METHODS OF THE 1991 KAMISHAK HERRING STOCK PROJECTION

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Regional Information Report[1] No. 2H90-16
Alaska Department of Fish and Game
Division of Commercial Fisheries, Central Region
333 Raspberry Road
Anchorage, Alaska 99518-1599

October 1990

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ACKNOWLEDGMENTS

Steve Fried reviewed the manuscript and provided many valuable comments.

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ABSTRACT

A stock assessment of Pacific Herring (*Clupea harengus pallasi*) from the Kamishak and Southern District in Lower Cook Inlet for the year 1991 was done. Z′ was defined as the instantaneous change in annual abundance, i.e. the net effect of concurrent natural mortality and recruitment on the unharvested spawning biomass. Age-specific Z′ was estimated from moving averages. Z′ for age-6 was then calculated from the mean of age-5 and -7 Z′. Only positive Z′ values for herring age-7 and older were used in the moving average. Mean weight was predicted from a regression model.

In the Kamishak District, the dominant age groups were expected to be ages-4, -7, and -8. The 1991 biomass was projected to be 17,256 tons (15,655 tonnes). If a 10% harvest rate was adopted, the projected harvest would be 1,565 tons (1,420 tonnes).

In the Southern District, the dominant age groups are expected to be ages-4, -6, and -7. The 1991 biomass was projected to be 5,637 tons (5,114 tonnes). The current management plan limits the Southern District harvest to 150-200 tons (136-181 tonnes).

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

INTRODUCTION

Harvests of sac roe Pacific herring (*Clupea harengus pallasi*) occurred throughout the Lower Cook Inlet herring management area since 1961 with the exception of the Barren Islands District (Figure 1). The sac roe fishery in Lower Cook Inlet was closed between 1980 and 1984 due to low stock abundance. Kamishak District was reopened in 1985, the Eastern and Outer Districts between 1985 and 1988, and the Southern District in 1989. This report deals only with Kamishak and Southern District stocks.

The objectives of this report were to (1) explain how the 1991 Kamishak and Southern District herring stock assessments were done, (2) present the biomass forecast for 1991, and (3) discuss forecast accuracy.

METHODS

Forecasts presented in this report were based only on the biomass observed on the spawning grounds because harvest rates are based this information. The data needed for these forecasts were estimates of (1) catch and unharvested spawning biomass (escapement), including age composition and mean weights; (2) age-specific natural mortality and recruitment rates; and (3) weight-at-age or growth. Harvest projections were based on the current management strategy of 10% exploitation rate.

Catch and Spawning Biomass Estimates

Catch biomass were obtained from fish harvest ticket summaries, while spawning biomass were estimated from aerial surveys. Separate estimates were made for the early and late spawning biomass. The former is observed during the fishery while the latter is observed after the fishery. They do not share the same age composition because the younger herring tend to spawn about a month later than the older herring. Together the catch and spawning biomass are the herring that survived from the previous year's spawning population.

Age composition and weight data were obtained from either commercial or test fish purse seine catches. Age was determined from scale circuli counts. Annual mean weights were weighted by the catch and spawning biomass estimates (Yuen and Bucher in prep).

Herring catch, age composition, and mean weight data from the Kamishak District were available for 1973-1979, 1981, 1983, and 1985-1990. Spawning biomass estimates, however, were not available until 1978. Because 1) forecasts could not be made without an escapement estimate, 2) alternate year data could not be used to estimate mortality satisfactorily, and 3) herring younger than age 3 were not included in the forecast, only data from 1978 and 1979, and 1985 through 1990 for ages 3 through 16 were used to build the models (Tables 1 and 2).

Mortality and Recruitment Function

Mortality in this report was defined as natural mortality as opposed to fishing mortality or total mortality which is the sum of natural and fishing mortality. They are typically reported as M, F, and Z in the literature, respectively. In this report, we will be dealing with M, recruitment or R, defined below, and Z′ which we will define as the instantaneous rate of change in annual abundance, essentially the net effect of concurrent natural mortality (M) and recruitment (R) on the unharvested spawning biomass (i.e. escapement). M and R are both instantaneous rates. Z′ defined here is not F + M + U or the instantaneous rate of loss from a stock as defined in Ricker (1975). In this report,

$$Z'_{i-1} = - \ln(N_{i,t} / S_{i-1,t-1}) = M + R,$$

where N = total abundance (catch + escapement)
S = spawner abundance,
i = age, and
t = year.

We define recruitment as the addition of new herring to the spawning population as a result of sexual maturity. This spawning population is the target of the 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.

Wespestad (1982) assumed that participation in the inshore spawning migration coincided with sexual maturity and used the term availability (to the fishery) in place of recruitment. He also estimated percentage of recruitment from percentage of maturity for Togiak herring. Instead, we track, by year class, the abundance of herring over time and if we found on the average greater numbers of age-6 herring than of age-5 herring on the spawning grounds, then we would define the age-5 herring as 'not fully recruited'. The rate of change, Z′, will have a negative value. On the other hand, if we find on the average the numbers of age-10 herring less than the numbers of age-9 herring, then we would define the age-9 herring as 'fully recruited' as mortality now exceeds any further addition of herring to the fishery. The rate of change, Z′, will have a positive value. Thus, according to Figure 2, age 7 is the apparent age of full recruitment for Kamishak herring where an average of the six annual Z′ values would have changed from negative to positive.

Three age-specific Z′ models were tested: median, average, and moving average. For all three models, there were at least two steps:

1) Only positive Z′ values for herring age-7 and older were considered.
2) Either an age specific median, average or moving average of Z′ was calculated from the remaining data points where the only most recent half of the data set was used (e.g. 3-year moving average if six data points were available).

Many of the Kamishak age specific Z′s calculated from the 1990 data were on the higher end of the observed range of values (Figure 2). Z′ for some age classes, e.g. age 5 and 11, appeared to have increased annually. This was not surprising for the older age classes. They were not abundant and were expected to become difficult to find over time as they were removed by the fishery. Therefore, moving average, which gives more weight to the most recent data, was one of the models tested. The moving average model included a third step where

3) Age-6 Z′ was derived from the average of the age-5 and -7 values.

The curve of Z′ moving averages depicted a decreasing rate of change with age with an exception at age-6. The moving average Z′ for age-6 was -0.32, indicating recruitment in excess of mortality, a departure from the curve where Z′ for the two age classes on either side of age-6 were positive where mortality greater than recruitment. To smooth out the curve at age-6, Z′ was interpolated from the age-5 and -7 values (Figure 3).

The Z′ model with the least bias and error was used to forecast the 1991 Kamishak and Southern District herring biomass. To examine forecast accuracy and bias, a cross validation procedure was used to forecast of Kamishak stock sizes for 1979 and 1986 through 1990. In a cross validation, all data from the harvest year being forecast, e.g. 1979, was removed from the data file. A mortality and growth forecast model was then built from the remaining data, e.g. 1978 and 1986 through 1990. After a forecast was made, the data from the harvest year being forecast was returned to the file, e.g. 1979, and the next harvest year was removed from the file, e.g. 1987, not 1986 because there was no 1985 escapement from which to forecast the 1986 biomass. This cycle was repeated for each harvest year that was preceded by a year with escapement data.

