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PACIFIC HERRING, *CLUPEA HARENGUS PALLASI*, STUDIES IN SAN FRANCISCO BAY, APRIL 1986 TO MARCH 1987

by

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and
Thomas O. Moore

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ABSTRACT

Herring schools were surveyed hydroacoustically and sampled in San Francisco Bay from late October 1986 to March 1987. Eight large schools (greater than 1000 tons each) spawned from December to February and seven smaller schools were detected throughout the spawning season. Total acoustic biomass estimate using a "visual integration" technique was 40,930 tons, and it was determined from spawn escapement and commercial landings that an additional 2240 tons were not detected. This is a slight increase from last season's total of approximately 42,200 tons. For the first time, biomass was also estimated using echo integration equipment. A total biomass was obtained of 33,050 tons, including herring not detected acoustically. This estimate must be considered preliminary and subject to revision after target strength of San Francisco Bay herring is determined.

Eighty-seven samples, containing a total of 13,125 herring, were collected with variable-mesh gill net and midwater trawl or obtained from the roundhaul and gill net fisheries. Mean body length (BL) of sampled herring decreased by about 20 mm from the beginning to the end of the spawning season. A combination of variable-mesh gill net and midwater trawl samples for a particular school closely approximates mean BL and age composition data from unbiased roundhaul samples.

Age-weight and age-length relationships were average to above average compared with those of the previous two seasons. The 1982 year class exhibited unusually good growth, with a mean BL of 202.8 mm for herring aged from stratified random samples.

The 1982 through 1985 year classes (5- through 2-yr olds) contributed 97% by number and 95% by weight to the total 1986-87 spawning biomass in San Francisco Bay. Good recruitment has occurred during the past four seasons. The weak 1981 year class contributed little to the total biomass as 6-yr olds.

Average catch per tow of young-of-the-year (YOY) herring is a potential index of abundance for recruitment 18 months later as 2-yr olds. Estimated recruitment has only varied by 15% during

the past three seasons and does not reflect the magnitude or trend in YOY catches in the bay.

ACKNOWLEDGMENTS

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Philip Law assisted on statistical analyses. Juana Lofgren helped in the word processing of appendices. The manuscript was reviewed by Tom Jow, Jerome Spratt, and Art Haseltine. Jerry also read some of the difficult ototliths.

Norm Lemberg, Washington Department of Fisheries, Seattle, contributed his time and equipment to facilitate the echo integration of acoustic data.

Chuck Armor of DFG's Bay-Delta Project provided us with samples of YOY, juvenile, and adult herring caught before the spawning season and allowed access to the extensive YOY data base from spring and summer trawling.

Thanks are extended to survey volunteers Debbie Dresser, Allen Grover, Vladimir Hvoschinsky, Dorothy Isaacson, Julene Jones, Karin Marsh, Nick Paszty, Phil Swartzell, Bob Tasto, Dave and Geoff Thomas, Yvette Tipton, Eb Ueber, and Jody Zaitlin.

Finally, we continue to appreciate the cooperation of the commercial fishermen in San Francisco Bay who provided us with samples and information.

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INTRODUCTION

This was the sixth year of field work by the California Department of Fish and Game (CDFG) Pacific Herring Research Project and the fifth in which acoustic surveys were conducted and samples were obtained throughout the October to March spawning season. Data have been presented for each season in administrative reports (Reilly and Moore 1982, 1983, 1984, 1985, 1986) and serve to complement biomass estimates from spawn deposition surveys (Spratt 1987a) and biological data of that portion of the herring population exploited by the commercial fishery (Spratt 1987b). The Pacific Herring Research Project has one major objective, to provide data necessary for long-term management of the herring roe fishery in California. Research, oriented to this objective during the 1986-87 herring season, included: 1) hydroacoustic estimation of spawning biomass of each school of adult herring in San Francisco Bay (Figure 1); 2) determination of length and age composition of herring in each school; 3) weight/age/length relationships; 4) examination of catch data of juvenile and young-of-the-year (YOY) herring from CDFG's Bay-Delta Project; and 5) sampling herring during the non-spawning season from San Francisco Bay.

METHODS

Non-spawning Season Field Sampling

The Bay-Delta Project, Stockton, collected samples of YOY, juvenile, and adult herring in San Francisco Bay from April to June 1986. All samples were frozen and delivered to the Menlo Park laboratory where they were thawed, measured, sexed if

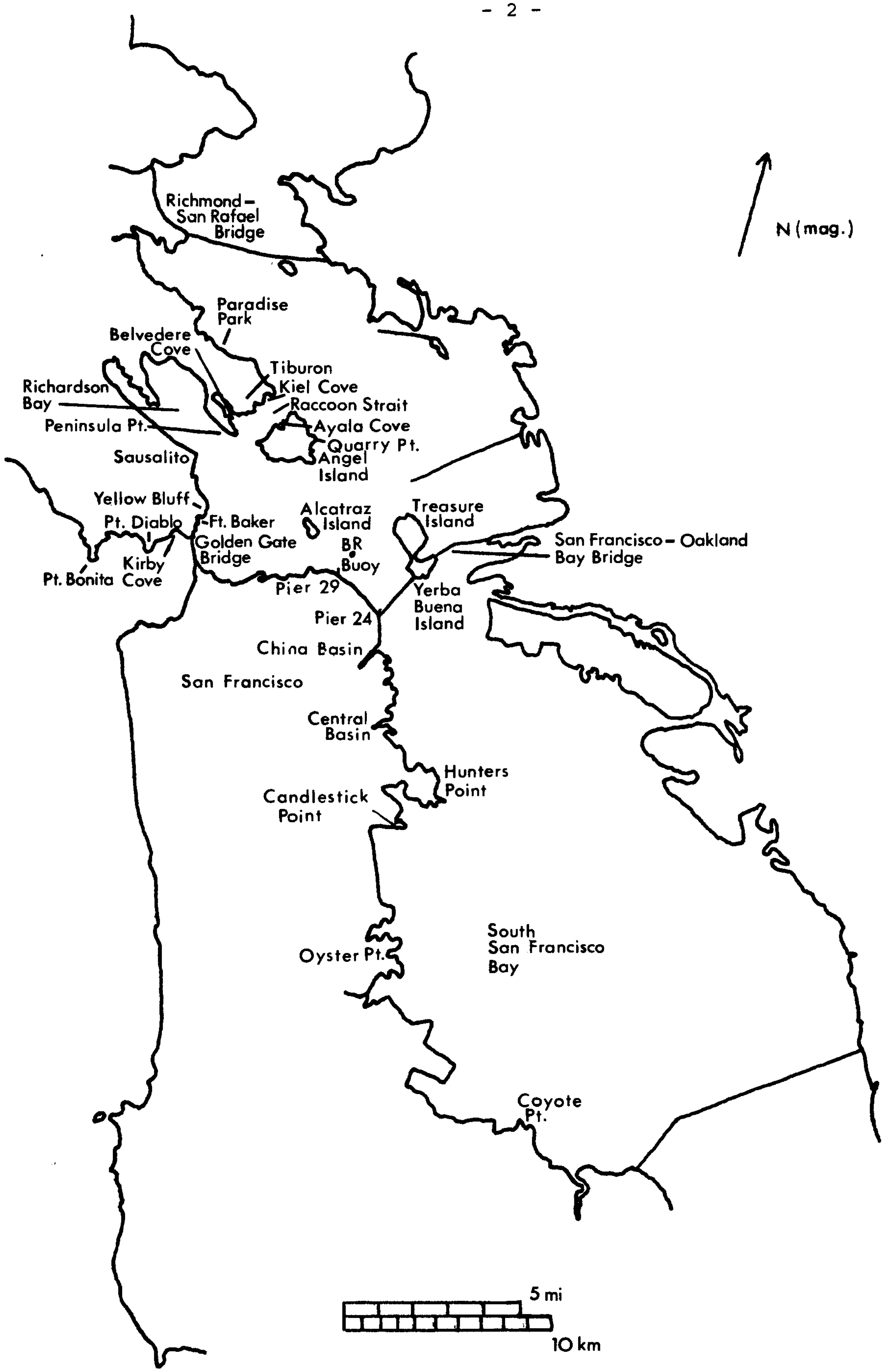

FIGURE 1. Pacific herring acoustic survey and sampling areas in San Francisco Bay.

possible, weighed, and subsampled for otolith aging.

Spawning Season Field Work

Research Vessel

The 23-ft R/V PANDALUS was used on all field days in San Francisco Bay from October to March.

Acoustic Monitoring

Hydroacoustic surveys were conducted 3 or 4 d each week. Areas surveyed included central San Francisco Bay and the Golden Gate bounded by the Richmond-San Rafael Bridge, Oakland-Bay Bridge, and Pt. Bonita (Figure 1), hereafter referred to as north bay, and southern bay waters between the Oakland-Bay Bridge and Oyster Point (Figure 1), hereafter referred to as south bay, Acoustic monitoring was done at a speed of approximately 8 kn.

Approximately 3 d each week a Raytheon model DE-719B recording fathometer depth sounder was used to locate herring schools. Schools subsequently were plotted on charts of San Francisco Bay using a combination of calculated horizontal school dimensions and bottom depths from acoustic echograms, and compass bearings from known landmarks. A Housten Instrument HI-PAD digitizer was used to calculate surface area of schools or portions of schools with approximately uniform density and height in the water column, based on visual examination of acoustic echograms.

Density estimates (tons/10^6 ft^2) were then assigned to different parts of each school based on calibration factors developed during charter of a purse seine vessel in 1983 (Reilly and Moore 1983) and modified from intercalibration factors obtained in 1985 from a Washington Department of Fisheries (WDF)

Biosonics model 101 echo sounder and model 120 echo integrator (Reilly and Moore 1985). Finally, school biomass was calculated for each school surveyed. This method, hereafter referred to as "visual integration", has been used since 1982.

This season, a scientific grade echo sounder, the Biosonics model 105, was acquired, enabling us for the first time to estimate biomass using the acoustic technique of echo integration. The data collection system includes the echosounder, narrow beam (6^o) 200 kHz transducer, an oscilloscope, a chart recorder, a video cassette recorder, and a digitizer. Reflected echoes from herring are converted to voltages, digitized after being attenuated by a factor of ten, and stored on tape. The echosounder incorporates a time-varied gain which insures that a particular fish will reflect the same amount of voltage regardless of its depth.

Tapes were processed in Seattle using WDF's echo integrator and interface (to increase attenuated voltages). The integrator prints out densities of herring (kg/m^3) for each depth stratum for each transect. Depth strata were arbitrarily chosen to be 5-10, 10-15, 15-20, 20-25, 25-30, and 30-40 m. An average density per m^2 was then calculated and multiplied by the surface area bisected by each transect to obtain a biomass estimate.

The estimate is scaled by a factor known as the "A constant". This incorporates system parameters of transmitter source level, receiver sensitivity, beam pattern factor of the transducer, and pulse width, and other factors including speed of sound in water, pi, and a target strength value for herring. The latter is related to the amount of reflected voltage and the size of the fish.

Biomass estimates for most schools were obtained this season using both the echo integration method and the visual integration method.

Sampling Gear Types

Gill Nets. During the spawning season, nylon multifilament, variable mesh gill nets were used to sample herring in depths from 6 to 65 ft. The mesh array consisted of five 10-ft long by 6-ft high panels with mesh size 1.5, 1.75, 2.0, 2.25, and 2.5 in. Nets were anchored and marked by floats. Soak times varied from 10 min to 15 h. All samples were separated by mesh size.

Midwater Trawl. A 12-ft square (mouth-opening), 65-ft long, double warp midwater trawl with an 0.5-in. stretched-mesh cod end was used throughout the season. Tow speed was approximately 3 kn and tow duration ranged from 5 to 30 min.

Commercial Fishery. From January 5 to March 12, 1987, samples were obtained from purse seine and lampara boats. Fish were either collected with a brail as they were brought to the side of the boat with the seine or lampara net or obtained from a bin at an offloading dock.

From December 1, 1986 to January 20, 1987, additional samples were taken from gill net boats.

Field Processing of Samples

Body length (BL), the Department's standard measurement for herring (Spratt 1981), was determined for all fish to the nearest mm from the tip of the snout to the end of the pigment underneath the last column of scales on the caudal peduncle. All fish were sexed and assigned a maturity code of either unripe, mature, or spent. One or more subsamples of approximately 17 fish per 10-mm size class were retained from each school for weighing and aging. This stratified random sampling for age composition allows us to age more older fish, which occur infrequently in random samples and have higher variability in growth. To improve age assignments for larger fish, additional herring ≥ 210 mm BL were selected and aged to augment the age-length data base.

Laboratory Processing of Samples

Length and Weight

All herring subsamples were returned to the Menlo Park laboratory, frozen, and thawed before processing. Thawed lengths were matched with fresh lengths from the field, or a correction factor of 1.021 (Reilly and Moore 1983) was applied to account for shrinkage. Fresh or corrected lengths were used in all data analyses. Weight was determined to the nearest 0.1 g; we have found no significant difference between fresh weight and thawed weight. Fish that were completely or partially spent were not weighed.

Otoliths

Otoliths were removed from herring, rubbed clean on wet paper towels, placed in ethanol, then stored dry in gelatin capsules. Otoliths were read in ethanol under a dissecting microscope by two readers independently. When disagreement occurred in aging, the first reader would re-examine the otoliths. If otoliths were of poor quality or agreement could not be reached, they were either sent to Jerome Spratt (CDFG-

Monterey) for another reading or the age determination was not used.

Assigned Age by Length

Using our age-length key for 1986-87 herring, ages were assigned to lengths of fish (2-mm intervals) not aged, based on the relative percentage composition of ages (from otoliths) for a particular size interval. All fish not aged were combined by assigned school numbers before ages were given to lengths.

Assigned School Numbers

A school number was used to define each herring school that spawned in San Francisco Bay. Each sample of herring was assigned to a school based on a combination of factors: 1) date of sample; 2) date of spawning as determined by egg deposition surveys; 3) hydroacoustic observations of schooling patterns and spawning events; 4) percentage of unripe females in the sample; 5) examination of daily landings of the commercial fleet and a knowledge of their fishing locations; and 6) miscellaneous information from conversations with fishermen.

Total Age Composition for Spawning Season

Total percentage age composition was calculated for the entire spawning season based on two separate biomass estimates by school: 1) the sum of spawn escapement estimate (Spratt 1987a) plus commercial catch; 2) our hydroacoustic biomass estimates (Spratt's estimates were used for schools not detected hydroacoustically). To calculate total percentage age composition by number, mean BL by school was converted to mean weight, using values from Appendix F. Each biomass estimate for each school was divided by the appropriate mean weight, and percentage age composition was used to calculate total number of fish by age for each school. Numbers for each age were then summed and divided by total number of fish. For schools not sampled, data from the nearest school, temporally, were used. To calculate total percentage age composition by weight, 1986-87 mean weight at age values were used along with percentage age composition by school.

