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Alaska Department of Fish and Game
Commercial Fisheries Management
and Development Division
P.O. Box 25526
Juneau, Alaska 99802-5526

December 1994

Abundance, Age, Sex, and Size Statistics for Pacific Herring in Lower Cook Inlet, 1993

by

Henry J. Yuen

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The Technical Fishery Report Series was established in 1987, replacing the Technical Data Report Series. The scope of this new series has been broadened to include reports that may contain data analysis, although data oriented reports lacking substantial analysis will continue to be included. The new series maintains an emphasis on timely reporting of recently gathered information, and this may sometimes require use of data subject to minor future adjustments. Reports published in this series are generally interim, annual, or iterative rather than final reports summarizing a completed study or project. They are technically oriented and intended for use primarily by fishery professionals and technically oriented fishing industry representatives. Publications in this series have received several editorial reviews and at least one *blind* peer review refereed by the division's editor and have been determined to be consistent with the division's publication policies and standards.

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ABSTRACT

The 1993 run biomass of Pacific herring *Clupea pallasi* in the Kamishak Bay District of the Lower Cook Inlet Management Area in Alaska was estimated to be 29,428.5 tonnes (32,439.0 tons) by dividing daily aerial survey estimates of biomass by daily expected proportion of run biomass. There were 12 consecutive days when aerial surveys could not be flown between 28 April and 9 May because of poor weather or turbid water. Herring were observed as late as 3 June. The district was opened to commercial purse seining on 21 April 1993 when 3,238.7 tonnes (3,570.0 tons) of sac roe herring were harvested. The spawning migration was sampled for sex, age, weight, and length before the fishery on 19 and 20 April and during the fishery on 21 April. No samples were collected after the fishery from the late season spawning migration. Age-5 herring from the 1988 year class were the largest component, 57.7%, of the catch. The next largest group, at 13.5%, was age-6 herring from the 1987 year class, followed by age-9 herring from the 1984 year class at 10.9%. Males represented 52.3% of the catch samples. Mean weight and length of both sexes combined were 185 g and 248 mm. The 1993 run biomass in the Southern District was estimated to be 445.7 tonnes (491.3 tons). This district was not opened to commercial fishing, so age-composition samples were not collected.

KEY WORDS: Abundance, age, *Clupea pallasi*, harvest, length, Lower Cook Inlet, Pacific herring, run biomass, sex, weight

INTRODUCTION

This report presents abundance and age composition data from samples collected during the 1993 herring spawning migration in Kamishak Bay. Kamishak Bay is in the southwestern corner of the Lower Cook Inlet Management Area. Herring that spawn in Kamishak Bay also migrate into Shelikof Strait during winter (Johnson et al 1988). Shelikof Strait is part of the adjacent Kodiak Management Area (Figure 1). In 1992 the Alaska Board of Fisheries adopted a management plan for the Kamishak herring stocks to limit the spring sac roe fishery in Kamishak Bay to 18% and the fall food/bait fishery in Shelikof Strait to 2% of the preseason forecast.

Preseason run biomass forecasts are based on a mean natural mortality rate and prior year's escapement abundance estimate (e.g., Yuen and Bucher 1993). Lower Cook Inlet area management biologists estimate both escapement and total run abundance directly from aerial surveys flown each year during the spring spawning migration in Kamishak Bay. Natural mortality, M, however, is calculated from the log-ratio of abundance, N, between successive age groups from the same year class:

$$M = \ln\left(\frac{N_{total\,run,\,i+1}}{N_{escapement,\,i}}\right), \qquad (1)$$

where i = age. This report also presents sex-composition data from Kamishak Bay that is not required by the forecast at this time.

The present-day commercial purse seine sac roe fishery in Kamishak Bay began in 1973. Entry into this fishery was limited in 1978, when 75 permits were issued (Schroeder 1989). This fishery was closed between 1980 and 1985 because of low population abundances. The Shelikof Strait food/bait fisheries began in the early 1920s as a late summer and fall reduction fishery producing fish meal and some salted food and bait products (Johnson et al. 1988). Presently, the Shelikof Strait fishery is primarily a fall and winter bait fishery producing frozen bait for the local longline and crab fleets.

This report also presents run biomass estimates for the Southern District. Commercial fishing for herring in this district began in 1914. Gillnets were used until purse seines were introduced in 1923. During its peak between 1924 and 1926, this fishery supported eight salteries before collapsing. The Southern District was reopened in 1969 for a new commercial fishery for sac roe herring but this fishery also collapsed in 1980. The Southern District was reopened for the sac roe fishery only during 1989.

The Alaska Department of Fish and Game (ADF&G) began documenting Lower Cook Inlet herring catches in 1961. Catch sampling for age, sex, weight, and length (AWL) data began in 1971. Run biomass assessment began in 1978 with a program of aerial surveys and test fishing for age composition. Annual summaries of catch and run biomass can be found in Lower Cook Inlet annual management reports (e.g., Bucher and Hammarstrom 1993). The 1971–1987 AWL data were summarized by Schroeder (1989). Sampling data after 1987 has been annually reported by Yuen et al. (1989, 1990, 1991).

METHODS

Biomass Estimates

Run biomass in this report refers to the spawning segment of the herring population estimated on the fishing grounds between mid April and June. These herring are considered recruited into the spawning population and available to the sac roe fishing fleet, although harvest limits are typically achieved by mid May. *Escapement biomass*, or the portion of the run biomass that spawned, was obtained by subtracting harvest from run biomass. Harvest was obtained directly from harvest receipts, or *fish tickets*, which document each sale by a licensed fisher.

Aerial surveyors fly a single-engine, fixed-wing aircraft as close to an altitude of 457 m (1,500 ft) as possible. Although they fly at various tidal stages, surveyors report the best water clarity and visibility of herring schools during the 3- to 4-h period following low slack tide. Numbers and distribution of herring schools, location and extent of milt, and visibility factors affecting survey conditions were recorded on index maps for each survey. Standard conversion factors were used to convert herring-school surface area to biomass: 1.38 tonnes/7 m^2 (1.52 tons/538 ft^2) for water depths < 4.9 m (16 ft), 2.33 tonnes/7 m^2 (2.56 tons/538 ft^2) for depths between 4.9 m and 7.9 m (16 and 26 ft), and 2.57 tonnes/7 m^2 (2.83 tons/538 ft^2) for depths > 7.9 m (26 ft). Aerial survey estimates were not calibrated in 1993.

Aerial surveyors have two methods of deriving a run biomass estimate from daily biomass estimates depending on herring schooling behavior. If herring appeared to be moving in all areas and periods, then each day's observed biomass was treated as new fish. If more than one survey was flown per day, the larger survey was used as the biomass estimate. If herring appeared to remain in a given area over several days, then only peak surveys were accumulated to obtain run biomass. In 1993, however, inclement weather obscured visibility for surveyors in the Kamishak Bay District, and the run biomass was estimated instead from an expansion of the limited aerial surveys that were flown (Yuen *in press a*). Yuen's method divides daily aerial survey estimate of biomass, b_d, by proportion of run biomass, p_d, expected on date d to obtain a daily estimate of run biomass B_d:

$$B_d = \frac{b_d}{\overline{p}_d}. \tag{2}$$

The mean of all daily estimates was the 1993 run biomass estimate:

$$\overline{B}_{1993} = \frac{\sum_{d=1}^{D} \frac{b_d}{\overline{p}_d}}{D}, \tag{3}$$

where D = number of days when aerial surveyors observe herring and p is greater than zero (Yuen *in press a*).

Age, Weight, Length, and Sex Compositions

Source of Samples

There were two sampling strata in Kamishak Bay during 1993: before and during the fishery. Samples were obtained before the fishery from commercial purse seiners who agreed to fish at a specified time and area as directed by ADF&G. Commercial catch samples were obtained immediately after the fishery from haphazardly selected fishing vessels. Fishing was limited to the area around McNeil River and Nordyke Island so there were neither temporal nor geographical distances between sampled vessels in 1993. Samples were dipnetted from the pursed seines of fishing vessels waiting for a tender to pump their fish out of their nets.

