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PACIFIC HERRING, *CLUPEA HARENGUS PALLASI*, STUDIES IN SAN FRANCISCO AND TOMALES BAYS, APRIL 1987 TO MARCH 1988

by

Paul N. Reilly
and
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ABSTRACT

Herring schools were surveyed hydroacoustically and sampled in San Francisco Bay from late October 1987 to March 1988. Nine large schools (greater than 1000 tons) and four smaller ones were detected. Total acoustic biomass estimate, using a combination of echo integration and "visual integration" methods, was 71,110 tons. Improved acoustic calibration parameters resulted in this estimate being close to the spawn escapement-plus-catch estimate of 68,881 tons. However, the two biomass survey methods are complementary and, when used together, provide a more accurate estimate of the spawning population than either method alone.

Eighty-two samples, containing a total of 16,316 herring, were collected with variable-mesh gill net, midwater trawl, or obtained from the roundhaul fishery. Mean body length decreased by more than 20 mm from the beginning to the end of the spawning season. Sex ratios favored males in November and December, while females were more abundant in February and March.

The 1982 through 1986 year classes (6- through 2-yr olds) contributed approximately 98% by weight and number to the total 1987-88 spawning biomass in San Francisco Bay. Herring year classes aged 7 and older each comprised no more than 1% of any school.

Above average recruitment occurred for the 1986 year class. Recruitment may not be complete for some year classes until age 3 yr. This was particularly evident for the 1985 year class.

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF APPENDICES

page

INTRODUCTION

This was the seventh year in which the California Department of Fish and Game (CDFG) Pacific Herring Research Project has conducted acoustic surveys and obtained herring samples during 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 1987). Biomass estimates using hydroacoustics are directly comparable with those from spawn deposition surveys (Spratt 1988a). Samples obtained from the roundhaul fishery and with our research nets complement those from the gill net fishery (Spratt 1988b) and together provide a complete assessment of the age, length, and sex composition of San Francisco Bay's spawning population, both fished and unfished.

The Pacific Herring Research Project has one major objective, to provide data necessary for long-term management of the herring roe and roe-on-kelp fisheries in California. Research, oriented to this objective during the 1987-88 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, sex, and age composition of each school; 3) weight/length/age relationships; 4) one hydroacoustic survey in Tomales Bay (Figure 2); 5) sampling young-of-the-year (YOY) herring during the non-spawning season in San Francisco Bay; and 6) sampling the experimental roe-on-kelp fishery in San Francisco Bay. Results from the roe-on-kelp sampling are presented in Moore and Reilly (1988).