Percent errors of the cross validated forecasts were calculated as

$$PE = (\text{forecast}-\text{observed})/\text{observed}.$$

These were used to obtain mean percent error:

$$MPE = \Sigma\ PE/n.$$

A positive MPE value means that the model tends to overforecast while a negative value means that 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. MPE will not provide an estimate of average error. Hence, mean absolute percent error was calculated as,

$$MAPE = \Sigma\ |PE|/n.$$

Because errors do not cancel out in the calculation of MAPE, MAPE will be always be larger than or equal to MPE.

Growth

Age-specific mean weights in year t were predicted from mean weight at data collected the previous year (t-1) and the multiple linear regression

$$weight_{i,t} = 51.95681 + 0.80805\ (age_{i-1,t-1}) + 0.79462\ (weight_{i-1,t-1}).$$

Regression coefficients were based on data collected in the Kamishak District between 1973 and 1990 for ages 2 to 16 (Figure 4, $r^2 = .92$, d.f. = 105).

Biomass Forecast

The forecast of apparent biomass was calculated as the product of predicted numbers of herring and their predicted mean weight:

$$Biomass_t = \Sigma\ N_{i,t}\ Weight_{i,t};$$

where $N_{i,t} = S_{i-1,t-1}\ e^{-(Mi-1+Ri-1)}$, and

$e = 2.7183$.

Harvest Projection

The Kamishak District total allowable harvest projection in this report was set at 10% of the biomass forecast for all age groups. The Shelikof Straits winter bait fishery projection for the fall of 1991 was equal to 1% of the biomass forecast. The actual bait fishery quota will be based on the total spawning biomass observed by aerial survey in the spring of 1991. 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.

The current management plan for the Southern District limits the harvest to 150-200 tons (136-181 tonnes).

Probability of Actual Biomass Deviating From the Forecast

The frequency distribution of the

biomass observed/biomass forecast from cross validation

ratio was used to estimate the probability that the 1991 biomass would exceed a given level. First, the ratios were assigned to one of 15 categories which range from 0.4 to 3.2 in 0.2 increments. Second, the frequency of occurrence in each category was expressed as a percentage of all cross validated forecasts.

Because, there were only 6 cross validated forecasts, percentages were in multiples of 1/6 or .17. Finally, the percentages were accumulated starting from the highest ratio category and proceeding to the smallest to obtain the cumulative probability of the 1991 biomass exceeding a given tonnage curve.

RESULTS

The moving average age specific Z′ model had the lowest MPE and MAPE and was used to forecast the 1991 herring biomass (Table 3). The effect of estimating Z′ as described above for the moving average model was a shift in the perceived age of full recruitment from age-7 to age-4 in addition to an increase in the age specific mortality rates. The Kamishak Z′ schedule for the older age classes was in closer agreement with the M schedule reported for Togiak than that reported for Prince William Sound (Table 4).

A biomass of 17,256 tons (15,655 tonnes) of herring is expected to return to the Kamishak District in 1991. Total allowable harvest was projected to be 1,726 tons (1,566 tonnes). The harvest allocation was 1,553 tons (1,409 tonnes) for the Kamishak spring sac roe fishery and 173 tons (157 tonnes) for the Shelikof Straits winter bait fishery (Table 5). Mean weight of individual herring should be 214 g. The age composition was forecasted to be 19% age-4, 27% age-7, and 22% age-8 from the 1987, 1984 and 1983 year classes respectively (Table 6).

A biomass of 5,637 tons (5,114 tonnes) of herring is expected to return to the Southern District in 1991. The current management plan for the Southern District limits the harvest to 150-200 tons (136-181 tonnes). Whether or not a fishery occurs in the Southern District during 1991 will be dependent on marketable roe recovery rates. Mean weight of individual herring should be a low 145 g because of 53% of the biomass was forecasted to be age-4. The remainder of the biomass was projected to be 15% age-6 and 19% age-7 (Table 7).

DISCUSSION

The abundance and biomass of Kamishak herring peaked in 1987. The decline in the Kamishak abundance and biomass is expected to continue in 1991, down about 13% from the 1990 levels (Figure 5).

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 4 and younger and 20% on age 5 and older. However, with the Kamishak stock projected to be down 50% from the 1987 level, a 10% harvest rate for all age groups is anticipated as a conservative management strategy unless the strength of the Kamishak stocks can be better assessed during the 1991 fishing season.

Last years model was based on median Z′ values. It forecast a biomass of 28,653 tons (26,048 tonnes). The 1990 observed biomass was considerably lower at 19,650 tons (17,826 tonnes). The moving average model used in this report will give more weight to the more recent data, i.e. this model increased the estimates instantaneous mortality. Cross validated moving average forecasts provides an estimate of the size of error to be expected as well as the bias of this model. The frequency distribution of actual/cross validated forecasts ratio indicated that the cross validated forecast were below the actual biomass observed for two thirds of the cases examined (Figure 6). Thus, the forecast error distribution is skewed, indicating a tendency to underforecast. There is a 67% chance that the 1991 biomass will exceed the 17,256 ton forecast presented in this report (Figure 8).

	Probability of 1991 Biomass Exceeding Tonnage in the Left Column
10,354	0.83
17,256	0.67
27,610	0.33
41,414	0.17

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Table 1. Kamishak abundance by age group and year of harvest used to derive Z', an instantaneous measure of concurrent mortality and recruitment, for Kamishak and Southern District herring stocks.

Yr (t)	Age (t)	Apparent Abundance	-Catch	=Spawning Abundance	Yr (t+1)	Age (t+1)	Apparent Abundance	Z'	Data Used In Model?[a]
78	2	180	60	120	79	3	4342	-3.59	
85	2	114	10	104	86	3	14547	-4.94	
86	2	51	4	47	87	3	40517	-6.76	Y
88	2	194	3	191	89	3	309	-0.48	Y
78	3	1161	388	773	79	4	4342	-1.73	
85	3	57	5	52	86	4	3030	-4.07	
86	3	14547	1096	13451	87	4	48332	-1.28	
87	3	40517	2328	38189	88	4	49514	-0.26	Y
88	3	9073	139	8934	89	4	5686	0.45	Y
89	3	309	3	306	90	4	10745	-3.56	Y
78	4	4235	1416	2819	79	5	8774	-1.14	
85	4	6679	568	6111	86	5	13637	-0.8	
86	4	3030	228	2802	87	5	3637	-0.26	
87	4	48332	3055	45277	88	5	27016	0.52	Y
88	4	49514	5526	43988	89	5	47239	-0.07	Y
89	4	5686	384	5302	90	5	7902	-0.4	Y
78	5	2632	880	1752	79	6	4975	-1.04	
85	5	8220	699	7521	86	6	11667	-0.44	
86	5	13637	1027	12610	87	6	25469	-0.7	
87	5	3637	478	3159	88	6	2838	0.11	Y
88	5	27016	5270	21746	89	6	26974	-0.22	Y
89	5	47239	7597	39642	90	6	29151	0.31	Y
78	6	261	87	174	79	7	271	-0.44	I
85	6	13243	1125	12118	86	7	21213	-0.56	I
86	6	11667	879	10788	87	7	19221	-0.58	I
87	6	25469	5106	20363	88	7	23837	-0.16	I
88	6	2838	601	2237	89	7	4940	-0.79	I
89	6	26974	4665	22309	90	7	22642	-0.01	I
78	7	311	104	207	79	8	633	-1.12	
85	7	8791	747	8044	86	8	16214	-0.7	
86	7	21213	1598	19615	87	8	18174	0.08	
87	7	19221	3625	15596	88	8	12314	0.24	Y
88	7	23837	5138	18699	89	8	14921	0.23	Y
89	7	4940	830	4110	90	8	4424	-0.07	Y
78	8	376	126	250	79	9	181	0.32	
85	8	14042	1193	12849	86	9	21264	-0.5	N
86	8	16214	1222	14992	87	9	10471	0.36	
87	8	18174	3745	14429	88	9	12435	0.15	Y
88	8	12314	2689	9625	89	9	8723	0.1	Y
89	8	14921	2778	12143	90	9	6444	0.63	Y
78	9	311	104	207	79	10	271	-0.27	N
85	9	5081	432	4649	86	10	8385	-0.59	N
86	9	21264	1602	19662	87	10	13713	0.36	
87	9	10471	2420	8051	88	10	5591	0.36	
88	9	12435	2735	9700	89	10	6082	0.47	Y
89	9	8723	1644	7079	90	10	4163	0.53	Y