The samples were packaged in 15-kg (33-lb) boxes and flown to Homer for processing. If there were more fish than was required for a sampling stratum, each 15-kg box was subsampled by dumping the same proportion from all of the 15-kg boxes into a sink and processing every fish in the sink. This was repeated as necessary.

Sample Sizes

Sample sizes, n, were set for the catch samples such that all of the estimated age class (i) proportions, p_i, from a multinomial distribution of k age groups were simultaneously within a specified distance, d, of their true population age proportions, π_i, 95% of the time (1 - α). That is,

$$P\left\{\bigcap_{i=1}^{k}\left|p_i-\pi_i\right|\le d\right\}\ge 1-\alpha\,, \tag{4}$$

where d and α, the confidence level, were chosen to be 0.05 and P was the probability of the hypothesis. Thompson (1987) calculated a maximum sample size of 510 for a worst-case scenario when three age classes were present in equal numbers and $d = \alpha = 0.05$. Any deviation in the number of age classes or unequal contributions by age class would result in a smaller sample size needed to achieve the same level of precision.

Samples were processed immediately to produce a timely age-composition summary for fishery managers. Although the number of fish collected was 510 plus a 30% allowance for unageable scales, not all of the collection was sampled. Instead, the minimum sample size was equal to the value of n that satisfied

$$\sum_{i=3}^{16} 2\left[1-\Phi\left(\frac{d\sqrt{n}}{\sqrt{(p_i(1-p_i))}}\right)\right]<0.05\,, \tag{5}$$

where p_i was the *a priori* age proportions obtained when about two-thirds of the collection (300 fish) was aged and the function Φ was the area under the standard normal distribution. After the ages of n fish were obtained, equation (2) was recalculated. If the *a priori* estimate of sample size was found to be insufficient, additional fish were processed.

Sex, Length, and Age Determination

Sex was determined from inspection of gonads or sex products. Fish were measured to the nearest millimeter from the tip of the snout to the end of the hyperal plate and weighed to the nearest gram. Estimates of standard error for lengths and weights by age class were derived according to the procedures for stratified random sampling described by Snedecor and Cochran (1967); i.e.,

$$SE = \sqrt{\sum \left(\frac{C_h}{C}\right)^2 \left(\frac{s_h^2}{n_h}\right)}, \qquad (6)$$

where C = the herring catch, h = stratum or sample, s_h^2 = sample variance, and n_h = sample size.

The scales of up to 20 fish were mounted on a glass slide. One scale was removed, preferably from the left side of the herring above the pectoral fin, 3 or 4 scales posterior of the operculum. If scales above the pectoral fin were not present on the left side, they were collected from the same area on the right side of the fish. If that was not possible, then the specimen was not used in the sample. The scales were cleaned, dipped in a 10% mucilage solution, and positioned unsculptured-side down on a labeled glass slide. Scale images were magnified 29x by a microfiche reader and the number of annuli per scale were counted to determine age.

Combining Samples with Similar Age Compositions

Chi-square test of independence (Snedecor and Cochran 1967) were used to determine if pairs of samples had similar age compositions. Samples with similar age compositions were combined.

RESULTS

Kamishak Bay District

A total of 10 successful aerial surveys were flown between 18 April and 3 June in the Kamishak Bay District (Table 1 and Figure 2). There were 12 consecutive days when aerial surveys could not be flown between 28 April and 9 May because of poor weather or turbid water. As in other years, Kamishak Bay District herring appeared earlier in the south (Bruin Bay, Amakdedori, Chenik, and Nordyke) than in the north (Oil Bay).

Herring appeared to be moving in all areas and periods. The sum of all surveys, however, was only 4,461.2 tonnes (4,917.6 tons; Table 1) because of 12 d of missing data during late April and early May when bad weather or turbid water precluded aerial surveys. Therefore, equations (2) and (3) were used to calculate a run biomass estimate of 29,428.5 tonnes (32,439.0 tons; Table 2). The preseason harvest projection was 2,351.5 tonnes (2,592.0 tons; Funk and Harris 1993). The district was opened to commercial fishing on 21 April with 60 permit holders making at least one delivery. The actual harvest was 3,238.7 tonnes (3,570.0 tons). The difference between run biomass and harvest biomass was escapement biomass; i.e., 26,189.8 tonnes (28,869.0 tons).

A total of 601 readable scale samples were collected prior to the fishery on 19 and 20 April and another 666 from commercial catch samples on 21 April (Table 3). Samples from all three dates (Tables 4, 5, and 6) and locations (Figure 3) had similar age compositions (Figure 4). Catch, escapement, and run biomass (Tables 6, 7, and 8) were assigned the age, sex, and size composition from the combined 21 April catch sample.

Age-5 herring from the 1988 year class composed the largest component, 57.7%, of the 1993 catch samples. The next largest group, at 13.5%, were age-6 herring from the 1987 year class, followed by age-9 herring from the 1984 year class at 10.9%. Males represented 52.3% of the catch samples. Mean weight and length of both sexes combined were 185 g and 248 mm. Updated abundance, escapement, age composition, and mean weight and lengths by age and year are presented in Appendices A–E.

Southern District

Aerial surveys were flown on seven dates between 26 April and 28 May in the Southern District (Table 9; Figure 5). The 1993 run biomass estimated, from the sum of all surveys, was 445.7 tonnes (491.3 tons). There was no fishery.

DISCUSSION

Bad weather limited the number of aerial surveys that could be flown for the third consecutive year. In response, a method was developed to estimate run biomass from daily biomass estimates and expected proportions on the survey date (Yuen *in press a*). When estimating run biomass with this method, at least eight qualifying aerial surveys are required to avoid double-digit prediction errors. For an aerial survey to qualify, herring must have been observed, and the expected proportion of run biomass on the date when herring were seen must be greater than zero. There were only six qualifying surveys in 1993.

The historical Kamishak herring age composition appears to follow one of three scenarios (Yuen *in press b*): (1) influx of age-4 herring in late April (e.g., 1988, 1990, 1992); (2) increase in the

abundance of age-3 and older herring in mid May (e.g., 1977 and 1986); or (3) no change in age-3 or age-4 herring over time (e.g., 1989). During 1993 no age-composition data were collected after the fishery on 21 April. We do not know if scenario 1 or 2 had occurred and selected scenario 3 to describe the events during 1993. The 1993 age composition in this report may be revised if a large proportion of age-3 herring appear in the run biomass during 1994.

On 20 May, 7.6 miles of milt was observed between Bluff and Anchor Points in the Southern District (Table 9). However, no herring were seen precluding a biomass estimate. Reports of juvenile herring are rare, but confirmed reports were made along the north shore of Kachemak Bay near Miller's Landing. At this time we do not know if the herring spawn between Bluff and Anchor Points and whether the juvenile observations near Miller's Landing are related. If they are not, we also do not know whether herring that spawn between Bluff and Anchor Points are part of the Southern District or the Upper Cook Inlet stocks.

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Table 1. Herring biomass estimates by area and date, Kamishak Bay District, Lower Cook Inlet, 1993.

