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Herring Report 22

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Stock Assessment of Pacific Herring, Bristol Bay, Alaska

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ABSTRACT

Studies were continued during 1983 to refine stock assessment techniques and management strategies for Pacific herring, *Clupea harengus pallasi*, spawning within Togiak District, Bristol Bay, Alaska. A total of 30 aerial surveys was flown (91 hours) from 6 April to 3 June, and 5,449 herring were sampled from variable mesh gill catches and chartered and commercial purse seine and gill net landings. Total herring spawning biomass was estimated to be 128,613 mt. Commercial harvest was 24,486 mt (exploitation rate, 19%). Age 5 and 6 herring (1978 and 1979 year classes, respectively) comprised about 80% of both the total spawning run and total harvest. Age 4 herring (1979 year class) accounted for only 4% of the total run and 1% of the harvest. A total of 96 linear km of milt was recorded during aerial surveys. The commercial spawn on kelp harvest (123 mt) removed about 1% of the total potential spawn deposition and 2% of the total standing crop of rockweed kelp, *Fucus* sp. Analysis of data concerning school density (biomass per unit surface area) and water depth indicated a highly significant difference (t-test $P<0.001$) between mean school density in shallow water (1.4 mt/50 m^2, 2-5 m water depth) and deep water (2.3 mt/50 m^2, greater than 5-8 m water depth). These results provide added credibility to past usage of different density factors in converting school surface area information to biomass estimates. Spawning biomass projections for 1984 indicated that 96,747 mt of herring should return to Togiak District. This could result in a harvest of 19,349 mt. If present aerial assessments are accurate, this projection should be conservative, since recruitment of younger age classes has been extremely variable and unpredictable. Results of harvest simulations using a herring population computer model indicated that present exploitation rates (20% of available biomass) should be maintained. Although maximum yield within the model was obtained at an exploitation rate of 30%, exploitation at the 20% level allowed for a larger spawning population to be maintained (52% larger) while producing only a small decrease in yield (7%).

INTRODUCTION

Since passage of the Fisheries Conservation Act in 1976, commercial fishing effort for Pacific herring, *Clupea harengus pallasi*, in the eastern Bering Sea has shifted from offshore harvests by foreign nations to inshore harvests by domestic fishermen. Prior to 1976 little information had been collected by U.S. investigators which could be used in managing the growing domestic fishery. Although several Federal and State funded projects were started to provide needed information (e.g., Barton et al. 1977; Wespestad 1978; Barton and Steinhoff 1980), development of a useful data base has been slow and costly.

The present project, partially funded under P.L. 88-309 (as amended). The Commercial Fisheries Research and Development Act was started in 1982 and is composed of studies which seek to refine stock assessment techniques and management strategies for herring spawning within northern Bristol Bay, Alaska or Togiak Fishing District (Figure 1). This area is estimated to serve as the spawning grounds for about 80% of the eastern Bering Sea herring biomass (Fried et al. 1983a). During 1983, 150 purse seine and 250 gillnet vessels were used to harvest 24,486 mt of herring for sac roe. Estimated ex-vessel value of this harvest was $10.5 million. During this same time 125 fishermen harvested 123 mt of spawn on kelp valued at $0.3 million. After the spawning season Togiak herring stocks contributed to most of a 3,238 mt harvest for food and bait in the eastern Aleutians (Unalaska Island). Eight purse seine vessels were used in this fishery and the ex-vessel value was estimated to be $0.8 million.

Specific objective of studies funded under the present project during 1983 were as follows:

1) to estimate biomass of spawning herring and commercial fishery exploitation rate within Togiak District;

2) to provide age composition, size, and sexual maturity information for the total spawning run, commercial harvest and spawning escapement;

3) to estimate extent of spawn deposition and loss of spawn as a result of spawn on kelp harvests;

4) to determine run timing and entry patterns of herring arriving on the spawning grounds; and

5) to develop methods to forecast herring abundance and determine optimum spawning goals.

STUDY AREA

The Togiak District extends from the tip of Cape Constantine westward to the tip of Cape Newenham, a shoreline distance of about 400 km (Figure 1). The

