increasing fish age, indicating that reader agreement decreased as fish grew older.

TABLE 2.—Comparison of reader agreement and coefficients of variation (CV = 100 × SD/mean) among ages assigned using scales, spines, and otoliths for two groups of fish (ages ≤3 and ≥4).

		Scales		Spines		Otoliths	
Otolith age	*N*	Agreement (%)	CV	Agreement (%)	CV	Agreement (%)	CV
≤3	90	88	4.12	82	6.79	98	0.62
≥4	17	59	8.63	71	4.24	88	2.07

Discussion

In general, we found that otoliths yielded the most precise age estimates for yellow perch in the Pymatuning Sanctuary. Scales and dorsal fin spines were equally useful for aging yellow perch. In comparison to otoliths, however, dorsal fin spines were slightly more precise than scales for aging older fish. In a similar study comparing five structures (scales, otoliths, dorsal fin spines, pectoral fin rays, and pelvic fin rays) for estimating walleye ages in Burt Lake, Michigan, Belanger and Hogler (1982) found that all methods yielded equivalent age estimates. Erickson (1983) concluded that ages derived from otolith sections were similar to ages derived from dorsal spines and scales of Lake Winnipeg walleyes. Kruse et al. (1993) used scales and otoliths for determining ages of black crappies *Pomoxis nigromaculatus* and found between-structure agreement was 94% or greater for all fish.

The majority of the research on comparing different methods of age determination has been done on exploited populations. Methods for determining ages of fish that are applied to unexploited fish populations can be expected to display a larger degree of variability (Belanger and Hogler 1982). Erickson (1979) found that differences between otolith ages and scales ages were (1) slight among fish from heavily exploited populations because of faster growth associated with higher fishing pressure, and (2) large among fish from unexploited populations because of the slower growth associated with the higher densities of unexploited populations. In contrast, in the unexploited Pymatuning Sanctuary, we found that agreement was high between the ages estimated using scales, spines, and otoliths. This could be a result of fast growth of yellow perch due to the high predator density in this system. A similar study of an unexploited walleye population in Wapun Lake, Manitoba, Campbell and Babaluk (1979) found that agreement between readers was highest when using dorsal spines, 80.6% of the sections being in complete agreement. They also concluded that scales gave poor results, only 59.8% being in complete agreement, and that mean ages assigned by two readers were not significantly different. In contrast, we found that, in general, precision between readers was higher for scale ages than for spine ages. However, spines were more precise for estimating ages of older fish.

Otoliths are often used as a benchmark for comparison of ages assigned using other structures. For example, ages of white crappies *Pomoxis annularis* based on otoliths seemed to be more accurate and more precise than those based on scales (Hammers and Miranda 1991). We found that ages based on otoliths, spines, and scales were all highly precise. In addition, we found that dorsal fin spines became more precise for estimating ages when the fish were age 4 and older, whereas the precision for ages determined using scales dropped for fish age 4 and older. Our findings seem to indicate that dorsal fin spines could be used as a benchmark for comparison of scale ages for older yellow perch instead of otoliths. Thus, fishery managers may be able to use a combination of aging techniques, scales for smaller (younger) fish and spines for larger (older) fish, to more accurately determine the age structure of yellow perch populations. Using this combination of structures may allow a more accurate depiction of the age structure of the yellow perch population being studied without needing to kill the larger, older fish in the population. A combination of aging structures may lead to differences in mean back-calculated lengths-at-age calculated from each structure, and this possible difference should be investigated before deciding to adopt a combination of structures for an age and growth study. However, using dorsal fin spines to check ages assigned using scales for larger fish may help to clear up possible errors in aging and in determining back-calculated lengths-at-age.

One disadvantage to using the dorsal fin-spine method is that preparation was more labor intensive than the scale method. Although preparation time was not recorded for each of the three methods, we estimate that the spine and otolith preparation times were both at least twice as long as that for scales. Another drawback to the spine method is that the sections were more difficult to read than the scale impressions. This difficulty was reflected by the lower percent agreement between readers for aging with dorsal spines rather than scales. Thus, if spines are one of the structures to be used for age determination, we suggest that the readers have thorough training. Finally, our findings suggest that the value of being able to determine the age of the older yellow perch in a population more precisely, without the need to kill larger and older fish, may outweigh the disadvantages of using dorsal fin spines instead of scales to estimate ages of yellow perch.

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