Biomass Estimates in Tonnes[a]

Date	Dry Bay	Oil Bay	Iniskin Bay	Cottonwood & Iliamna Bay	Ursus Cove	Fort. Bluff	Bruin & Amakd.	Chenik & Nordyke	Kamishak	Douglas Reef	Total
4/18	DNS	DNS	0.0	DNS	0.0	0.0	0.0	0.0	DNS	DNS	0.0
4/20	DNS	DNS	DNS	DNS	DNS	DNS	0.0	0.0	DNS	DNS	0.0
4/23	0.0	0.0	0.0	0.0	0.0	0.0	205.9	1,122.8	0.0	0.0	1,328.8
4/25	0.0	0.0	0.0	0.0	0.0	96.0	237.4	117.2	0.0	0.0	450.6
4/27	0.0	0.0	41.4	1.4	0.0	154.3	56.0	27.6	53.3	0.0	333.8
5/10	0.0	0.0	809.7	0.0	0.0	0.0	0.0	0.0	25.7	0.0	835.3
5/17	0.0	25.7	81.4	0.0	170.5	13.8	1.4	8.3	0.0	0.0	300.9
5/21	0.0	0.0	0.0	0.0	11.1	0.0	1.4	34.5	0.0	0.0	46.9
5/28	0.0	0.0	191.8	15.2	225.5	0.0	170.4	469.7	92.4	0.0	1,164.8
6/3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	DNS	DNS	0.0
Total	0.0	25.7	1,124.2	16.5	407.1	264.1	672.4	1,780.0	171.3	0.0	4,461.2

Biomass Estimates in Tons[a]

Date	Dry Bay	Oil Bay	Iniskin Bay	Cottonwood & Iliamna Bay	Ursus Cove	Fort. Bluff	Bruin & Amakd.	Chenik & Nordyke	Kamishak	Douglas Reef	Total
4/18	DNS	DNS	0.0	DNS	0.0	0.0	0.0	0.0	DNS	DNS	0.0
4/20	DNS	DNS	DNS	DNS	DNS	DNS	0.0	0.0	DNS	DNS	0.0
4/23	0.0	0.0	0.0	0.0	0.0	0.0	227.0	1,237.7	0.0	0.0	1,464.7
4/25	0.0	0.0	0.0	0.0	0.0	105.8	261.7	129.2	0.0	0.0	496.7
4/27	0.0	0.0	45.6	1.5	0.0	170.1	61.7	30.4	58.7	0.0	368.0
5/10	0.0	0.0	892.5	0.0	0.0	0.0	0.0	0.0	28.3	0.0	920.8
5/17	0.0	28.3	89.7	0.0	187.9	15.2	1.5	9.1	0.0	0.0	331.7
5/21	0.0	0.0	0.0	0.0	12.2	0.0	1.5	38.0	0.0	0.0	51.7
5/28	0.0	0.0	211.4	16.7	248.6	0.0	187.8	517.7	101.8	0.0	1,284.0
6/3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	DNS	DNS	0.0
Total	0.0	28.3	1,239.2	18.2	448.7	291.1	741.2	1,962.1	188.8	0.0	4,917.6

[a] DNS = did not survey

Table 2. Daily aerial survey estimates, expected proportion of total run biomass, and predicted total run biomass, Kamishak Bay District, Lower Cook Inlet, 1993.

Date	Combined Aerial Survey (tonnes)	Expected Daily Proportion	Daily Predicted Run Biomass[a]
4/23	1,328.8	0.015	88,584
4/25	450.6	0.012	37,550
4/27	333.8	0.032	10,433
5/10	835.3	0.095	8,793
5/17	300.9	0.030	10,031
5/21	46.9	0.000	0
5/28	1,164.8	0.055	21,179
Mean			29,428

Date	Combined Aerial Survey (tons)	Expected Daily Proportion	Daily Predicted Run Biomass[a]
4/23	1,464.7	0.015	97,647
4/25	496.7	0.012	41,392
4/27	368.0	0.032	11,500
5/10	920.8	0.095	9,693
5/17	331.7	0.030	11,057
5/21	51.7	0.000	0
5/28	1,284.0	0.055	23,345
Mean			32,439

[a] Daily predicted run biomass equals daily combined aerial survey divided by expected daily proportion of run biomass.

Table 3. Sample sizes of readable herring scales, Kamishak Bay District, Lower Cook Inlet, 1993.

April	Sample	Sample Size	P
19	Bruin Bay	403	0.952
19	Nordyke	198	0.748
	Combined 19 April	601	0.986
20	Nordyke	201	0.933
21	Commercial catch (a.m.)	430	0.964
21	Commercial catch (p.m.)	236	0.814
	Combined Catch	666	0.991

Table 4. Age, sex, and size composition of herring fish samples obtained prior to the fishery from Bruin Bay and Nordyke Island in the Kamishak Bay District, Lower Cook Inlet, 19 April 1993.

Sample Period	Age	Numbers of Fish						% of Total	Weight			Length			Biomass		
		Male	Imm. Female	Ripe Female	Spawned Female	Unknown	Total		Mean (g)	SD	Number Weighed	Mean (mm)	SD	Number Measured	No. Fish x 1,000	Tons	Tonnes
Bruin Bay	1																
	2																
	3	0	0	1	0	0	1	0.2	139	0.0	1	219	0.0	1			
	4	8	1	0	0	0	9	2.2	118	16.5	9	220	4.6	9			
	5	116	12	93	0	1	223	55.3	151	24.8	222	238	16.6	222			
	6	19	5	29	0	0	53	13.2	205	30.4	53	260	9.0	53			
	7	9	2	16	0	0	27	6.7	218	37.2	27	263	11.5	27			
	8	13	0	21	0	0	34	8.4	249	31.0	33	272	10.4	34			
	9	18	0	21	0	0	39	9.7	265	31.8	39	277	11.1	39			
	10	4	1	5	0	0	10	2.5	275	36.6	10	279	16.1	10			
	11	1	0	2	0	0	3	0.7	300	46.9	3	285	13.1	3			
	12	1	0	2	0	0	3	0.7	307	37.9	3	292	8.1	3			
	13																
	14	1	0	0	0	0	1	0.2	260	0.0	1	280	0.0	1			
	15																
	16																
Sample Total		190	21	190	0	1	403	100.0	187	55.2	401	251	21.9	402			
Nordyke Island	1																
	2																
	3																
	4	4	0	4	0	0	8	4.0	138	29.7	8	232	14.0	8			
	5	53	8	36	0	0	97	49.0	156	29.2	97	238	11.0	97			
	6	7	0	18	0	0	25	12.6	194	33.6	25	252	11.8	25			
	7	3	1	10	0	0	14	7.1	232	31.2	14	263	9.5	14			
	8	8	0	7	0	0	15	7.6	235	26.0	15	267	8.5	15			
	9	14	0	14	0	0	28	14.1	256	28.5	28	273	10.2	28			
	10	3	0	7	0	0	10	5.1	301	29.4	10	284	10.4	10			
	11																
	12	0	0	1	0	0	1	0.5	290	0.0	1	282	0.0	1			
	13																
	14																
	15																
	16																
Sample Total		92	9	97	0	0	198	100.0	194	55.4	198	251	19.2	198			

– continued –

Table 4. (Page 2 of 2).

Sample Period	Age	Numbers of Fish: Male	Imm. Female	Ripe Female	Spawned Female	Unknown	Total	% of Total	Weight: Mean (g)	SD	Number Weighed	Length: Mean (mm)	SD	Number Measured	Biomass: No. Fish x 1,000	Tons	Tonnes
	1																
	2																
	3	0	0	1	0	0	1	0.2	139	0.0	1	219	0.0	1	8	1.2	1.1
	4	12	1	4	0	0	17	2.8	127	25.0	17	226	11.5	17	136	19.1	17.4
	5	169	20	129	0	1	320	53.2	152	26.3	319	238	15.1	319	2,557	429.8	389.9
	6	26	5	47	0	0	78	13.0	202	31.6	78	258	10.6	78	625	139.0	126.1
	7	12	3	26	0	0	41	6.8	223	35.4	41	263	10.7	41	329	80.7	73.2
Combined	8	21	0	28	0	0	49	8.2	245	30.0	48	271	10.0	49	385	103.9	94.3
Samples	9	32	0	35	0	0	67	11.1	261	30.6	67	275	10.9	67	537	154.4	140.1
	10	7	1	12	0	0	20	3.3	288	34.9	20	281	13.4	20	160	50.9	46.1
	11	1	0	2	0	0	3	0.5	300	46.9	3	285	13.1	3	24	8.0	7.2
	12	1	0	3	0	0	4	0.7	303	32.1	4	290	8.4	4	32	10.7	9.7
	13																
	14	1	0	0	0	0	1	0.2	260	0.0	1	280	0.0	1	8	2.3	2.1
	15																
	16																
Combined Total		282	30	287	0	1	601	100.0	189	55.3	599	251	21.0	600	4,802	1,000.0	907.2
Sex Composition (%)		46.9	5.0	47.8	0.0												
Not Aged		39	4	35	0	0	78	13.0	208	53.7	78	258	19.0	78			
Sex Composition (%)		50.0	5.1	44.9	0.0												

Table 5. Age, sex, and size composition of herring samples obtained prior to the fishery from Nordyke Island in the Kamishak Bay District, Lower Cook Inlet, 20 April 1993.