METHODS

Spawning Season Field Work

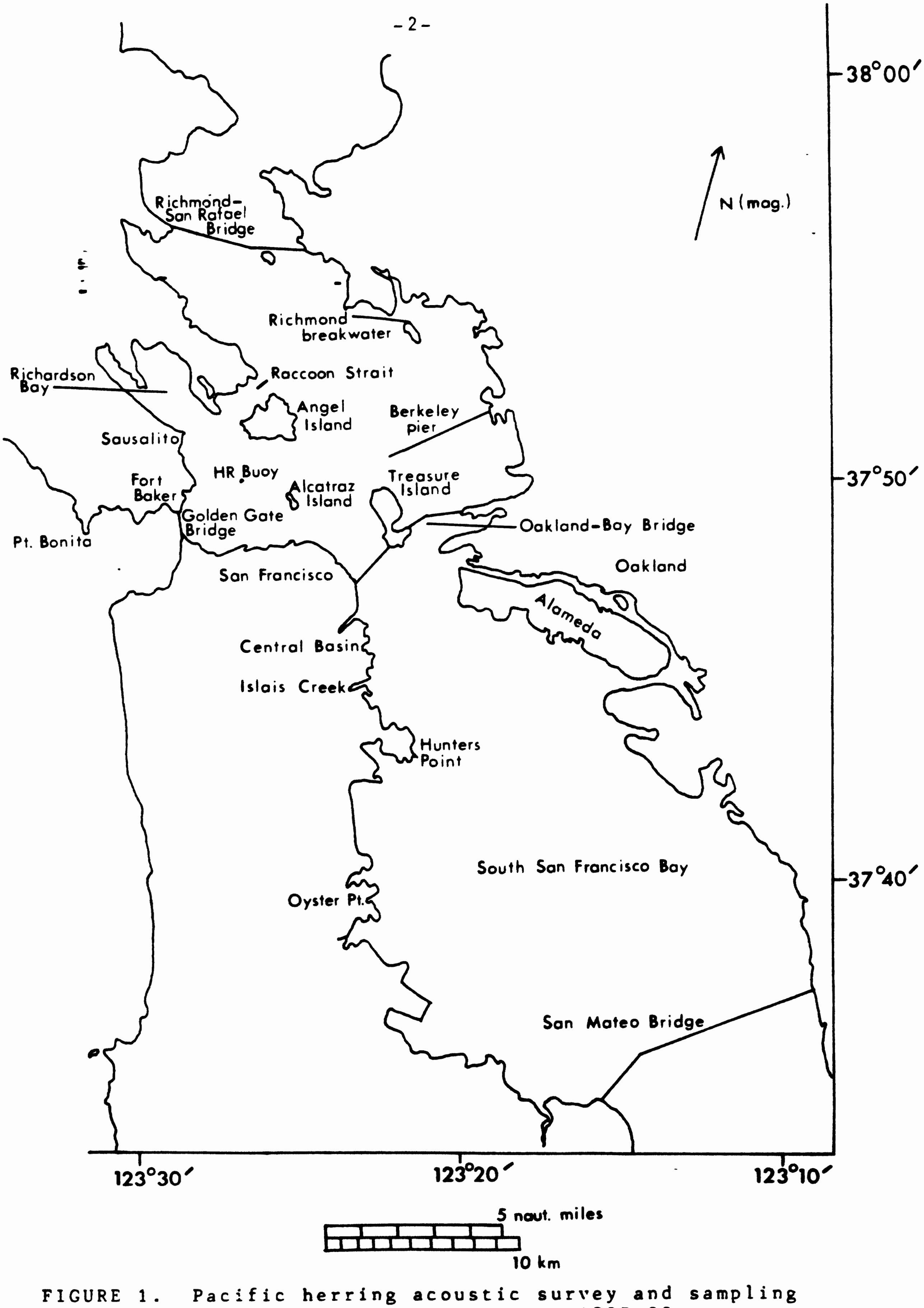

FIGURE 1. Pacific herring acoustic survey and sampling areas in San Francisco Bay, 1987-88.

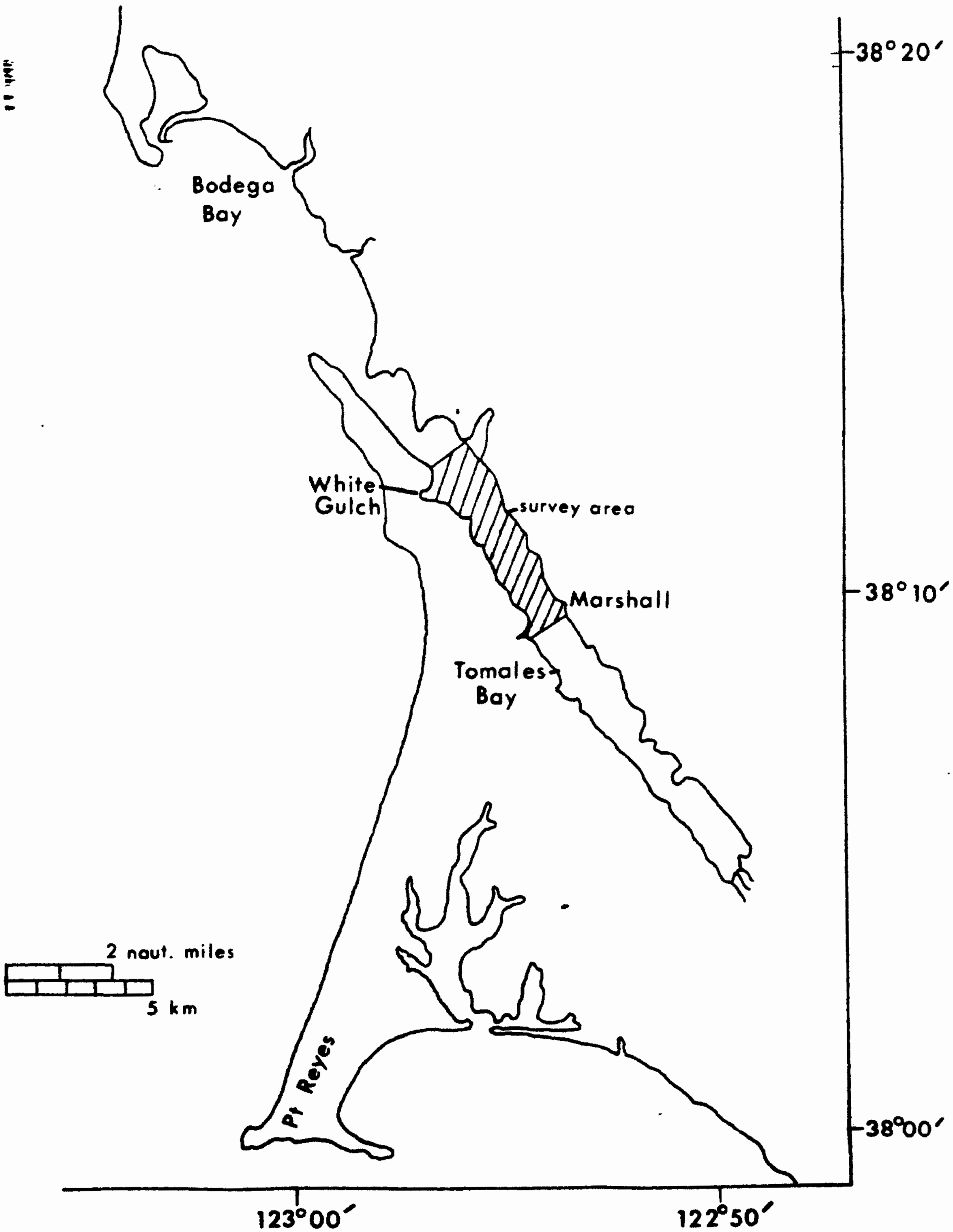

FIGURE 2. Pacific herring acoustic survey areas in Tomales Bay, 1988.

