Comparing the Use of Dorsal Fin Spines with Scales to Back-Calculate Length-at-Age Estimates in Walleyes

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Reference: Borkholder, B.D., and A.J. Edwards. 2001. North American Journal of Fisheries Management 21:935–942.

Abstract – The use of scales to age and back-calculate previous lengths has long been used as a management tool in fisheries. However difficulties with using scales to interpret ages in older fish have led managers to investigate other bony structures. Dorsal fin spines have been used and evaluated for aging fishes, but their utility for back-calculation estimates is largely unknown. We compared back-calculation estimates along two different scale transects and three dorsal fin spine transects in walleyes *Stizostedion vitreum*. Back-calculation estimates were obtained using the standard Fraser-Lee proportional method and a regression equation derived from the body length / spine radius relationship. Dorsal spines were easier to interpret than were scales, especially for older-aged walleye. Back-calculated lengths among transects both within the two structures and between the two structures agreed quite favorably. Our data suggest that the Fraser-Lee proportional method applied to dorsal fin spines closely approximates the back-calculated lengths obtained from scales. While differences in back-calculated lengths estimated from each structure were observed among individual walleye, reliable estimates of back-calculated lengths for a walleye population, as compared with scale estimates, were obtained from dorsal fin spines. Scales are much easier to prepare, however, and have a longer history of use for back-calculating lengths at age. The use of scales for aging and back-calculating length-at-age estimates in younger fish is recommended, but managers may wish to consider the use of spines for obtaining length-at-age estimates from older individuals.

Introduction

Age and growth information are valuable management data used by fisheries biologists to monitor populations. While scales have been the most common structure used for aging freshwater fish, other structures have been used, including otoliths, fin rays, opercles, and vertebrae. As managers continue to seek structures that provide accurate age estimates, each new structure should be validated using fish of known age (Beamish and McFarlane 1983). Often, however, new structures are simply compared to current techniques, as validation is not always possible (Belanger and Hogler 1982). Several studies have focused on comparing ages enumerated from different bony structures in an attempt to quantify the precision and to identify possible bias associated with each structure. Eight different structures have been compared for aging walleyes *Stizostedion vitreum*, including pectoral rays, scales, otoliths, vertebrae, opercles, pelvic rays, brachiostegal rays, and dorsal spines (Campbell and Babaluk 1979; Olson 1980; Belanger and Hogler 1982; Erickson 1983; and Heidinger and Clodfelter 1987; Kocovsky and Carline 2000). Comparisons have been made between scales and pectoral fin rays in white sucker *Catostomus commersoni* (Beamish 1973), and between scales and pelvic fin rays in whitefish *Coregonus clupeaformis* (Mills and Beamish 1980). Ages determined from scales and otoliths have been compared in alewives *Alosa pseudoharengus*

(O’Gorman et al. 1987) and in striped bass *Morone saxatilis* and smallmouth bass *Micropterus dolomieui* (Heidinger and Clodfelter 1987). Scales have generally been found to underestimate ages relative to other structures, especially for older individuals and in slow-growing populations (Campbell and Babaluk 1979; Mills and Beamish 1980; Erickson 1983; Kocovsky and Carline 2000). Since scale growth is assumed to be proportional to body growth (Whitney and Carlander 1956; Hile 1970; Bagenal 1974; and Erickson 1983), annuli become crowded on the scale edges in slow-growing populations and in older fish, making scale interpretation difficult. Because this crowding effect does not create as many difficulties in aging dorsal spines, Campbell and Babaluk (1979) and Olson (1980) both recommended dorsal spines for determining age in walleyes when non-invasive techniques are required.

Often associated with aging fish is the use of bony structures to back-calculate length-at-age estimates to examine growth rates. Scales were the first structure used to back-calculate lengths (Lea 1910; Fraser 1916; Lee 1920), and have been widely used since (Carlander 1982; Jearld 1983; Carlander 1987; Busacker et al. 1990; Ricker 1992; Pierce et al. 1996; Hurley et al. 1997; Klumb et al. 1999). Francis (1990) provides a comprehensive review of the various back-calculation techniques. Essentially, there are two methods of back-calculating lengths at age: 1) proportional methods, where the length of the individual and the size of the bony structure at time of capture are taken into account in the model, and 2) regression methods, which largely ignore fish length and bony structure size at capture (Francis 1990). The Fraser-Lee equation has been widely used and recommended (Carlander 1981, 1982; Ricker 1992; Klumb et al. 1999), and is the proportional method formula used by the widely-distributed computer program DisBCal (Frie 1982).

