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

by

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ABSTRACT

Scale pattern analysis was used to determine the origins (spawning stocks) of Pacific herring caught in the Domestic food and bait fishery at Dutch Harbor and incidentally in foreign trawl fisheries. Mixing proportion estimates of 1983 age 6 herring indicated that the Togiak stock was the main one present in the Dutch Harbor fishery; however, the analysis is incomplete at present. Significant estimates of the stock composition in the 1982 incidental trawl catches could not be made because length measurements were made to the nearest centimeter and scales were not collected consistently from the preferred body area. The age composition of the 1982 summer incidental catches was similar to that of the 1982 eastern Bering Sea spawning stocks, i.e., age 5 herring were dominant.

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INTRODUCTION

Coastal spawning stocks of Pacific herring (Clupea harengus pallasi) may make extensive migrations after the spring spawning season. Some Bering Sea spawning stocks overwinter near the Pribilof Islands and some may pass through the Aleutian Islands during the summer (Wespestad and Barton, 1981). The exact spawning stocks involved and their relative abundances in specific offshore wintering grounds or summer migration areas has not been determined. Stock identification is important to determine stock composition in the summer fisheries, on wintering grounds, and in the incidental catches of trawl fisheries. It is also important to determine if several stocks mingle in eastern Bering Sea coastal areas before migrating to individual spawning grounds.

Scale pattern analysis was used for the first time on Pacific herring in 1982 to determine the stock composition of fish caught in the Dutch Harbor food and bait fishery (Walker and Schnepf, 1982). The results indicated that Togiak, Nelson Island and Port Moller stocks were present in the fishery. The Togiak stock provides for the largest roe fishery in Western Alaska and the Nelson Island stock is designated for subsistence use only.

The objectives of this study are to 1) determine the separability of major spawning stocks of herring in eastern Bering Sea, north Alaska Peninsula and Aleutian areas by scale pattern characters from two or more age classes of herring, and 2) examine stock composition of herring collected from the domestic summer food and bait fishery and from offshore overwintering grounds if spawning stocks are separable.

METHODS

The main assumption in the use of scale measurements to separate stocks of herring is that fish from different areas experience different growth patterns that are reflected on their scales. Scale characters (e.g. radius measurements to annuli) from known spawning populations can then be used to classify the characters of herring from mixed stock areas or fisheries to their stock of origin.

The methods of measurement and statistical analysis follow those of our 1982 scale pattern analysis. Scale samples from the following spawning stocks were obtained from the Alaska Department of Fish and Game (ADF&G): Norton Sound, Cape Romanzof, Nelson Island, Goodnews Bay, Security Cove, Togiak, Port Moller, Canoe Bay and Dutch Harbor (Fig. 1). Scale characters developed from these samples (standards) were used to classify ADF&G scale samples from the 1983 Dutch Harbor food and bait

fishery (unknowns) to stock of origin. The Fisheries Research Institute participated in the scale collections at Togiak and the Dutch Harbor fishery.

The National Marine Fisheries Service (NMFS) provided 1,490 useable scale samples and associated length data that were collected by NMFS observers on foreign trawlers during 1982. Several scales were collected from a herring and placed in an envelope. We selected the best scale from each fish and mounted it. About 90% of the scales could be aged and we made measurements on 373 scales from age 5 herring.

All the data obtainable from the age-weight-length forms provided by ADF&G are being placed on a computer tape for future analysis of the age-length frequencies. The body location from which the scale was collected is also recorded. A summary of the 1982 and 1983 samples is given in Table 1.

Scale Collection

After the 1982 analysis, there was concern about the sampling procedure to collect a scale. Five areas on the left side of the body have been designated by ADF&G as possible sources for a scale sample. The preferred area designated by ADF&G is directly behind the opercle and below the lateral line (Fig. 2). For NMFS samples the designated preferred area is above the lateral line and below the dorsal fin. Since scales develop at different rates on different parts of the body we needed to determine the effect of body location on scale measurements. To do this we collected two scales from each of the five areas on 25 herring (10-inch bait herring from Port Orchard, Wa.). Also a preferred area scale was taken from the right side of the body to compare with one from the left side. Four scale characters were used in the statistical analysis: 1) total scale size through age 7, 2) growth ratio of years 3+4/years 1+2, 3) proportional growth of year 2/all years, and 4) back calculated length of year 2.

Construction of Standards

Age 6 herring were used in the 1983 analysis because they were the predominant age class for all stocks except Canoe Bay (Table 2). In 1982 when age 5 herring were most abundant, the Canoe Bay samples also differed from the other stocks. Standards were also constructed for 1983 age 5 herring since they were sufficiently abundant in most samples. The Norton Sound standard was constructed of samples from three subdistricts weighted according to ADF&G biomass estimates and the Togiak standard was likewise constructed from four subdistricts (Table 3).

To begin the age 6 analysis, a standard was constructed from Togiak, Security Cove and Goodnews Bay samples because these stocks were in close proximity to each other. Since the Canoe Bay sample contained an insufficient number of age 6 scales, we began the analysis with six standards. All standards contained 200 scales except Cape Romanzof (n = 177) and Nelson Island n = 131). The sampling period usually lasts several weeks during the spring spawning season, so scale standard samples were randomly chosen from the ADF&G samples to represent the entire spawning season. However, the Nelson Island sample was collected on one day, so this stock may not have been well represented.

The age 5 analysis began with standards from Norton sound (n = 200), Cape Romanzof (n = 104), Goodnews Bay and Security Cove combined equally (n = 200), Togiak (n = 200) and Port Moller (n = 148). The other stocks contained an insufficient number of age 5 scales.

Unknowns

The ADF&G sampling lasted for most of the 1983 herring fishing season at Dutch Harbor and ended only when the major companies stopped processing and the season quota was nearly met. The sampling was conducted from 20 July through 20 August and included samples from several local areas of fishing, but mainly from an area off Eider Point (Fig. 3).

The age 6 unknowns consisted of 677 scales and the age 5 unknowns of 133 scales. When the age 6 unknowns were stratified by one- or two-day time periods, it was enough to also stratify by local area; however, more desirable samples sizes were obtained by stratifying by five-day periods. The age 5 unknowns have not yet been analyzed.

Character Selection

The scale characters used for the 1983 analysis were essentially the same used for the 1982 analysis (Table 4). The scale measurements basically involved annual growth (distance between annuli), cumulative annual growth, proportional annual growth, backcalculated body lengths and ratios between annual growth increments.

