May 1984, a specimen of *S. meadi* was collected at a depth of 412 m using a 17 m otter trawl at lat. 28°59.85′N, long. 79°55.98′W. The shark measured 430 mm in length and weighed 0.4 kg. This shark, together with its stomach contents, is deposited at the Ichthyological Museum of the Florida Department of Natural Resources, St. Petersburg (FSBC 16208). Examination of the reproductive system revealed a developing right ovary measuring 4.4 cm long and 0.6 cm wide. The left ovary was atrophied. Follicles teased from the right ovary measured 0.75 mm in diameter. The nidamental glands were 3.0 mm wide and 8.0 mm long. The oviduct, from nidamental gland to vagina, was 82 mm long and 1.0 mm wide. Gut content examination revealed several cephalopod beaks and tentacles, shrimp remains, and the articulated caudal skeleton from a relatively large, unidentified teleost.

This specimen of *S. meadi* is the third and largest female collected to date. Burgess et al. (1979) reported on the collection of a 385 mm total length female in which the right ovary measured 33.2 mm and the left 8.9 mm in length. This represents about 8.6% of the total length of the shark. The right ovary of the specimen reported in this paper represents about 10.2% of the shark's total length. This specimen is immature, but the allometric increase in ovary length, and the fact that the left ovary was completely atrophied suggests that the specimen might be considered a subadult (maturation begun). The small size of the Florida Bahama specimens compared with the North Carolina examples led Burgess et al. (1979) to suggest geographical size segregation. This large specimen from off the central Florida east coast does not support this segregation. Discovery, in gut content examination, of the large, teleost caudal skeleton suggests an unexpected ability to prey on relatively large fishes.

Acknowledgments

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GLENN R. PARSONS

Department of Marine Sciences
University of South Florida
140 Seventh Avenue South
St. Petersburg, FL 33701

A COMPARISON OF SCALE AND OTOLITH AGING METHODS FOR THE ALEWIFE, *ALOSA PSEUDOHARENGUS* [1]

Beginning in 1971, the Maine Department of Marine Resources monitored the harvests of anadromous alewives ascending the Damariscotta River (Libby 1982). Part of this monitoring assessed changes in age composition within and between years. Aging was done by interpreting the number of scale annuli in terms of fish age as has been done in earlier investigations (Havey 1961; Rothschild 1963; Marcy 1969). However, scale annuli were sometimes difficult to interpret, so in 1979, methods for removing and reading alewife otoliths were studied. A relatively fast and efficient method was developed for removing otoliths. The ease with which the otoliths were processed to age fish prompted an analysis of which method (scales or otoliths) was best for determining the age of an alewife. This paper compares the precision of reproducibility and accuracy between the scale and otolith methods.

Materials and Methods

Alewives, *Alosa pseudoharengus*, were taken daily from the commercial harvest throughout the fishing period for their otoliths and scales. The fish were taken to the laboratory, sexed, and measured for length and weight. About 10 scales were removed from the left side above the lateral line just posterior to the dorsal fin. The scales were cleaned and put into envelopes labeled with the length and sex of the alewife. In 1963, Rothschild described the alewife scale and characteristics of the annuli.

Otoliths were collected and stored as follows: A

[1]This study was conducted in cooperation with the U.S. Department of Commerce, National Marine Fisheries Service, under Public Law 89-304, as amended, Commercial Fisheries Research and Development Act, Project AFC-21-1.

transverse cut was made at the point of attachment of the operculum, which severed the head leaving some attachment of skin to the body. The head was then pulled away from the body removing the gills, leaving the skull clear of the gills and viseral blood. When time did not permit for further processing, all the heads from a day's sample were placed onto a tray and frozen for later analysis. For otolith removal, the head was held ventral side up and a transverse cut was made into the skull at the point of dorsal musculature attachment (Fig. 1a). A correct cut was sliced through the ends of the semicircular canals containing the sagitta otolith (Fig. 1b). Kornegay, in 1978, described the sagitta otolith that is used for age determination of the alewife.

Each otolith was extracted with microforceps, placed on absorbent paper, and rubbed lightly to remove any adhering tissue. After drying, otoliths were placed in depressions in black Plexiglas[2] trays and covered with Permount (see Libby 1982). Williams and Bedford (1974) described the growth and collection of otoliths and interpretation of otolith annuli in general. The Atlantic herring, *Clupea harengus*, otolith which is similar to the alewife otolith, was described by Watson (1964). He reported on the high validity of its use for aging and the high reproducibility of readings between readers.