TOGIAK HERRING FISHING DISTRICT

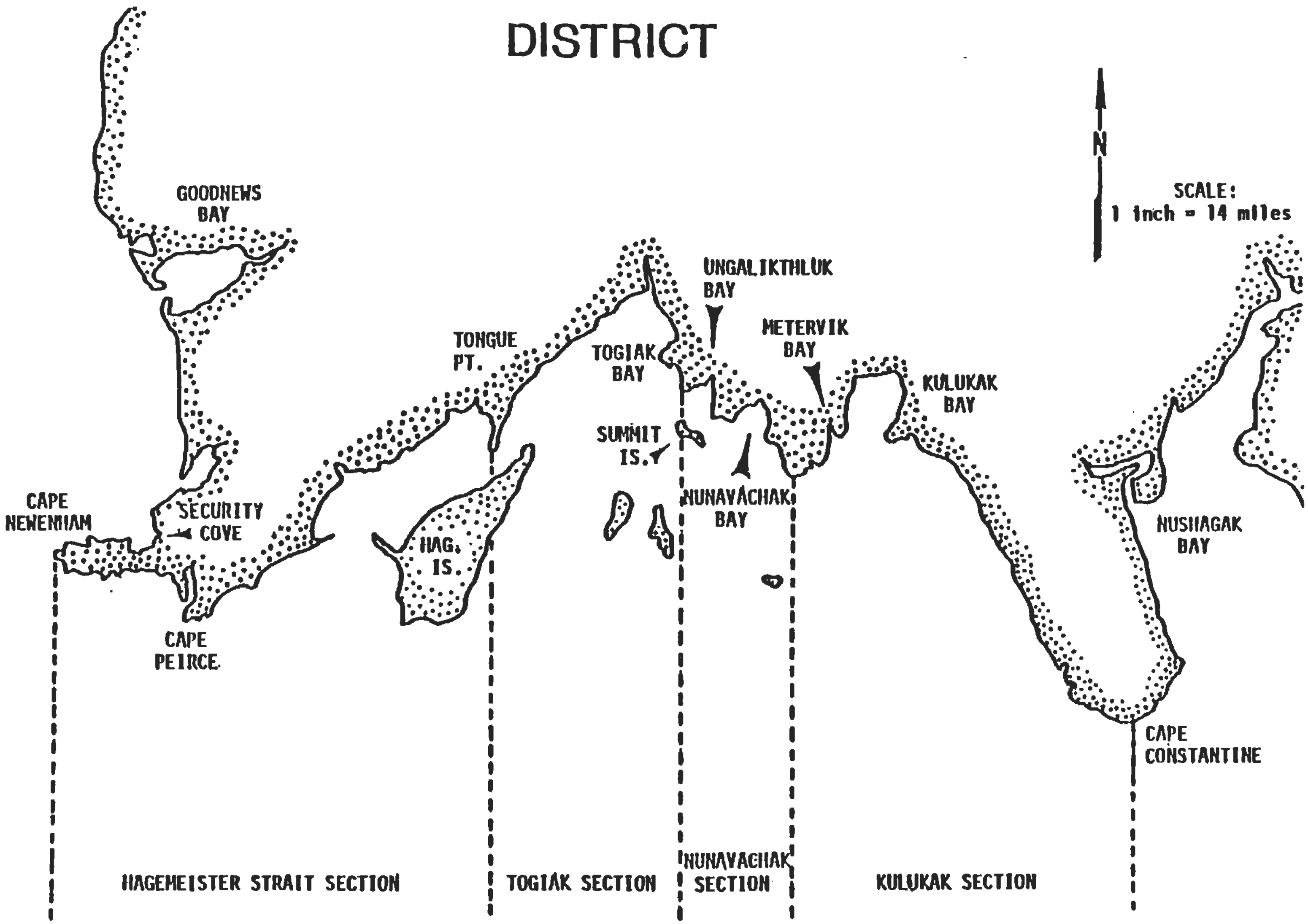

Figure 1. Togiak Commercial Fishing District, Bristol Bay, Alaska.

area is characterized by rocky headlands and several large, shallow, bays with water depths ranging from 0.0 - 5.5 m at mean low water. Maximum tidal range is about 3.4 m. Bottom deposits are typically clayey mud, but some gravel areas are present. Rockweed kelp, *Fucus* sp., is the predominate intertidal vegetation; eelgrass, *Zostera* sp., is the predominate subtidal vegetation in many of the bays. Inshore waters are usually ice-covered during winter months and ice scouring can be extensive. Surface water temperatures and salinities during spring months range from 3-12° C and 22-33°/₀₀, respectively.

METHODS

Aerial surveys were flown using fixed-wing, single engine and rotary-wing dual engine aircraft to estimate herring biomass. Data collection methods were similar to those described by Barton and Steinhoff (1980). Most surveys were flown at altitudes of about 500 m and during periods of low tide. All herring schools sighted were recorded on standardized charts. Surface area estimates were made for each school sighted using a survey tube having a calibrated grid. For extremely large schools, surface area was estimated by measuring the time required to fly over the school at a known, constant, airspeed. Surface area estimates were converted to metric ton equivalents by applying information obtained from capturing and landing schools of known surface area using chartered purse seine vessels. Conversion factors of 1.2, 2.5, and 3.0 mt/50 m^2 surface area were used for schools sighted in water depths of 5 m or less, greater than 5 m to 8 m, and greater than 8 m, respectively. After the field season, all data obtained from commercial purse seine test sets were re-examined, using analysis of variance techniques and t-tests (Sokal and Rohlf 1969), to determine whether these conversion factors were affected by data from 1983 sets.

Test fishing with variable mesh gill nets (26 April to 26 May) and chartered purse seine (28 April to 18 May) and gill net (1 and 7 May) vessels was done to determine age, size (standard length, mm; weight, g); and sexual maturity of herring. Aging was done using a microfiche reader to examine scales mounted between glass slides. Attempts were made to age 213 herring each week from each fishing section so that all seven important age classes (ages 3 through 9) would be represented to with ± 10% of their true contribution in 95% of all samples (Goodman 1965; Snedecor and Cochran 1977). Commercial catch samples were obtained and treated similarly. Sampling effort was concentrated in areas having the largest herring concentrations. Results of sampling were used to identify different segments of the spawning population to aid in interpretation of aerial survey data. Chi-square testing procedures were used to examine age composition differences among selected time periods (Steel and Torrie 1960).

Commercial catch estimates were obtained from processors as hailed estimates during the season and from delivery receipts after the season. Harvest goals during the season were determined as biomass estimates became available. Present management strategy is to harvest 10-20% of available spawning biomass. Actual exploitation rate was calculated using final catch and total run estimates. Commercial catches made prior to aerial assessments used to calculate total run size were added to assessment estimates. Spawning escapement biomass (total run minus catch) was used to make projections of spawning biomass available in 1984 using the general relationship:

$$B_{t+1} = B_t \left(e^{[G-M]}\right) \left(R_{t+1} / R_t\right) \quad \text{where}$$

B_{t+1} = expected 1984 biomass of age $t+1$ herring,

B_t = estimated 1983 biomass of age t herring,

G = instantaneous growth rate of herring during age t to $t+1$,

M = instantaneous natural mortality rate of herring during age t to $t+1$.

