FRI-UW-8501
March 1985

FISHERIES RESEARCH INSTITUTE
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FEASIBILITY OF USING SCALE ANALYSIS METHODS TO IDENTIFY BERING SEA HERRING STOCKS

by

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Annual Report

to

North Pacific Fisheries Management Council
Contract No. 83-ABC-00165

Approved

Submitted March 14, 1985

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EXECUTIVE SUMMARY

Mixing proportion estimates of the herring stocks in the 1984 Dutch Harbor food and bait fishery were determined by scale pattern analysis. Five eastern Bering Sea stocks (Norton Sound, Cape Romanzof, Nelson Island, Togiak, and Port Moller) and one from the south side of the Alaska Peninsula (Simeonof Island) were examined in two separate linear discriminant function (LDF) analyses, one involving age 7 herring and the other involving age 6 herring. More scales were available for the age 7 analysis, and the unknowns were stratified by sample date into four groups. Age 6 unknowns could only be stratified into two groups. The Cape Romanzof stock was not included in the final analyses because it misclassified heavily with the adjacent stocks of Norton Sound and Nelson Island.

The Togiak stock was highly favored by the age 7 and the age 6 mixing proportion estimates. The overall age 7 estimate was 78.9% Togiak, 11.6% Port Moller, and 9.6% Nelson Island. Togiak estimates at all time periods were significant. Norton Sound and Simeonof Island received only negative estimates. The overall age 6 estimate was 100% Togiak. Port Moller received an estimate of 15.9% in the second time period, but all other estimates besides those for Togiak were negative.

Classificatory accuracies in the age 7 analysis were higher than those in the age 6 analysis. The age 7 overall five-way accuracy was 74.9%, and for age 6 it was 62.8%. The lowest individual accuracy for both ages belonged to Port Moller. It was heavily misclassified as Togiak. Simeonof Island had the highest individual accuracy, and the scales from the herring of this stock can be separated from those of Bering Sea herring simply by visual inspection.

The age 6 unknowns of the 1983 Dutch Harbor fishery were classified with the 1984 age 7 standards, and the mixing proportion estimates were compared to those from the 1983 LDF analysis. The 1983 LDF analysis was different in that only the Port Moller herring of greater length were represented, with the smaller herring having been separated and eliminated earlier. In 1984, Port Moller herring could not be separated, so estimates for this stock were higher than in 1983, and estimates for Togiak were lower. Estimates for Norton Sound and Nelson Island were somehwat different than in 1983, but not outside of the corresponding confidence limits.

Mean herring length was compared between three groups of samples. One group consisted of the 1982 age 5, 1983 age 6, and 1984 age 7 standards. Another group was comprised of mean lengths back-calculated from 1984 age 7 standards. The third group included 1984 age 5, 6, and 7 samples. The stocks of Norton Sound, Nelson Island, Togiak, and Port Moller were studied. Nelson Island lengths in 1984 were smaller than lengths estimated from samples in 1982 and 1983.

Port Moller age 7 lengths were greater lengths estimated from 1982 and 1983 samples.

Otoliths and scales from four Togiak herring were compared. The age determined from otoliths agreed with that determined from the scales of the same fish. Annuli were measured on the otoliths and the scales, and proportionate growth compared.

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FEASIBILITY OF USING SCALE ANALYSIS METHODS TO IDENTIFY BERING SEA HERRING STOCKS

INTRODUCTION

Pacific herring of the eastern Bering Sea migrate in the spring to spawn in Alaskan coastal waters. Although their migratory patterns are yet obscure, it is believed that the herring remain in coastal waters until fall, at which time the majority are believed to return to a wintering area northwest of the Pribilof Islands (Wespestad and Barton 1981). In late summer, prior to this return migration, large numbers of herring are found in the vicinity of Unalaska Island, and it appears that these fish originate from the major spawning stocks of the eastern Bering Sea (Fig. 1). This is a matter of importance because the spawning herring are exploited by sac roe fisheries while the herring near Unalaska Island are subjected to a food and bait fishery based out of Dutch Harbor. It is therefore possible that these two fisheries are exploiting the same resource.

In an effort to determine the stock composition of the herring taken by the Dutch Harbor fishery, scale pattern analysis was first used in 1982 with samples representing the major spawning stocks of the eastern Bering Sea, and with samples representing the Dutch Harbor fishery (Walker and Schnepf 1982). This work was continued in 1983, and results indicated that the Togiak stock was the major contributor to the food and bait fishery (Rogers et al. 1984). The Togiak stock is by far the largest stock of the eastern Bering Sea, and provides for the largest sac roe fishery of western Alaska. Research results indicated that other stocks were contributing to the food and bait fishery, but at much lesser proportions.

The primary objective of this study was to verify previous results with another year of refined research. The stock composition in the 1984 Dutch Harbor fishery was estimated from two age classes of herring. The results of this study were based on data collected in 1984, and the methods follow those of the previous two years.

METHODS

The main assumption in the use of scale measurements to separate stocks of herring is that different growth patterns are displayed by fish from different areas. Scale characters such as the distance between adjacent annuli or back-calculated length are used to separate samples ("standards") representing known spawning stocks. These standards can then be used to classify samples ("unknowns") representing a mixed-stock population of unknown origin. Previous research has demonstrated that precise scale selection with reference to the body is imperative to obtain accurate results (Rogers et al. 1983).

We first used linear discriminant function (LDF) analysis to separate stocks of herring in 1983 and this type of analysis was also used in 1984. Results were obtained through the use of computer program BMDP7M (Dixon and Brown 1979). Previously, we had used polynomial discriminant function (PDF) analysis (Cook 1982) on herring. In all three years, the Alaska Department of Fish and Game (ADF&G) provided scale samples, mounted and aged. These samples were collected on the spawning grounds and from the Dutch Harbor fishery, usually during a span of several weeks.

Construction of Standards

Standards were constructed for age 6 and age 7 herring of 1984. These were the preponderant age classes for most stocks (Table 1). Those stocks represented by standards were Norton Sound, Cape Romanzof, Nelson Island, Security Cove - Goodnews Bay, Togiak, Port Moller, and Simeonof Island (Table 2). For age 7, all standards consisted of 200 scales except Cape Romanzof (n = 159) and Simeonof Island (n = 80). The only stock not represented in previous years was Simeonof Island; it is actually a stock from the south side of the Alaska Peninsula, and was included to test the theory that herring from this region may enter the Dutch Harbor fishery. For age 6, the standards consisting of less than 200 scales were Norton Sound (n = 100), Cape Romanzof (n = 86), Nelson Island (n = 100), and Simeonof Island (n = 100). Large standards (n = 200) are preferred, but size was sometimes limited by the number of scales available. A relatively small sample representing the Unalaska Island stock was obtained and 38 age 7 scales were measured, not enough to develop a standard, but enough to use in a comparison of frequency distributions. All scale measurements were performed at the Fisheries Research Institute (FRI), with scales magnified 50 times.

Frequency distributions of scale size and standard body length were plotted for all age 6 and age 7 standards and unknowns, and the Unalaska Island sample (Figs. 2-9). Unlike the previous two years, none of the standards exhibited a scale size distribution that was strikingly different from the others. No distribution was wide nor

markedly bimodal, and a north to south gradient was apparent, in which northern stocks were characterized by smaller scales at age relative to the more southern stocks. This gradient coincides with the north to south gradient of body length that was evident in past years. However, the overall relationship of the standard length frequency distributions for 1984 was slightly different than in the previous two years. The mean of the Nelson Island distribution was not greater than that for the more northerly situated stock of Cape Romanzof, neither for age 6 nor age 7. Bimodality was evident in the scale size and standard length distributions of Unalaska Island, but the sample size was small. The mean values for the frequency distributions of this stock were relatively small, as in 1983. The age 6 and 7 standard length distributions for Simeonof Island showed a higher frequency about the mean in comparison with the Bering Sea stocks, and the frequency distributions for this stock were situated intermediate to those of the Bering Sea stocks.

The decision regarding selection of standards for use in the LDF analysis partly depended on the observed frequency distributions. The Security Cove - Goodnews Bay standard was ommitted because 1982 and 1983 results made it certain that misclassification with Togiak would be high. Security Cove and Goodnews Bay were therefore regarded as part of Togiak, although the frequency distributions for their characters were slightly different. The distributions for all the other standards were distinct enough so that they could be entered into the LDF analysis without modification, although heavy misclassification among the northern stocks was anticipated. In 1982 and 1983, the standard length distribution for Port Moller was bimodal, indicating the presence of two coexisting stocks. For 1984, this distribution was only slightly wide, and the age 7 standards of Norton Sound, Cape Romanzof, and Nelson Island also displayed relatively wide standard length distributions. For the three subdistricts in Norton Sound and the four sections in Togiak, representation was weighted according to biomass as in the previous two years of research, since these are geographically wide areas.

Construction of Unknowns

The 1984 Dutch Harbor fishery lasted for a relatively short time, and samples were collected on eight consecutive days, July 20-27. Before 1984, sampling was spread throughout the period of approximately one month, and we could then stratify the samples by various time intervals when conducting our analysis. With the 1984 samples, stratification by time was limited to four 2-day intervals for age 7 and two 4-day intervals for age 6. A total of 436 age 7 and 112 age 6 scales could be measured.

Samples were collected from purse seiners which in 1984 were operating within Unalaska Bay. Although a few neighboring locations

had additionally been represented in the previous two years, location proved to be unrelated to mixing proportions. Time, on the other hand, had been shown to be a factor.

Character Selection

A total of 30 scale characters were initially entered into each LDF analysis (Tables 3-4). For all standards and the unknowns, the measurement of each character is presented in Tables 5-6. The only characters actually used for classification were those with an F-to-enter value in excess of 4.000. Characters of lower value do not usually enhance discrimination between stocks. The major character types were annual scale growth, cumulative scale growth, proportionate scale growth, and back-calculated length-at-age.

For the final classification of age 7 herring, ten scale characters were used. In relative order of importance they were: 1) back-calculated length at age 4, 2) scale growth in the fifth year, 3) back-calculated length at age 1, 4) length at age 7 (back-calculated for unknowns), 5) scale growth in the seventh year, 6) ratio of growth in the seventh year to growth in the third and fourth years, 7) proportion of growth in the fifth year, 8) ratio of growth in the sixth year to growth in the fifth year, 9) ratio of growth in the third year to growth in the second year, 10) proportion of growth in the fourth year.

For the final classification of age 6 herring, eight scale characters were used. In relative order of importance they were: 1) proportion of growth in the first year, 2) length at age 6 (back-calculated for unknowns), 3) ratio of growth in the fourth year to growth in the third year, 4) ratio of growth in the sixth year to growth in the fifth year, 5) scale growth in the second year, 6) scale size at age 2, 7) ratio of growth in the second year to growth in the first year, 8) back-calculated length at age 3.

Classification Procedures

Six standards were initially involved in the LDF analysis of age 7 herring. They were Norton Sound, Cape Romanzof, Nelson Island, Togiak, Port Moller, and Simeonof Island. When the classification matrix was estimated, an overall unweighted accuracy of 64.2% was achieved (Table 7). Although this is a desirable overall accuracy for a six-class analysis, the individual classificatory accuracy for Cape Romanzof was very low at 34.0%. Misclassification was high between this standard and those of Norton Sound and Nelson Island. No specific reason, such as sampling date or location, was evident for the cause of misclassification in either direction, so Cape Romanzof was

simply ommitted from the analysis. Therefore, some consideration should be given to this stock when judging the final results. The remaining five stocks were involved in the final LDF analysis of age 7 herring.

The LDF analysis of age 6 herring initially involved the same six standards as the age 7 analysis. And as with the age 7 herring, misclassification of the Cape Romanzof standard was high. The overall unweighted accuracy was 54.4%, but the individual accuracy for Cape Romanzof was only 23.5% (Table 8). Thus, the same procedure was followed as in the age 7 analysis, and the final age 6 analysis involved the same five stocks.

Unknowns were classified in the final five-way analyses, and nearly unbiased point estimates of the mixing proportions were calculated along with corresponding 90% confidence intervals. Positive point estimates are all those greater than zero, and negative estimates are constrained to a value of zero. Point estimates with a lower 90% confidence limit above zero are significant. Larger unknown sample sizes are desirable, so stratification of the unknowns was limited to sample sizes greater than 30.

RESULTS

In 1984, for the first time, a complete discriminant analysis was performed for each of two age classes of herring. Results for the two age classes could afterwards be compared for verification. It was also possible to use the age 7 standards to classify 1983 age 6 unknowns, so that 1984 results could be compared to those of 1983.

With the additional data of 1982 and 1983, growth patterns for herring of the 1977 year class could be observed and compared to lengths back-calculated from 1984 age 7 scales. Length measurements for 1984 herring of ages 4-8 were also compared, although due to small sample size, those for age 8 may be biased. Otolith growth was also examined and compared to scale growth.

Classification of Standards

Classificatory accuracies for 1984 age 7 herring were substantially improved over the accuracies obtained for this year class in either of the previous two years. In some part, this may be reflective of improved scale sampling technique. The unweighted overall accuracy for the final five-class analysis was 74.9% (Table 7). Simeonof Island had a high individual accuracy of 92.5%. Scales from the herring of this stock were so different from those of Bering Sea herring that they could actually be separated by visual inspection alone. The lowest individual accuracy, 63.5%, belonged to Port Moller. A relatively high proportion of the scales from this standard were misclassified as Togiak. In 1983, Port Moller was split into two standards and was then found to misclassify relatively little with Togiak.

Classificatory accuracies for the 1984 age 6 herring were not as high as for age 7 . The unweighted overall accuracy for the final five-class analysis was 62.8% (Table 8). Simeonof Island again had a high individual accuracy, at 90.0%. Port Moller had a low individual accuracy of 46.5%, again being greatly misclassified as Togiak. The individual accuracies for Norton Sound and Nelson Island would have likely been higher if the size of these standards was 200 rather than 100.

Classification of Unknowns

The 436 scales representing the age 7 herring of the 1984 Dutch Harbor fishery were stratified by time, such that there was classification by four groups in addition to the total (Table 9). The first time period was represented by 56 scales, and later time periods were

represented by progressively larger sample sizes. Confidence intervals were much tighter than those of the year before, and mixing proportion estimates for the two years were roughly comparable. The overall estimate obtained for 1984 was 9.6% Nelson Island, 78.9% Togiak, and 11.6% Port Moller. Estimates for Norton Sound and Simeonof Island were negative at all time periods. Nelson Island received higher estimates for earlier time periods while Port Moller received higher estimates for later periods. All estimates for Togiak were significant, and the highest estimate was in the last time period.

