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SCALE PATTERN ANALYSIS TO ESTIMATE THE ORIGIN OF HERRING IN THE DUTCH HARBOR FISHERY

by

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ABSTRACT

Scale patterns and back calculated lengths were used to classify age 5 herring caught in the Dutch Harbor food and bait fishery to stock of origin. Five standards were used: Norton Sound, Cape Romanzof, Nelson Island, Togiak, and Port Moller. Norton Sound and Cape Romanzof fish were not detected in the Dutch Harbor samples. Overall classificatory accuracy was 73.4% for a three way analysis using Nelson Island, Togiak, and Port Moller stocks. Point estimates for the origin of all Dutch Harbor age 5 herring scales were 43.3% Togiak, 35.4% Nelson Island, and 21.3% Port Moller, with broadly overlapping 90% confidence intervals.

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INTRODUCTION

The recent development of a substantial fishery for Pacific herring (*Clupea harengus pallasi*) in the Dutch Harbor area of the Aleutian Islands has generated concern by Alaska Department of Fish and Game (ADF&G) management biologists over the stock composition of the catch. Of interest is whether stocks exploited by roe fisheries along the western coast of Alaska may also be harvested by the Dutch Harbor fishery, and whether the fish in the Dutch Harbor area are from one or several spawning stocks.

Rowell (1981) explored the feasibility of using a linear discriminant function with backcalculated lengths for stock identification of Bering Sea herring. In this study, Fisheries Research Institute (FRI) biologists have used scale pattern analysis with a polynomial discriminant function to distinguish between spawning stocks in the eastern Bering Sea and to classify scales from herring caught at Dutch Harbor to one of the spawning stocks.

METHODS

The basic assumption underlying the use of scale pattern analysis to separate stocks of herring is that fish from a given area grow in a characteristic manner, which is reflected in patterns on the scales which can then be used to identify fish in a mixed stock population (Cook et al. 1980). Scale characters of herring from known spawning stocks ("standards") were used to classify scale characters of individuals sampled from the Dutch Harbor fishery ("unknowns") to their stock of origin.

Construction of Standards

Because the variance of mixing proportion estimates is inversely proportional to standard sample size, the most accurate results are obtained when fish are classified using a large ($n \approx 200$) standard sample of herring of the same cohort (Cook 1980). Our analysis was limited to age 5 herring, the dominant age class in the 1982 roe and food and bait fisheries. Scales from eight spawning stocks were measured: Norton Sound, Cape Romanzof, Nelson Island, Goodnews Bay, Security Cove, Togiak, Port Moller, and Canoe Bay (Fig. 1). The standard from Norton Sound was constructed of samples from three subdistricts (St. Michael, Unalakleet, and Cape Denbigh) weighted according to biomass estimates provided by ADF&G biologists (Table 1). A standard from Togiak district was constructed using samples from four Togiak sections (Hagemeister, Kulukak, Togiak, and Nunavachak) weighted according to biomass estimates. All scales were collected and aged by ADF&G biologists.

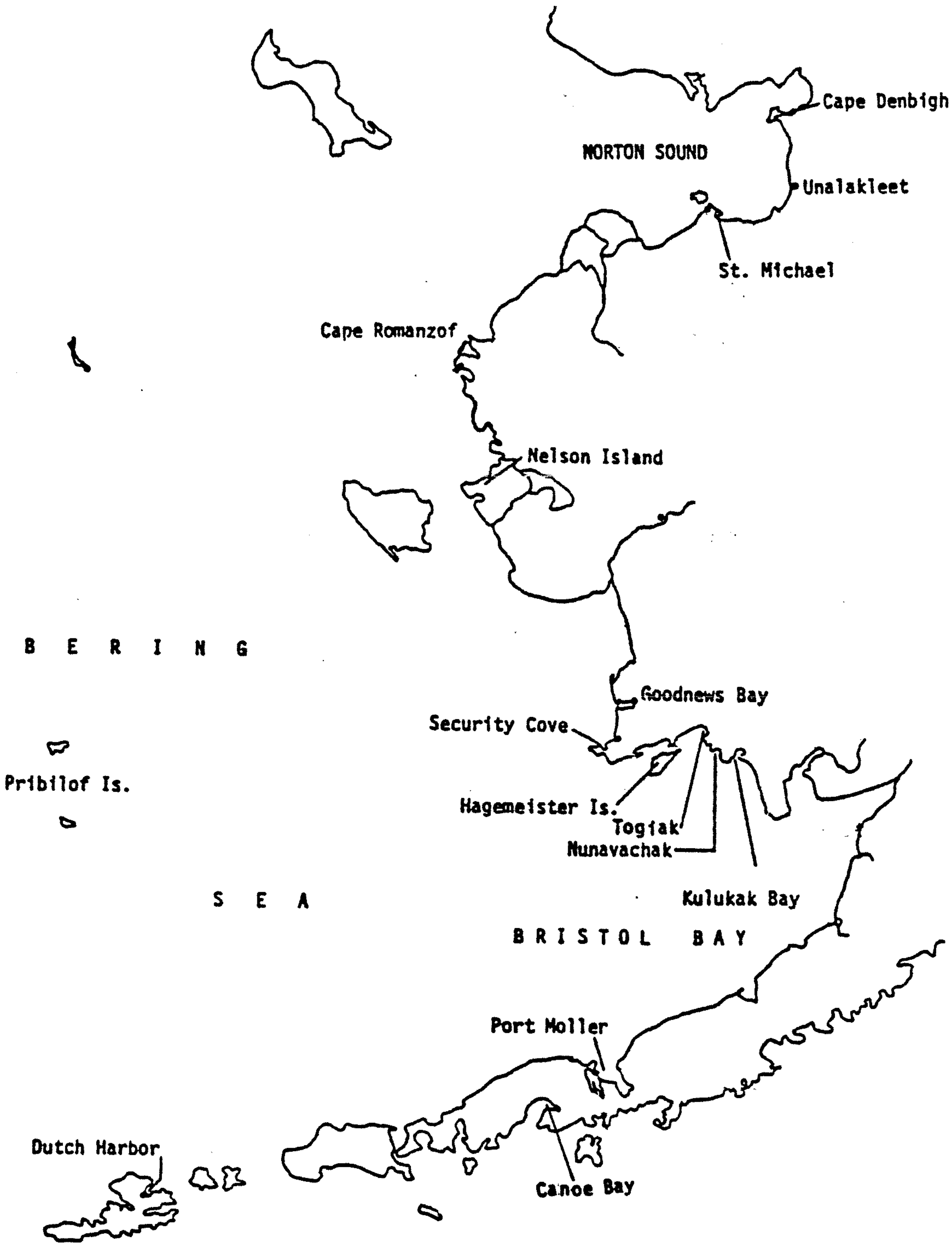

Fig. 1. Eastern Bering Sea study area.