-Continued-

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Yr (t)	Age (t)	Apparent Abundance	-Catch	=Spawning Abundance	Yr (t+1)	Age (t+1)	Apparent Abundance	Z'	Data Used In Model?[a]
85	10	2968	252	2716	86	11	3435	-0.23	N
86	10	8385	632	7753	87	11	5669	0.31	
87	10	13713	3147	10566	88	11	6756	0.45	Y
88	10	5591	1230	4361	89	11	4922	-0.12	N
89	10	6082	1158	4924	90	11	1870	0.97	Y
85	11	2398	204	2194	86	12	2576	-0.16	N
86	11	3435	259	3176	87	12	2309	0.32	
87	11	5669	1371	4298	88	12	2160	0.69	
88	11	6756	1488	5268	89	12	3486	0.41	Y
89	11	4922	943	3979	90	12	882	1.51	Y
85	12	571	49	522	86	13	808	-0.44	N
86	12	2576	194	2382	87	13	1861	0.25	
87	12	2309	580	1729	88	13	761	0.82	
88	12	2160	475	1685	89	13	1419	0.17	Y
89	12	3486	675	2811	90	13	503	1.72	Y
86	13	808	61	747	87	14	439	0.53	
87	13	1861	432	1429	88	14	284	1.62	
88	13	761	166	595	89	14	124	1.57	Y
89	13	1419	271	1148	90	14	198	1.76	Y
86	14	101	8	93	87	15	73	0.24	
87	14	439	110	329	88	15	64	1.64	Y
88	14	284	63	221	89	15	428	-0.66	N
89	14	124	30	94	90	15	119	-0.24	N
89	15	428	75	353	90	16	77	1.52	Y

[a] N = -Z not used if older than age-7.
I = Age-6 Z' = -0.32 not used. Instead interpolate between age-5 and age-7 to obtain Z' = 0.10.
Y = Moving average of most recent half of data set.

Table 2. Kamishak mean weight by age group and year of harvest used to derive regression of $weight_{t+1}$ on age_t and mean $weight_t$.

Harvest Year	Age (t)	Wt	Age (t+1)	Wt
77	2	45	3	62
78	2	18	3	73
85	2	48	3	89
88	2	15	3	68
73	3	91	4	115
74	3	86	4	59
75	3	63	4	95
76	3	66	4	97
77	3	62	4	88
78	3	62	4	105
85	3	80	4	107
86	3	89	4	123
87	3	81	4	118
88	3	78	4	115
89	3	68	4	134
73	4	105	5	139
74	4	115	5	102
75	4	59	5	127
76	4	95	5	113
77	4	97	5	118
78	4	88	5	130
85	4	125	5	155
86	4	107	5	157
87	4	123	5	160
88	4	118	5	154
89	4	115	5	160
73	5	122	6	162
74	5	139	6	137
75	5	102	6	147
76	5	127	6	154
77	5	113	6	166
78	5	118	6	159
85	5	155	6	188
86	5	155	6	193
87	5	157	6	195
88	5	160	6	196
89	5	154	6	180
73	6	139	7	178
74	6	162	7	160
75	6	137	7	176
76	6	147	7	173
77	6	154	7	154
78	6	166	7	187
85	6	182	7	215
86	6	188	7	210
87	6	193	7	216
88	6	195	7	223
89	6	196	7	209
73	7	170	8	195
74	7	178	8	173
75	7	160	8	195
76	7	176	8	200
77	7	173	8	189

-Continued-

Table 2. (page 2 of 2)

Harvest Year	Age (t)	Wt	Age (t+1)	Wt
78	7	154	8	222
85	7	205	8	232
86	7	215	8	235
87	7	210	8	235
88	7	216	8	244
89	7	223	8	230
73	8	190	9	212
74	8	195	9	200
75	8	173	9	209
76	8	195	9	212
77	8	200	9	205
78	8	189	9	200
85	8	219	9	248
86	8	232	9	248
87	8	235	9	248
88	8	235	9	254
89	8	244	9	246
73	9	187	10	271
74	9	212	10	226
75	9	200	10	219
76	9	209	10	222
77	9	212	10	216
78	9	205	10	245
85	9	238	10	261
86	9	248	10	264
87	9	248	10	260
88	9	248	10	266
89	9	254	10	257
74	10	271	11	236
75	10	226	11	247
77	10	222	11	200
85	10	246	11	271
86	10	261	11	273
87	10	264	11	262
88	10	260	11	285
89	10	266	11	268
75	11	236	12	229
85	11	255	12	277
86	11	271	12	272
87	11	273	12	280
88	11	262	12	288
89	11	285	12	265
85	12	275	13	287
86	12	277	13	286
87	12	272	13	287
88	12	280	13	298
89	12	288	13	273
86	13	287	14	280
87	13	286	14	262
88	13	287	14	292
89	13	298	14	301
86	14	295	15	270
87	14	280	15	282
88	14	262	15	303
89	14	292	15	253

Table 3. Kamishak jackknifed forecast results.

Year	Biomass (Tons)	Jackknife Forecast			Absolute % Error		
		Median	Average	Mov Avg	Median	Average	Mov Avg
79	3,315	1,521	1,658	1,120	0.54	0.50	0.66
86	26,001	12,403	13,212	12,031	0.52	0.49	0.54
87	35,332	48,444	39,745	26,709	0.37	0.12	0.24
88	29,548	104,477	105,477	82,283	2.54	2.57	1.78
89	35,701	39,296	40,131	27,216	0.10	0.12	0.24
90	19,650	28,653	30,315	27,316	0.46	0.54	0.39

	Biomass (Tonnes)	Jackknife Forecast			% Error		
		Median	Average	Mov Avg	Median	Average	Mov Avg
79	3,007	1,380	1,504	1,016	-0.54	-0.50	-0.66
86	23,588	11,252	11,986	10,914	-0.52	-0.49	-0.54
87	32,053	43,948	36,056	24,230	0.37	0.12	-0.24
88	26,806	94,781	95,688	74,647	2.54	2.57	1.78
89	32,388	35,649	36,407	24,690	0.10	0.12	-0.24
90	17,826	25,994	27,502	24,781	0.46	0.54	0.39
Mean % Error					0.40	0.39	0.08
Mean Absolute % Error					0.75	0.73	0.64
Greatest Absolute % Error					2.54	1.60	1.34

Table 4. Comparison of Kamishak Z′ with Togiak and Prince William Sound M schedules[a].