The age 6 herring of the 1984 Dutch Harbor fishery were represented by 112 scales, and stratification of these scales resulted in the classification of two groups in addition to the total (Table 10). The first group consisted of 39 scales, and 73 were in the other. As could be expected, confidence intervals were not as tight as in the age 7 analysis. Mixing proportion estimates were not drastically different from those for the age 7 class, and the same general conclusion was evident, in that the age 6 results also indicated a strong presence of Togiak herring in the Dutch Harbor fishery. In fact, the overall age 6 estimate was unanimous: 100% Togiak. Port Moller received an estimate of 15.9% in the second time period, and all other estimates, besides those for Togiak, were negative.

Classification of 1983 Unknowns with 1984 Standards

The 1983 age 6 unknowns were classified with the age 7 standards of 1984, and results were compared to those obtained from the LDF analysis in 1983 (Table 11). The 443 scales representing the 1983 Dutch Harbor fishery were stratified into five time intervals as they had been in the analysis of that year. The 1983 LDF analysis involved the stocks of Norton Sound, Nelson Island, Togiak, and Port Moller, but not that of Simeonof Island. The Port Moller stock was divided in 1983, and the LDF analysis included the part comprised of larger herring. To use the 1984 age 7 standards for classification, the characters developed for the 1984 age 6 analysis were applied, so that growth in the seventh year would be disregarded as a character.

There were some considerable differences between the mixing proportion estimates for the 1984 standards and those for the standards of 1983. Most obvious was that use of the 1984 Togiak standard resulted in lower estimates than in 1983, whereas the opposite was true for Port Moller. In 1984 the Port Moller standard was more similar to the Togiak standard and the unknowns than in 1983, when the Port Moller 1 standard was developed from exclusively larger herring. Simeonof Island received slight estimates in the last two time periods, but visual inspection of the scales classified to this stock revealed that poor quality was a factor. For Norton Sound and Nelson Island, the use of 1984 standards also resulted in a dissimi-

lar set of estimates than in 1983, but not beyond corresponding confidence limits. Confidence intervals for the 1984 standards were tighter than those for the 1983 standards, and comparable to those for the 1984 age 7 unknowns.

Analysis of Growth Patterns

Frequency distributions of standard length were plotted for age-specific samples of 1984 herring (Figs. 10-14). Random samples were developed with the use of the AWL forms supplied by ADF&G for the stocks of Norton Sound, Cape Romanzof, Nelson Island, Togiak, and Port Moller. Herring ages 4-8 were represented, but age 8 samples were small. Optimal sample size was 100. Very few age 4 herring were taken from Nelson Island, so they could not be represented. Means and standard deviations were calculated, and no major inconsistencies were apparent. For the stocks of Norton Sound, Cape Romanzof, and Nelson Island, standard deviation increased with age through age 7, but this was not so for the stocks of Togiak and Port Moller.

Three years of data were available for herring of the 1977 year class, so that for each year mean lengths could be compared to lengths back-calculated from scales of 1984 age 7 herring. These lengths could further be compared to those of 1984 herring representing other year classes. In 1982, the 1977 year class was age 5, so comparisons were restricted to age 5-7 herring. Length-at-age was graphed for herring samples from Norton Sound, Nelson Island, Togiak, and Port Moller (Fig. 15). Mean length-at-capture for the standards of the 1982, 1983, and 1984 analyses was plotted alongside back-calculated mean length for the 1984 age 7 standards, and plotted alongside these lengths was mean length for the samples of 1984 age 5, 6, and 7 herring. Two major discrepancies are apparent from the graph. One is that the 1984 samples, including the age 7 standard, for Nelson Island have lower mean values than would be projected by the means of the 1982 and 1983 standards. Consequently, the back-calculated means are lower, also. The other major discrepency is that the back-calculated lengths for Port Moller are greater than those of the 1982 and 1983 standards, and those of the 1984 age 5 and 6 samples. The lower mean values for the 1982 and 1983 standards can be attributed to bimodal frequency distributions. The plots for Norton Sound match up as well as would be anticipated, as do those for Togiak. The means for 1982 and 1983 standards would be expected to closely match the back-calculated means.

Otolith Analysis

Otoliths and scales were taken from several Togiak herring so that growth comparisons could be made. The otoliths from four herring

were soaked in 50% glycerin solution, polished with fine-grain dental equipment, and mounted with epoxy on glass slides. Scales from the four herring were mounted on a glass slide and aged. The otoliths were viewed through a dissecting scope at 50 power so that annuli could be discerned, and age was determined. Ages from the otoliths agreed with those from the scales; two herring were age 7, one was age 6, and the other age 5. The annuli on each otolith were measured with a micrometer along a radius perpendicular to the total length of the otolith, where there appears to be less growth distortion (Fig. 16). Scales were magnified 50 times and measured as in the LDF analysis. Yearly proportionate growth was then determined and compared between the scales and otoliths corresponding to each herring (Table 12). Similarities in growth were apparent when the radius of measurement on the otolith was begun at the edge of the nucleus.

DISCUSSION

Mixing proportion estimates from the 1984 herring study are comparable to those from the 1983 study in a number of ways. Most notable is that the Togiak stock was again found to contribute to the Dutch Harbor fishery at high proportions. For the age 7 herring of 1984, the Nelson Island stock was estimated to be a minor contributor to the fishery, as it was for the age 6 herring of 1983. And once again, there was evidence of Port Moller herring in the fishery. The same general pattern was apparent in the estimates of both years, whereas stocks of smaller herring (Norton Sound and Nelson Island in 1983, Nelson Island in 1984) received higher estimates at earlier time periods and stocks of larger herring (Togiak in 1983, Togiak and Port Moller in 1984) received higher estimates at later time periods.

There was some significant new information provided by the mixing proportion estimates of 1984. Norton Sound was not detected as a contibutor to the fishery. This was also the case in 1982. Simeonof Island was added to the analysis, marking the first time that a stock from outside of the Bering Sea was included, and it received only negative estimates. Also for the first time, estimates were derived for two age classes rather than just one. While estimates for the two classes were roughly comparable, there was a major difference, in that the Nelson Island stock received only negative estimates in the age 6 analysis.

Classificatory accuracies for the 1984 age 7 analysis were quite satisfactory, and a great improvement over those of the 1982 and 1983 analyses. Consistently precise selection of preferred scales by the ADF&G sampling crews, at all field stations, was likely a factor. The success of scale pattern analysis depends on precise definition of the preferred body area for selection of scales. The 1984 frequency distributions for scale size, when compared with those of 1982 or 1983, clearly show the difference that resulted from a coordinated effort at all sampling locations to precisely locate and select preferred scales. One effect of this difference was that proportionate scale growth became a much more valuable character for discrimination of stocks. The greatest overall effect was improved accuracies and increased confidence.

Since the classificatory accuracies of the 1984 standards were improved, these standards could be used to classify the 1983 unknowns with higher accuracy. However, the unknowns suffer as well as the standards in 1983 from greater variation in scale size. Therefore, inaccurate representation by some unknown scales must, to some degree, bias the mixing proportion estimates. This was likely the case for Simeonof Island. Use of the 1984 standards is complicated by the difference in quality of Port Moller from the year before. Since this standard in 1983 represented only the larger herring from the district, mixing proportion estimates for that year do not compare

with those for the 1984 standard. If estimates for the 1984 standards of Port Moller and Togiak were merged, they would compare favorably to those for the 1983 Togiak standard. There were more unknowns classified to the 1984 Norton Sound standard than the 1983 standard, and the reason for this must lie with the 1983 unknowns, since the 1984 standard received only negative estimates with the 1984 unknowns.

Use of the 1984 standards to classify 1983 unknowns implies that data collection can be minimized. Not all standards need to be from samples collected in the same year, as long as standards are restricted to one year class of herring. Thus, sampling can be concentrated in different locations each year. One standard may itself consist of scales collected in different years, which would be a concept ideal for weak year classes. With standards already developed, mixing proportion estimates could be determined soon after the unknowns were made available. If other mixed-stock herring fisheries should arise, these possibilities should not be disregarded. Beforehand, further research into herring length distributions is necessary.

The analysis of herring mean lengths for the stocks of Norton Sound, Nelson Island, Togiak, and Port Moller showed that certain inconsistencies exist which need to be resolved. The 1984 Nelson Island lengths were smaller than projected by 1982 and 1983 lengths. Since all 1984 sampling of this stock was conducted in one day, bias is possible. The 1982 and 1983 Port Moller standards had bimodal frequency distributions for herring length and this caused the mean lengths for these samples to be lower than those back-calculated from the 1984 age 7 standard. The frequency distributions for the age 6 and 7 standards of 1984 were wide, suggesting the coexistence of two stocks, but the evidence for this thoery is not as apparent as it was in the previous two years. The herring of Port Moller deserve closer attention.

Classification in the 1984 age 6 analysis was not as accurate as in the age 7 analysis. Part of the reason for this may be the smaller size of the standards for Norton Sound and Nelson Island, but regardless of sample size, Norton Sound was misclassified heavily as Nelson Island. The reason for this may be seen in the frequency distributions of standard length for these stocks. The Port Moller standard had the lowest individual accuracy in both the age 6 and age 7 analyses, and was heavily misclassified as Togiak. In 1983, when Port Moller was divided into two standards, much of the misclassification with Togiak was eliminated.

The herring of Simeonof Island display a very different growth pattern than that of Bering Sea stocks. Classificatory accuracies for Simeonof Island were high, and all 1984 mixing proportion estimates were negative. From this it may be assumed that only Bering Sea herring exist in the Dutch Harbor fishery.

There still exists the possibility that a stock which contributes substantially to the fishery was not represented in the analysis. That stock would then be classified as the most similar stock that was represented. This possibility will exist as long as the Alaska Peninsula/Aleutian Islands region remains unsurveyed or unsampled. If the Unalaska Island stock is representative of this entire region, then herring stocks from this region are characterized by a mean length-at-age comparable to that of northern Bering Sea stocks. Therefore, those unknown scales classified as Nelson Island may be of another stock.

Otolith annuli can be measured, and proportionate measurements compare with those of scales. If the variability of scale measurements had not been reduced in 1984, otoliths would deserve serious investigation. Since accurate results can be obtained with scales and they can be processed efficiently, scale pattern analysis is practical.

CONCLUSIONS

The basic conclusion of this report is that Togiak is the most abundant stock in the Dutch Harbor fishery. Analyses for two age classes of herring support this conlusion, and this is the same conclusion that was drawn from the results of the 1983 analysis on herring. It appears that other Bering Sea stocks exist in the fishery, but at low proportions. In consideration of previous findings, the mixing proportion estimates for Port Moller may be optimistic. It is possible that a stock which enters the fishery was not represented in the analysis. If so, it is likely one from the Aleutian Islands/ Alaska Peninsula region, and may, therefore, account for the unknowns classified as Nelson Island. Based on the character of the Simeonof Island herring scales, it is concluded that only Bering Sea herring enter the fishery.

The classificatory accuracies of the age 7 analysis were favorable. Precise selection of preferred scales by samplers is important, and until this year, variability in scale measurements was a problem . At the current accuracy level, scale pattern analysis with herring is practical. Classificatory accuracies of the age 6 analysis were lower than those of the age 7 analysis, and the greatest problem was misclassification of Port Moller with Togiak. This was also a problem for age 7 herring, but not as severe. Although not so apparent in 1984, it still appears that two stocks exist at Port Moller. Norton Sound misclassified heavily with Nelson Island, and it is possible that the Nelson Island sample was biased. Classificatory accuracies for Cape Romanzof were very low due to misclassification with Norton Sound and Nelson Island, so it could not be included in the final analyses. It appears that this stock deserves a portion of the mixing proportion estimates for Nelson Island.

With consistently accurate representation of stocks, more than one year of data can be included in a discriminant analysis, provided that all data pertains to a single year class. Standards from different years can be used together, and each standard itself can consist of scales collected in different years. Herring scale pattern analysis could evolve to be very efficient.

RECOMMENDATIONS

Future scale pattern analysis with Bering Sea herring should include the following:

1) Sampling of stocks at Port Heiden, Unimak Island, and Adak/Atka Islands.

2) Collection of scales from herring at the wintering grounds northwest of the Pribilof Islands.

3) Sampling of the Nelson Island stock for a period of at least two weeks.

4) Herring in the 1985 Dutch Harbor fishery or in other areas of mixing could be classified with the 1984 standards, but research on 1985 spawning stocks would be desirable.

ABSTRACT

Scale pattern analysis was applied to eastern Bering Sea herring stocks so that the origins of the herring in the 1984 Dutch Harbor food and bait fishery could be determined. Two separate analyses were performed, one with age 7 and one with age 6 herring. The final analysis for both ages included four Bering Sea stocks and one from the south side of the Alaska Peninsula. These stocks were separated by scale characters which included yearly growth increments, proportionate scale growth, and back-calculated lengths. Mixing proportion estimates of the stocks present in the fishery indicated that one stock, Togiak, was predominant. Further research was performed to support the analysis. This included a comparison of lengths through 3 years of data, a comparison of scales and otoliths, and a comparison of mixing proportion estimates determined by 1984 scales and by those of 1983.

REFERENCES

Cook, R. C. 1982. Stock identification of sockeye salmon (Oncorhynchus nerka) with scale pattern recognition. Can. J. Fish. Aquat. Sci. 39(4):611-617.

Dixon, W. J. and M. B. Brown (eds.). 1979. Biomedical computer program P-series. Health Sci. Computing Facility, Univ. California, Los Angeles. 880 pp.

Rogers, D. E., K. N. Schnepf, and P. R. Russell. 1983. Feasibility of using scale analysis methods to identify Bering Sea herring stocks. Fish. Res. Inst., Univ. Washington, Preliminary Report to National Marine Fisheries Service. 25 pp.

Rogers, D. E., K. N. Schnepf, and P. R. Russell. 1984. Feasibility of using scale analysis methods to identify Bering Sea herring stocks. Univ. Washington, Fish. Res. Inst. Annu. Rep. FRI-UW-8402. 48 pp.

Walker, R. V. and K. N. Schnepf. 1982. Scale pattern analysis to estimate the origin of herring in the Dutch Harbor fishery. Univ. Washington, Fish. Res. Inst. Final Rep. FRI-UW-8219. 21 pp.