Sample Period	Age	Numbers of Fish						% of Total	Weight			Length			Biomass		
		Male	Imm. Female	Ripe Female	Spawned Female	Unknown	Total		Mean (g)	SD	Number Weighed	Mean (mm)	SD	Number Measured	No. Fish x 1,000	Tons	Tonnes
	1																
	2																
	3	1	0	0	0	0	1	0.3	158	0.0	1	237	0.0	1	13	2.3	2.1
	4	3	1	6	0	0	10	2.8	124	18.3	10	223	8.0	10	135	18.4	16.7
	5	95	6	88	1	0	190	52.9	154	18.1	190	237	8.5	190	2,561	433.6	393.4
	6	28	6	21	0	0	55	15.3	194	29.4	55	253	10.9	55	741	158.7	144.0
	7	12	1	10	0	0	23	6.4	226	31.5	23	264	10.1	23	310	77.4	70.2
	8	13	0	17	0	0	30	8.4	248	42.4	30	270	12.4	30	404	110.4	100.2
	9	15	0	13	0	0	28	7.8	255	35.1	28	270	8.0	28	377	106.0	96.1
	10	6	0	7	0	0	13	3.6	270	42.5	13	278	13.8	13	175	52.1	47.3
	11	5	0	0	0	0	5	1.4	290	13.4	5	283	10.4	5	67	21.5	19.5
	12	2	0	1	0	0	3	0.8	304	1.2	3	292	11.6	3	40	13.5	12.3
	13	0	0	1	0	0	1	0.3	396	0.0	1	315	0.0	1	13	5.9	5.3
	14																
	15																
	16																
Combined Total		180	14	164	1	0	359	100.0	187	52.8	359	249	18.7	359	4,838	1,000.0	907.2
Sex Composition (%)		50.1	3.9	45.7	0.3												
Not Aged		12	0	16	0	0	28	7.8	188	50.0	28	248	19.6	28			
Sex Composition (%)		42.9	0.0	57.1	0.0												

Table 6. Age, sex, and size composition of herring commercial sac roe harvest from Nordyke Island and McNeil Cove in the Kamishak Bay District, Lower Cook Inlet, 21 April 1993.

		Numbers of Fish							Weight			Length			Biomass		
Sample Period	Age	Male	Imm. Female	Ripe Female	Spawned Female	Unknown	Total	% of Total	Mean (g)	SD	Number Weighed	Mean (mm)	SD	Number Measured	No. Fish x 1,000	Tons	Tonnes
First 30-min opening at 1100 h	1																
	2																
	3																
	4	5	0	2	0	0	7	1.6	129	15.7	7	225	6.4	7			
	5	148	6	108	2	0	264	61.4	152	21.8	264	237	9.3	264			
	6	30	1	26	0	0	57	13.3	196	29.6	57	254	10.7	57			
	7	13	0	9	0	0	22	5.1	231	35.7	22	266	10.8	22			
	8	10	1	8	0	0	19	4.4	250	35.0	19	271	14.4	19			
	9	18	1	19	0	0	38	8.8	265	35.4	38	273	10.6	38			
	10	6	0	11	0	0	17	4.0	284	25.0	17	280	10.3	17			
	11	0	0	2	0	0	2	0.5	330	27.6	2	288	6.4	2			
	12	1	0	1	0	0	2	0.5	317	8.5	2	292	1.4	2			
	13	0	0	1	0	0	1	0.2	382	0.0	1	296	0.0	1			
	14	1	0	0	0	0	1	0.2	318	0.0	1	293	0.0	1			
	15																
	16																
Sample Total		232	9	187	2	0	430	100.0	184	54.3	430	247	18.7	430			
Second 15-min opening at 1925 h	1																
	2																
	3	1	0	0	0	0	1	0.4	88	0.0	1	198	0.0	1			
	4	3	0	4	0	0	7	3.0	134	28.8	7	227	11.0	7			
	5	61	0	59	0	0	120	50.8	152	18.8	120	238	9.4	120			
	6	16	0	17	0	0	33	14.0	188	24.1	33	252	9.0	33			
	7	7	0	7	0	0	14	5.9	229	38.7	14	267	8.1	14			
	8	10	0	7	0	0	17	7.2	240	37.3	17	268	13.1	17			
	9	16	0	19	0	0	35	14.8	254	40.4	35	273	13.6	35			
	10	1	0	6	0	0	7	3.0	314	38.3	7	286	8.7	7			
	11	1	0	1	0	0	2	0.8	275	76.4	2	282	31.8	2			
	12																
	13																
	14																
	15																
	16																
Sample Total		116	0	120	0	0	236	100.0	188	55.1	236	250	19.5	236			

– continued –

Table 6. (Page 2 of 2).

Sample Period	Age	Numbers of Fish: Male	Imm. Female	Ripe Female	Spawned Female	Unknown	Total	% of Total	Weight: Mean (g)	SD	Number Weighed	Length: Mean (mm)	SD	Number Measured	Biomass: No. Fish x 1,000	Tons	Tonnes
	1																
	2																
	3	1	0	0	0	0	1	0.2	88	0.0	1	198	0.0	1	26	2.5	2.3
	4	8	0	6	0	0	14	2.1	131	22.4	14	226	8.8	14	367	53.1	48.2
	5	209	6	167	2	0	384	57.7	152	20.9	384	237	9.3	384	10,077	1,691.0	1,534.1
	6	46	1	43	0	0	90	13.5	193	27.9	90	253	10.1	90	2,362	502.5	455.9
	7	20	0	16	0	0	36	5.4	230	36.3	36	266	9.7	36	945	239.6	217.4
Combined	8	20	1	15	0	0	36	5.4	245	35.9	36	270	13.6	36	945	255.6	231.9
Harvest	9	34	1	38	0	0	73	11.0	260	38.0	73	273	12.1	73	1,916	548.9	497.9
	10	7	0	17	0	0	24	3.6	293	31.8	24	282	10.1	24	630	203.2	184.4
	11	1	0	3	0	0	4	0.6	302	56.5	4	285	19.1	4	105	35.0	31.7
	12	1	0	1	0	0	2	0.3	317	8.5	2	292	1.4	2	52	18.3	16.6
	13	0	0	1	0	0	1	0.2	382	0.0	1	296	0.0	1	26	11.0	10.0
	14	1	0	0	0	0	1	0.2	318	0.0	1	293	0.0	1	26	9.2	8.3
	15																
	16																
Combined Total		348	9	307	2	0	666	100.0	185	54.5	666	248	19.0	666	17,476	3,570.0	3,238.7
Sex Composition (%)		52.3	1.4	46.1	0.3												
Not Aged		38	1	28	0	0	67	10.1	189	58.5	67	249	20.3	67			
Sex Composition (%)		56.7	1.5	41.8	0.0												

Table 7. Age, sex, and size composition of herring escapement biomass from Kamishak Bay District, Lower Cook Inlet, 1993.

