METHODS OF THE 1993 KAMISHAK HERRING STOCK PROJECTION

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Regional Information Report[1] No. 2A93-06
Alaska Department of Fish and Game
Division of Commercial Fisheries, Central Region
333 Raspberry Road
Anchorage, Alaska 99518-1599

January 1993

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ACKNOWLEDGMENTS

Steve Fried and Linda Brannian reviewed the manuscript and provided many valuable comments.

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ABSTRACT

The 1993 abundance of Pacific Herring *Clupea pallasi* in the Kamishak Bay District of Lower Cook Inlet, Alaska, was forecasted from an exponential decay model using estimated 1992 escapement, age-specific natural mortality and recruitment rates, and predicted 1993 mean weights. The 1992 aerial surveys of run biomass were interrupted by bad weather. Therefore, a preliminary 1992 run biomass estimate was derived from daily aerial survey estimates of biomass divided by a preliminary estimate of expected daily proportion. The preliminary run biomass estimate minus the final harvest biomass estimate yielded a preliminary estimate of escapement biomass. There were also no late season age composition data collected during 1992. In order to make the historical age composition data comparable with the current year data, the 1986 age composition was restated without the late (mid-May and later) samples prior to the estimation of annual mortality and recruitment rates.

The 1993 Kamishak Bay District herring spawning biomass was forecast to have a strong recruitment from the 1988 year class. Age-5 herring was predicted to be 66% of the 26,186 tonne (28,805 ton) forecast biomass based on the high proportion of age-4 herring found in the 1992 catch samples. Mean weight of the biomass was predicted to be 172 g. The next largest age group, age-6, was only 12% of the total forecast biomass. If a 10% harvest rate was adopted, the projected harvest would be 2,356 tonnes (2,592 tons) in the Kamishak sac roe fishery and 262 tonnes (288 tons) in the Shelikof Straits bait fishery and supersedes the projected harvest presented to the public in the Alaska Board of Fisheries report.

KEY WORDS: *Clupea pallasi,* herring, forecast, Lower Cook Inlet.

INTRODUCTION

This report presents a forecast of the 1993 herring run biomass for the Kamishak Bay District in Lower Cook Inlet. Run biomass was defined as the segment of the herring population participating in the spring spawning migration and observed by aerial surveyors on the fishing grounds between mid-April and June. Observed herring are considered recruited into the fishery and available to the sac roe fishing fleet even though harvest limits are typically achieved by mid-May. Escapement biomass was defined as the unharvested run biomass.

The Lower Cook Inlet Management Area consists of all waters within 3 mi of the shoreline, west of the longitude of Cape Fairfield in the Gulf of Alaska, north of the latitude of Cape Douglas in the Shelikof Straits, and south of the latitude of Anchor Point in Cook Inlet. This management area is subdivided into four management districts: Kamishak Bay, Southern, Outer, and Eastern (Figure 1). The forecast in this report is only for the Kamishak Bay District.

A history of commercial fishing for Pacific herring *Clupea pallasi* in Lower Cook Inlet can be found in Schroeder (1989). Fishing for herring began in 1914 as a gillnet fishery for salteries in the Southern District (Kachemak Bay). Purse seines were introduced in 1923. This fishery grew to a peak between 1924 and 1926 before its collapse. The herring stocks in the Southern District are presently recovering in abundance.

A purse seine fishery for oil and meal reduction began in 1939 in the Eastern District (Resurrection Bay). Harvest levels peaked between 1944 and 1946 before the fishery collapsed during the late 1950s. There were no records of age composition from this fishery. Samples obtained recently, however, rarely exceed age 4.

The present-day sac roe fishing started as early as 1969 in the Eastern and Southern Districts and in 1973 in the Kamishak Bay District. During 1978, herring biomass fell to a low (e.g. 1,093 tonnes (1,202 tons) in the Kamishak Bay District) and all fishing Districts were closed to commercial fishing. The Kamishak Bay, Eastern, and Outer Districts were reopened in 1985. The Southern District was reopened to fishing only during 1989. The Eastern and Outer Districts were closed again in 1990. Currently, all of the Lower Cook Inlet sac roe harvest is from the Kamishak Bay District where roe recovery rates are higher because the fish are older. The Kamishak Bay harvest and total run biomass peaked in 1987 at 5,574 and 32,120 tonnes ((6,132 and 35,332 tons).

METHODS

Bad weather grounded the aerial surveyors for 18 consecutive days in May and age composition samples were not obtained after the fishery was completed in April. The 1993 forecast was therefore prepared in the following sequence. First, we had to estimate the 1992 run and escapement biomass. Then we had to either estimate the missing late season herring age composition or restate the historical database by excluding all late season samples so the two would be comparable. Only then could we convert biomass to abundance and estimate age-specific natural mortality and recruitment rates. The 1993 abundances by age were predicted from the updated natural mortality and recruitment rates as well as the 1992 escapement abundance estimates. Forecast abundance was converted to biomass with a predicted mean weight-at-age. Age-specific biomass were summed to obtain run biomass. Finally, the harvest was projected using the current management strategy and forecast biomass.

Database

The historical abundance, age composition, and mean weight-at-age database used to prepare the 1993 forecast were the same as that used to prepare the 1992 forecast (Yuen and Bucher 1992) with the following exceptions. We calculated a preliminary estimate of the 1992 run biomass by dividing daily aerial survey estimates of run biomass by preliminary estimates of expected daily proportion. The 1992 escapement biomass was the preliminary 1992 run biomass estimate minus the 1992 final harvest estimate. Final run biomass estimate and age composition data were not available for the 1993 forecast.

During 1991 and 1992, we were not able to obtain late season age composition samples once the harvest was completed in April because of budget restrictions. We did expect the situation to change in the future. We chose therefore to restate the historical age composition without the late season samples instead of estimating any missing late-season age composition samples. When we had age composition samples from both the early, e.g. April-May, and late, e.g. May-June, spawning migrations, we noticed a tendency for younger aged herring to appear in the later samples. We therefore tested the historical database, to determine which year, if any, had late season samples that were statistically younger. Our purpose of restating the historical age compositions was to build a forecast model with historical data similar to the current year data used in the forecast.