Wespestad, V. G. and L. H. Barton. 1981. Distribution, migration, and status of Pacific herring. Pages 509-525 in D. W. Hood and J. A. Calder (eds.). The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. 1. U.S. Gov. Print. Office, Washington, D.C.

Table 1. Age compositions of 1984 Pacific herring spawning stock samples and the Dutch Harbor food and bait fishery sample. Included are the dates within which samples were obtained.

Location	Date	Percent age composition										
		1	2	3	4	5	6	7	8	9	10+	n
Norton Sound	6/ 6-7/ 1	-	-	11.0	7.7	39.0	14.4	24.4	2.0	0.9	0.7	1,367
Cape Romanzof	5/27-6/17	-	-	1.5	5.7	26.9	19.3	36.1	4.8	3.5	2.2	735
Nelson Island	6/2	-	-	-	0.4	13.6	27.9	50.2	4.6	1.8	1.6	566
Goodnews Bay	5/ 9-6/ 2	-	-	0.3	3.6	18.4	26.8	41.3	3.4	2.9	3.3	697
Security Cove	5/ 7-6/ 2	-	-	0.1	1.5	11.6	26.7	43.9	6.2	6.1	3.9	940
Togiak	5/ 1-5/30	-	-	0.6	3.9	12.5	34.2	35.5	4.4	5.5	3.4	1,083
Port Moller	5/15-6/ 7	0.1	0.3	5.7	11.5	17.2	19.3	41.8	2.5	0.4	1.1	2,772
Unalaska Island	6/7	-	-	36.6	9.9	5.6	7.7	33.8	3.5	2.1	0.7	142
Simeonof Island	4/19-4/23	-	-	-	1.8	0.3	55.7	41.6	0.6	-	-	341
Dutch Harbor unknown origin	7/20-7/27	-	-	-	-	0.4	15.4	65.8	6.9	1.9	9.6	1,288

Table 2. The initial construction of spawning stock standards for the discriminant function analysis of 1984 age 6 and 7 Pacific herring.

Stock (district or area)	Subdistrict or section	Estimated biomass[a]	Percent of district biomass[b]	No. of scales measured	
				Age 7	Age 6
Norton Sound	Cape Denbigh		27	114	58
	Unalakleet		3	28	13
	St. Michael		70	58	29
TOTAL		21,000	100	200	100
Cape Romanzof		5,500		159	68
Nelson Island		10,000		200	100
Goodnews Bay		3,700		100	91
Security Cove		4,600		100	109
Togiak	Hagemeister		14	31	19
	Togiak		17	24	27
	Nunavachak		7	30	31
	Kulukak		62	115	123
TOTAL		104,200	100	200	200
Port Moller		-		200	200
Unalaska Island		-		38	0
Simeonof Island		-		80	100

[a]Aerial survey estimates (personal communication, Robert C. Lebida, Alaska Department of Fish and Game, September 4, 1984).

[b]Biomass distribution on date of peak survey (personal communication, Robert C. Lebida, Alaska Department of Fish and Game, September 4, 1984).

Table 3. Scale characters examined for use in the discriminant function analysis of age 7 Pacific herring.

Character number*	Description
1	Distance between focus and first annulus.
2	Distance between first and second annuli.
3	Distance between second and third annuli.
4	Distance between third and fourth annuli.
5	Distance between fourth and fifth annuli.
6	Distance between fifth and sixth annuli.
7	Distance between sixth and seventh annuli.
8	Distance from focus to second annulus.
9	Distance from focus to third annulus.
10	Distance from focus to fourth annulus.
11	Distance from focus to fifth annulus.
12	Distance from focus to sixth annulus.
13	Distance from focus to seventh annulus.
14	Proportion of scale growth in first year.
15	Proportion of scale growth in second year.
16	Proportion of scale growth in third year.
17	Proportion of scale growth in fourth year.
18	Proportion of scale growth in fifth year.
19	Proportion of scale growth in sixth year.
20	Proportion of scale growth in seventh year.
21	Back-calculated length at age 1.
22	Back-calculated length at age 2.
23	Back-calculated length at age 3.
24	Back-calculated length at age 4.
25	Back-calculated length at age 5.
26	Back-calculated length at age 6.
27	Length at age 7 (back-calculated for unknown summer samples).
28	Ratio of growth in third year to growth in second year.
29	Ratio of growth in sixth year to growth in fifth year.
30	Ratio of growth in seventh year to growth in third and fourth years.

*Scale characters 1-13 are in inches and characters 21-27 are in millimeters. Character 13 is total scale size for all spawning samples.

Table 4. Scale characters examined for use in the discriminant function analysis of age 6 Pacific herring.

Character number*	Description
1	Distance between focus and first annulus.
2	Distance between first and second annuli.
3	Distance between second and third annuli.
4	Distance between third and fourth annuli.
5	Distance between fourth and fifth annuli.
6	Distance between fifth and sixth annuli.
7	Distance from focus to second annulus.
8	Distance from focus to third annulus.
9	Distance from focus to fourth annulus.
10	Distance from focus to fifth annulus.
11	Distance from focus to sixth annulus.
12	Proportion of scale growth in first year.
13	Proportion of scale growth in second year.
14	Proportion of scale growth in third year.
15	Proportion of scale growth in fourth year.
16	Proportion of scale growth in fifth year.
17	Proportion of scale growth in sixth year.
18	Back-calculated length at age 1.
19	Back-calculated length at age 2.
20	Back-calculated length at age 3.
21	Back-calculated length at age 4.
22	Back-calculated length at age 5.
23	Length at age 6 (back-calculated for unknown summer samples).
24	Proportion of growth in first three years.
25	Proportion of growth in last three years.
26	Ratio of growth in second year to growth in first year.
27	Ratio of growth in third year to growth in second year.
28	Ratio of growth in fourth year to growth in third year.
29	Ratio of growth in fifth year to growth in fourth year.
30	Ratio of growth in sixth year to growth in fifth year.

*Scale characters 1-11 are in inches and characters 18-23 are in millimeters. Character 11 is total scale size for all spawning samples.

Table 5. Sample sizes (n), means, and standard deviations for 1984 age 7 herring scale characters considered for discriminant function analysis.

Scale character number		Location								
		Norton Sound (200)	Cape Romanzof (159)	Nelson Island (200)	Security Cove Goodnews Bay (200)	Togiak (200)	Port Moller (200)	Unalaska Island (38)	Simeonof Island (80)	Dutch Harbor unknown (436)
1	$\bar{X}$	4.42	4.25	4.00	4.44	4.38	4.24	3.55	5.70	4.36
	S.D.	.61	.58	.56	.55	.60	.77	.53	.41	.60
2		3.26	3.44	3.63	3.64	3.66	4.31	3.70	3.56	3.64
		.41	.40	.39	.46	.46	.76	.54	.33	.47
3		2.33	2.60	2.91	2.81	2.85	2.91	2.99	2.28	2.89
		.42	.40	.35	.40	.36	.46	.36	.29	.38
4		1.09	1.24	1.34	1.37	1.38	1.27	1.52	1.12	1.37
		.21	.21	.22	.24	.22	.25	.19	.17	.22
5		.95	1.08	1.16	1.11	1.15	1.09	.87	.56	1.16
		.20	.18	.19	.21	.18	.20	.18	.12	.19
6		.68	.62	.61	.61	.63	.54	.42	.50	.60
		.16	.15	.13	.11	.12	.11	.08	.11	.12
7		.47	.50	.53	.55	.61	.56	.32	.40	.61
		.11	.13	.11	.10	.10	.12	.07	.10	.12
8		7.68	7.69	7.64	8.08	8.04	8.55	7.24	9.25	8.00
		.62	.56	.55	.59	.60	.74	.73	.59	.59
9		10.02	10.29	10.55	10.90	10.89	11.46	10.23	11.53	10.89
		.71	.66	.70	.62	.59	.73	.82	.75	.61
10		11.11	11.54	11.89	12.27	12.27	12.73	11.76	12.65	12.27
		.79	.73	.77	.68	.59	.67	.88	.80	.64
11		12.05	12.61	13.05	13.38	13.42	13.83	12.62	13.21	13.43
		.86	.81	.83	.76	.62	.71	.94	.83	.68

Table 5. Sample sizes (n), means, and standard deviations for 1984 age 7 herring scale characters considered for discriminant function analysis - cont'd.

Scale character number	Location								
	Norton Sound (200)	Cape Romanzof (159)	Nelson Island (200)	Security Cove Goodnews Bay (200)	Togiak (200)	Port Moller (200)	Unalaska Island (38)	Simeonof Island (80)	Dutch Harbor unknown (436)
12	12.73 .87	13.24 .84	13.66 .87	13.99 .80	14.04 .65	14.36 .72	13.04 .96	13.71 .88	14.03 .70
13	13.21 .89	13.74 .87	14.19 .89	14.53 .83	14.66 .68	14.92 .74	13.36 .97	14.11 .90	14.64 .73
14	.336 .045	.310 .042	.282 .036	.306 .039	.299 .040	.284 .049	.266 .036	.404 .023	.298 .041
15	.247 .024	.251 .025	.256 .025	.251 .028	.249 .029	.289 .049	.276 .031	.252 .016	.249 .029
16	.176 .027	.189 .025	.205 .021	.193 .024	.194 .022	.195 .029	.224 .023	.161 .015	.198 .023
17	.082 .014	.090 .013	.095 .014	.094 .014	.094 .015	.085 .017	.114 .012	.079 .010	.094 .014
18	.071 .014	.078 .011	.082 .012	.076 .013	.078 .011	.073 .013	.065 .011	.040 .008	.079 .012
19	.052 .012	.045 .011	.043 .009	.042 .007	.043 .008	.036 .007	.031 .006	.036 .007	.041 .008
20	.036 .008	.036 .009	.037 .008	.038 .007	.042 .007	.037 .008	.024 .005	.028 .006	.042 .008
21	85.3 10.6	80.7 10.7	73.6 9.3	84.6 11.2	83.8 11.8	81.0 14.9	65.4 9.0	109.9 6.4	83.2 11.6
22	148.2 8.4	146.0 9.5	140.4 7.7	153.7 11.2	153.6 11.0	163.3 12.9	133.4 10.0	178.5 8.5	152.7 10.5

Table 5. Sample sizes (n), means, and standard deviations for 1984 age 7 herring scale characters considered for discriminant function analysis - cont'd.

Scale character number	Location								
	Norton Sound (200)	Cape Romanzof (159)	Nelson Island (200)	Security Cove Goodnews Bay (200)	Togiak (200)	Port Moller (200)	Unalaska Island (38)	Simeonof Island (80)	Dutch Harbor unknown (436)
23	193.2 9.3	195.4 10.5	193.8 8.5	207.1 9.4	207.9 9.2	218.9 11.5	188.5 10.0	222.2 8.1	207.9 9.9
24	214.2 11.0	218.9 11.3	218.5 8.9	233.1 8.4	234.3 8.1	243.1 10.2	216.5 10.3	243.8 7.9	234.0 9.6
25	232.5 12.2	239.4 12.4	239.9 9.2	254.2 8.2	256.2 7.8	264.0 10.4	232.5 9.9	254.6 7.4	256.1 9.8
26	245.6 11.7	251.2 12.1	251.0 9.4	265.7 8.3	268.2 7.6	274.2 10.3	240.1 10.0	264.3 7.4	267.6 9.9
27	254.7 11.6	260.6 12.5	260.8 9.9	276.0 8.3	279.9 7.8	284.9 10.4	246.0 10.1	271.9 7.4	279.2 10.0
28	.720 .124	.760 .110	.807 .110	.783 .141	.790 .133	.694 .150	.819 .116	.642 .078	.805 .137
29	.750 .224	.591 .166	.536 .147	.558 .122	.559 .126	.501 .118	.489 .099	.926 .237	.532 .134
30	.142 .043	.131 .036	.125 .029	.132 .025	.146 .027	.135 .033	.071 .018	.117 .026	.144 .031

Table 6. Sample sizes (n), means, and standard deviations for 1984 age 6 herring scale characters considered for discriminant function analysis.

Scale character number		Location							
		Norton Sound (100)	Cape Romanzof (68)	Nelson Island (100)	Security Goodnews Bay (200)	Togiak (200)	Port Moller (200)	Simeonof Island (100)	Dutch Harbor unknown (112)
1	$\bar{X}$	4.09	3.80	3.60	4.10	4.13	3.90	5.12	4.17
	S.D.	.75	.63	.54	.59	.50	.63	.42	.50
2		4.00	4.21	4.39	4.32	4.47	4.82	3.96	4.42
		.45	.52	.43	.45	.50	.75	.46	.45
3		1.89	2.08	2.11	2.12	2.13	2.12	2.12	2.10
		.34	.33	.28	.28	.27	.31	.32	.27
4		1.47	1.61	1.72	1.66	1.65	1.65	1.09	1.69
		.33	.29	.26	.25	.27	.30	.22	.24
5		.81	.82	.87	.85	.84	.88	.79	.89
		.18	.16	.15	.15	.16	.20	.17	.16
6		.62	.65	.73	.77	.78	.74	.48	.84
		.15	.16	.17	.16	.17	.19	.11	.18
7		8.09	8.01	7.99	8.42	8.60	8.72	9.08	8.59
		.75	.66	.55	.68	.62	.80	.63	.55
8		9.99	10.09	10.10	10.54	10.73	10.84	11.20	10.69
		.73	.71	.56	.71	.66	.76	.76	.61
9		11.46	11.69	11.82	12.20	12.37	12.49	12.29	12.38
		.77	.81	.61	.73	.72	.74	.79	.67
10		12.27	12.51	12.70	13.05	13.21	13.37	13.08	13.26
		.83	.86	.64	.76	.73	.73	.83	.70
11		12.89	13.16	13.42	13.82	14.00	14.11	13.56	14.11
		.87	.90	.66	.81	.76	.78	.86	.76

Table 6. Sample sizes (n), means, and standard deviations for 1984 age 6 herring scale characters considered for discriminant function analysis - cont'd.