The character selection method of Cook and Lord (1978), which involves a Kruskal-Wallis test, was used to determine which characters would lead to the best possible discrimination between standards. As was the case in 1982 the best characters were those of absolute scale size and backcalculated lengths. The three final characters used in the age 6 analysis were 1) scale growth in the second year, 2) scale size at age 3, and 3) backcalculated length of age 6. For the initial multi-class analysis, however, the best characters were total scale size and length at capture. The frequency distributions of these characters are shown in Figures 4 and 5.

Classification Procedures

Unknown scales were individually classified to standards with a polynomial discriminant function. The age 6 classification began as a 6-class analysis (six standards), was then reduced to a 5-class analysis and finally a 2-class analysis between Nelson Island and Togiak. The age 5 classification began as a 5-class analysis and ended as a 4-class analysis that will be used to determine classificatory accuracy and to compare with the results from the analysis of the age 6 standards.

To obtain point estimates and 90% confidence intervals for unknown samples, samples size should be at least 25, but preferably much larger. A positive estimate is any point estimate greater than zero obtained in the classification of an unknown sample to a stock. A significant estimate is a point estimate with a 90% confidence interval not including zero.

RESULTS

Comparison of Scale Types

Scale measurements were analyzed to determine whether location on the body from which a scale was collected would have an effect on scale pattern analysis. A two-way analysis of variance was calculated for each of four scale characters (Table 5). The results indicated that body area is critical for absolute scale size, which is an important character in scale pattern analysis. However, paired t-tests of measurements from preferred scales on the left and right side of the body did not detect a significant difference. Left and right-side scales were digitized (measured) the same way. The left-side scales were digitized at an upward angle and right-side scales at a downward angle (as scales occur on the fish). By turning right-side scales upside down for measurement, the mirror image phenomenon of scale growth is accounted for and differences between sides of the body are reduced. It was therefore recommended to ADF&G that when preferred scales on the left side of the body cannot be found, the right side should be examined for a preferred scale before collecting from the next body area (usually behind the pectoral fin).

1982 Incidental Catches

Age composition of herring in the 1982 incidental catches in trawl fisheries were determined by location and dates of sampling (Table 6). Herring caught north of 60°N were primarily of ages 3-5 in March and age 5 in November. Those caught in the southeastern Bering Sea were primarily ages 8 and 9 in July and then age 5 in August and September. The dominance of older herring in July was probably caused by the tendency for older herring to spawn and move offshore earlier in the spring than

for younger herring. The age 5 herring were predominant in the 1982 spawning populations.

Samples of 100 scales or more from the 1982 incidental catch samples were processed (selected, cleaned and mounted) and 373 age 5 scales were digitized. These unknowns were analyzed with the standards constructed for the 1982 scale pattern analysis. The scales could not be accurately classified because there were two major problems in the collections of unknowns: 1) fork lengths were rounded to the nearest centimeter rather than millimeter; and 2) scales were taken from all body areas, i.e., they were not consistently available from a single area.

Classification of Standards

The results of the classification of the 1983 age 6 standards are given in Table 7. The overall classificatory accuracy of the 6-class analysis was low (45.1%). The percentages of correct classifications ranged from 39.7% (Nelson Island) to 51.5% (Norton Sound). The Cape Romanzof and Norton Sound samples misclassified heavily with each other in 1982 but not in 1983. The Norton Sound standard in 1982 had a bimodal distribution for scale size and the Cape Romanzof standard, which consisted of relatively small scale sizes, overlapped with the smaller mode. A bimodal distribution was not evident in the Norton Sound samples in 1983 and the Cape Romanzof and Norton Sound samples did not misclassify very much with each other. There was a bimodal length frequency distribution for the 1983 Port Moller samples and the first mode closely matched the Cape Romanzof and Dutch Harbor length frequencies.

Apparently stocks of faster growing herring occur from Norton Sound south to a point near Port Moller, where they tend to be replaced by stocks of slower growing herring. There were three ADF&G sampling locations wihtin Port Moller and one produced mainly small age 6 herring, while the others produced quite large age 6 herring. The Port Moller standard was provisionally eliminated from the rest of the age 6 analysis until further work can be done to better define the stock. It was thus necessary to consider the possibility that some part of the final mixing proportions belong to the Port Moller stock.

An overall accuracy of 55.9% was obtained in the 5-class analysis of Norton Sound, Cape Romanzof, Nelson Island, Togiak and Dutch Harbor. The correct classifications ranged from 40.5% (Nelson Island) to 63% (Togiak) and were closer than the 6-class analysis to producing meaningful point estimates. As expected, correct classifications for Cape Romanzof and Togiak improved without Port Moller in the analysis, but Nelson Island still misclassified heavily as in the 1982 analysis. The age 6 unknowns were classified with the five standards to determine which stocks were not contributing to the Dutch Harbor fishery. Surprisingly, Norton Sound and especially Cape Romanzof stocks were well

represented; however, only 443 of the unknown scales were from the preferred body area, while 234 were from the second and third body area. When only scales from the preferred area were classified there were drastically different results. For example, 82 unknown scales were classified as Cape Romanzof (12.1%), when all unknown scales were used but the number dropped to 13 or 2.9% when only preferred scales were used.

There was little problem in obtaining preferred scales for the standards because ADF&G sampling produced large numbers of good scales. However, samples from the food and bait fishery were not so good because the herring had been pumped at least once before scales were taken.

Classification with the five standards indicated that Norton Sound, Cape Romanzof and Dutch Harbor spawning stocks were not present in significant numbers in the fishery. Positive estimates were not obtained for these stocks; therefore, a 2-class analysis was conducted for Nelson Island and Togiak and this produced correct classification percentages of 78.6% and 77.9% respectively. Security Cove and Goodnews Bay scales were not included in the final Togiak standard to reduce misclassification with Nelson Island. The estimated biomasses of these stocks were small relative to the Togiak stock (Table 3, Fig. 6).

The results of the classification of the 1983 age 5 standards are given in Table 8. The overall accuracy for the 5-class analysis was 51.8% and correct classifications ranged from 35.5% (Security Cove/Goodnews Bay) to 67.3% (Cape Romanzof). The results of the age 5 classification of standards were similar to the age 6 classification. Total scale radius and fish length were generally the best characters for separation.