Age	Kamishak Z′	Togiak M	Prince William Sound M
2	-2.71	0.103	0.343
3	-1.12	0.103	0.343
4	0.01	0.103	0.343
5	0.07	0.103	0.343
6	0.10	0.103	0.344
7	0.13	0.226	0.365
8	0.29	0.348	0.450
9	0.50	0.471	0.667
10	0.70	0.593	1.108
11	0.97	0.715	1.887
12	0.95	0.838	3.139
13	1.66	0.960	5.020
14	1.64	1.083	
15	1.52		

[a] Funk and Savikko 1990

Table 5. Harvest allocation of 1991 Kamishak herring spawning biomass (tons).

	Biomass	Allocation	Harvest
Total Biomass	17,256		
Total Allowable Harvest		10%	1,726
Shelikof Bait Fishery		1%	- 173
Remaining Allowable Harvest for Sac Roe Fishery			1,553

Table 6. Forecast of 1991 Kamishak District herring abundance and projected harvest.

Age	1990 Escapement (x1,000)	Recruit & Mortality Z'	1991 Population (x1,000)	Mean Wt (g)	1991 Biomass (tons)	Fraction by No.	Harvest Rate	1991 Harvest	Fraction by Wt.
2	6	-2.71							
3	5,048	-1.12	90	67	7	0.00	0.10	1	0.00
4	10,387	0.01	15,471	124	2,115	0.19	0.10	211	0.12
5	7,274	0.07	10,284	162	1,836	0.13	0.10	184	0.11
6	24,794	0.10	6,782	183	1,368	0.08	0.10	137	0.08
7	20,327	0.13	22,435	200	4,946	0.27	0.10	495	0.29
8	3,787	0.29	17,849	224	4,407	0.22	0.10	441	0.26
9	5,658	0.50	2,834	241	753	0.03	0.10	75	0.04
10	3,714	0.70	3,432	255	965	0.04	0.10	96	0.06
11	1,679	0.97	1,844	264	537	0.02	0.10	54	0.03
12	783	0.95	636	274	192	0.01	0.10	19	0.01
13	476	1.66	303	272	91	0.00	0.10	9	0.01
14	186	1.64	91	279	28	0.00	0.10	3	0.00
15			36	302	12	0.00	0.10	1	0.00
	84,113		82,087	214	17,256			1,726	

Table 7. Forecast of 1991 Southern District herring abundance and projected harvest.

Age	1990 Escapement (x1,000)	Recruit & Mortality Z'	1991 Population (x1,000)	Mean Wt (g)	1991 Biomass (tons)	Fraction by No.	Harvest Rate	1991 Harvest	Fraction by Wt.
2	4	-2.71							
3	6671	-1.12	60	72	5	0.00	0.03	0	0.00
4	2672	0.01	20,446	113	2,551	0.53	0.03	82	0.05
5	6422	0.07	2,645	151	441	0.07	0.03	14	0.01
6	8170	0.10	5,988	171	1,130	0.15	0.03	36	0.02
7	1408	0.13	7,393	185	1,505	0.19	0.03	48	0.03
8	608	0.29	1,236	210	286	0.03	0.03	9	0.01
9	477	0.50	455	225	113	0.01	0.03	4	0.00
10	458	0.70	289	238	76	0.01	0.03	2	0.00
11	273	0.97	227	243	61	0.01	0.03	2	0.00
12	145	0.95	103	257	29	0.00	0.03	1	0.00
13	3	1.66	56	258	16	0.00	0.03	1	0.00
14	0	1.64	1	286	0	0.00	0.03	0	0.00
15			0	292	0	0.00	0.03	0	0.00
	27,311		38,900	160	6,214			200	

