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An evaluation of different structures to age freshwater fish from a northeastern US river

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Abstract Largemouth bass, *Micropterus salmoides* (Lacepède), smallmouth bass, *Micropterus dolomieu* Lacepède, and yellow perch, *Perca flavescens* (Mitchill), were collected from the Hudson River, New York, USA, to compare the precision of age estimates derived from scales and otoliths. Similar procedures were used to compare otolith and spine ages from brown bullhead, *Ameiurus nebulosus* (Lesueur). Overall percent agreement between readers ranged from 91% to 98% for otoliths compared with 38% to 67% for scales and spines. Disagreement rates associated with scales and spines increased as fish grew older. Average percent error between readers was about an order of magnitude higher for scales and spines than for otoliths. Ages estimated from scales and spines progressively decreased as age increased based on otolith examination. The use of scales and spines to age largemouth bass, smallmouth bass, yellow perch and brown bullheads from the northeastern US was less precise and will likely lead to underestimation of age of larger and older fish.

KEYWORDS: ageing, northeastern US, otoliths, precision, scales, spines.

Introduction

Estimates of fish ages provide important demographic parameters to analyse and assess fish populations. Historically, scales have been widely used to age freshwater fish, although otoliths have been found to be more accurate and precise structures to age fish (DeVries & Frie 1996). Ictalurids are routinely aged using pectoral spines, but recent research (Buckmeier, Irwin, Betsill & Prentice 2002) has found that otoliths provide more accurate and precise age estimates for channel catfish *Ictalurus punctatus* (Rafinesque).

Ageing fish with otoliths was more accurate, showed greater precision and provided higher estimates of age compared with scales for various species in a number of waterbodies in the southern US (e.g. Boxrucker 1986; Welch, Van Den Avyle, Betsill & Driebe 1993; Besler 2001). However, in more northern latitudes (>40° N) in North America and Europe, mixed results were reported when age estimates and precision of scale and otolith ages were compared (Skurdal, Vollestad & Qvenild 1985; Barbour & Einarsson 1987; Mosegaard, Appelberg & Nangstroem-Klevbom 1989; Robillard & Marsden 1996; Isermann, Meerbeek, Scholten & Willis 2003). A comparison of spine and otolith ages for ictalurids has only been conducted in southern US waterbodies (Nash & Irwin 1999; Buckmeier *et al.* 2002). The objectives of this paper were to compare age estimates and reader precision between scales and otoliths of largemouth bass, *Micropterus salmoides* (Lacepède), smallmouth bass, *Micropterus dolomieu* Lacepède, and yellow perch, *Perca flavescens* (Mitchill), and between otoliths and spines for brown bullhead, *Ameiurus nebulosus* (Lesueur), collected from the upper Hudson River located in northeastern USA.

Materials and methods

Fish were collected from the upper Hudson River north of Albany, New York, USA (42°45′ N), 19–80 km north of the confluence with the Mohawk River using DC electric fishing in June 2002 and 2004. For largemouth bass, smallmouth bass and yellow perch, scales were removed from below the lateral line and behind the pectoral fin (DeVries & Frie 1996). Pectoral spines were removed from brown bullheads (Buckmeier *et al.* 2002). After scale and spine removal, sagittal otoliths were extracted from the same fish (Buckmeier *et al.* 2002). Some additional fish were

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collected in 2004 and otoliths were obtained, but scale and spine samples were not taken.

Scale and spine processing and age enumeration were conducted by experienced readers at Ecologic, Inc. (Syracuse, NY, USA). Scales were placed between two microscope slides or impressions were made onto acetate. Some larger scales were briefly soaked in a 5% acetic acid solution to facilitate softening and clearing of the scale. Pectoral spines were sectioned just above the basal recess using either a Dremel cutting wheel or jewellers saw and were generally less than 0.5-mm thick. Spine sections were soaked in a 5% acetic acid solution for at least 24 h and placed between two microscope slides.

Scales were magnified and viewed with a microfiche projector. Spine sections were observed under either a compound or dissecting microscope. For scale samples, we assumed that annulus formation was either complete or was forming in June based on observations made by Maraldo & MacCrimmon (1979) for largemouth bass in Canada. Thus, the outer margin was considered to be the final annulus. Scales and spines were aged independently by two readers; if agreement of age assignment did not occur, then these two readers re-examined the structure together and reached concurrence. If an age could not be agreed upon, a third interpreter assisted in making the final age interpretation.