The Security Cove/Goodnews Bay standard was combined with the Togiak standard for a 4-class analysis. The overall accuracy increased to 65.2% and correct classifications ranged from 50.0% (Togiak) to 75.7% (Cape Romanzof). The Togiak samples misclassified heavily with the Port Moller stock. The age 5 analysis has not been carried any further as yet.

Classification of Unknowns

Age 6 mixing proportion estimates and 90% confidence intervals were calculated for five time periods, which usually covered five days each (Table 9). Estimates for one- and two-day periods were also obtained but produced information of little use. No differences were detected between local fishing locations.

Significant estimates for Nelson Island were obtained for the first two time periods, but not the last three. Scales collected in August classified heavily as Togiak, while those collected in July did not

classify as heavily, although still greater than Nelson Island. The overall mixing proportion was 87.6% Togiak, 12.4% Nelson Island.

The 90% confidence intervals were extremely wide and overlapped for the first time period, but the sample size was only 25. The small sample size was caused by a low proportion of preferred scales taken during this time. Confidence intervals were approximately half as wide for the remaining time periods, with no overlaps.

DISCUSSION

Mixing proportion estimates of age 6 herring indicated that Togiak was the major stock present in the Dutch Harbor food and bait fishery. However, the anlaysis is incomplete until the Port Moller standard is reconstructed with the smaller fish separate from the larger fish. The Port Moller standard last year consisted of generally larger fish. Until further analysis is completed, it should be assumed that Port Moller fish are present in the fishery to some degree, based on the work performed in 1982, and have most likely been classified as Togiak fish.

The classification of unknown individuals to the Nelson Island standard has been perplexing. In 1982 the Nelson Island estimates were high in relation to the estimated biomass of the stock. It seemed strange that a stock farther north than Togiak and very much smaller would classify consistently as high as it did. Nelson Island estimates were still large enough to cause concern in the 1983 analysis, but as in 1982 the estimates decreased over time.

There is some question whether some stocks not included in our standards are contributing significantly to the Dutch Harbor fishery. A spawning stock from Dutch Harbor itself showed nothing in the analysis, but there may be other stocks in the Aleutian Islands that need to be included in our standards.

Prior to our final report (March 1984) we will complete the analysis of the 1983 age 5 samples and a 1983 analysis with two standards constructed from Port Moller samples. We will also conduct linear analyses to examine within and between stock variability in the important stock separation characters and then attempt stock separation based on linear differences. In addition we plan to process the scales from the 1983 incidental catches to at least estimate the age compositions in the catches if stock separation is not practical.

The following are recommendations for future work:

1) Development of linear functions to examine standards.

2) Collection of quality unknown origin scales from areas other than Dutch Harbor and the classification of these by the spawning stock standards.

3) Surveys of the Aleutian Islands for spawning stocks and collection of samples from the larger spawning stocks.

4) Increased sampling at Nelson Island.

5) Collection of unknown origin scales from wintering grounds to determine the degree of mixing.

No samples from wintering grounds have been collected as yet. If samples were available we should be able to determine from age composition and scale patterns whether herring stocks are homogeneous or tend to be segregated on the wintering grounds. This information would be important to management of any future winter fisheries.

REFERENCES

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

Fried, S. M. and D. C. Whitmore. Pacific herring stocks and fisheries in the eastern Bering Sea: Preliminary Report for 1983. Alaska Dept. Fish and Game Report to NPFMC (processed).

Walker, R. V. and K. N. Schnepf. 1982. Scale pattern analysis to estimate the origin of herring in the Dutch Harbor fishery. Fish. Res. Inst., Univ. of Washington. 21 p. (processed).

Wepestad, V. G. and L. H. Barton. 1981. Distribution, migration, and status of Pacific herring. In D. W. Hood and J. Calder [eds,]. The eastern Bering Sea shelf: Oceanography and resources. Vol. 1. p. 509-525. U. S. Gov. Print Off., Washington, D.C.