R_{t+1} = estimated mean proportion of herring recruited to spawning population at age $t+1$, and

R_t = estimated mean proportion of herring recruited to spawning population at age t.

Instantaneous growth rates were calculated from the von Bertalanffy growth curve and weight-length regression (Ricker 1975) developed by Fried and Wespestad (in press) using data from 1978-1982. Instantaneous natural mortality rates were obtained from Wespestad's (1982) catch curve analysis (Ricker 1975) of Bering Sea Pacific herring data obtained from foreign offshore and domestic inshore catches during 1959-1981. Age-specific recruitment proportions were obtained from Soviet studies (Naumenko 1979 cited in Wespestad 1982).

Spawn deposition was estimated as linear km of milt recorded during aerial surveys. Spawn on kelp harvest estimates were obtained from processors as hailed estimates during the season and from delivery receipts after the season. Harvest goals during the season were based upon removal of kelp (rockweed) rather than spawn. Present management strategy is to harvest 10% of the lower 80% confidence interval of estimated rockweed standing crop. Herring egg loss due to spawn on kelp harvests was calculated under the assumption that 75% of the harvest weight was comprised of eggs (McBride, ADF&G, unpublished data). Proportion of total potential egg deposition this loss represented was estimated by assuming the percentage of eggs within the commercial harvest (8.8% sac roe recovery) represented a minimum estimate of the percentage of eggs within the entire spawning run.

Evaluation of present harvest strategies was accomplished using a computer program, developed by Fried and Wespestad (in press), which simulated population dynamics of Bering Sea Pacific herring stocks. Exploitation rates ranging from 0.00 to 0.60 were examined for effects upon total yield and spawning biomass of the simulated population. Each experiment consisted of 20 replicated 100 year simulations at a constant level of exploitation. For each experiment the exploitation rate was incremented by 0.10. To begin each experiment the population was set equal to that estimated by cohort analysis for 1978 (Wespestad 1982), assuming that Togiak District Pacific herring represented 82% of the total eastern Bering Sea population.

RESULTS AND DISCUSSION

A total of 30 aerial surveys was flown on 27 days during the 1983 season, from 6 April to 3 June. About half of these surveys were made under fair to excellent conditions. All assessment surveys were made using a fixed-wing, single engine aircraft (91 hrs). Surveys done in conjunction with chartered purse seine vessels to obtain biomass conversion factor data were made using a rotary-wing, dual engine aircraft. A total of six successful purse seine sets were made during the field season. Although linear regression of school density (dependent variable) and water depth (independent variable) did not show a significant relationship (ANOVA, $P>0.05$), a highly significant difference (t-test, $P<0.001$) was found between mean school density in shallow water (1.4 mt/50 m^2, 2-5 m water depth) and deep water (2.3 mt/50 m^2, greater than 5 m water depth). See Appendix Table 1 for tests of significance. Overall mean school density, calculated from all data points including two without water depth information, was 2.6 mt/50 m^2. These results are similar to those used to convert school surface area to biomass during the last two seasons (i.e., 1.2 mt/50 m^2, water depth 2-5 m; 2.5 mt/50 m^2, water depth greater than 5 m to 8 m; and 3.0 mt/50 m^2, water depth greater than 8 m). In view of the small sample size (19 density estimates, 1978-1983) and to maintain consistency, the same three conversion factors used in the past will be used again next season. Hydroacoustic equipment will be available for use next season to obtain more information on school density and to examine the relationship between density and water depth. If this equipment functions satisfactorily, many more density estimates can be added to the existing data base and re-calculation of conversion factors could be undertaken with greater confidence.

A total of 5,449 herring was sampled from test fishing and commercial landings (Appendix Table 2-6). The test fish samples (3,357 fish) was comprised of 61% variable mesh gill net, 34% chartered purse seine, and 5% chartered gill net samples. The commercial landing samples (2,092 fish) consisted of 55% purse seine and 45% gill net samples. Herring comprised 98% of all pelagic fishes captured in variable mesh gill nets. Other schooling fishes present in catches were boreal smelt, *Osmerus mordax*, capelin, *Mallotus villosus*, and saffron cod, *Eleginus gracilis*.

Although the relative proportion of young, newly recruited herring (age 4 and less) increased as the season progressed (Appendix Tables 2-6), it was not possible to identify separate abundance peaks for young and old (age 5 and greater) herring as had been done in past seasons. Total herring biomass was calculated by combining the peak aerial survey estimate (103,583 mt, 18 May) with commercial removals prior to that survey (24,486 mt, 3-11 May) and estimated wastage (544 mt due to vessel mishaps, abandoned gear, etc.). This resulted in a total estimated 1983 herring biomass of 128,613 mt (Table 1).

Total commercial herring harvest in Bristol Bay was 24,486 mt, the largest in the history of the fishery (Table 2). Commercial exploitation was estimated to be 19% of total spawning biomass.

Ages 5 and 6 herring (1978 and 1977 year classes, respectively) comprised about 80% of both the total spawning run and commercial catch (Figure 2). Age 4 herring (1979 year class) accounted for only 4% of the total run and 1% of the commercial catch. The poor recruitment of age 4 herring into the spawning population accounted for the inability to identify separate spawning peaks for young and old herring.

