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A Critique on the use of Otoliths for Aging Gulf of St. Lawrence Herring (*Clupea harengus* L.)

by

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INTRODUCTION

Aging of Atlantic herring has traditionally been done from scales. Scales are large, clearly ringed, easy to collect and hence offer distinct advantages over otoliths which are small, awkward to handle and require special techniques for examination. In spite of this, more and more workers in recent years have been changing from scales to otoliths for aging herring. There are valid reasons for the change, the most practical being that new catching and handling techniques (chiefly trawling and pumping) remove the scales before the biologist has an opportunity to collect them. An equally valid reason is that populations or races of herring can be identified more readily and precisely from otoliths than from scales (Einarsson, 1951). Other reasons involve regenerated scales and the greater likelihood of mismatching scales and fish.

The validity of aging herring by scales has been frequently demonstrated and even though interpretations of age are often complicated by secondary checks there is little disagreement between workers regarding the age composition of samples involving large numbers of individuals. This is either demonstrated or implied by many investigators including Dahl (1907), Hjort and Lea (1911), Lea (1919), Wood (1937), Jean (1956) and Tibbo (1957).

In contrast, the validity of aging herring from otoliths has not been demonstrated convincingly except for young fish. For example, there is little disagreement in results of aging from otoliths by workers in the Bay of Fundy and Gulf of Maine where the majority of herring caught commercially are less than 4 years old. But in areas such as Georges Bank, the Gulf of St. Lawrence and the south coast of Newfoundland, where mean ages frequently exceed six years there is often no more agreement among individual investigators than might be expected by chance alone. This was demonstrated in a recent exchange of herring otoliths between workers in Poland, United States and Canada sponsored by the International Commission for Northwest Atlantic Fisheries (ICNAF), and coordinated by the junior author. Disagreement in age reading for individual fish ranged from one to five (5) years for fish that were probably not more than 6 years old; mean ages of samples differed by nearly a year and there was little agreement in year-class composition beyond age 4.

Comparisons of age estimates using scales and otoliths from the same fish have occasionally been made but the results have been inconclusive. Humphreys (1966), studied age structure of herring stocks in Newfoundland waters and reported general agreement between ages from scales and otoliths. However, his overall results, which were based on otolith readings, showed lower values for mean age than those reported by Tibbo (1957) and Olsen (1961) who used scales. It is quite possible that the difference resulted, at least in part, from the change in method of aging.

Tibbo and Graham (1963) reported 57% agreement between ages from scales and otoliths with the mean age from scales lower by 0.3 years than that from otoliths.

The present paper tests the reliability of the otolith method of aging herring in the Gulf of St. Lawrence, an area where older herring dominate commercial catches.

MATERIALS AND METHODS

Six samples of herring involving 1150 individual fish were obtained from the commercial fishery in the Gulf of St. Lawrence during May 1966 (Table 1 and Figure 1) and scales and otoliths were taken from each fish.

Total lengths of all fish in the samples ranged from 23.5 to 35.5 cm.

Scale-otolith comparisons involved 1030 (90%) of the fish in the combined samples (Table 1). Discards were due chiefly to scales that were regenerated. Only four (4) pairs of otoliths were unreadable.

The scale method used was described by Tibbo (1957). Scales were examined with a projector and positions of winter rings were plotted. The technique used for mounting and examining otoliths was described by Watson (1965). Otoliths were examined under reflected light using a zoom microscope and low magnification (10X).

For this paper "age" is defined as the number of winter rings on the scales and otoliths and in this way differs from most definitions which consider season of hatching in assigning age to individual fish. Our definition, while inadequate for some studies, assures uniformity in aging from both scales and otoliths and hence makes the results directly comparable.

Comparisons are made of (a) agreements and disagreements between scale and otolith ages; (b) lengths at various ages using both scales and otoliths and (c) age composition of samples based on the two aging techniques.

RESULTS

The results of a comparison of scale and otolith readings for individual and combined samples (Table 2 and Figure 2) show good agreement between the age estimates for young fish. There were no disagreements at age 3; only 3 out of 224 cases at age 4 and only 5 out of 60 cases at age 5. Beyond age 5, however, there is little agreement and this get progressively poorer as age increases. For example, there was only 1 agreement in 32 cases at age 9 and none at age 10 (11 cases).