Scales and otoliths were collected from 536 fish. Thirty-one fish were discarded because the otoliths or scales were unreadable or the shape of the otolith revealed that the fish was a blueback, *A. aestivalis*. Price (1978) explained the difference in otolith morphology between the two species. A final count of

[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

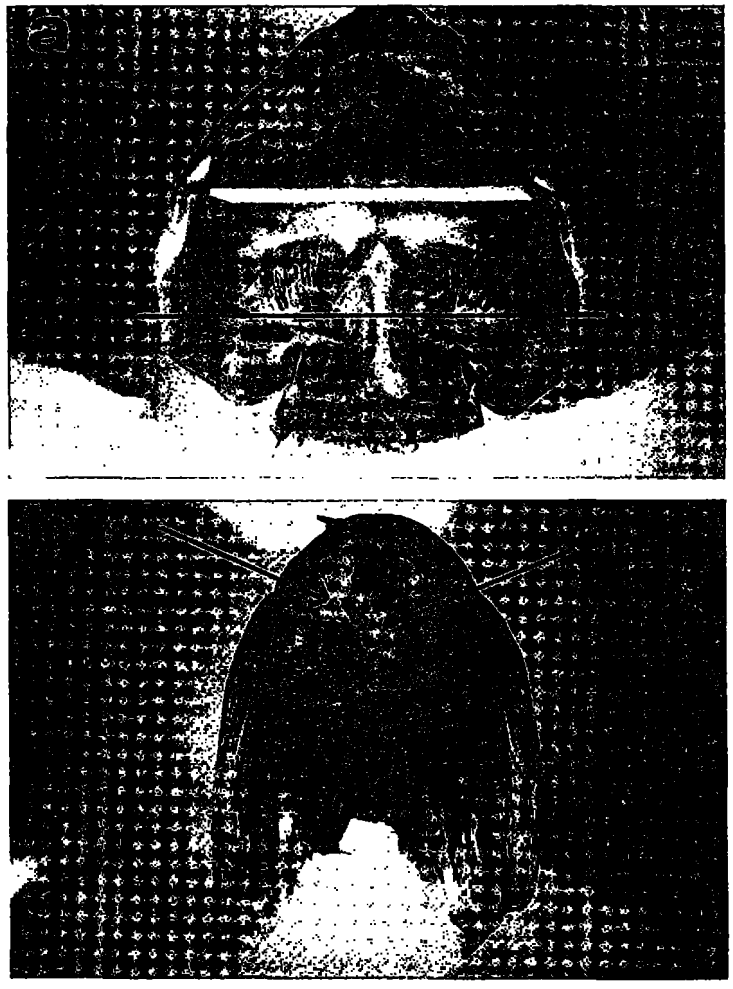


FIGURE 1.—a) Ventral side of head of *Alosa pseudoharengus*. Dark line shows musculature attachment to the skull where transverse cut is made. b) Section of skull cut away showing posterior ends of the semicircular canals containing the sagitta otoliths.

505 alewives was used for the analysis. Otoliths and scales were read using a binocular dissecting scope at 30×-60×.

Each otolith and scale for an age shown in Figure 2 was collected from the same fish. The otoliths were taken from the left side of the head and each scale was chosen for the best annuli appearance of all scales from that fish. The scale annuli shown are at the anterior portion of the scale that is normally covered by surrounding scales. The otoliths were photographed with a 35 mm camera mounted on a microscope at 11×.

Aging was done independently by two people (readers; subsequently referred to as R_1 and R_2). Ages derived from scales and otoliths by each reader were referred to as an age set. Scales and otoliths were read without knowledge of fish length or sex. A true age was established for each fish by reexamining scales and otoliths together with length and sex. The five age sets were compared to show 1) the precision of aging reproducibility (measurement of how close the ages are for two or more readings); and 2) the aging accuracy (age determinations compared with the true age).

Three analyses were used to evaluate precision and accuracy. Percent agreement (PA) compared two to three age sets to reveal what portion of the fish were aged alike between age sets. An index of average percent error (APE) developed by Beamish and Fournier (1981) was used to show the degree of variation between age sets. APE is expressed as

$$\frac{1}{N}\sum_{j=i}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{|X_{ij}-X_j|}{X_j}\right]$$

where N is the number of fish aged; R is the number of ways each is aged; X_{ij} is the ith determination of

