

2A89-01

FORECAST OF THE PACIFIC HERRING BIOMASS  
IN PRINCE WILLIAM SOUND, 1989

By

Linda K. Brannian

Regional Information Report <sup>1</sup>/<sub>1</sub> No. 2A89-01

Alaska Department of Fish and Game  
Division of Commercial Fisheries  
Region II  
333 Raspberry Rd  
Anchorage, Alaska 99518

January 1989

<sup>1</sup>/<sub>1</sub> Contribution 89-01 from the Prince William Sound area. The Regional Information Report Series was established in 1988 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate needs for up-to-date information, reports in this series may contain preliminary data.

ACE 6238696/c

## AUTHORS

Linda K. Brannian is Region II Regional Biometrician for the Alaska Department of Fish and Game, Division of Commercial Fisheries, 333 Raspberry Rd., Anchorage Alaska 99518.

## ACKNOWLEDGEMENTS

Many people contributed toward the collection and processing of herring age, size, sex, and abundance data used in the report. In particular I would like to acknowledge Gene Sandone who in developing the 1988 forecast prepared the template for the spreadsheets and text used in 1989. I would also like to acknowledge James Brady for collecting and summarizing the aerial survey data, Evelyn Biggs for contributing the spawning biomass estimate from the spawn deposition survey, and Drew Crawford and Sam Sharr for collecting, processing, and summarizing herring age, sex, and size data.

TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES . . . . .	iv
LIST OF FIGURES . . . . .	iv
LIST OF APPENDICES . . . . .	v
ABSTRACT . . . . .	vii
INTRODUCTION . . . . .	1
METHODS . . . . .	1
RESULTS . . . . .	3
LITERATURE CITED . . . . .	5
APPENDICES . . . . .	14

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1.	Prince William Sound District year class composition of the 1988 Pacific herring harvest, escapement, and total run biomass and the 1989 projected biomass. Natural mortality rate (M) at age 8 = 0.45 . . . . .	6
2.	Prince William Sound District projection of the 1989 Pacific herring biomass with natural mortality at age 8 = 0.45 . . . . .	7

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1.	Prince William Sound herring biomass from aerial surveys (line), spawn surveys (crosses), and an index of abundance as mile-days of spawn (diamonds). The 1989 biomass (triangle) was projected from the spawn survey estimate . . . . .	8
2.	Historical year class strength of Prince William Sound herring in number of 4-year-old fish. . . . .	9
3.	Age composition of the Prince William Sound herring population in 1988 compared to that projected from 1987. . . . .	10
4.	Age composition by weight of the Prince William Sound herring biomass in 1988 compared to that projected from 1987 . . . . .	11
5.	Age composition of the Prince William Sound herring population in 1988 and projected for 1989 . . . . .	12
6.	Age composition by weight of the estimated 1989 biomass of Prince William Sound herring . . . . .	13

LIST OF APPENDICES

	<u>Page</u>
APPENDIX A: COMMERCIAL HERRING HARVEST BY GEAR TYPE	
A.1 - Prince William Sound commercial purse seine harvest by age and year class, April 21, 1988 . . . . .	14
A.2 - Prince William Sound commercial purse seine harvest by age and year class, April 22, 1988 . . . . .	15
A.3 - Prince William Sound commercial purse seine harvest by age and year class, 1988 . . . . .	16
A.4 - Prince William Sound commercial gill net harvest by age and year class, 1988 . . . . .	17
A.5 - Prince William Sound commercial purse seine pound harvest by age and year class, 1988 . . . . .	18
APPENDIX B: HERRING BIOMASS DISTRIBUTION BY AGE AND STRATUM	
B.1 - Prince William Sound herring biomass distribution by age and year class, Montague Island, 1988. --- Biomass estimated from spawn deposition survey in this area . . . . .	19
B.2 - Prince William Sound herring biomass distribution by age and year class, Valdez Area, 1988. Biomass estimated from spawn deposition survey in this area . . . . .	20
B.3 - Prince William Sound herring biomass distribution by age and year class, North Shore Area, 1988. Biomass estimated from spawn deposition survey in this area . . . . .	21
B.4 - Prince William Sound herring biomass distribution by age and year class, Naked Island, 1988. Biomass estimated from spawn deposition survey in this area . . . . .	22
B.5 - Prince William Sound herring biomass distribution by age and year class which contributed roe for the wild spawn-on-kelp harvest in the Valdez Arm, 1988 .	23
B.6 - Prince William Sound herring biomass distribution by age and year class which contributed roe for the wild spawn-on-kelp harvest in the Fairmount Bay area, 1988 . . . . .	24

LIST OF APPENDICES (Continued)

	<u>Page</u>
APPENDIX C: 1988 PRINCE WILLIAM SOUND HERRING BIOMASS PROJECTION	
C.1 - Prince William Sound 1989 herring projection biomass spreadsheet; Natural Mortality at age 8 = 0.3 . . . . .	25
C.2 - Prince William Sound 1989 herring projection biomass spreadsheet; Natural Mortality at age 8 = 0.6 . . . . .	26

## ABSTRACT

The 1988 Prince William Sound spawning migration of Pacific herring (*Clupea harengus pallasii*) was 524 million herring weighing 58,621 short tons. An estimated 48,812 tons escaped harvest to spawn. The 1988 escapement biomass was projected forward one year to represent the 1989 spawning biomass adjusting for growth, mortality, and recruitment. The 1989 spawning biomass of herring in Prince William Sound is projected to be 54,899 short tons with an individual size of 127 grams per fish. The recommended total allowable harvest is 10,980 tons and represents 20% of the forecasted biomass. Following the management plan the allocations would be 1,400 tons for the food and bait fishery, 824 tons for the natural spawn-on-kelp fishery, 1,063 tons for the pound spawn-on-kelp fishery, 7,270 for the seine sac roe fishery, and 423 tons for the gill net sac roe fishery. This translates into 103 and 85 tons of product, respectively, for the natural spawn-on-kelp and pound spawn-on-kelp fisheries.

KEY WORDS: Forecast, Pacific herring, spawning biomass, projection

## INTRODUCTION

The Prince William Sound herring stock is defined as those Pacific herring (*Clupea harengus pallasii*) populations that spawn within coastal waters between Point Whitt and Cape Fairfield. Spawning is wide spread throughout the area and takes place between mid April and early May.

Beginning in late March, Department staff survey the coastline of Prince William Sound twice weekly from small aircraft until a significant biomass of herring is observed. Daily surveys are then conducted to assess the accumulation of herring biomass, its distribution, and map observed miles of spawn. Following spawning, Department SCUBA divers estimate the average density of spawn deposition and the total spawning biomass is back calculated from total number of eggs observed, mean fish weight, fecundity, and sex ratio.

In Prince William Sound, there are three independent estimates or indices of herring biomass (Figure 1) (Brady 1987). Aerial survey estimates of herring biomass date back to 1974 and have ranged from 1,321 tons in 1975, an estimate thought to be low due to poor visibility, to 51,090 tons in 1981. Mapped mile-days of spawn date back to 1978 and have ranged from 36.3 (1978) to 236.9 (1988) mile-days. Spawn deposition surveys were conducted in 1983-84 and 1988. A spawning biomass of 58,581 tons was estimated in 1988, 1.7 times the aerial survey estimate of 34,270 tons of herring. A similar relationship existed between 1984 spawn deposition and aerial survey estimates.