To test if the later samples were younger, cumulative age proportions, S, from 1973-79, 1983, and 1985-90 were compared with a one-sided 2-sample Smirnov test (Conover 1980). Age classes whose proportions were less than 0.001 were not included in the tests. In this test, if the null hypothesis, $S_{\text{late}} \leq S_{\text{early}}$, was rejected, the alternate hypothesis would be herring collected in the later samples were younger than those collected from April through mid-May. The exact date when the younger herring appeared in the late samples, $d_{m,y}$, however, varied among years. Therefore $d_{m,y}$ in the tests was allowed to vary from day 2 to the last sample date D_y. Thus, D_y-*1* pairs of early and late samples were compared for each year *y* with the Smirnov test. The earliest date *m* when the null hypothesis was rejected, was used to define the start of the late component. Age compositions for the years found to have a statistically younger late component were subsequently recalculated without the benefit of the late samples.

Natural Mortality and Recruitment

Because the sac roe fishery occurred once a year and for a very short period, we could estimate the natural mortality and recruitment, M_i+R_i that occurred between fisheries (May to mid-April of the following year) simply as

$$M_i+R_i=-\ln\frac{N_{i+1,\,t+1}}{N_{i,\,t}} \qquad (1)$$

where $N_{i,t}$ = abundance of age *i* fish in year *t* immediately after the fishery, i.e., the escapement, and $N_{i+1,t+1}$ = abundance of age *i+1* fish in year *t+1* immediately before the fishery, i.e., the over winter survivors from the previous year spawning population plus any new recruits (Ricker 1975).

Natural mortality and recruitment M_i+R_i is positive whenever herring aged *i* are fully recruited, that is, the loss of age *i* fish M_i exceeded any gain through recruitment R_i of individuals into the spawning population. M_i+R_i is negative when the opposite is true. Recruitment was defined as the addition of new herring to the spawning population as a result of sexual maturity. The Kamishak spawning population is the target of a purse seine fishery. There have been herring as young as age-1 on the spawning grounds during the month of April. Even though they can be captured with a trawl, they are not considered recruited into the fishery as they rarely appear in the purse seine harvest.

Only positive estimates of M_i+R_i for age-8 and older were considered while mixed values of M_i+R_i for ages-7 and younger were allowed (Table 1). A moving average of M_i+R_i, i.e. the most recent 2 of 4, 3 of 5, or 4 of 8 estimates, was used because the recent values tend to be greater. This was expected for the older age classes as they tend to be rare and become more so over time as they are removed by the fishery.

Forecast

The age-specific exponential decay model used to predict herring abundance was

$$N_{i,t}=N_{i-1,t-1}e^{-(M_{i-1}+R_{i-1})} \tag{2}$$

where t = 1993 for the forecast. Predicted mean weights-at-age, $w_{i,t}$, were used to convert abundance $N_{i,t}$ into biomass B_i where

$$B_{i,t}=N_{i,t}w_{i,t} \tag{3}$$

Age-specific mean weights were predicted from both previous age and weight data as

$$w_{i,t}=a+b_1(i-1)+b_2w_{i-1,t-1} \tag{4}$$

where a and b are regression coefficients. Finally, run biomass was the sum of the age-specific biomasses,

$$B_t=\sum_{i=3}^{16} B_{i,t} \tag{5}$$

Reconstructed Forecast Performance

We tested the forecast model with a cross-validation. In this procedure, a forecast F_y was made for every year y in the data set. Data from the year being forecast (abundance, M_i+R_i, and mean weight), however, was removed temporarily and not used to build the forecast model. Of course, we could reconstruct the forecast only for those years which had escapement estimates from the previous year. They were 1979 and 1986-1992 and therefore Y =8, the number of years that we tested.

Both mean absolute percent error (MAPE):

$$MAPE = 100 \frac{\sum_{y=1}^{Y} \left| \frac{F_y - R_y}{R_y} \right|}{Y} \qquad (6)$$

and mean percent error (MPE):

$$MPE = 100 \frac{\sum_{y=1}^{Y} \frac{F_y - R_y}{R_y}}{Y} \qquad (7)$$

were used to compare prediction errors from the weighted quotient model (Armstrong 1978) where R_y = observed run biomass.

Positive MPE indicate the model overforecasts while negative values suggest the model tends to underforecast. Small MPE values mean that overforecast errors tend to be compensated by underforecast errors. Large values of MPE indicate that a strong bias exists. MAPE provides an estimate of average error. Because errors do not cancel in the calculation of MAPE, it will always be larger than or equal to MPE.

The 80% confidence interval was estimated as:

$$B_{1993} \pm t_{0.20} SD \qquad (8)$$

where

$$SD = \sqrt{\frac{\sum_{y=1}^{Y} (F_y - B_y)^2}{Y-1}} \ . \qquad (9)$$

The frequency distribution of the ratio

$$\frac{B_y}{F_y} \qquad (10)$$

was used to estimate the probability that the 1993 biomass would exceed a given level. The ratios were assigned to one of 8 categories which range from 0.6 to 2.0 in 0.2 increments. The frequency of occurrence in each category was expressed as a percentage of all cross-validated forecasts. Finally, the percentages were accumulated starting from the highest ratio category and proceeding to the smallest to obtain the cumulative probability of the 1993 biomass exceeding a given tonnage.

Projected Harvest

The Kamishak Bay District total allowable harvest projection in this report was set at 10% of the 1993 forecasted run biomass for all age groups. The Shelikof Straits winter bait fishery projection for the fall of 1993 was equal to 1% of the forecast. The actual bait fishery quota will be based on the total spawning biomass observed by aerial survey in the spring of 1993. For the purposes of this forecast, the estimated bait allocation was subtracted from the predicted total allowable herring harvest and the remainder was allocated to the Kamishak spring sac roe fishery. This prevents the sum of the sac roe and bait harvest from exceeding the allowable biological harvest.

RESULTS

Historical Age Composition

Only harvest year 1986 had a late (after April 28) spawning migration of significantly younger herring (d_{max} = .449, n = 11, p = 0.95). There were 3 other years, 1979, 1985, and 1988, that had an increase in the proportion of younger fish later in the year, but the difference between cumulative curves was not found to be statistically significant (Figure 2). The restated 1986 age composition, abundance estimates, escapement, and mean weight used in to prepare the 1993 forecast are summarized in the Appendices.