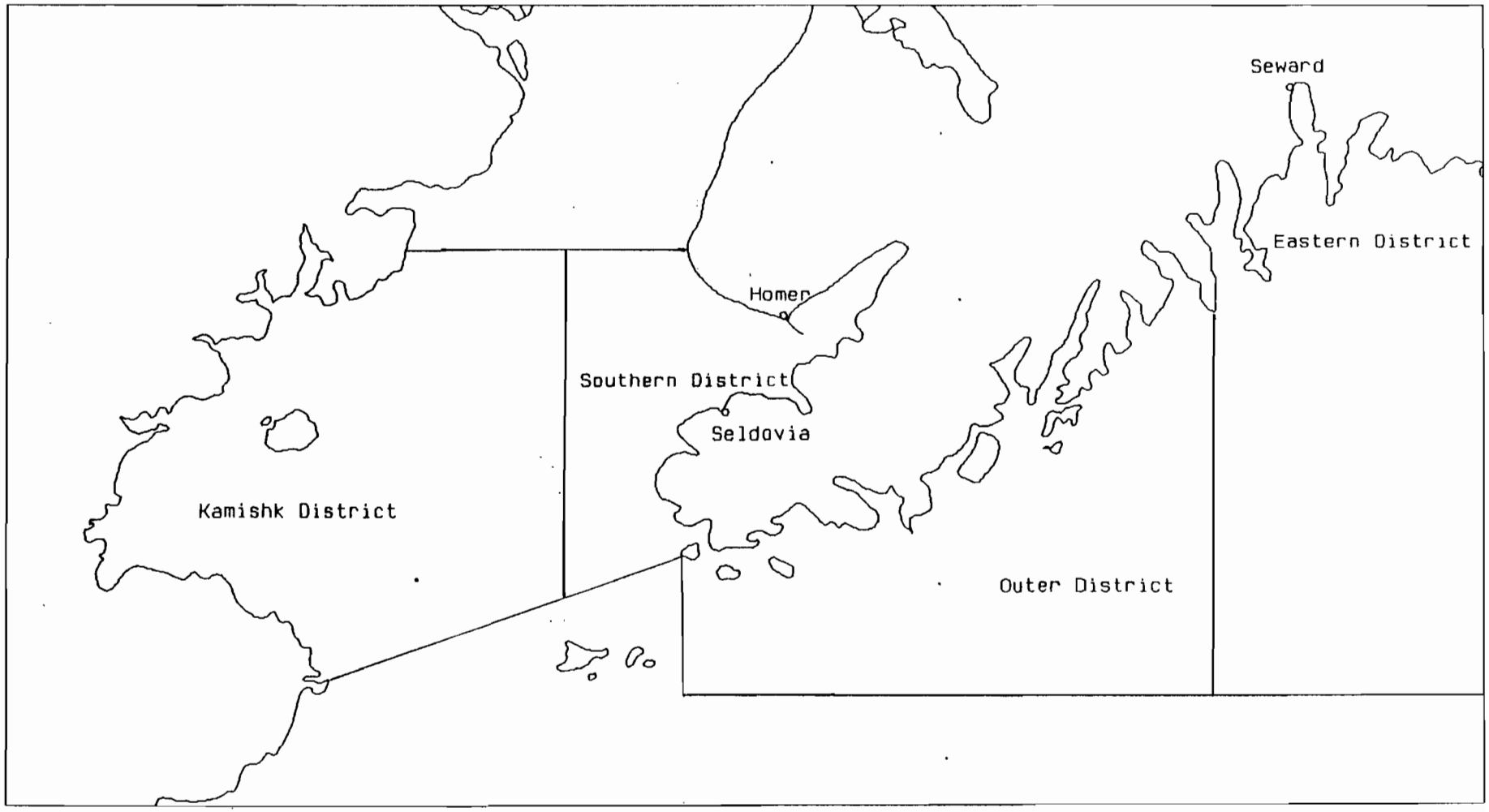
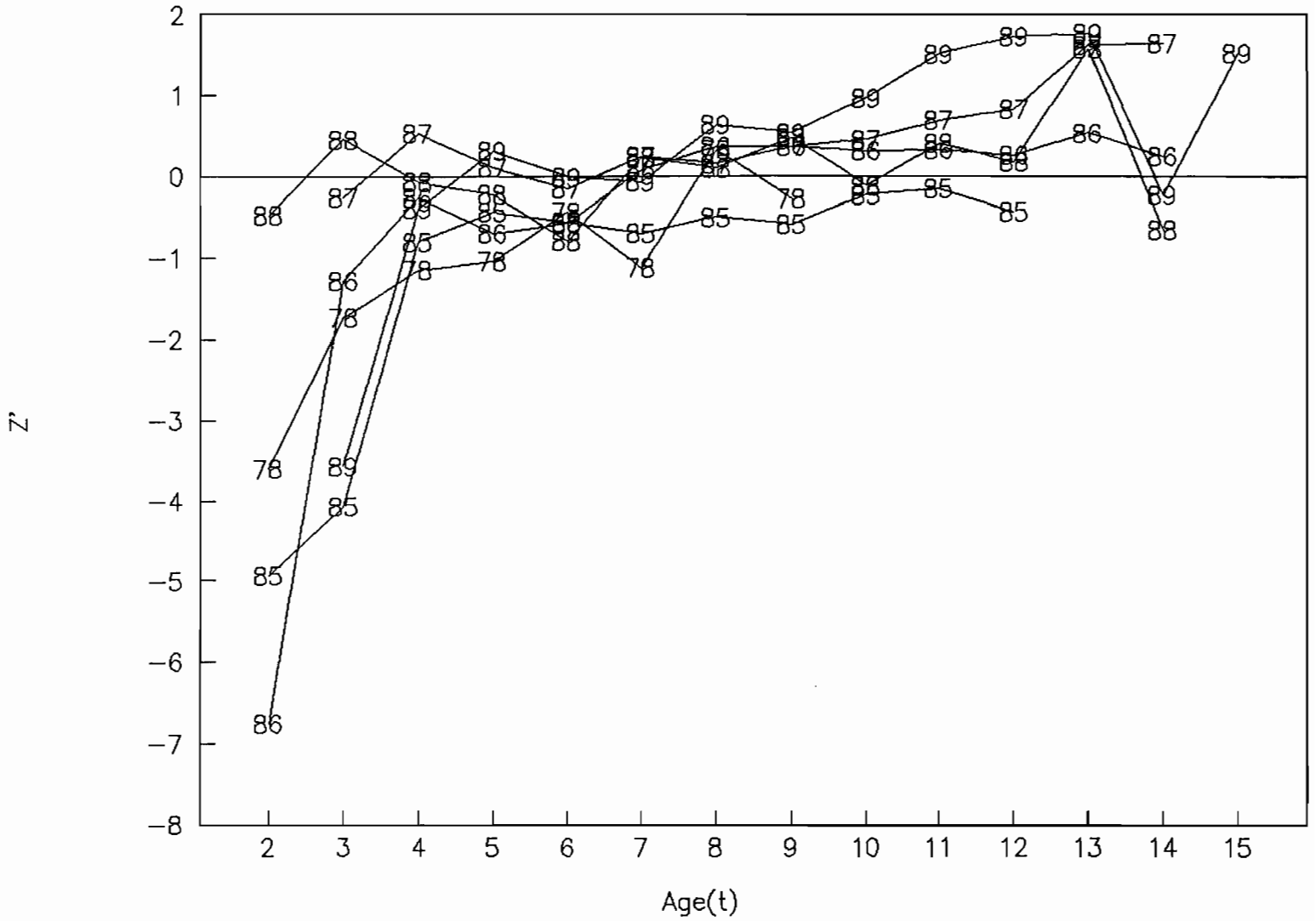
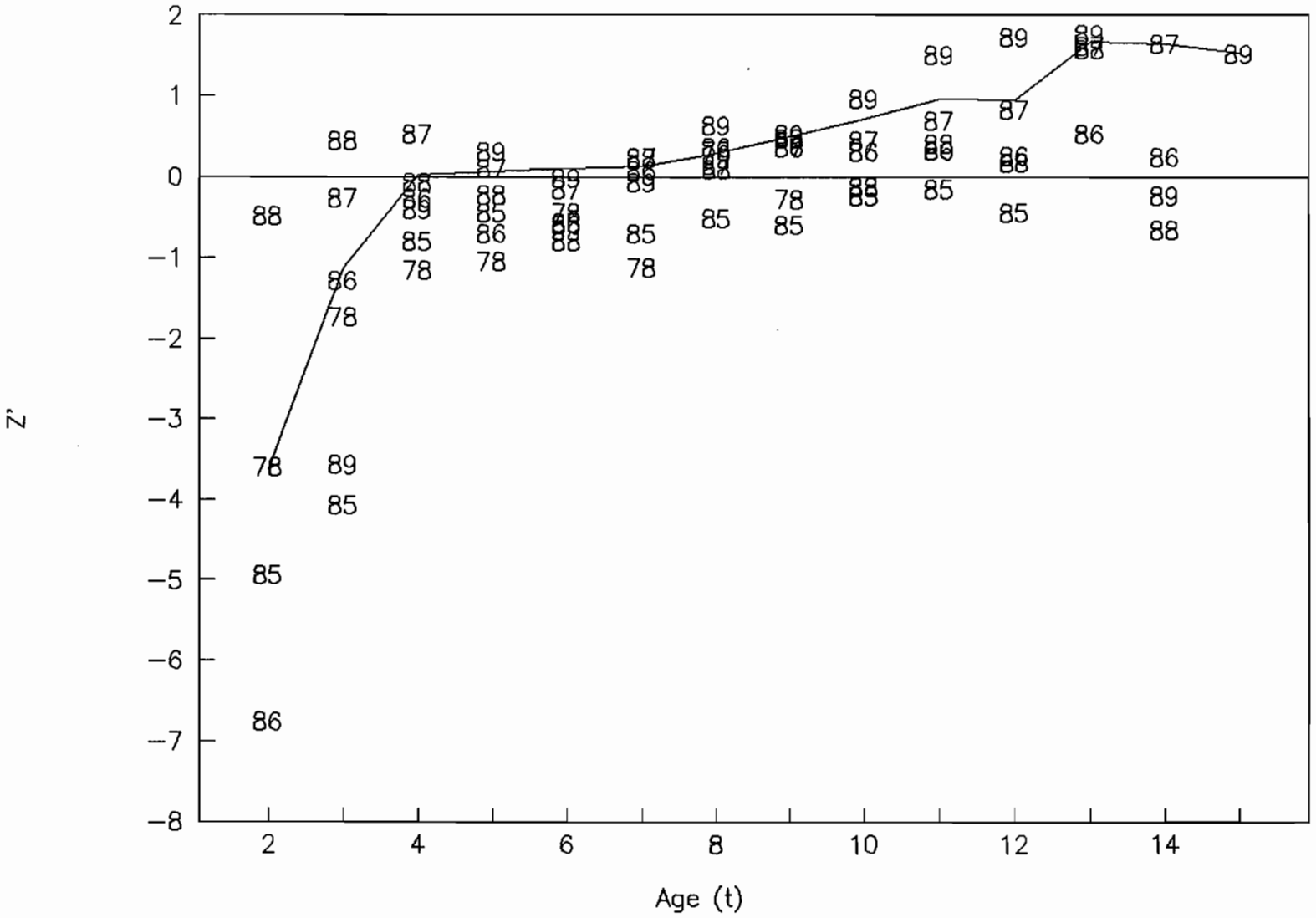