Scale character number	Location							
	Norton Sound (100)	Cape Romanzof (68)	Nelson Island (100)	Security Cove Goodnews Bay (200)	Togiak (200)	Port Moller (200)	Simeonof Island (100)	Dutch Harbor unknown (112)
12	.317	.289	.268	.297	.295	.276	.378	.296
	.053	.047	.038	.039	.036	.041	.028	.034
13	.311	.320	.327	.313	.320	.342	.292	.314
	.034	.034	.031	.028	.031	.051	.027	.029
14	.147	.158	.157	.153	.152	.150	.156	.149
	.024	.021	.019	.018	.016	.021	.019	.016
15	.114	.122	.128	.120	.118	.117	.080	.120
	.023	.019	.018	.017	.017	.020	.015	.015
16	.063	.062	.065	.061	.060	.063	.058	.063
	.013	.011	.010	.010	.011	.014	.011	.010
17	.048	.050	.054	.056	.056	.053	.035	.060
	.010	.012	.012	.011	.011	.013	.008	.012
18	79.3	73.5	66.8	78.2	79.3	74.4	100.0	80.7
	13.1	11.7	10.0	10.9	10.0	12.2	7.8	9.3
19	157.1	155.0	148.4	160.5	165.2	166.3	177.3	166.2
	12.4	9.8	10.6	10.9	10.9	14.4	9.3	10.2
20	193.9	195.1	187.6	200.8	206.0	206.6	218.7	206.7
	11.1	8.8	10.2	9.8	10.3	12.8	9.6	9.6
21	222.4	226.2	219.4	232.4	237.5	238.0	239.8	239.4
	10.2	9.7	10.2	8.5	9.9	11.7	8.1	9.6
22	238.2	242.0	235.6	248.5	253.7	254.8	255.3	256.5
	9.6	9.6	9.6	8.6	9.7	11.3	7.3	9.5

Table 6. Sample sizes (n), means, and standard deviations for 1984 age 6 herring scale characters considered for discriminant function analysis - cont'd.

Scale character number	Location							
	Norton Sound (100)	Cape Romanzof (68)	Nelson Island (100)	Security Cove Goodnews Bay (200)	Togiak (200)	Port Moller (200)	Simeonof Island (100)	Dutch Harbor unknown (112)
23	250.1	254.6	249.1	263.3	268.7	268.9	264.6	272.8
	9.8	9.9	9.2	9.0	10.0	12.0	7.0	9.7
24	1.019	1.150	1.252	1.079	1.105	1.282	.779	1.081
	.262	.292	.254	.207	.216	.343	.109	.208
25	.478	.499	.485	.494	.480	.451	.543	.479
	.098	.94	.080	.076	.074	.103	.105	.076
26	.791	.778	.822	.792	.781	.785	.521	.812
	.176	.120	.135	.128	.124	.139	.137	.118
27	.574	.525	.518	.517	.518	.546	.751	.531
	.173	.132	.120	.101	.104	.129	.194	.100
28	.775	.811	.850	.926	.947	.876	.619	.968
	.175	.193	.207	.188	.206	.260	.164	.206
29	.206	.197	.200	.198	.190	.189	.204	.202
	.055	.043	.040	.041	.042	.060	.053	.040
30	.178	.185	.202	.194	.190	.189	.141	.203
	.041	.037	.038	.038	.039	.046	.027	.038

Table 7. Decision arrays for the discriminant function analysis of 1984 age 7 Pacific herring in (a) six-class and (b) five-class situations. Overall classificatory accuracies were calculated as the unweighted mean of individual accuracies.

(a) Six-class: Norton Sound vs. Cape Romanzof vs. Nelson Island vs. Togiak vs. Port Moller vs. Simeonof Island — Overall accuracy: 64.2%

Calculated decision	Correct decision					
	Norton Sound	Cape Romanzof	Nelson Island	Togiak	Port Moller	Simeonof Island
Norton Sound	127 (63.5%)	37	13	1	0	4
Cape Romanzof	46	54 (34.0%)	41	7	2	2
Nelson Island	17	45	119 (59.5%)	19	9	0
Togiak	6	19	25	150 (75.0%)	65	1
Port Moller	2	4	2	22	124 (62.0%)	0
Simeonof Island	2	0	0	1	0	73 (91.2%)
Total	200	159	200	200	200	80

(b) Five-class: Norton Sound vs. Nelson Island vs. Togiak vs. Port Moller vs. Simeonof Island — Overall accuracy: 74.9%

Calculated decision	Correct decision				
	Norton Sound	Nelson Island	Togiak	Port Moller	Simeonof Island
Norton Sound	147 (73.5%)	28	2	0	6
Nelson Island	40	145 (72.5%)	20	14	0
Togiak	10	24	145 (72.5%)	59	0
Port Moller	2	3	32	127 (63.5%)	0
Simeonof Island	1	0	1	0	74 (92.5%)
Total	200	200	200	200	80

Table 8. Decision arrays for the discriminant function analysis of 1984 age 6 Pacific herring in (a) six-class and (b) five-class situations. Overall classificatory accuracies were calculated as the unweighted mean of individual accuracies.

(a) Six-class: Norton Sound vs. Cape Romanzof vs. Nelson Island vs. Togiak vs. Port Moller vs. Simeonof Island — Overall accuracy: 54.4%

Calculated decision	Correct decision: Norton Sound	Cape Romanzof	Nelson Island	Togiak	Port Moller	Simeonof Island
Norton Sound	50 (50.0%)	20	13	12	5	8
Cape Romanzof	18	16 (23.5%)	15	11	17	0
Nelson Island	19	17	64 (64.0%)	12	24	0
Togiak	4	9	1	105 (52.5%)	59	2
Port Moller	2	6	6	56	93 (46.5%)	0
Simeonof Island	7	0	1	4	2	90 (90.0%)
Total	100	68	100	200	200	100

(b) Five-class: Norton Sound vs. Nelson Island vs. Togiak vs. Port Moller vs. Simeonof Island — Overall accuracy: 62.8%

Calculated decision	Correct decision: Norton Sound	Nelson Island	Togiak	Port Moller	Simeonof Island
Norton Sound	52 (52.0%)	17	16	10	10
Nelson Island	30	67 (67.0%)	16	30	0
Togiak	8	6	117 (58.5%)	64	0
Port Moller	3	9	47	93 (46.5%)	0
Simeonof Island	7	1	4	3	90 (90.0%)
Total	100	100	200	200	100

Table 9. Five-class mixing proportion estimates of age 7 herring in the 1984 Dutch Harbor food and bait fishery.

Sample date	Sample size	Mixing proportion estimates (%) and 90% confidence intervals				
		Norton Sound	Nelson Island	Togiak	Port Moller	Simeonof Island
7/20-21	56	0(0-14)	56.3(24-89)	43.7(8- 80)	0 (0-23)	0(0-1)
7/22-23	96	0(0- 8)	17.2(0-38)	77.3(46-100)	5.5(0-31)	0(0-1)
7/24-25	101	0(0- 7)	9.8(0-28)	75.3(44-100)	14.8(0-42)	0(0-1)
7/26-27	183	0(0- 4)	0 (0-11)	87.7(61-100)	12.3(0-36)	0(0-1)
7/20-27	436	0(0- 4)	9.6(0-21)	78.9(59- 99)	11.6(0-28)	0(0-1)

Table 10. Five-class mixing proportion estimates of age 6 herring in the 1984 Dutch Harbor food and bait fishery.

Sample date	Sample size	Mixing proportion estimates (%) and 90% confidence intervals				
		Norton Sound	Nelson Island	Togiak	Port Moller	Simeonof Island
7/20-23	39	0(0-34)	0(0-21)	100 (29-100)	0 (0-69)	0(0-9)
7/24-27	73	0(0-21)	0(0-19)	84.1(16-100)	15.9(0-71)	0(0-5)
7/20-27	112	0(0-21)	0(0-17)	100 (42-100)	0 (0-59)	0(0-5)

Table 11. Mixing proportion estimates of age 6 herring in the 1983 Dutch Harbor food and bait fishery, derived from a) 1984 age 7 standards and b) 1983 age 6 standards.

a) Sample date	Sample size	Mixing proportion estimates (%) and 90% confidence intervals				
		Norton Sound	Nelson Island	Togiak	Port Moller	Simeonof Island
7/20-25	25	40.2(0-82)	29.0(0-75)	17.7(0- 65)	13.2(0-48)	0 (0-2)
7/26-30	86	5.7(0-18)	17.9(0-42)	72.5(39-100)	3.9(0-26)	0 (0-2)
8/1-5	99	11.5(0-25)	10.6(0-31)	61.6(30- 93)	16.3(0-40)	0 (0-1)
8/8-12	129	2.9(0-10)	0 (0-16)	75.9(46-100)	18.5(0-42)	2.6(0-5)
8/16-20	104	10.8(0-23)	0 (0-17)	76.3(44-100)	12.8(0-37)	0.1(0-4)
7/20-8/20	443	9.8(4-16)	6.0(0-18)	69.4(50- 89)	14.0(0-28)	0.7(0-2)

b) Sample date	Sample size	Mixing proportion estimates (%) and 90% confidence intervals			
		Norton Sound	Nelson Island	Togiak	Port Moller 1
7/20-25	25	38.9(0-80)	18.0(0-70)	43.2(0-100)	0 (0-32)
7/26-30	86	14.0(0-34)	2.4(0-30)	83.6(37-100)	0 (0-25)
8/1-5	99	0 (0-15)	0 (0-26)	100 (53-100)	0 (0-26)
8/8-12	129	0 (0-13)	6.8(0-31)	93.1(50-100)	0.2(0-26)
8/16-20	104	0 (0-14)	3.6(0-29)	96.4(50-100)	0 (0-28)
7/20-8/20	443	3.1(0-13)	3.0(0.20)	93.8(62-100)	0 (0-19)

b) Rogers et al., 1984.

Table 12. Comparison of scale growth measurements vs. otolith growth measurements for each of four Togiak herring.

Herring length		Yearly proportion of growth						
		1	2	3	4	5	6	7
287	Scale	.284	.265	.204	.107	.054	.048	.038
	Otolith	.326	.273	.179	.093	.055	.040	.034
270		.281	.242	.213	.098	.073	.059	.034
		.276	.245	.205	.087	.083	.063	.041
252		.280	.317	.182	.104	.077	.040	
		.293	.323	.166	.101	.065	.052	
249		.374	.261	.226	.090	.049		
		.391	.276	.198	.083	.052		

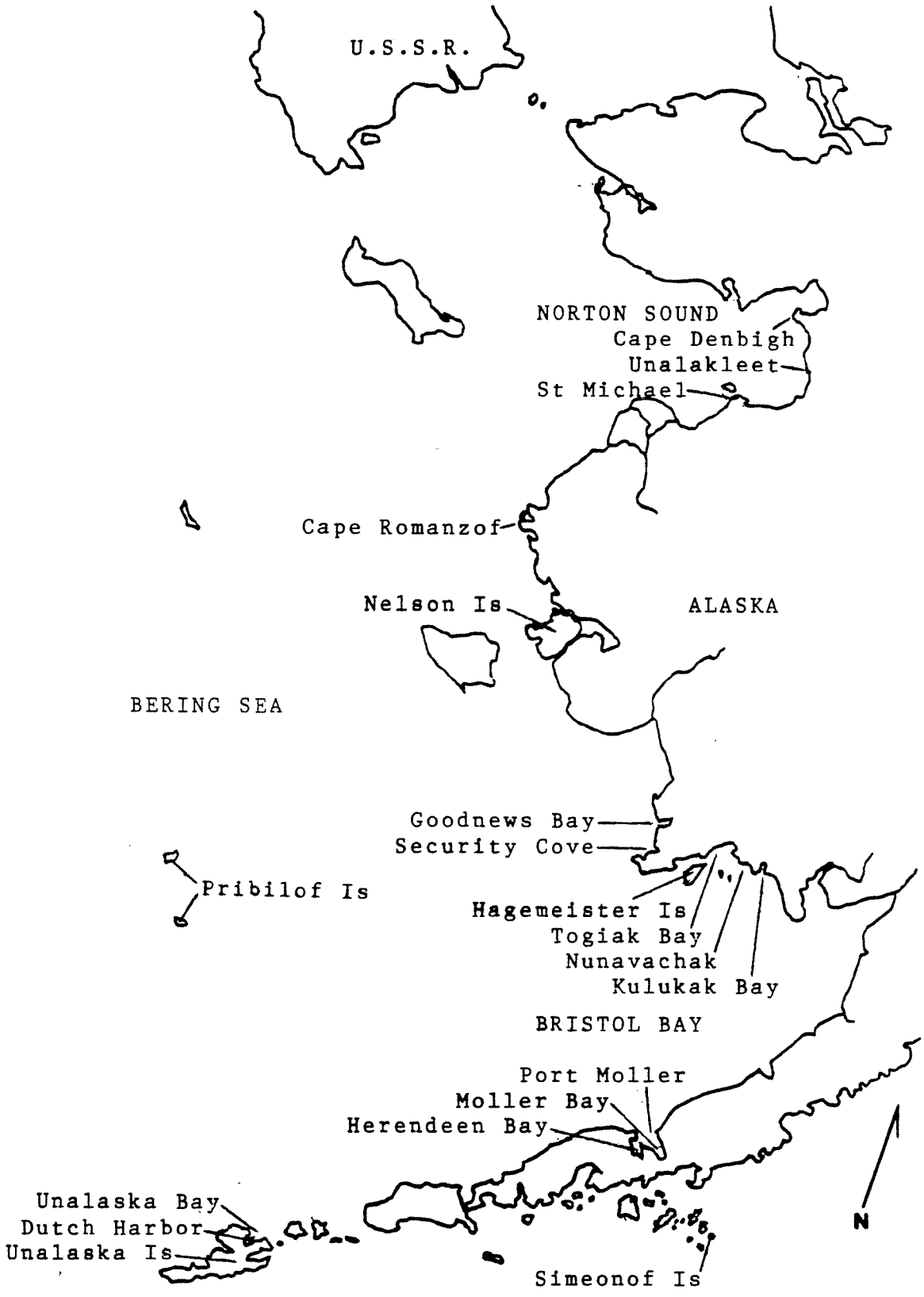

Fig. 1. Locations of interest in the 1984 herring study.