Table 1. The construction of spawning stock standards used to determine the origin of age 5 Pacific herring from the Dutch Harbor food and bait fishery in 1982.

Stock (District or area)	Subdistrict or section	Estimated biomass[a]	% of district biomass[b]	No. scales measured	Scales used in combined standards
Norton	St. Michael		58.0	116	90
	Unalakleet		7.5	15	11
	Cape Denbigh		34.5	69	55
Total		15,800	100.0	200	156[c]
Cape Romanzof		4,400		200	44[c]
Nelson Island		3,600		186	
Goodnews Bay		3,900		100	8[d]
Security Cove		7,500		100	15[d]
Togiak	Hagemeister		18.6	37	33
	Togiak		35.8	72	64
	Nunavachak		20.2	40	35
	Kulukak		25.4	51	45
Total		88,700	100.0	200	177[d]
Port Moller				200	
Canoe Bay				28	

[a]Aerial survey biomass estimates (Fried et al. 1982).

[b]Biomass distribution on date of peak survey (personal communication, Stephen M. Fried, Alaska Department of Fish and Game, October 5, 1982).

[c]Combined Norton Sound/Cape Romanzof standard used in the four class analysis.

[d]Combined Togiak/Security Cove/Goodnews Bay standard used in the five class analysis.

Desired standard samples (n=200) were available from all stocks except Nelson Island (n=186) and Canoe Bay (n=28). As there were so few age 5 scales from Canoe Bay, that stock was not included in the analysis. In addition, the age structure of the Canoe Bay stock was very different from that of the eastern Bering Sea stocks and from that of the Dutch Harbor catches (Table 2). The dominant age classes at Canoe Bay were ages 6, 4 and 9, while the other groups were predominantly ages 5, 4, and 8.

A standard from the Togiak vicinity, composed of scales from Goodnews Bay, Security Cove, and the four Togiak sections (Table 1), was used in the initial five-class analysis. After the five-class analysis, a composite standard of Norton Sound and Cape Romanzof scales was constructed, with the two stocks weighted by biomass estimates. This standard was used in the four-class analysis.

Sample Composition of Herring Unknowns

The Dutch Harbor food and bait fishery operated in four locations in the eastern Aleutian Islands: 1) in Unalaska Bay, 2) on Chelan Bank, and 3) in Makushin Bay (all three locations near Unalaska Island), and 4) near Akun and Akutan Islands (Fig. 2). Scale samples were collected by ADF&G biologists from all of these areas throughout the fishing period. All readable age 5 scales collected from the fishery were measured and classified (n=584). The majority of the scales were aged by ADF&G biologists; FRI biologists determined the ages of the remaining scales.

The unknown scales were also stratified by fishing date (Fig. 2). Unalaska Bay scales were separated into two periods (8/10-16 and 8/22-27), as were Chelan Bank scales (8/18-19 and 8/24-27). A late sample from Unalaska Bay (9/9) was classified separately. Fish from the first two days of fishing (8/5 and 8/9) appeared to have an age structure composed largely of older fish (Table 2), but there were insufficient age 5 scales to classify these separately (n=10). However, these scales were included in the overall analysis. Combinations of area and time period were also analyzed.

Scale Measurement

Two fish scale technicians used a microcomputer-based digitizing system developed at FRI to measure and compute scale characters. Herring scales mounted between glass slides were rear-projected onto the digitizing surface at 50 power, and measurements were made along a radius 40 degrees dorsal or ventral from the anterior-posterior axis of the scale. This axis avoids disruption of scale patterns often found along the anterior-posterior axis.

Character Selection

In the initial five-class analysis, six characters were used: five backcalculated lengths (at ages 1 through 5) and one proportion (propor-

Table 2. Age composition of spawning stocks and Dutch Harbor fishery samples for Pacific herring in 1982. Compositions are derived from ADF&G counts of aged scales for gear types used in standards constructed for this study (Norton Sound through Togiak) or from FRI counts of aged scales (Port Moller, Canoe Bay, and Dutch Harbor).

Stock	Age composition (percent)								N
	2	3	4	5	6	7	8	9+	
Norton Sound	-	7.0	23.5	55.8	7.9	.8	3.6	1.4	1536
Cape Romanzof	.3	3.9	17.0	52.8	11.4	1.5	5.3	7.8	1215
Nelson Island	-	9.6	10.6	53.0	9.9	1.6	8.8	6.5	385
Goodnews Bay	-	8.8	26.9	42.7	5.4	.5	6.9	8.8	536
Security Cove	-	2.6	29.1	54.0	4.3	.3	5.0	4.7	643
Togiak	-	.6	18.8	50.2	3.6	.9	14.9	11.0	2131
Port Moller	.2	2.6	26.0	46.0	7.6	2.3	8.8	6.5	883
Canoe Bay	-	12.3	30.3	6.2	31.2	1.8	2.4	15.8	709
Dutch Harbor:									
8/5-8/9	-	.8	6.3	16.7	18.3	26.2	23.0	8.7	126
8/10-9/9	-	.2	9.7	61.7	10.3	6.1	8.4	3.6	1683