Research Vessels

The 23-ft R/V PANDALUS was used on all field days in San Francisco Bay. The acoustic survey in Tomales Bay was conducted onboard F/V CHRISTINE and F/V EVA U.

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 hr. Most samples were separated by mesh size.

Midwater Trawl. A 12-ft square (mouth opening), 65-ft long, double warp midwater trawl with a 0.5-in. stretched-mesh cod end was used throughout the season. Tow speed was approximately 3-4 kn and tow duration ranged from 2 to 27 min.

Roundhaul Nets. From January 5 to February 26, 1988, 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.

Non-spawning Season Field Work

Samples of YOY herring were collected with the midwater trawl in San Francisco Bay during April, May, July, and August 1987 in order to compare growth with previous year classes.

Acoustic Monitoring and Processing

Standard Acoustic Surveys

Hydroacoustic surveys were conducted 3 or 4 d each week in San

Francisco Bay. Areas surveyed were waters bounded by the Richmond-San Rafael Bridge, Oakland Bay Bridge, and Pt. Bonita (Figure 1), hereafter referred to as north bay, and 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.

A Raytheon model DE-719B recording fathometer depth sounder was used to locate and delineate herring schools 2-3 d each week. The paper recordings from this unit allowed us to estimate biomass using a technique we call "visual integration".

A scientific grade echo sounder, the Biosonics model 105, was used to conduct acoustic transects over herring schools on an approximately weekly basis; this allows biomass estimation using the acoustic technique of echo integration. The data collection system consists of the echo sounder, narrow beam (6^{o}) 200 kHz transducer, oscilloscope, chart recorder, video cassette recorder, and digitizer. Reflected echoes from herring are converted to voltages, digitized after being attenuated by a factor of ten, and stored on tape. The echo sounder incorporates a time-varied gain which insures that a particular fish will reflect the same amount of voltage regardless of its depth.

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

Visual Integration

Visual integration has been used to estimate biomass since 1982. Herring schools were plotted on charts of San Francisco Bay using the horizontal extent of herring traces, measured from the Raytheon paper recordings, bottom depth (also from the echosounder), compass bearings, and landmarks. A Housten Instrument HI-PAD digitizer was used to calculate surface area of portions of schools with approximately uniform density and height in the water column, based on visual examination of the paper recordings.

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 121 echo integrator (Reilly and Moore 1985). Finally, school biomass was calculated for each school surveyed.

Echo Integration

Tapes were processed in Seattle using WDF's echo integrator and interface (to increase attenuated voltages). The integrator calculates densities of herring per unit volume 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 30-70 m. The first 5 m were not integrated due to the absence of herring and the presence of air bubbles from vessel wakes. An average density per unit area was then calculated and multiplied by the surface area bisected by each transect to obtain a biomass estimate.

Dual Beam Transducer Survey

A special survey was conducted with Biosonics personnel to obtain back-scattering cross section values ( ) for San Francisco Bay herring on January 2, 1988. These values are a measure of the reflected voltage from single fish targets and are related to target strength (TS) by the equation

$$TS = 10\log \sigma.$$

A dual beam transducer, echo sounder, and processor were used to discriminate single echoes from a herring school. Approximately 9000 herring targets in north and south bay waters were individually discriminated. Average back-scattering cross section (σ) was 4.94 x 10^{-5} m^2. Herring averaged 185 mm in BL and 96 g in weight, and average σ_w (σ per kg) was 5.15 x 10^{-4}. This value was incorporated into the scaling equation, and is equivalent to a target strength of -32.9 dB/kg. This is almost identical to the value of -33.0 dB/kg selected last year (based on WDF studies of Washington herring).

Calibration Parameters and "A" Constant

The integration 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, plus other factors including speed of sound in water, pi, and the average back-scattering cross section of herring.

The first three parameters are calibrated in an acoustics laboratory. This season, two sets of calibrations to determine transmitter source level (transmitted pressure at 1 m from the transducer) and receiver sensitivity (the through system gain at 1 m from the transducer) were performed, one each by the Applied Physics Laboratory in Seattle and by Biosonics, Inc. The beam pattern factor is a measure of how transmitted pressure within the acoustic beam changes with the angular distance from the acoustic axis. This year the correct beam pattern factor was obtained from Biosonics for our transducer. Last season, a value from a sister transducer was used which proved to be erroneous. Acoustic biomass estimates for last season were recalculated this year.