The purpose of this report is to present a Prince William Sound herring biomass projection for the 1989 spring spawning migration and the resulting harvest guidelines.

## METHODS

The 1989 Prince William Sound herring biomass was projected from the 1988 unharvested spawning biomass, adjusting for growth, mortality, and recruitment. During the 1988 spawning migration, the age structure of the population varied through time and by area. Consequently, in order to more precisely estimate the contribution of each year class to the total run area-specific biomass estimates were associated with individual, or sets of herring age, weight, and length (AWL) samples obtained from non-selective gear. Non-selective gear types included purse seines and beach seines. The 1988 herring AWL sample summaries will be published later as a Technical Fisheries Report.

Prince William Sound was divided into 4 strata and the spawn deposition survey was designed to estimate the unharvested spawning biomass in each (Biggs and Funk 1989). Biomass estimates were proportioned to number at age using the corresponding AWL samples collected in each stratum and indicated by Biggs and Funk (1988).

The 1988 escapement or unharvested biomass was the sum of the spawn survey biomass estimates for each stratum and an estimate of the herring which contributed roe to the natural spawn-on-kelp harvest. The biomass which contributed to this removal was not accounted for in the spawn deposition survey nor was there any fishery induced mortality. Natural spawn-on-kelp associated herring biomass was back-calculated from the sold product as 8.0 short tons of herring per ton of spawn-on-kelp.

In 1988 removals of Pacific herring from Prince William Sound included harvests in the purse seine and gill net sac roe fisheries and fishery induced mortality resulting from impounding herring. Catch data were thought to be final and represent figures summarized from the fish ticket database residing in the Cordova Area office. AWL samples were collected each fishing period and from several pounds. The age structure was estimated as the sum of the catch-at-age from each commercial fishing period and total pound mortality. The total inshore spawning migration in 1988 was the sum of catch (all removals) and escapement.

Age-specific instantaneous rates of natural mortality (M) were used to project the annual survival of the escapement biomass. Direct estimates of natural mortality rates, however, were not available for Prince William Sound herring. Therefore, a range of age-specific mortality rates were employed in the projection calculations. These natural mortality rates represent the range of rates used by Funk and Sandone (*In press*) in their assessment of Prince William Sound herring using cohort analysis. These age-specific schedules are identified by the mortality rate assigned to age-8 herring (age interval 8-9). The mortality schedules used in this report were M at age-8 of 0.3, 0.45, and 0.6.

Age-specific instantaneous growth rates (G) were based on herring weight at age calculated from a weight-age relationship using 1973-87 Prince William Sound herring data (Funk and Sandone *In press*). The availability (A) of a cohort at age (Funk and Sandone *In press*) was used to estimate that portion of the total cohort biomass which was expected to contribute to the spawning biomass. Availability was defined as that portion of the total cohort which was on the spawning grounds during the spring harvest period.

The 1988 escapement biomass was projected forward in time one year to represent the 1989 spawning biomass as follows:

$$B_{1989,t+1} = E_{1988,t} e^{(G-M)} A_{1989,t+1} / A_{1988,t}$$

where:

- $B_{1989,t+1}$  = 1989 projected biomass for age  $t+1$   
 $E_{1988,t}$  = 1988 escapement biomass for age  $t$ ,  
 $A_{1989,t+1}$  = Availability in 1989 of age  $t+1$ , and  
 $A_{1988,t}$  = Availability in 1988 of age  $t$   
 $G$  = Instantaneous rate of growth for age  $t$   
 $M$  = Instantaneous rate of natural mortality for  
age  $t$

The total 1989 projected biomass was determined by summing the age-specific biomass projections. A minimal projected biomass of age-3 herring for the 1989 spawning migration was estimated by substituting the relationship between availability of age-4 to age-3 herring for the unavailable age-3 to age-2 availability relationship. The availability of age-2 herring was not estimated but was considered less than the availability of age-3 herring. Since the actual age-4 to age-3 herring availability relationship was most likely smaller than the age-3 to age-2 relationship, the projection of age-3 herring was considered a minimal estimate.

## RESULTS

In 1988, age distribution was estimated from herring collected during each commercial fishing period and during the period seining of herring for introduction into pounds was allowed (Appendices A.1-A.5). Herring were also collected in areas of significant biomass accumulation throughout Prince William Sound in order to describe the age structure of the unharvested spawning biomass (Appendices B.1-B.6). Either, volunteered commercial or departmental vessels made multiple purse seine sets to capture herring from March 30 through April 24. A total of 7,834 herring were weighed, measured, and aged.

Year class strength as 4-year-old fish has been estimated for 1969-84 using catch-at-age analysis (Figure 2). Year class strength has ranged from 463 million herring from spawning in 1976 to 13 million from spawning in 1973. Age-4 herring from the 1984 year class represented 81% of the total number of herring in the 1988 spawning population. This level of abundance has not been seen since the 1976 year class.

The 1988 Prince William Sound spawning migration consisted of 524 million herring weighing 58,621 tons (Table 1). An estimated 48,812 tons escaped harvest to spawn. This was greater than the projected inshore return of 43,992 tons (Sandone 1988). The 4-year old return was twice the number predicted with fewer age-7 and -8 fish surviving (Figure 3). The greatest difference between forecasted biomass and the actual return was also in age-4 herring (Figure

4).

A schedule of increasing natural mortality with age where M of 0.45 at age 8 was used (Table 2) to project the 1989 population. Projection of the 1989 spawning biomass was also done using natural mortality schedules of 0.3 and 0.6 at age 8 (Appendix C.1 and C.2). The schedule using M of 0.45 at age 8 was chosen for publication in the 1989 statewide herring forecast. All further discussion will be based on this forecast (Table 2).

It is theorized that 100% of a year class does not spawn until age 7. Estimates of the proportion of an age class who spawn and therefore are available for harvest range from 22% of the age-3 fish to 88% of the age-6 fish. Projection of the younger ages (3-4 years) which are not fully recruited are difficult as few age 2 or 3 fish were detected in the Department's 1988 sampling program.

The 1989 spawning biomass of herring in Prince William Sound is projected to be 54,899 tons. An estimated 84.3% of the total number of fish will be age 5 in 1989 with minor numbers of age 4 through 9 (Figure 5). The average size of an individual is expected to be 127 grams. An estimated 82.1% of the biomass will be age 5 with a forecast of 124 grams per individual (Figure 6). Potentially this describes the age and weight composition of the purse seine harvest though the Department tries to capitalize on time and area differences in age composition if they exist to harvest older fish. In 1988, the Prince William Sound harvest was 61.5% age 4 by weight compared to 73.5% by weight for the total population. Due to mesh size selectivity, few age 3 to 5 year-old fish were captured by the gill net fleet and in 1988 the gill net harvest was only 4.4% age 3-5 by weight.