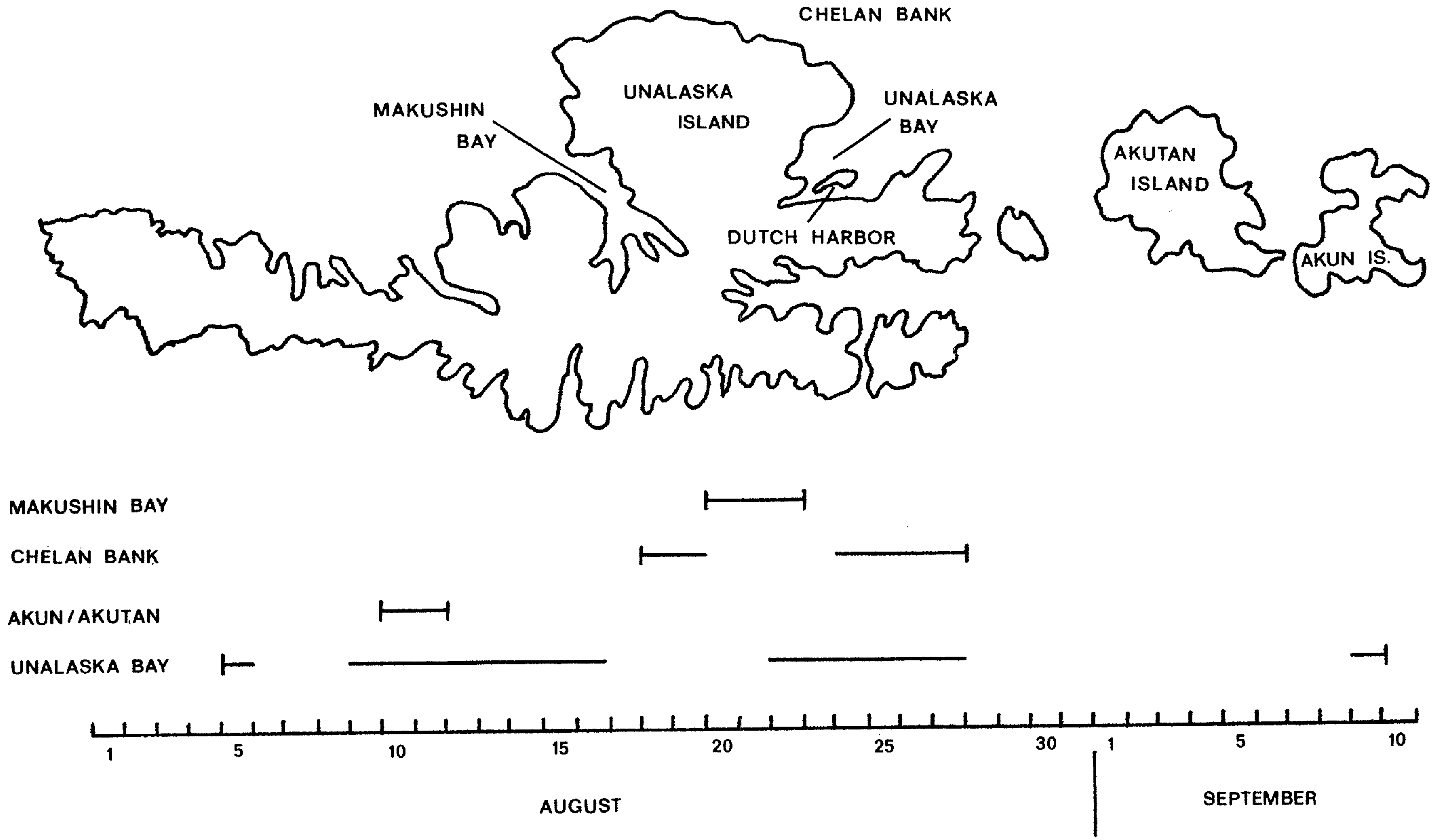

Fig. 2. Locations and periods of fishing for Pacific herring in the vicinity of Dutch Harbor, 1982.

tion of scale growth in first year, i.e., distance from focus to first annulus divided by total scale size). Backcalculated lengths were computed by a straight linear formula with no correction:

$$\text{Length at age i} = \frac{\text{distance to annulus i}}{\text{total scale size}} \times \text{length at capture.}$$

Classification accuracy in the five-class analysis was poor. One cause of this was concentration on backcalculated length characters. Length-at-age characters are all highly dependent on length at capture. While length at capture is a good discriminator between most of the stocks, the use of several dependent characters adds little additional power to the analysis. In addition, fish will classify to stocks largely on the basis of length (shorter fish to shorter stocks) and stocks having similar mean lengths will misclassify to each other (Norton Sound and Cape Romanzof; Togiak and Port Moller).

For the three- and four-way analyses, characters dependent only on scale measurements were examined in addition to back— calculated lengths. Thirty characters were tested, of five basic types (Table 3): 1) scale distances between annuli, 2) cumulative scale size at age, 3) proportion of scale growth in each year, 4) backcalculated lengths, and 5) combinations and ratios of distances between annuli. (Characters of types 1) and 2) are based on absolute scale measurements, and could be affected by bias between stocks in the body area of scale collection. However, these types provided good discrimination, and information from collecting biologists indicates techniques were standardized.) Four characters were chosen, one from each of the first four categories: 1) scale distance between the second and third annuli (scale growth in the third year); 2) total size of scale at age 5; 3) proportion of scale growth in the second year; and 4) backcalculated length at age 5.

Characters were selected using the method of Cook and Lord (1978). Kruskal-Wallis H-statistics were calculated for each character, and the sums of ranks (used in computing the H-statistic) of the different stocks were compared in a pairwise fashion. A set of characters was chosen to include large H-statistics, large differences in sums of ranks for each pairwise comparison of stocks, and independence from other characters chosen. Frequency distributions, means, and standard deviations for the characters used are shown in Appendix Figures 1-4.

Classification and Point and Variance Estimation Procedures

Patterns of selected scale characters in the standards were used to classify scales of individual fish in the Dutch Harbor fishery samples to their probable stock of origin. The methods of classification and point estimation are described by Cook (1982a and b) and Cook et al. (1981). The technique has been summarized by Myers et al. (1981):

> The classification technique used was Specht's (1966) polynomial discriminant function adapted to the leaving-one-out approach (Lachenbruch 1967). The smoothing

Table 3. Scale characters examined for use in the discriminant function analyses of 1982 age 5 Pacific herring from the eastern Bering Sea.