Studies have demonstrated that otoliths can also be used for back-calculating lengths at age (Erickson 1983; Heidinger and Clodfelter 1987; Campana 1990; and Schramm et al. 1992). The potential of using dorsal fin spines to back-calculate lengths at age in walleyes is unknown. Dorsal fin spines have been shown to be easier to use when interpreting ages than are scales, especially in slower-growing populations and older individuals (Campbell and Babaluk 1979; and Olson 1980). We compared back-calculated length-at-age estimates (BCLs), using both the Fraser-Lee and regression methods, of three walleye populations using scales and dorsal fin spines.

Methods

Walleyes were collected from three lakes within Minnesota. Green Lake is located in Chisago County north of Minneapolis / St. Paul, Mille Lacs Lake is located in Mille Lacs County near the center of the state, and Island Lake is located in St. Louis

County north of Duluth. Samples were taken from walleyes harvested by Tribal fishermen from Green and Mille Lacs Lakes, and by electrofishing in Island Lake. Samples were collected during April of 1998, immediately following ice-out.

Each walleye was measured to the nearest millimeter. A sample of scales was collected from the region immediately above the lateral line and even with the end of the pectoral fin. A pair of side cutters was used to clip the second full dorsal fin spine at the point of attachment.

Scale samples were cleaned in warm water and impressions made in acetate slides. Scale impressions were viewed using a microfiche viewer at 24X. Dorsal fin spines were first soaked in bleach to remove the layer of skin on the bone. Spines were set in two-part epoxy resin, and 0.3 to 0.5 mm thin sections were cut using a Buehler Isomet™ low speed bone saw. The use of this bone saw and a diamond wafering blade allowed us to get clean, readable cuts without the need to polish them as in Kocovsky and Carline (2000). Three sections were cut near the base for viewing. Spines were examined using a microfiche viewer at 60X.

Scales and spine sections were aged independently by two different readers for 266 walleyes. A virtual annulus was assigned to the spine and scale edges since these were early spring samples (Klumb et al. 1999). Individual walleye where scale and spine ages differed by one year were viewed again independently by both readers. If perfect agreement was achieved, these fish were also used for back-calculations. When ages between scales and spines were in disagreement by more than 2 years, these fish were excluded from additional analysis.

For walleyes where agreement was achieved, both structures were placed on two different michrofiche viewers set side by side. Both readers re-examined each structure and verified the location of presumed annuli. The scale focus, each annulus, and the scale edge was identified and marked on transparency paper. This was repeated along two transects for each scale. The first transect was from the focus to the anterior-median edge, hereafter referred to as the anterior transect (AT) (Hurley et al. 1997). The second transect ran from the focus to the anterior-lateral corner of the scale, referred to as the diagonal transect (DT) (Hurley et al. 1997) (Figure 1).

For each spine cross-section, the focus, annuli, and edges were marked on overhead transparency paper along three distinct transects. With the spine section orientated so that the groove is up (Figure 1), one half of the spine section is typically more elongated (E) while the other is typically more compressed (C). The transect running from the focus horizontally (H) across the elongated (E) portion is referred to as the HE transect (Figure 1). The transect running towards the anterior corner of the elongated plane is referred to as the AE transect. Along the compressed plane, the horizontal transect is referred to as the HC transect.

Regression analysis was used to create a model to back-calculate length-at-age. Analysis used fish total length (L_c) and the radius of the spine (S_c) along the HE transect for 1177 walleyes collected from the study lakes. The relationship between fish length at capture and spine radius was found to be curvilinear, therefore the data were $\log_e$ transformed (Ln). The regression coefficients from least-squares analysis were back-transformed (e^x) to develop an equation which was used to back-calculate lengths at age in the 1998 collections.