Age (years)	Percent of Total	Biomass		
		No. of Fish x 1,000	Tons	Tonnes
1	0.0	0	0.0	0.0
2	0.0	0	0.0	0.0
3	0.1	211	20.5	18.6
4	2.1	2,975	429.6	389.8
5	57.7	81,615	13,674.6	12,405.5
6	13.5	19,102	4,063.8	3,686.6
7	5.4	7,644	1,937.9	1,758.0
8	5.4	7,654	2,067.1	1,875.3
9	11.0	15,486	4,438.2	4,026.3
10	3.6	5,089	1,643.7	1,491.2
11	0.6	849	282.6	256.3
12	0.3	423	148.0	134.2
13	0.1	212	89.1	80.9
14	0.1	211	74.0	67.1
15	0.0	0	0.0	0.0
16	0.0	0	0.0	0.0
	100.0	141,574	28,869.0	26,189.8

Table 8. Age, sex, and size composition of herring run biomass from Kamishak Bay District, Lower Cook Inlet, 1993.

Age (years)	Percent of Total	Biomass		
		No. of Fish x 1,000	Tons	Tonnes
1	0.0	0	0.0	0.0
2	0.0	0	0.0	0.0
3	0.1	237	23.0	20.9
4	2.1	3,342	482.7	438.0
5	57.7	91,692	15,365.6	13,939.6
6	13.5	21,464	4,566.3	4,142.5
7	5.4	8,589	2,177.5	1,975.4
8	5.4	8,599	2,322.7	2,107.2
9	10.9	17,402	4,987.1	4,524.2
10	3.6	5,719	1,846.9	1,675.6
11	0.6	954	317.6	288.0
12	0.3	475	166.3	150.8
13	0.1	238	100.1	90.9
14	0.1	237	83.2	75.4
15	0.0	0	0.0	0.0
16	0.0	0	0.0	0.0
	100.0	158,948	32,439.0	29,428.5

Table 9. Herring biomass estimates by area and date, Southern District, Lower Cook Inlet, 1993.

Biomass in Tonnes[a]

Date	Anchor Pt & Bluff Pt	West Spit	East Spit Mud Bay North Shore	Bear Cove	Mallard Bay	Glacier Spit	Peterson Bay China Poot	Total
4/26	DNS	0.0	1.4	0.0	0.0	0.0	0.0	1.4
4/30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/10	DNS	DNS	0.0	0.0	35.1	1.4	0.0	36.5
5/18	DNS	DNS	23.4	101.5	2.7	40.6	6.9	175.2
5/20	[b]	DNS	DNS	DNS	DNS	DNS	DNS	[b]
5/21	0.0	0.0	0.0	196.9	20.7	0.0	0.0	217.5
5/28	0.0	1.4	0.0	13.8	0.0	0.0	0.0	15.2
Total	0.0	1.4	24.8	312.2	58.5	42.0	6.9	445.7

Biomass in Tons[a]

Date	Anchor Pt & Bluff Pt	West Spit	East Spit Mud Bay North Shore	Bear Cove	Mallard Bay	Glacier Spit	Peterson Bay China Poot	Total
4/26	DNS	0.0	1.5	0.0	0.0	0.0	0.0	1.5
4/30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/10	DNS	DNS	0.0	0.0	38.7	1.5	0.0	40.2
5/18	DNS	DNS	25.8	111.9	3.0	44.8	7.6	193.1
5/20	[b]	DNS	DNS	DNS	DNS	DNS	DNS	[b]
5/21	0.0	0.0	0.0	217.0	22.8	0.0	0.0	239.8
5/28	0.0	1.5	0.0	15.2	0.0	0.0	0.0	16.7
Total	0.0	1.5	27.3	344.1	64.5	46.3	7.6	491.3

[a] DNS = did not survey

[b] 7.6 mi of milt seen, but fish not observed

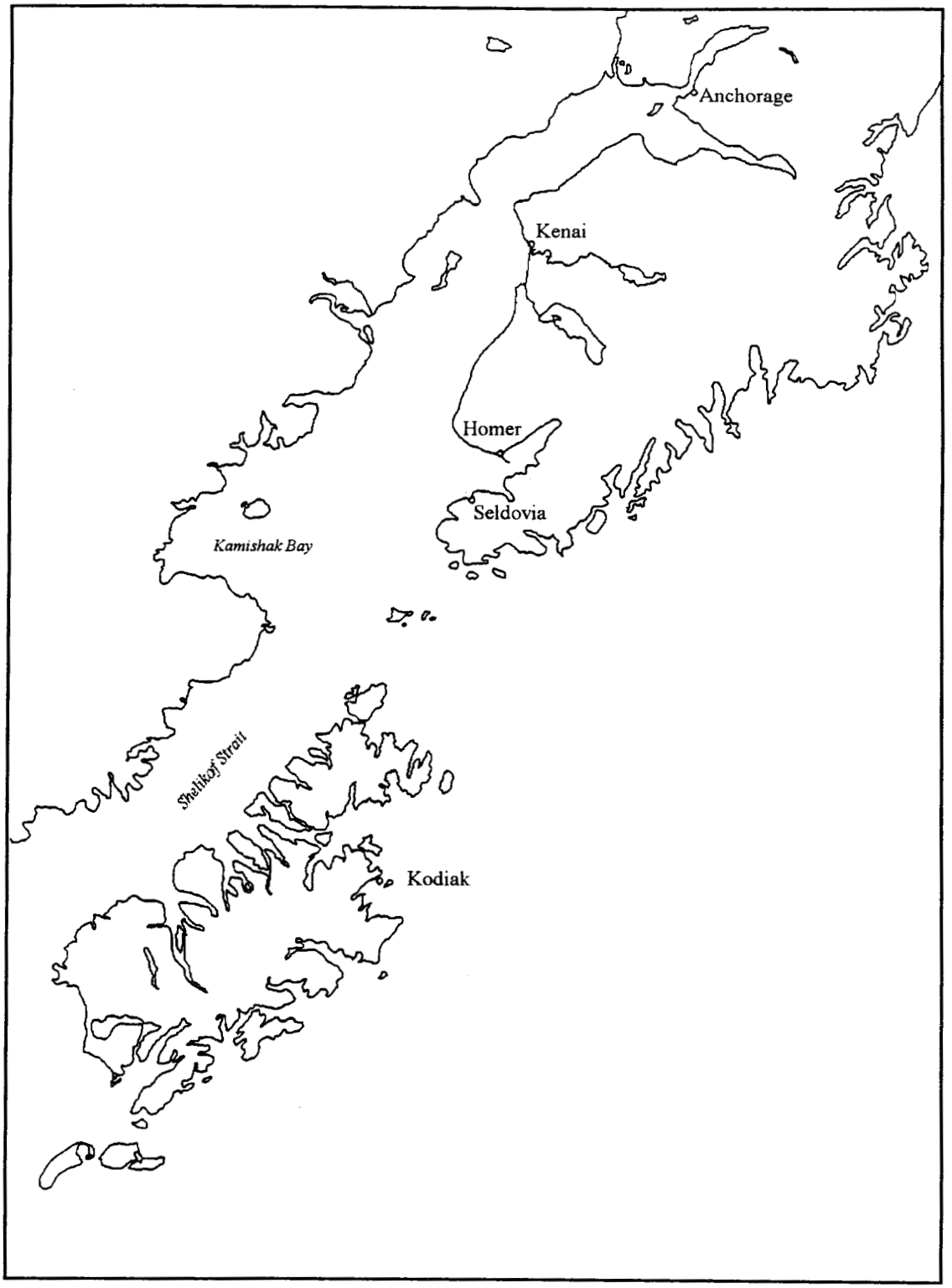

Figure 1. Kamishak Bay and Shelikof Strait.