Character No.	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 from focus to second annulus
7	Distance from focus to third annulus
8	Distance from focus to fourth annulus
9	Distance from focus to fifth annulus
10	Distance from focus to edge of scale (fifth annulus or end of plus growth
11	Proportion of scale growth in first year (char 1/char 10)
12	Proportion of scale growth in second year (char 2/char 10)
13	Proportion of scale growth in third year (char 3/char 10)
14	Proportion of scale growth in fourth year (char 4/char 10)
15	Proportion of scale growth in fifth year (char 5/char 10)
16	Backcalculated length at age 1 (char 1/char 10 x length at capture)
17	Backcalculated length at age 2 (char 6/char 10 x length at capture)
18	Backcalculated length at age 3 (char 7/char 10 x length at capture)
19	Backcalculated length at age 4 (char 8/char 10 x length at capture)
20	Backcalculated length at age 5 (char 9/char 10 x length at capture)
21	Proportion of scale growth in first two years (char 6/char 10)
22	Proportion of scale growth in first three years (char 7/char 10)
23	Proportion of scale growth in first four years (char 8/char 10)
24	Proportion of scale growth in second and third years (char 12 + 13)
25	Ratio of first two years' growth to last three years' growth (char 6/char 3 + 4 + 5)
26	Ratio of first three years' growth to last two years' growth (char 7/char 4 + 5)
27	Ratio of first years' growth to first three years' growth (char 1/char 7)
28	Ratio of first two years' growth to first three years' growth (char 6/char 7)
29	Ratio of last (fifth) years' growth to first years' growth (char 5/char 1)
30	Ratio of last two years' growth to first two years' growth (char 4 + 5/char 6)

> parameter was estimated using the maximum likelihood method of Habbema et al. (1974). Point estimates of the proportions of the . . . . stocks in the unknowns were determined by the classification matrix correction procedure (Cook and Lord 1978). . . Variance estimates and 90% confidence intervals of the corrected point estimates were obtained using the formulae of Pella and Robertson (1979).

Although the five-class analysis lacked sufficient accuracy to give acceptable point estimates, a trial run on the unknown samples indicated the Norton Sound and Cape Romanzof stocks were not present in the Dutch Harbor fishery area. The Norton Sound/Cape Romanzof combined stock was not detected in the four-class analysis (i.e., no positive point estimates were obtained). A final three-class analysis using the Nelson Island, Togiak, and Port Moller stocks was used in the classification of unknown samples presented in this report. Point estimates and 90% confidence intervals were obtained for combinations of fishing location and time period where samples of 25 or more fish were available.

The term 'positive estimate' refers to any point estimate greater than zero obtained for a stock in the classification of unknowns from one of the combinations described above. The term (statistically) 'significant estimate' refers to a point estimate whose 90% confidence interval does not include zero.

RESULTS

Classification of Standards

The results of classifying the various combinations of stock standards are shown in Table 4. Overall classificatory accuracy of the 5-class analysis was only 44.8%. The percentages of fish correctly classified as Norton Sound, Cape Romanzof, Nelson Island, Togiak, and Port Moller, were 50.5%, 45.0%, 30.1%, 47.5% and 51.0%, respectively. Nelson Island misclassified heavily with all stocks. Norton Sound and Cape Romanzof cross-classified with each other, as did Togiak and Port Moller.

In the 4-class analysis, overall accuracy jumped to 63.6%, with correct classification percentages of 62.5%, 49.5%, 73.0%, and 69.5% for Norton, Romanzof, Nelson Island, Togiak, and Port Moller, respectively. Nelson Island again had the lowest accuracy, and misclassified with all stocks.

The 3-class analysis yielded an accuracy of 73.4% overall, with accuracies of 65.6%, 76.0%, and 78.5% for Nelson Island, Togiak, and Port Moller. Highest misclassifications were with Nelson Island.

Table 4. Decision arrays for 1982 age 5 herring of the Eastern Bering Sea for a) 5-class, b) 4-class, c) 3-class situations. The overall classificatory accuracies were calculated as the unweighted means of accuracies on the diagonals of the decision arrays.

a) 5-class:
Norton Sound vs. Cape Romanzof vs. Nelson Island vs. Togiak vs. Port Moller

Overall accuracy: 44.8%

Calculated decision	Correct decision (%)				
	Norton	Romanzof	Nelson	Togiak	Moller
Norton	101 (50.5)	48 (24.0)	41 (22.0)	2 (1.0)	8 (4.0)
Romanzof	53 (26.5)	90 (45.0)	31 (16.7)	5 (2.5)	16 (8.0)
Nelson	30 (15.0)	42 (21.0)	56 (30.1)	40 (20.0)	27 (13.5)
Togiak	8 (4.0)	11 (5.5)	37 (19.9)	95 (47.5)	47 (23.5)
Moller	8 (4.0)	9 (4.5)	21 (11.3)	58 (29.0)	102 (51.0)
Total	200	200	186	200	200

b) 4-class:
Norton Sound/Cape Romanzof vs. Nelson Island vs. Togiak vs. Port Moller

Overall accuracy: 63.6%

Calculated decision	Correct decision (%)			
	Norton	Nelson	Togiak	Moller
Norton	125 (62.5)	40 (21.5)	0 (0.0)	31 (15.5)
Nelson	49 (24.5)	92 (49.5)	33 (16.5)	20 (10.0)
Togiak	9 (4.5)	33 (17.7)	146 (73.0)	10 (5.0)
Moller	17 (8.5)	21 (11.3)	21 (10.5)	139 (69.5)
Total	200	186	200	200

c) 3-class:
Nelson Island vs. Togiak vs. Port Moller

Overall accuracy: 73.4%

Calculated decision	Correct decision (%)		
	Nelson	Togiak	Moller
Nelson	122 (65.6)	36 (18.0)	32 (16.0)
Togiak	35 (18.8)	152 (76.0)	11 (5.5)
Moller	29 (15.6)	12 (6.0)	157 (78.5)
Total	186	200	200

Classifications of Unknowns

Mixing proportion estimates and 90% confidence intervals were calculated for various combinations of fishing location and time periods (Table 5). Estimates for Norton Sound and Cape Romanzof stocks are not included, as no postive estimates were obtained for these stocks for any combination of location and period. However, confidence intervals centered on the zero estimates include positive values.