The computer program DisBCal (Frie 1982) was used to compute BCLs for both the scale and spine data using the Fraser-Lee (FL) formula (Fraser 1916; and Lee 1920):

$$L_i = K + (L_c - K)*(S_i/S_c), \text{ where}$$

L_i is the back calculated length at age *i* (BCL),

S_i is the distance between the focus and annulus *i*,

L_c is the length at capture,

S_c is the radius of the scale along the transect, and

K is the standard intercept value of 55 mm (Carlander 1982). Wilcoxin signed-rank tests were used to check for significant differences between the mean BCLs from the scale AT transect and the BCLs from the other transects. The AT transect was chosen as the benchmark for comparisons, as this has been the transect recommended for standard use (Jearld 1983).

Results

Perfect agreement between structures after the initial aging occurred for 127 of the fish. Interpreted ages between structures were off by ± 1 year for 98 of the fish and by ± 2 years for 21 individuals (Figure 2). The largest discrepancy between structures was from a 660 mm individual aged to 11 years on the spine and to 5 years on the scale. In all instances where disagreement in assigned ages was • 3 years, the spine assigned an age of 8 years or older. Twenty-seven fish were added after a second reading, giving us 154 individuals ranging from 3 to 10 years in age to be used for calculating BCLs.

Back-calculated lengths obtained using the Fraser-Lee formula along the three spine transects compared much more favorably to the BCLs obtained using the scale transects than did the spine BCLs obtained using a regression equation. Francis (1990) reported that the problem with using regression models to compute BCLs is that they do not take into account the length of the fish and the radius of the structure at the time of capture. Results and discussions of spine BCLs will be only for those obtained using the Fraser-Lee formula.

Regression analysis was used to compare BCLs within each structure (Table 1). Back-calculated lengths between the two scale transects showed a relationship close to 1:1 with an intercept of 0 (slope = 1.0078, intercept = -4.858 mm). Back-calculated lengths from the three spine transects were also close to a 1:1 relationship (slope range 0.9895 - 1.0050, intercept range -13.154 to 1.538 mm) (Table 1). Back-calculated lengths between the two structures were also compared (Table 1, Figure 3), and were found to be significant (*F* range 9,743 - 13,149, R^2 range 0.9156 to 0.9361).

Mean BCLs for each lake's walleye population were estimated (Table 2). Comparisons were made between the scale AT transect and each of the other transects. For the Green Lake population, no significant differences were observed between the mean BCLs along the AT transect and between those along the DT or HC transects (Table 2). The spine HE transect underestimated length-at-age relative to the scale AT transect for ages 3 and 4 by 12 mm, or 3.2% and 2.7%, respectively. For the Island Lake population, no differences were obdddserved between the mean BCLs along the AT transect and the spine transects HE and HC (Table 2). For both the Green and Island Lake populations, when significant differences were observed, the BCLs along the spine AE transect overestimated length-at-age relative to the scale AT transect by 0.8% to 11.4% (4 mm to 20 mm). In the Mille Lacs Lake population, mean BCLs calculated using the two spine transects HE and HC underestimated length-at-age relative to the scale for ages 1 to 4 along the HE transect, and for ages 1 to 5 along the HC transect. Differences ranged from 3.3% to 8.6% (11 mm to 28 mm) along the HE transect, and from 1.3% to 8.9% (6 mm to 24 mm) along the HC transect. Length-at-age estimates along the AE transect for the Mille Lacs population only differed at ages 2 and 3, and were 10 mm and 16 mm, respectively.

Discussion

In general, ages interpreted from dorsal spines and scales agreed favorably through age 5, after which scales appeared to underestimate the age of walleyes in these three lakes (Figure 2). Schram (1989) reported that scale analysis was unreliable for older walleyes, and that compressed outer annuli caused underestimates of the true age. Kocovsky and Carline (2000) demonstrated that ages from spines more closely agreed with otoliths than did scales in older walleye, and that scales underestimated age with respect to otoliths. An inability to identify outer annuli on the scales from the older aged individuals would explain the discrepancies observed in this study. Annuli crowding was observed in spines from older fish, presumably after individuals reached sexual maturity. However, though crowded, annuli appeared to be distinguishable upon close examination. Comparing age-frequency distributions from our spine data with those from otoliths for Mille Lacs Lake walleye, spines have proven effective at identifying strong and weak year classes, although they have tended to underestimate the abundance of the oldest year classes (Richard Bruesewitz, MNDNR, personal communication).