Guideline harvest levels are set by the Board of Fisheries in accordance with the Prince William Sound herring management plan, last revised in 1986 (5AAC27.360). All fisheries will be managed on a guideline harvest level of 0-20% overall exploitation rate of the estimated spawning biomass. If the harvestable surplus is above 8,500 tons the winter food and bait fishery is allocated 1,400 tons, the natural spawn-on-kelp fishery 824 tons, and the pound spawn-on-kelp fishery 1,063 tons of herring. The remaining harvestable surplus is then divided between the sac roe fisheries, with 94.5% allocated the purse seine fishery and 5.5% to the gill net fishery.

In 1989 the recommended total allowable harvest is 10,980 tons and represents 20% of the forecasted biomass. Following the management plan the allocations would be 1,400 tons for the food and bait fishery, 824 tons for the natural spawn-on-kelp fishery, 1,063 tons for the pound spawn-on-kelp fishery, 7,270 for the seine sac roe fishery, and 423 tons for the gill net sac roe fishery. This translates into 103 and 85 tons of product, respectively, for the natural spawn-on-kelp and pound spawn-on-kelp fisheries.

#### LITERATURE CITED

- Biggs, E.D. and F. Funk. 1988. Pacific herring spawning ground surveys for Prince William Sound, 1988, with historic overview. Alaska Department of Fish and Game, Division of Commercial Fisheries, Region II Regional Information Report No. 2C88-07, Anchorage.
- Brady, J. A. 1987. Distribution, timing and relative biomass indices for Pacific herring as determined by aerial surveys in Prince William Sound 1978 to 1987. Prince William Sound Data Report No. 87-14. Alaska Department of Fish and Game, Commercial Fisheries Division, Anchorage.
- Funk, F. C., and G. J. Sandone. *In press*. Stock assessment of Prince William Sound Herring 1973-1987, using cohort analysis. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fisheries Bulletin, Juneau.
- Sandone, G.J. 1988. Prince William Sound 1988 herring biomass projection. Alaska Department of Fish and Game, Division of Commercial Fisheries, Region II Regional Information Report No. 2A88-21, Anchorage.

Table 1. Prince William Sound District year class composition of the 1988 Pacific herring harvest, escapement, and total run biomass and the 1989 projected biomass. Natural mortality rate (M) at age 8 = 0.45.

Year Class	1988 Harvest (tons) <sup>a</sup>				Total	Escapement (tons)	1988 Total Run		1989 PWS Projected Herring Biomass					
	Age Class	Purse S.	Gill Net	Pound			No. of Fish (tons) (* 1,000)	X by Wt.	X by No.	Year Class	Age Class	No. of Fish (tons) (* 1,000)	X by Wt.	X by No.
1987														
1987	1	0	0	0	0	0	0.0	0.0	1987	2	0	0	0.0	
1986	2	0	0	0	0	0	0.0	0.0	1986	3	1	8	0.0	
1985	3	59	0	16	75	704	1.3	1.9	1985	4	1,596	14,067	2.9	
1984	4	4,779	5	1,245	6,029	37,058	43.087	73.5	1984	5	45,056	330,471	84.3	
1983	5	527	11	81	619	2,810	3,429	5.8	1983	6	2,596	16,713	4.3	
1982	6	346	27	27	400	1,712	2,113	3.6	1982	7	1,515	8,881	2.3	
1981	7	1,101	122	96	1,319	3,026	4,345	7.4	1981	8	2,249	12,311	4.1	
1980	8	749	117	67	933	2,244	3,176	5.4	1980	9	1,504	7,831	2.7	
1979	9	120	28	18	166	558	724	1.2	1979	10	297	1,492	0.4	
1978	10	52	18	5	75	111	186	0.3	1978	11	38	184	0.0	
1977	11	90	15	0	105	195	300	0.5	1977	12	30	144	0.0	
1976	12	72	16	0	87	395	482	0.8	1976	13+	17	82	0.0	
1975	13+	0	0	0	0	0	0	0.0						
Total		7,896	358	1,555	9,809	48,812	58,621 <sup>b</sup>	523,903	100.0	100.0	54,899 <sup>c</sup>	392,184	100.0	

<sup>a</sup> Does not include the bait/food harvest of 1,189.5 tons September-November 1987.

<sup>b</sup> Includes 772.8 tons of herring associated with the natural spawn-on-keep fishery and 48,039.2 tons estimated from the spawn deposition survey.

<sup>c</sup> The mean weight of fish is 127 g.

Table 2. Prince William Sound District projection of the 1989 Pacific herring biomass with natural mortality at age 8 = 0.45.

Age (t)	Mean Wt. at time t (g) <sup>a</sup>	Age Interval	G <sub>t</sub> <sup>b</sup>	M <sub>t</sub> <sup>c</sup>	e <sup>(G-M)</sup>	A <sub>t</sub> <sup>d</sup>	A <sub>(t+1)</sub> /A <sub>(t)</sub>	A <sub>(t+1)</sub> /A <sub>(t)</sub> e <sup>(G-M)</sup>	1989 Projected Biomass					
									Age Class	1988 Escapement (tons)	1989 <sup>e</sup> Projection (tons)	% by Weight	Number of fish(*1,000)	% by Number
2	53.4	2-3	0.392	0.343	1.05		2.45	2.58	2	0	0			
3	79.1	3-4	0.264	0.343	0.92	0.22	2.45	2.27	3	704	1	0.0	8	0.0
4	102.9	4-5	0.184	0.343	0.85	0.54	1.43	1.22	4	37,058	1,596	2.9	14,067	3.6
5	123.7	5-6	0.130	0.343	0.81	0.77	1.14	0.92	5	2,810	45,056	82.1	330,471	84.3
6	140.9	6-7	0.094	0.344	0.78	0.88	1.14	0.88	6	1,712	2,596	4.7	16,713	4.3
7	154.8	7-8	0.068	0.365	0.74	1.00	1.00	0.74	7	3,026	1,515	2.8	8,881	2.3
8	165.7	8-9	0.050	0.450	0.67	1.00	1.00	0.67	8	2,244	2,249	4.1	12,311	3.1
9	174.2	9-10	0.037	0.667	0.53	1.00	1.00	0.53	9	558	1,504	2.7	7,831	2.0
10	180.8	10-11	0.027	1.108	0.34	1.00	1.00	0.34	10	111	297	0.5	1,492	0.4
11	185.8	11-12	0.020	1.887	0.15	1.00	1.00	0.15	11	195	38	0.1	184	0.0
12	189.5	12-13	0.015	3.139	0.04	1.00	1.00	0.04	12	395	30	0.1	144	0.0
13	192.4	13-14	0.011	5.020	0.01	1.00	1.00	0.01	13+	0	17	0.0	82	0.0
14	194.5	14-15												
									Total	48,812	54,899	100.0	392,184	100.0

<sup>a</sup> Weight at time t = 200.943[1-exp(-0.293(t+1.689))]<sup>3.196</sup>

<sup>b</sup> Instantaneous growth rate G = ln(W<sub>t+1</sub>/W<sub>t</sub>)

<sup>c</sup> Instantaneous natural mortality rate (M)

<sup>d</sup> Availability schedule

<sup>e</sup> Projection<sub>(t+1)</sub> = Escapement<sub>(t)</sub> × A<sub>(t+1)</sub>/A<sub>(t)</sub>e<sup>(G-M)</sup>