Source level and receiver sensitivity (mean of two calibrations) were estimated to be 218.25 and -129.125 decibels, respectively. The correct beam pattern factor was 5.79 x 10^{-4}. Incorporating these values and σ_w into the scaling equation produced an A constant of 0.138. Last season, an A constant of 0.088 was derived. Adjusting for average weight differences between herring this season and last season, the correct A constant should have been 0.144 last season and corresponds to a 64% increase in the original echo integration biomass estimate.

Field Processing of Samples

For all fish sampled, body length (BL) was determined to the nearest mm measuring from the tip of the snout to the end of the pigment underneath the last column of scales on the caudal peduncle (Spratt 1981). All fish except YOYs were sexed and recorded as either unripe, ripe, or spent; spent herring were excluded from age, weight, and length analyses. Subsamples of approximately 17 fish per 10-mm size class were retained from each school for weighing and aging. Additional herring ≥ 210 mm BL were selected to augment the age-length data base.

An experiment was conducted to investigate weight loss from extrusion of eggs and milt due to stress from capture. Herring were sexed, measured and bagged individually as soon as possible after capture (not standard procedure) and subsequently weighed.

Laboratory Processing of Samples

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 1.020 for males and 1.023 for females was applied to account for shrinkage. Fresh or corrected lengths were used in all analyses. Weight was determined to the nearest 0.1 g; previously we found no significant difference between fresh and thawed weight (Reilly and Moore 1985). Fish that were partially spent (determined subjectively by examination) were not weighed.

Otoliths were removed from herring, rubbed clean on wet paper towels, placed in ethanol, and 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 agreement could not be reached they were sent to Jerome Spratt (CDFG-Monterey) for another reading.

Assigned Ages and School Numbers

Ages were assigned to unaged fish within 2-mm intervals based on the percentage composition of fish aged using otoliths for that particular size interval. All fish aged or assigned an age were then combined by school number to determine total age composition.

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 locations; 4) percentage of unripe females in each sample; 5) examination of daily landings of the commercial fleet (highest landings coincide with spawning events); and 6) miscellaneous information from fishers.

Total Age Composition for Spawning Season

Total percentage age composition was calculated for the entire spawning season based on two separate biomass estimates for each school: 1) the sum of spawn escapement estimate (Spratt 1988a) plus commercial catch; 2) our visual integration biomass estimate

(Spratt's estimates were used for schools not detected hydroacoustically). To calculate total percentage age composition by number of fish, 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 the total number of fish. For schools not sampled, data from the nearest school, temporally, were used. To calculate total percentage age composition by weight, 1987-88 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 BL by sex and maturity stage and length frequencies for each sample and school were generated. Other statistical analyses were performed using programs from ABSTAT.

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.

RESULTS

Acoustic Monitoring of Herring Schools in San Francisco Bay

On October 26 the first adult herring of the season were captured in Raccoon Strait. Biomass was too small to be estimated by either

TABLE 1. Summary of Herring Schools in San Francisco Bay and Biomass Estimates, November 1987 to March 1988.

School number	Spawn dates	Spawn area[1]	Spawn escapement (tons)[2]	Commercial catch (tons)	Acoustic biomass estimate (tons): Visual integration	Echo integration	Best estimate
1	Nov 3	SA	trace	0	–[3]	–[4]	none
2	Nov 24,29	SA	130	26	370	135[5]	370
3	Nov 29-30	SF	2350	326	–[3]	1450[5]	1450
4	Dec 7-11	SF,HP	3900	1467	2445[6]	2925[7]	5370
5	–[8]	–[8]	–[8]	100	25	115	115
6	Dec 26-27	SF,AL	1865	0	10,750[9]	7750	7750
7	Jan 3-6	SF,OA,TI	16,000	1722	26,280	18,450	26,280
8	Jan 7-8	SA	2100	155	2580	3380	3380
9	Jan 16-18	HP	2240	725	3690	3320	3505
10	Jan 25-28	SF,SA	22,570	2268	3970[5]	9850	9850
11	Feb 8-13	HP	9000	1517	5690	9390	9390
12	–[10]	–[10]	–[10]	391	2130	2535	2335
13	–[11]	–[11]	–[11]	29	180	495	495
			60,155	8726	58,110	59,795	70,290

[1] Legend: AL-Alameda; HP-Hunters Point; OA-Oakland; SA-Sausalito to Fort Baker; SF-San Francisco; TI-Treasure Island.
[2] from Spratt (1988a).
[3] not surveyed with visual integration equipment prior to spawn.
[4] not surveyed with echo integration equipment prior to spawn.
[5] entire school not detected acoustically prior to spawn
[6] first part of school
[7] second part of school
[8] herring present near Sausalito December 5-8; 100 tons caught by gill net fleet; subsequent survey yielded no spawn deposition.
[9] includes unripe fish that did not spawn with this school.
[10] herring present near San Francisco February 14-26; 391 tons caught by roundhaul fleet; subsequent survey yielded no spawn deposition.
[11] herring present near Sausalito February 29-March 14; 29 tons caught by roundhaul fleet; subsequent survey yielded no spawn deposition.

integration method, and trace quantities of egg membranes were found in Sausalito several weeks later; the spawn occurred on approximately November 3 (Table 1).