Otoliths for largemouth bass, smallmouth bass and yellow perch were processed and aged following the procedures of Hoyer, Shireman & Maceina (1985), Maceina & Betsill (1987) and Maceina (1988). For black bass and yellow perch, whole otoliths were soaked in a 1:1 solution of ethanol and glycerine for about 4 weeks. Otoliths were examined independently by two readers in whole view for fish displaying up to six or seven annuli. In older fish, or where annuli were not clearly visible, otoliths were sectioned (Maceina 1988) and annuli were counted by two readers. Bullhead otoliths were sectioned, processed and viewed independently by two readers following the procedures of Buckmeier *et al.* (2002). Where disagreement in enumeration of age occurred, an age was assigned after concurrent viewing without the assistance of a third reader. The outer edge was considered an annulus as annulus formation was visible on some otoliths or would be completed shortly if fish were not collected. This assignment was consistent among scales, spines and otoliths.

For scales, spines and otoliths, Pearson correlation coefficients were computed between the age assignments of the first and second readers. Percent agreement among the range of ages examined and total percent agreement were computed, and the average percent error (APE) between readers was derived using the formula presented by Beamish & Fournier (1981):

$$\mathrm{APE} = \frac{1}{R}\sum_{i=1}^{R}\frac{|x_{ij} - x_j|}{x_j} \times 100,$$

where x_{ij} is the ith age determination of the jth fish, x_j the average age calculated for the jth fish and R the number of times each fish is aged.

The APE is not only sensitive to age disagreement, but also to the magnitude in the difference in age assignment between or among readers (Beamish & Fournier 1981).

Results

Percent agreement of ages between independent readers was higher for otoliths than for scales and spines (Table 1; Fig. 1). Percent agreement ranged from 91% to 98% for otoliths compared with 40–67% for scales and spines. For largemouth bass, smallmouth bass and yellow perch, agreement between scale age assignment was greater than 80% for young fish (ages 1 to 3–4), but decreased to less than 60% for fish older than age 7. Percent agreement

Table 1. Comparison of percent agreement rates, average percent error (APE), the Pearson correlation coefficient (r) between reader age assignment and agreement rates between scales/spines and otoliths from fish collected from the Hudson River

Species	Percent agreement		APE		r between readers		Percent agreement between scale/spine and otolith
	Scale/spine	Otolith	Scale/spine	Otolith	Scale/spine	Otolith	
Smallmouth bass	67	94	4.3	0.5	0.92	> 0.99	43
Largemouth bass	57	91	7.3	0.5	0.80	> 0.99	20
Yellow perch	65	98	5.4	0.2	0.91	> 0.99	47
Brown bullhead	40	92	9.1	0.8	0.68	0.99	18

Largemouth bass, smallmouth bass and yellow perched were aged using scales and otoliths and brown bullhead were aged with spines and otoliths.

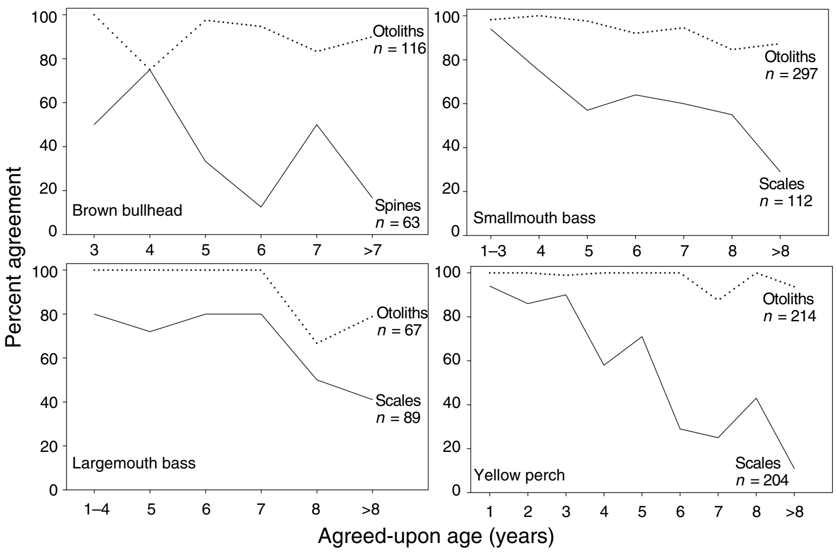

Figure 1. Agreement rates between independent readers that assigned ages to scales and otoliths over a range of agreed-upon ages for four species of fish collected from the Hudson River.