For most (94%) disagreements, otolith readings were lower than scale readings (Table 2). In 17 cases, however, otolith ages were one year older and in 2 cases they were two years older than scale ages. Scale ages were greater than otolith ages in 309 of the cases. The difference was mostly 1 year but ranged to 4 years and tended to increase with age.

Apparently percentage agreement within samples depends on relative numbers of the various age groups represented. Thus the low percentage agreement (42.9%) in the Caraquet sample reflects the high number of older fish in that sample.

Length frequencies for the various age groups as determined by scales and otoliths (Figure 3) for combined samples shows almost identical frequencies for ages 3 and 4 and similar frequencies for age 5. For ages 6, 7 and 8, however, the frequencies obtained with otoliths are skewed to the right a result of including more larger herring in younger age groups. Chi-square tests confirm that for ages 6 to 8 inclusive the apparent differences in length frequency distributions are statistically significant.

Age composition of combined samples obtained separately from scales and otoliths (Figure 4) shows that the relative strength of the various age groups agrees well up to age 6. Otolith age 7 is apparently an accumulation of scale ages 7 and 8 as it is almost equal to the sum of them. Age compositions by the two methods were subjected to a chi-square test with the hypothesis that both sets of data represented fish taken from the same population. The chi-square value (x^2 = 87.573) does not support this hypothesis (P = <0.01). Mean ages of the combined samples by the two methods were 6.38 ± 0.06 years from scales and 6.01 ± 0.05 years from otoliths.

The observed length ranges, mean lengths and coefficients of variability for the various age groups as determined by scales and otoliths (Table 3) are similar for ages 3, 4 and 5 but for ages 6, 7 and 8 the range in length is greater, mean lengths are significantly different and there is more variability for otolith ages than for scale ages.

Plotting mean lengths for different age groups as determined from scales (Figure 5A) and otoliths (Figure 5B) shows an acceptable growth curve for agreed ages. Mean lengths for scale ages disagreeing with otolith ages (Figure 5A) differ only slightly from this growth curve whereas mean lengths for otolith ages disagreeing with scale ages (Figure 5B) are much more variable and are widely scattered from the growth curve. The deviation is almost entirely in the direction that results from a tendency to estimate lower ages from otoliths than from scales.

DISCUSSION AND CONCLUSIONS

All the evidence presented supports the hypothesis that age estimates from scales are more accurate than those from otoliths. There is good agreement up to age 5 but beyond that otolith-ages are consistently lower than scale-ages. In addition the range in mean lengths obtained from otolith ages do not fit an acceptable growth curve (Figure 5B).

The disagreements between readings are probably due to difficulties in observing the outer winter rings on both scales and otoliths. However, these difficulties appear to be less severe with scales. For older herring the margins of the otoliths show little contrast between hyaline (winter) and opaque (summer) growth zones. This results in a lower value of ages estimated from otoliths than those from scales. Using higher magnification for otoliths only tends to complicate age reading.

For areas where large and old herring constitute a high proportion of the total stock it is undoubtedly more accurate to use scales for all population parameters that involve age.

SUMMARY

Scales and otoliths from 1150 herring were examined to test the accuracy with which age can be determined. Comparison of results by the two methods showed disagreements increasing with age and an overall agreement of only 68.0%. Ages from scales were higher than those from otoliths. Mean lengths from otolith-aged herring were more variable than those from scale-aged fish and length distributions beyond age 5 were significantly different. In the Gulf of St. Lawrence, where larger and older herring predominate in the catches, scales are more reliable than otoliths for age analysis.

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Table I. Scale and Otolith Samples from Southern Gulf of St. Lawrence--Spring Fishery, 1966.

Locality	Total No. of fish Sampled	Readable Scales	Readable Otoliths	No. of Compared Ages
Caraquet	250	226	248	224
Pt. Sapin	250	213	250	213
Egmont Bay	150	145	150	145
N. Rustico	200	162	199	162
Souris	200	187	199	187
Magdalen Is.	100	99	100	99
Total	1,150	1,032	1,146	1,030

Table II. Comparison of herring ages from scales and otoliths. Identical ages are shown in squares.

Scale ages Otolith age	3	4	5	6	7	8	9	10	10+	Total
3	[39]	3								42
4		[221]	3	1						225
5			[55]	7	1	1				64
6				[103]	35	17	3	2		160
7			2	11	[212]	189	14	3	3	434
8					6	[69]	14	6	4	99
9							[1]		2	3
10									1	1
10+									2	2
Total	39	224	60	122	254	276	32	11	12	1,030

Table III. Observed ranges, mean lengths, standard errors and coefficients of variability for different age groups as determined by scales (S) and otoliths (O).