Computer Processing of Samples

Length, weight, sex, and age data from all herring samples were entered in an IBM XT microcomputer using dBase III programs. Mean, standard deviation, standard error, and size frequencies of BL, by sex, were generated for each sample and each school by gear type using CDFG microcomputer programs. Other statistical analyses were performed using programs from ABSTAT and SPSS/PC.

Supplementary Data

Local precipitation and barometric pressure data were obtained from the National Climatic Data Center, Asheville, North Carolina, for San Francisco International Airport. These were used to determine if a relationship exists with spawning events.

Data from the Bay-Delta Project were examined to determine catch-per-unit-effort (CPUE) of YOY herring and length frequencies of YOY and juvenile herring. From 1983 until 1986, during spring and early summer, the project conducted extensive surface-to-30-ft midwater trawling near the Golden Gate Bridge (Figure 1) for out-migrant, marked salmon smolts. Incidental catches of YOY herring are used as an indicator of the strength of the year class of new recruits which will appear in the fishery approximately 18 mo later as 2-yr olds.

Bay-Delta project personnel used fork length (FL) to measure herring. A regression developed previously (Reilly and Moore 1986) was used to convert FL to BL before length frequency histograms for YOY and juvenile herring were examined.

RESULTS

Non-spawning Season Sampling, Bay-Delta Project Samples

Length frequencies for 7320 YOY and 1883 juvenile (age 1+ yr) herring from San Francisco Bay during April to June 1986 showed a separation ranging from 70 to 90 mm BL in April to 90 to 110 mm BL in June (Figure 2). The vertical dashed line partitions the year classes based on otolith aging. The decrease in modal BL for YOY herring from April to May is most likely the result of a later- spawning cohort moving into the sampling area. Growth of YOY herring was greater than that of the previous season while juveniles averaged 10 to 35 mm smaller than those in 1985 (Reilly and Moore 1986).

Age composition of stratified random samples of herring from April to June 1986 indicate a wide range of BL for YOYs and juveniles. Some overlap occurred between 1+- and 2+-yr-old fish. Few herring older than 2+ yr were captured (Table 1).

Acoustic Monitoring

Summary of Herring Schools

During the previous three seasons, spawning has started within 2 d of October 30 on the north side of Raccoon Strait (Figure 1). This season was no exception; a small school (number 1) spawned on the night of October 28 in Kiel Cove (Table

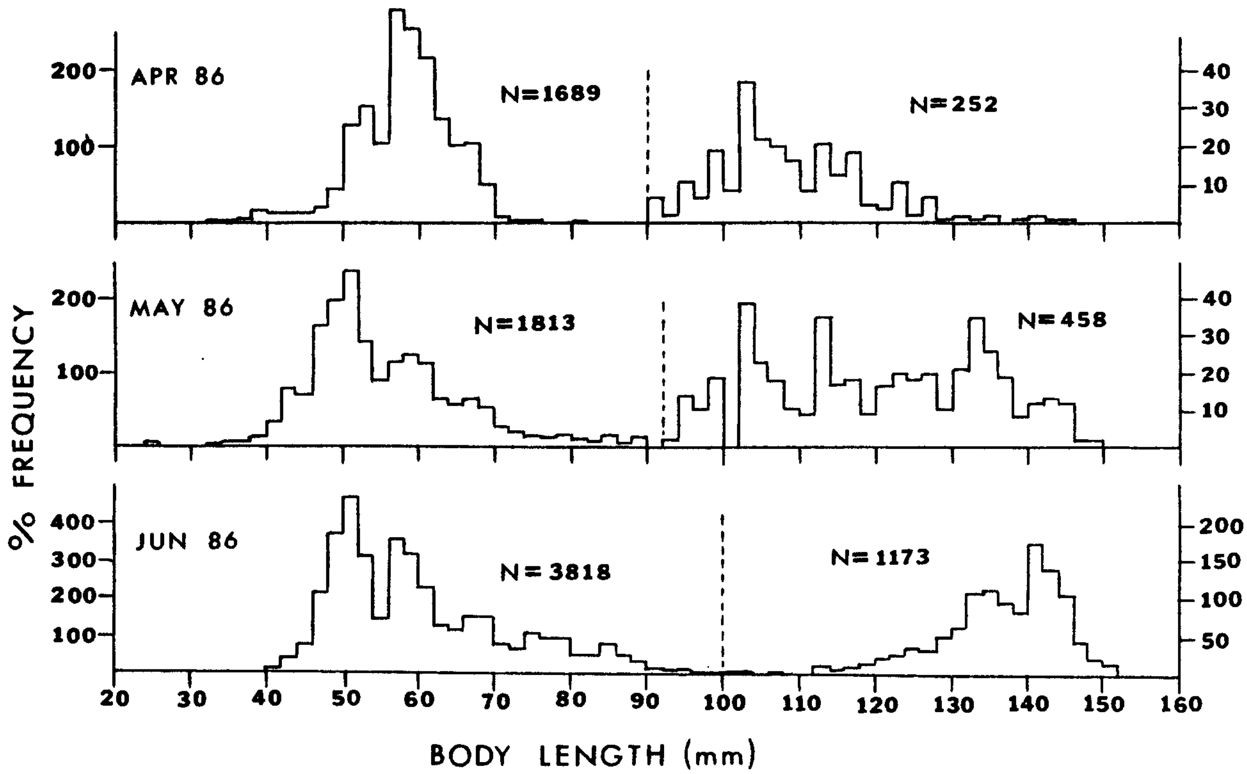

FIGURE 2. Number of Pacific herring (2-mm intervals) from Bay-Delta Project midwater trawl samples, San Francisco Bay, April to June 1986.

TABLE 1. Length and Age Composition of Pacific Herring Sampled from Bay-Delta Project by Midwater Trawl in San Francisco Bay, April to June 1986.

Body length (mm)	Age (yr) 0	Age (yr) 1+	Body length (mm)	Age (yr) 1+	2+	3+	4+	5+
42-43	1		130	5				
44	3		132	2				
46	4		134	4				
48	2		136	5	1			
50	3		138	3				
52	2		140	6				
54	2		142	2				
56	4		144	3				
58	4		146	2				
60	6		148		2			
62	7		150	1	3			
64	3		152		6			
66	3		154		11			
68	1		156		1			
70			158		2			
72	1		160					
74	1		162		3			
76	3		164		2			
78	2		166		2			
80	3		168		5			
82	1		170		3			
84	3		172					
86	2		174		1			
88			176		2	1		
90			178			1		
92			180		1	1	1	
94	1		182					
96			184					
98			186			1		
100		1	188					
102		1	190					
104		1	192					
106		2	194				1	
108		2	196					1
110		2	198				1	
112		2	200					1
114		5						
116		2						
118		6						
120		3						
122		4						
124		2						
126		3						
128		4						

2). The size of the school, its short residency in the bay prior to spawning, and the presence of large schools of anchovies in north bay waters make these herring difficult to detect acoustically.

Anchovies were abundant in north bay waters during the first 3 wk in November, and repeated attempts to locate herring mixed in with these schools, using variable-mesh gill nets and midwater trawl, yielded no adults until November 17. From then until November 20 small quantities of primarily unripe herring (school 2) were caught near Sausalito. Herring abruptly disappeared from this area with no evidence of spawning, and no further activity was detected for the remainder of the month in north bay waters.

By the November 30 opening of the commercial season activity had shifted to the south bay as in the past two seasons. Although only localized traces of herring activity were detected on an acoustic survey November 29, significant quantities of herring (school 3) were present 1 d later in the same area, and gill net vessels landed 476 tons from this school during the next 3 d. A hydroacoustic estimate of the entire school was not obtained prior to spawning. Sex composition and mean BL were different than the mid-November herring.

On December 1, as landings peaked from school 3, a new school (4) was found in central south bay waters. A trawl sample yielded 75% unripe fish on December 1 and 58% unripe fish on December 3. Spawning occurred December 7 and 8 along the San Francisco shoreline and gill netters landed 481 tons from this school.

TABLE 2. Summary of Herring Schools in San Francisco Bay, October 1986 to March 1987.

Assigned school number	Spawning dates	Spawning location[1]	Spawn escapement estimate (tons)[2]	Commercial catch (tons)	Hydroacoustic biomass estimate (tons) "visual" integ.	Hydroacoustic biomass estimate (tons) echo integ.
1	Oct 28	KC	3	0	-[3]	-[4]
2[5]	-	-	0	0	80	215
3	Nov 29-30	SF	400	476	-[3]	-[4]
4	Dec 7-8	SF	2700	481	1195	655
5	Dec 11	SAUS	230	305	160[6]	-[4]
6	Dec 17-19	SF	4600	435	2000	2855
7	Dec 28	SF	13,100	0	4235	5190
8	Jan 4-10	BELV, TIB, AI, SAUS	8015	1891	7700	5535
9	Jan 11	COY	20	0	-[3]	-[4]
10	Jan 18-23	SF	14,700	2665	10,910	8970
11	Jan 31	SF	130	53	4035	2700
12	Feb 20	SAUS	50	0	135	-[4]
13	Feb 23-26	BELV,	3570		1005	1415
				1780		
14	Feb 23-25	SF	1200		9475	2590
15[7]	-	-	0	12	-[3]	100
			48,718	8098	40,930	30,225

[1] Legend: AI-Angel Island; BELV-Belvedere; COY-Coyote Point; KC-Kiel Cove; SAUS-Sausalito; SF-San Francisco from Pier 29 to Candlestick Point; TIB-Tiburon.

[2] from Spratt 1987a.

[3] not surveyed with visual integration equipment prior to spawning.

[4] not surveyed with echo integration equipment prior to spawning.

[5] herring present near Sausalito Nov 17-20; subsequent surveys yielded no spawn deposition.

[6] entire school not detected hydroacoustically prior to spawning.

[7] herring present near Sausalito March 2-16; subsequent surveys yielded no spawn deposition.

Similar to the previous season, a small school (5) was present in early December in Raccoon Strait and near Angel Island. Fishing effort shifted to Sausalito and 305 tons were caught during a spawn which peaked on December 11.

As school 4 spawned along the shore on December 8, a new school (6) was acoustically monitored in the central south bay. A variable-mesh gill net sample 2 d later yielded 60% unripe fish. On December 16, a large midwater trawl sample (1002 fish) yielded 48% unripe fish, but on the next day a large spawn began along the San Francisco shoreline. This school provided the "XH" gill net vessels with the remainder of their quota.

During December it was difficult to correlate acoustically detected herring schools with discrete spawns. A "trickle spawn" behavior pattern seemed prevalent in which the leading edge of a school, containing riper fish, would break off and spawn, followed by an occasional increase in the volume of the main body of the school as more unripe fish entered the bay.

On December 19, five discrete concentrations of herring were detected from Raccoon Strait to near Hunters Point. By December 28, the majority of these fish had merged into one large school (7) which spawned along the San Francisco shoreline.

A midwater trawl sample December 30 near the Oakland-Bay Bridge contained a mixture of spent and pre-spawning herring. Seventy-five percent of the pre-spawners were unripe and signified the presence of the next school (8). These fish remained south of Alcatraz during the next week. During this time, in a behavioral pattern similar to last season, a large school (also considered to be school 8) moved rapidly into north bay waters from seaward of the Golden Gate Bridge on January 4 and began to spawn along Tiburon, Belvedere and Sausalito. Also on January 4, a trawl sample near Alcatraz still contained 70% unripe fish. These herring apparently moved to Angel Island and spawned from January 7 to 10. Spawning in north bay waters was continuous from January 4 to 10. School 8 was responsible for the entire quota for the "even" gill net vessels.

A small school (9) spawned on January 10 at Coyote Point but could not be separated acoustically from the main body before that date.

On January 12 the first signs of school 10 were detected and sampled south of Yerba Buena Island; almost 70% of the herring were unripe. On the next day a small school appeared in Raccoon Strait and near Sausalito and contained 25 to 30% unripe fish. Biomass increased in south bay waters and gill netters began to catch the riper part of the school from January 13 to 16. Activity near Sausalito diminished as herring south of Alcatraz consolidated into two large masses on either side of the Oakland-Bay Bridge. Those south of the bridge (school 10) spawned from January 18 to 23 and provided the "odd" gill net vessels with their entire quota and lampara vessels with approximately 525 tons. On January 23 the second large school (11) was located between the Golden Gate Bridge and China Basin. These fish spawned January 31 to February 2 along the San Francisco shoreline and were difficult to fish by roundhaul vessels, yielding only about 50 tons.

The first appearance of new fish (schools 12, 13, and 14) occurred January 26 near Sausalito. A roundhaul sample contained 30% unripe herring. By January 30 biomass had increased and the main body had moved east of Angel Island during high tide, For the next 3 wk large concentrations of herring were scattered throughout north and south bay waters with no spawning evident. Most fish were ripe by February 16. A small spawn (school 12) occurred February 20 near Sausalito. The main body had consolidated into a north bay school (13) and south bay school (14), the latter being available to purse seiners at low tide near Alcatraz. On February 23, spawning began simultaneously near Belvedere and Tiburon and along the San Francisco shoreline. The roundhaul fleet pursued these two schools throughout their residency in the bay and landed 1780 tons.

Very little activity occurred in March. A small school (15) mixed with anchovies was detected and sampled in Raccoon Strait and near Sausalito from March 2 to March 16 but no spawn could be located. Only a few purse seiners remained in the fishery and landed approximately 10 tons.

Acoustic Biomass Estimates for San Francisco Bay

Our total hydroacoustic biomass estimate, using visual integration, was 40,930 tons (Table 2); this does not include schools 1, 3, and 9, which were not detected. Spawn escapement estimate and catch for these schools was about 900 tons. In addition, 1340 tons were landed from schools 13 and 14 before the visual integration survey. Thus, an adjusted visual integration biomass estimate would be 43,170 tons. This compares with 56,800 tons from spawn escapement and catch. During the past five spawning seasons visual integration estimates have differed from catch-plus-escapement estimates by a range of 10 to 38% and have shown the same trend of a substantial decline in 1983-84 followed by a gradual increase the next three seasons (Table 3).