Positive estimates were obtained for the remaining three stocks (Nelson Island, Togiak, and Port Moller) for all combinations of location and period, except for Port Moller in Unalaska Bay on 9/9. These estimates were all statistically significant with the exception of one estimate for Togiak (Akun/Akutan), two for Port Moller (Akun/Akutan; Chelan Bank during 8/18-19), and three for Nelson Island (Unalaska Bay during 8/22-27 and on 9/9; Chelan Bank during 8/24-27).

Although each stock exhibited a range of estimates, estimates for Togiak were generally above 40%, those for Nelson Island above 30%, and those for Port Moller above 20%. This trend is reflected in the overall estimate for all unknown scales of 43.3% from Togiak, 35.4% from Nelson Island, and 21.3% from Port Moller.

DISCUSSION

Mixing proportion estimates of herring from Nelson Island, Togiak, and Port Moller showed a rough equivalence. Although confidence intervals were wide and broadly overlapping, the Togiak stock seems to rank highest in abundance, followed by Nelson Island and Port Moller. The lack of any positive estimates for Norton Sound and Cape Romanzof stocks indicate that these stocks are not present in detectable numbers in the Dutch Harbor fishery.

Estimates for Nelson Island seemed to decrease over time, while those for Togiak increased. This may indicate migrational movement through the area and a changing stock composition for the fishery. The estimates for Port Moller are relatively stable over time, showing no clear trend.

The classification accuracies of the standards and the mixing proportion estimates and confidence intervals of the unknowns are well within the range of estimations previously obtained in work on sockeye and coho salmon. If the stocks used for standards are the only stocks contributing to the Dutch Harbor fishery, then our results reflect the origins of the catch. However, if there are stocks from the Alaska Peninsula or the Aleutian Islands which contribute heavily to the fishery but have not been included in the standards, scales from those fish will be misclassified to one of the standards used. In addition, if these fish resemble one of the included stocks more strongly than the others, that stock will show a disproportionately higher percentage.

Table 5. Estimates of the mixing proportions of age 5 eastern Bering Sea herring in the Dutch Harbor food and bait fishery in 1982.

			Mixing proportion estimates (%) within 90% confidence intervals		
Fishing location	Fishing dates	Sample size	Nelson Island	Togiak	Port Moller
Akun/ Akutan	8/10-11	46	72.7(38.2-100)	6.2(0 -29.4)	21.1(0 -44.8)
Unalaska Bay	8/10-16	160	39.2(20.5-57.9)	39.8(24.5-55.0)	21.0(8.8-33.2)
	8/22-27	84	13.0(0 -35.5)	67.4(46.6-88.2)	19.6(4.7-34.4)
	8/10-27	244	30.2(14.7-45.7)	49.3(36.1-62.4)	20.5(10.6-30.4)
	9/9	32	7.8(0 -42.4)	92.2(60.8-100)	0
	8/5-9/9	286	26.2(11.8-40.7)	53.2(40.7-65.7)	20.6(11.4-29.7)
Chelan Bank	8/18-19	71	39.4(12.5-66.4)	52.7(29.6-75.7)	7.9(0 -22.7)
	8/24-27	76	22.0(0 -45.8)	36.6(16.9-56.2)	41.1(22.6-60.2)
	8/18-27	147	30.4(11.7-49.1)	44.3(28.6-60.1)	25.2(12.5-38.0)
Makushin Bay	8/20-22	105	51.9(27.8-74.1)	31.2(13.0-49.4)	17.8(3.0-32.6)
Unalaska/ Akum/ Chelan-pooled	8/10-19	250	46.8(30.4-63.2)	39.5(26.3-52.8)	13.7(3.9-23.5)
Unalaska/ Chelan/ Makushin-pooled	8/20-27	265	30.6(15.8-45.5)	44.2(31.8-56.6)	25.2(15.2-35.1)
All locations	8/10-27	542	37.9(25.7-50.1)	40.8(30.9-50.6)	21.3(13.7-29.0)
	8/5-9/9	584	35.4(23.6-47.2)	43.3(33.6-53.0)	21.3(13.9-28.7)

Misclassification of the Nelson Island stock in the classification of standards could be due to its intermediate position in the distributions of scale characters used. A stock having characters of intermediate values can misclassify to both extremes, while stocks at one end of the range can only misclassify toward the center. The distributions of two scale characters (size of scale at age 5 and scale growth in the third year) for Nelson Island are intermediate between Togiak and Port Moller. Fish of Togiak or Port Moller origin with characters in the tails of their respective distributions which overlap the center region may classify as Nelson Island fish, in addition to fish of true Nelson Island origin. However, the other characters should provide discrimination between Nelson Island and other stocks.

There are several recommendations for future scale pattern work on eastern Bering Sea herring:

1) surveying, sampling and estimation of stock size of all spawning stocks on the Alaska Peninsula and in the eastern Aleutians, and collection of scales from all major spawning stocks;

2) additional scale collection from Nelson Island and Port Moller, to ensure adequate sample sizes and accommodation of analysis of other age classes; and

3) ensuring consistent scale collection techniques among all field crews.

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REFERENCES CITED

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

Cook, R. C. 1982b. A constrained mixing proportion estimator. (Submitted). 10 pp.

Cook, R. C., and G. E. Lord. 1978. Identification of stocks and Bristol Bay sockeye salmon, *Oncorhynchus nerka*, by evaluating scale patterns with a polynomial discriminant method. Fish. Bull. 76(2):415-423.

Cook, R. C., R. M. Conrad, K. W. Myers, R. V. Walker, and C. K. Harris. 1980. The mixing proportions of Asian and Alaskan sockeye salmon in and around the landbased driftnet fishery area as determined by scale pattern recognition. (Document submitted to annual meeting of the INPFC, Anchorage, U.S.A., November 1980). 58 pp. Fish. Res. Inst., Univ. Washington, Seattle.