Little hydroacoustic activity was observed until November 18 when school 2 first appeared near Sausalito. Midwater trawl samples showed this small school to be mixed with anchovies; herring comprised 40% by weight of fish sampled. Spawning occurred sporadically from November 24 to 29 in Sausalito. On opening day of the XH gill net season (November 29) several boats landed a total of 26 tons from this school.

The first significant (>1000 tons) school (3) of the season was detected November 29 between the Oakland Bay and Golden Gate Bridges. A trawl sample contained only 23% unripe herring; these ripened rapidly and spawning occurred during the next 2 d along the San Francisco waterfront. Gill netters landed 326 tons from this school.

On December 2 the first wave of school 4 was encountered at high tide between Hunters Point and the Oakland Bay Bridge. A trawl sample yielded 79% unripe fish. Landings from this part of the school peaked December 7 and 8 as spawning occurred at San Francisco and Hunters Point. A second wave of herring appeared December 7 and spawned December 9-11 as landings declined and peaked again. The XH fleet exceeded their quota on December 11 and their season was closed; a total of 1467 tons was caught from school 4. A visual integration estimate was obtained on December 2 of the first wave in the south bay, and an echo integration survey was completed December 7 of the second portion of the school.

On December 3, using the Raytheon echo sounder, a small school was detected and sampled near Sausalito. The same school was echo integrated on December 5. Although no spawn was discovered in north bay waters, gill netters landed 100 tons from Sausalito December 7-8 and these fish were considered to be from school 5.

Part of school 6 first appeared in Raccoon Strait on December 9: a trawl sample yielded 72% unripe herring. These fish were echo integrated the next day, as was a larger body of fish near San Francisco. On December 11 a trawl sample of the main body near Alcatraz Island contained 52% unripe fish. The northern part of the school was again sampled December 14 and contained 67% unripe herring. Echo integration of the southern portion on December 17 indicated a significant increase in biomass with only 26% unripe fish. On the next day visual integration yielded the largest biomass present so far this season, from west of Alcatraz Island to Hunters Point. Apparently both parts of the school had coalesced by this time and new fish (school 7) had also moved into the bay; a trawl sample near Alcatraz yielded 92% unripe fish. Significant spawning did not occur until December 25. Based on the difference between the echo and the visual integration estimates, it is likely that the latter contained approximately 3000 tons of herring which spawned with the next school (7).

On December 28 a tremendous quantity of herring (part of school 7) was visually integrated from near Harding Rock (HR) buoy to Islais Creek with a break in distribution near the Oakland Bay Bridge. Two days later trawl samples yielded 68% unripe fish near Alcatraz Island and only 39% unripe fish in central south bay. Echo integration of the same part of the school at low tide between the Oakland Bay and Golden Gate Bridges produced more than 10,000 tons. On the next day a second massive school was visually integrated at high tide from north of Treasure Island to the Richmond-San Rafael Bridge and contained only 23% unripe herring. Together, these fish were considered as school 7 and contained the largest acoustic biomass of the season. During our special dual beam survey January 2, parts of the school were still present in north and south bays but echo integration was not possible. By the next day (the season opener for the odd gill net and roundhaul fleets), spawning had already commenced along the Oakland shoreline and an echo integration survey of the second part of the school yielded considerably less biomass than the visual integration survey. The commercial catch during the January 3-6 spawn in Oakland, San Francisco, and Treasure Island was 1722 tons.

As spawning was tapering off, a new school (8) moved into the bay near Sausalito on January 5. Visual and echo integration estimates were obtained one day apart on January 5 and 6. Spawning occurred January 7-8 near Sausalito and 155 tons were caught by the fleet.

In early January, schools were entering the bay in rapid succession. On January 8, a school (9) was visually integrated near San Francisco. The same school was echo integrated January 11 and a trawl sample contained 67% unripe herring. Before these fish began spawning on January 16 at Hunters Point (commercial catch 725 tons) the first signs of school 10 were detected. A January 13 trawl sample of school 10 yielded 92% unripe herring. Although school 10 subsequently was the largest school estimated from spawn deposition surveys, repeated acoustic surveys during the next 2 wks yielded significantly less biomass. Echo integration surveys were conducted January 19, 22, and 27 on separate portions of school 10, but the total biomass estimate was only 9390 tons. A visual integration survey on January 25 yielded less than 4000 tons. Even when the confidence limits from spawn deposition sampling (Spratt 1988a) are considered, it is likely that acoustic surveys underestimated this school significantly.

Between February 1 and 8, several portions of a new school (11) were scattered throughout north and south bay waters and were reported as far south as the San Mateo Bridge where gill net and roundhaul boats caught fish. The best acoustic trace of this school occurred with our echo integration equipment on February 8 when herring had coalesced into a dense mass between Alcatraz Island and Central Basin. Approximately 1500 tons were caught, primarily by the roundhaul fleet, before and during the February 8-13 spawn at Hunters Point.