-7-

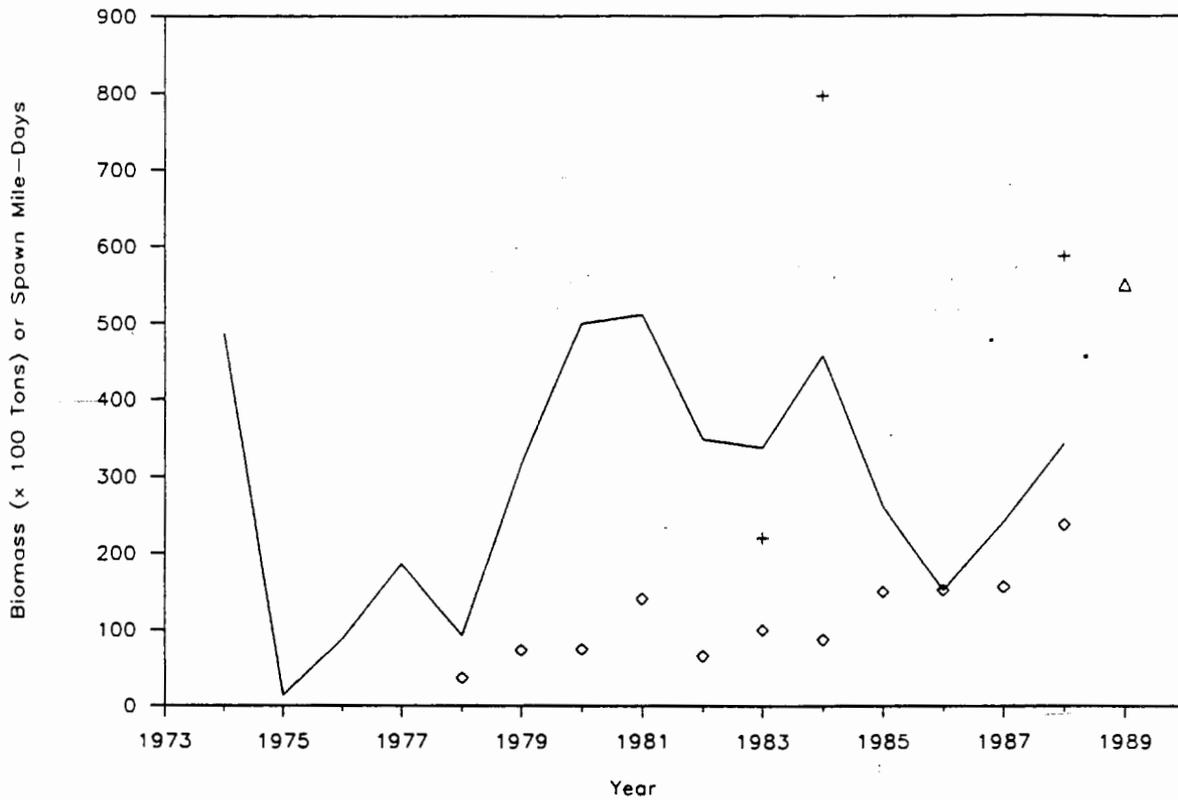


Figure 1. Prince William Sound herring biomass from aerial surveys (line), spawn surveys (crosses), and an index of abundance as mile-days of spawn (diamonds). The 1989 biomass (triangle) was projected from the spawn survey estimate.

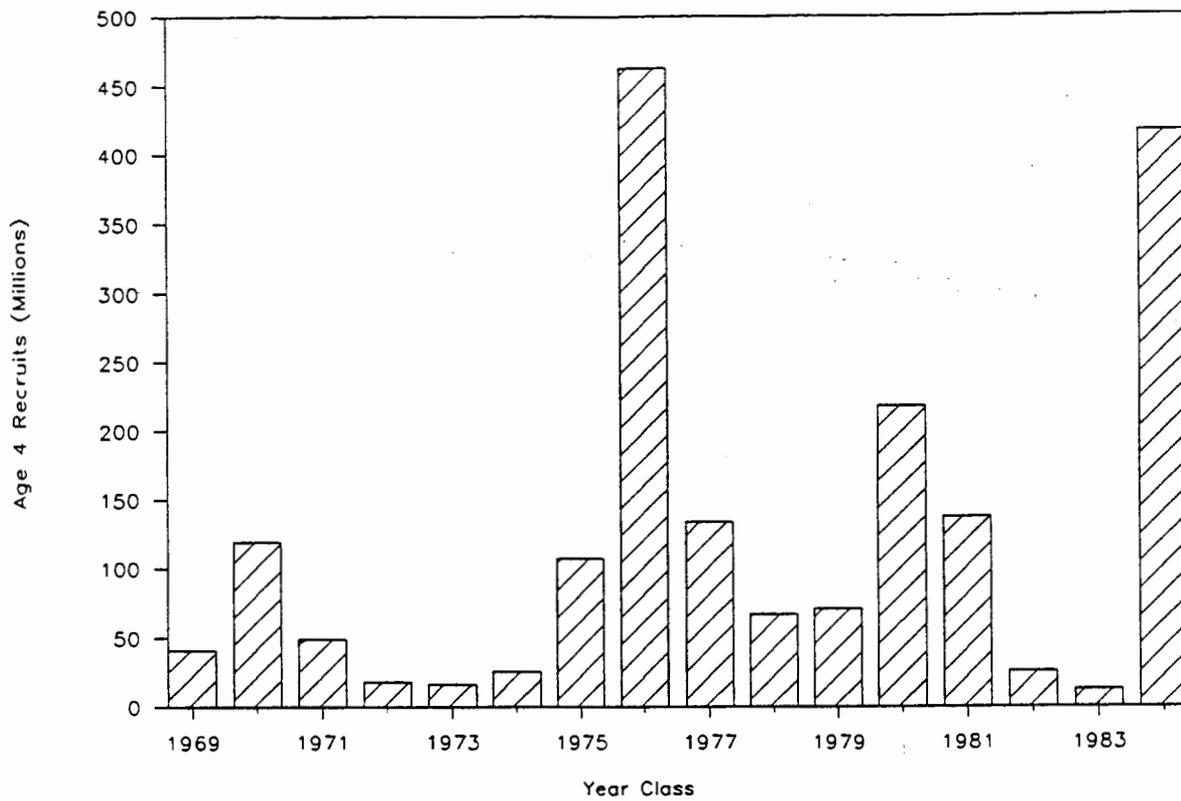


Figure 2. Historical year class strength of Prince William Sound herring in number of 4-year-old fish.