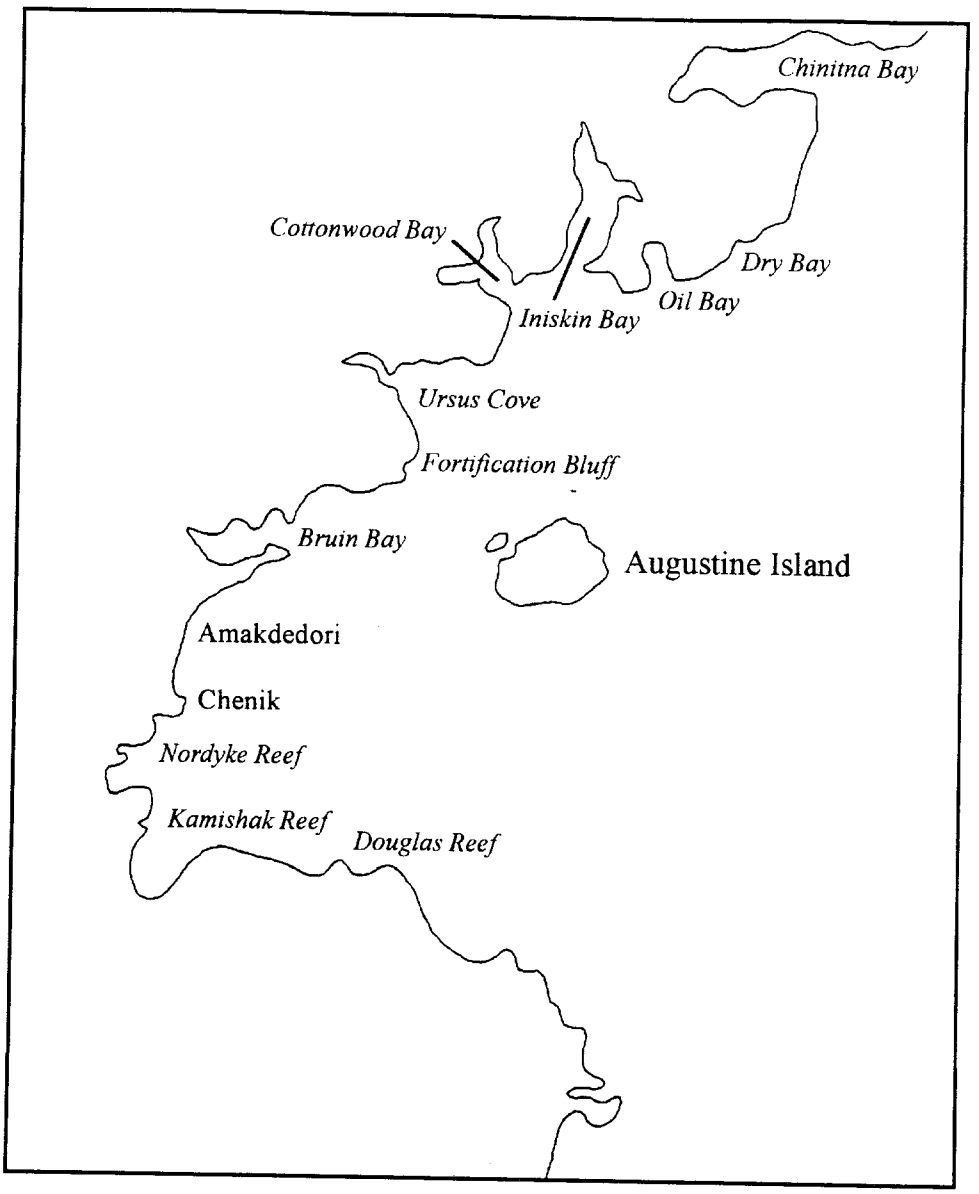

Figure 2. Kamishak Bay District aerial survey landmarks, Lower Cook Inlet.

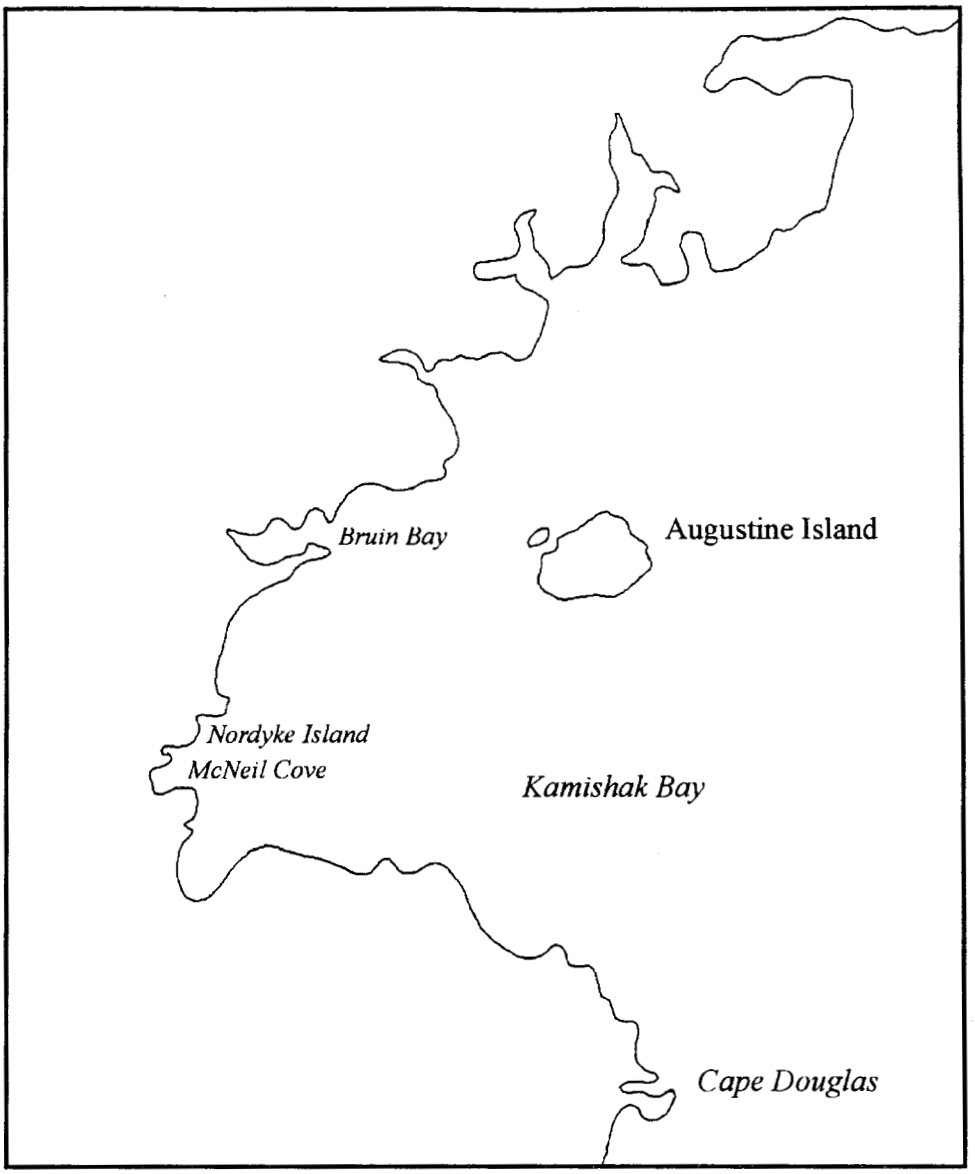

Figure 3. Kamishak Bay District sac roe herring sample sites, 1993.