The echo integration estimate also must be adjusted to account for schools not detected and for herring landed from a school prior to a survey. Based on spawn escapement surveys, approximately 1485 tons were not detected with the echo integration equipment and 1340 tons were landed from schools 13 and 14 before biomass data collection. Adding this to the 30,225 ton total biomass estimate yields 33,050 tons, only 58% of the total estimate from catch plus escapement. However, this echo integration estimate must be considered preliminary and subject to revision after "A" constant parameters, particularly target strength, are estimated more accurately. If target strength values for San Francisco Bay herring are less than the -33 decibels per kg using in the scaling factor equation, biomass estimates will increase. The above value is currently used by WDF and was derived from comparisons of net haul and acoustic density (Lemberg 1978).

Herring Samples from San Francisco Bay

Eighty-seven samples of adult herring were collected in San Francisco Bay from October 27, 1986 to March 16, 1987 (Appendix A); these contained a total of 13,125 fish. Herring were sampled from all schools except numbers 9 and 12.

Commercial gill net samples are biased due to mesh selectivity and were not included in size and age composition

TABLE 3. Summary of Acoustic and Spawn Escapement-plus-Catch Biomass Estimates for San Francisco Bay, 1982-83 to 1986-87.

Season	Biomass estimate (tons) Visual integration[1]	Escapement-plus-catch[2]
1982-83	65,000	59,200
1983-84	25,000	40,400
1984-85	35,000	46,100
1985-86	42,200	49,100
1986-87	43,200	56,800

[1] includes biomass known to be missed by acoustic surveys or caught previous to acoustic surveys.

[2] data from Spratt (1987a).

data combined by school. However, aged fish from these samples were used as part of an age-length key and a gill net length frequency histogram was generated.

Length Composition

Variable-mesh Gill Net Samples. A total of 3769 herring was obtained from 25 samples (Appendix B) from all schools except 9, 12 and 15. Samples grouped by assigned school number showed the usual trend of decreasing mean BL from the beginning to the end of the season (Table 4); however, mean BL for schools sampled from late November (school 3) to early January (school 8) was fairly uniform and only varied by 4 mm.

A series of gill net length frequency histograms was generated for 1.5-, 1.75-, 2.0-, 2.25-, and 2.5-in. mesh plus commercial mesh (Figures 3-8). All commercial samples were combined due to the similarity of length composition in December and January. All samples from 2.5-in. mesh were combined due to low numbers. Monthly mean BL varied by as much as 17.7 mm for a particular mesh size, primarily due to the preponderance of large herring in school 1 sampled in October. Mean BL data from the past six seasons for mesh sizes 1.25 to 2.25 in. are summarized in Table 5. All means for 1986-87 are within the range of previous means for a particular month and mesh size except for November-December for the three largest meshes. Unweighted means were calculated by averaging each monthly mean in order to compare with weighted means without the effect of sample size.

The shift in length composition to smaller fish as the season progressed is apparent from observing which mesh size catches the highest proportion of fish. Without exception, in

TABLE 4. Number of Pacific Herring by Body Length (2-mm Intervals), Combined by Assigned School Number, from Variable-Mesh Gill Net Samples, San Francisco Bay, October 1986 to February 1987.

Body length (mm)	Assigned School Number 1	2	3	4	5	6	7	8	10
130-139									
140-149								5	2
150-151							1	3	
152								12	1
154	1							6	1
156	2				1	1	3	11	3
158	1		1			1		15	5
160								21	1
162				1	1	3	5	43	10
164	4			3		3	2	33	5
166	1		2	2	3	1	1	62	9
168	6		3	2	2	6	1	48	7
170	1	1	5	2	3	2	2	49	5
172	12		11	1	10	6	5	75	6
174	10	2	11	7	7	8	5	39	9
176	5	1	6	6	3	5	8	61	9
178	11	2	3	1	5	8	7	38	10
180	8	1	19	4	7	10	5	24	5
182	34	3	14	4	5	13	2	49	3
184	31		7	7	9	10	4	26	6
186	31	9	12	6	9	15	5	36	3
188	21	6	7	3	9	13	1	42	4
190	25	3	5	4	6	15	6	40	
192	51	9	14	3	3	13	6	54	9
194	31	6	5	2	2	9	6	24	1
196	57	5	5	1	4	8	4	56	12
198	31	3	3	3	3	6	1	31	
200	25	4	3	2	5	6	4	19	7
202	46	2	7	1	1	3	4	49	4
204	33	3	2	1	3	1	7	18	3
206	41	2				4	2	36	4
208	36	3	1	1		3		25	1
210	35	1	1			2	1	20	2
212	35	1	3			2	1	21	1
214	20	1	2			2		7	
216	19	1	2			1		15	
218	12					1		4	
220	5	1				1	2	2	
222	8		1					2	1
224	6							1	
226	1							1	
228	3								
230	1							1	
232		1							
N	700	71	155	67	101	182	101	1124	149
Mean	198.1	194.3	186.2	183.0	183.7	187.3	185.3	183.6	180.2

TABLE 4. (cont'd.)

Body length (mm)	Assigned school number 11	13	14	Body length (mm)	Assigned school number 11	13	14
130-139		1	1	190	3	22	2
140-149		8	3	192	2	33	4
150-151		5		194	2	29	4
152	1	11	5	196	1	36	7
154		15		198		22	3
156	1	20	5	200	2	16	2
158	3	18	1	202		28	3
160		22	3	204		11	4
162	2	49	8	206		10	2
164	4	49	9	208		6	1
166	5	73	10	210		8	2
168	3	70	5	212		4	2
170	3	51	13	214		3	1
172	3	72	14	216		2	1
174	4	39	8	218		1	
176	6	46	8	220		2	
178	1	26	5	222		1	1
180	3	20	2				
182	1	29	8	N	53	908	158
184	3	14	2	Mean	175.3	177.4	177.9
186		15	2				
188		21	7				

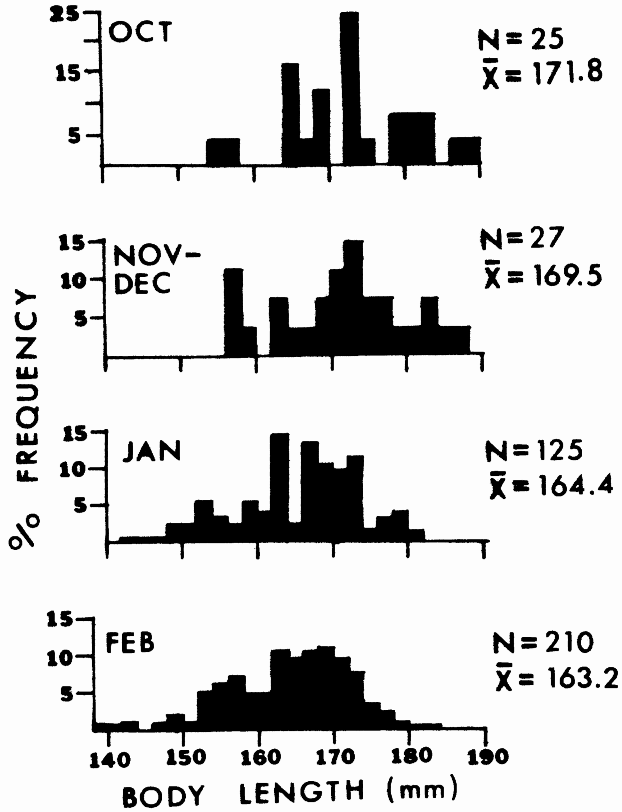

FIGURE 3. Percent length frequencies (2-mm intervals) from 1.5-in. mesh gill net samples, San Francisco Bay, October 1986 to February 1987.

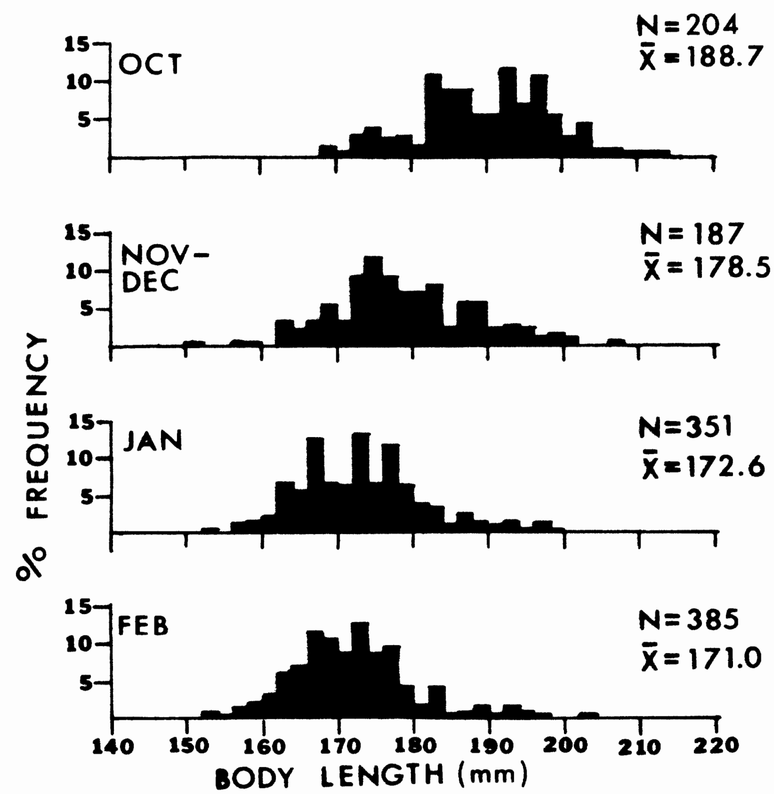

FIGURE 4. Percent length frequencies (2-mm intervals) from 1.75-in. mesh gill net samples, San Francisco Bay, October 1986 to February 1987.

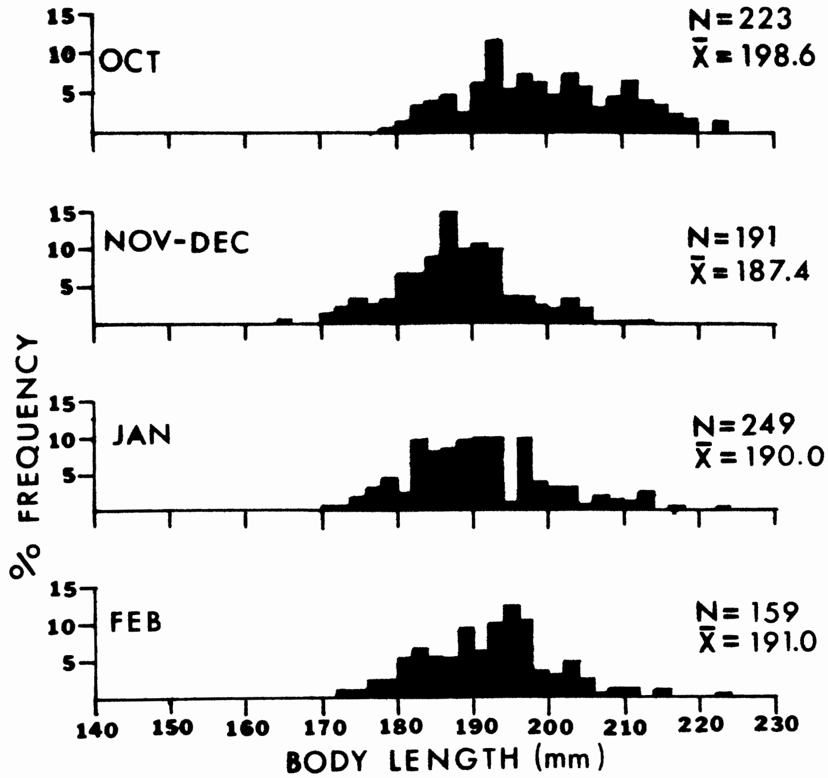

FIGURE 5. Percent length frequencies (2-mm intervals) from 2.0-in. mesh gill net samples, San Francisco Bay, October 1986 to February 1987.

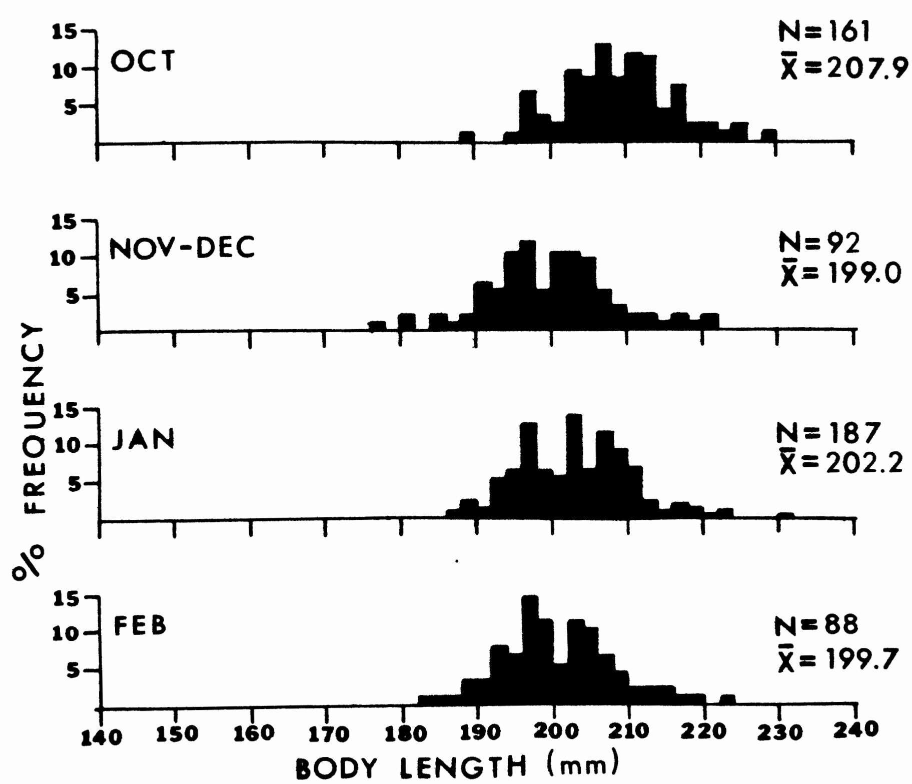

FIGURE 6. Percent length frequencies (2-mm intervals) from 2.25-in. mesh gill net samples, San Francisco Bay, October 1986 to February 1987.

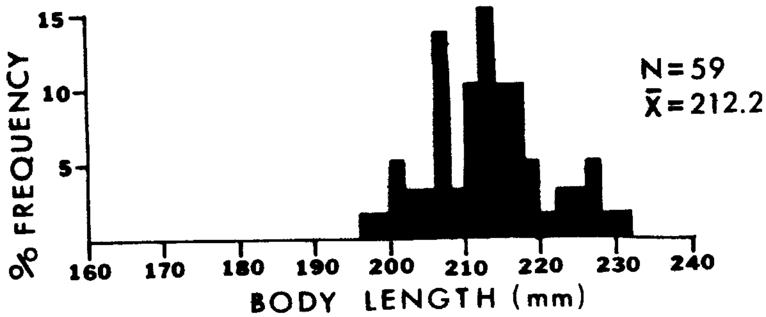

FIGURE 7. Percent length frequencies (2-mm intervals) from 2.5-in. mesh gill net samples, San Francisco Bay, October 1986 to February 1987.