Cook, R. C., K. W. Myers, R. V. Walker, and C. K. Harris. 1981. The mixing proportion of Asian and Alaskan sockeye salmon in and around the landbased fishery area - 1972-1976 samples. (Document submitted to annual meeting of the INPFC, Vancouver, B.C., Canada, October 1981). 81 pp. Fish. Res. Inst., Univ. Washington, Seattle.

Fried, S. M., C. Whitmore, and D. Bergstrom. 1982. Pacific herring stocks and fisheries in the eastern Bering Sea: Preliminary report for 1982. Report to the North Pacific Fisheries Management Council. 13 pp.

Habbema, J. D. F., J. Hermans, and K. van den Broek. 1974. A stepwise discriminant analysis program using density estimation. Pages 101-110 *in* Compstat. 1974, Proc. Computational Statistics, Physica Verlag, Vienna.

Lachenbruch, P. A. 1967. An almost unbiased method of obtaining confidence intervals for the probability of misclassification in discriminant analysis. Biometrics 23:639-645.

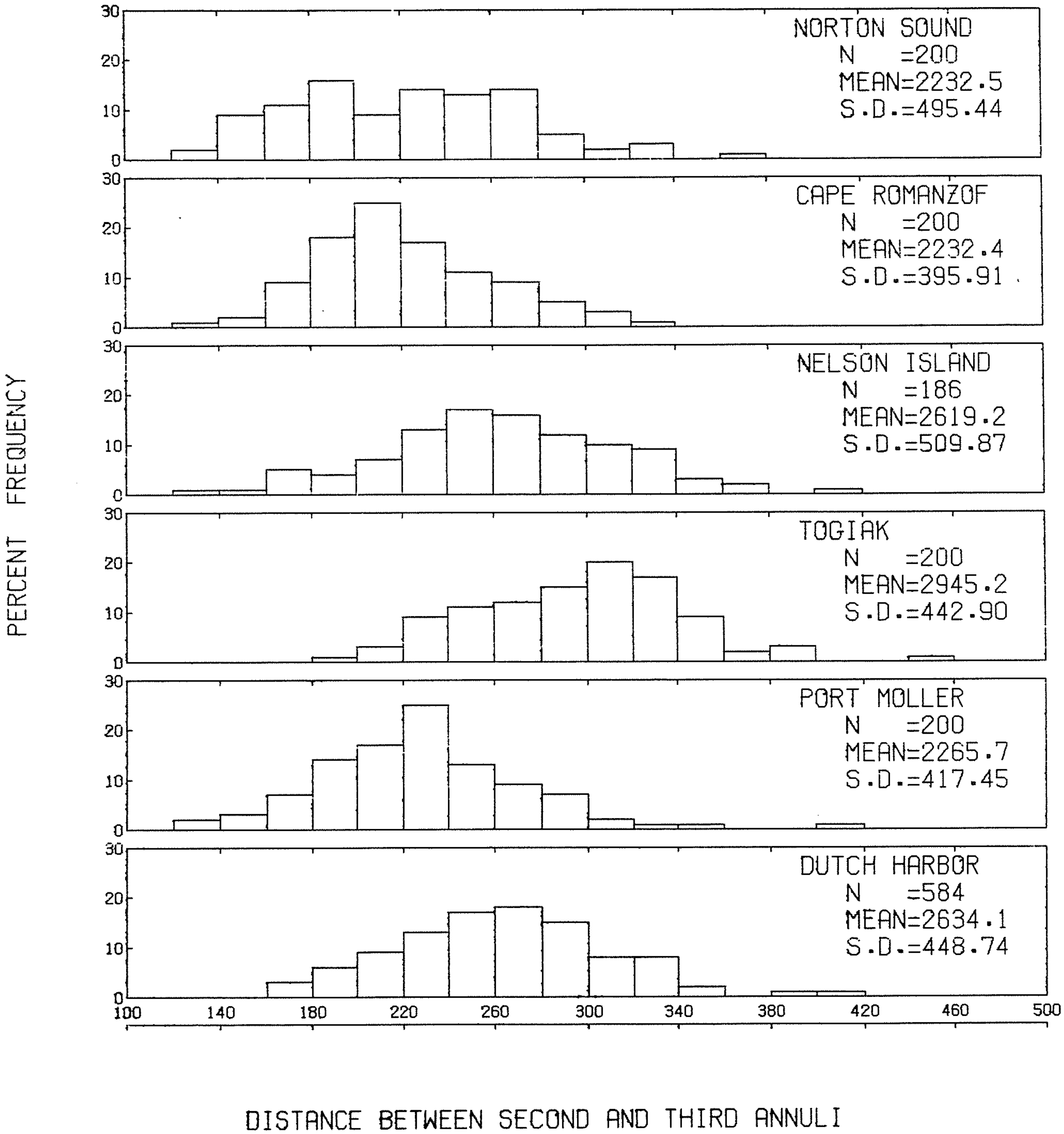
Myers, K. W., R. C. Cook, R. V. Walker, and C. K. Harris. 1981. The continent of origin of coho salmon in the Japanese landbased driftnet fishery area in 1979. (Document submitted to annual meeting of the INPFC, Vancouver, B.C., Canada, November 1981). 34 pp. Fish. Res. Inst., Univ. Washington, Seattle.

Pella, J. J. and T. L. Robertson. 1979. Assessment of composition of stock mixtures. Fish. Bull. 77(2):387-398.