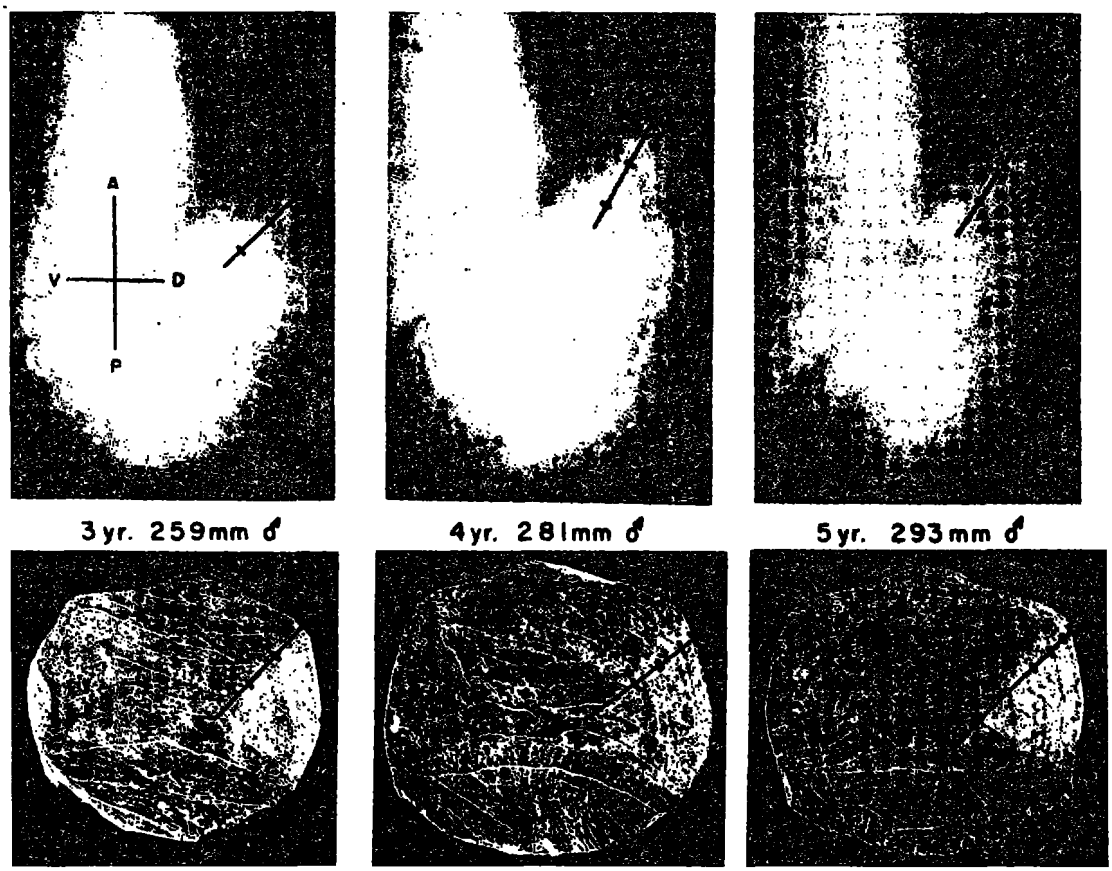


FIGURE 2.—Gross comparisons of otoliths and scales of alewives from ages 3 through 7. The otolith and scale were taken from the same fish for each age. The age-3 otolith shows: A - anterior; P - posterior; D - dorsal; and V - ventral orientation of the otoliths

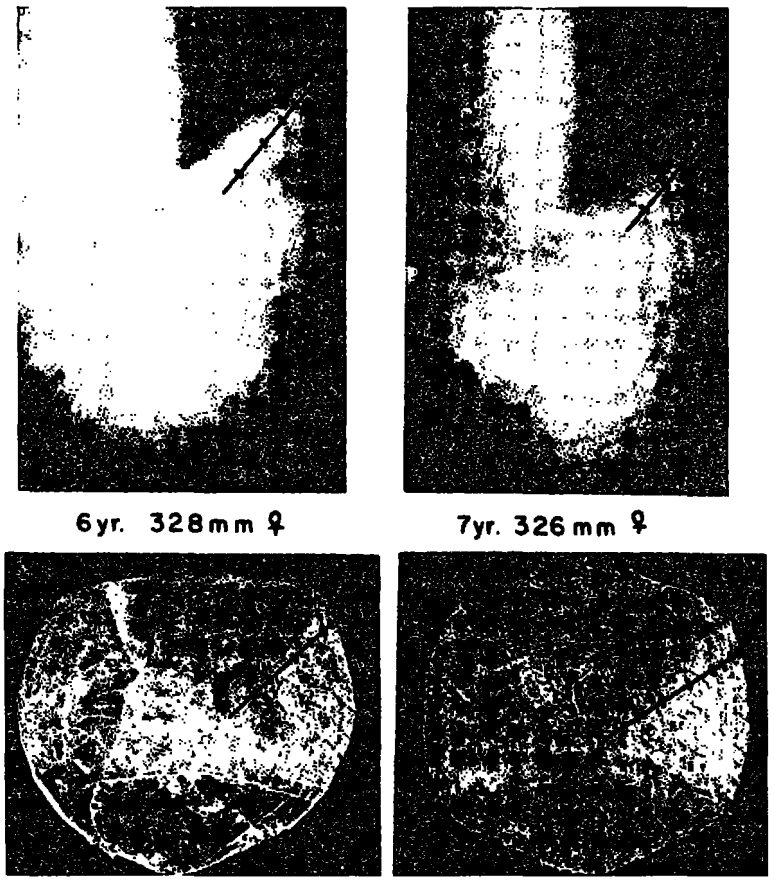
the jth fish; the X_j is the mean age calculated for the jth fish. The third method used the mean coefficient of variation (V) (Chang 1982). This was an alternative index to APE that provided a statistical test of reproducibility between agings. The coefficient was a measure of the standard deviation between all ages of fish divided by the mean age. The sum of the coefficients was then divided by the number of fish aged. PA, APE, and V are all expressed as percents.