Spawn deposition was extensive. A total of 96 linear km of milt was recorded during aerial surveys. Most spawning occurred 2-19 May. Extensive subtidal spawning

Table 1. Pacific herring spawning population biomass within Togiak District, Bristol Bay, Alaska, 1983, and projections for 1984.

	1983 Biomass (mt)			1984 Projected Biomass (mt)	
Age	Total Run	Catch[1]	Escapement	Total Run	Catch[2]
3	45	4	41	?	
4	5,061	224	4,837	86	
5	42,233	6,386	35,847	5,901	
6	60,383	13,201	47,182	36,958	
7	2,468	685	1,783	42,699	
8	3,363	686	2,677	1,475	
9+	15,060	3,844	11,216	9,628	
Total	128,613	25,030	103,583	96,747	19,349

[1] Includes 544 mt of wastage (e.g., catch lost through vessel mishaps, abandoned gear, etc.). Commercial catch equaled 24,486 mt.

[2] Catch based upon 20% estimated exploitation of projected return.

Table 2. Estimated herring spawning biomass and commercial harvest of herring and herring spawn on kelp within Togiak District, Bristol Bay, Alaska, 1967-1983.

Spawning Biomass (mt)	Harvest (mt)		Ex-vessel Value (dollars)	Exploitation Rate (%)
	Herring	Spawn on Kelp		
		1983		
128,600	24,286	123	10,801,700	19
		1982		
88,800	19,556	107	6,350,500	22
		1981		
143,900	11,374	172	4,238,000	8
		1980		
62,300	17,774	86	3,299,600	29
		1979		
216,800	10,115	188	6,948,200	5
		1977		
172,600	7,033	150	2,419,800	4
		1976		
?	2,535	125	?	?
		1975		
?	0	134	?	0
		1974		
?	112	50	?	?
		1967-1973		
?	392	162	?	?

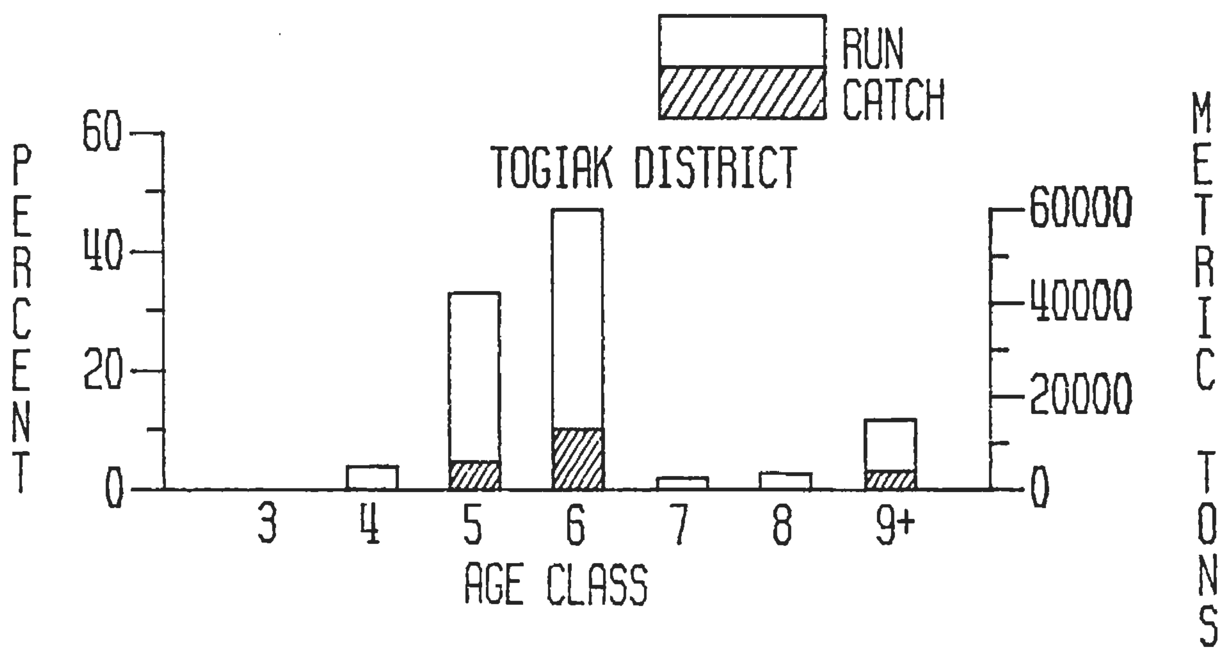

Figure 2. Age class composition of the total spawning run and commercial harvest of Pacific herring in Togiak District, Bristol Bay, Alaska, 1983.

was documented within Metervik and Ungalikthluk Bay, and along the west shore of Hagemeister Island.

Total commercial spawn on kelp harvest was 123 mt (Table 2). This resulted in an estimated removal of 92 mt of herring eggs, the amount of spawn deposited by 1,048 mt of herring, or about 1% of total potential egg deposition. About 2% of the total standing crop of rockweed was removed (7% of the lower 80% confidence interval).

An attempt was made to generate a forecast of herring spawning biomass available in 1984. Mean growth and mortality rates for each age class, as well as estimates of mean recruitment to the spawning population, were used to project estimated 1983 spawning escapement (total run minus catch) forward 1 year (Appendix Table 7). This resulted in a total spawning biomass estimate of 96,747 mt for 1984 (Table 1). Assuming aerial survey estimates were accurate in 1983, the 1984 projection should represent a minimal estimate of available biomass since recruitment of younger age classes is so variable and difficult to predict. Biomass projections for ages 6-9+ are probably the most reliable.