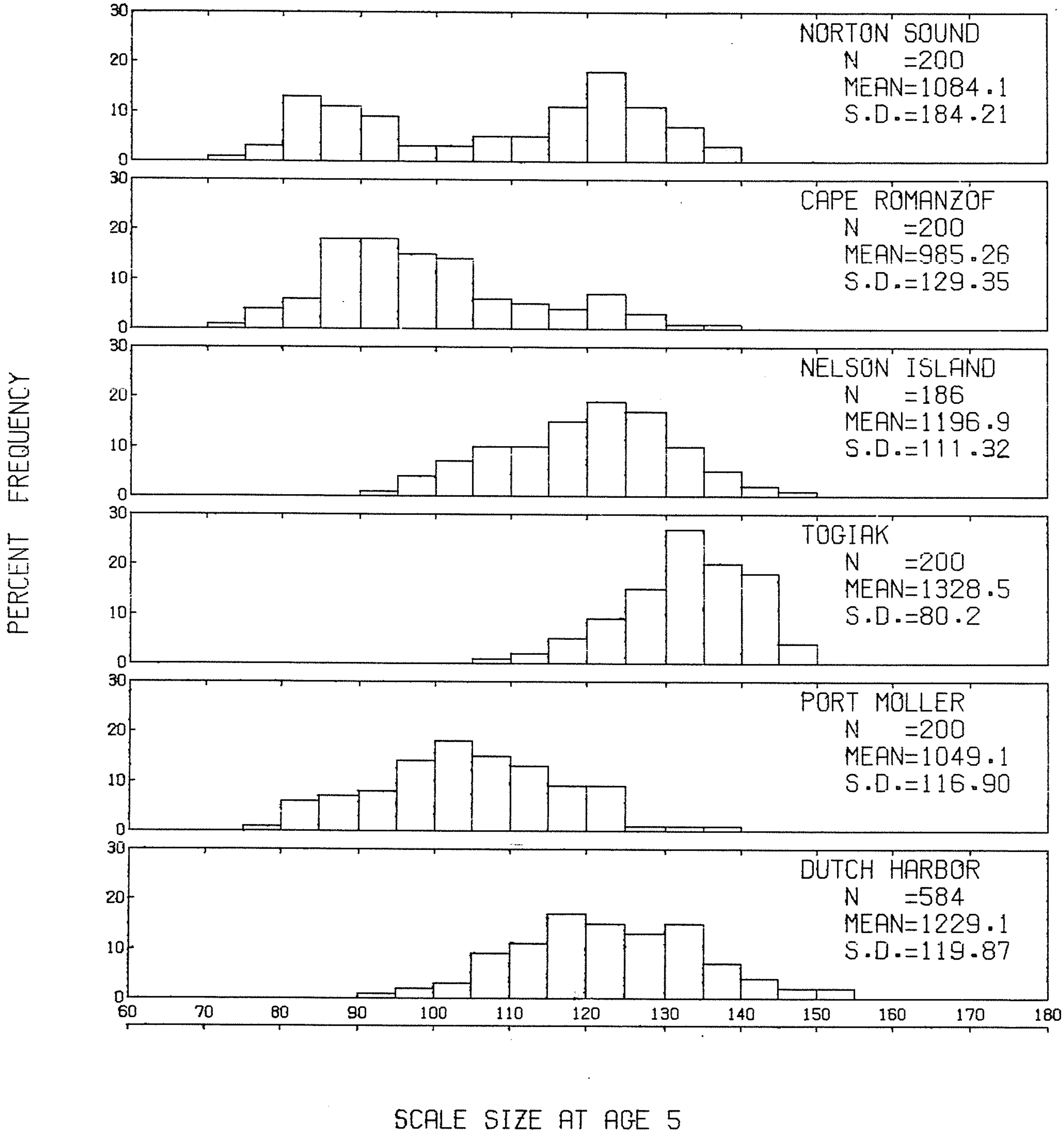
Rowell, K. A. 1981. Feasibility of scale pattern analysis techniques for stock identification and growth of Pacific herring (*Clupea harengus pallasi*) from four spawning locations of the eastern Bering Sea. Alaska Dept. Fish and Game. 59 pp.

Specht, D. F. 1966. Generation of polynomial discriminant functions for pattern recognition. Stanford Univ. Tech. Rep. 6764-5. 127 pp.