Age	Highest and Lowest Length	O.R	$\bar{X}$	$S\bar{x}$	C.V
3 S	237 - 277	41	262.8	1.579	3.8
O	237 - 295	59	263.9	1.696	4.2
4 S	251 - 305	55	284.1	.516	2.7
O	251 - 307	57	284.4	.517	2.7
5 S	276 - 315	40	296.8	.941	2.5
O	276 - 315	40	297.9	.969	2.6
6 S	286 - 315	30	303.8	.553	2.0
O	290 - 343	54	308.1	.751	3.1
7 S	298 - 325	28	310.8	.365	1.9
O	291 - 346	56	314.6	.395	2.6
8 S	299 - 344	46	318.1	.443	2.3
O	299 - 354	56	321.8	1.062	3.3

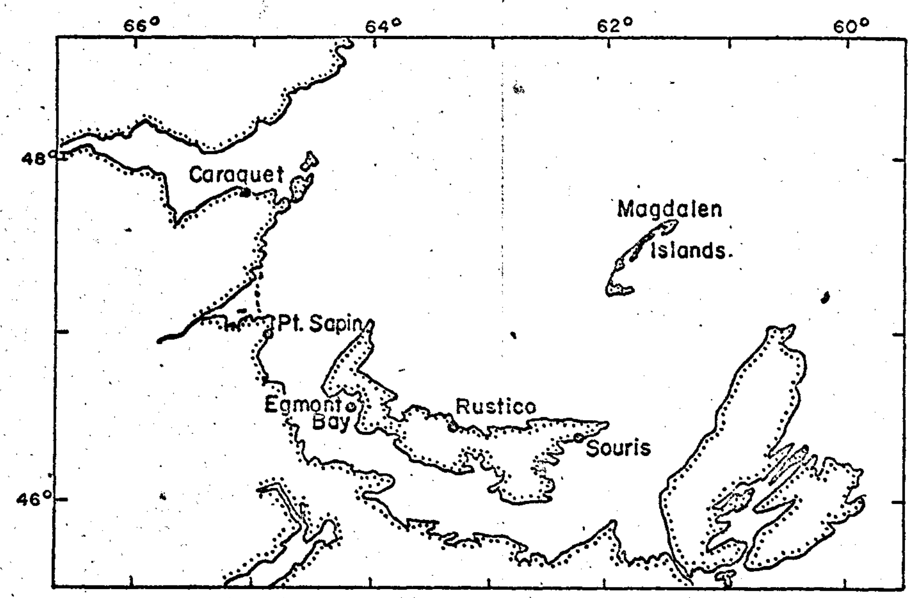

Fig. 1. Sampling locations in the southern Gulf of St. Lawrence.