The difference between PA and APE or V is that the former measures the actual agreement between age sets and the latter measures the amount of variation between age sets. Two treatments (a treatment was the comparison of two or more age sets) that had the same PA values might have differing degrees of variation and therefore different values of APE or V. The smaller the APE or V values, the less variation there was between age determinations.

Values for PA, APE, and V were computed for 10 treatments: scales vs. otoliths from R_1; scales vs. otoliths from R_2; scales from R_1 vs. R_2; otoliths from R_1 vs. R_2; scales from R_1 and R_2 vs. true age; otoliths from R_1 and R_2 vs. true age; male scales from R_1 vs. R_2; female scales from R_1 vs. R_2; male otoliths from R_1 vs. R_2; and female otoliths from R_1 vs. R_2. Treatments were also compared as to the relative sizes of the PA, APE, and V values.

Results

Figure 2 compares the physical appearance of otoliths and scales for ages 3 through 7. The photograph of the age-3 otolith shows its orientation as it lies in the sacculus. The dorsal side, including the anti-rostrum, shows the best contrast between the light opaque (summer growth) regions and the dark hyaline (winter growth) regions. The annular rings



in the sacculus. Lines drawn on the otoliths and scales show annular growth.

at this site are, for the most part, continuous and distinct. The annular markings on the scales are not as distinct or as sharp in contrast as on the otoliths. The scale annuli from the first three ages are well defined, but in ages 6 and 7 the outer annuli start to run together and the scale margin shows wear from resorption and deterioration. In contrast, the age-6 and -7 otoliths still reveal distinct annular rings.

PA, APE, and V values for all 10 treatments are presented by treatment comparisons in Table 1. The scale vs. otolith treatments were compared to determine how similar the two readers were in interpreting scale and otolith annuli. The PA values (82.6%, 80.4%) are relatively close to one another along with the values for APE and V. These values did reveal that R_1 had more agreement and less variability between aging scales and otoliths than did R_2. Table 1b shows a higher percentage agreement and less variability between R_1 and R_2 for otoliths than for scales.

Comparisons made between treatments of scales to true age and treatments of otoliths to true age are shown in Table 1c. The agreement of otolith ages to true ages was 10% greater and had half the variation of scale ages. Treatment comparison between male and female scale values were about the same (Table 1d), whereas the otolith values between sexes are quite different (Table 1e). The female otolith treatment had a higher PA value and lower APE and V values than did the male treatment.

Discussion

The scale vs. otolith treatment (Table 1a) revealed no real difference in the aging ability of each reader. There were also higher PA and lower V values for the treatment of otolith to true age (Table 1c). Therefore, the outcome for other treatments could be attributed to differences in the aging methods rather than the aging ability of the readers.

The results of the statistical tests (Table 1b) suggest that the method of estimating alewife ages from otoliths is superior to the method using scales. Ages derived from otoliths revealed a higher reproducibility and less variability than those obtained from scales. These differences between methods were inherent within the otoliths of female alewives, which provided the greatest accuracy and lowest variability (Table 1e) within all types of statistical comparisons.

Female alewives, at one time during their lives, possibly achieve a faster rate of growth than males. Cooper (1961), Havey (1961), and Libby (1982) showed that females are larger than males at age. This attribute of females would have the same effect on the growth of the otolith resulting in wider opaque zones with more distinct hyaline rings than male otoliths. Female scales would also have greater growth but possibly because of scale resorption and deterioration they were less easy to read than otoliths.