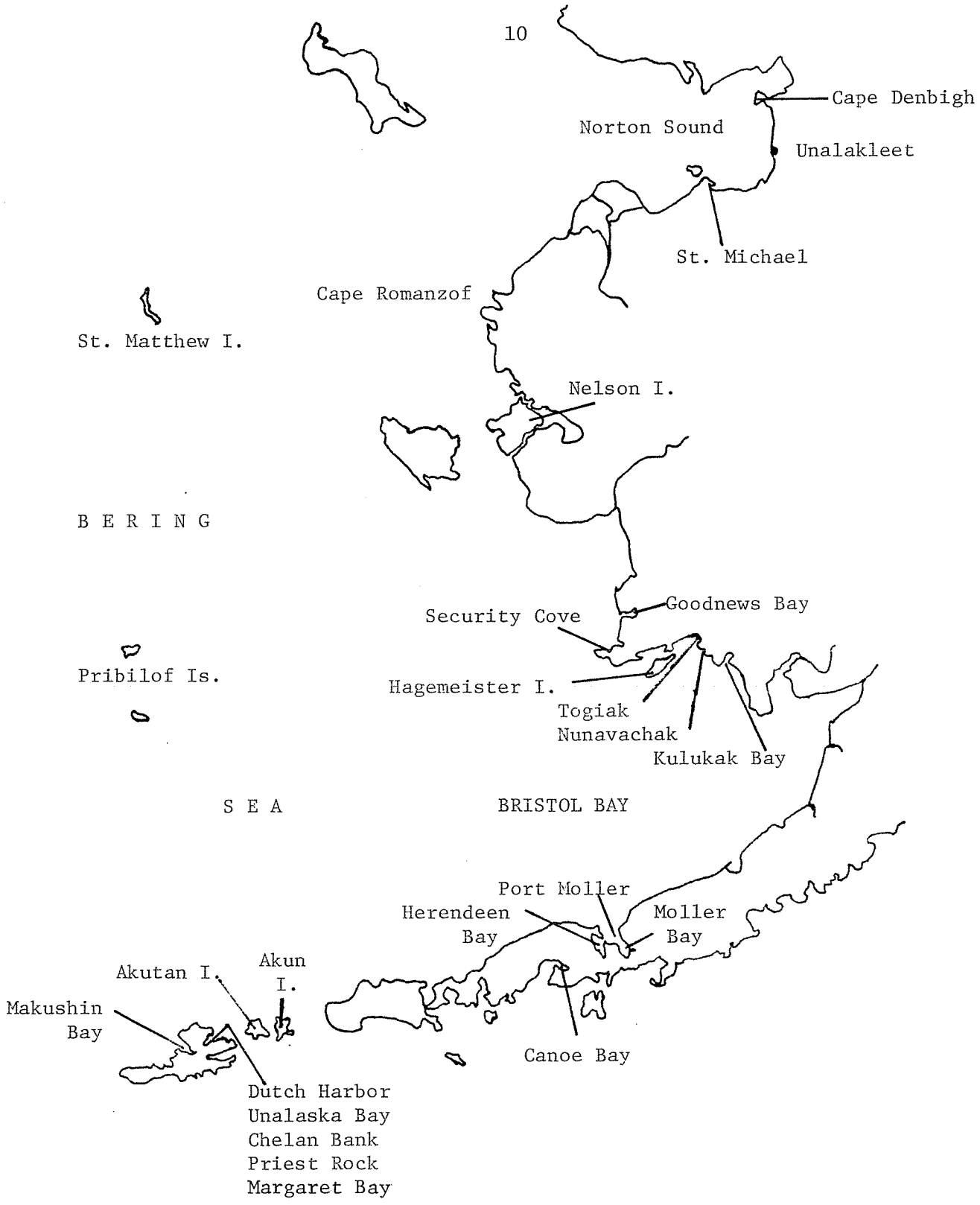
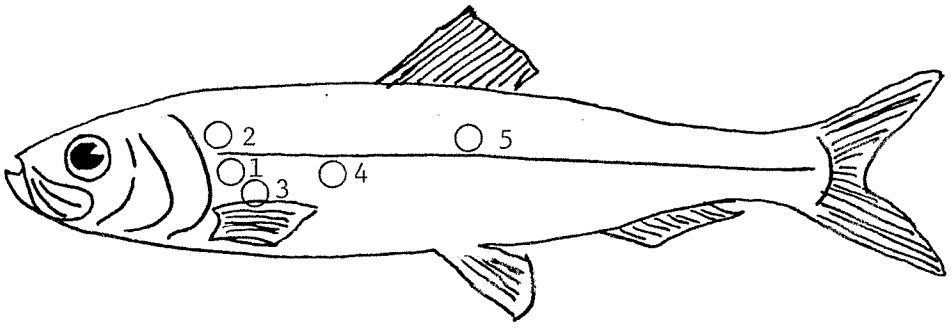
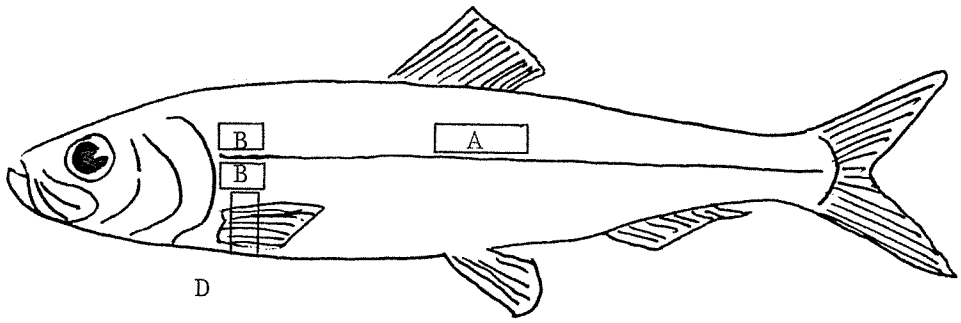


Fig. 1. Eastern Bering Sea study area.



ADF&G--Zone 1 is preferred



NMFS--Zone A is preferred

Fig. 2. Body zones for herring scale sampling by Alaska Department of Fish and Game (top) and National Marine Fisheries Service (bottom).

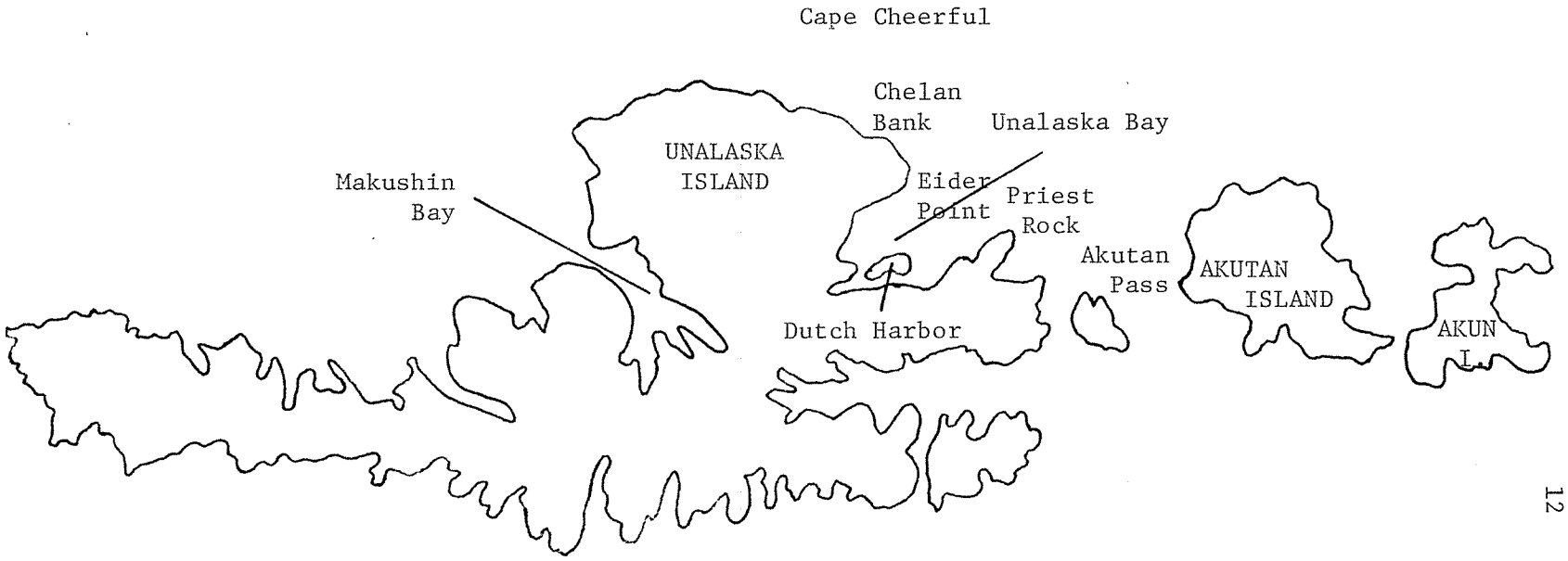


Fig. 3. Fishing locations of the Dutch Harbor herring food and bait fisheries in 1982 and 1983.