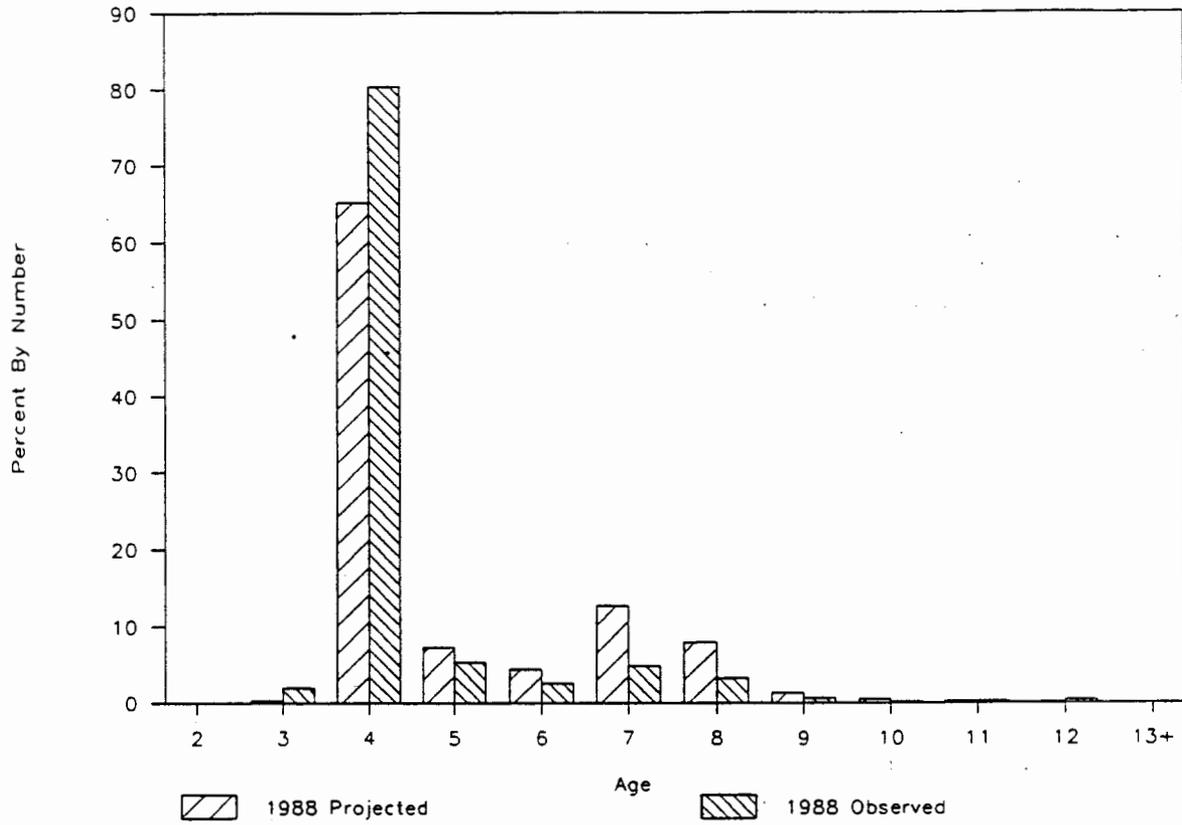


Figure 3. Age composition of the Prince William Sound herring population in 1988 compared to that projected from 1987.

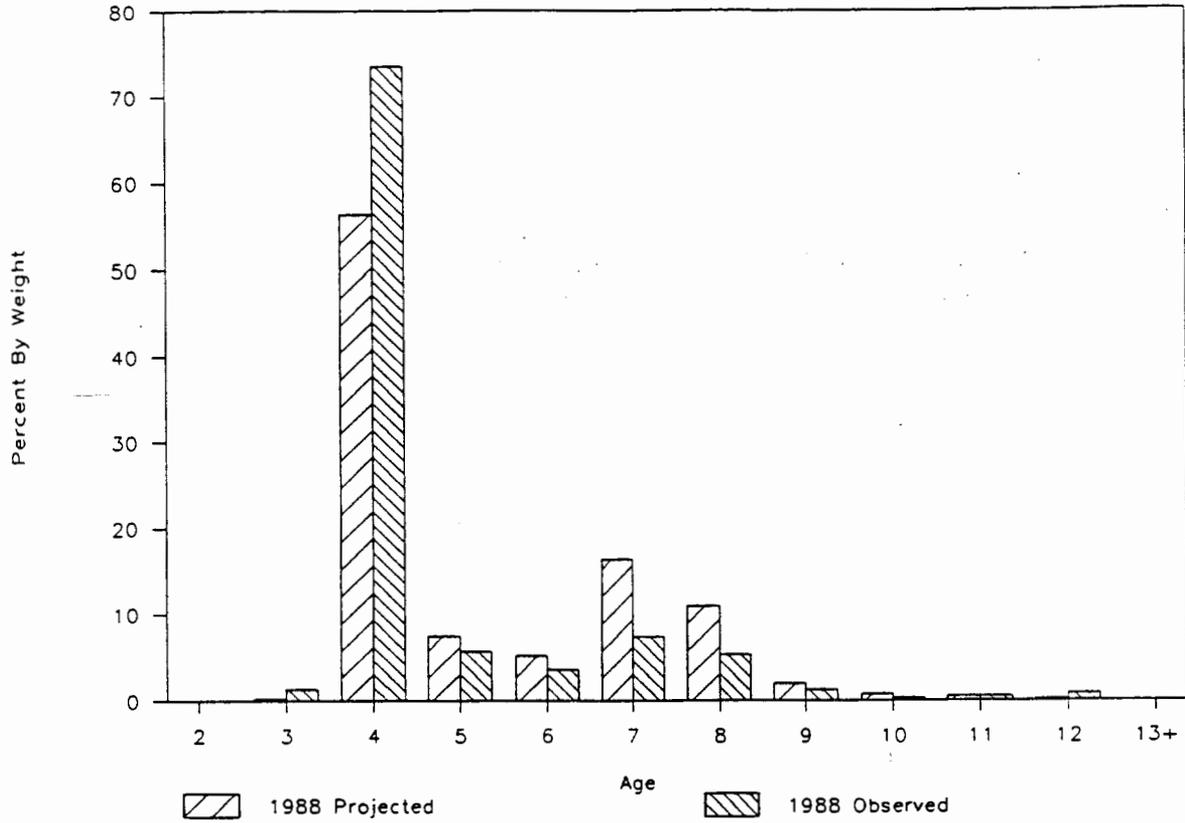


Figure 4. Age composition by weight of the Prince William Sound herring biomass in 1988 compared to that projected from 1987.