Other investigators have mentioned the ease of interpreting annuli of otoliths compared with scales, but have remarked that otoliths are less convenient to collect and store (Norden 1967; Kornegay 1978). The method presented in this paper was found to be more effective in obtaining both otoliths, unbroken, than the commonly used transverse cut made to the side of the head. The method of storage eliminated transferring and handling individual otoliths each time they were used. A disadvantage in using otoliths was that the fish had to be sacrificed. More care was required initially to obtain otoliths than scales, but the technique was quickly learned. The use of otoliths for aging alewives was more accurate and less subjective than aging with the use of scales.

Acknowledgments

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TABLE 1.—Percent agreement (PA), average percent error (APE), and mean coefficient of variation (V) values for five treatment comparisons: a) scales and otoliths for R_1 against R_2; b) scales of R_1 and R_2 against otoliths of R_1 and R_2; c) scales of R_1 and R_2 and true age against otoliths R_1 and R_2 and true age; d) scales of R_1 and R_2 for males against scales of R_1 and R_2 for females; and e) otoliths of R_1 and R_2 for males against otoliths of R_1 and R_2 for females. S = scales; O = otoliths; 1 = R_1; 2 = R_2; A = true age.

	Treatment cmparisons									
	a		b		c		d		e	
	S_1O_1	S_2O_2	S_1S_2	O_1O_2	S_1S_2A	O_1O_2A	$S_1S_2♂$	$S_1S_2♀$	$O_1O_2♂$	$O_1O_2♀$
PA	82.6	80.4	85.0	89.0	78.8	87.7	84.0	85.8	86.5	92.2
APE	1.9	2.3	1.8	1.1	2.1	1.2	1.9	1.6	1.5	0.8
V	2.7	3.2	2.5	1.6	2.8	1.5	2.7	2.3	2.1	1.2

of Marine Resources, for her help and expertise in being a "reader"; Robert Guillard and James Rollins, Bigelow Laboratory for Ocean Sciences, for photographic services; and Vicki Averill, Maine Department of Marine Resources, for typing this manuscript.

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DAVID A. LIBBY

Maine Department of Marine Resources
Marine Resources Laboratory
West Boothbay Harbor, ME 04575

PROBABLE CAUSES OF THE RAPID GROWTH AND HIGH FECUNDITY OF WALLEYE, *STIZOSTEDION VITREUM VITREUM*, IN THE MID-COLUMBIA RIVER[1]

The introduction of walleye, *Stizostedion vitreum vitreum*, into the Pacific Northwest of the United States is not documented; however, they are now found throughout the mid-Columbia River (Fig. 1) and downstream of Bonneville Dam (Durbin[2]). The construction of dams has transformed the Columbia River from a free-flowing river into a series of low water-velocity impoundments with physical characteristics (Table 1) that closely match the model for ideal walleye habitat proposed by Kitchell et al. (1977a).

We studied basic life history factors of mid-Columbia River walleye for 2 yr to determine how well these exotic predators have adapted to their new environment. We found that our walleye grew at a rate approaching the highest previously reported, that they were highly fecund, and that they matured at an early age. We evaluated these high growth and reproductive rates against environmental and genetic variables. We believe these data will help to identify the ever increasing role of walleye in the aquatic ecosystem of the Columbia River and similar river-reservoir systems.

[1]Technical paper no. 6723, Oregon Agricultural Experiment Station, Oregon State University, Corvallis, OR 97331.
[2]Durbin, K. 1977. News column. Oregon Department of Fish and Wildlife, P.O. Box 3503, Portland, OR 97208. Mimeogr., 3 p.

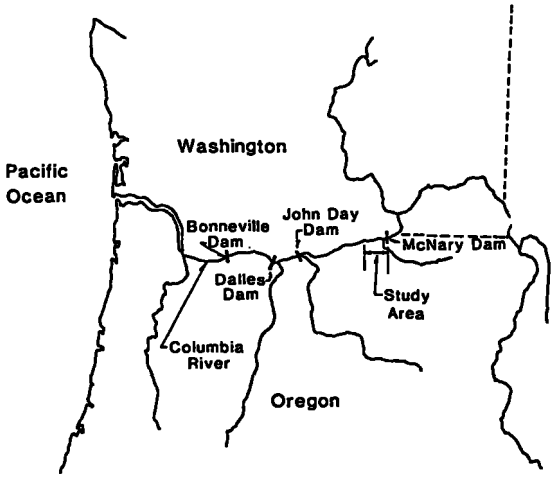

FIGURE 1.—Map of the lower and mid-Columbia River showing the locations of the major dams and the John Day pool study area where walleye were collected during 1980-81.