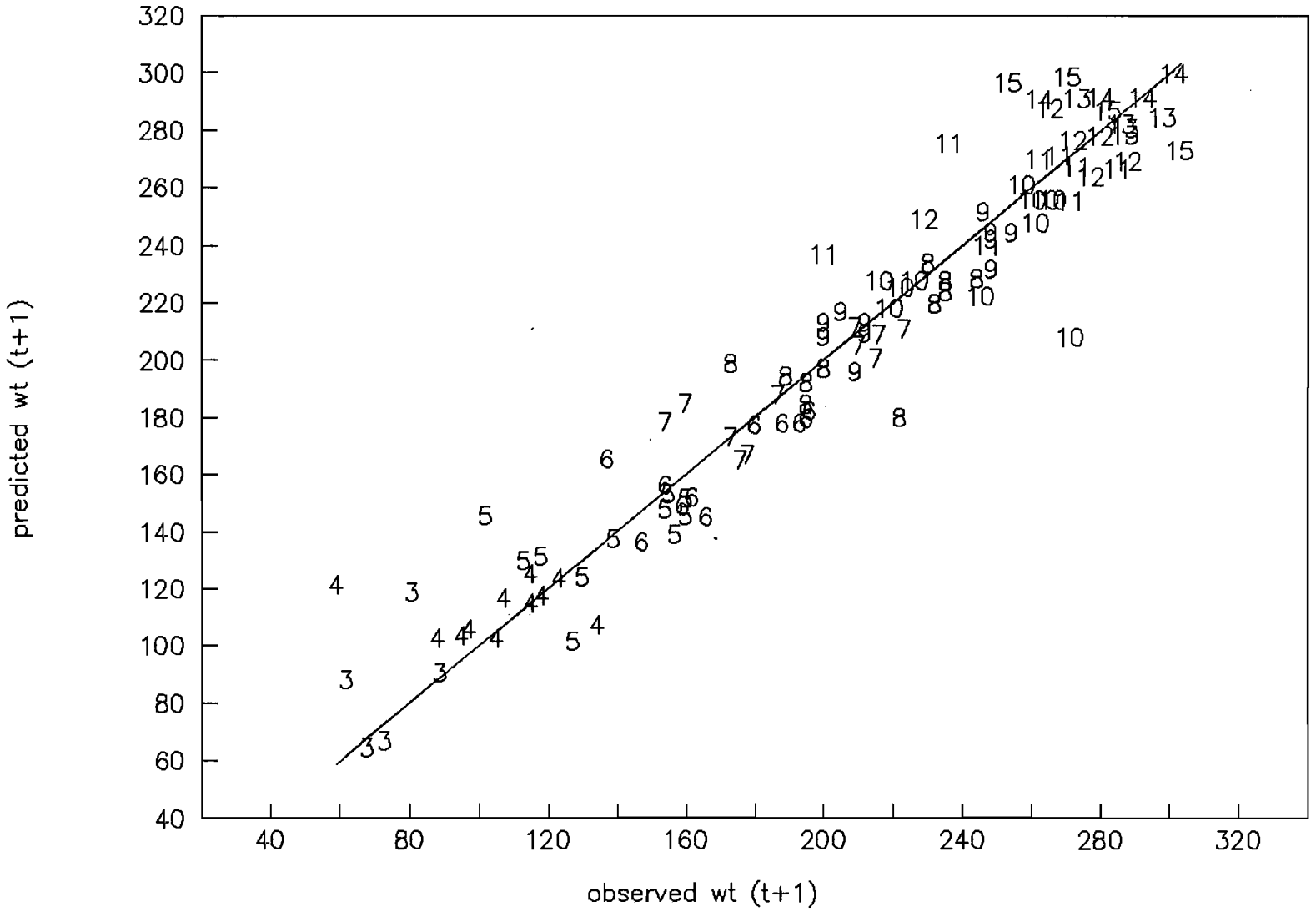
Figure 1. Kamishak, Southern, Outer, and Eastern Districts of Lower Cook Inlet Management Area.