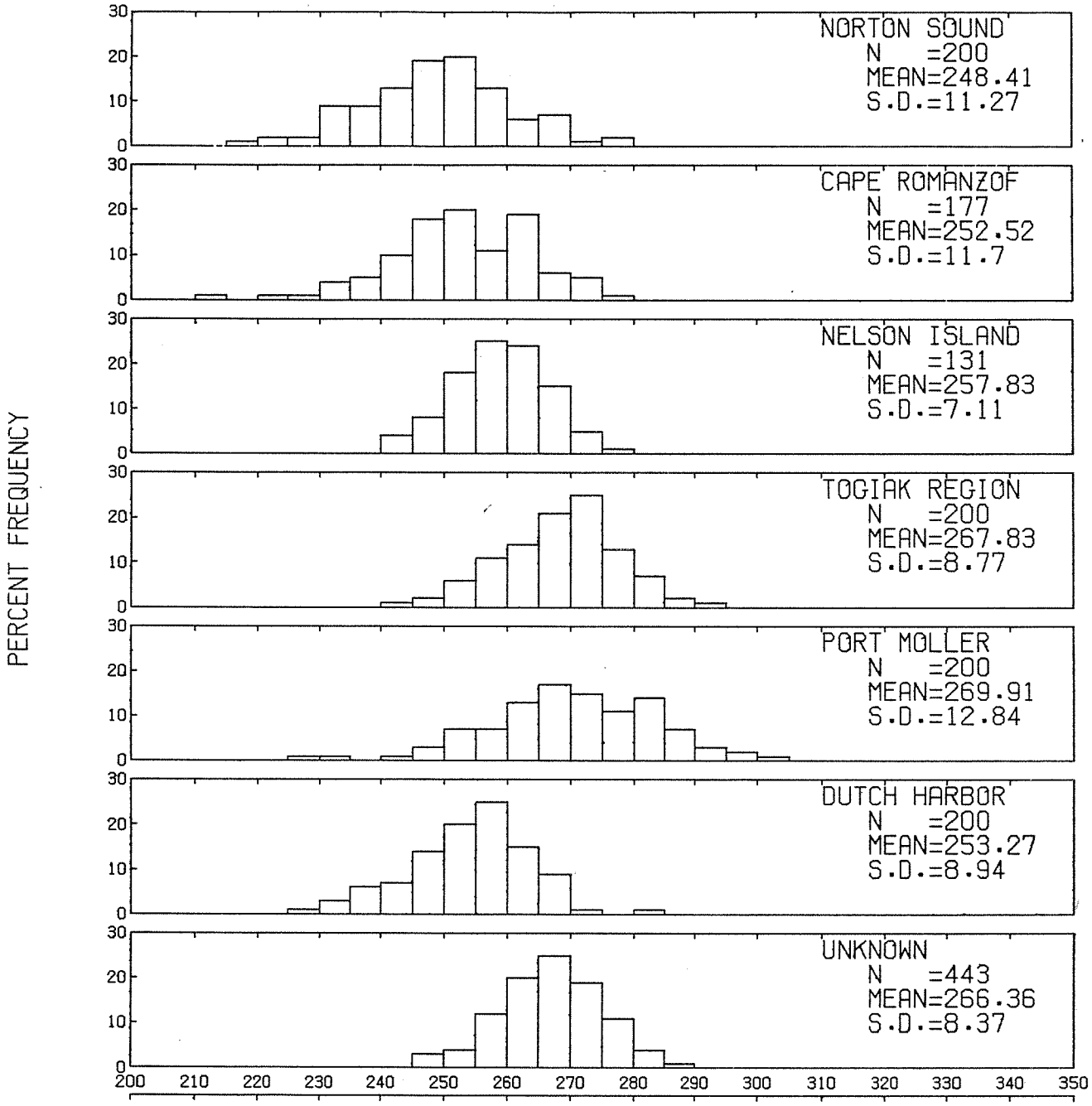


Fig. 4. Frequency distributions of standard body length at age 6 for age 6 herring. The unknown group is from the Dutch Harbor fishery, with lengths back-calculated to time of spawning. (Lengths in mm.)