Forecast

A biomass of 28,805 tons (26,186 tonnes) of herring is expected to return to the Kamishak Bay District in 1993 (Table 2). Herring mean weight is predicted to be 172 g. The age composition is forecasted to be 74% age-5 and 11% age-6 from the 1988 and 1987 year classes respectively. The relationship between 1993 and 1992 weight and age (R^2 = 0.95, d.f. = 89; Figure 3) is

$$w_{i,1993}=60.04989+1.50925(i-1)+0.76936w_{i-1,1992} \quad (11)$$

Projected Harvest

Total allowable harvest is projected to be 2,619 tonnes (2,881 tons). The harvest allocation was 2,356 tonnes (2,592 tons) for the Kamishak spring sac roe fishery and 262 tonnes (288 tons) for the Shelikof Straits winter bait fishery (Table 3).

DISCUSSION

The abundance and biomass of Kamishak herring peaked in 1987. The downturn that followed may have reversed itself during 1990 (Figure 4). The recent upturn is expected to continue in 1993 because of the strong recruitment of age-4 herring in 1992.

During 1991 and 1992, our aerial surveys of herring biomass were interrupted by bad weather and our budgets did not allow us to obtain age composition samples during the month of May when age-3 and -4 herring proportions were expected to increase. In response, we developed two new methods where total run biomass could be estimated by dividing daily biomass estimates by expected daily proportions and where the late age composition of age-3 and -4 herring could be estimated from their early age composition. We used the results from early versions of the two methods in order to produce a forecast in time for the Alaska Board of Fisheries meeting in November, 1992. Testing and final versions of the two methods are not expected until early 1993. Therefore, the forecast in this report may be subject to revision if the final versions differ from the early methods.

The Kamishak herring harvest policy calls for harvest rates of 10 to 20%. Past management strategies in Lower Cook Inlet has allowed for a 10% harvest rate on herring age 5 and younger and 20% on age 6 and older. Because age-5 herring is projected to be 74% of the abundance or 66% of the 1993 biomass, a 10% harvest rate for all age groups is anticipated as a conservative management strategy.

The projected harvest in this and the Alaska Board of Fisheries report (Bucher and Hammarstrom 1992) are different. The 1993 projected harvest of 2,182 tonnes (2,400 tons) in the Alaska Board of Fisheries report was based on a management plan where the 1993 harvest was to be based on the 1992 estimated run biomass of 21,888 tonnes (24,077 tons). The projected harvest of 2,356 tonnes (2,592 tons) in this report is based the management plan adopted by the Alaska Board of fisheries in November of 1993 where the 1993 harvest is based on the 1993 forecast.

Cross-validation results used to measure performance of the forecast model are presented in Table 4. The cross-validation SD, 10,303, was used to calculate an 80% confidence interval around the forecast of 12,933 to 39,440 tonnes (14,226 to 43,384 tons). MPE was -0.06 and MAPE was 0.27. Two alternate methods of deriving M_i+R_i were also tested with a cross-validation. If median M_i+R_i were used, the SD would have doubled to 21,222. Similarly if mean M_i+R_i were used, SD would have been 21,810. Both had similar MPEs, 0.25, and MAPEs, 0.54. While the tests indicated that the moving average was the better performer, the comparison was not entirely fair. When the historical forecast was reconstructed, the models used either the early or late half of the available M_i+R_i estimates as the moving average. Technically, it should have used the most recent half prior to the year being cross-validated. Unfortunately, this has the effect of reducing our M_i+R_i sample size as we cross-validate the earlier years. During the cross-validation process, 1988 stood out as a very difficult year to forecast. The moving average had the effect of removing that year from the data base and in the process improving the forecast for all years after 1988. If we reject the moving average forecast because of the unfair tests, the forecast based on the median and mean would have been 30,247 and 29,404 tonnes (33,272 and 32,344 tons), respectively.

Cross-validated forecasts provide an estimate of the size of error to be expected as well as the bias of this model. Half of the cross-validated forecasts were below the observed biomass (< -0.05) while only 2 of the 8 reconstructed forecasts were above (> 0.05; Table 4). This suggests a greater tendency to underforecast than overforecast. The probability of the 1993 run biomass exceeding various thresholds were based on the observed/cross-validated forecast ratio (Table 4) and are indicated below.

	Probability of 1993 Biomass Exceeding Tonnage in the Left Column
28,805	0.88
34,566	0.62
40,327	0.50
46,088	0.38
57,610	0.12

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Table 1. Kamishak abundance by age group and year of harvest used to derive M+R, an instantaneous measure of concurrent mortality and recruitment, for Kamishak Bay District herring stocks.

Yr (t)	Age (i)	Abundance (x 1,000)	-Catch	=Escapement (x 1,000)	Yr (t+1)	Age (i+1)	Abundance[a] (x 1,000)	M+R	Data Used In Model?
78	2	167	55	112	79	3	4,934	-3.79	
88	2	205	6	199	89	3	1,544	-2.05	
90	2	10	0	10	91	3	9,010	-6.80	
78	3	1,199	400	799	79	4	4,241	-1.67	
85	3	111	10	101	86	4	2,366	-3.15	
86	3	899	67	832	87	4	48,226	-4.06	
87	3	41,071	2342	38,729	88	4	49,857	-.25	
88	3	9,071	120	8,951	89	4	5,756	.44	
89	3	1,544	12	1,532	90	4	10,739	-1.95	
90	3	5,225	154	5,071	91	4	6,104	-.19	
91	3	9,010	1102	7,908	92	4	87,710	-2.41	
78	4	4,052	1353	2,699	79	5	8,060	-1.09	
85	4	6,693	569	6,124	86	5	10,849	-.57	
86	4	2,366	178	2,188	87	5	3,622	-.50	
87	4	48,226	3098	45,128	88	5	27,515	.49	
88	4	49,857	5593	44,264	89	5	47,063	-.06	
89	4	5,756	388	5,368	90	5	7,897	-.39	
90	4	10,739	364	10,375	91	5	7,237	.36	
91	4	6,104	697	5,407	92	5	19,537	-1.28	
78	5	2,734	915	1,819	79	6	5,782	-1.16	
85	5	8,237	700	7,537	86	6	11,487	-.42	
86	5	10,849	816	10,033	87	6	25,570	-.94	
87	5	3,622	476	3,146	88	6	2,809	.11	
88	5	27,515	5338	22,177	89	6	27,215	-.20	
89	5	47,063	7599	39,464	90	6	29,131	.30	
90	5	7,897	603	7,294	91	6	8,663	-.17	
91	5	7,237	787	6,450	92	6	5,474	.16	
78	6	278	93	185	79	7	423	-.83	
85	6	13,252	1124	12,128	86	7	22,092	-.60	
86	6	11,487	864	10,623	87	7	18,774	-.57	
87	6	25,570	5133	20,437	88	7	24,120	-.17	
88	6	2,809	592	2,217	89	7	4,947	-.80	
89	6	27,215	4704	22,511	90	7	22,438	.00	
90	6	29,131	4327	24,804	91	7	35,724	-.36	
91	6	8,663	945	7,718	92	7	5,180	.40	