Schram (1989) verified the formation of annuli in dorsal spines for marked, and later recaptured, walleyes. Known years at large corresponded to changes in annuli counts for between 48% and 55% of the walleyes, and were within 2 years in 79% of the walleyes (Schram 1989). This population was characterized by older individuals, up to 20 years. Slow growth and compressed annuli at the edges may have accounted for such low percent agreement. Schram (1989) reported that annuli in scales from this population are severely crowded at the edge, making scale interpretation unreliable. The relationship between years at large and annuli counts in dorsal fin spines should be investigated in younger walleyes, where annuli crowding should not be a problem. Despite these limitations, dorsal spines can still be sampled from live fish, unlike otoliths, and do seem to be more accurate for age determination than scales for older walleyes.

Most fisheries managers are generally not interested in the BCLs of individual fish, but rather of populations so that growth rates can be inferred. Hurley et al. (1997) found that, except for ages 1, 2, and 3, BCLs in walleyes were identical using transects AT and DT on the scale. Significant differences observed in their study were generally small (0.1 - 6.3mm). We also found that mean BCLs between AT and DT were generally the same, and only observed significant differences at age 1 on Island Lake, and age 2 on Mille Lacs (Table 2), which were also small, 4mm and 7mm, respectively. In the Green and Island Lake walleye populations, mean length-at-age estimates using the spine data were generally not different from the mean values using scales measured along the AT transect. In the Mille Lacs Lake walleye population, the AE transect provided the best length-at-age estimates compared to the scale AT transect. We suggest managers report the transects used both in scale and spine studies. The spine HE transect appears to correspond better with the scale DT transect, i.e. growth stanzas are widest between successive annuli. The HC transect appears to physically correspond best with the AT transect, and is the transect preferred in our aging studies. The HC transect provided accurate length-at-age estimates relative to the scale AT transect in two of the populations. Managers interested in intensively managing specific populations may need to investigate which spine transects provide BCLs that more closely approximate those obtained from scales, as the HE and HC transects provided equivalent estimates on two of the lakes, whereas the AE transect provided better estimates for the Mille Lacs Lake population.

Klumb et al. (1999) reported that BCLs from scales consistently underestimated actual lengths in marked and later recaptured individual walleyes. Our results indicate that, except in the Mille Lacs Lake population, spine transects HE and HC provide equivalent estimates of growth compared to scales. This suggests that spines may underestimate growth as well. Further work should investigate whether BCLs calculated along the AE transect might be closer to the actual lengths observed, as these BCLs were generally larger than scale BCLs in the Green and Island Lake populations. These questions could be addressed with a mark-recapture study similar to Klumb et al. (1999).

Some of the differences observed in BCLs between structures in this study might be related to lack of replicated measurements on both scales and spines. Pierce et al. (1996) measured anterior radii and interannular distances on 10 scales per individual fish in pumpkinseed *Lepomis gibbosus* and golden shiners *Notemigonus crysoleucas*. Replicated measurements were then averaged for each fish. They reported that this provided more precise estimates for back-calculations. Newman and Weisberg (1987) reported that for brown trout *Salmo trutta*, between-scale (within fish) variance was not a significant source of variation. We didn’t use multiple scales or spine sections for our aging. The Minnesota Department of Natural Resources Duluth area office typically presses up to four scales, but only measures and back-calculates lengths from a single scale (John Lindgren, MNDNR, personal communication). Managers and technicians generally do not have time to age and measure multiple samples for each individual, especially when several thousand fish are aged each sampling season. Future studies might address whether between-scale or between-spine differences are evident in walleyes, and if this variation is significant.

Another source of variation not addressed in this study is the variation in measuring and marking the annuli for digitizing. In an inter-office investigation, MNDNR personnel demonstrated that where the mark is digitized will lead to differences in BCLs (John Lindgren, MNDNR, personal communication). They tested differences in digitizing each mark (each annulus) at the mark's front, middle, and back on the transparency paper. While we attempted to be consistent in the actual digitizing process, digitizing the center of each mark, this might be a source of variability not addressed in our study. We recommend that consistency be maintained when digitizing marks to minimize this source of variation.