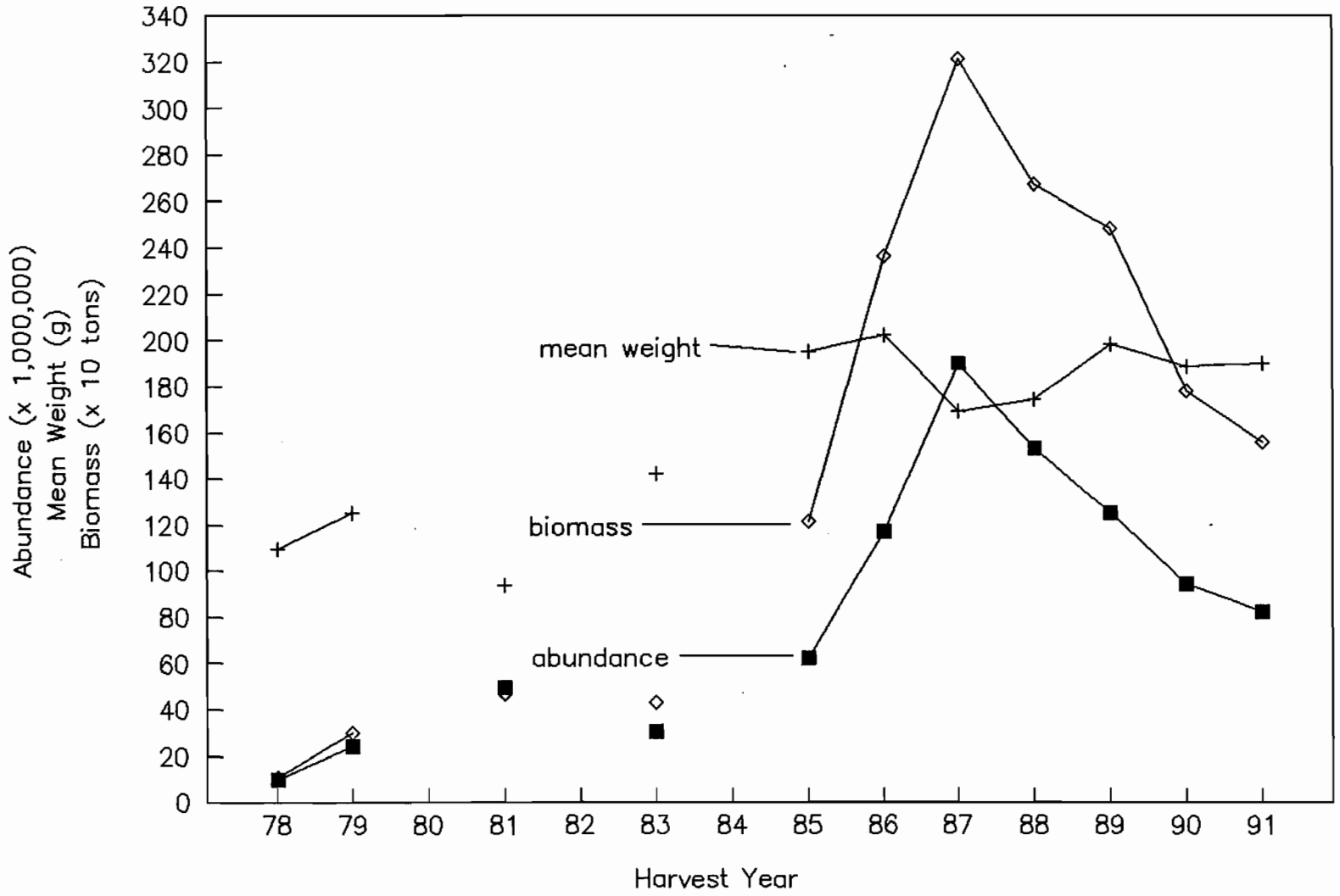
2. Kamishak age specific Z′ by harvest year.



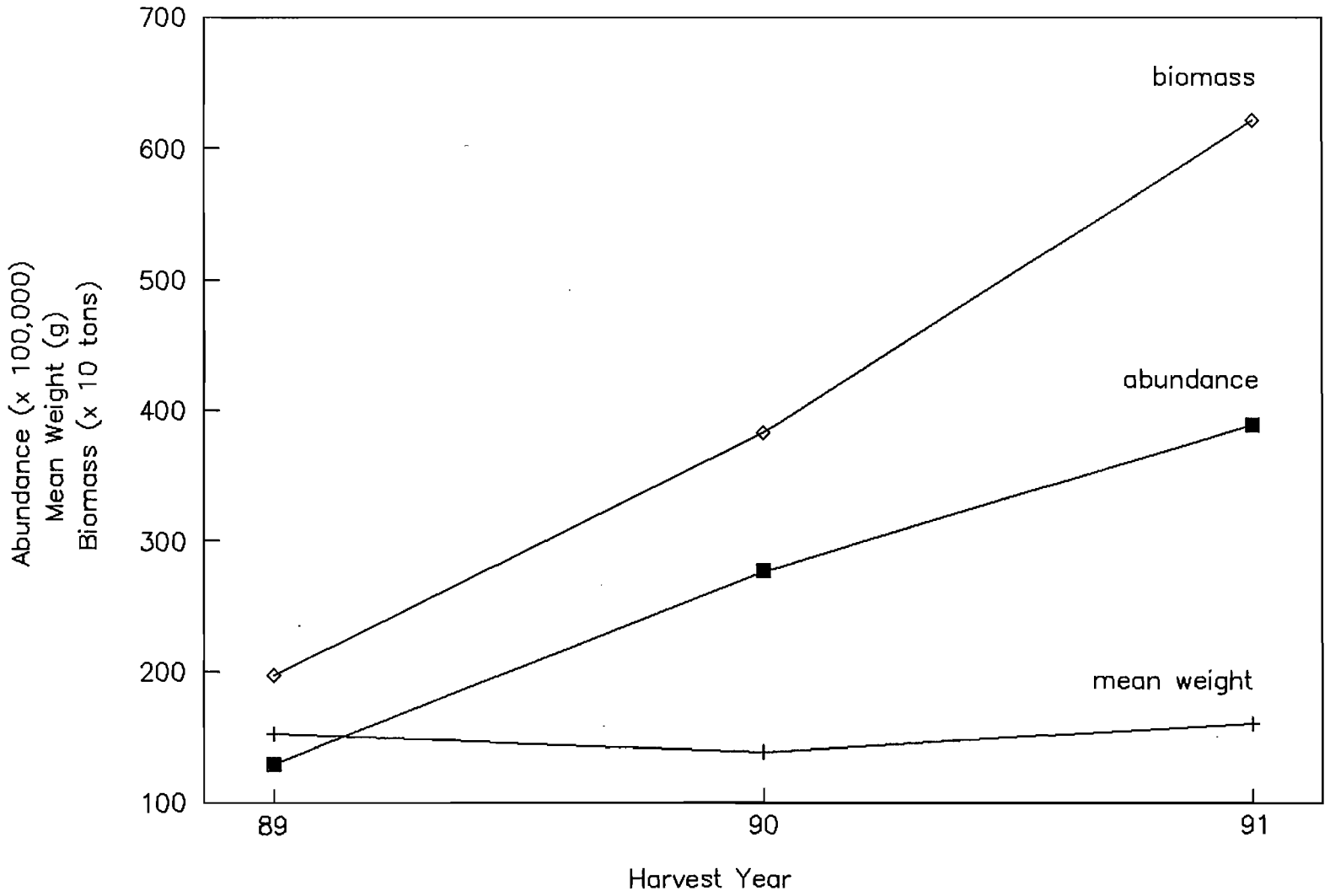
3. Kamishak observed Z′ and moving averages by age.