Present harvest strategies were examined using a computer model developed by Fried and Wespestad (in press) for eastern Bering Sea herring. Within this model maximum sustained yield (MSY) was achieved at an exploitation rate of 30% (78,487 mt) of available spawning biomass (Table 3). However, yield at an exploitation rate of 20%, the current maximum rate allowed under State management policy, only decreased potential yield from 78,487 to 72,910 mt (a 7% decrease), but allowed a 52% increase in spawning biomass to 309,853 from 204,026 mt. Since eastern Bering Sea herring stocks appear to be below MSY levels, and since productivity and yield drop sharply at rates above 30%, it appears that current exploitation rate ceilings should be maintained to allow stocks to rebuild and to provide greater protection against future flucutations in spawning biomass.

Table 3. Togiak District, Bristol Bay, Alaska, Pacific herring harvest and spawning biomass obtained from computer simulations using different constant exploitation rate levels (E). Results of 20 replicated 100-year simulations for each level of E.

E	Spawning Biomass (mt) After Harvest[1]			Harvest (mt)[1]		
(90%)	Mean	S. Dev.	Range	Mean	S. Dev.	Range
0	648,654	107,649	203,057-839,095	0	0	0
10	448,756	68,027	181,443-578,216	48,388	7,296	19,606- 62,420
20	309,853	42,449	148,300-386,414	72,910	10,008	35,318- 94,967
30	204,026	24,010	118,055-263,589	78,487	9,227	45,657-101,687
40	104,822	18,844	68,118-147,394	56,431	11,651	33,919- 80,414
50	34,227	18,780	14,735-106,724	18,180	18,133	1,574- 99,247
60	20,148	12,065	12,808- 87,458	7,970	17,867	412-119,067

[1] Results based on data from computer program simulations done by Fried and Wespestad (in press), assuming herring spawning within Togiak District represent 82% of total eastern Bering Sea Pacific herring spawning biomass.

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APPENDICES

Appendix Table 1. Conversion estimates (metric tons of Pacific herring per 50 m^2 school surface area) obtained from test purse seine fishing, Togiak District, Alaska, 1978-1983. Results of statistical tests used to examine whether a relationship existed between school density and water depth are shown.

Year	Water Depth (m)	School Density (mt/50 m^2)	Weight Est.
1981	2	1.1	Landed
1980	3	1.2	Landed
1983	3	1.0	In net
1983	3	1.8	In net
1983	4	1.1	In net
1983	4	1.7	In net
1983	4	2.2	In net
1980	5	1.1	Landed
1980	5	1.2	In net
1979	6	2.4	Landed
1980	6	3.0	In net
1980	6	2.6	In net
1981	6	1.7	Landed
1980	8	1.6	In net
1981	8	4.0	Landed
1982	8	1.9	In net
1983	8	1.5	In net
1978	?	6.7	In net
1978	?	11.0	In net

For all school density data, $\overline{Y}$ (mean density) = 2.57, s. dev. = 2.45, n = 19

For water depths 2-5 m, $\overline{Y}_1$ = 1.38, s_1 (s. dev.) = 0.418, n = 9

For water depths 6-8 m, $\overline{Y}_2$ = 2.34, s_2 (s. dev.) = 0.855, n = 8

To test for differences between mean densities at water depths of 2-5 m and 6-8 m, the variances of the means must first be compared. The test statistic used is the ratio of the greater variance over the lesser one:

$$F_S = (s_2)^2 / (s_1)^2 = (0.855)^2 / (0.418)^2 = 4.184$$

This is a two-tailed test since the null hypothesis is: $(s_1)^2 = (s_2)^2$. Therefore, the critical test statistic value is:

$$F_{.025[7,8]} = 4.53, \text{ for an acceptable type I error of } 0.050.$$

Since the calculated test statistic is less than the critical value, the null hypothesis is accepted (i.e., variances are not significantly different). Therefore, a t-test can be used to test the mean densities. The test statistic used is:

Appendix Table 1. Conversion estimates (metric tons of Pacific herring per 50 m² school surface area) obtained from test purse seine fishing, Togiak District, Alaska, 1978-1983. Results of statistical tests used to examine whether a relationship existed between school density and water depth are shown (continued).

$$t_s = \frac{(\overline{Y}_2 - \overline{Y}_1)}{\sqrt{\{[(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2] / [n_1 - n_2 - 2]\}\{[(n_1 + n_2) / n_1 n_2]\}}}$$

$$t_s = \frac{(2.34 - 1.38)}{\sqrt{\{[(9 - 1)(0.175) + (8 - 1)(0.731)]/[9 + 8 - 2]\}\{[(9 + 8) / 72]\}}}$$

$$t_s = 9.358$$

The critical test statistic value for a type I error of 0.050 is:

$$t_{.05[15]} = 2.131$$

Since the calculated test statistic is greater than the critical value, the null hypothesis is rejected (i.e., the means are significantly different).

To determine whether differences among density measurements can be accounted for by linear regression (density versus water depth), analysis of variance (ANOVA) testing procedures were used on the following data:

	Water Depth (X)					
	2	3	4	5	6	8
Density (Y)	1.1	1.2	1.1	1.1	2.4	1.6
		1.0	1.7	1.2	3.0	4.0
		1.8	2.2		2.6	1.9
					1.7	1.5

The following ANOVA table was obtained:

Source of Variation	d.f.	S.S.	M.S.	F_s
Among groups	5	4.3995	0.8799	0.6043 n.s.
Within groups	11	16.0158	1.4560	
Total	16	20.4153		

Appendix Table 1. Conversion estimates (metric tons of Pacific herring per 50 m^2 school surface area) obtained from test purse seine fishing, Togiak District, Alaska, 1978-1983. Results of statistical tests used to examine whether a relationship existed between school density and water depth are shown (continued).