Another moderately large school (12) was first located in the south bay at high tide on February 16. Echo integration of this school yielded 2535 tons (45 tons of roundhaul landings were made prior to the survey). A second echo integration survey on February 24 yielded only 2040 tons; however, 391 tons had been taken by roundhaul boats by this date, thus making the two estimates comparable. A visual integration survey yielded 2130 tons on February 22. Although no spawn was detected from this school, more than 10% spent herring occurred in trawl samples between February 22 and 26.

A few roundhaul boats continued to fish from February 29 to March 4, during which time the last school (13) of the season was detected acoustically and sampled by trawl. This small school remained near Sausalito until March 14, but no spawn could be located. Only scattered herring were caught incidentally to anchovies during the rest of March.

Acoustic Biomass Estimates for San Francisco Bay

A best biomass estimate is presented for the 1987-88 season (Table 1) based on both acoustic survey techniques. This best estimate reflects the maximum biomass present in closest proximity to a spawn, but also considers the presence of separate schools, one ripe and one unripe, on successive survey days, such as occurred December 17 and 18. When visual and echo integration estimates were fairly similar for a particular school (9 and 12), the average was used as the best estimate. Our total acoustic biomass estimate was 70,290 tons. In addition, it was determined from landings that 820 tons of herring were taken by the roundhaul fleet prior to those acoustic surveys which produced the best estimate. Thus, our adjusted acoustic estimate is 71,110 tons. This is approximately 3% greater than the spawn escapement-plus-catch estimate of 68,881 tons. If 2830 tons from schools 12 and 13 (for which no spawn escapement was found) are added to the escapement-plus-catch biomass, the total estimates from the two methods differ by only 600 tons.

Our revised acoustic biomass estimate for the 1986-87 season, incorporating both acoustic integration methods, is 54,265 tons. In addition, it was determined that 1140 tons were caught by the roundhaul fleet prior to acoustic surveys on individual schools, and one school of 875 tons (spawn escapement plus catch) was not surveyed. Thus, the best acoustic estimate for 1986-87 is 56,280 tons, 1% less than the spawn escapement-plus-catch estimate of 56,816 tons (Spratt 1987).

Tomales Bay Acoustic Survey

The presence of the gill net fleet precluded acoustic biomass estimates based on standard transects. In addition, the shallow topography of the bay may cause boat avoidance to be a significant factor. Although the survey was conducted at night, herring were only detected in small discrete patches near the bottom. During 2 hr of acoustic surveys, nine small patches of herring were located. All but one had densities ranging from 3 to 47 tons per $10^6 ft^2$. These would be considered low to moderately low densities in San Francisco Bay. An average patch measured 200 ft in diameter; this would equate to a range of 0.08 to 1.47 tons per patch. One patch had a density of 188 tons/$10^6 ft^2$ (moderately high for San Francisco Bay standards); this would have yielded 5.9 tons of herring.

Herring Samples from San Francisco Bay

Eighty-two samples of adult herring were collected in San Francisco Bay from October 26, 1987 to March 14, 1988 (Appendix A); these contained a total of 16,316 fish. Herring were sampled from all 13 schools.

Length Composition

Variable-mesh Gill Net Samples. Many of this season's herring schools were not adequately sampled with this gear. Only 865 fish were obtained from nine samples (Appendix B). Only samples from schools 4, 7, and 9 (Appendix A) were sufficiently large (n>100) to provide useful comparisons of length composition. Mean BL decreased substantially from school 7 (early January) to school 9 (late January)(Table 2); this is typical each season as smaller herring begin to appear in large quantities.

Length frequency histograms for each mesh size were combined for all samples this season (Figure 3). Mean BL data by mesh size from the past seven seasons are summarized in Table 3. While there is

TABLE 2. 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 1987 to February 1988.

Body length (mm)	Assigned School Number 1	4	7	8	9	10	11
144-145					1	1	
146					1		
148					1		
150					1	1	
152		2	1			2	1
154			2				3
156		1	1		1	1	3
158		5	1		5	2	1
160		2			5		2
162		5	4	1	4	3	4
164		3	6		2	1	7
166		10	5	4	5	4	2
168		6	2	3	5		4
170		7	2		4		4
172	2	7	5	1	4	1	3
174		4	3	1	8		1
176	1	6	6	2	9	1	
178	2	5	7	6	5		4
180	1	9	3	4	4		3
182	1	15	9	9	12		3
184	5	19	4	5	3		3
186	1	27	14	8	11	3	2
188	6	21	5	10	13	1	2
190	3	14	11	1	8	1	3
192	2	25	15	7	13	1	4
194	3	11	9	6	3		1
196	1	18	9	6	5		1
198	1	10	8	2	4		2
200	3	10	4	3	2	1	4
202	2	8	13	6	2	1	
204		7	1	3	2		
206	2	7	5	3			3
208	1	3	5	2	1		
210	5	4	6	1			1
212	3	4	5	1	2		2
214		2	3	1			
216	2	3		3	1		1
218	2	3	2	1	1		
220			1	1			
222		1		2			2
224				1			
226			1		1		
N	49	284	178	104	149	25	76
Mean	196.0	188.0	189.6	191.4	181.9	170.8	180.3