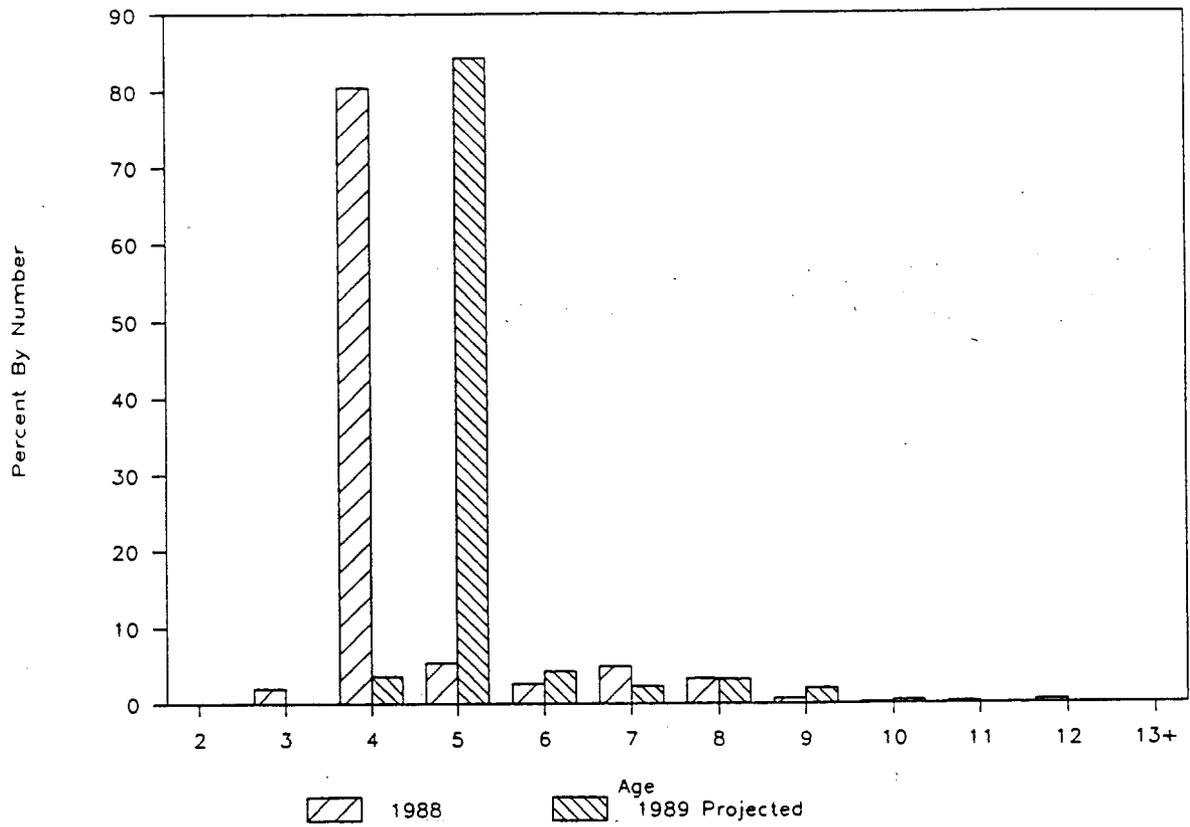


Figure 5. Age composition of the Prince William Sound herring population in 1988 and projected for 1989.

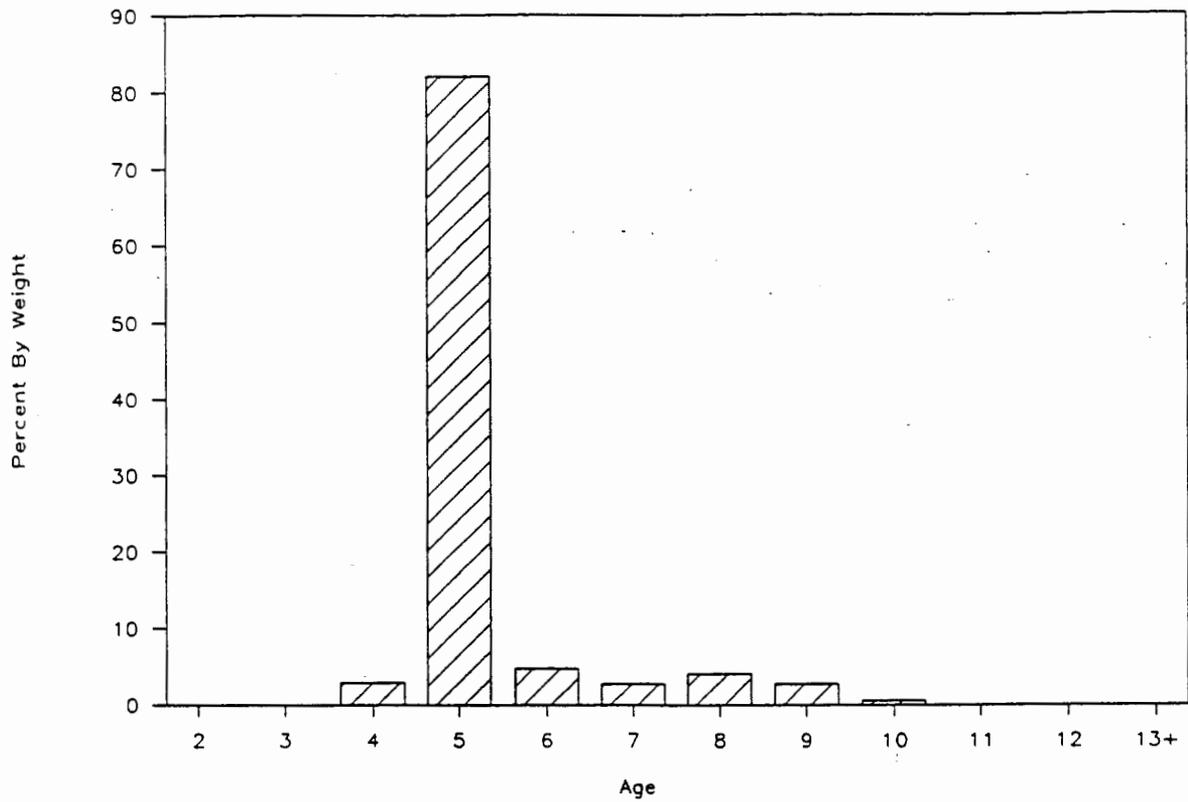


Figure 6. Age composition by weight of the estimated 1989 biomass of Prince William Sound herring.

Appendix A.1. Prince William Sound commercial purse seine harvest by age and year class, April 21, 1988.

Fishing Period on April 21								
Year Class	Age Class	Number Sampled	% by Number	Mean Weight (g)	Weighting Factor (g)	% by Weight	Biomass (st)	Number of Fish (* 1,000)
1987	1	0	0.0	0	0	0.0	0	0
1986	2	0	0.0	0	0	0.0	0	0
1985	3	10	1.1	66	660	0.7	23	317
1984	4	612	69.7	96	58,752	59.7	2,053	19,403
1983	5	67	7.6	122	8,174	8.3	286	2,124
1982	6	35	4.0	151	5,285	5.4	185	1,110
1981	7	79	9.0	157	12,403	12.6	433	2,505
1980	8	56	6.4	168	9,408	9.6	329	1,775
1979	9	5	0.6	182	910	0.9	32	159
1978	10	2	0.2	203	406	0.4	14	63
1977	11	6	0.7	186	1,116	1.1	39	190
1976	12	6	0.7	205	1,230	1.3	43	190
1975	13+	0	0.0	0	0	0.0	0	0
Total		878	100.0	112	98,344	100.0	3,437	27,836

Appendix A.2. Prince William Sound commercial purse seine harvest by age and year class April 22, 1988.

Fishing Period on April 22								
Year Class	Age Class	Number Sampled	% by Number	Mean Weight (g)	Weighting Factor (g)	% by Weight	Biomass (st)	Number of Fish (* 1,000)
1987	1	0	0.0	0	0	0.0	0	0
1986	2	0	0.0	0	0	0.0	0	0
1985	3	8	1.3	68	544	0.8	36	479
1984	4	444	72.2	93	41,292	61.1	2,726	26,589
1983	5	30	4.9	122	3,660	5.4	242	1,797
1982	6	17	2.8	144	2,448	3.6	162	1,018
1981	7	64	10.4	158	10,112	15.0	668	3,833
1980	8	36	5.9	177	6,372	9.4	421	2,156
1979	9	7	1.1	190	1,330	2.0	88	419
1978	10	3	0.5	193	579	0.9	38	180
1977	11	4	0.7	195	780	1.2	51	240
1976	12	2	0.3	217	434	0.6	29	120
1975	13+	0	0.0	0	0	0.0	0	0
Total		615	100.0	110	67,551	100.0	4,459	36,829

Appendix A.3. Prince William Sound commercial purse seine harvest by age and year class, 1988.