The critical test statistic for an acceptable type I error of 0.050 is:

$$F_{.05(5,11]} = 3.20$$

Since the calculated test statistic is less than the critical value, the null hypothesis is accepted (i.e., groups do not differ significantly). Although unlikely, it is still possible for linear regression to be significant, if S.S. among groups is greater than the product of M.S. within groups and $F_{.05[1,11]}$:

$$(M.S._{within}) (F_{.05[1,11]}) = (1.4560) (4.84) = 7.047$$

However, $S.S._{among}$ (4.3995) is less than the above value. Therefore, it is impossible for regression to be significant.

Appendix Table 2. Age, sex and size data for Pacific herring captured by variable mesh gillnets in Togiak District, Bristol Bay, Alaska, 1983.

Sample Period	Age (years)	Sex: Male	Sex: Female	Sex: Unknown	Total	Percent of Total	Weight: Mean (gm)	Weight: Std. Dev.	Weight: Number Weighed	Std. Length: Mean (mm)	Std. Length: Std. Dev.	Std. Length: Number Measured
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-	-	-
4/22- 4/28	5	10	11	-	21	19.3	233	22.5	20	256	8.5	20
	6	24	24	-	48	44.0	281	33.2	48	269	9.6	48
	7	1	-	-	1	.9	289	-	1	276	-	1
	8	4	2	-	6	5.5	343	47.9	6	288	7.5	6
	9+	16	17	-	33	30.3	394	38.9	33	297	12.9	33
Period total		55	54	-	109	100.0	310	69.7	108	276	18.6	108
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	-	1	-	1	.4	183	-	1	247	-	1
4/29- 5/ 5	5	27	12	-	39	14.2	234	28.5	39	253	7.3	39
	6	49	41	-	90	32.7	291	38.5	90	268	7.5	90
	7	3	5	-	8	2.9	327	43.5	8	276	9.5	8
	8	13	11	-	24	8.7	401	37.0	24	294	7.2	24
	9+	65	48	-	113	41.1	404	39.1	113	296	8.7	113
Period total		157	118	-	275	100.0	339	76.5	275	280	18.2	275
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	7	2	-	9	2.5	175	17.7	9	237	7.7	9
5/ 6- 5/12	5	71	57	-	128	35.1	231	33.0	128	255	9.6	128
	6	85	82	-	167	45.8	276	39.3	167	269	9.1	167
	7	7	3	-	10	2.7	290	37.3	10	279	8.3	10
	8	8	2	-	10	2.7	328	36.0	10	288	5.0	10
	9+	23	18	-	41	11.2	373	50.7	41	297	9.1	41
Period total		201	164	-	365	100.0	270	59.3	365	267	16.8	365
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	3	-	-	3	.5	124	30.7	3	210	15.9	3
	4	30	33	-	63	9.9	151	19.0	63	226	7.8	63
5/13- 5/19	5	165	107	1	273	43.0	209	31.7	273	250	9.6	273
	6	130	117	-	247	38.9	260	37.1	247	266	8.3	247
	7	4	8	-	12	1.9	302	42.6	12	275	8.8	12
	8	5	-	-	5	.8	337	38.7	5	286	7.5	5
	9+	17	15	-	32	5.0	366	53.8	32	296	8.8	32
Period total		354	280	1	635	100.0	233	59.3	635	257	18.1	635
	1	-	-	-	-	-	-	-	-	-	-	-
	2	2	-	-	2	.3	52	4.9	2	157	1.4	2
	3	2	6	-	8	1.2	107	21.2	8	202	12.0	8
	4	60	64	-	124	18.5	156	24.6	124	228	8.7	123
5/20- 5/26	5	158	142	-	300	44.8	196	27.8	300	246	9.8	300
	6	109	97	1	207	30.9	244	29.6	207	264	8.7	207
	7	5	-	-	5	.7	267	34.6	5	272	7.3	5
	8	2	-	-	2	.3	313	12.7	2	288	4.9	2
	9+	7	14	-	21	3.1	331	31.3	21	290	8.2	21
Period total		345	323	1	669	100.0	207	49.7	669	249	18.7	668
	1	-	-	-	-	-	-	-	-	-	-	-
	2	2	-	-	2	.1	52	4.9	2	157	1.4	2
	3	5	6	-	11	.5	112	23.8	11	204	13.0	11
	4	97	100	-	197	9.6	155	23.1	197	228	8.7	196
All periods	5	431	329	1	761	37.1	209	33.0	760	250	10.1	760
	6	397	361	1	759	37.0	264	38.9	759	267	8.8	759
	7	20	16	-	36	1.8	299	42.5	36	276	8.5	36
	8	32	15	-	47	2.3	368	50.5	47	291	7.2	47
	9+	128	112	-	240	11.7	385	48.1	240	296	9.5	240
Total		1112	939	2	2053	100.0	250	74.6	2052	260	21.1	2051

Appendix Table 3. Age, sex and size data for Pacific herring captured by chartered commercial purse seine vessels in Togiak District, Bristol Bay, Alaska, 1983.