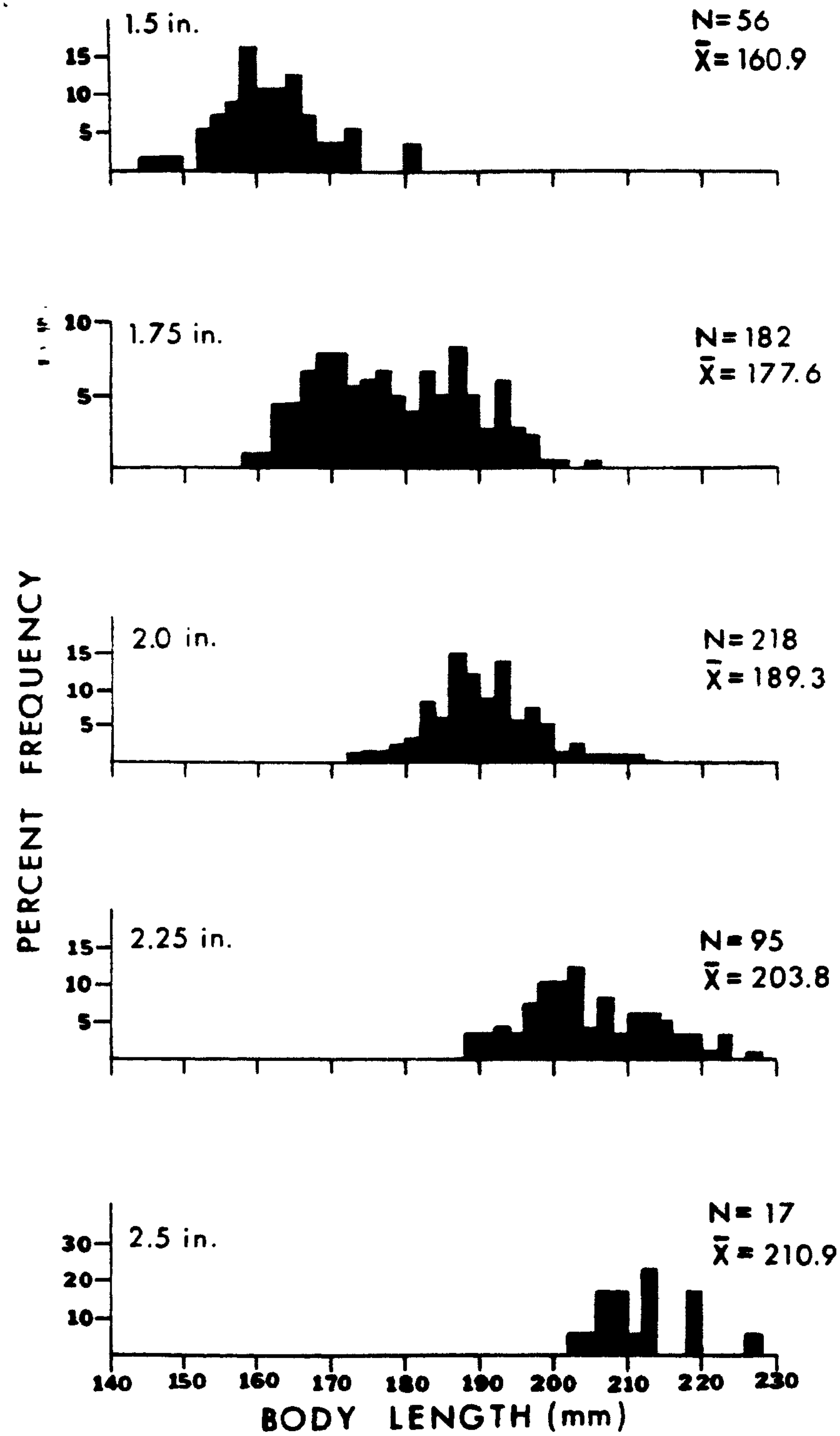

FIGURE 3. Percent length frequencies (2-mm intervals) from variable-mesh gill net samples, San Francisco Bay, October 1987 to February 1988.

TABLE 3. Summary of Mean Body Length (mm) by Mesh Size from Variable-mesh Gill Net Samples from San Francisco Bay, 1981-82 to 1987-88.

	Mesh Size (in.)									
	1.5		1.75		2.0		2.25		2.5	
Season	N	Mean BL	N	Mean BL	N	Mean BL	N	Mean BL	N	Mean BL
1981-82	198	165.1	455	175.1	697	191.4	117	205.1	5	206.6
1982-83	909	165.1	2142	182.4	1580	196.8	462	208.7	68	215.6
1983-84	758	159.8	752	181.5	424	196.4	53	204.0	0	-
1984-85	212	163.3	684	173.6	701	189.0	212	201.8	34	206.5
1985-86	261	165.8	851	176.5	736	191.8	354	201.4	66	211.4
1986-87	387	164.6	1127	175.9	822	191.9	528	203.0	59	212.2
1987-88	56	160.9	182	177.6	218	189.3	95	203.8	17	210.9
Total	2781	163.4	6193	178.6	5178	193.2	1821	204.2	249	211.9

usually considerable overlap in length frequency distribution between adjacent meshes, mean BL for a particular mesh size has fallen within a fairly narrow range (6-9 mm), demonstrating the selective nature of this sampling gear.