-Continued-

Table 1. (page 2 of 3)

Yr (t)	Age (i)	Abundance (x 1,000)	-Catch	=Escapement (x 1,000)	Yr (t+1)	Age (i+1)	Abundance[a] (x 1,000)	M+R	Data Used In Model?
78	7	262	88	174	79	8	255	-.38	
85	7	8,696	739	7,957	86	8	18,151	-.82	
86	7	22,092	1666	20,426	87	8	17,647	.15	
87	7	18,774	3612	15,162	88	8	12,423	.20	
88	7	24,120	5160	18,960	89	8	14,965	.24	
89	7	4,947	825	4,122	90	8	4,400	-.07	
90	7	22,438	2333	20,105	91	8	13,236	.42	
91	7	35,724	3690	32,034	92	8	14,934	.76	
78	8	394	131	263	79	9	342	-.26	not used
85	8	13,843	1177	12,666	86	9	23,354	-.61	not used
86	8	18,151	1368	16,783	87	9	10,645	.46	
87	8	17,647	3696	13,951	88	9	12,567	.10	
88	8	12,423	2687	9,736	89	9	8,586	.13	
89	8	14,965	2796	12,169	90	9	6,445	.64	
90	8	4,400	647	3,753	91	9	2,089	.59	
91	8	13,236	1462	11,774	92	9	5,185	.82	
78	9	328	110	218	79	10	170	.25	
85	9	5,097	433	4,664	86	10	9,805	-.74	not used
86	9	23,354	1762	21,592	87	10	13,805	.45	
87	9	10,645	2454	8,191	88	10	5,644	.37	
88	9	12,567	2743	9,824	89	10	6,121	.47	
89	9	8,586	1615	6,971	90	10	4,188	.51	
90	9	6,445	789	5,656	91	10	3,646	.44	
91	9	2,089	45	2,044	92	10	1,218	.52	
78	10	328	110	218	79	11	170	.25	
85	10	2,980	253	2,727	86	11	3,443	-.23	not used
86	10	9,805	739	9,066	87	11	5,498	.50	
87	10	13,805	3182	10,623	88	11	6,810	.44	
88	10	5,644	1231	4,413	89	11	4,878	-.10	not used
89	10	6,121	1168	4,953	90	11	2,050	.88	
90	10	4,188	444	3,744	91	11	1,447	.95	
91	10	3,646	270	3,376	92	11	1,828	.61	

-Continued-

Table 1. (page 3 of 3)

Yr (t)	Age (i)	Abundance (x 1,000)	-Catch	=Escapement (x 1,000)	Yr (t+1)	Age (i+1)	Abundance[a] (x 1,000)	M+R	Data Used In Model?
78	11	131	44	87	79	12	169	-.66	not used
85	11	2,408	204	2,204	86	12	2,743	-.22	not used
86	11	3,443	259	3,184	87	12	2,294	.33	
87	11	5,498	1335	4,163	88	12	2,202	.64	
88	11	6,810	1485	5,325	89	12	3,414	.44	
89	11	4,878	938	3,940	90	12	856	1.53	
90	11	2,050	211	1,839	91	12	731	.92	
91	11	1,447	112	1,335	92	12	306	1.47	
85	12	574	49	525	86	13	829	-.46	not used
86	12	2,743	206	2,537	87	13	2,026	.22	
87	12	2,294	579	1,715	88	13	420	1.41	
88	12	2,202	481	1,721	89	13	1,219	.34	
89	12	3,414	662	2,752	90	13	490	1.73	
90	12	856	94	762	91	13	492	.44	
91	12	731	22	709	92	13	304	.85	
86	13	829	62	767	87	14	445	.54	
87	13	2,026	476	1,550	88	14	475	1.18	
88	13	420	92	328	89	14	272	.19	
89	13	1,219	234	985	90	14	294	1.21	
90	13	490	34	456	91	14	158	1.06	
91	13	492	22	470	92	14	608	-.26	not used
86	14	66	5	61	87	15	37	.50	
87	14	445	112	333	88	15	66	1.62	
88	14	475	103	372	89	15	299	.22	
89	14	272	51	221	90	15	157	.34	
88	15	66	14	52	89	16	194	-1.32	not used
89	15	299	57	242	90	16	43	1.73	

[a] 1992 abundance estimates based on preliminary estimate of 1992 run biomass (daily aerial survey estimates of run biomass divided by preliminary estimate of expected daily proportion) and preliminary age composition (with no adjustment for missing late samples). Final run biomass estimate and age composition data were not completed at this time.

Table 2. Forecast of 1993 Kamishak District herring abundance and projected harvest by age class.