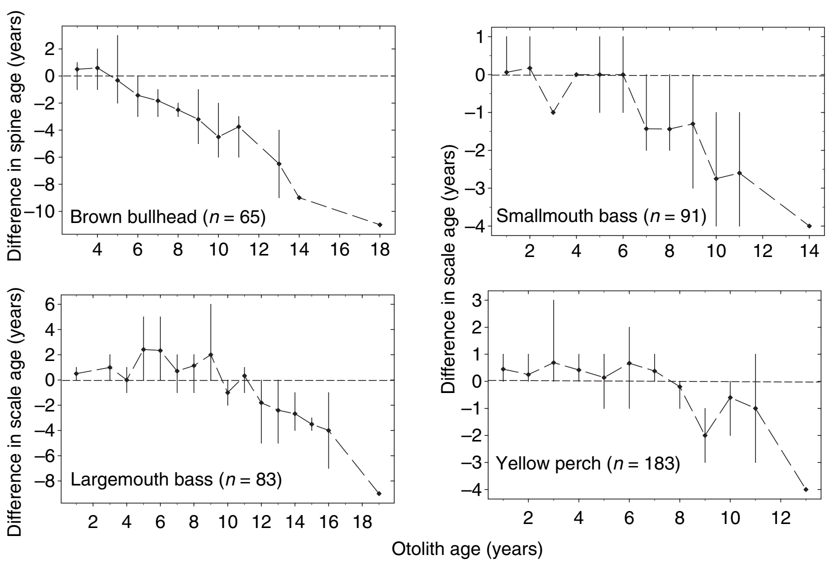

Figure 2. Differences in mean age and the range in age differences determined from spines and scales compared with otoliths (spine or scale age minus otolith age) for four species of fish collected from the Hudson River.

between readers who examined brown bullhead spines was generally low (< 50%) for all ages except for age-4 fish (Fig. 1). Percent agreement between readers for otolith ages decreased with fish age, but overall agreement over the range of ages were typically greater than 90% (Fig. 1).

Average percent error in reader precision was about an order of magnitude higher for scales and spines than for otoliths (Table 1). Similarly, the correlation coefficients between ages assigned by readers for scales and spines were much lower than for otoliths (Table 1).

Average agreed-upon age estimates for scales were within 1 year of the agreed-upon otolith ages for smallmouth bass and yellow perch estimated to be up to 6–7 years old using otoliths (Fig. 2). For fish estimated to be older than this from otoliths, scale ages were less than otolith ages and these differences progressively increased with older fish. For largemouth bass, scale ages were greater than otolith ages for fish that were estimated up to 9 years old with otoliths. After age 11, average scale ages were lower than otolith ages. For brown bullheads estimated to be older than age 3 from otoliths, ages estimated from spines were progressively less than otolith age as the fish grew older. Agreement between scale or spine and otolith ages was low and ranged from 18% to 47% among the species examined (Table 1). Finally, for fish that were less than 5 years old (with otoliths), agreement rates between otolith and scale ages varied among species and was 79% for smallmouth bass, but was only 52% and 35% for yellow perch and largemouth bass respectively.

The maximum ages of fish aged with spines and scales were 9, 10, 12 and 14 for brown bullhead, smallmouth bass, yellow perch and largemouth bass compared with maximum ages of 18, 14, 19 and 13 years old, respectively, estimated from otolith examination of the same fish.

Discussion

The opaque band formation on otoliths were not validated as true annuli in fish from the Hudson River, but otoliths have been verified as accurate ageing structures for largemouth bass (Taubert & Tranquilli 1982; Hoyer *et al.* 1985; Buckmeier 2002) and smallmouth bass (Heidinger & Clodfelter 1987) in locations south of the Hudson River. Although otolith annulus formation has not yet been validated for yellow perch and brown bullhead, otoliths serve as accurate ageing structures for other percids (Erickson 1983; Heidinger & Clodfelter 1987) and ictalurids (Buckmeier *et al.* 2002). Maraldo & MacCrimmon (1979) validated scale annuli up to 7 years old for largemouth bass in a Canadian lake (45° 02′ N), which was near the Hudson River, but sample size was small ($n = 8$). Scales, spines and otoliths have not been validated as accurate ageing structures for these four species in the northeastern US. In the nearby Delaware River basin (40°30′ N), percent agreement for scale readings of American shad *Alosa sapidissima* (Wilson) ranged from 34% to 49% for known age 3 to 6-year-old fish (McBride, Hendricks & Olney 2005). In addition, accuracy using scales from these fish declined to less than 13% for known age fish older than 6 years old and scales over- and underestimated the true age of young and older fish respectively (McBride *et al.* 2005).