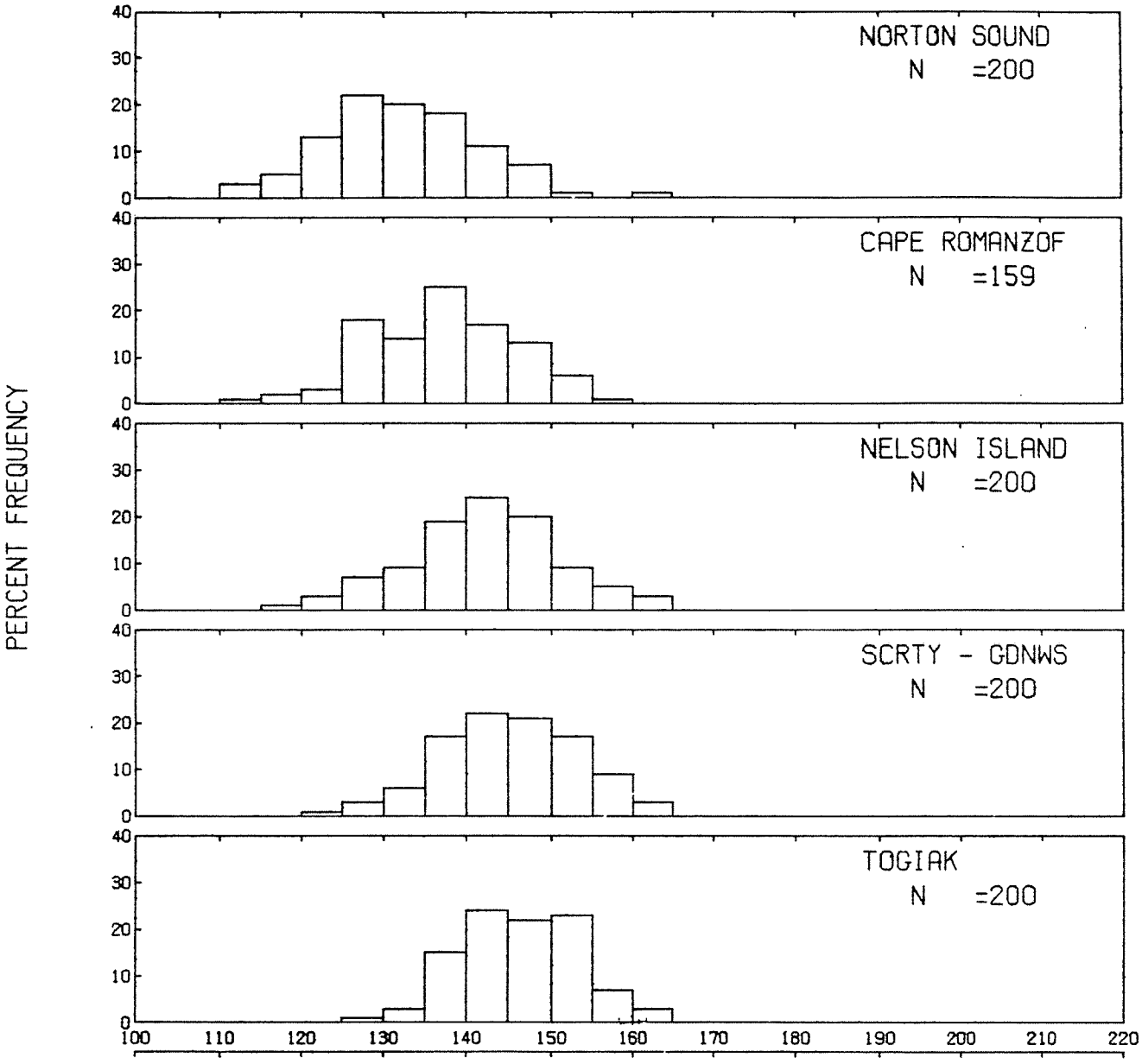

Fig. 2. Frequency distributions of scale size at age 7 for the 1984 age 7 herring standards representing the western Alaskan coastal spawning stocks considered for discriminant function analysis. Measurements are in 0.1 inches with scales magnified 50X.

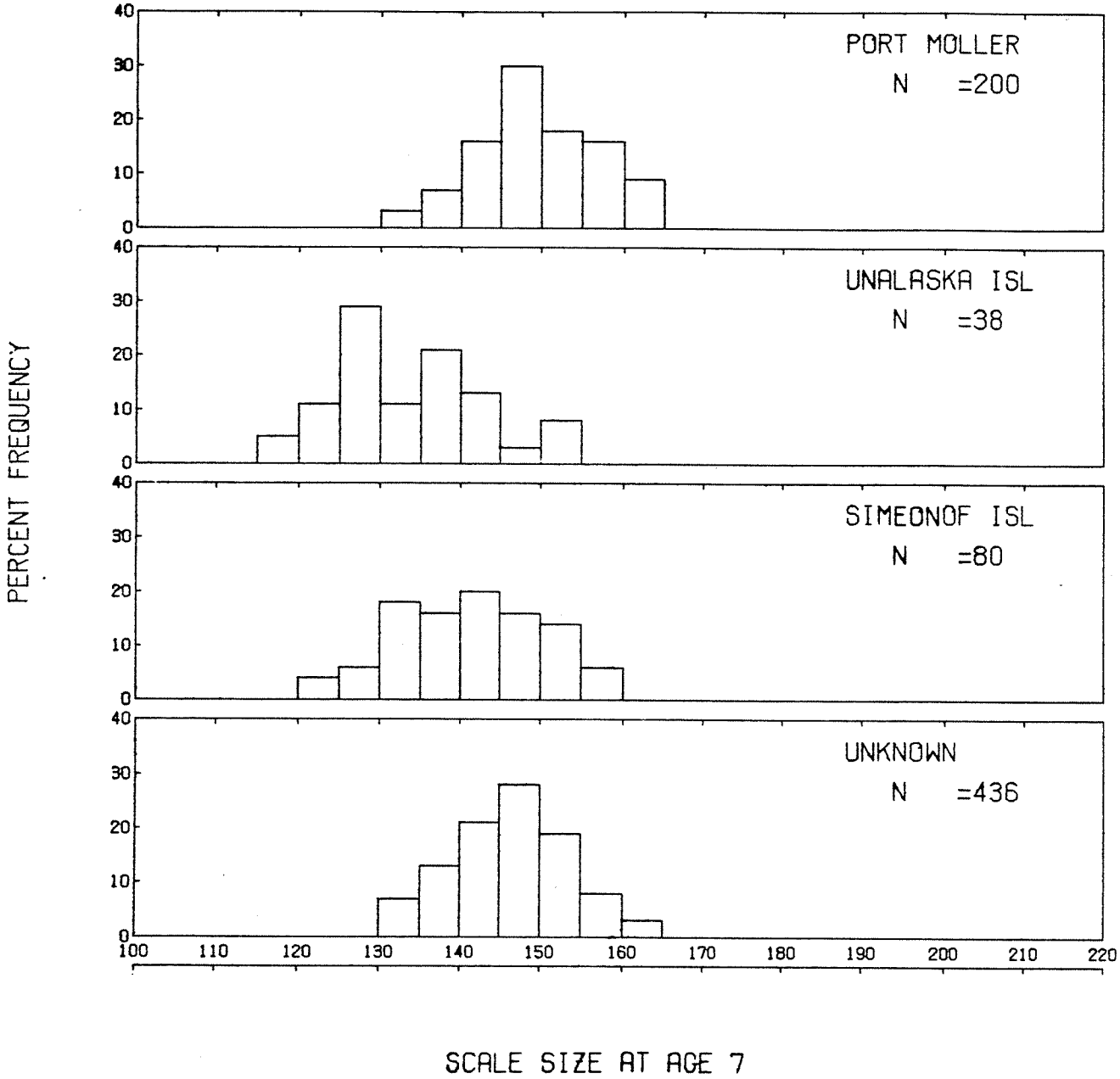

Fig. 3. Frequency distributions of scale size at age 7 for the 1984 age 7 herring standards representing the Alaska Peninsula spawning stocks considered for discriminant function analysis. Also, frequency distributions for the Dutch Harbor unknown origin sample and the spawning stock sample obtained from Unalaska Island. Measurements are in 0.1 inches with scales magnified 50X.

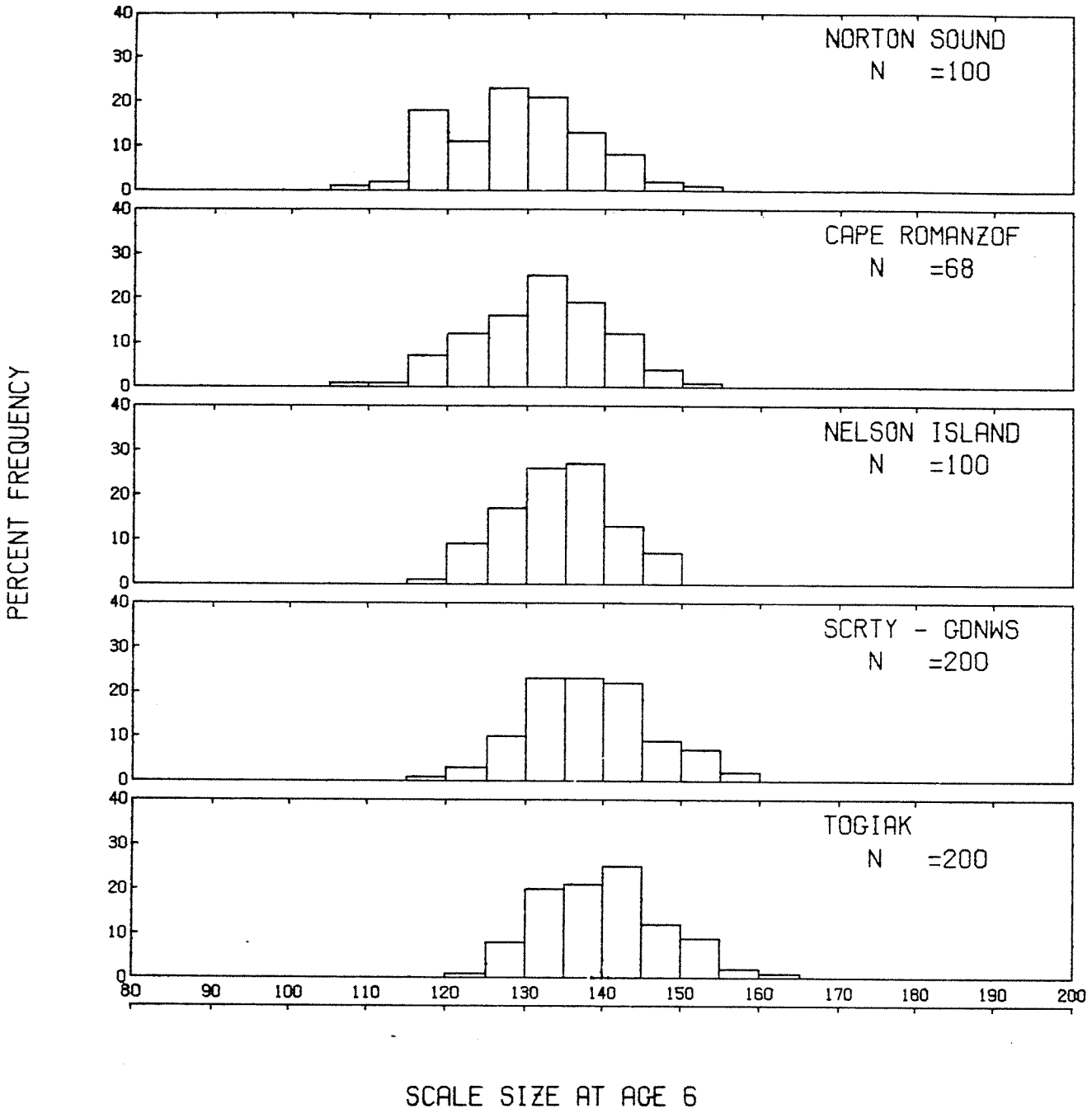

Fig. 4. Frequency distributions of scale size at age 6 for the 1984 age 6 herring standards representing the western Alaskan coastal spawning stocks considered for discriminant function analysis. Measurements are in 0.1 inches with scales magnified 50X.

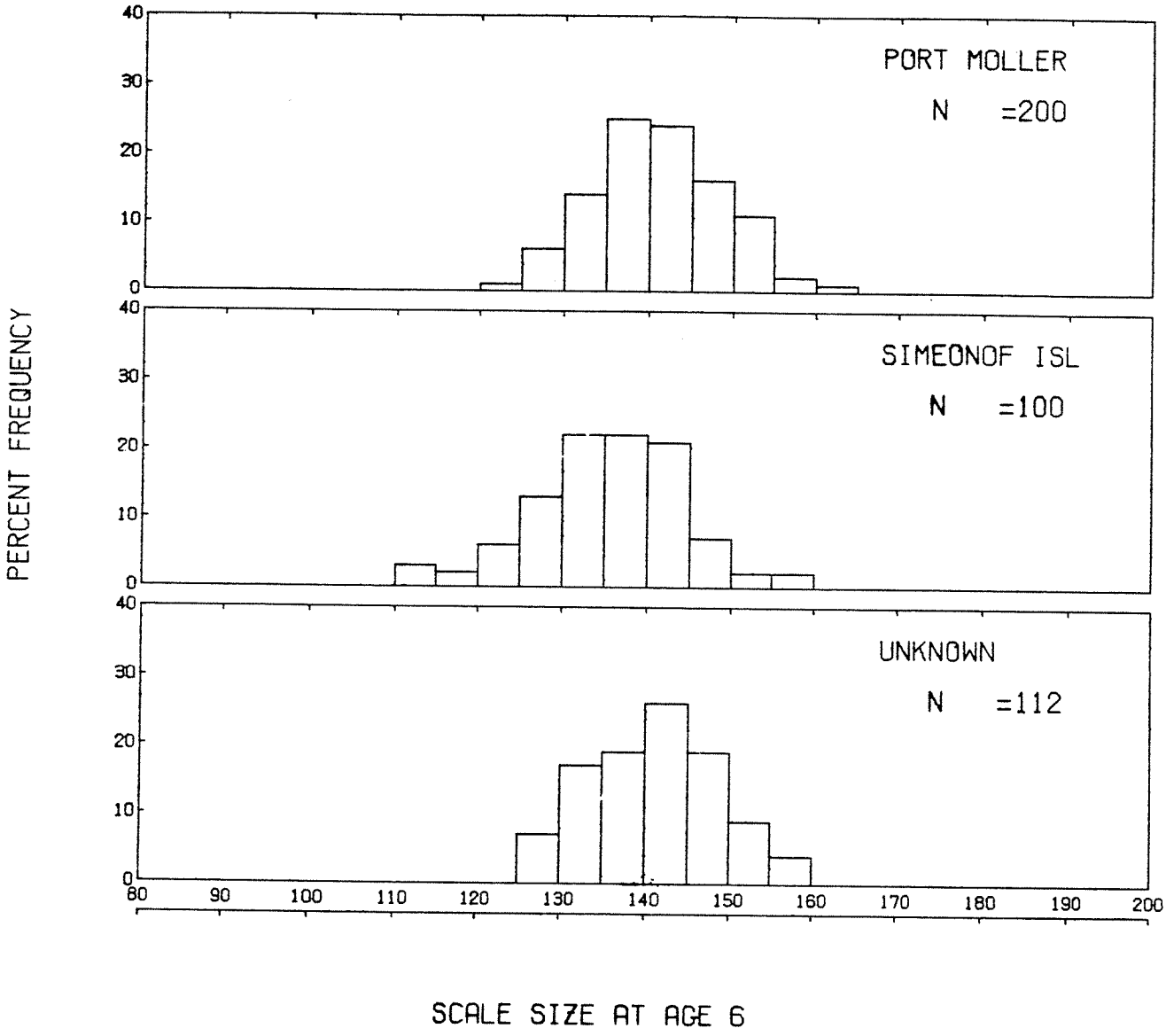

Fig. 5. Frequency distributions of scale size at age 6 for the 1984 age 6 herring standards representing the Alaska Peninsula spawning stocks considered for discriminant function analysis. Also, frequency distribution for the Dutch Harbor unknown origin sample. Measurements are in 0.1 inches with scales magnified 50X.