Age	1992 Estimated Escapement[a]	Instantaneous Mortality & Recruitment	1993 Abundance Forecast (x1,000)	Proportion by Numbers	Predicted Mean Weight(g)	1993 Forecast Biomass (tons)	Harvest Rate	1993 Total Allowable Harvest (tons)	Proportion by Weight
2	0	-4.43							
3	830	-1.02	0	0.00	63	0	0.10	0	0.00
4	79,368	-0.34	2,312	0.02	141	358	0.10	36	0.01
5	17,690	0.02	111,836	0.74	155	19,109	0.10	1,911	0.66
6	4,954	-0.19	17,292	0.11	188	3,569	0.10	357	0.12
7	4,689	0.34	5,999	0.04	231	1,522	0.10	152	0.05
8	13,520	0.68	3,344	0.02	247	908	0.10	91	0.03
9	4,694	0.48	6,846	0.05	252	1,899	0.10	190	0.07
10	1,103	0.82	2,890	0.02	278	885	0.10	89	0.03
11	1,655	1.31	488	0.00	309	166	0.10	17	0.01
12	277	1.00	448	0.00	310	153	0.10	15	0.01
13	275	0.82	102	0.00	293	33	0.10	3	0.00
14	550	0.28	121	0.00	336	45	0.10	5	0.00
15	0	1.73	416	0.00	350	160	0.10	16	0.01
Total	129,605		152,094			28,805		2,881	
Mean					172				

[a] 1992 escapement based on preliminary estimate of 1992 run biomass (daily aerial survey estimates of run biomass divided by preliminary estimate of expected daily proportion), preliminary age composition (with no adjustment for missing late samples), and final catch biomass estimate. Final run biomass estimate and age composition data were not completed at this time.

Table 3. Allocation of the 1993 Kamishak Bay District herring projected harvest.

	Exploitation Rate	Harvest[a] (tons)
Kamishak Bat Sac Roe Fishery	9%	2,592
Shelikof Straits Bait Fishery	1%	288
Total	10%	2,881

[a] Supercedes projected harvest in Alaska Board of Fisheries report (Bucher and Hammarstrom 1992). This update was based on the 1993 forecast (according to a recently adopted management plan) instead of the 1992 run biomass.

Table 4. Kamishak herring cross-validated forecast results.

Yr	Escapement (x 1,000)	Cross-Validated Yr+1 Population (x 1,000)	Mean Wt (g)	Cross-Validated Biomass (tons)	Observed Biomass (tons)	Error (tons)	Error (%)	Observed/Cross-Validated Ratio
89	6,596	20,770	111	2,533	3,315	-782	-.24	1.31
86	56,633	60,016	212	13,987	26,001	-12,014	-.46	1.86
87	98,092	95,656	226	23,811	35,332	-11,521	-.33	1.48
88	163,156	298,787	151	49,598	29,548	20,050	.68	0.60
89	128,539	165,680	151	27,501	27,419	83	.00	1.00
90	105,230	97,414	214	22,883	19,655	3,228	.16	0.86
91	84,292	87,771	201	19,435	19,599	-164	-.01	1.01
92	79,383	72,699	210	16,799	24,077	-7,278	-.30	1.43

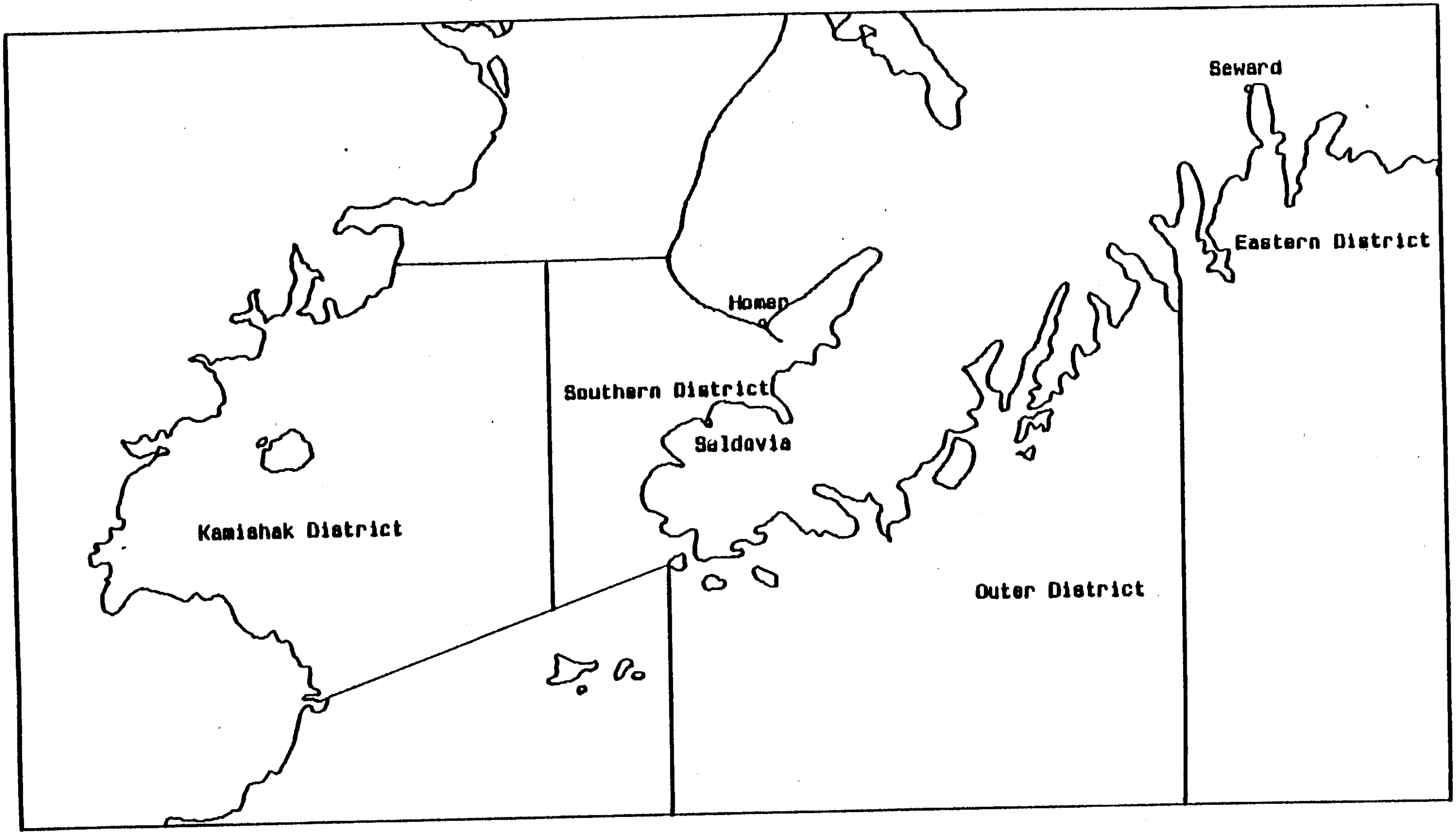

Figure 1. Kamishak Bay, Southern, Outer, and Eastern Districts of Lower Cook Inlet management area.