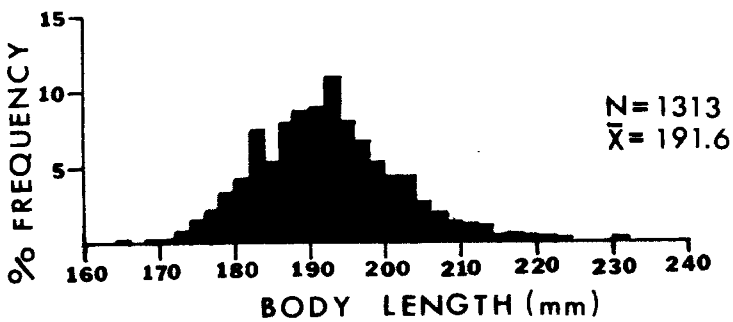

FIGURE8. Percent length frequencies (2-mm intervals) from commercial gill net samples, San Francisco Bay, December 1986 to January 1987.

TABLE 5. Summary of Mean Body Length (mm) by Mesh Size from Variable-Mesh Gill Net Samples from San Francisco Bay, 1982-1987.

		Mesh Size (in.)									
		1.25		1.5		1.75		2.0		2.25	
Month/year		N	mean BL	N	mean BL	N	mean BL	N	mean BL	N	mean BL
Oct	1986	-	-	25	171.8	204	188.7	223	198.6	161	207.9
Nov-Dec	1982	-	-	89	168.6	631	186.4	737	200.1	266	211.9
"	1983	-	-	17	173.3	158	189.6	173	198.7	26	205.8
"	1984	-	-	29	167.4	196	180.0	332	191.7	130	203.5
"	1985	-	-	55	167.2	311	179.4	333	193.1	201	201.4
"	1986	-	-	27	169.5	187	178.5	191	187.4	92	199.0
Jan	1982	-	-	-	-	-	-	345	190.6	77	207.6
"	1983	-	-	510	163.7	817	180.7	501	195.3	145	204.9
"	1984	15	147.4	293	160.7	371	180.7	210	194,9	27	202.2
"	1985	-	-	146	162.1	419	171.2	323	186.1	82	199.0
"	1986	-	-	148	164.7	361	172.8	277	191.0	102	202.6
"	1987	-	-	125	164.4	351	172.6	249	190.0	187	202.2
Feb-Mar	1982	-	-	198	165.1	455	175.1	352	192.2	40	200.3
"	1983	-	-	310	166.3	694	180.8	342	191.9	51	202.8
"	1984	41	140.4	448	158.7	223	177.2	41	193.9	-	-
"	1985	-	-	37	165.0	69	169.8	46	189.6	-	-
"	1986	-	-	58	167.3	179	178.7	126	190.2	51	199.1
"	1987	-	-	210	163.2	385	171.0	159	191.0	88	199.7
Weighted grand mean			142.3		163.4		178.7		193.3		204.2
Unweighted grand mean			143.9		165.8		178.4		192.6		203.1

each season the 2.0-in. mesh caught the most fish in October, November and December, while in January more herring were caught with the 1.75-in. mesh. The February-March period is similar to January except for 1984 (the El Nino period) when growth rates were low, small fish predominated, and the 1.5-in. mesh caught the most fish.

Midwater Trawl Samples. The trawl yielded 3673 herring in 20 samples (Appendix C) from all schools except 1, 2, 9 and 12. Sample 490 was excluded from the total length and age composition data due to a suspected bias towards small fish. Combined school mean BL (Table 6) averaged 6 mm less than that from gill net samples. Mean BL from the two gear types was more similar in November and December when fewer small fish occurred in the schools.

Purse Seine and Lampara Net Samples. We measured 4370 herring from 29 samples (Appendix D) taken from January 5 to March 12 from schools 8, 10, 11, 13, 14 and 15. Samples 529 (school 14) and 536 (school 15) were excluded from the total length and age composition data due to a bias caused by individual handling of fish by crew members. In addition, sample 529 resulted from a missed set. The roundhaul fishery occurs when younger fish comprise the bulk of the biomass and mean BL does not vary much between schools; this season the range was 170.1 to 177.9 mm (Table 7). Mean BL averaged 3.6 mm greater than that of trawl samples and 5.3 mm less than that of gill net samples for the same schools sampled.

During the past six seasons, mean BL of all fish sampled from the roundhaul fleet has ranged from 162 to 181 mm (Table 8).

TABLE 6. Number of Pacific Herring by Body Length (2-mm Intervals), Combined by Assigned School Number, from Midwater Trawl Samples, San Francisco Bay, December 1986 to March 1987.

Body	Assigned School number							
length (mm)	3	4	5	6	7	8	10	11
130-139						3		5
140-149				6	5	26		16
150-151				1	2	11		4
152			1	4	2	21	5	16
154		1		3	1	13	2	11
156	1			4	3	37	4	13
158		3	1	4	3	34	4	16
160	1	3		9	5	32	4	10
162		9	1	22	6	49	6	25
164	1	3	2	23	10	64	2	21
166	1	1	2	36	18	71	9	24
168	1	7	4	39	11	66	5	27
170	5	6	2	32	22	55	7	25
172	6	10	3	62	18	76	11	17
174	3	8	2	53	7	56	3	23
176	3	10	5	76	19	57	8	17
178	5	9	5	54	14	34	3	10
180	5	11	7	60	11	40	1	6
182	8	17	3	82	20	40	4	12
184	3	12	6	58	15	28	3	7
186	4	18	2	76	25	34	4	8
188	5	11	2	51	22	25	3	2
190	5	13	4	50	7	20	2	2
192	1	9	2	62	14	30	2	6
194	2	8	1	24	6	19		3
196	2	2	1	35	3	28		3
198	1	5		15	7	16	1	5
200	3	2		15	11	10		1
202	3	1		21	9	17	2	1
204		1		10	6	9		
206	1	2		9	5	8		
208				8	2	5	1	1
210	3		1	5	1	6		
212	1			5	3	3		
214				5	1			
216				2	1	4		
218				1				
220					1	1		
222				1				
224				1	1			
226								
228								
230				1				
N	74	182	57	1025	317	1048	96	337
Mean	184.3	181.5	179.1	182.3	181.3	174.5	172.3	168.3

TABLE 6. (cont'd.)

Body length (mm)	Assigned school number 13	14	15	Body length (mm)	Assigned school number 13	14	15
130-139	3	7	2	188-189	2	1	4
140-149	8	6	6	190	2		11
150-151	5	2	2	192	3	1	4
152	4	4	1	194	1	1	5
154	4	6	2	196	3	2	5
156	10	6	5	198	1		8
158	9	7	6	200	2		4
160	9	4	9	202	2		4
162	9	5	10	204	1	1	6
164	5	6	9	206	2		5
166	16	9	12	208	1		3
168	8	5	7	210	1		2
170	8	7	10	212			1
172	23	7	10	214			
174	9	5	10	216		1	1
176	7	3	12	218			
178	2	4	2	220			
180	5	3	11	222			
182	2	2	9	224		1	
184		1	4	N	170	107	210
186	3		8	Mean	169.3	165.6	178.1

TABLE 7. Number of Pacific Herring by Body Length (2-mm Intervals), Combined by Assigned School Number, from Purse Seine and Lampara Net Samples, San Francisco Bay, January to March 1987.

Body	Assigned School Number					
length (mm)	8	10	11	13	14	15
130-139	1	2	3	7	7	4
140-149	2	5	34	40	10	15
150-151	1		12	11	3	4
152	1	2	17	25	10	12
154	2	5	19	29	10	7
156	2	6	33	57	20	29
158	1	6	33	55	20	20
160	1	8	36	69	20	18
162	7	18	67	91	39	43
164	5	16	58	77	46	29
166	9	30	78	143	58	41
168	11	19	55	93	45	32
170	5	23	54	101	45	35
172	13	46	81	158	46	42
174	12	21	46	74	34	20
176	9	31	57	80	46	30
178	5	20	31	44	26	19
180	3	17	20	43	11	17
182	8	14	30	44	22	22
184	3	8	17	36	6	26
186	7	12	17	21	11	21
188	1	6	10	24	6	25
190	2	7	2	13	7	26
192	9	11	7	28	8	29
194	2	6	15	16	8	10
196	3	8	10	20	12	16
198	1	10	8	11	9	15
200	3	4	7	16	3	15
202	2	4	6	10	9	19
204		7	2	5	5	8
206	2	2	4	3	7	6
208		2	2	6	1	3
210	4	1	1	7	2	3
212	1	1	1	3	1	
214		2		2		1
216	1			1	2	
218				1		
220		2		1		
222						
224						
226	1					
N	140	382	873	1465	615	662
Mean	177.9	176.4	170.1	171.3	172.2	176.0

These fluctuations are determined by the relative strength of year classes as well as periods of unusual growth, as in the El Niño event of 1983-84. For example, 19.2% of all fish sampled in 1982-83 were less than 170 mm BL, compared with 76.2% in 1983-84. The 1981 year class, first recruited to the fishery in 1982-83, is relatively weak, whereas the combination of poor growth and a strong 1982 year class caused a dramatic shift in size composition the following year. In comparison, herring sampled in 1986-87 showed an average size distribution (Table 8).

Comparison of Length Composition by Gear Type. In previous reports (Reilly and Moore 1982, 1983, 1984, 1985, 1986) we have discussed biases inherent in the variable-mesh gill net and midwater trawl samples. The mesh array of the gill net, while sampling the entire size range of a herring school, selects for a higher proportion of larger fish than is found randomly in a school. Size and speed limitations of the trawl may allow for net avoidance by some of the largest and strongest fish. The possibility also exists of size stratification by depth (Hay et al. 1986). If larger herring tend to remain deeper and nearer the bottom than smaller fish, trawl samples will always have a smaller mean BL then gill net samples.

In the absence of unbiased roundhaul samples, a combination of gill net and trawl samples for each school may be the most accurate representation of the size composition of those herring schools spawning before or after the roundhaul fishery. During the past six seasons, there have been 17 schools adequately sampled by each of the three gear types (Table 9). Differences

TABLE 8. Number of Pacific Herring by Body Length (2-mm Intervals) from Roundhaul Samples, 1981-82 to 1986-87 Seasons.

Body length (mm)	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
< 140	2	9	247	27	16	24
140-141	4	4	84	6	3	8
142	6	6	130	10	2	23
144	7	3	146	8	6	16
146	12	6	223	20	8	26
148	3	9	187	26	7	33
150	6	7	274	38	15	31
152	21	17	399	82	40	67
154	27	29	334	103	28	72
156	26	55	522	154	57	147
158	33	42	428	178	88	135
160	27	76	441*	180	113	152
162	56	136	498	344	218	265
164	56	120	345	312	213	231
166	68	178	302	309*	276	359
168	79	157	235	238	256	255
170	89	196	121	210	260	263*
172	115	267	145	234	353	386
174	103*	173	82	159	281	207
176	105	261	94	139	309	253
178	88	252	92	109	268*	145
180	74	241*	79	78	228	111
182	91	340	147	107	313	140
184	51	238	128	83	243	96
186	53	310	129	83	253	89
188	60	186	81	64	181	72
190	50	205	93	47	166	57
192	41	236	90	54	207	92
194	22	124	68	28	120	57
196	22	166	51	34	136	69
198	20	106	34	24	100	54
200	12	64	20	16	84	48
202	9	77	14	19	70	50
204	5	52	7	15	57	27
206	3	42	5	8	43	24
208	4	13	2	7	26	14
210	2	17	3	3	16	18
212	3	11	3	5	18	7
214		7		3	7	5
216	1	4		2	6	4
218	1	3			3	1
220		3			2	3
222	1		1	1	2	
224	1	2			1	
226						1
N	1459	4452	6294	3566	5099	4137
Mean BL	175.2	180.8	162.4	169.3	178.5	172.6

* Median BL

TABLE 9. Comparison of Gill Net, Midwater Trawl, and Roundhaul Samples, San Francisco Bay, 1981-82 to 1986-87.

Year	School number	Mean BL gill net	Mean BL trawl	Ave. mean BL gill net-trawl	Mean BL roundhaul	Diff. in mean BL
1981-82	-	178.4	171.9	175.1	175.2	0.1
1982-83	12	184.4	171.1	177.8	180.1	2.3
	13	182.2	175.7	178.9	178.6	0.3
1983-84	7	174.6	165.2	169.9	169.3	0.6
	8	171.0	157.3	164.1	160.8	3.3
	9	164.9	156.3	160.6	161.4	0.8
	11	161.3	161.6	161.4	160.3	1.1
1984-85	10-11	178.1	169.1	173.6	169.2	4.4
1985-86	5	184.3	178.8	181.6	181.1	0.5
	7	178.6	175.1	176.8	175.6	1.2
	8	182.7	174.0	178.3	178.0	0.3
	9	184.4	179.2	181.8	179.9	1.9
1986-87	8	183.6	174.5	179.0	177.9	1.1
	10	180.2	172.3	176.2	176.4	0.2
	11	175.3	168.3	171.8	170.1	1.7
	13	177.4	169.3	173.3	171.3	2.0
	14	177.9	165.6	171.7	172.2	0.5
					mean =	1.3

between the combined mean BL from gill net and trawl samples and that of roundhaul samples ranged from 0.1 to 4.4 mm and averaged only 1.3 mm.

Commercial Gill Net Samples. By regulation, minimum mesh size remained at 2.125 in. throughout the fishing season for the third year in a row. We obtained 12 samples containing 1313 fish from schools 3, 4, 6, 8 and 10 (Appendix E); mean BL by school fell within a narrow range of only 2 mm (Table 10), reflecting a uniform size composition throughout the commercial season. During this same period, mean BL by school from our gill net samples only varied by 7.1 mm.

It appears that the effective mesh size of the monofilament commercial gear may be smaller than an equivalent multifilament mesh. For example, during January 1986 (Reilly and Moore 1986) and January 1987, weighted mean BL from all commercial samples was 192.6 mm, while the weighted mean BL from our 2.0- and 2.25-in. meshes was 190.5 and 202.3 mm, respectively. The proximity of the means for 2.0-in. mesh and commercial mesh (which should be 2.125-in.) supports the contention by some fishermen that, while the 2.125-in. mesh may be legally measurable as such (due to elasticity), it effectively functions as a smaller mesh.