Our results indicate that there is good agreement between scale and spine BCLs in those fish within the 0 to 10 age range that we were able to accurately age. We did not address the problem of length-at-age estimates from incorrectly-aged individuals. This will obviously affect estimates, leading to less accurate BCLs. Presumably, since dorsal fin spines appear to be easier to interpret when aging older fish, BCLs may be more accurate for fish at ages greater than 5 years. Managers interested in age structure and growth rates of walleye populations may benefit from using spines collected from older individuals. In our spring sampling, adult spawning walleye are targeted. Spine-interpreted ages range from 4 to 22, averaging in the age 5 to 9 year range. This is in the range where spine / scale age agreement breaks down (Figure 2), with scales showing a consistent bias towards underestimating ages. In our sampling, spines are collected for aging and obtaining BCLs from individuals larger than 300 mm (age 3+), while scales are collected for aging and back-calculating length-at-age estimates from the smaller individuals. Managers interested in growth for younger individuals, e.g., age 5 or less, would not gain much by using dorsal spines. Scales are much easier to prepare, and have a longer history of use for back-calculating lengths at age. We still advocate the use of scales for aging younger fish, but recommend managers consider the use of spines for obtaining BCLs from older individuals.

Acknowledgments

The Fond du Lac Division of Resource Management thanks Fond du Lac tribal bandmembers who patiently waited and allowed our field staff to measure and obtain bony structures from harvested walleye. Assistance for the field and lab portions of this study was received from Sean Thompson, Gary Martineau, and Terry Perrault (Fond du Lac); and Sonny Myers, Darren Vogt, and Carlye Gunderson (1854 Authority). Tom Jones, Rick Bruesewitz, John Lindgren, Pete Rust, Neil Kmiecik, Joe Dan Rose, Nancy Costa, Rick Gitar, Jeff Schuldt, and Frank Stone provided comments as the manuscript evolved. Greg Busacker, Keith Hurley, and Richard Zweifel provided insightful reviews on an earlier draft that greatly improved the manuscript.

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Table 1. Results of the regression analysis comparing back-calculated lengths (BCLs) at age along three spine transects, HE, HC, and AE, and two scale transects, AT, and DT, showing the slope of the regression line, intercept (Intcpt), the *F* - ratio, and R^2 value. The Fraser-Lee model was used to calculate BCLs using both the spine and scale data. A standard intercept of 55 mm was used for all Fraser-Lee calculations. For all comparisons, the degrees of freedom were 890 and the $P < 0.00001$.

Comparison	Slope	Intcpt	F	R^2
Between scale transects				
AT - DT	1.0078	-4.858	35,877	0.9756
Between spine transects				
HE - HC	0.9895	1.538	12,083	0.9308
HE - AE	0.9924	-6.844	24,706	0.9649
HC - AE	1.0050	-13.154	14,331	0.9414
Between spine and scale transects				
HE - AT	0.9685	3.463	10,619	0.9220
HE - DT	0.9957	-7.957	13,149	0.9361
HC - AT	0.9899	-5.741	9,743	0.9156
HC - DT	1.0104	-14.924	9,831	0.9163
AE - AT	0.9649	9.761	11,608	0.9282
AE - DT	0.9839	5.547	12,456	0.9327

Table 2. Mean back-calculated lengths (BCLs) at age in mm for walleye collected from Green, Island, and Mille Lacs Lakes, Minnesota. Length-at-age estimates were calculated along two scale transects, AT and DT, and along three spine transects, HE, HC, and AE using the Fraser-Lee formula. The number of fish aged in each population is indicated. Wilcoxin signed-rank tests were used to compare mean BCLs along the AT transect with the BCLs calculated along the other transects, with significant differences noted with an * (α = 0.05).

Lake	Age	AT	DT	HE	HC	AE
Green Lake						
N = 35	1	155	159	155	155	175*
	2	256	260	255	261	275*
	3	369	366	357*	365	372
	4	445	439	433*	440	449
	5	500	495	490	495	504*
	6	523	521	515	516	517
	7	491	495	493	496	498
Island Lake						
N = 30	1	137	141*	143	127	151*
	2	207	214	222	199	229
	3	281	286	288	271	294
	4	340	341	344	332	351*
	5	381	381	388	386	394
	6	412	411	414	416	419
	7	443	442	443	444	443
	8	470	470	470	469	469
Mille Lacs						
N = 89	1	153	156	144*	140*	152
	2	235	242*	219*	214*	225*
	3	325	327	297*	301*	309*
	4	398	401	385*	385*	398
	5	452	454	447	446*	456
	6	492	493	486	487	494
	7	521	521	519	518	523
	8	552	550	551	552	553
	9	568	563	570	569	572

Figure 1. Scale showing the anterior transect AT and the diagonal transect DT used for aging and back-calculation, and a cross section of a dorsal fin spine showing the horizontal elongated transect HE, the horizontal compressed transect HC, and the anterior elongated transect AE used for aging and back-calculation estimates in walleye. Both the scale and spine cross section are from a 665 mm female walleye taken from Mille Lacs Lake, Minnesota.   NOT DISPLAYED DUE TO SIZE OF IMAGE.