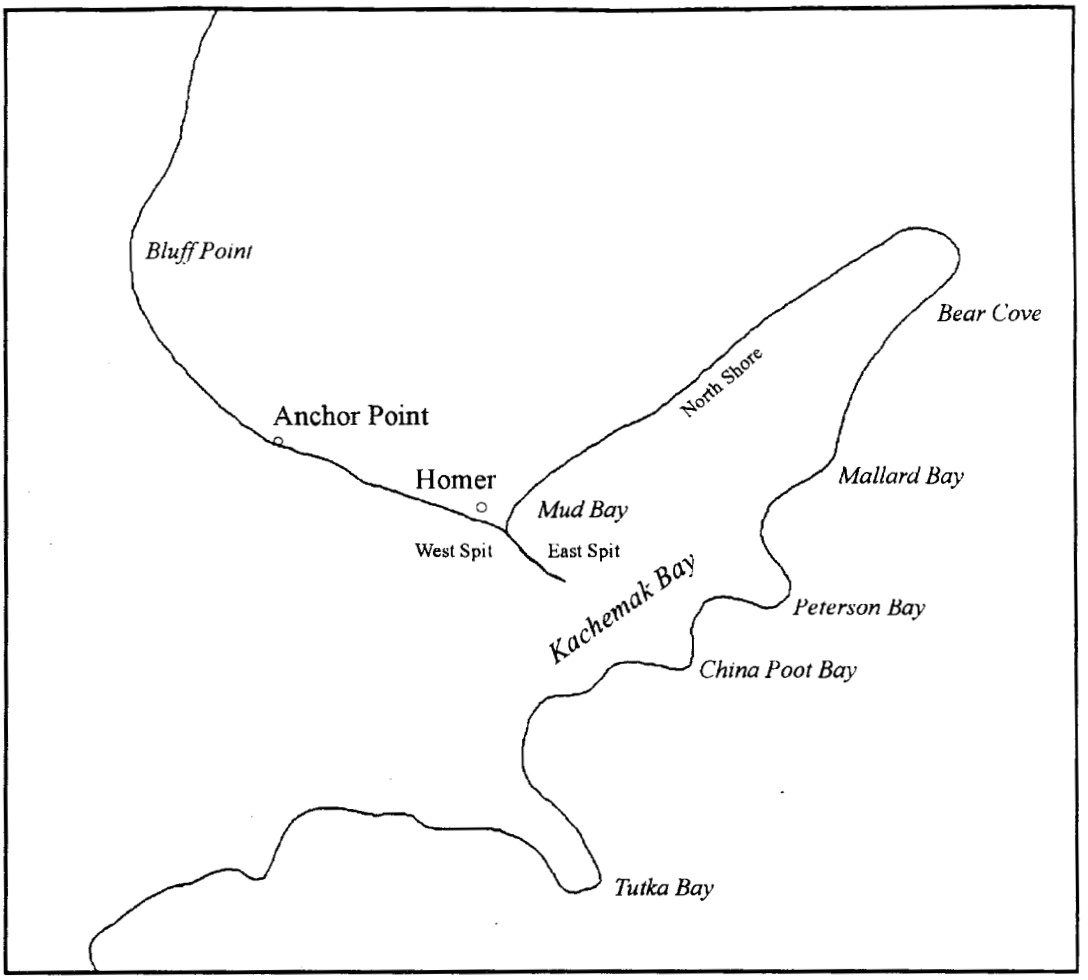

Figure 4. Southern District aerial survey landmarks, Lower Cook Inlet.

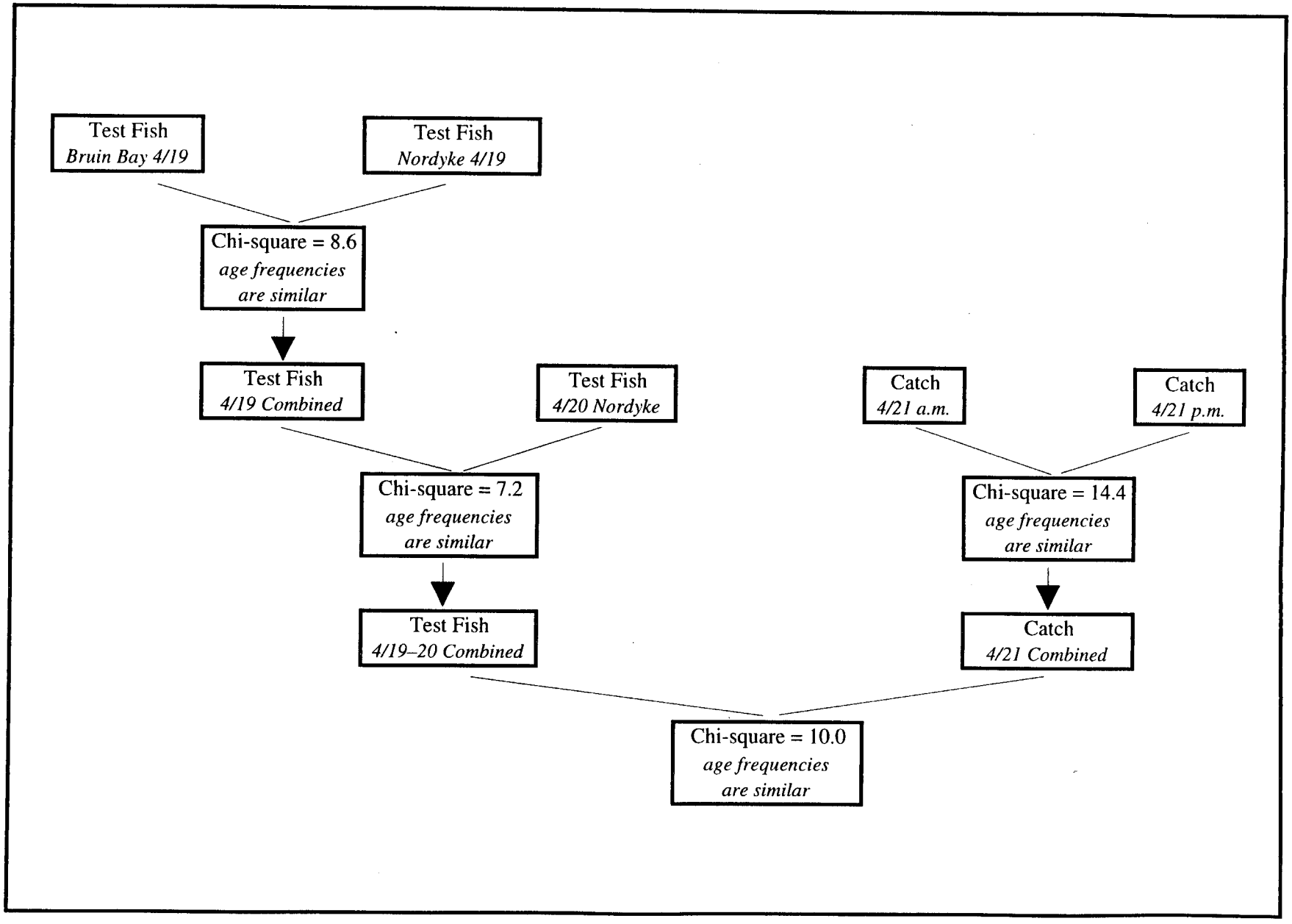

Figure 5. Chi-square test of independent age composition by sample and date, Kamishak Bay District, 1993.

APPENDIX

Appendix A. Kamishak Bay District herring run abundance (x 1,000) by year class.