Sex Ratios

The usual trend of an increasing percentage of females in herring schools as the season progressed was again apparent this season (Table 11), with several exceptions. Schools 2 and 15, both small in biomass, were in contrast to this trend and interestingly were the only schools for which spawning could not

TABLE 10. Number of Pacific Herring by Body Length (2-mm Intervals Combined by Assigned School Number, from Commercial Gill Net Samples, San Francisco Bay, December 1986 to January 1987.

Body length (mm)	Assigned school number and month 3 Dec	4 Dec	6 Dec	8 Jan	10 Jan	Total
164-165					1	1
166						
168				1	2	3
170					3	3
172					9	9
174	2		1		17	20
176	3		2	4	20	29
178	7	1	6	6	23	43
180	6	6	7	11	26	56
182	16	12	17	26	27	98
184	11	9	19	9	22	70
186	19	13	24	26	22	104
188	26	26	24	13	25	114
190	20	28	22	11	36	117*
192	22	31	23	37	32	145
194	20	27	20	17	21	105
196	15	22	12	17	21	87
198	14	8	14	13	20	69
200	10	6	7	17	18	58
202	9	11	6	13	20	59
204	3	2	2	5	22	34
206	3	1	2	7	12	25
208	1	2		1	12	16
210	2	4	2	2	5	15
212		1	1	2	9	13
214	1	1			3	5
216	1			4	2	7
218	1			1	2	4
220				1	1	2
222				1		1
224						
226						
228						
230	1					1
N	213	211	211	245	433	1313
Mean	191.7	192.5	190.5	192.5	191.0	191.6
	8.2	6.7	6.8	9.2	11.1	8.9

*Median BL

TABLE 11. Percentage by Number Sex Composition of Pacific Herring Samples from San Francisco Bay, by School, Gears[1] Combined, October 1986 to March 1987.

School	Month	N	Percentage Male	Percentage Female
1	Oct	700	70	30
2	Nov	71	41	59
3	Nov	229	54	46
4	Dec	249	57	43
5	Dec	158	56	44
6	Dec	1207	50	50
7	Dec	418	49	51
8	Jan	2474	50	50
10	Jan	515	49	51
11	Feb	1263	47	53
13	Feb	2543	44	56
14	Feb	1056	47	53
15	Mar	922	64	36

[1] gear types are variable-mesh gill net, midwater trawl, purse seine, and lampara net.

be verified. This is the first year in which the first spawning school has been sampled; the percentage of males was extremely high. The transition to a higher proportion of females than males usually occurs in January.

Previous and current data indicate a trend of increasing percentage of female herring with increasing mesh size in variable-mesh gill net samples (Table 12, part 1). This is most likely due to a combination of delayed maturity of some 2-yr-old females (thus avoiding the fishery until they are 3-yr olds) and selective mortality of younger males in the fishery, and results in the survival of a higher proportion of larger, older females than males.

During the past four seasons we have compared percentage of females in samples from 2.125- and 2.25-in. mesh within the same month and year. The 2.25-in. mesh yielded an average of 69.2% females, compared with 54.4% from the 2.125-in. mesh (Table 12, part 2). Use of 2.25-in. mesh in the gill net fishery would result in a significant increase in roe content.

Weight and Length

Weights and lengths for 1576 herring collected from October 1986 to March 1987 were used to generate the following equations using natural logarithm transformations:

For unripe males

$$\ln W = -12.46 + 3.26 \ln L \qquad r = .98,\ n = 38$$

For unripe females

$$\ln W = -12.78 + 3.33 \ln L \qquad r = .99,\ n = 281$$

For ripe males

$$\ln W = -12.52 + 3.28 \ln L \qquad r = .98,\ n = 646$$

For ripe females

TABLE 12. Percentage by Number of Female Herring by Gill Net Mesh Size from San Francisco Bay.

part 1. variable-mesh gill net

Mesh size (in.)	1981-1982	1982-1983	1983-1984	1984-1985	1985-1986	1986-1987[1]	mean
1.5	37	36	38	36	30	42	36.5
1.75	53	42	52	43	37	45	45.3
2.0	57	52	64	48	49	55	54.2
2.25	79	65	73	62	63	67	68.2
2.5	-[2]	-[2]	-[2]	-[2]	80	83	81.5

[1]excludes October 1986 sample
[2]insufficient sample size

part 2. 2.125-in. commercial and 2.25-in. DFG mesh

Month and year	2.125 in	2.25 in
Dec 1984	43	53
Dec 1985	50	56
Dec 1986	51	67
Jan 1984	62	85
Jan 1985	53	77
Jan 1986	55	73
Jan 1987	56	68
Feb 1986	65	75
Mean	54.4	69.2

$$\ln W = -12.70 + 3.31 \ln L \qquad r = .98,\ n = 611$$

For all ripe herring

$$\ln W = -12.84 + 3.34 \ln L \qquad r = .98,\ n = 1257$$

A plot of these untransformed data points for all ripe fish shows the expected curvilinear relationship between length and weight (Figure 9). Estimated weights at length for ripe males, for ripe females, and for all ripe fish are presented in Appendix F.

Last season, the calculated weight/length regression for 991 ripe herring was:

$$\ln W = -12.82 + 3.34 \ln L \qquad r = .99$$

An overall test between the two regressions for all ripe herring was not significant at the 95% level of significance ($F = 4.86$, $p = 0.008$, d.f. = 2265). All estimated weights for the 1986-87 season are within 2% above that of the previous season and continue to indicate good growth.

Length at Age

Mean BL at age has been fairly similar during the past three seasons except for the 1982 year class which has shown above average growth (Table 13). As 2-yr olds, this year class had poor growth (along with 3- to 6-yr-old fish) during the El Niño event of the 1983-84 season. Mean BL for the 1982 year class as 5-yr olds is 5-6 mm higher than that of 5-yr olds from the previous two seasons. Herring aged as 9-yr olds were too few to include in the mean weight and length table.

Weight at Age

Mean weight at age for 5- to 7-yr-old herring exceeded that of the previous two seasons (Table 13) while mean weights for

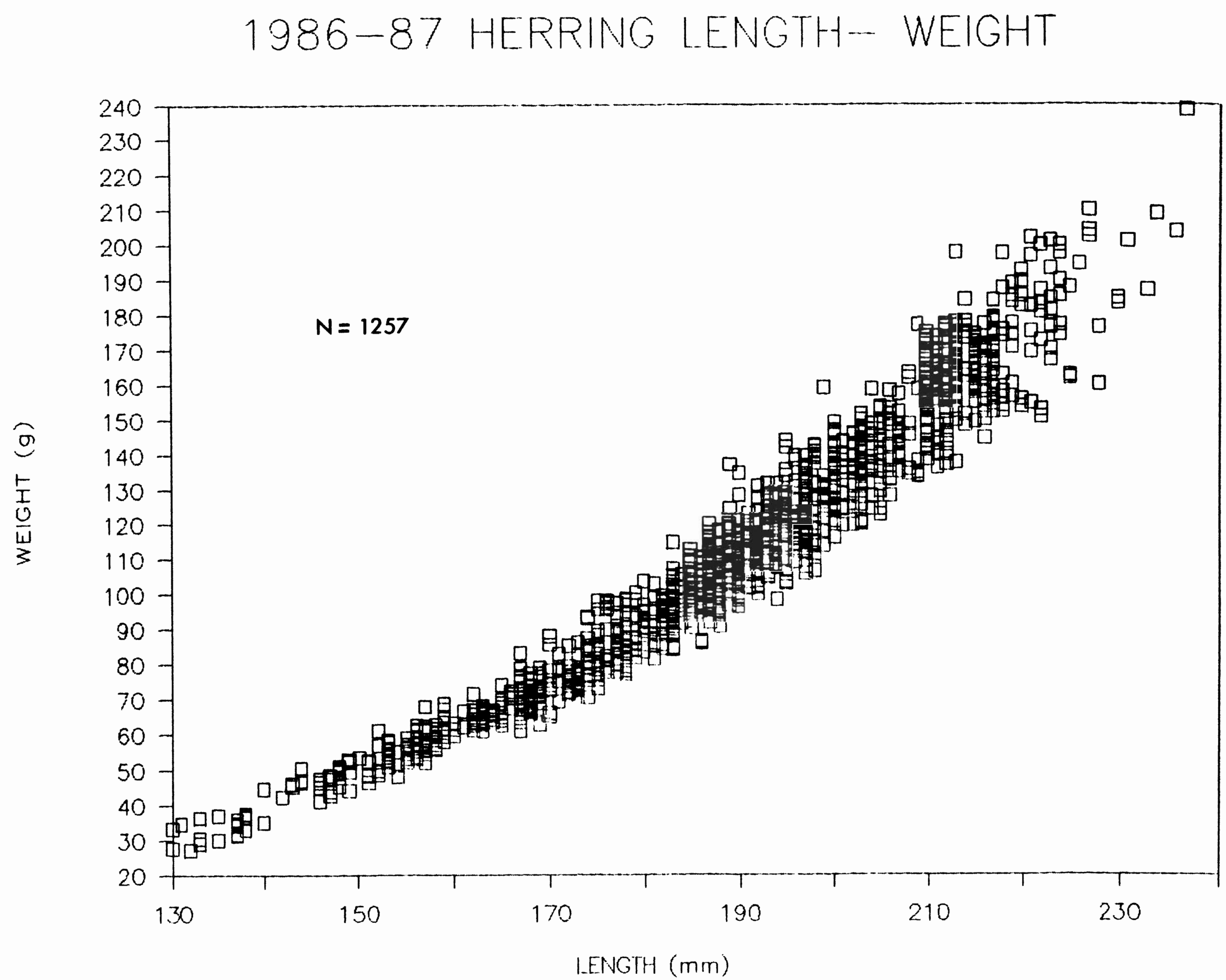

FIGURE 9. Length-weight relationship for ripe adult herring from San Francisco Bay, October 1986 to March 1987.

TABLE 13. Mean Length and Weight of San Franciaco Bay Herring by Season, 1983-84 to 1986-87.

Age (yr)	Mean BL 1986-87	1985-86	1984-85	1983-84
2	160	162	161	153
3	179	178	182	172
4	190	194	190	182
5	204	199	198	194
6	209	206	204	201
7	215	211	210	210
8	218	217	213	214

Age (yr)	Mean wt. (g) 1986-87	1985-86	1984-85	1983-84
2	61.5	63.5	64.1	47.3
3	89.7	88.6	96.5	68.3
4	112.8	118.5	111.2	81.6
5	140.2	127.4	126.0	99.7
6	152.3	141.5	138.1	111.4
7	160.5	155.4	148.8	127.8
8	166.7	166.3	156.1	135.6

other year classes were average and more similar to past seasons. The above average growth of the 1982 year class particularly stands out. Differences between weight at age during the past three seasons and the 1983-84 season are dramatic. Weights at age in 1983-84 were 17 to 29% less than corresponding ones of the following three seasons (Table 13).

Age Composition

Pairs of otoliths were aged for 1485 herring from stratified random samples from variable-mesh gill nets, midwater trawl, and purse seine and lampara net samples (Table 14). Differences in mean BL at age between these data and Table 13 are due to the pooling of data in Table 14 into 2-mm intervals and the exclusion of spent or partially spent fish in Table 13.

Three random samples were aged from the commercial gill net fishery from schools 3, 4, and 6 (Table 15). The higher mean BL for 3-yr olds results from the use of 2.125-in. mesh which selects only the largest fish of this year class. The lower mean BL for 5-yr olds results from the difference between random samples here and the stratified random samples in Table 14. The fact that mean BL for 4-yr olds is fairly similar for both types of sampling is a result of the mean BL inherent in 2.125-in. mesh; the entire size range of 4-yr olds is well represented in 2.125-in. mesh.

An additional 137 large herring were selected for aging (Appendix G) for use in construction of an age-length key.

Variable-mesh Gill Net Samples. Samples for age composition were obtained for all schools except 9, 12, and 15 (Table 16, part 1). This was the first season in which a sample of the first

TABLE 14. Number of Pacific Herring at Age by Body Length (2-mm Intervals) from All San Francisco Bay Samples (Excluding Commercial Gill Net), October 1986 to March 1987.

Size interval	Age (yr)							
(mm)	2	3	4	5	6	7	8	9
130-139	6							
140-149	39							
150	13							
152	22							
154	18	1						
156	33	2						
158	34	5						
160	14	5						
162	40	10						
164	22	14						
166	30	20						
168	33	10	7					
170	16	20						
172	27	26	6	1				
174	10	34	4					
176	10	23	15					
178	4	22	8					
180	2	22	15					
182		31	25	5				
184		10	23	4				
186		33	24	3				
188		13	28	3				
190		8	25	3	1			
192		15	31	16				
194		9	23	14	3			
196		6	19	21	2	4		
198		1	15	14	4			
200		2	18	29	3	3		
202		1	11	39	8	1		
204			5	22	2	3		
206			5	18	4	4	2	
208			2	14	3	6		
210			2	25	9	6	2	
212			3	23	9	5	3	
214			1	7	6	5	6	
216				10	4	8	4	1
218						3	6	
220				6	2	5	4	1
222				3	3	4	4	
224				2		3	5	1
226						1	2	
228						1	2	
230						2		1
232							1	
N	373	343	315	282	63	64	41	4
Mean	160.5	177.5	189.2	202.8	207.6	212.7	218.3	222.5
Std.dev.	9.3	9.6	9.1	8.7	7.7	8.4	5.9	6.0

TABLE 15. Number of Pacific Herring at Age by Body Length (2-mm Intervals) from Commercial Gill Net Samples, San Francisco Bay, December 1986 to January 1987.