Figure 2. Age assigned using scales versus age assigned using dorsal fin spines from individual walleye sampled from Green Lake, Chisago County; Island Lake, St. Louis County; and Mille Lacs Lake, Mille Lacs County, Minnesota. The 1:1 line is included for reference. N = 266 walleye aged. NOT DISPLAYED DUE TO SIZE OF IMAGE.

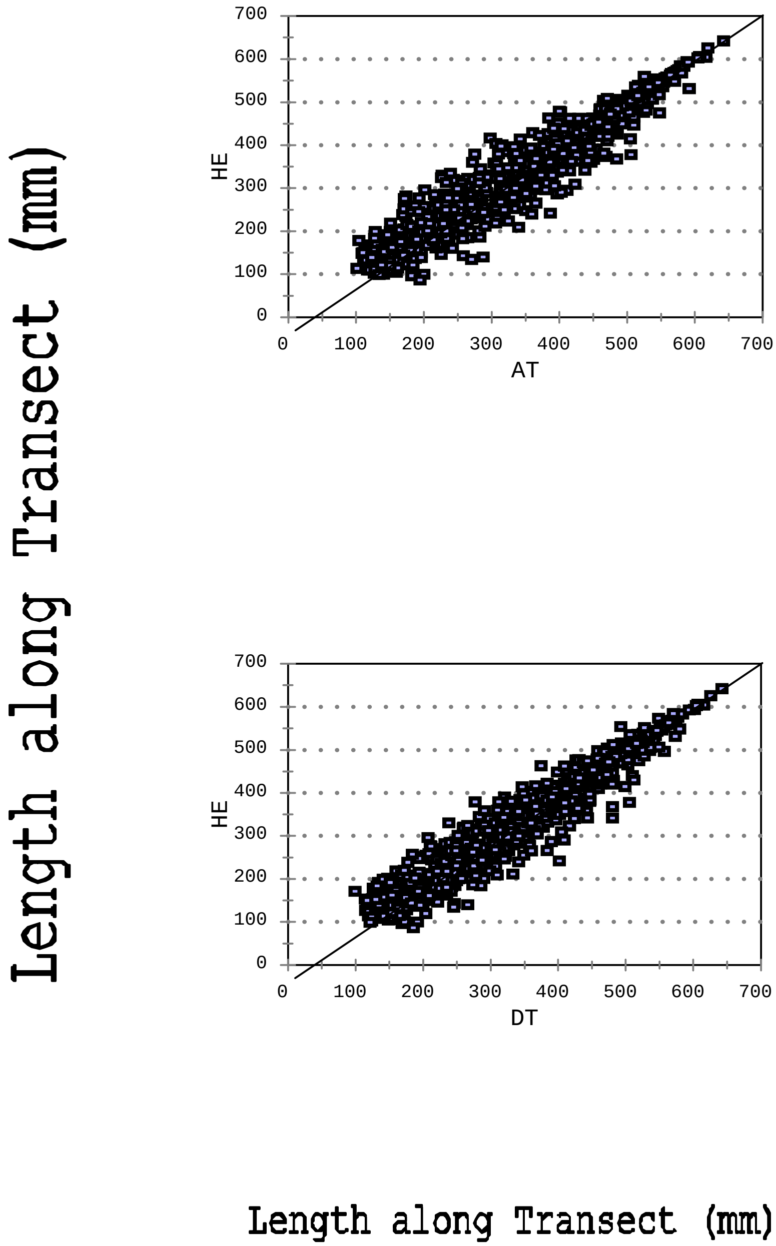

Figure 3. Back-calculation estimates using the Fraser-Lee proportional method between the dorsal fin spine horizontal elongated transect HE and the scale anterior transect AT, and between the spine horizontal compressed transect HC and the scale anterior transect AT. N = 154 walleye. Ages assigned ranged from 3 to 10 years. The 1:1 line is included for reference.