Year Class	Run Abundance (x 1,000) by Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
66	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	131	169	0	0	0	0
68	0	0	0	0	0	0	0	0	0	328	170	0	0	0	0	0
69	0	0	0	0	0	0	0	0	328	170	0	0	0	0	0	0
70	0	0	0	0	0	0	0	394	342	0	0	0	0	0	0	0
71	0	0	0	0	0	0	262	255	0	0	0	0	0	0	0	0
72	0	0	0	0	0	278	423	0	0	0	109	0	0	103	37	0
73	0	0	0	0	2,734	5,782	0	0	0	217	0	574	767	445	66	194
74	0	0	0	4,052	8,060	0	0	0	1,411	0	2,408	2,606	2,026	475	299	43
75	0	0	1,199	4,241	0	1,601	0	1,194	0	2,980	3,321	2,294	420	272	157	0
76	0	167	4,934	0	8,007	0	2,279	0	5,097	8,586	5,498	2,202	1,219	294	0	0
77	0	0	0	36,834	0	6,946	0	13,843	21,361	13,805	6,810	3,414	490	26	0	0
78	0	0	3,203	0	5,318	0	8,696	15,791	10,645	5,644	4,878	856	137	774	0	0
79	0	0	0	11,178	0	13,252	21,054	17,647	12,567	6,121	2,050	189	388	52	0	0
80	0	0	1,845	0	8,237	11,805	18,774	12,423	8,586	4,188	422	390	52	0	0	0
81	0	0	0	6,693	13,645	25,570	24,120	14,965	6,445	986	2,328	104	0	0	0	0
82	0	0	111	3,015	3,622	2,809	4,947	4,400	418	1,551	210	0	0	0	0	0
83	0	0	14,513	48,226	27,515	27,215	22,438	4,369	6,606	1,260	0	0	0	0	0	0
84	0	0	41,071	49,857	47,063	29,131	10,752	19,016	3,832	0	0	0	0	0	0	0
85	0	0	9,071	5,756	7,897	2,692	6,600	1,890	0	0	0	0	0	0	0	0
86	0	205	1,544	10,739	2,245	6,969	1,890	0	0	0	0	0	0	0	0	0
87	90	0	5,225	1,960	24,878	4,724	0	0	0	0	0	0	0	0	0	0
88	0	10	2,888	111,689	20,154	0	0	0	0	0	0	0	0	0	0	0
89	29	0	1,167	734	0	0	0	0	0	0	0	0	0	0	0	0
90	1,705	0	52	0	0	0	0	0	0	0	0	0	0	0	0	0
91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix B. Kamishak Bay District herring escapement abundance (x 1,000) by year class.

Year Class	Escapement Abundance (x 1,000) by Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
66	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	
67	0	0	0	0	0	0	0	0	0	0	87	148	0	0	0	
68	0	0	0	0	0	0	0	0	0	218	149	0	0	0	0	
69	0	0	0	0	0	0	0	0	218	149	0	0	0	0	0	
70	0	0	0	0	0	0	0	263	299	0	0	0	0	0	0	
71	0	0	0	0	0	0	174	223	0	0	0	0	0	0	0	
72	0	0	0	0	0	185	370	0	0	0	109	0	0	95	28	
73	0	0	0	0	1,819	5,057	0	0	0	217	0	525	709	333	52	
74	0	0	0	2,699	7,048	0	0	0	1,411	0	2,204	2,410	1,550	372	242	
75	0	0	799	3,708	0	1,601	0	1,194	0	2,727	3,071	1,715	328	221	155	
76	0	112	4,316	0	8,007	0	2,279	0	4,664	7,939	4,163	1,721	985	268	0	
77	0	0	0	36,834	0	6,946	0	12,666	19,752	10,623	5,325	2,752	456	26	0	
78	0	0	3,203	0	5,318	0	7,957	14,601	8,191	4,413	3,940	762	115	716	0	
79	0	0	0	11,178	0	12,128	19,468	13,951	9,824	4,953	1,839	167	359	26	0	
80	0	0	1,845	0	7,537	10,916	15,162	9,736	6,971	3,744	310	361	26	0	0	
81	0	0	0	6,124	12,617	20,437	18,960	12,169	5,656	716	2,155	52	0	0	0	
82	0	0	101	2,788	3,146	2,217	4,122	3,753	373	1,436	105	0	0	0	0	
83	0	0	13,420	45,128	22,177	22,511	20,105	2,907	6,115	630	0	0	0	0	0	
84	0	0	38,729	44,264	39,464	24,804	7,062	17,601	1,916	0	0	0	0	0	0	
85	0	0	8,951	5,368	7,294	1,747	6,109	945	0	0	0	0	0	0	0	
86	0	199	1,532	10,375	1,458	6,449	945	0	0	0	0	0	0	0	0	
87	0	0	5,071	1,263	23,030	2,362	0	0	0	0	0	0	0	0	0	
88	0	10	1,786	103,345	10,077	0	0	0	0	0	0	0	0	0	0	
89	29	0	1,080	367	0	0	0	0	0	0	0	0	0	0	0	
90	1,705	0	26	0	0	0	0	0	0	0	0	0	0	0	0	
91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Appendix C. Kamishak Bay District herring age composition (%) by year of harvest.

Harvest Year	Harvest Composition (%) by Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
78	0.0	1.7	12.1	41.0	27.6	2.8	2.6	4.0	3.3	3.3	1.3	0.3	0.0	0.0	0.0	0.0
79	0.0	0.0	20.1	17.3	32.9	23.5	1.7	1.0	1.4	0.7	0.7	0.7	0.0	0.0	0.0	0.0
80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
81	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
82	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	0.0	0.0	0.2	10.8	13.3	21.4	14.1	22.4	8.2	4.8	3.9	0.9	0.0	0.0	0.0	0.0
86	0.0	0.0	12.4	2.6	11.7	10.2	18.1	13.6	18.4	7.4	2.8	2.2	0.7	0.1	0.0	0.0
87	0.0	0.0	8.8	11.7	1.8	19.4	13.6	13.9	9.3	12.0	5.0	2.2	1.8	0.4	0.0	0.0
88	0.1	0.0	0.5	21.8	20.8	2.3	20.1	10.5	10.7	4.8	5.8	1.9	0.4	0.4	0.1	0.0
89	0.0	0.0	0.1	1.8	36.0	22.3	3.9	13.3	7.7	5.5	4.4	3.1	1.1	0.2	0.3	0.2
90	0.0	0.0	1.5	3.6	6.0	43.1	23.2	6.4	7.9	4.4	2.1	0.9	0.3	0.3	0.0	0.1
91	0.0	0.0	12.0	7.6	8.6	10.3	40.3	16.0	0.5	2.9	1.2	0.2	0.2	0.0	0.0	0.0
92	0.0	0.0	0.6	61.4	13.6	3.8	3.6	10.4	3.6	0.8	1.3	0.2	0.2	0.4	0.0	0.0
93	0.0	0.0	0.2	2.1	57.7	13.5	5.4	5.4	11.0	3.6	0.6	0.3	0.2	0.2	0.0	0.0

Appendix D. Kamishak Bay District herring mean weight (g) by harvest year and age.

Harvest Year	Mean Weight (g) by Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
78	0	16	61	85	121	168	170	188	204	217	212	247	0	0	0	0
79	0	0	68	98	128	156	170	197	210	221	272	265	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	64	125	155	182	205	220	238	248	255	275	0	0	0	0
86	0	0	88	104	155	189	215	233	249	261	272	281	292	295	0	0
87	0	0	91	134	162	198	218	241	251	267	276	275	288	288	287	0
88	3	18	84	123	163	196	218	236	248	261	266	280	298	262	282	0
89	0	0	98	131	158	199	228	245	254	268	285	288	298	293	313	296
90	0	0	90	135	162	182	220	245	256	273	289	303	310	333	269	299
91	0	0	79	118	172	208	214	259	267	288	280	229	413	0	0	0
92	0	0	99	116	156	210	229	234	266	304	303	279	333	349	0	0
93	0	0	88	131	152	193	230	245	260	293	302	317	382	318	0	0

Appendix E. Kamishak Bay District herring mean length (mm) by harvest year and age.

Harvest Year	Mean Length (mm) by Age															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
78	0	120	172	191	212	235	235	243	247	252	248	252	0	0	0	0
79	0	0	186	208	224	237	246	255	258	254	274	268	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	173	208	220	230	237	242	248	252	255	253	0	0	0	0
86	0	0	185	197	220	233	241	247	250	254	256	259	259	262	0	0
87	0	0	185	209	221	233	238	245	247	251	254	255	259	256	256	0
88	70	117	182	208	228	239	246	251	254	257	258	262	263	263	266	0
89	0	0	191	214	225	242	251	256	259	260	266	266	265	267	263	265
90	0	0	185	212	227	232	248	258	261	263	268	275	274	283	257	267
91	0	0	182	205	229	240	240	253	271	260	260	247	285	0	0	0
92	0	0	200	208	228	249	252	253	263	272	272	273	267	280	0	0
93	0	0	198	226	237	253	266	270	273	282	285	292	296	293	0	0