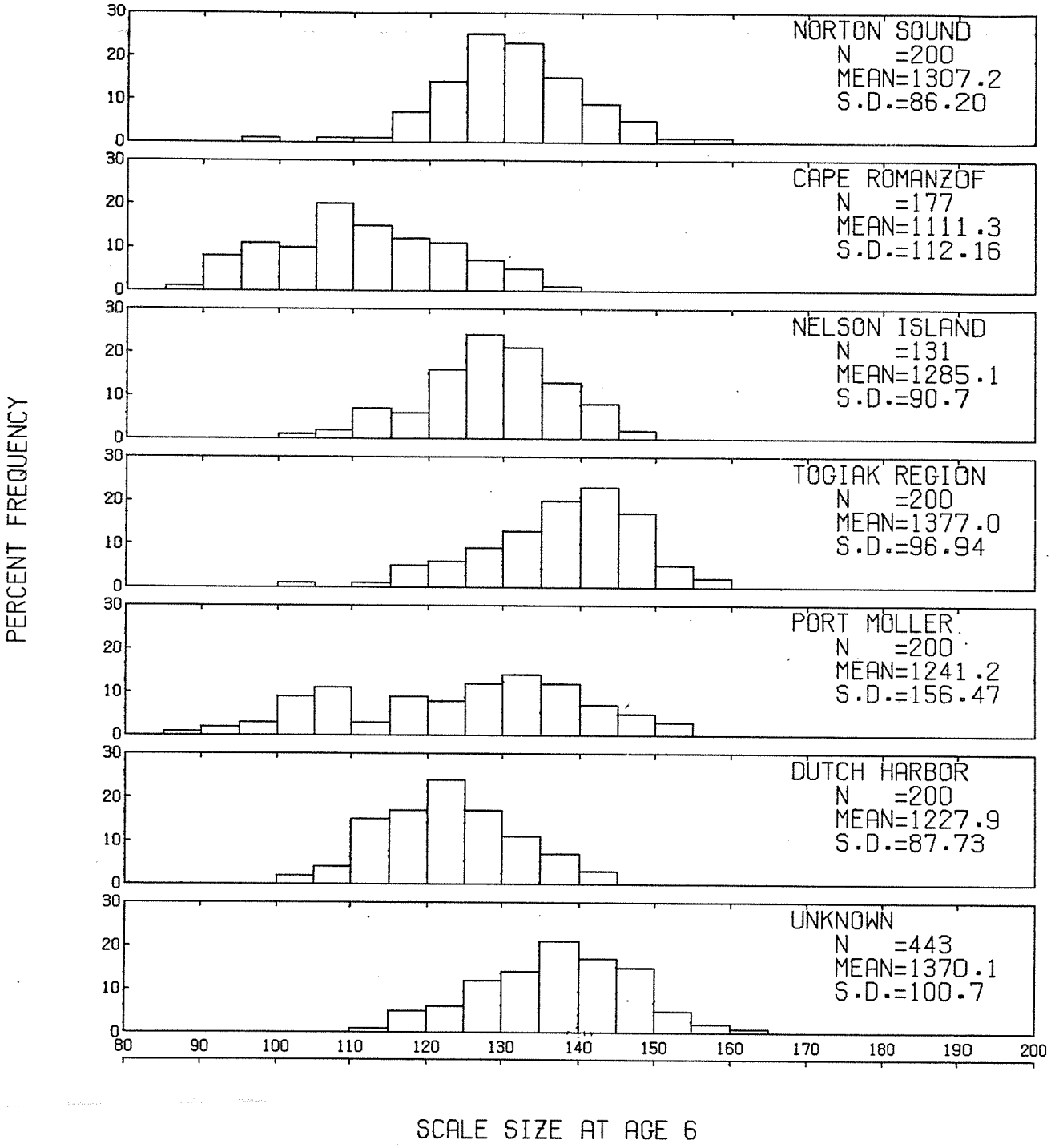


Fig. 5. Frequency distributions of scale size at age 6 for age 6 herring. The unknown group is from the Dutch Harbor fishery. Measurements are 0.1 inches at 50X.

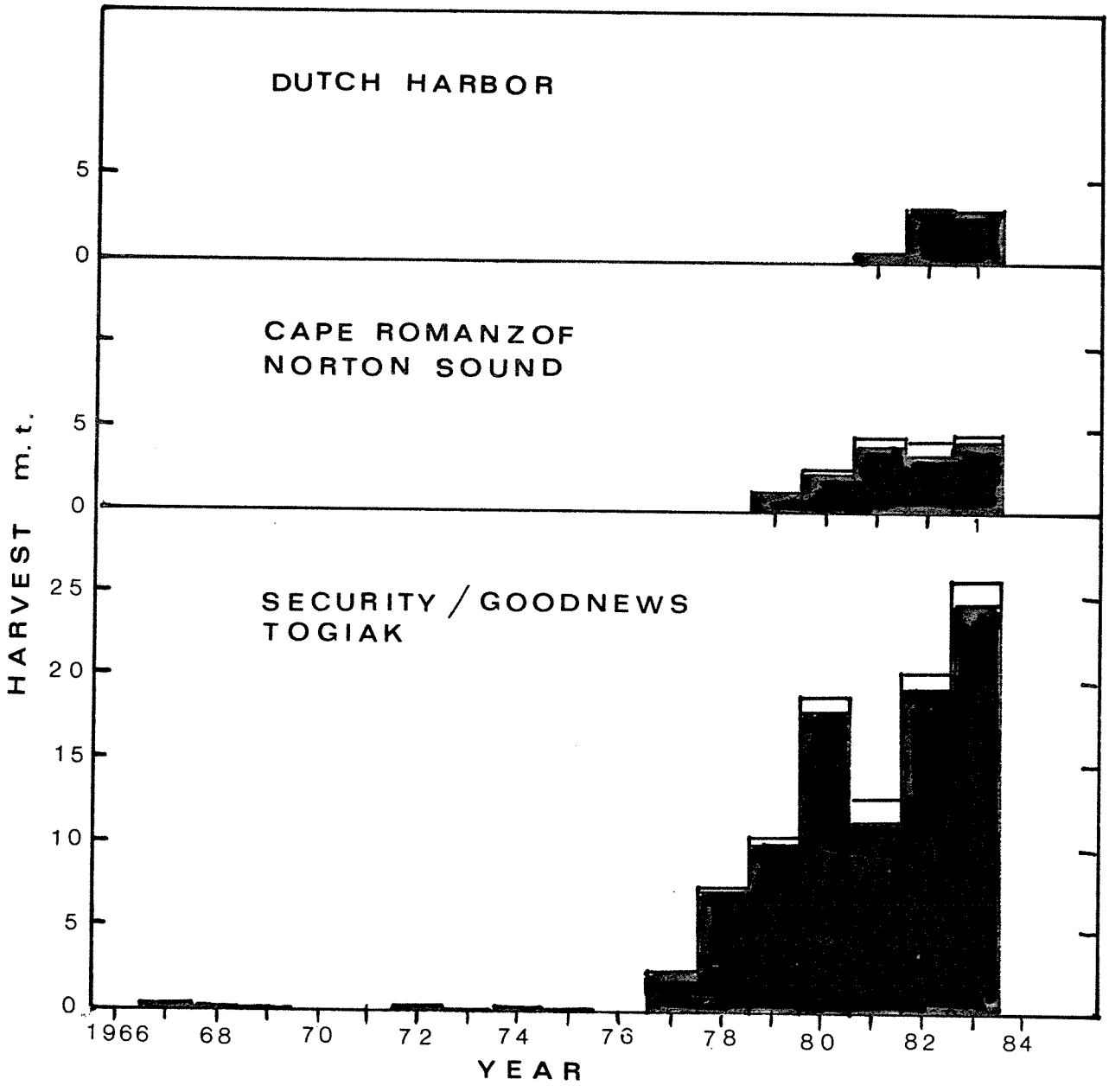


Fig. 6. Annual harvests of Pacific herring in U.S. fisheries in the Bering Sea, 1966-1983.

Table 1. Sample sizes for Pacific herring data from (1) known-origin spawning stocks and (2) unknown mixed-stock fisheries.