Age assignment from spines and scales was less precise than from otoliths for fish collected from the upper Hudson River, and scale ages were progressively lower than otolith ages for older fish. Imprecise and inaccurate age enumeration from scales has been attributed to reabsorption, deposition of false annuli due to stress and food limitation, and annuli becoming obscure because scale growth tends to cease as fish grow older (Beamish & McFarlane 1987; DeVries & Frie 1996). Underestimation and lack of precision to age ictalurids using spines may occur due to expansion of the central lumen, which may obliterate early formed annuli, the appearance of multiple growth rings and poor sectioning techniques (Buckmeier *et al.* 2002). However, basal recess spine sections examined for brown bullheads from the Hudson River may have provided lower age estimates when compared with sections made from the articulating process of the spine (Nash & Irwin 1999). Nevertheless, otoliths continue to grow and form annuli even as body growth slows and asymptotic length is reached, and annuli reabsorption does not appear to occur during periods of food limitation or stress (DeVries & Frie 1996).

Reader agreement for ages compared between scales and otoliths was high (> 80%) for black crappie, *Pomoxis nigromaculatus* (Lesueur), and white bass, *Morone chrysops* (Rafinesque), less than 6–7 years old from South Dakota, USA (Kruse, Guy & Willis 1993; Soupir, Blackwell & Brown 1997). However, Soupir *et al.* (1997) found annuli on white bass scales were difficult to interpret after age 6. For yellow perch in Pennsylvania, USA, percent agreement between readers was 96% and 83% for otoliths and scales, but scale age agreement was 59% for fish that were ≥4 years old (Niewinski & Ferreri 1999), similar to the results in this study. Also similar to results of this study, yellow perch from Lake Michigan, USA, had a greater number of annuli on their otoliths than on scales when more than seven annuli were visible on otoliths (Robillard & Marsden 1996). In addition, APE values between readers were only about 16-25% less for yellow perch otoliths compared with scales; thus, Robillard & Marsden (1996) recommended otoliths be used to age these fish from Lake Michigan.

Age agreement between scale readers was low and scale ages were less than otoliths in long-lived walleye *Sander vitreus* (Mitchill) populations in Canada (Erickson 1983), similar to the results for black bass and yellow perch from the Hudson River. For walleye (< age 10) collected from South Dakota, Isermann *et al.* (2003) found 51% age agreement between scale readers, which was slightly less than that found for the three species aged from scales in the Hudson River (57–67%). Age agreement among readers using scales of various ages of American shad in Pennsylvania, USA, ranged from 50% to 77% (McBride *et al.* 2005).

Whole and sectioned otolith age agreement was 87–88% for walleye (Isermann *et al.* 2003), which was also slightly less than otolith age agreement rates for Hudson River fishes.

Reader precision was high for both scales and otoliths obtained from roach, *Rutilus rutilus* (L.), in Sweden, but ages discerned from scales were much lower than those observed from fish that were > 10–11 years old estimated from otolith examination (Mosegaard *et al.* 1989). For brown trout, *Salmo trutta* L., arctic charr *Salvelinus alpinus* (L.) and white fish *Coregonus clupeaformis* (Mitchill), scale-age estimates were less than otolith ages for fish estimated to be greater than 3–5 years old from otoliths (Jonsson 1976; Skurdal *et al.* 1985; Barbour & Einarsson 1987). From these comparative studies in northern latitudes (> 40° N) and the results collected from the Hudson River, underestimation of age using scales likely occurs at mid- to later-life stages of fish.

Spine and otolith age comparisons for precision or bias have not been made for ictalurids in northern latitudes, but in Alabama, USA, agreement in age assignment for basal recess sections of spines was much lower than for otoliths for flathead catfish, *Pylodictis olivaris* (Rafinesque) (Nash & Irwin 1999), and channel catfish (Buckmeier *et al.* 2002), which was observed for brown bullheads from the Hudson River. After age 4, ages estimated from basal recess spine examination progressively underestimated age compared with otolith estimates for a long-lived flathead catfish population (maximum age 28 years; Nash & Irwin 1999), analogous to long-lived brown bullheads from the Hudson River.

In conclusion, age determination from scales and spines of largemouth bass, smallmouth bass, yellow perch and brown bullheads from the northeastern US were likely less accurate and will probably lead to underestimation of age of larger and older fish. Thus, estimates of growth will be higher for older fish and survival using catch-curve regression will be lower if scales and spines are used to age fish from this region. In addition, age estimates from these structures will likely be less precise than for otoliths. However, validation of otoliths as accurate ageing structures has not been conducted for these species in the northeastern US and warrants investigation. These results also suggested that scales, in some instances, may provide reasonable estimates of age for younger fish, but validation of this structure using marked or known-age fish should be conducted. Beamish & McFarlane (1987) warned that scale ages may be unreliable structures for ageing fish and these results confirmed this observation.

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