Sample Period	Age (years)	Sex: Male	Sex: Female	Sex: Unknown	Total	Percent of Total	Weight: Mean (gm)	Weight: Std. Dev.	Weight: Number Weighed	Std. Length: Mean (mm)	Std. Length: Std. Dev.	Std. Length: Number Measured
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-	-	-
4/22- 4/28	5	5	12	-	17	9.7	240	30.1	17	254	5.8	17
	6	25	24	-	49	28.0	295	30.9	49	271	8.4	49
	7	3	7	-	10	5.7	340	28.3	10	281	6.4	10
	8	3	4	-	7	4.0	368	37.6	7	284	7.1	7
	9+	45	47	-	92	52.6	410	40.5	92	298	8.5	92
Period total		81	94	-	175	100.0	355	72.3	175	284	17.3	175
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	1	1	-	2	.9	179	9.2	2	238	2.8	2
4/29- 5/ 5	5	21	18	-	39	18.1	261	47.2	36	258	7.4	39
	6	42	46	-	88	40.7	305	34.6	77	270	6.4	88
	7	4	5	-	9	4.2	320	38.2	8	278	10.4	9
	8	5	6	-	11	5.1	384	32.0	11	286	6.4	11
	9+	38	29	-	67	31.0	413	49.4	65	299	11.3	67
Period total		111	105	-	216	100.0	336	73.9	199	278	18.0	216
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	1	3	-	4	1.7	193	33.3	4	244	7.8	4
5/ 6- 5/12	5	28	41	-	69	29.4	237	34.3	69	256	11.2	69
	6	59	72	1	132	56.2	280	35.8	132	269	9.2	132
	7	2	3	-	5	2.1	312	74.7	5	280	12.3	5
	8	5	-	-	5	2.1	299	38.2	4	284	16.0	5
	9+	12	8	-	20	8.5	371	58.4	20	298	10.0	20
Period total		107	127	1	235	100.0	274	53.5	234	268	15.4	235
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	10	18	-	28	5.6	164	15.3	28	233	6.0	28
5/13- 5/19	5	113	91	-	204	40.5	198	25.2	204	250	8.9	204
	6	125	99	-	224	44.4	241	28.2	224	266	8.2	224
	7	6	2	-	8	1.6	274	33.8	8	277	7.2	8
	8	4	4	-	8	1.6	307	23.6	8	290	9.3	8
	9+	18	14	-	32	6.3	324	31.5	32	295	9.3	32
Period total		276	228	-	504	100.0	226	45.7	504	260	16.2	504
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	12	22	-	34	3.0	168	19.9	34	235	7.0	34
All periods	5	167	162	-	329	29.1	216	38.3	326	253	9.6	329
	6	251	241	1	493	43.6	267	40.9	482	268	8.4	493
	7	15	17	-	32	2.8	313	47.4	31	279	8.6	32
	8	17	14	-	31	2.7	348	47.9	30	286	9.2	31
	9+	113	98	-	211	18.7	394	54.2	209	298	9.7	211
Total		575	554	1	1130	100.0	276	78.1	1112	269	19.0	1130

Appendix Table 4. Age, sex and size data for Pacific herring captured by chartered commercial gillnet vessels in Togiak District, Bristol Bay, Alaska, 1983.

Sample Period	Age (years)	Sex Male	Sex Female	Sex Unknown	Total	Percent of Total	Weight Mean (gm)	Weight Std. Dev.	Weight Number Weighed	Std. Length Mean (mm)	Std. Length Std. Dev.	Std. Length Number Measured
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	1	-	-	1	2.6	172	-	1	235	-	1
4/29- 5/ 5	5	5	3	-	8	20.5	241	33.5	8	255	7.9	8
	6	19	7	-	26	66.7	292	39.8	26	269	9.4	26
	7	1	-	-	1	2.6	365	-	1	282	-	1
	8	-	-	-	-	-	-	-	-	-	-	-
	9+	1	2	-	3	7.7	412	39.3	3	299	5.3	3
Period total		27	12	-	39	100.0	290	59.4	39	268	14.8	39
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	1	-	1	.9	135	-	1	208	-	1
	4	2	-	-	2	1.7	171	24.0	2	233	5.7	2
5/ 6- 5/12	5	19	26	-	45	39.1	232	22.7	45	253	6.8	45
	6	21	29	-	50	43.5	273	30.6	50	267	8.0	50
	7	-	1	-	1	.9	281	-	1	279	-	1
	8	-	2	-	2	1.7	343	70.7	2	277	5.7	2
	9+	6	8	-	14	12.2	338	29.4	14	292	6.5	14
Period total		48	67	-	115	100.0	263	47.6	115	264	15.5	115
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-	-	-
5/13- 5/19	5	4	7	-	11	55.0	228	30.1	11	253	10.0	11
	6	5	2	-	7	35.0	261	31.9	7	272	8.4	7
	7	1	-	-	1	5.0	263	-	1	270	-	1
	8	1	-	-	1	5.0	290	-	1	282	-	1
	9+	-	-	-	-	-	-	-	-	-	-	-
Period total		11	9	-	20	100.0	244	34.5	20	262	13.3	20
	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	1	-	1	.6	135	-	1	208	-	1
	4	3	-	-	3	1.7	171	17.0	3	234	4.2	3
All periods	5	28	36	-	64	36.8	232	25.3	64	254	7.4	64
	6	45	38	-	83	47.7	278	35.0	83	268	8.5	83
	7	2	1	-	3	1.7	303	54.4	3	277	6.2	3
	8	1	2	-	3	1.7	325	58.6	3	279	4.9	3
	9+	7	10	-	17	9.8	351	41.6	17	293	6.8	17
Total		86	88	-	174	100.0	267	50.9	174	264	15.1	174

Appendix Table 5. Age, sex and size data for Pacific herring captured by commercial purse seine vessels during commercial openings in Togiak District, Bristol Bay, Alaska, 1983.