Size interval (mm)	Age (yr) 3	4	5	6	7	8
174-175		1				
176	1	1				
178	1	3				
180	2	3				
182	7	10	2			
184	3	9	1			
186	10	13	6			
188	8	14	10			
190	4	20	7	1		
192	8	18	10			
194	3	14	13			
196	5	10	9		1	
198		10	11			
200		4	8		1	
202		3	9	3		
204		1		1		
206			2		1	
208			1			
210		1		2	1	
212		1	1			
214				1		
216					1	
230						1
N	52	136	90	8	5	1
Mean	187.7	190.4	194.5	204.3	205.6	230.0
Std. dev.	5.0	6.4	5.9	7.4	7.9	-

TABLE 16. Percentage (by Number) Age Composition of Pacific Herring Samples, Combined by Assigned School Number, Based on Otolith Aging and Subsequent Age Assignments by Length, from San Francisco Bay, October 1986 to March 1987.

part 1. from variable-mesh gill net samples

School	Age (yr)								Number	Number
number	2	3	4	5	6	7	8	9	aged	assigned
1	2	11	20	22	14	18	12	1	136	564
2		32	34	18	5	7	4		70	1
3	8	36	32	18	5	1			78	77
4	4	40	43	11		2			66	1
5	13	31	42	13	1				64	37
6	7	30	40	22	1		T*		22	160
7	15	30	28	21	3	3			49	52
8	24	28	24	19	3	2	T*		169	955
10	29	30	22	16	2	1			6	143
11	32	38	17	13					0	53
13	35	31	19	13	1	1	T*		19	888
14	35	29	20	13	2	1			7	151

part 2. from midwater trawl samples,

School	Age(yr)								Number	Number
number	2	3	4	5	6	7	8	9	aged	assigned
3	8	38	32	18	2	2			10	64
4	15	38	38	9					17	165
5	18	33	42	5		2			12	45
6	17	36	32	12	2	1	T*		131	894
7	22	33	30	13	2	T*		T*	147	170
8	39	33	17	9	1	1	T*		156	891
10	38	41	17	4					21	75
11	54	28	15	3	T*	T*			0	336
13	53	30	9	6	2	T*			2	167
14	61	24	10	3	1	1			2	105
15	36	23	24	14	1	2			55	153

part 3. from roundhaul samples

School	Age(yr)							Number	Number
number	2	3	4	5	6	7	8	aged	assigned
8	33	32	22	9	1	2	1	6	133
10	36	35	17	9	2	1		72	310
11	48	33	14	4	1	T*		96	775
13	47	33	14	5	T*	1	T*	108	1357
14	42	35	15	7	1	T*		7	605
15	35	29	23	10	2	1		46	616

part 4. from commercial gill net samples.

School	Age(yr)						Number	Number
number	3	4	5	6	7	8	aged	assigned
3,4,6	17	47	31	3	2	T*	292	15

*T trace amount, less than 0.05 percent

spawning school (late October) was obtained and age composition was very different from all succeeding schools. Forty-five percent of this school consisted of herring 6 yr and older. However, the 3-ton spawn escapement estimate does not contribute much to the total biomass and age composition for the spawning season. The usual trend can be seen of an increasing percentage of 2-yr-old fish as the season progressed, while 4- and 5-yr-old fish became less frequent in later schools. Herring 6 yr and older comprised less than 10% by number of all schools sampled after mid-November. The weak 1981 year class (6-yr olds) is poorly represented beginning with school 2.

Midwater Trawl Samples. Age class composition data showed the same general trend as gill net sample data (Table 16, part 2). However, trawl samples yielded a higher percentage of 2-yr-old fish and a lower percentage of herring 5 yr and older than gill net samples. The last school of the season, for which no spawn could be found, contained fewer younger fish than the previous schools. This was contrary to the overall trend of dominance of younger fish in schools later in the season. Herring 6 yr and older comprised no more than 4% by number of any school sampled.

Purse Seine and Lampara Net Samples. Roundhaul samples were confined to the latter half of the spawning season (January to March) and showed a more uniform age composition (Table 16, part 3). A slight increase in 2-yr olds and a corresponding decrease in 4-yr olds did occur from January to February (schools 8 to 14), while the age composition of school 15 did not conform to the general trend. Herring 6 yr and older comprised no more than 4% by number of roundhaul samples.

Commercial Gill Net Samples. Approximately 100 fish were randomly sampled and aged from each of three schools in December (Table 16, part 4). The majority of herring were 4- and 5-yr olds, with faster growing 3-yr olds also contributing significantly to the catch. The weak 1981 year class was poorly represented as 6-yr olds.

Comparison of Age Composition by Gear Type. Previous data (Reilly and Moore 1984, 1985, 1986) have shown that variable-mesh gill net samples are biased towards older, larger herring and overestimate their proportion in schools. As noted previously, it is believed that midwater trawl samples may overestimate the proportion of smaller fish due to avoidance or size stratification in the water column. In the absence of roundhaul fishing and samples, as occurs from October to December, the best approximation of the age composition of a school may result from a combination of our variable-mesh gill net and midwater trawl samples. This year, we were able to sample five schools with gill net, trawl, and roundhaul. Comparisons were made between the age composition of roundhaul samples and the arithmetic, unweighted mean of gill net and trawl samples for each age class (Table 17). All Chi Square comparisons showed no significant differences ($p = 0.05$) between frequency distributions. However, comparisons of roundhaul and gill net age composition data (see Table 16) were significantly different in four of five cases, and one comparison between trawl and roundhaul samples was significantly different. Trawl samples are thus closer to the

TABLE 17. Comparison of Percentage Age Composition Data from Roundhaul Samples and Combination of Variable-mesh Gill Net and Midwater Trawl Samples, San Francisco Bay, January to February, 1987.

School number	Gear type	Age(yr) 2	3	4	5	6-9	Chi Square probability value
8	RH	33	32	22	9	4	0.53
	GN-MT	32	30	22	14	3	
10	RH	36	35	17	9	3	0.77
	GN-MT	34	36	19	10	1	
11	RH	48	33	14	4	1	0.21
	GN-MT	43	33	16	8	0	
13	RH	47	33	14	5	1	0.34
	GN-MT	44	31	14	9	2	
14	RH	42	35	15	7	1	0.43
	GN-MT	48	27	15	8	2	

unbiased roundhaul samples than are gill net samples.

Total Age Composition for Spawning Season. The 1982 through 1985 year classes contributed 97% by number and 95% by weight to the total 1986-87 spawning biomass in San Francisco Bay (Table 18). Good recruitment has occurred during the past four seasons. The weak 1981 year class is beginning to cycle out of the fishery, while mortality factors and the strong showing of younger fish have resulted in the poor representation of herring 7 yr and older.

Catch of YOY Herring and Recruitment

Bay-Delta Project data have been examined during the past 4 yr to determine if a relationship exists between average catch per tow of YOY herring during the spring in San Francisco Bay and the magnitude of subsequent recruitment to the spawning grounds as 2-yr olds. Average catch per tow increased substantially from 1983 to 1985 and in 1986 was similar to that of 1985 (Table 19). Recruitment was calculated from percentage by number of 2-yr olds in each school, catch plus spawn escapement estimates (Spratt 1985, 1986, 1987a), and mean weight-at-age (Table 13, Reilly and Moore 1986). Estimated recruitment has only varied by 15% during the past three seasons and does not reflect the magnitude or trend in YOY catches in the bay.

Tides, Barometric Pressure, Rainfall and Spawning

From October 1986 to March 1987 there were nine tidal cycles in which the highest tide (+5.5 ft. or greater) during a 24-hr period occurred at night (sunset to sunrise) (Figure 10). Five spawns occurred on four of these cycles within the season. If the

TABLE 18. Total Percentage Age Composition for 1983-84 through 1986-87 Spawning Seasons in San Francisco Bay.[1]

part 1. percent by number

based on spawn escapement-plus-catch biomass estimates

Season	Age(yr) 2	3	4	5	6	7	8&9
1986-87	29.2	33.6	23.1	11.2	1.6	1.1	0.2
1985-86	32.5	32.1	25.3	5.3	3.2	1.5	0.1
1984-85	38.7	43.9	5.7	4.8	5.4	1.4	0.1
1983-84	56.6	11.9	15.8	12.6	2.9	0.2	0.0

based on hydroacoustic biomass estimates

Season	Age(yr) 2	3	4	5	6	7	8&9
1986-87	35.1	34.0	19.6	9.0	1.4	0.8	0.1
1985-86	31.6	31.7	25.9	5.5	3.4	1.7	0.2
1984-85	37.1	44.6	5.7	5.0	5.8	1.6	0.2
1983-84	51.1	11.7	16.5	15.8	4.3	0.5	0.1

part 2. percent by weight

based on spawn escapement-plus-catch estimates

Season	Age(yr) 2	3	4	5	6	7	8&9
1986-87	19.0	31.9	27.8	16.6	2.6	1.8	0.3
1985-86	22.1	30.6	32.2	7.3	4.9	2.6	0.3
1984-85	27.8	47.5	7.0	6.7	8.4	2.3	0.3
1983-84	42.1	12.7	20.1	19.6	5.1	0.4	0.0

based on hydroacoustic biomass estimates

Season	Age(yr) 2	3	4	5	6	7	8&9
1986-87	23.8	33.7	24.5	13.9	2.4	1.4	0.3
1985-86	21.6	30.0	32.8	7.4	5.2	2.7	0.3
1984-85	26.4	47.9	7.0	7.0	8.8	2.6	0.3
1983-84	36.2	12.0	20.1	23.5	7.1	1.0	0.1

[1]Data from 1983-84 to 1985-86 have been revised subsequent to publication of previous administrative reports.

TABLE 19. Monthly Average Catch per Tow of Young-of-the-Year Pacific Herring in San Francisco Bay, April to June, 1983 to 1986[1/] and Recruitment Estimates 1985 to 1987.

	Year							
	1983		1984		1985		1986	
Month	Number of tows	Catch per tow	Number of tows	Catch per tow	Number of tows	Catch per tow	Number of tows	Catch per tow
April	67	152.9	50	290.6	90	1364.3	87	582.8
May	180	377.7	110	677.6	230	1109.8	88	914.5
June	150	113.3	110	1204.6	70	2246.3	162	2099.0
mean		239.9		820.6		1372.5		1398.3
Recruitment of 2-yr olds (1000s)		185,742		162,422		168,962		-

[1/]data from Bay-Delta Project

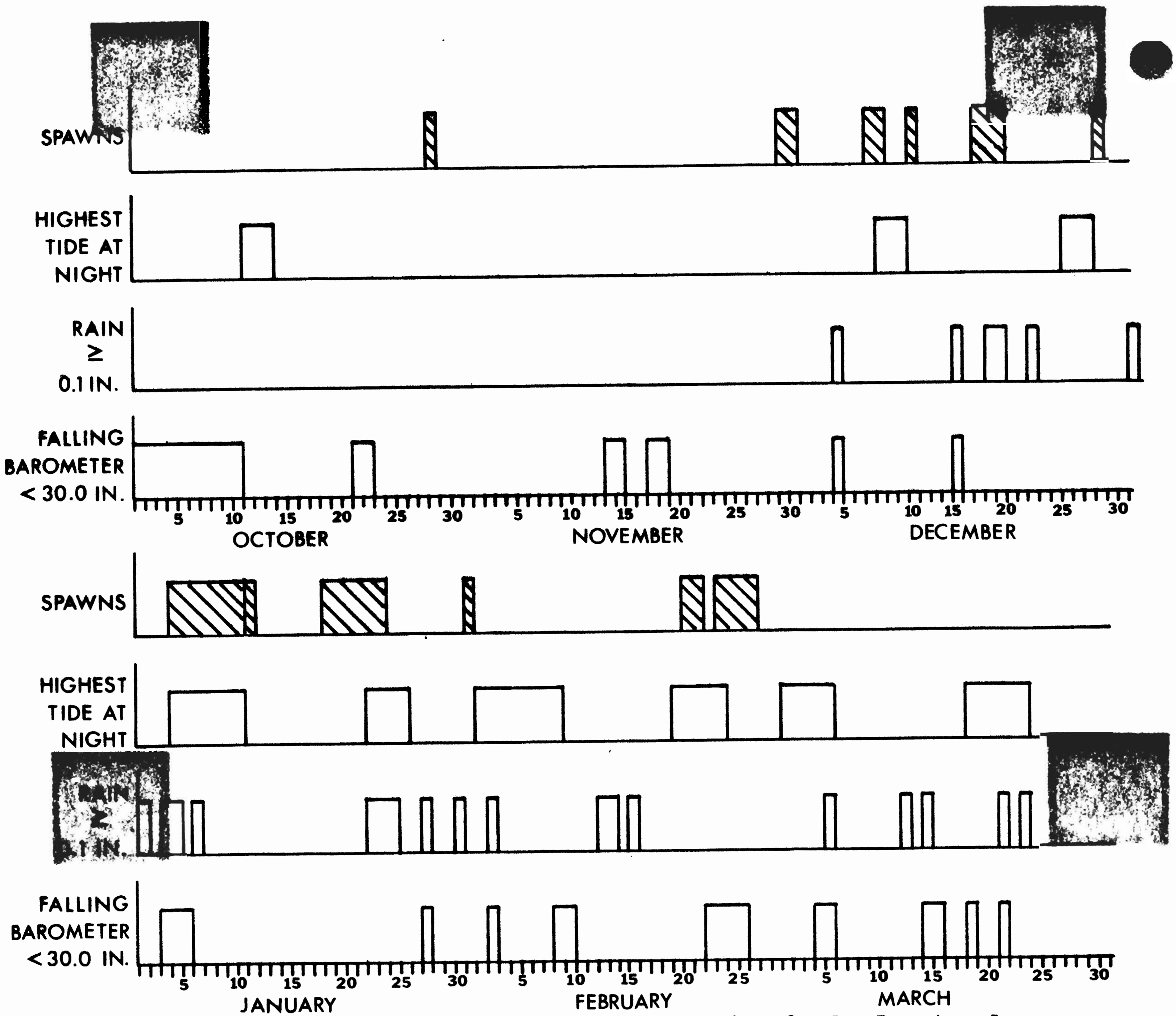

FIGURE 10. Spawning events, tide, rainfall, and barometric pressure data for San Francisco Bay, October 1986 to March 1987.

morning hours after sunrise following these cycles are included, then eight of the 12 major spawns are associated with these cycles. Of the four remaining spawns, three were associated with morning high tides while the other occurred on an afternoon high tide.

Average highest tide height associated with the 12 major spawns was 5.9 ft. with a range of 4.8 to 6.9 ft. High tides continue to be a major influence on the timing of spawns in San Francisco Bay.

Periods of falling barometric pressure (Figure 10), though numerous, appeared to have little correlation with the onset of spawning as was seen in the 1981-82 season (Reilly and Moore 1983).

Total rainfall during the spawning season amounted to 10.04 in. with the majority (8.3 in.) falling in the last half of the six-month season. Periods of significant rainfall ($\geq$0.1 in.) began in December and were numerous throughout the rest of the season (Figure 10). Total rainfall was less than normal and local rainfall and delta outflows did little to inhibit spawning activity as was seen in previous years (Reilly and Moore 1983, 1986). When significant rainfall did occur approximate to a spawn, a period of high tides at night was also coincident.

DISCUSSION

Hydroacoustic biomass estimates, using the visual integration technique, have been within 40% of the sum of the commercial catch and spawn escapement estimates during each of the past five seasons. In general there has been good agreement between the largest schools detected acoustically and the largest spawns during a season. However, estimates for individual schools occasionally have differed widely with the two methods. For example, after January 23, the end of the largest spawn of the season, both visual and echo integration methods yielded a large biomass still present (school 11) in San Francisco Bay. Spawn surveys found only small quantities of egg deposits on January 31, date of the next spawn, and landings during the January 24-31 period were minimal. The concept of discrete schools may be valid as a spawn occurs, but herring from one school, instead of spawning, may break off and join an incoming school of unripe fish, complicating the separation of schools acoustically. For most schools, however, temporal and spatial separations occur and acoustic survey methods are valid.