Location	Year	No. Lengthed	No. Aged	Digitized Age 5	Digitized Age 6
(1) Bering Sea					
Norton Sound					
Cape Denbigh	82	553	464	69	0
	83	911	847	120	120
Unalakleet	82	257	219	15	0
	83	713	665	59	60
Saint Michael	82	896	836	116	0
	83	990	937	19	19
Cape Romanzof	82	1,388	1,228	201	0
	83	976	800	105	177
Nelson Island	82	436	393	184	0
	83	260	223	0	131
Security Cove	82	723	676	99	0
	83	854	694	90	100
Goodnews Bay	82	602	546	99	0
	83	1,179	989	99	99
Togiak					
Hagemeister	82	350	290	37	0
	83	886	852	21	20
Togiak	82	580	500	72	0
	83	872	785	101	100
Nunavachak	82	630	547	40	0
	83	515	434	20	20
Kulukak	82	920	894	51	0
	83	897	839	60	60
Alaska Peninsula					
Port Moller					
Moller Bay	82	292	292	70	0
	83	187	158	25	35
Port Moller	82	65	53	10	0
	83	179	155	25	5

Table 1, cont'd

Location	Year	No. Lengthed	No. Aged	Digitized Age 5	Digitized Age 6
Herendeen Bay	82	660	514	120	0
	83	1,346	1,133	98	160
Canoe Bay	82	806	714	28	0
	83	847	798	0	0
Aleutian Islands					
Margaret Bay	82	--	--	--	--
	83	824	728	0	200
(2) Aleutian Islands					
Akun	82	70	56	4	0
	83	--	--	--	--
Akutan	82	120	99	42	0
	83	80	79	6	31
Unalaska Bay	82	987	880	286	0
	83	1,164	1,049	97	457
Chelan Bank	82	452	419	147	0
	83	265	245	17	113
Makushin Bay	82	291	289	105	0
	83	--	--	--	--
Priest Rock	82	--	--	--	--
	83	164	162	12	75
Incidental Catch	82	1,490	1,343	373	0
	83	--	--	--	--

Table 2. Age composition of spawning stocks and Dutch Harbor fishery samples of Pacific herring in 1983.

Location	Dates	Age composition (percent) 2	3	4	5	6	7	8	9+	10+	n
Spawning stocks											
Bering Sea[a]											
Norton Sound	5/14-6/18	--	--	13.7	25.3	45.5	10.4	0.9	4.2		--
Cape Romanzof	5/13-5/30	--	0.3	14.4	22.8	43.1	6.9	2.1	10.4		--
Nelson Island	5/14	--	--	--	9.0	77.4	7.5	2.2	3.9		--
Security Cove	5/2-5/25	--	0.2	8.9	26.2	46.7	6.9	3.6	7.5		--
Goodnews Bay	5/5-6/2	--	Trace	14.1	26.5	47.0	4.7	0.6	7.1		--
Togiak	4/26-5/26	--	Trace	3.9	32.9	47.0	1.9	2.6	11.7		--
Alaska Peninsula[b]											
Canoe Bay	5/30-6/10	0	49.5	11.3	20.8	3.3	9.0	1.6	1.6	2.9	797
Port Moller	5/8-5/31	0.2	0.6	3.8	27.9	58.9	5.0	1.3	1.5	0.8	1,447
Aleutian[b]											
Dutch Harbor	4/15-6/10	2.6	6.6	3.7	1.4	69.7	12.5	2.7	0.3	0.5	729
Dutch Harbor fishery											
Aleutian[b]											
Dutch Harbor	7/20-8/20	0	0	0.7	18.8	69.1	5.1	1.2	4.3	0.8	1,537

[a]Age composition acquired through personal communication with Stephen M. Fried, Alaska Department of Fish and Game, 16 November 1983. Sample sizes unknown.

[b]Age composition determined by FRI counts of readable scales.

Table 3. The construction of spawning stock standards used to determine the origin of Pacific herring from the Dutch Harbor food and bait fishery in 1983.

Stock (District or area)	Subdistrict or section	Estimated biomass[a]	% of District biomass[b]	No. of Scales measured		Scales used in combined standards	
				Age 6	Age 5	Age 6	Age 5
Norton Sound	St. Michael		10	20	20		
	Unalakleet		30	60	60		
	Cape Denbigh		60	120	120		
Total		25,500	100	200	200		
Cape Romanzof		5,000		177	104		
Nelson Island		13,500		131	0		
Goodnews Bay		2,900		100	100	4[c]	5[d]
Security Cove		5,800		100	100	9[c]	9[d]
Togiak	Hagemeister		10	19	20	17	20
	Togiak		50	100	100	94	95
	Nunavachak		10	20	20	18	16
	Kululak		30	60	60	58	55
Total		127,000	100	199	200	187[c]	186[d]
Port Moller				200	148		
Canoe Bay				0	0		
Dutch Harbor				200	0		

[a]Aerial survey biomass estimates (Fried and Whitmore 1983).

[b]Biomass distribution on date of peak survey (personal communication, Stephen M. Fried, Alaska Department of Fish and Game, 2 September 1983).

[c]Combined Togiak, Security Cove, Goodnews Bay standard used in the age 6 six- and five-class analysis.

[d]Combined Togiak, Security Cove, Goodnews Bay standard used in the age 5 four-class analysis.

Table 4. Scale characters examined for use in the discriminant function analyses of 1983 age 6 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 between fifth and sixth annuli.
7	Distance from focus to second annulus (char 1+2).
8	Distance from focus to third annulus (char 7+3).
9	Distance from focus to fourth annulus (char 8+4).
10	Distance from focus to fifth annulus (char 9+5).
11*	Distance from focus to sixth annulus (char 10+6).
12	Proportion of scale growth in first year (char 1/11).
13	Proportion of scale growth in second year (char 2/11).
14	Proportion of scale growth in third year (char 3/11).
15	Proportion of scale growth in fourth year (char 4/11).
16	Proportion of scale growth in fifth year (char 5/11).
17	Proportion of scale growth in sixth year (char 6/11).
18	Back-calculated length at age 1 (char 1/11 x length at capture).
19	Back-calculated length at age 2 (char 7/11 x length at capture).
20	Back-calculated length at age 3 (char 8/11 x length at capture).
21	Back-calculated length at age 4 (char 9/11 x length at capture).
22	Back-calculated length at age 5 (char 10/11 x length at capture).
23	Length at age 6 (length at capture).
24	Proportion of scale growth in first two years (char 7/11).
25	Proportion of scale growth in first three years (char 8/11).
26	Proportion of scale growth in first four years (char 9/11).
27	Ratio of growth in sixth year to growth in first year (char 6/1).
28	Ratio of growth in third year to growth in second year (char 3/2).
29	Ratio of growth in sixth year to growth in fifth year (char 6/5).
30	Ratio of growth in fourth and fifth years to growth in first two years (char 4+5/7).