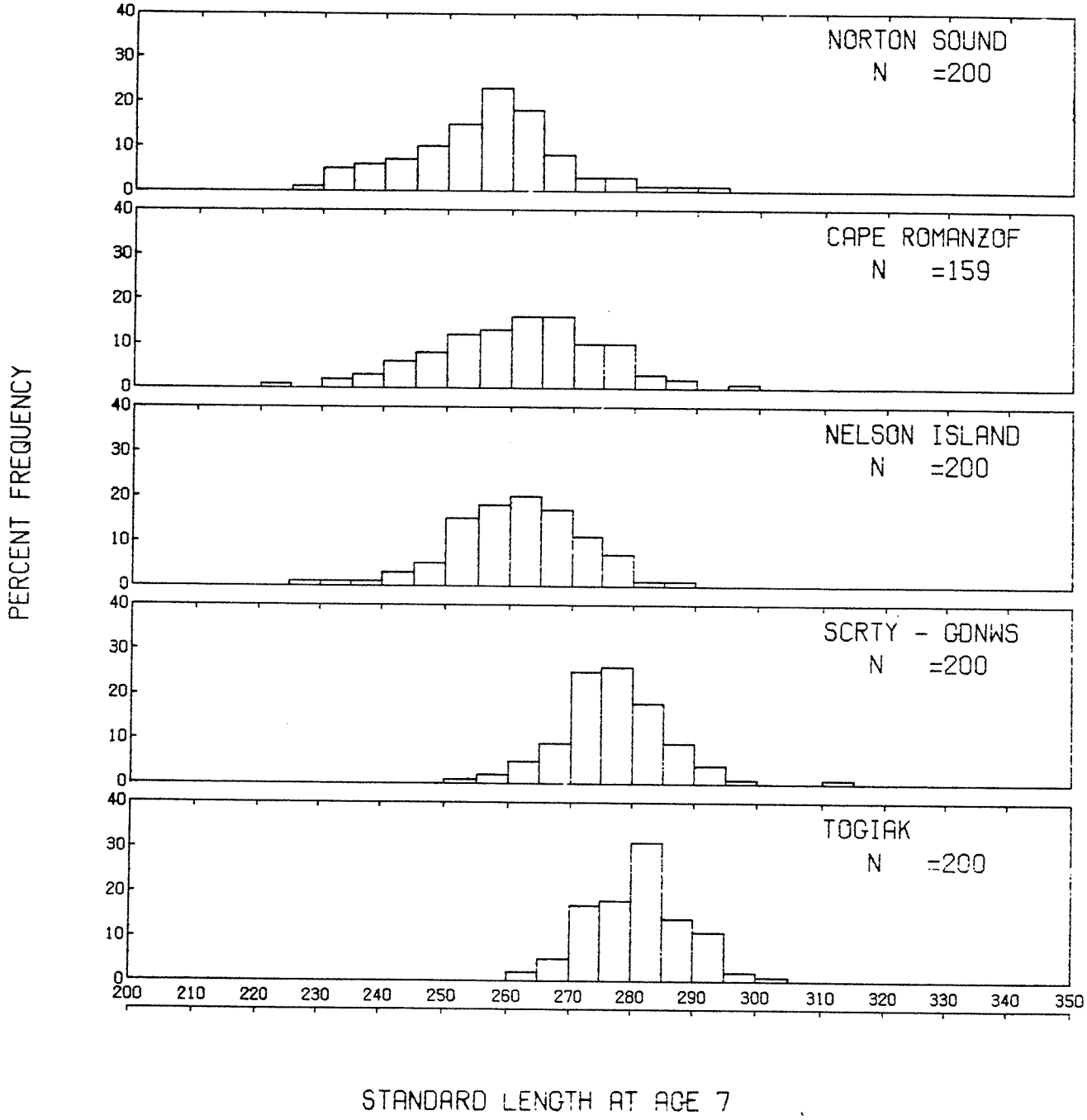

Fig. 6. Frequency distributions of standard length at age 7 for the 1984 age 7 herring standards representing the western Alaskan coastal spawning stocks considered for discriminant function analysis. Lengths are in millimeters.

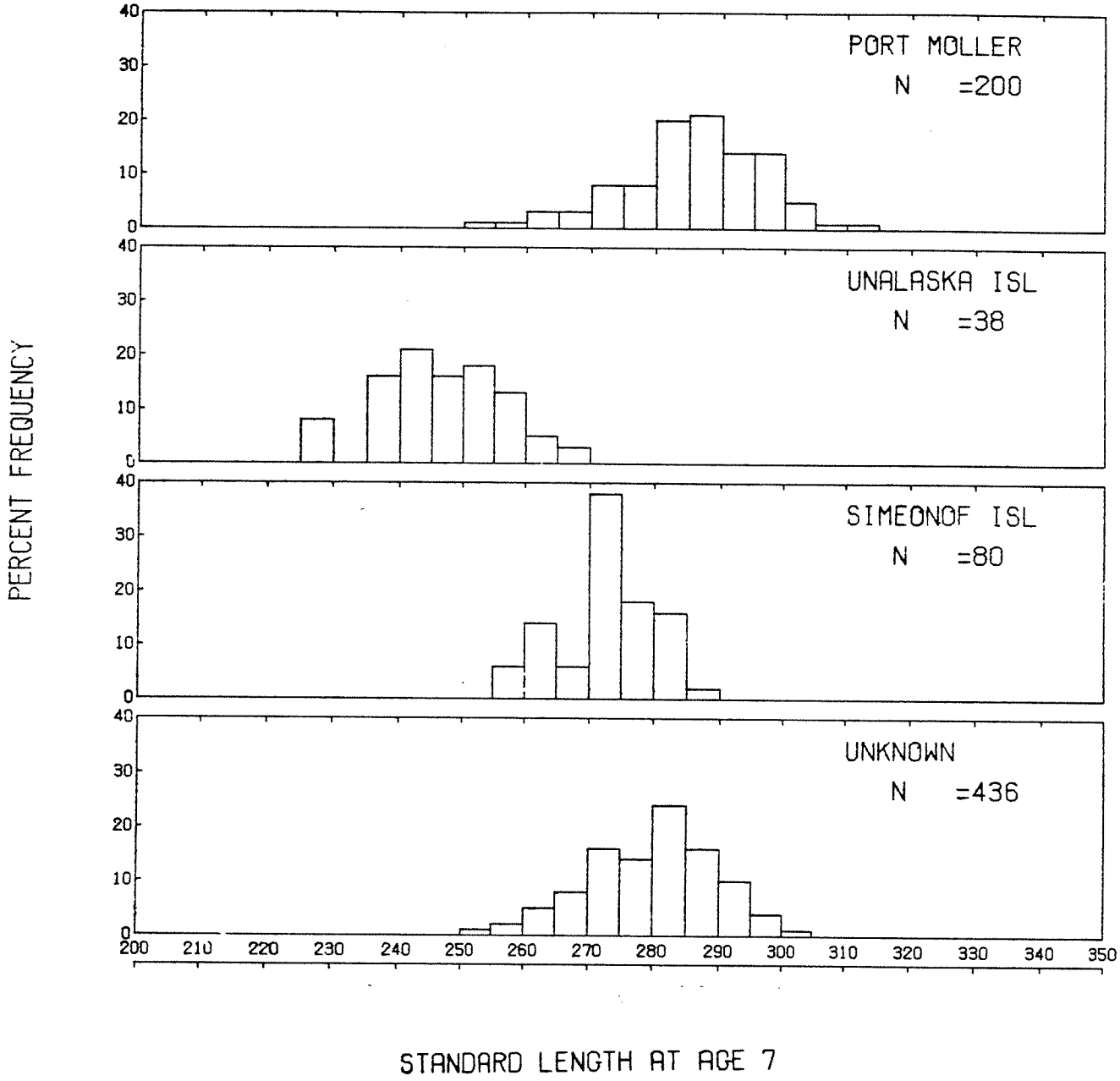

Fig. 7. Frequency distributions of standard length at age 7 for the 1984 age 7 herring standards representing the Alaska Peninsula spawning stocks considered for discriminant function analysis. Also, frequency distributions for the Dutch Harbor unknown origin sample and the spawning stock sample obtained from Unalaska Island. Lengths are in millimeters.

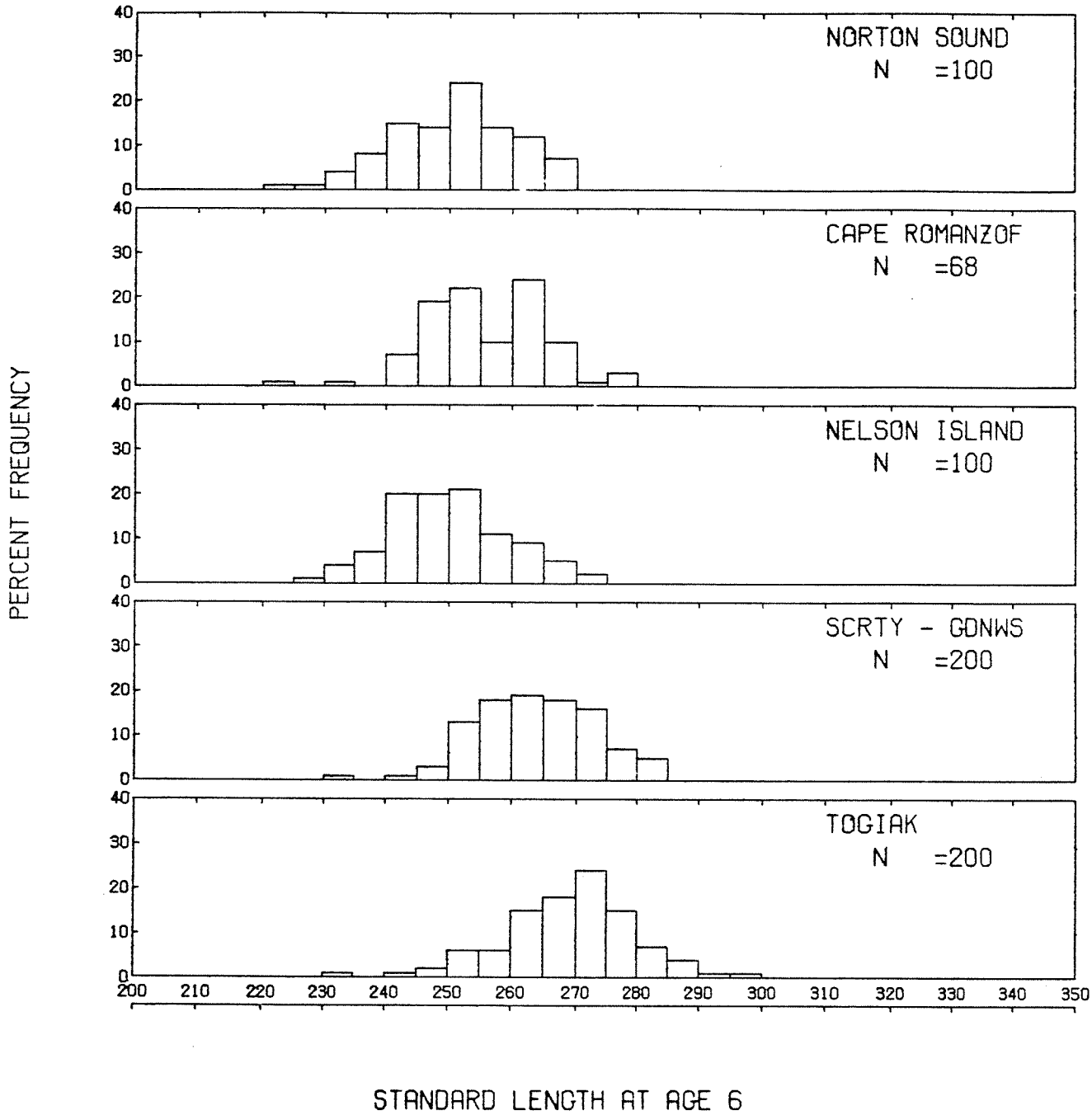

Fig. 8. Frequency distributions of standard length at age 6 for the 1984 age 6 herring standards representing the western Alaskan coastal spawning stocks considered for discriminant function analysis. Lengths are in millimeters.