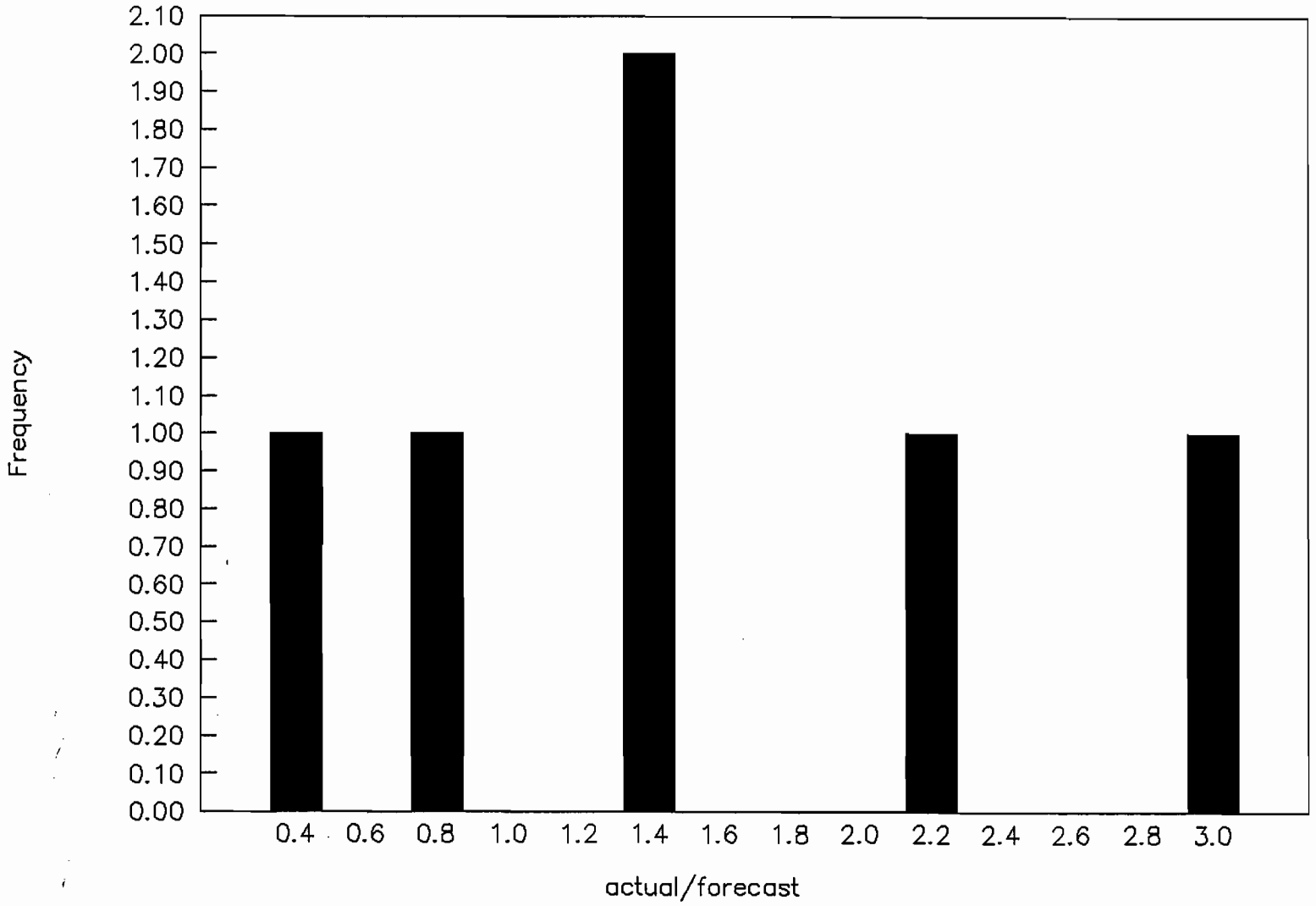
4. Kamishak observed $weight_{t+1}$ and $weight_{t+1}$ predicted from $weight_t$ and age_t.



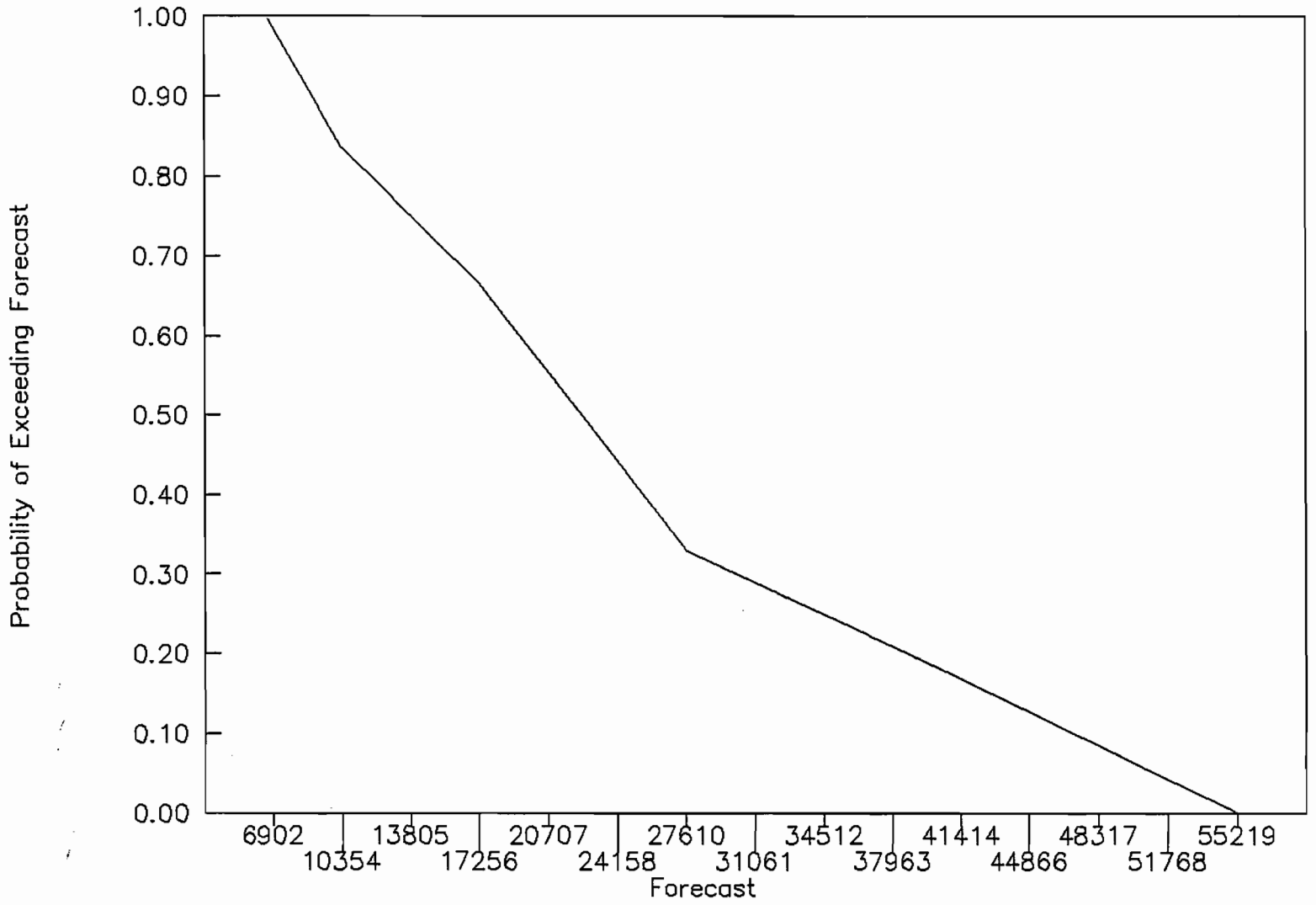
5. Kamishak District herring abundance, mean weight, and biomass by year.



6. Southern District herring abundance, mean weight, and biomass by year.



7. Frequency distribution of actual:cross validated forecast ratios for Kamishak herring.



8. Probability of 1991 Kamishak herring biomass exceeding given tonnage.