Year Class	Age Class	Number Sampled	% by Number	Mean Weight (g)	% by Weight	Harvest (tons)	Number of Fish (* 1,000)
1987	1	0	0.0		0.0	0	0
1986	2	0	0.0		0.0	0	0
1985	3	18	1.2	67	0.7	59	796
1984	4	1,056	70.7	94	60.5	4,779	45,991
1983	5	97	6.5	122	6.7	527	3,921
1982	6	52	3.5	148	4.4	346	2,128
1981	7	143	9.6	158	13.9	1,101	6,337
1980	8	92	6.2	173	9.5	749	3,931
1979	9	12	0.8	188	1.5	120	578
1978	10	5	0.3	196	0.7	52	243
1977	11	10	0.7	191	1.1	90	430
1976	12	8	0.5	210	0.9	72	310
1975	13+	0	0.0		0.0	0	0
Total		1,493	100.0	111	100.0	7,895.9	64,665

Appendix A.4. Prince William Sound commercial gill net harvest by age and year class, 1988.

Year Class	Age Class	Number Sampled	% by Number	Mean Weight (g)	Weighting Factor (g)	% by Weight	Harvest (st)	Number of Fish (* 1,000)
1987	1	0	0.0	0	0	0.0	0	0
1986	2	0	0.0	0	0	0.0	0	0
1985	3	0	0.0	0	0	0.0	0	0
1984	4	11	1.9	125	1,375	1.4	5	37
1983	5	21	3.7	136	2,856	3.0	11	71
1982	6	48	8.5	153	7,344	7.6	27	162
1981	7	200	35.4	164	32,800	34.1	122	676
1980	8	180	31.9	174	31,320	32.6	117	608
1979	9	39	6.9	191	7,449	7.8	28	132
1978	10	24	4.2	199	4,776	5.0	18	81
1977	11	21	3.7	188	3,948	4.1	15	71
1976	12	21	3.7	202	4,242	4.4	16	71
1975	13+	0	0.0	0	0	0.0	0	0
Total		565	100.0	170	96,110	100.0	358.1	1,910

Appendix A.5. Prince William Sound commercial purse seine pound harvest by age and year class, 1988.

Year Class	Age Class	Number Sampled	% by Number	Mean Weight (g)	Weighting Factor (g)	% by Weight	Harvest (st)	Number of Fish (* 1,000)
1987	1	0	0.0	0	0	0.0	0	0
1986	2	0	0.0	0	0	0.0	0	0
1985	3	8	1.4	71	564	1.0	16	205
1984	4	489	84.7	90	44,174	80.1	1,245	12,501
1983	5	28	4.9	103	2,887	5.2	81	716
1982	6	9	1.6	105	945	1.7	27	230
1981	7	22	3.8	155	3,414	6.2	96	562
1980	8	16	2.8	148	2,362	4.3	67	409
1979	9	4	0.7	163	650	1.2	18	102
1978	10	1	0.2	187	187	0.3	5	26
1977	11	0	0.0	0	0	0.0	0	0
1976	12	0	0.0	0	0	0.0	0	0
1975	13+	0	0.0	0	0	0.0	0	0
Total		577	100.0	96	55,183	100.0	1,555.0	14,750

Appendix B.1. Prince William Sound herring biomass distribution by age and year class, Montague Island, 1988.  
 Biomass estimated from spawn deposition survey in this area.

Montague Island								
Year Class	Age Class	Number Sampled	% by Number	Mean Weight (g)	Weighting Factor (g)	% by Weight	Biomass (st)	Number of Fish (* 1,000)
1987	1	0	0.0	0	0	0.0	0	0
1986	2	0	0.0	0	0	0.0	0	0
1985	3	14	2.5	71	994	1.8	483	6,165
1984	4	495	87.1	93	46,035	84.1	22,347	217,992
1983	5	25	4.4	106	2,650	4.8	1,286	11,010
1982	6	13	2.3	143	1,859	3.4	902	5,725
1981	7	11	1.9	144	1,584	2.9	769	4,844
1980	8	6	1.1	167	1,002	1.8	486	2,642
1979	9	0	0.0		0	0.0	0	0
1978	10	1	0.2	104	104	0.2	50	440
1977	11	1	0.2	81	81	0.1	39	440
1976	12	2	0.4	218	436	0.8	212	881
1975	13+	0	0.0	0	0	0.0	0	0
Total		568	100.0	96	54,745	100.0	26,575	250,140

Appendix B.4. Prince William Sound herring biomass distribution by age and year class, Naked Island, 1988.  
 Biomass estimated from spawn deposition survey in this area.

Naked Island Area								
Year Class	Age Class	Number Sampled	% by Number	Mean Weight (g)	Weighting Factor (g)	% by Weight	Biomass (st)	Number of Fish (* 1,000)
1987	1	0	0.0	0	0	0.0	0	0
1986	2	0	0.0	0	0	0.0	0	0
1985	3	10	1.8	63	630	1.1	120	1,731
1984	4	397	72.8	93	36,921	63.1	7,044	68,713
1983	5	38	7.0	115	4,370	7.5	834	6,577
1982	6	17	3.1	143	2,431	4.2	464	2,942
1981	7	39	7.2	158	6,162	10.5	1,176	6,750
1980	8	28	5.1	173	4,844	8.3	924	4,846
1979	9	11	2.0	187	2,057	3.5	392	1,904
1978	10	0	0.0	0	0	0.0	0	0
1977	11	2	0.4	222	444	0.8	85	346
1976	12	3	0.6	221	663	1.1	126	519
1975	13+	0	0.0	0	0	0.0	0	0
Total		545	100.0	107	58,522	100.0	11,165	94,329

Appendix B.5. Prince William Sound herring biomass distribution by age and year class which contributed roe for the wild spawn-on-kelp harvest in the Valdez Arm, 1988.

Herring Associated with the Wild Spawn-on-Kelp, Valdez Arm								
Year Class	Age Class	Number Sampled	% by Number	Mean Weight (g)	Weighting Factor (g)	% by Weight	Biomass (st)	Number of Fish (* 1,000)
1987	1	0	0.0	0	0	0.0	0	0
1986	2	1	0.2	50	50	0.1	0	5
1985	3	5	1.1	61	305	0.7	2	25
1984	4	327	69.0	84	27,468	59.9	154	1,666
1983	5	40	8.4	93	3,720	8.1	21	204
1982	6	12	2.5	116	1,392	3.0	8	61
1981	7	33	7.0	144	4,752	10.4	27	168
1980	8	39	8.2	137	5,343	11.7	30	199
1979	9	5	1.1	164	820	1.8	5	25
1978	10	7	1.5	169	1,183	2.6	7	36
1977	11	3	0.6	163	489	1.1	3	15
1976	12	2	0.4	167	334	0.7	2	10
1975	13+	0	0.0	0	0	0.0	0	0
Total		474	100.0	97	45,856	100.0	258	2,416

Appendix B.6. Prince William Sound herring biomass distribution by age and year class which contributed roe for the wild spawn-on-kelp harvest in the Fairmount Bay area, 1988.