Because of the inherent variability in spawn escapement and acoustic biomass estimation, and because of occasional anomalous spawning behavior patterns, it is important to continue both methods of quantification to obtain the most accurate and complete interpretation of biomass trends. On two occasions, schools (2 and 15) were detected acoustically, samples were obtained, but no spawn was found. Conversely, schools from October to mid-December are more difficult to monitor acoustically because of their relatively short residence times in the bay prior to spawning.

The Alaska herring fishery is managed on a real-time basis since the majority of spawning stocks appear on the grounds during a short time period. The protracted nature of the spawning season in San Francisco Bay, the longest on the West

Coast, necessitates a management strategy attuned to quota adjustments for the following season after the completion of all spawns for the present season.

The need for revision of the biomass estimate from echo integration data results from the lack of information on the acoustical properties of herring specifically from San Francisco Bay. Since the average length of herring from San Francisco Bay is less than that of Washington, the target strength value used by Lemberg (1978) may not have been appropriate for biomass estimates here. A calibration survey is planned for next season which hopefully will obtain target strength values for individual herring. Since results from echo integration are dependent on scaling parameters, a simple multiplicative factor may be applied without the need to re-integrate data tapes.

The possibility also exists that daytime densities of herring schools in San Francisco Bay are so high as to cause an acoustic shadowing effect resulting in underestimation of biomass. The narrow pulse width and high frequency of the echo sounder were selected to minimize this effect. A night survey is planned for next season to compare estimates of the same school in the daytime.

During the process of echo integration, the operator must manually "track" the bottom to avoid integrating the relatively large bottom echo. This may result in either an overestimate in biomass, if the bottom echo is frequently integrated, or an underestimate if herring close to the bottom are excluded. As the skill of the operator improves, any bias from this effect will be minimized.

The 1986-87 herring spawning population in San Francisco Bay is composed primarily of four recently recruited year classes of average to above average strength. Results from Bay-Delta Project trawling in 1986 indicate that recruitment of 2-yr olds for next season's fishery also may be normal or better. Length-weight and age-weight relationships are average to above average. One of the most consistent results during the 6 yr of this study has been the increase in percentage of females with increased gill net mesh size. Fishermen could use mesh larger than 2.125 in. and increase the roe content of landed fish.

The gradual switch from 2.25- to 2.125-in. mesh, which began in the January 1983 gill net fishery, has caused fishing mortality to increase for 3- and 4-yr old-herring. This may be a partial cause of the shift of the age class structure to fewer herring aged 6 yr and older. The proportion dropped from 45 to 54% of the gill net catch (Spratt 1981) during the first two seasons of the fishery sampled (1977-78, 1978-79) to 7% this season (Spratt 1987b). Other contributing factors in the present age class structure are the weakness of the 1981 year class (6-yr olds) and mortality to the 1980 and older year classes during the El Niño event.

The need to continue sampling with both variable-mesh gill net and midwater trawl is apparent from a comparison with unbiased roundhaul samples. A better approximation of age class structure results from combining samples from our two types of research gear. This also improves the estimation of mean length and sex ratio for those schools not sampled with roundhaul nets.

These values are used in the calculation of spawn escapement estimates.

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APPENDIX A. Summary of Adult Herring Samples from San Francisco Bay, October 1986 to March 1987.

Sample number	Date	Location	Gear	Number measured	Number aged	Assigned school number
454	Oct 27	KC	GN	14	14	1
455	Oct 29	KC	GN	686	122	1
456	Nov 17	PP	GN	7	7	2
457	Nov 19	BELV	GN	46	45	2
458	Nov 20	BELV	GN	18	18	2
459	Dec 1	SB	MT	149	16	4
460	Dec 1	SB	MT	74	10	3
461	Dec 1	SB	GN	155	78	3
462	Dec 1	SB	CGN	106	102	3
463	Dec 2	SB	CGN	107	2	3
464	Dec 3	SB	CGN	100	2	4
465	Dec 3	SB	MT	33	1	4
466	Dec 8	SB	CGN	111	96	4
467	Dec 9	SF	GN	67	66	4
468	Dec 10	YBI	GN	182	22	6
469	Dec 12	RAC	MT	57	12	5
470	Dec 12	BELV	GN	101	64	5
471	Dec 15	SB	CGN	100	94	6
472	Dec 15	SB	CGN	111	2	6
473 1/	Dec 16	YBI	MT	355	134	6
474 1/	Dec 16	YBI	MT	355	0	6
475 1/	Dec 16	YBI	MT	292	0	6
476	Dec 24	RAC	MT	220	101	7
477	Dec 27	YBI	MT	46	46	7
478	Dec 27	YBI	MT	23	0	6
479	Dec 27	YBI	GN	101	49	7
480	Dec 30	SF	MT	485	33	8
481	Dec 30	SF	MT	51	0	7
482	Jan 4	BELV	GN	50	47	8
483	Jan 4	SF	MT	563	124	8
484	Jan 5	TIB	CGN	124	2	8
485	Jan 5	TIB	RH	140	7	8
486	Jan 5	BELV	GN	683	99	8
487	Jan 7	TIB	CGN	121	0	8
488	Jan 9	AI	GN	192	14	8
489	Jan 9	AI	GN	199	9	8
490	Jan 12	SB	MT	50	0	8
491	Jan 12	SB	GN	112	3	10
492	Jan 13	PP	MT	96	21	10
493	Jan 13	PP	RH	111	65	10
494	Jan 14	SB	CGN	112	3	10
495	Jan 14	HP	CGN	111	2	10
496	Jan 19	ALC	RH	170	1	11
497	Jan 19	SB	CGN	102	6	10
498	Jan 20	SB	CGN	108	11	10
499	Jan 21	SF	RH	180	82	11
500	Jan 21	SF	RH	164	16	11
501	Jan 21	SF	RH	105	3	10
502	Jan 21	SF	GN	53	0	11

APPENDIX A. (cont'd)

Sample number	Date	Location	Gear	Number measured	Number aged	Assigned school number
503	Jan 21	SB	GN	37	4	10
504	Jan 23	SB	RH	166	4	10
505	Jan 23	ALC	MT	218	1	11
506	Jan 26	SAUS	RH	129	4	13
507	Jan 26	YBI	RH	200	0	11
508	Jan 28	SAUS	RH	146	84	13
509	Jan 28	SAUS	RH	114	15	13
510	Jan 28	SAUS	GN	20	0	13
511	Jan 30	SB	RH	159	2	11
512	Jan 30	SAUS	RH	179	0	13
513	Feb 2	SAUS	RH	131	1	13
514	Feb 2	SAUS	RH	150	3	13
515	Feb 3	HR	RH	142	1	13
516	Feb 3	SAUS	GN	100	3	13
517	Feb 6	SF	MT	107	2	14
518	Feb 6	SF	MT	119	0	11
519	Feb 9	SAUS	RH	140	2	13
520	Feb 10	TIB	RH	196	0	13
521	Feb 10	TIB	RH	138	0	13
522	Feb 10	TIB	GN	144	5	13
523	Feb 12	SB	RH	132	0	14
524	Feb 16	AI	MT	170	3	13
525	Feb 16	AI	GN	221	8	13
526	Feb 16	HP	RH	159	5	14
527	Feb 18	ALC	RH	156	3	14
528	Feb 19	ALC	RH	168	2	14
529	Feb 20	PP	RH	176	2	14
530	Feb 20	AI	GN	237	1	13
531	Feb 24	TIB	GN	186	3	13
532	Feb 25	HP	GN	158	7	14
533	Mar 2	PP	MT	54	53	15
534	Mar 10	SAUS	RH	154	43	15
535	Mar 10	SAUS	RH	165	0	15
536	Mar 11	SAUS	RH	57	5	15
537	Mar 11	SAUS	RH	181	3	15
538	Mar 12	SAUS	RH	162	0	15
539	Mar 13	PP	MT	29	0	15
540	Mar 16	PP	MT	127	4	15

Legend: AI-Angel Island; ALC-Alcatraz; BELV-Belvedere Cove; HP-Hunters Point; HR-Harding Rock Buoy; PP-Peninsula Point; RAC-Raccoon Strait; SAUS-Sausalito to Pt. Cavallo; SB-South San Francisco Bay between Oakland-Bay Bridge and Hunters Point; SF-San Francisco between Oakland-Bay Bridge and Golden Gate Bridge; TIB-Tiburon; YBI-Yerba Buena Island.

Legend: CGN-commercial gill net, 2.125-in. mesh
GN-5-panel gill net, mesh sizes 1.5, 1.75, 2.0, 2.25,

APPENDIX A. (cont'd)

2.5 in.
MT- 12- by 12-ft (mouth opening) midwater trawl
RH- commercial purse seine or lampara net

[1]One of three parts of sample.

APPENDIX B. Number of Pacific Herring by Body Length (2-mm Intervals) from Variable-mesh Gill Net Samples in San Francisco Bay, October 28, 1986 to February 25, 1987.

Body length	Sample number									
(mm)	454	455	456	457	458	461	467	468	470	479
130-139										
140-149										
150-151										1
152										
154		1								
156		2						1	1	3
158		1				1		1		
160										
162							1	3	1	5
164		4					3	3		2
166		1				2	2	1	3	1
168		6				3	2	6	2	1
170		1		1		5	2	2	3	2
172		12				11	1	6	10	5
174		10		2		11	7	8	7	5
176		5		1		6	6	5	3	8
178		11		1	1	3	1	8	5	7
180		8		1		19	4	10	7	5
182		34		2	1	14	4	13	5	2
184		31				7	7	10	9	4
186		31		5	4	12	6	15	9	5
188	1	20	1	3	2	7	3	13	9	1
190		25		2	1	5	4	15	6	6
192		51	1	6	2	14	3	13	3	6
194		31		5	1	5	2	9	2	6
196	1	56		4	1	5	1	8	4	4
198		31		3		3	3	6	3	1
200	1	24	2	1	1	3	2	6	5	4
202	1	45		2		7	1	3	1	4
204		33	1	2		2	1	1	3	7
206	2	39	1	1				4		2
208	2	34	1	1	1	1	1	3		
210	1	34		1		1		2		1
212		35		1		3		2		1
214		20			1	2		2		
216		19		1		2		1		
218	3	9						1		
220	1	4			1			1		2
222	1	7				1				
224		6								
226		1								
228		3								
230		1								
232					1					
N	14	686	7	46	18	155	67	182	101	101
Mean	209.1	197.8	200.4	192.8	195.8	186.2	183.0	187.3	183.7	185.3

APPENDIX B. (cont'd)

Body length (mm)	Sample number 482	486	488	489	491	502	503	510	516	522
142-143		1								
144					1					
146				2					1	
148		2	1							1
150		2		1						1
152		4	2	6	1	1			1	1
154		4	1	1	1				4	2
156		7	2	2	2	1	1		2	1
158	1	10	2	2	5	3			1	3
160	1	12	5	3	1				3	6
162	3	24	4	12	6	2	4	2	1	8
164	1	19	4	9	4	4	1		5	10
166	4	35	9	14	8	5	1	3	6	8
168	1	28	7	12	6	3	1		6	12
170	3	29	10	7	3	3	2		9	13
172	2	47	12	14	4	3	2	3	9	7
174	3	23	7	6	7	4	2	1	9	6
176	3	31	11	16	6	6	3	1	6	4
178		25	5	8	5	1	5	3	3	5
180	2	10	7	5	4	3	1		5	5
182	7	23	9	10	3	1		1	4	4
184		22	2	2	5	3	1		2	5
186	1	26	3	6	2		1	1	1	1
188	1	23	14	4	3		1	1	2	
190	2	26	7	5		3			3	6
192	1	40	7	6	6	2	3		1	6
194	2	11	7	4	1	2		1	4	6
196	2	31	14	9	11	1	1	2	4	5
198		22	6	3						3
200	2	14	1	2	6	2	1		1	4
202	1	31	8	9	4			1	1	2
204		14		4	2		1			2
206	3	25	4	4	2		2			2
208		17	6	2			1		1	
210	3	8	4	5	1		1		2	1
212	1	13	6	1			1			2
214		6	1						1	
216		11	2	2					1	
218		2	1	1						1
220		2								1
222			2		1				1	
224		1								
226		1								
228										
230		1								
N	50	683	192	199	112	53	37	20	100	144
Mean	183.1	184.4	184.9	179.6	179.6	175.3	181.9	178.8	177.0	177.9

APENDIX B. (cont'd)

Body length (mm)	Sample number 525	530	531	532
130-139	1			1
140-141				2
142	1	1		
144				
146		1		
148			3	1
150		2	2	
152	1	4	4	5
154	1	8		
156	3	9	5	5
158	2	2	10	1
160	1	8	4	3
162	6	21	11	8
164	8	15	11	9
166	10	31	15	10
168	17	19	16	5
170	10	10	9	13
172	17	22	14	14
174	8	9	6	8
176	14	12	9	8
178	6	5	4	5
180	6	2	2	2
182	8	6	6	8
184	4	2	1	2
186	5	4	3	2
188	11	2	5	7
190	5	3	5	2
192	16	3	7	4
194	10	6	2	4
196	12	6	7	7
198	7	7	5	3
200	6	3	2	2
202	8	7	9	3
204	2	2	5	4
206	5	2	1	2
208	3	2		1
210	4		1	2
212	1		1	2
214		1	1	1
216	1			1
218				
220	1			
222				1
N	221	237	186	158
Mean	182.5	173.4	176.0	177.9

APPENDIX C. Number of Pacific Herring by Body Length (2-mm Intervals) from Midwater Trawl Samples in San Francisco Bay, December 1, 1986 to March 16, 1987.