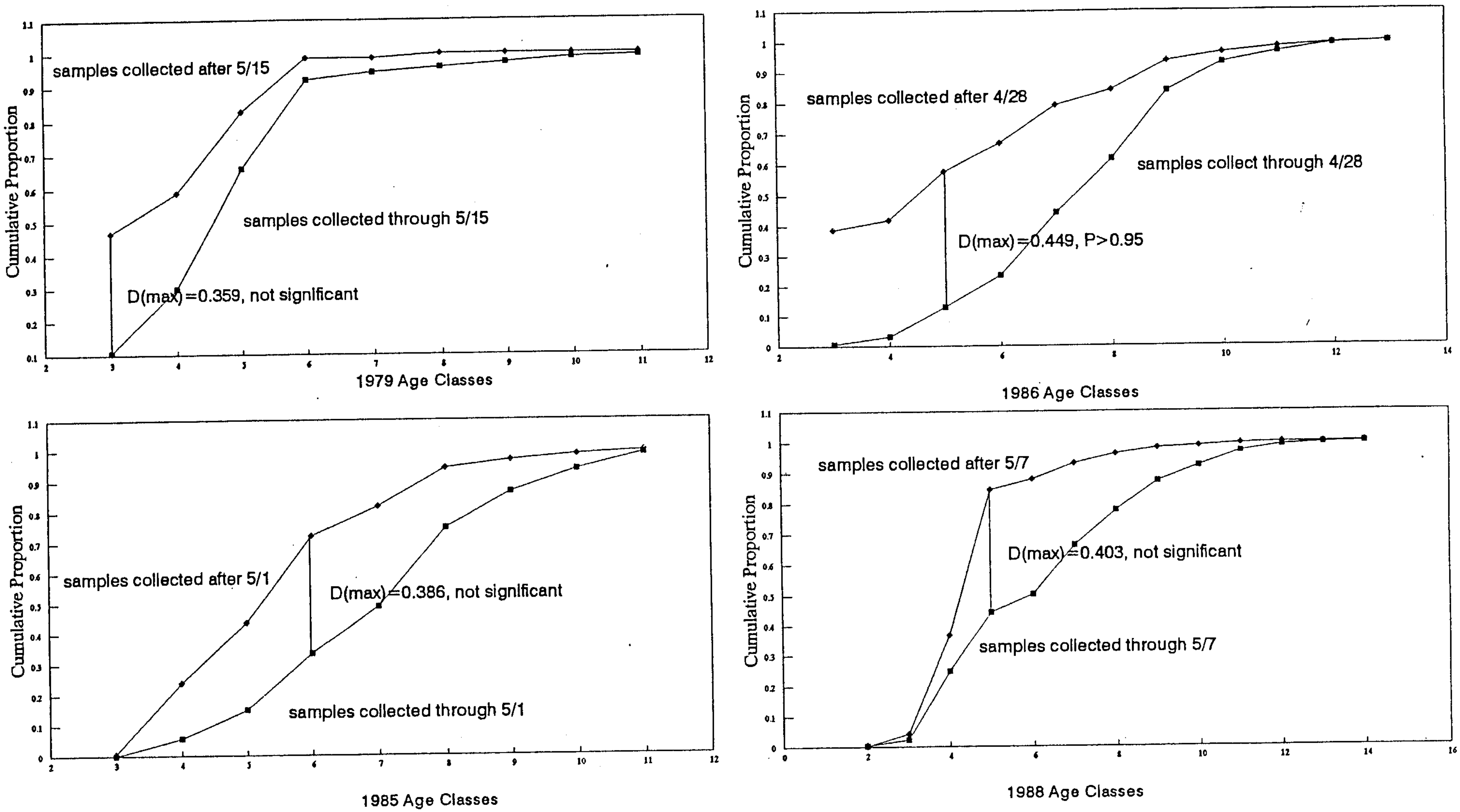

Figure 2. Comparison of cumulative age compositions from early and late Kamishak Bay District herring samples, 1979, 1985, 1986, and 1988.