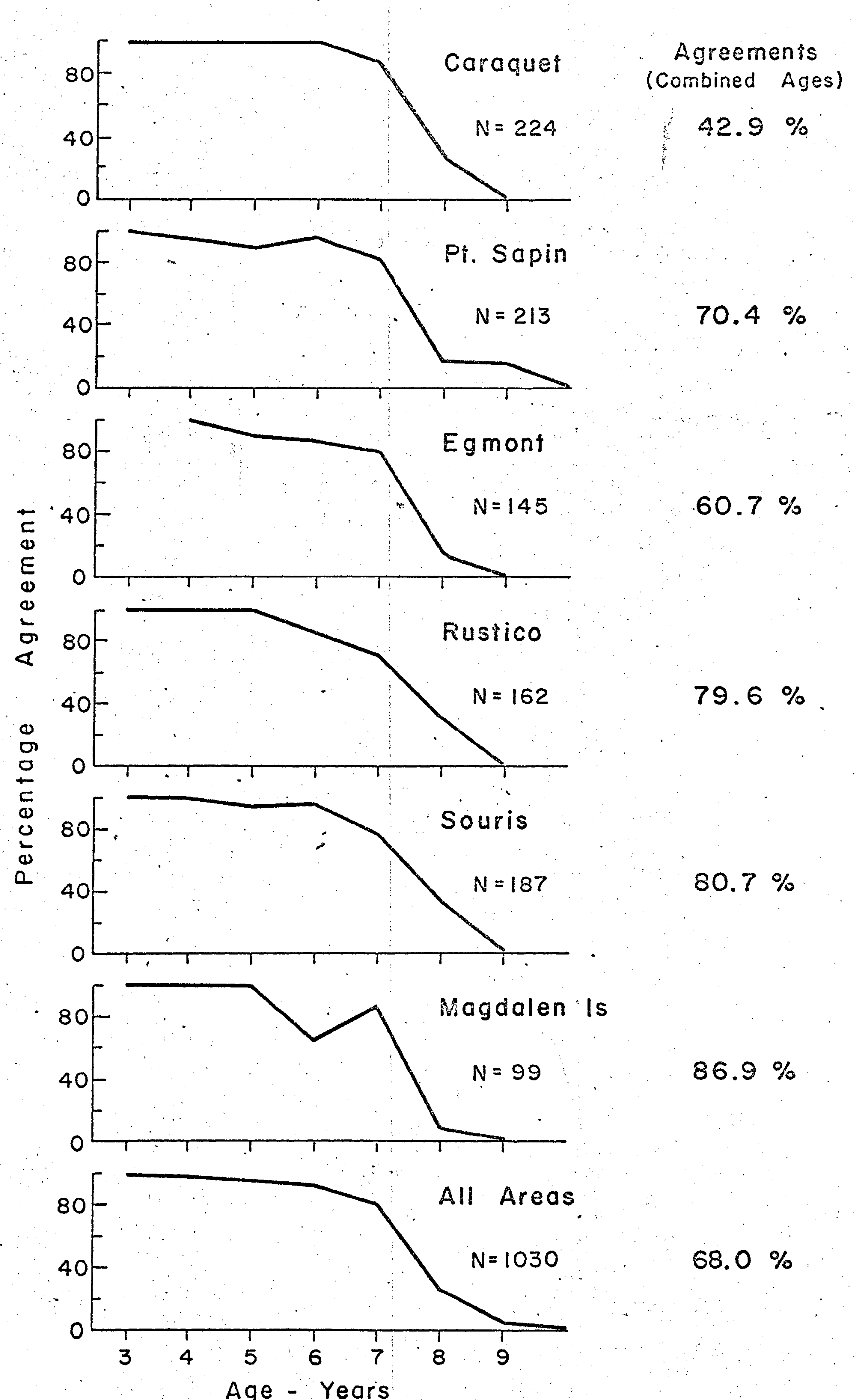

Fig. 2. Levels of agreements between scale and otolith ages by individual samples and for the whole area.