Body length (mm)	Sample number 459	460	465	469	473	474	475	473-475	476	477
142-143										1
144										
146					2	1	1	4	1	
148					1		1	2	1	
150						1		1	2	
152				1	1	2	1	4	1	1
154	1					1	2	3	1	
156		1				2	2	4	3	
158	2		1	1	2		2	4	1	2
160	3	1			3	3	3	9	3	1
162	9			1	11	5	6	22	4	2
164	2	1	1	2	6	9	7	22	6	
166	1	1		2	11	14	10	35	12	2
168	7	1		4	12	12	15	39	8	1
170	6	5		2	16	10	6	32	14	5
172	8	6	2	3	21	17	23	61	10	3
174	6	3	2	2	21	15	17	53	5	
176	9	3	1	5	27	26	20	73	17	
178	7	5	2	5	18	14	21	53	9	3
180	7	5	4	7	21	25	14	60	7	3
182	15	8	2	3	22	33	26	81	13	4
184	8	3	4	6	23	20	14	57	11	1
186	16	4	2	2	23	27	22	72	16	6
188	9	5	2	2	21	17	12	50	14	3
190	9	5	4	4	22	19	8	49	6	
192	6	1	3	2	18	23	17	58	12	1
194	7	2	1	1	5	11	7	23	5	
196	1	2	1	1	13	14	8	35	3	
198	4	1	1		5	5	5	15	6	
200	2	3			3	4	8	15	8	2
202	1	3			9	7	4	20	6	1
204	1				4	5	1	10	4	1
206	2	1			2	3	3	8	2	2
208					3	3	1	7	2	
210		3		1	1	3	1	5	1	
212		1			3		2	5	3	
214					3	1	1	5	1	
216					1	1		2		1
218						1		1		
220									1	
222						1		1		
224					1			1		1
230							1	1		
N	149	74	33	57	355	355	292	1,002	220	46
Mean	181.0	184.3	183.6	179.1	182.3	182.9	181.2	182.2	181.7	181.6

APPENDIX C. (cont'd)

Body length (mm)	Sample number 478	480	481	483	490	492	505	517	518	524
130-139		2		1	3		1	7	4	3
140-141				1			2		1	
142		2		2	1		1	1		1
144		1			2		2	1	1	
146		5	1	5	2		4	2		4
148		7	1	3	2		3	2	2	3
150		1		10			1	2	3	5
152		7		14	4	5	9	4	7	4
154		2		11	3	2	6	6	5	4
156		16		21	4	4	10	6	3	10
158		13		21	3	4	11	7	5	9
160		18	1	14	4	4	3	4	7	9
162		18		31		6	17	5	8	9
164	1	28	4	36	2	2	14	6	7	5
166	1	24	4	47	6	9	14	9	10	16
168		31	2	35	1	5	18	5	9	8
170		20	3	35	2	7	17	7	8	8
172	1	37	5	39	2	11	11	7	6	23
174		28	2	28	3	3	14	5	9	9
176	3	30	2	27		8	12	3	5	7
178	1	14	2	20	1	3	8	4	2	2
180		20	1	20		1	3	3	3	5
182	1	28	3	12	2	4	7	2	5	2
184	1	11	3	17		3	5	1	2	
186	4	20	3	14	1	4	7		1	3
188	1	14	5	11		3	2	1		2
190	1	9	1	11		2	1		1	2
192	4	14	1	16		2	6	1		3
194	1	9	1	10	1		1	1	2	1
196		16		12	1		2	2	1	3
198		6	1	10		1	5			1
200		6	1	4			1			2
202	1	7	2	10		2			1	2
204		7	1	2				1		1
206	1	6	1	2						2
208	1	2		3		1			1	1
210		2		4						1
212		2		1						
216		1		3				1		
220		1								
224								1		
N	23	485	51	563	50	96	218	107	119	170
Mean	186.5	175.9	179.0	173.3	161.5	172.3	169.2	165.6	166.7	169.3

APPENDIX C. (cont'd)

Body length (mm)	Sample number 533	539	540
130-139	1		1
140-141			
142			1
144			1
146			1
148	1	1	1
150		2	
152			1
154	1		1
156	2		3
158	2		4
160	1	1	7
162	4		6
164			9
166	3		9
168			7
170	1		9
172	4	1	5
174	3	4	3
176	4	1	7
178		1	1
180	3	4	4
182		1	8
184		1	3
186	5	1	2
188	2		2
190	2	1	8
192	1		3
194	2	2	1
196	1		4
198	3		5
200		2	2
202	2	1	1
204	2	3	1
206	1	1	3
208	2	1	
210	1		1
212			1
216			1
N	54	29	127
Mean	180.1	183.4	176.0

APPENDIX D. Number of Pacific Herring by Body Length (2-mm Intervals) from Purse Seine and Lampara Net Samples in San Francisco Bay, January 5 to March 12, 1987.

Body length (mm)	Sample number									
	485	493	496	499	500	501	504	506	507	508
130-139	1	1	1				1			
140-141			2	1					1	
142				2	1				1	1
144		1	1	4					3	
146			1	2			1		3	1
148	2	2	3	3	2		1	1	1	1
150	1		3	3	2			1	3	
152	1		5	1	5		2	1	2	1
154	2		4	2	2	3	2	2	4	3
156	2	1	14	3	6	2	3	4	6	4
158	1		9	7	2	1	5	2	9	11
160	1	5	5	7	6	1	2	3	9	9
162	7	10	21	10	11	3	5	4	18	12
164	5	5	8	18	10	4	7	5	13	6
166	9	7	16	15	16	13	10	8	25	5
168	11	5	7	10	13	5	9	8	12	10
170	5	6	7	8	9	11	6	9	13	11
172	13	16	12	17	12	11	19	15	25	8
174	12	4	10	7	8	6	11	2	7	11
176	9	7	9	12	10	7	17	9	12	11
178	5	5	3	7	6	4	11	4	7	3
180	3	2	4	9		10	5	5	3	8
182	8	7	7	10	6	4	3	10	3	5
184	3	4	2	2	9	2	2	10	3	2
186	7	7	1	4	7	1	4		3	4
188	1	3	3	2	3	1	2	1	1	4
190	2	1				2	4	1	2	1
192	9	1	1	2	2	3	7	4	2	2
194	2	1	3	2	4		5		5	4
196	3	2	3	3	2	3	3	5		
198	1	3	1	2	2	5	2	3	2	1
200	3	2		1	2	1	1	3		3
202	2	2	2	1	2		2	2	1	1
204				1	1	1	6			
206	2				3		2	1	1	
208			1	1			2	4		1
210	4			1			1	1		2
212	1	1	1							
214							2			
216	1									
220						1	1	1		
226	1									
N	140	111	170	180	164	105	166	129	200	146
Mean	177.9	175.2	170.5	170.8	172.9	175.8	177.7	177.4	169.0	172.5

APPENDIX D (cont'd)

Body length (mm)	Sample number 509	511	512	513	514	515	519	520	521	523
130-139		2	2		1		1	2	1	1
140-141			2	1						
142				1		1	1	4	3	
144	2	1				1			1	
146			3	1	1	2	1	1	3	1
148	1	2	1		2	1		1	1	2
150		1	2		3	1	2	1	1	
152	1	4	2	5	2	4	1	6	2	3
154		7	6	2	2	4	3	4	3	1
156	3	4	10	6	7	6	3	12	2	4
158	2	6	8	1	4	4	6	13	4	5
160	7	9	8	6	8	5	3	10	10	3
162	3	7	12	9	14	10	4	13	10	11
164	1	9	10	6	10	11	8	9	11	6
166	6	6	24	22	16	12	15	20	15	13
168	7	13	8	11	9	6	10	14	10	5
170	9	17	15	5	3	12	21	8	8	12
172	11	15	27	14	15	19	16	24	9	17
174	6	14	4	6	7	9	8	12	9	2
176	8	14	6	9	8	6	4	15	4	13
178	7	8	4	1	10	4	3	4	4	5
180	7	4	4	4	1	3	2	3	6	1
182	7	4	3	4	4	2	4	2	3	5
184	3	1	1	5	4	2	5		4	
186	1	2	2	3	1	3	1	3	3	2
188	1	1	3	1	3	3	4	3	1	1
190	3		2	3	1		1		1	
192	5		2	2	3	2	2	4	2	2
194		1	1		4	1	3	1	2	2
196	3	2	2		1	1	4	2	2	5
198	4	1	1		1				1	2
200	2	4	2			2	1	2	1	1
202				1	2	1	1	2		2
204			1	1		1		1	1	1
206			1			1				4
208						1				
210	2			1			1			
212	1				2					
214	1						1			
216						1				
218					1					
N	114	159	179	131	150	142	140	196	138	132
Mean	176.4	169.8	168.5	170.4	171.2	170.5	172.1	168.3	169.4	173.0

APPENDIX D.(cont'd)

Body length (mm)	Sample number 526	527	528	529	534	535	536	537	538
130-139	3		3	5		1		3	
140-141			1	4			1		
142	2			1	1			4	1
144				2	1	1			
146			1	1	1			2	1
148	1	1	1	2	1	1		1	
150	2		1	5	1	2			1
152	3	3	1	6	3	2	1	4	3
154	4	2	3	5	2	3	1		2
156	3	6	7	13	6	6	3	10	7
158	5	5	5	14	1	8	3	5	6
160	7	4	6	4	2	2	2	4	10
162	14	5	9	13	9	11	2	15	8
164	11	13	16	8	7	11	2	4	7
166	14	19	12	16	9	11	1	15	6
168	13	16	11	8	4	7	2	9	12
170	13	12	8	10	5	12	3	9	9
172	9	8	12	17	17	7	1	12	6
174	3	10	19	3	5	7	1	4	4
176	13	9	11	8	8	4	3	15	3
178	5	9	7	2	6	2	4	6	5
180	3	1	6	4	2	5	3	3	7
182	4	6	7	3	11	2	1	4	5
184	3	3		2	10	3	1	6	7
186	5	1	3	5	4	6	2	9	2
188	1	2	2		10	9	2	4	2
190	2	1	4	1	5	9	3	3	9
192	2	3	1	3	7	8	1	8	6
194	2	2	2	2	2	2	5	3	3
196		5	2		3	4	4	4	5
198	6	1		2	4	6	2	2	3
200			2	1	2	2	1	3	8
202	2	3	2	2	4	7		5	3
204	1		3	1		2	1	3	3
206	1	2			1		1	2	3
208		1		1		1			2
210		2				1			2
212	1			1					
214				1					1
216	1	1							
N	159	156	168	176	154	165	57	181	162
Mean	171.2	173.5	171.4	166.9	176.4	176.2	178.2	174.0	177.6

APPENDIX E. Number of Pacific Herring by Body Length (2-mm Intervals) from Commercial Gill Net Samples in San Francisco Bay, December 1, 1986 to January 20, 1987.

Body length (mm)	Sample number									
	462	463	464	466	471	472	484	487	494	495
164-165									1	
166										
168								1	1	
170									2	
172									4	
174	1	1				1			7	2
176	2	1				2		4	7	5
178	3	4	1		2	4	2	4	12	5
180	3	3	5	1	1	6	5	6	8	6
182	8	8	6	6	8	9	7	19	5	5
184	3	8	6	3	7	12	5	4	7	8
186	10	9	5	8	12	12	14	12	5	10
188	9	17	14	12	15	9	6	7	4	8
190	11	9	15	13	12	10	9	2	10	10
192	13	9	17	14	13	10	27	10	5	12
194	11	9	10	17	6	14	7	10	9	5
196	5	10	7	15	6	6	13	4	4	5
198	10	4	3	5	8	6	7	6	4	7
200	5	5	2	4	4	3	5	12	6	4
202	6	3	4	7	3	3	5	8		9
204	1	2	2		1	1	4	1	5	4
206	1	2		1	1	1	5	2	1	2
208		1	1	1			1		2	2
210	1	1	1	3		2		2	2	
212				1	1			2	1	
214	1		1							
216	1							4		1
218		1					1			
220								1		1
222							1			
224										
226										
228										
230	1									
N	106	107	100	111	100	111	124	121	112	111
Mean	192.4	191.1	191.5	193.5	191.1	189.9	193.0	192.0	187.3	191.4

APPENDIX E. (Cont'd)

Body length (mm)	Sample number 497	498
168-169	1	
170		1
172	4	1
174	6	2
176	6	2
178	3	3
180	9	3
182	11	6
184	3	4
186	3	4
188	7	6
190	9	7
192	5	10
194	3	4
196	4	8
198	3	6
200	1	7
202	5	6
204	5	8
206	5	4
208	3	5
210		3
212	4	4
214	1	2
216	1	
218		2
N	102	108
Mean	190.2	195.4

APPENDIX F. Estimated Weight at Length for Pacific Herring from San Francisco Bay, 1986-87

Body length(mm)	Males	Females	Both	Body length(mm)	Males	Females	Both
130	31.0	31.5	30.7	220	173.7	180.3	178.3
132	32.6	33.1	32.3	222	178.9	185.8	183.7
134	34.2	34.8	34.1	224	184.3	191.4	189.3
136	35.9	36.6	35.7	226	189.7	197.2	195.0
138	37.7	38.4	37.5	228	195.3	203.0	200.8
140	39.5	40.3	39.4	230	200.9	209.0	206.8
142	41.4	42.2	41.3	232	206.7	215.1	212.9
144	43.3	44.2	43.3	234	212.6	221.3	219.1
146	45.3	46.3	45.3	236	218.6	227.6	225.4
148	47.4	48.4	47.4	238	224.8	234.1	231.8
150	49.5	50.6	49.6				
152	51.7	52.9	51.8				
154	54.0	55.2	54.1				
156	56.3	57.7	56.5				
158	58.7	60.1	59.0				
160	61.2	62.7	61.5				
162	63.7	65.3	64.1				
164	66.3	68.1	66.8				
166	69.0	70.8	69.6				
168	71.8	73.7	72.4				
170	74.6	76.7	75.3				
172	77.5	79.7	78.3				
174	80.5	82.8	81.4				
176	83.6	86.0	84.6				
178	86.8	89.3	87.8				
180	90.0	92.7	91.2				
182	93.3	96.1	94.6				
184	96.7	99.7	98.1				
186	100.2	103.3	101.7				
188	103.8	107.1	105.4				
190	107.4	110.9	109.2				
192	111.2	114.8	113.1				
194	115.0	118.8	117.1				
196	119.0	122.9	121.2				
198	123.0	127.1	125.4				
200	127.1	131.4	129.6				
202	131.3	135.9	134.0				
204	135.6	140.4	138.5				
206	140.0	145.0	143.1				
208	144.5	149.7	147.8				
210	149.1	154.5	152.6				
212	153.8	159.5	157.5				
214	158.7	164.5	162.5				
216	163.6	169.7	167.7				
218	168.6	174.9	172.9				

APPENDIX G. Number of Pacific Herring at Age by Body Length (2-mm Intervals) for Selected Fish from San Francisco Bay, December 1986 to February 1987.

Body length (mm)	Age (yr) 4	5	6	7	8	9
210-211	4	24	7	1		
212	4	26	2	5		
214		9	3	5		
216	1	13	5	1		
218		7	2	2	2	
220		3				
222	1	2	1	2		1
224						
226				1		
228						
230						
232						
234			1			
236				1	1	
N	10	84	21	18	3	1