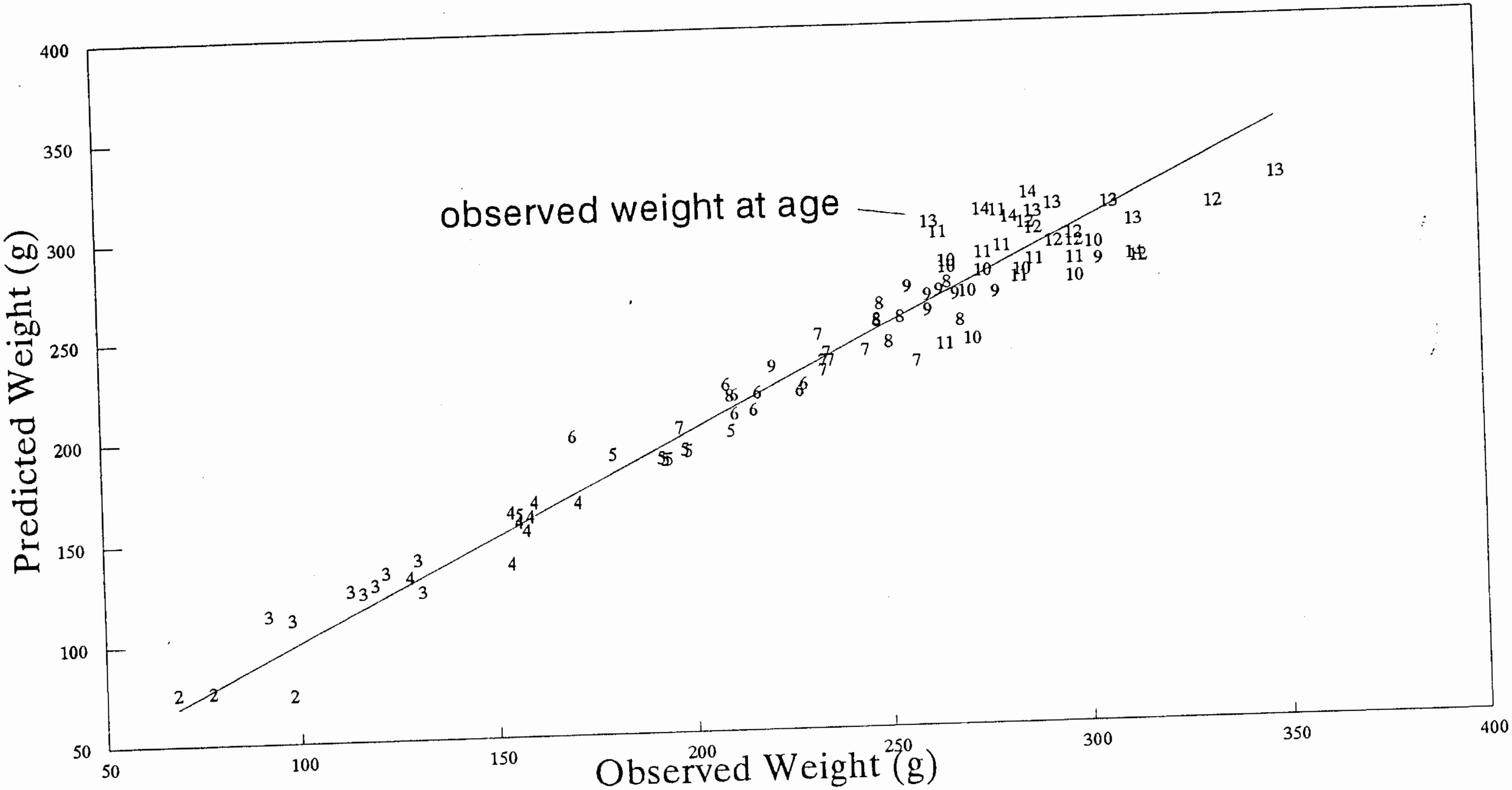

Figure 3. Observed $weight_{i,t}$ and $weight_{i,t}$ predicted from $weight_{i-1,t-1}$ and age_{i-1} for Kamishak Bay District herring.

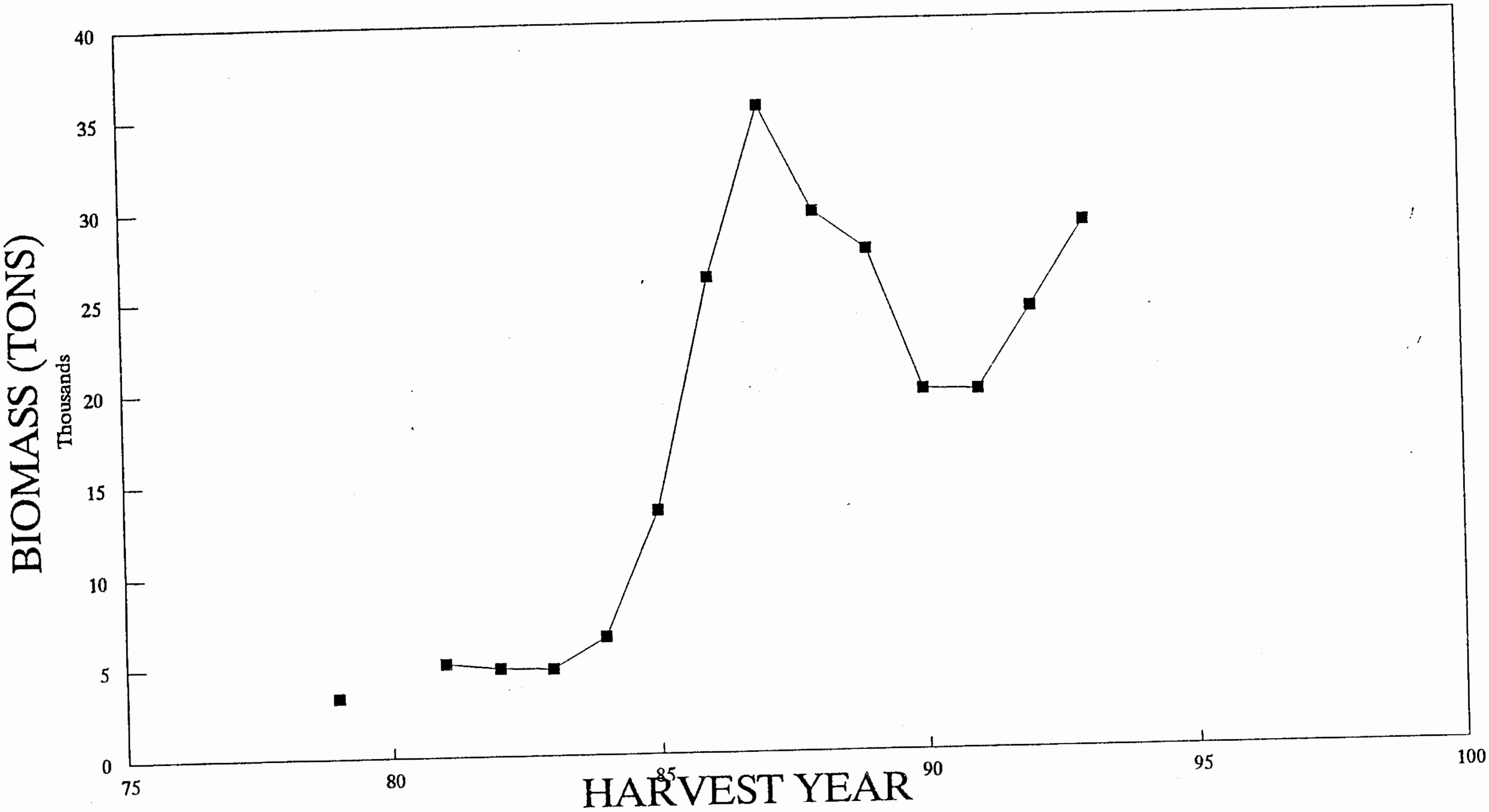

Figure 4. Kamishak Bay District herring estimated biomass by year, 1979, 1986-1992, and the forecast for 1993.