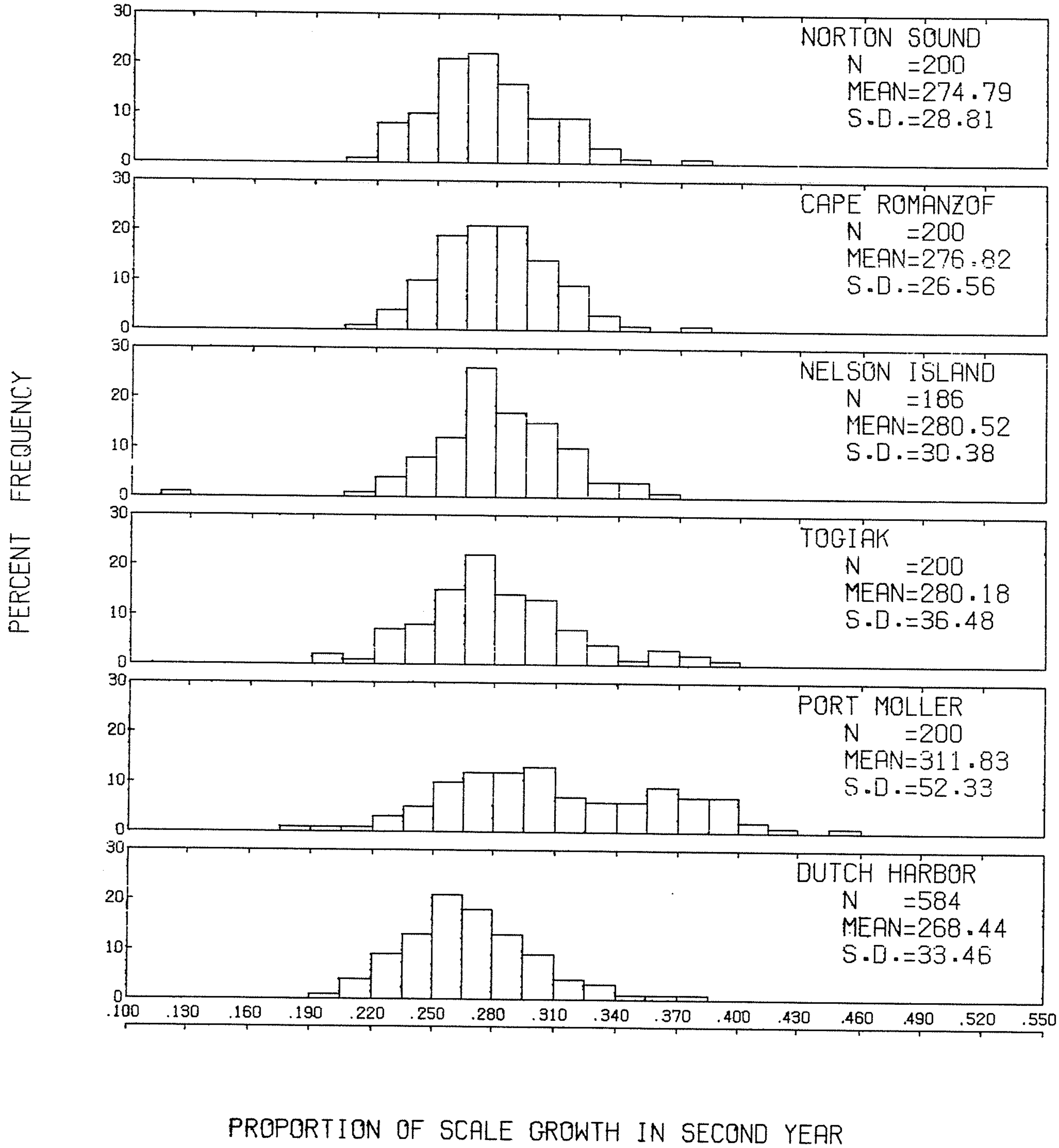
APPENDIX FIGURES



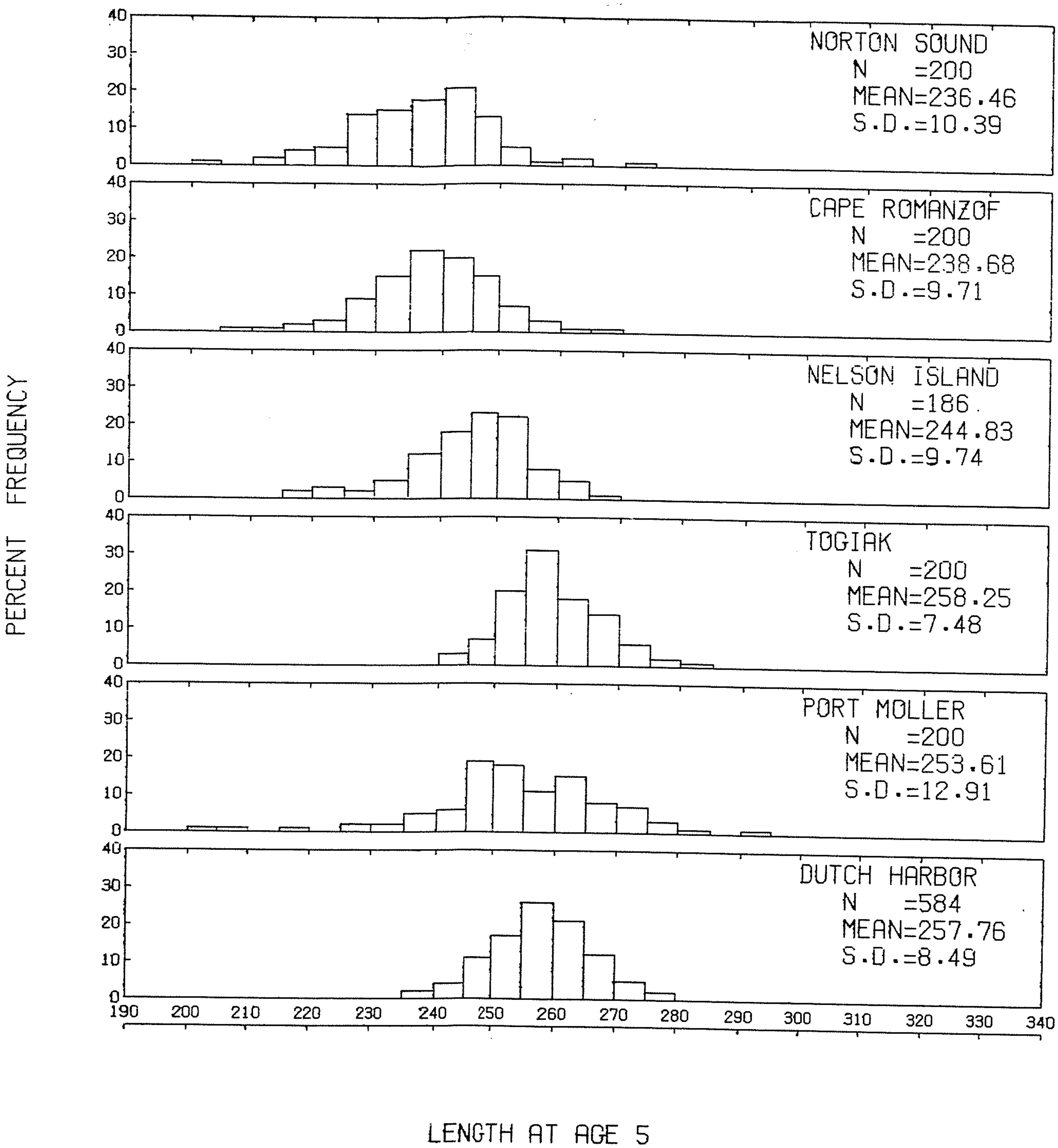
Appendix Fig. 1. Means, standard deviations (S.D.), and frequency distributions of the distance between the second and third annuli on scales of age 5 Pacific herring from the eastern Bering Sea. Measurements are 0.01 inches at 50 x.



Appendix Fig. 2. Means, standard deviations (S.D.), and frequency distributions of scale size at age 5 for age 5 Pacific herring from the eastern Bering Sea. Measurements are 0.1 inches at 50 x.



Appendix Fig. 3. Means, standard deviations (S.D.), and frequency distributions of the proportion of scale growth in the second year for age 5 Pacific herring from the eastern Bering Sea. Mean and standard deviations are proportion x 100.



Appendix Fig. 4. Means, standard deviations (S.D.), and frequency distributions of length at age 5 for age 5 Pacific herring from the eastern Bering Sea. Lengths are in millimeters.