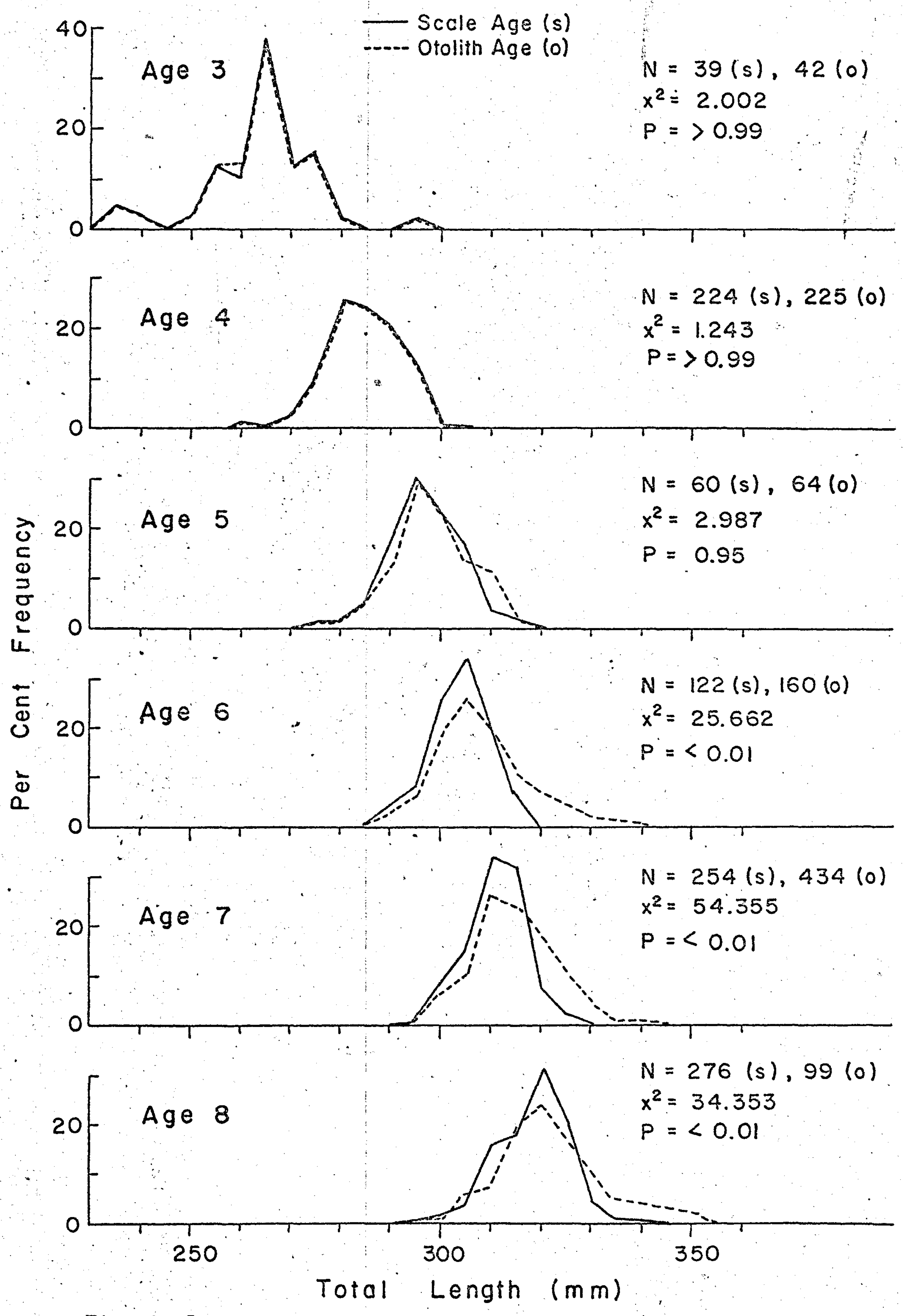

Fig. 3. Length frequencies of herring age groups as determined by scales and otoliths. Numbers of fish (N), chi-squares (x^2) and probability (P) values are included.

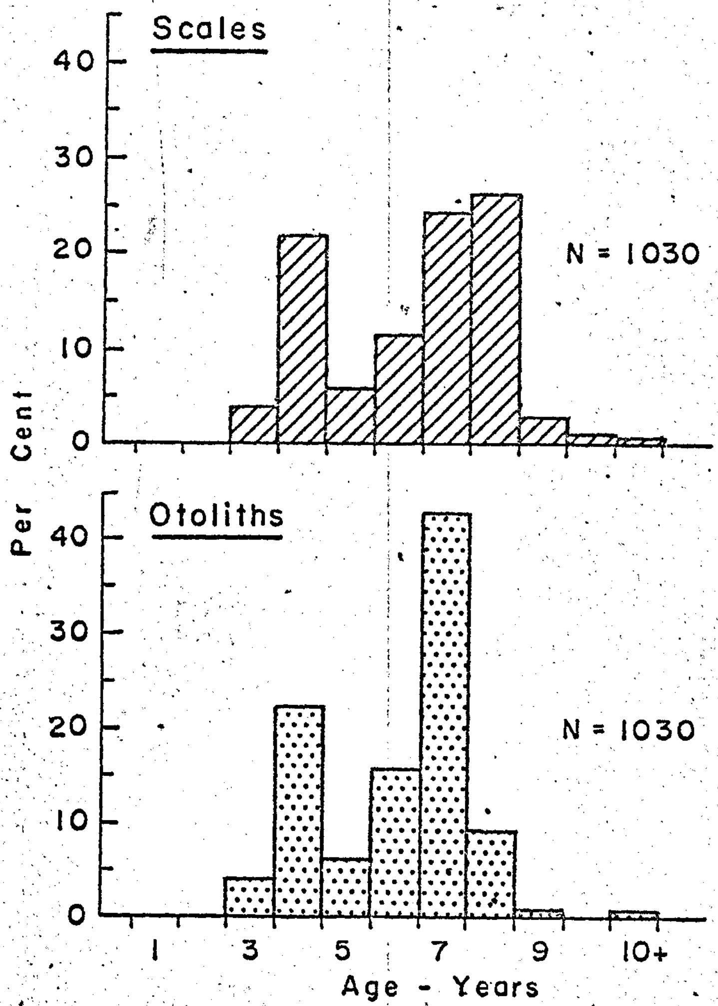

Fig. 4. Age compositions from scales and otoliths (combined samples).