Appendix A. Kamishak Bay District herring age composition (%) by year of harvest, 1978-1992.

	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
78	.0	1.7	12.1	40.9	27.6	2.8	2.7	4.0	3.3	3.3	1.3	.3	.0	.0	.0	.0
79	.0	.0	20.1	17.3	32.9	23.5	1.7	1.0	1.4	.7	.7	.7	.0	.0	.0	.0
80	no samples															
81	.0	.0	6.5	74.2	16.1	3.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
82	no samples															
83	.0	.0	6.0	36.7	17.4	22.8	7.5	3.9	4.6	.7	.4	.0	.0	.0	.0	.0
84	no samples															
85	.0	.0	.2	10.8	13.3	21.4	14.1	22.4	8.2	4.8	3.9	.9	.0	.0	.0	.0
86	.0	.0	.8	2.2	10.2	10.8	20.8	17.1	22.0	9.2	3.2	2.6	.8	.1	.0	.0
87	.0	.0	23.7	27.7	1.9	12.5	9.3	8.6	5.0	6.5	2.6	1.1	1.0	.2	.0	.0
88	.0	.2	7.0	34.4	17.2	1.7	14.7	7.6	7.6	3.4	4.1	1.3	.3	.3	.0	.0
89	.0	.0	1.5	5.1	37.4	21.4	3.9	11.5	6.6	4.7	3.7	2.6	.9	.2	.2	.1
90	.0	.0	6.0	12.3	8.6	29.4	23.8	4.4	6.7	4.4	2.2	.9	.5	.3	.2	.0
91	.0	.0	9.9	6.8	8.1	9.7	40.4	14.8	2.6	4.3	1.7	.9	.6	.2	.0	.0
92	.0	.0	.6	61.4	13.6	3.8	3.6	10.4	3.6	.8	1.3	.2	.2	.4	.0	.0

Appendix B. Kamishak Bay District abundance (x 1,000) by age and year of harvest, 1978-1992.

	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
78		167	1199	4052	2734	278	262	394	328	328	131	33					9906
79			4934	4241	8060	5782	423	255	342	170	170	169					24546
80	no samples																
81			3203	36834	8007	1601											49645
82	no samples																
83			1845	11178	5318	6946	2279	1194	1411	217	109						30497
84	no samples																
85			111	6693	8237	13252	8696	13843	5097	2980	2408	574					61891
86			899	2366	10849	11487	22092	18151	23354	9805	3443	2743	829	66			106084
87			41071	48226	3622	25570	18774	17647	10645	13805	5498	2294	2026	445	37		189660
88	90	205	9071	49857	27515	2809	24120	12423	12567	5644	6810	2202	420	475	66		154274
89			1544	5756	47063	27215	4947	14965	8586	6121	4878	3414	1219	272	299	194	126473
90	29	10	5225	10739	7897	29131	22438	4400	6445	4188	2050	856	490	294	157	43	94392
91			9010	6104	7237	8663	35724	13236	2089	3646	1447	731	492	158			88537
92			917	87710	19537	5474	5180	14934	5185	1218	1828	306	304	608			143201

Appendix C. Kamishak Bay District herring escapement (x 1,000) by age and year of harvest, 1978-1992.

	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
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	1819	5057	0	0	0	217	0	525	709	333	52	
74	0	0	0	2699	7048	0	0	0	1411	0	2204	2410	1550	372	242	
75	0	0	799	3708	0	1601	0	1194	0	2727	3071	1715	328	221	155	
76	0	112	4316	0	8007	0	2279	0	4664	7939	4163	1721	985	268	0	
77	0	0	0	36834	0	6946	0	12666	19752	10623	5325	2752	456	26	0	
78	0	0	3203	0	5318	0	7957	14601	8191	4413	3940	762	115	0	0	
79	0	0	0	11178	0	12128	19468	13951	9824	4953	1839	167	0	0	0	
80	0	0	1845	0	7537	10916	15162	9736	6971	3744	310	0	0	0	0	
81	0	0	0	6124	12617	20437	18960	12169	5656	716	0	0	0	0	0	
82	0	0	101	2788	3146	2217	4122	3753	373	0	0	0	0	0	0	
83	0	0	13420	45128	22177	22511	20105	2907	0	0	0	0	0	0	0	
84	0	0	38729	44264	39464	24804	7062	0	0	0	0	0	0	0	0	
85	0	0	8951	5368	7294	1747	0	0	0	0	0	0	0	0	0	
86	0	199	1532	10375	1458	0	0	0	0	0	0	0	0	0	0	
87	0	0	5071	1263	0	0	0	0	0	0	0	0	0	0	0	
88	0	10	1786	0	0	0	0	0	0	0	0	0	0	0	0	
89	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
90	1705	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Appendix D. Kamishak Bay District herring mean weight (g) by age and year of harvest, 1978-1992.

	Age															
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
78		16	61	85	121	168	170	188	204	217	212	247				
79			68	98	128	156	170	197	210	221	272	265				
80	no samples															
81			70	88	124	121										
82	no samples															
83			74	118	137	160	182	196	210	218	253					
84	no samples															
85			64	125	155	182	205	220	238	248	255	275				
86			90	92	154	192	216	234	251	261	271	284	293	303		
87			79	122	154	193	211	235	248	264	275	275	288	288	287	
88		14	77	113	159	194	217	236	248	261	266	280	298	262	282	
89			98	131	158	199	228	245	254	268	285	288	298	293	313	296
90	4	17	82	130	160	180	209	233	249	256	266	264	286	307	275	299
91			77	119	171	198	211	258	269	278	298	298	314	313		
92			99	116	156	210	229	234	266	304	303	279	333	349		

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