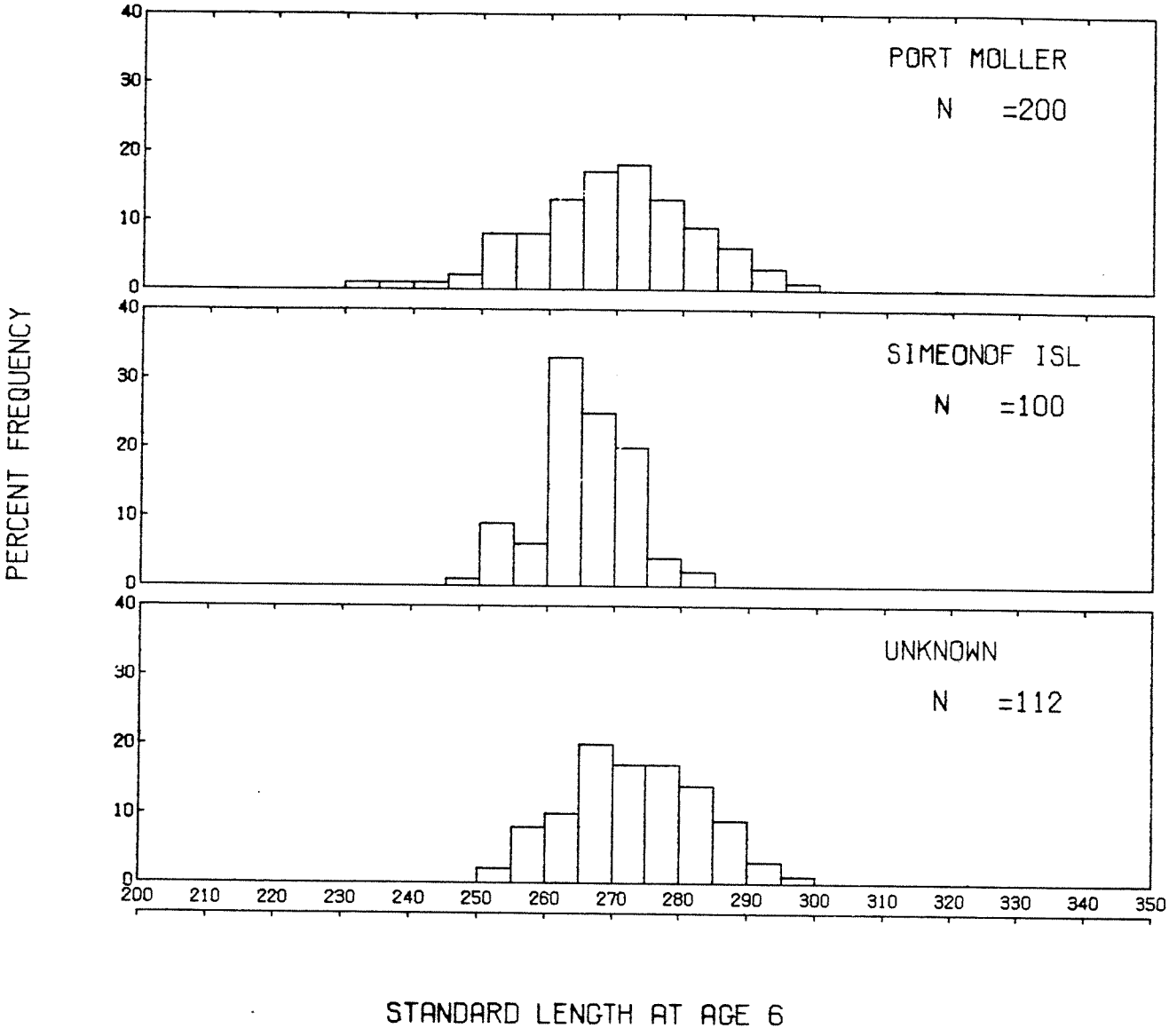

Fig. 9. Frequency distributions of standard length at age 6 for the 1984 age 6 herring standards representing the Alaska Peninsula spawning stocks considered for discriminant function analysis. Also, frequency distribution for the Dutch Harbor unknown origin sample. Lengths are in millimeters.

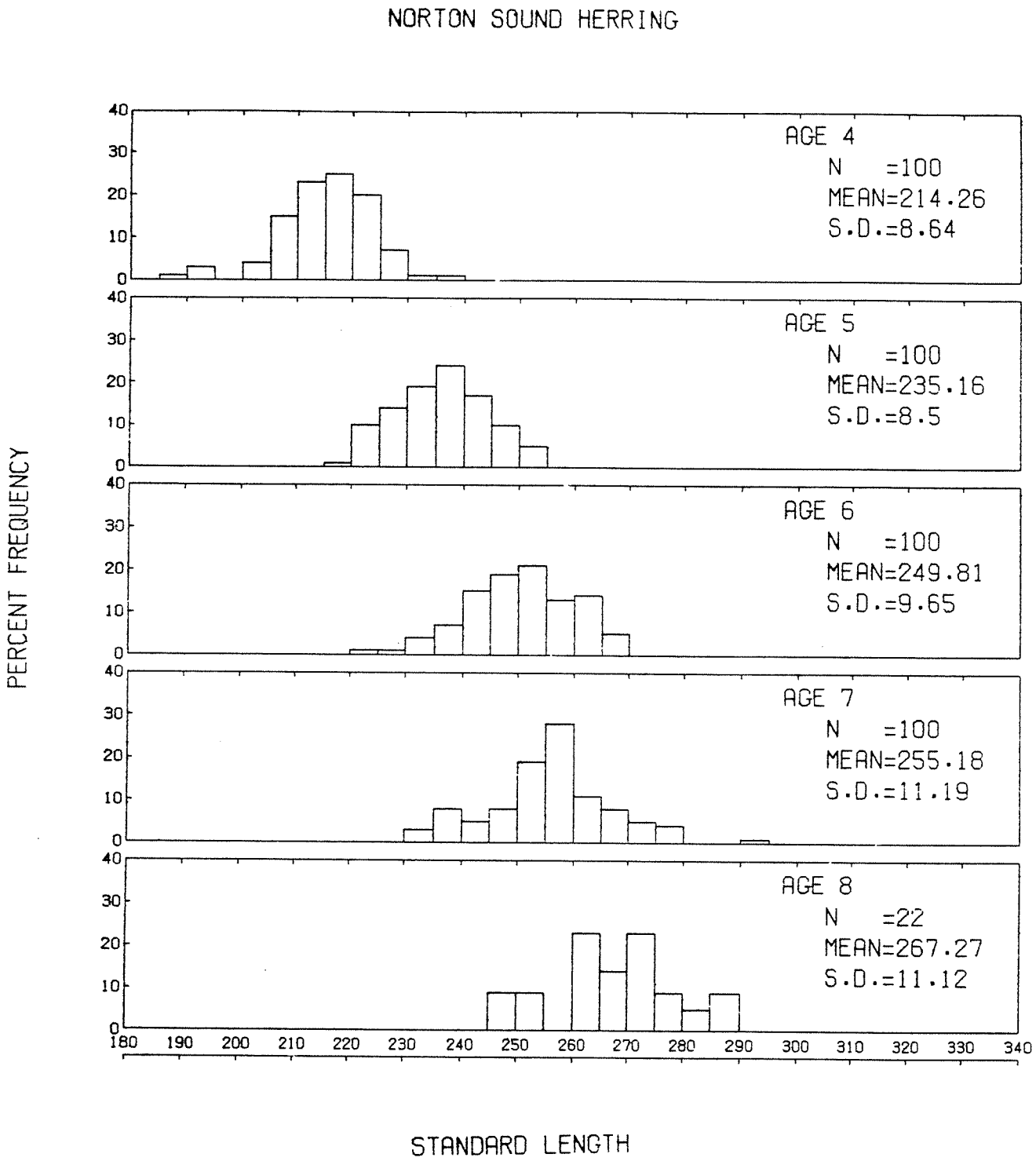

Fig. 10. Frequency distributions of standard length for age-specific samples of 1984 Norton Sound herring. Lengths are in millimeters.

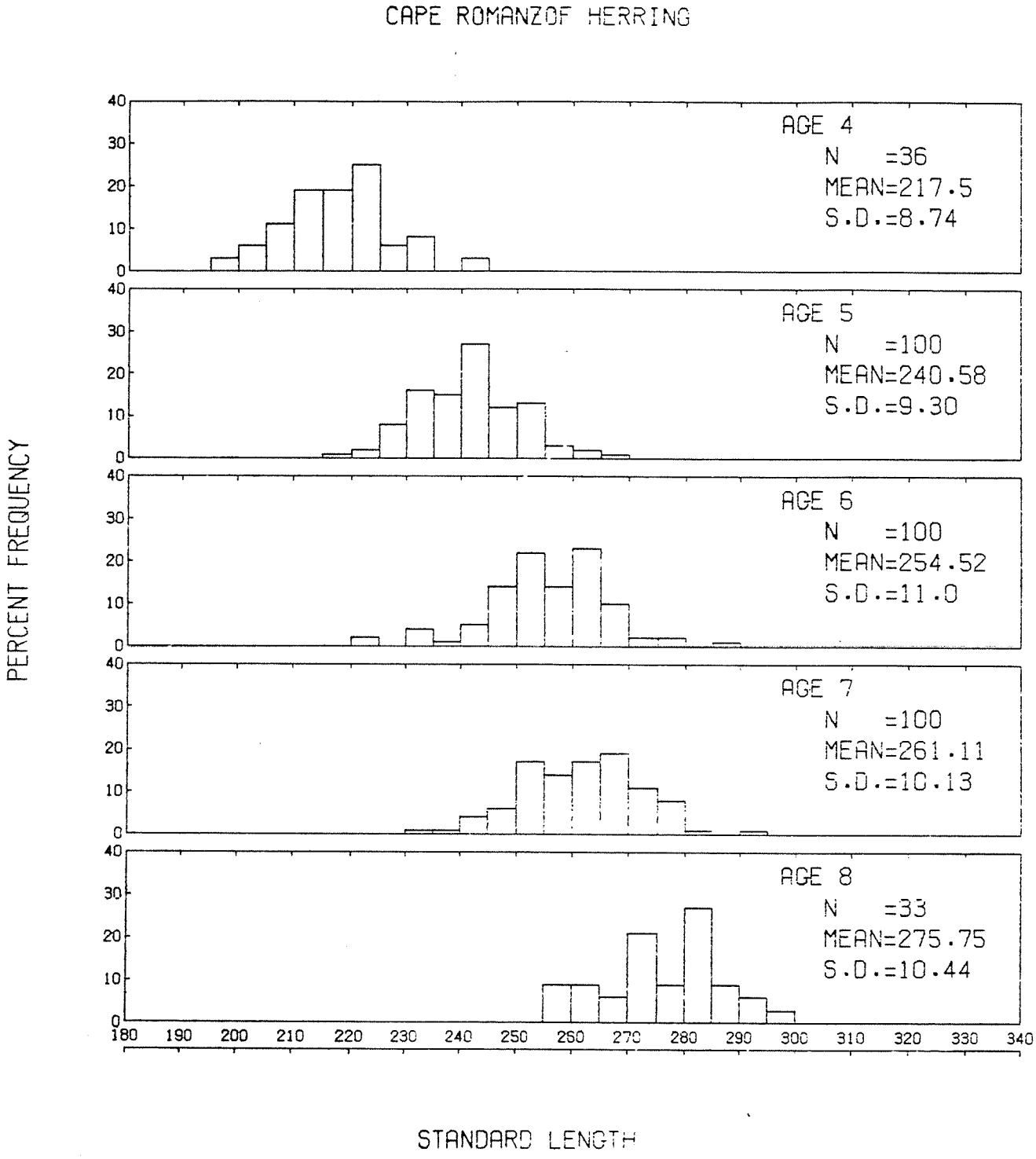

Fig. 11. Frequency distributions of standard length for age-specific samples of 1984 Cape Romanzof herring. Lengths are in millimeters.

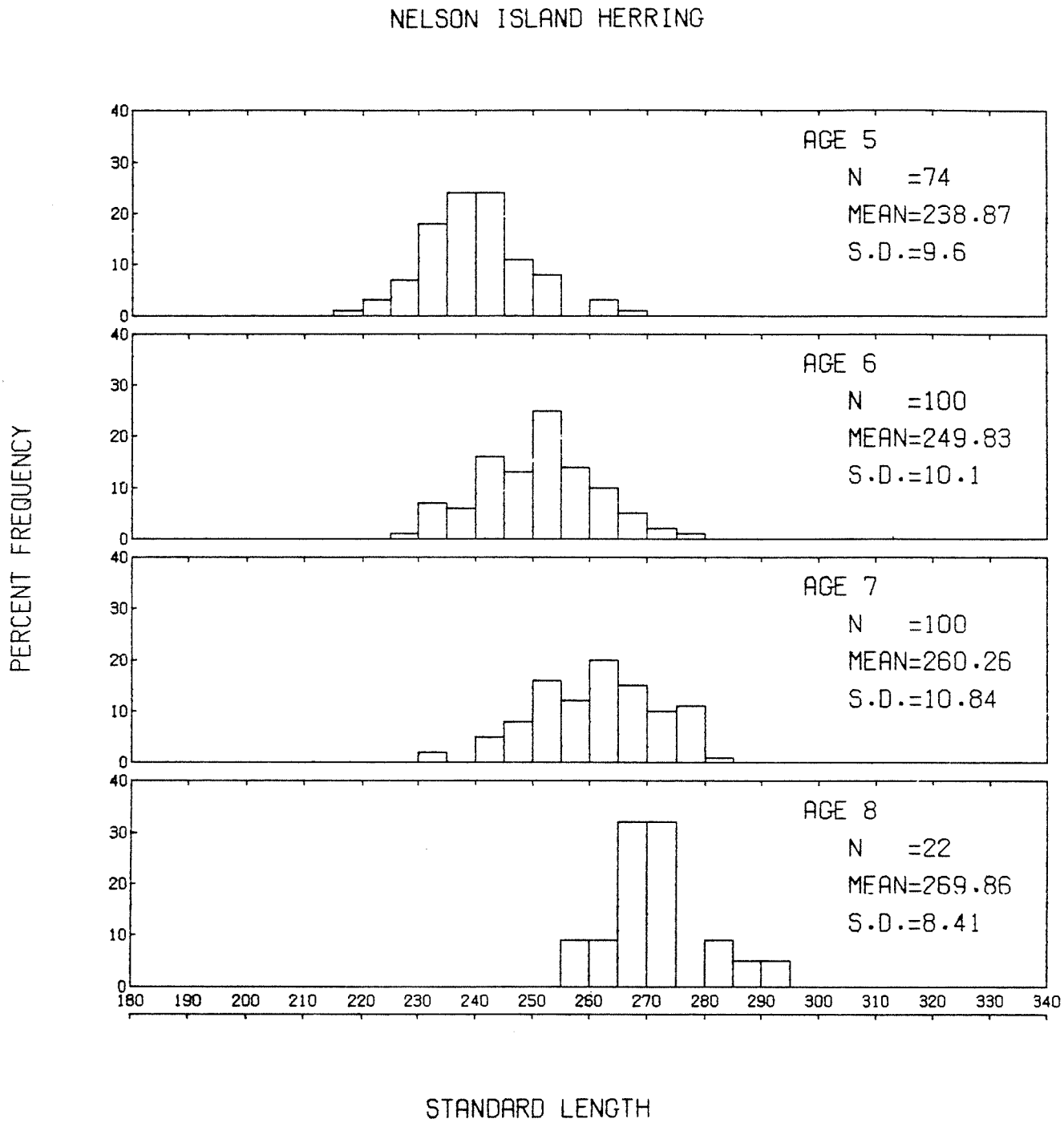

Fig. 12. Frequency distributions of standard length for age-specific samples of 1984 Nelson Island herring. Lengths are in millimeters.