*Total scale size for all spawning samples.

Table 5. Two-way analysis of variance and paired t-test results for four scale characters, tested for variance in scale growth among body areas of Pacific herring.

Two-way analysis of variance (model III) results; 25 fish, 5 body areas on each, 2 scales within each area.

Scale character	F statistic obtained		
	Body area effect	Fish effect	Interaction effect
(1) Total scale size (through 7 years)	32.68**	11.95***	1.76
(2) Growth ratio (years 3+4/years 1+2)	2.25	84.48***	1.46
(3) Proportional growth (year 2/all years)	0	136.50***	2.30
(4) Back-calculated length (years 1+2/all x length)	4.03	146.93***	1.42

Paired t-test results; comparing growth of preferred scales taken from either side of the body (n=25).

Scale character	t statistic
(1)	1.68
(2)	1.08
(3)	0.93
(4)	1.86

**Significant at $\alpha = 0.01$.

***Significant at $\alpha = 0.001$.

Table 6. Age composition of the incidental catch of Pacific herring in 1982.

Approximate location	Dates	Age composition (percent) 2	3	4	5	6	7	8	9	10+	n
60°14' - 178°47'W	3/7-3/15	0	32.6	38.1	26.6	1.4	0.9	0.4	0	0	218
54°37' - 165°23'W	7/6-7/16	0	0	0	8.0	10.7	7.2	38.4	21.4	14.3	112
55°22' - 165°73'W	8/5-8/9	0	0	6.4	41.0	12.8	3.2	18.0	7.7	10.9	156
56°34' - 164°29'W	8/1-8/19	0	0.8	24.8	44.8	9.6	2.4	8.0	3.2	6.4	125
55°04' - 165°47'W	8/8-8/24	0	0	7.8	46.1	8.7	2.5	18.1	9.8	7.0	358
55°13' - 166°13'W	9/9-9/28	0	0	15.6	64.4	6.2	1.2	10.0	1.3	1.3	160
55°85' - 166°38'W	9/14-9/26	0	3.5	9.2	56.3	5.7	2.3	11.5	8.0	3.5	87
60°27' - 178°35'W	11/29	0	0	11.0	67.7	14.2	0.8	5.5	0.8	0	127

Table 7. Decision arrays for 1983 age 6 herring of the eastern Bering Sea for (a) 6-class, (b) 5-class, and (c) 2-class analyses. The overall classificatory accuracies were calculated as the unweighted means of accuracies on the diagonals of the decision arrays.

(a) 6-class: Norton Sound vs. Cape Romanzof vs. Nelson Island vs. Togiak/Security Cove/Goodnews Bay vs. Port Moller vs. Dutch Harbor — Overall accuracy: 45.1%

Calculated decision	Correct decision (%)					
	Norton Sound	Cape Romanzof	Nelson Island	Togiak/SC/GB	Port Moller	Dutch Harbor
Norton Sound	103 (51.5)	16	21	20	8	17
Cape Romanzof	11	81 (45.8)	13	5	36	37
Nelson Island	33	12	52 (39.7)	34	14	29
Togiak/SC/GB	29	1	20	95 (47.5)	34	10
Port Moller	6	34	8	39	95 (47.5)	10
Dutch Harbor	18	33	17	7	13	97 (48.5)
Total	200	177	131	200	200	200

(b) 5-class: Norton Sound vs. Cape Romanzof vs. Nelson Island vs. Togiak/Security Cove/Goodnews Bay vs. Dutch Harbor — Overall accuracy: 55.9%

Calculated decision	Correct decision (%)				
	Norton Sound	Cape Romanzof	Nelson Island	Togiak/SC/GB	Dutch Harbor
Norton Sound	118 (59.0)	20	22	16	10
Cape Romanzof	9	109 (61.6)	17	8	33
Nelson Island	31	12	53 (40.5)	39	37
Togiak/SC/GB	24	5	22	126 (63.0)	9
Dutch Harbor	18	31	17	11	111 (55.5)
Total	200	177	131	200	200

(c) 2-class: Nelson Island vs. Togiak — Overall accuracy: 78.3%

Calculated decision	Correct decision (%)	
	Nelson Island	Togiak
Nelson Island	103 (78.6)	44
Togiak	28	155 (77.9)
Total	131	199

Table 8. Decision arrays for 1983 age-5 herring of the eastern Bering Sea for (a) 5-class and (b) 4-class analyses. 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. Security Cove/Goodnews Bay vs. Togiak vs. Port Moller — Overall accuracy: 51.8%

Calculated decision	Correct decision (%)				
	Norton Sound	Cape Romanzof	SC/GB	Togiak	Port Moller
Norton Sound	117 (58.5)	12	33	25	2
Cape Romanzof	9	70 (67.3)	34	1	15
SC/GB	39	17	71 (35.5)	38	14
Togiak	34	1	42	79 (39.5)	31
Port Moller	1	4	20	57	86 (58.1)
Total	200	104	200	200	148

(b) 4-class: Norton Sound vs. Cape Romanzof vs. Togiak/Security Cove/Goodnews Bay vs. Port Moller — Overall accuracy: 65.2%

Calculated decision	Correct decision (%)			
	Norton Sound	Cape Romanzof	Togiak/SC/GB	Port Moller
Norton Sound	140 (70.0)	14	30	3
Cape Romanzof	12	78 (75.7)	13	18
Togiak/SC/GB	47	5	100 (50.0)	31
Port Moller	1	7	57	96 (64.9)
Total	200	104	200	148

Table 9. Estimates of the mixing proportions of age 6 eastern Bering Sea herring in the 1983 Dutch Harbor food and bait fishery. (Mixing proportion estimates (%) within 90% confidence intervals.)

Time period	Sample size	Nelson Island	Togiak
7/20-25	25	38.7 (9.1-68.3)	61.3 (31.7-90.8)
7/26-30	86	32.9 (16.1-49.6)	67.1 (50.4-83.9)
8/1-5	99	5.6 (0-20.6)	94.4 (79.4-100)
8/8-12	129	2.0 (0-15.7)	98.0 (84.3-100)
8/16-20	104	8.5 (0-23.3)	91.5 (76.6-100)
7/20-8/20	443	12.4 (2.6-22.2)	87.6 (77.8-97.4)