Herring Associated with the Wild Spawn-on-Kelp, Fairmount Bay								
Year Class	Age Class	Number Sampled	% by Number	Mean Weight (g)	Weighting Factor (g)	% by Weight	Biomass (st)	Number of Fish (* 1,000)
1987	1	0	0.0	0	0	0.0	0	0
1986	2	0	0.0	0	0	0.0	0	0
1985	3	22	1.3	70	1,540	0.8	4	52
1984	4	1174	67.2	95	111,530	56.3	290	2,771
1983	5	123	7.0	118	14,514	7.3	38	290
1982	6	66	3.8	146	9,636	4.9	25	156
1981	7	177	10.1	158	27,966	14.1	73	418
1980	8	132	7.6	169	22,308	11.3	58	312
1979	9	20	1.1	185	3,700	1.9	10	47
1978	10	9	0.5	201	1,809	0.9	5	21
1977	11	14	0.8	198	2,772	1.4	7	33
1976	12	11	0.6	203	2,233	1.1	6	26
1975	13+	0	0.0	0	0	0.0	0	0
Total		1748	100.0	113	198,008	100.0	515	4,126

Appendix C.1. Prince William Sound 1989 herring projection biomass spreadsheet:  
 Natural Mortality at age 8 = 0.3.

Age (t)	Mean Wt. (g) <sup>a</sup>	Age Interval	G <sub>t</sub> <sup>b</sup>	M <sub>t</sub> <sup>c</sup>	e <sup>(G-M)</sup>	A <sub>t</sub> <sup>d</sup>	A <sub>(t+1)</sub> /A <sub>(t)</sub>	A <sub>(t+1)</sub> /A <sub>(t)</sub> e <sup>(G-M)</sup>	1989 Projected Biomass					
									Age Class	Escapement (tons)	1989 <sup>e</sup> Projection (tons)	% by Weight	Number of fish(*1,000)	% by Number
2	53.4	2-3	0.392	0.193	1.22		2.45	2.99	2	0	0	0.0		0.0
3	79.1	3-4	0.264	0.193	1.07	0.22	2.45	2.63	3	704	1	0.0	10	0.0
4	102.9	4-5	0.184	0.193	0.99	0.54	1.43	1.41	4	37,058	1,855	2.9	16,344	3.6
5	123.7	5-6	0.130	0.193	0.94	0.77	1.14	1.07	5	2,810	52,347	82.1	383,953	84.3
6	140.9	6-7	0.094	0.194	0.90	0.88	1.14	1.03	6	1,712	3,016	4.7	19,417	4.3
7	154.8	7-8	0.068	0.215	0.86	1.00	1.00	0.86	7	3,026	1,761	2.8	10,319	2.3
8	165.7	8-9	0.050	0.300	0.78	1.00	1.00	0.78	8	2,244	2,613	4.1	14,303	3.1
9	174.2	9-10	0.037	0.517	0.62	1.00	1.00	0.62	9	558	1,747	2.7	9,098	2.0
10	180.8	10-11	0.027	0.958	0.39	1.00	1.00	0.39	10	111	345	0.5	1,734	0.4
11	185.8	11-12	0.020	1.737	0.18	1.00	1.00	0.18	11	195	44	0.1	213	0.0
12	189.5	12-13	0.015	2.989	0.05	1.00	1.00	0.05	12	395	35	0.1	167	0.0
13	192.4	13-14	0.011	4.870	0.01	1.00	1.00	0.01	13+	0	20			
14	194.5													
Total									48,812	63,784	100.0	455,558	100.0	

<sup>a</sup> Weight at time t = 200.943[1-exp(-0.293(t+1.689))]<sup>3.196</sup>  
<sup>b</sup> Instantaneous growth rate G = ln(W<sub>t+1</sub>/W<sub>t</sub>)  
<sup>c</sup> Instantaneous natural mortality rate (M)  
<sup>d</sup> Availability schedule  
<sup>e</sup> Projection<sub>(t+1)</sub> = Escapement<sub>(t)</sub> × A<sub>(t+1)</sub>/A<sub>(t)</sub>e<sup>(G-M)</sup>

-25-

ACE 6238727

Appendix C.2. Prince William Sound 1989 herring projection biomass spreadsheet;  
 Natural Mortality at age 8 = 0.6.

										1989 Projected Biomass				
Age (t)	Mean Wt. (g) <sup>a</sup>	Age Interval	G <sub>t</sub> <sup>b</sup>	M <sub>t</sub> <sup>c</sup>	e <sup>(G-M)</sup>	A <sub>t</sub> <sup>d</sup>	A <sub>(t+1)</sub> /A <sub>(t)</sub>	A <sub>(t+1)</sub> /A <sub>(t)</sub> e <sup>(G-M)</sup>	Age Class	1988	1989 <sup>e</sup>	% by Weight	Number of fish(*1,000)	% by Number
										Escapement (tons)	Projection (tons)			
2	53.4	2-3	0.392	0.493	0.90		2.45	2.22	2	0	0			
3	79.1	3-4	0.264	0.493	0.80	0.22	2.45	1.95	3	704	1	0.0	7	0.0
4	102.9	4-5	0.184	0.493	0.73	0.54	1.43	1.05	4	37,058	1,374	2.9	12,108	3.6
5	125.7	5-6	0.130	0.493	0.70	0.77	1.14	0.80	5	2,810	38,780	82.1	284,439	84.3
6	140.9	6-7	0.094	0.494	0.67	0.88	1.14	0.76	6	1,712	2,234	4.7	14,385	4.3
7	154.8	7-8	0.068	0.515	0.64	1.00	1.00	0.64	7	3,026	1,304	2.8	7,644	2.3
8	165.7	8-9	0.050	0.600	0.58	1.00	1.00	0.58	8	2,244	1,936	4.1	10,596	3.1
9	174.2	9-10	0.037	0.817	0.46	1.00	1.00	0.46	9	558	1,294	2.7	6,740	2.0
10	180.8	10-11	0.027	1.258	0.29	1.00	1.00	0.29	10	111	256	0.5	1,284	0.4
11	185.8	11-12	0.020	2.037	0.13	1.00	1.00	0.13	11	195	32	0.1	158	0.0
12	189.5	12-13	0.015	3.289	0.04	1.00	1.00	0.04	12	395	26	0.1	124	0.0
13	192.4	13-14	0.011	5.170	0.01	1.00	1.00	0.01	13+	0	15	0.0	70	0.0
14	194.5													
Total									48,812	47,252	100.0	337,556	100.0	

<sup>a</sup> Weight at time t = 200.943[1-exp(-0.293(t+1.689))] <sup>3.196</sup>

<sup>b</sup> Instantaneous growth rate G = ln(W<sub>t+1</sub>/W<sub>t</sub>)

<sup>c</sup> Instantaneous natural mortality rate (M)

<sup>d</sup> Availability schedule

<sup>e</sup> Projection<sub>(t+1)</sub> = Escapement<sub>(t)</sub> x A<sub>(t+1)</sub>/A<sub>(t)</sub>e<sup>(G-M)</sup>