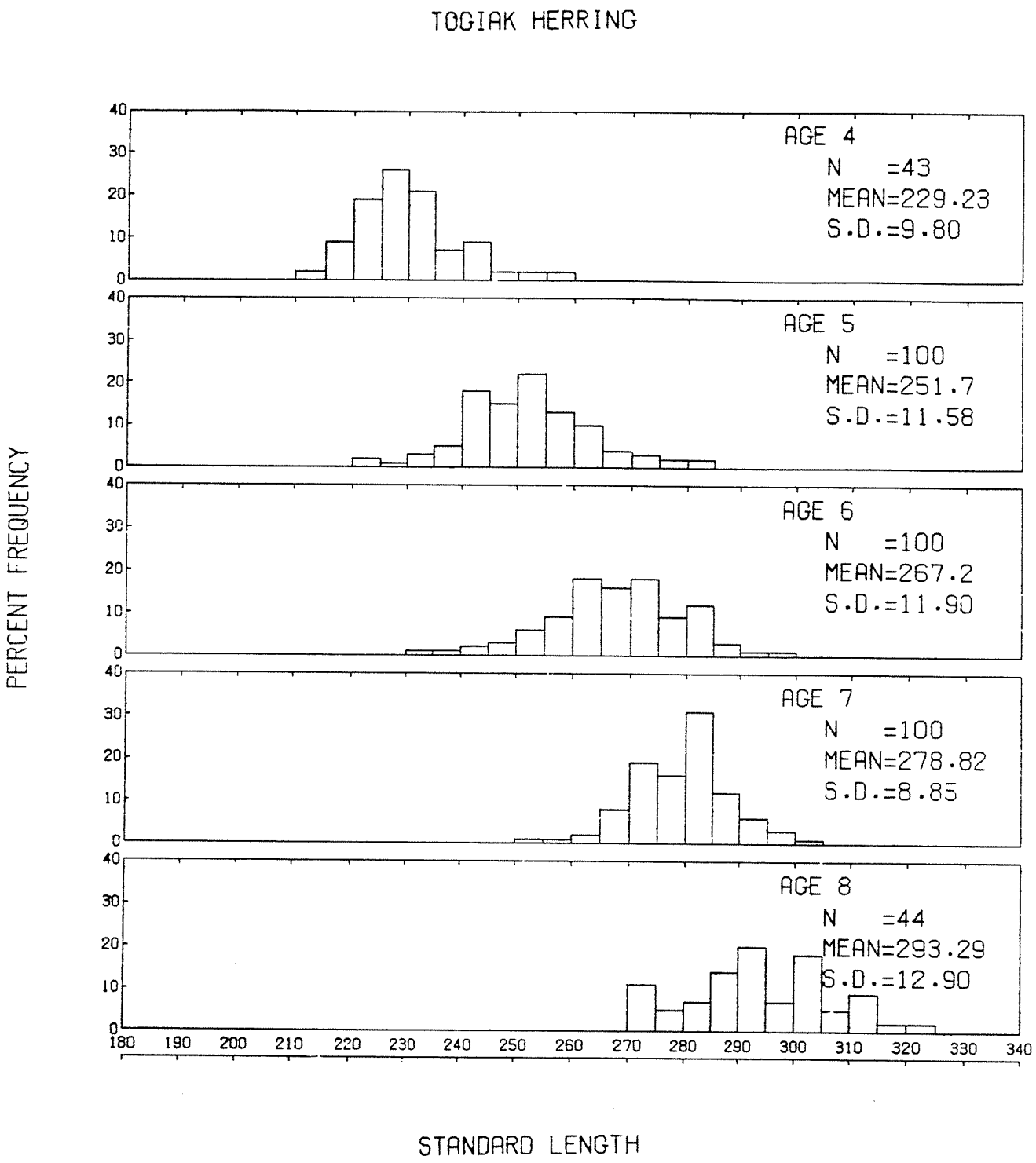

Fig. 13. Frequency distributions of standard length for age-specific samples of 1984 Togiak herring. Lengths are in millimeters.

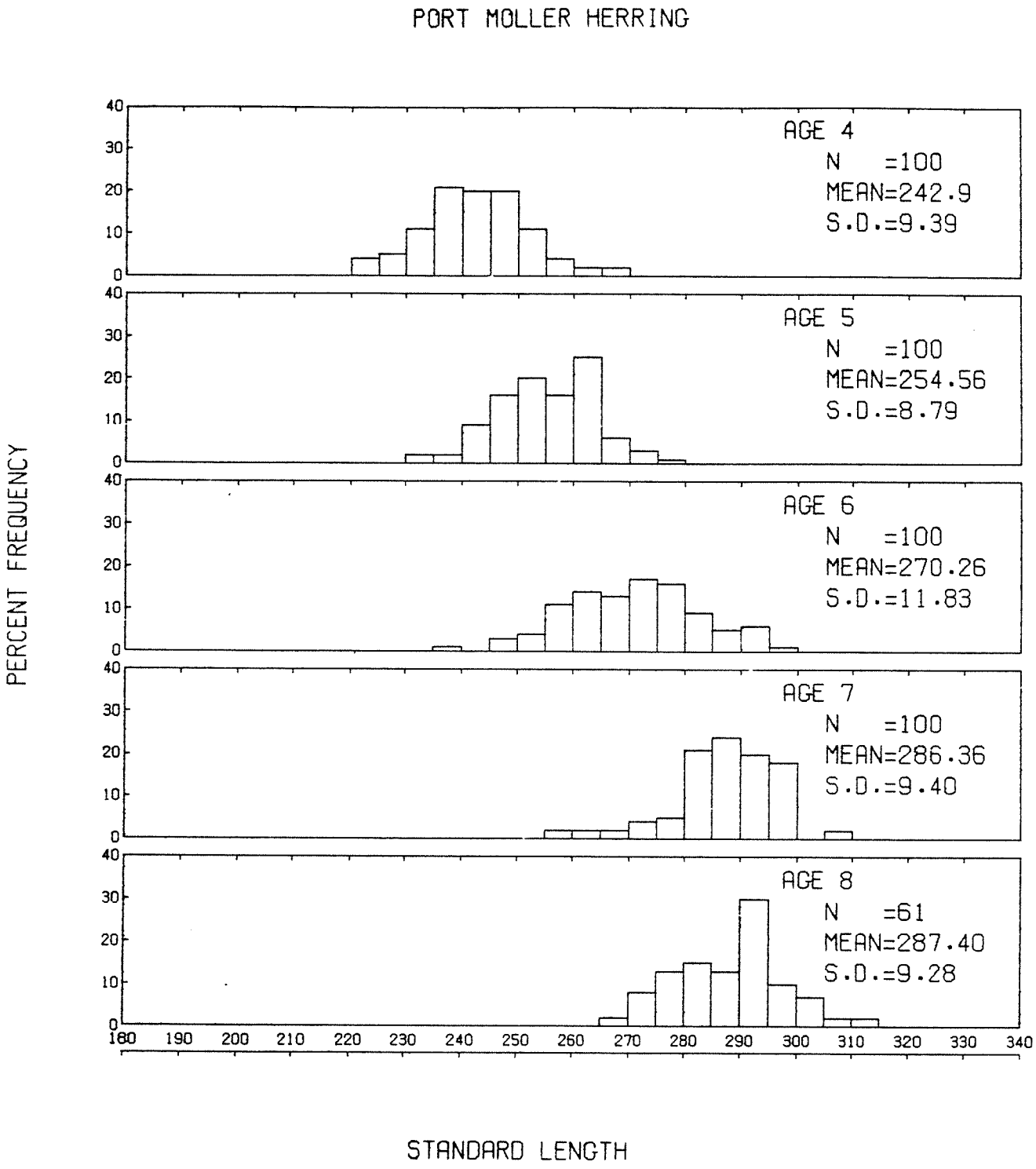

Fig. 14. Frequency distributions of standard length for age-specific samples of 1984 Port Moller herring. Lengths are in millimeters.

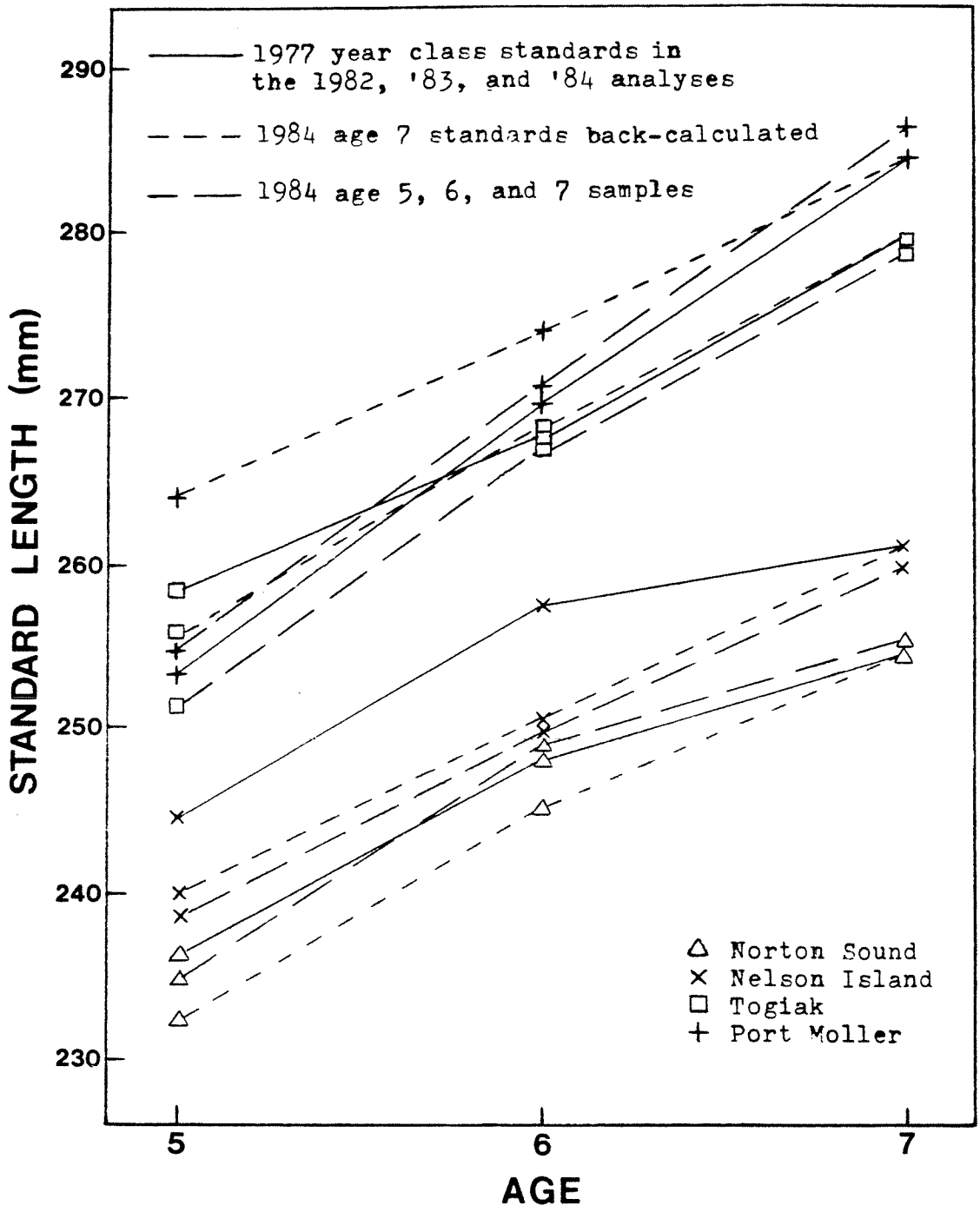

Fig. 15. Mean length by age for herring samples representing the stocks of Norton Sound, Nelson Island, Togiak, and Port Moller.

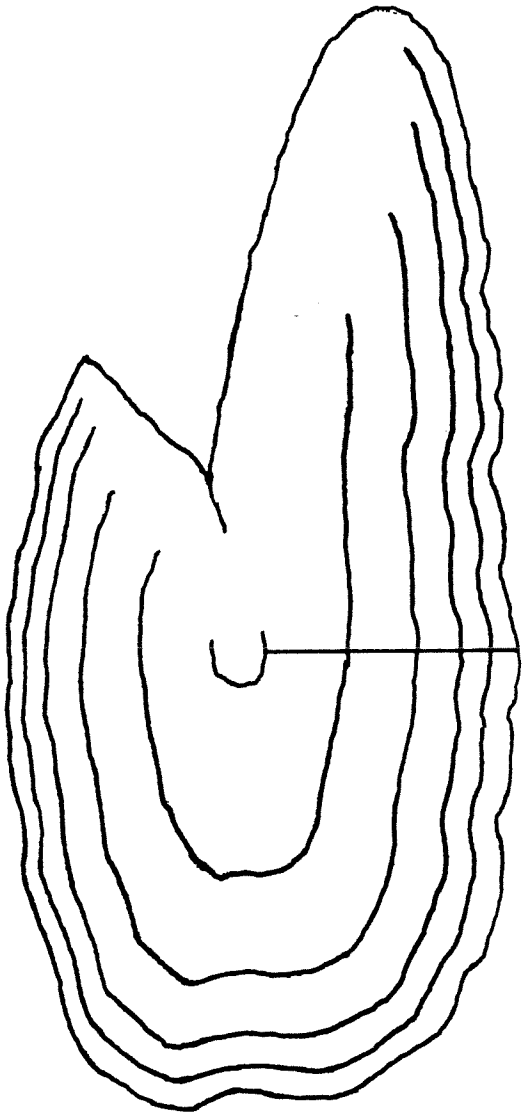

Fig. 16. Representation of an age 5 otolith with the radius of measurement drawn over it.