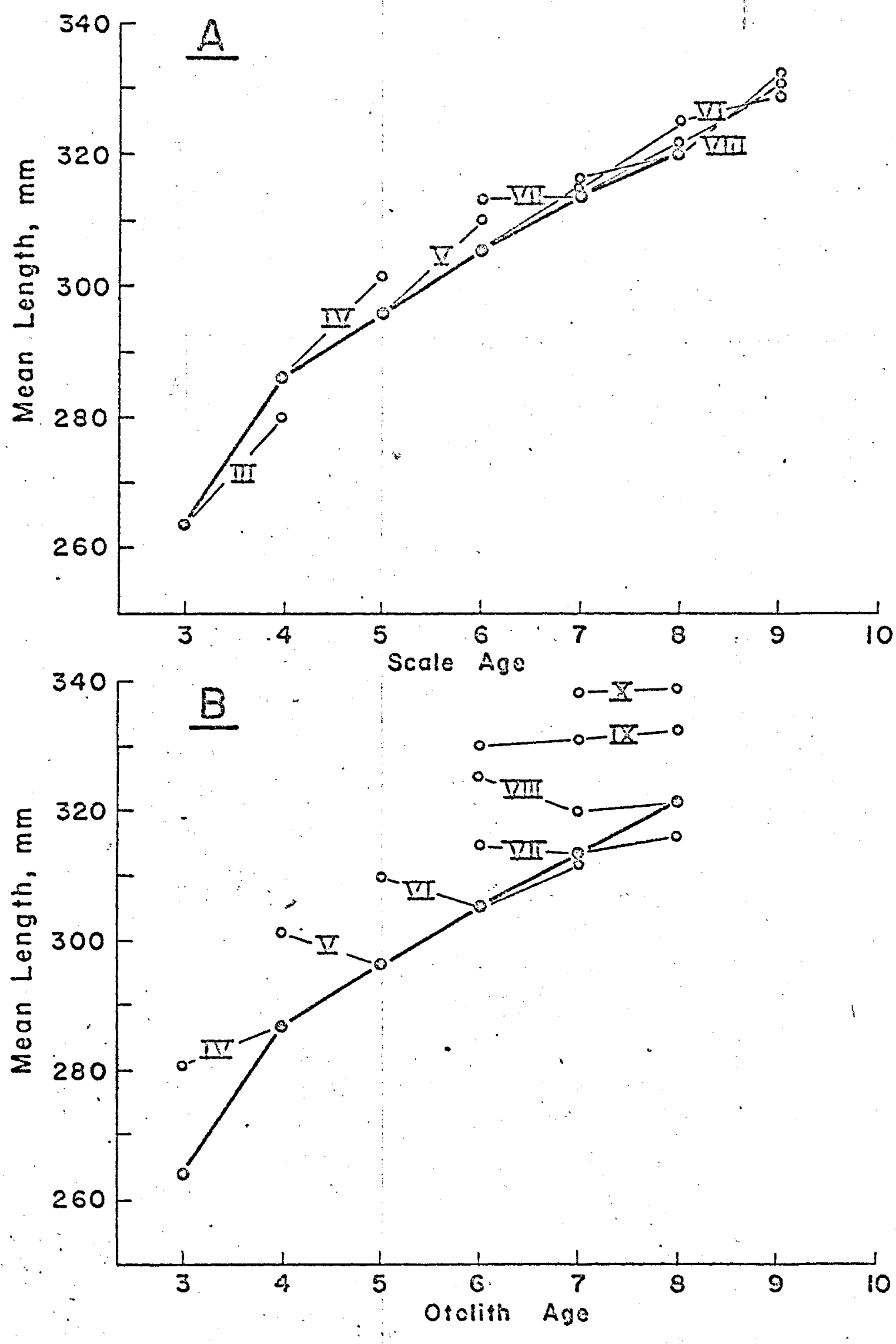

Fig. 5. Mean lengths at various ages by scales (A) and by otoliths (B). Agreed ages are shown as black dots, disagreements as open circles.