Sample Period	Age (years)	Sex			Total	Percent of Total	Weight			Std. Length		
		Male	Female	Unknown			Mean (gm)	Std. Dev.	Number Weighed	Mean (mm)	Std. Dev.	Number Measured
4/29- 5/ 5	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	3	3	-	6	.7	182	8.3	6	233	4.1	6
	5	96	105	-	201	24.6	239	31.4	181	254	7.5	201
	6	226	224	-	450	55.0	288	34.8	404	268	7.5	450
	7	8	14	-	22	2.7	337	49.4	20	279	9.7	22
	8	12	12	-	24	2.9	343	54.0	22	287	6.2	24
	9+	56	59	-	115	14.1	387	44.6	104	296	9.6	115
Period total		401	417	-	818	100.0	292	59.4	737	269	15.6	818
5/ 6- 5/12	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	1	-	-	1	.3	86	-	1	191	-	1
	4	9	10	-	19	5.7	176	21.1	18	234	8.7	19
	5	82	65	-	147	44.3	230	28.9	147	253	8.7	147
	6	68	81	-	149	44.9	284	28.6	149	267	7.1	149
	7	1	4	-	5	1.5	312	30.9	5	275	7.3	5
	8	2	-	-	2	.6	344	40.3	2	293	9.9	2
	9+	5	4	-	9	2.7	355	45.6	9	292	10.1	9
Period total		168	164	-	332	100.0	256	47.8	331	260	14.2	332
All periods	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	1	-	-	1	.1	86	-	1	191	-	1
	4	12	13	-	25	2.2	177	18.8	24	233	7.8	25
	5	178	170	-	348	30.3	235	30.6	328	254	8.0	348
	6	294	305	-	599	52.1	287	33.2	553	268	7.4	599
	7	9	18	-	27	2.3	332	46.9	25	278	9.3	27
	8	14	12	-	26	2.3	343	52.3	24	287	6.5	26
	9+	61	63	-	124	10.8	384	45.3	113	296	9.7	124
Total		569	581	-	1150	100.0	281	58.4	1068	267	15.8	1150

Appendix Table 6. Age, sex and size data for Pacific herring captured by commercial gillnet vessels during commercial openings in Togiak District, Bristol Bay, Alaska, 1983.

Sample Period	Age (years)	Sex: Male	Sex: Female	Sex: Unknown	Total	Percent of Total	Weight: Mean (gm)	Weight: Std. Dev.	Weight: Number Weighed	Std. Length: Mean (mm)	Std. Length: Std. Dev.	Std. Length: Number Measured
4/29- 5/ 5	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	-	1	-	1	.1	219	-	1	234	-	1
	5	176	98	-	274	35.2	240	26.7	247	257	8.1	273
	6	232	151	-	383	49.2	284	31.1	350	269	8.7	383
	7	14	4	-	18	2.3	291	36.9	18	275	8.4	18
	8	11	4	-	15	1.9	360	39.9	14	289	12.3	15
	9+	44	44	-	88	11.3	376	48.5	81	298	11.0	88
Period total		477	302	-	779	100.0	281	52.8	711	268	15.3	778
5/ 6- 5/12	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-	-	-
	5	48	36	-	84	51.5	227	28.1	84	255	8.4	84
	6	43	30	-	73	44.8	276	34.1	73	269	8.0	73
	7	2	-	-	2	1.2	302	25.5	2	277	15.6	2
	8	-	-	-	-	-	-	-	-	-	-	-
	9+	3	1	-	4	2.5	326	48.0	4	291	7.5	4
Period total		96	67	-	163	100.0	253	41.4	163	262	11.9	163
All periods	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
	4	-	1	-	1	.1	219	-	1	234	-	1
	5	224	134	-	358	38.0	237	27.7	331	256	8.2	357
	6	275	181	-	456	48.4	283	31.7	423	269	8.6	456
	7	16	4	-	20	2.1	292	35.5	20	275	8.7	20
	8	11	4	-	15	1.6	360	39.9	14	289	12.3	15
	9+	47	45	-	92	9.8	374	49.4	85	297	10.9	92
Total		573	369	-	942	100.0	276	52.1	874	267	15.0	941

Appendix Table 7. Information used in making 1984 Togiak District Pacific herring spawning biomass forecast.

Age	Standard Length (mm)[1]	Age Interval	Growth Rate[2]	Natural Mortality[3]	Recruitment Correction[4]
3	216				
		3-4	0.293	0.25	2.005
4	235				
		4-5	0.229	0.15	1.127
5	251				
		5-6	0.176	0.18	1.035
6	264				
		6-7	0.129	0.23	1.001
7	274				
		7-8	0.100	0.29	1.000
8	282				
		8-9	0.085	0.36	1.000
9	289				
		9-10	0.060	0.45	1.000
10	294				

[1] Length at age calculated using relationship from Fried and Wespestad (in press):

$$L = 315.44 \left\{1-e^{[-0.22(t+2.23)]}\right\}$$

[2] Instantaneous growth rate calculated using equation from Ricker (1975):

$G = 3.479\ [\ln(L_{t+1}) - \ln(L_t)]$, where

3.479 is the value obtained from the length-weight relationship given by Fried and Wespestad (in press).

[3] Instantaneous natural mortality rates calculated from catch data for the period 1959-1981 as presented in Wespestad (1982).

[4] Recruitment correction calculated from relationship:

R_{t+1} / R_t , where

recruitment at age i (R_i) obtained from data presented by Naumenko (1979) as cited in Wespestad (1982).