Midwater Trawl Samples. The trawl was our most effective sampling tool this season, yielding 11,272 fish in 40 samples (Appendix C) from all schools except the first one. Mean BL by school was fairly uniform between mid-November (school 2) and early January (school 8), varying by less than 6 mm (Table 4). One month later (school 11), mean BL had decreased by approximately 15 mm as smaller herring joined the prespawning aggregations. Mean BL then remained below 165 mm for the duration of the season. This season, for schools 4, 7, and 9, gill net mean BL averaged 8 mm greater than that of trawl mean BL. Last season's mean BL by school from trawl samples ranged from 166 to 184 mm.

Purse Seine and Lampara Net Samples. We measured 4179 herring from 33 samples (Appendix D) taken from January 5 to February 26 from schools 7-12. This season, unlike most, the roundhaul fleet began fishing before the traditional influx of smaller herring. Mean BL from the first two schools sampled was approximately 20 mm greater than that of the last two schools sampled (Table 5). Mean BL averaged 2.8 mm greater (range 0.2 to 5.8 mm) than that of trawl samples from schools 7-12. Gill net sample mean BL from schools 7 and 9 averaged 5.2 mm greater than roundhaul sample means from those schools.

During the past seven seasons, annual mean BL of all fish sampled from the roundhaul fleet has ranged from 162 to 181 mm (Table 6). These fluctuations are determined by the relative strength of year classes as well as periods of unusual growth, as shown in samples from

TABLE 4. Number of Pacific Herring by Body Length (2-mm Intervals), Combined by Assigned School Number, from Midwater Trawl Samples, San Francisco Bay, November 1987 to March 1988.

Body	Assigned School Number									
length (mm)	2	3	4	5	6	7	8	9	10	11
130-139						2		8	16	23
140-141						1	1	3	11	8
142						2		10	10	27
144					1	1		8	13	15
146					2	12	2	17	32	51
148			1		2	8	3	29	34	67
150			2		6	13	3	25	52	58
152	1	1	3		13	33	7	54	92	113
154	1	4	1	3	14	23	2	41	70	96
156	1	3	7	6	22	50	10	75	139	162
158		1	12	4	32	43	3	60	89	101
160	3	1	13	9	44	38	5	61	68	129
162	6	1	19	3	64	94	12	81	107	159
164	5	3	15	5	38	46	9	44	78	102
166	6	7	22	6	77	91	12	72	79	109
168	11	4	12	3	45	48	10	52	65	69
170	10	3	10	7	52	58	4	40	57	62
172	13	5	28	10	80	74	13	50	68	68
174	6	5	13	7	49	45	11	29	46	37
176	15	13	24	8	80	92	13	49	55	37
178	12	10	23	4	81	60	12	34	50	31
180	17	12	35	6	66	42	12	28	36	27
182	30	21	28	15	105	91	25	43	68	42
184	21	11	24	8	79	59	14	40	45	20
186	35	14	41	6	115	80	28	50	52	25
188	12	13	31	8	78	73	16	35	36	26
190	19	13	33	8	89	60	17	24	40	14
192	17	15	41	6	113	83	13	33	44	27
194	12	12	35	7	73	38	8	10	24	16
196	14	11	26	5	83	37	10	27	29	16
198	8	4	20	9	49	43	8	19	19	9
200	4	7	22	3	50	36	8	11	15	12
202	11	4	24		58	34	15	11	14	8
204	1	2	12	3	46	22	8	10	5	6
206	4	4	8	1	51	34	8	5	7	5
208	1	1	5		17	13	1	3	9	7
210	1		7		12	12	2	8	7	3
212	1		8	1	9	11	1	2	1	5
214	1		2	1	4	3	2	2	2	4
216	1		1		10	3	2	2	2	1
218		2	2	2	4	7	2	1	1	2
220					2	6		1	1	3
222		1	1		1	2	3			2
224						1			1	
226						1				
228						1				
232					1					
N	300	208	611	164	1817	1626	335	1207	1689	1804
Mean	184.2	184.8	184.7	180.4	183.5	179.2	182.4	170.9	169.3	164.9

TABLE 4. (continued)

Body length (mm)	Assigned school number 12	13
130-139	14	5
140-141	3	3
142	15	10
144	12	12
146	29	22
148	17	18
150	27	27
152	62	46
154	36	40
156	78	57
158	52	49
160	58	59
162	103	74
164	52	48
166	64	45
168	48	38
170	29	20
172	30	25
174	10	13
176	15	23
178	11	7
180	2	2
182	6	4
184	5	3
186	3	3
188	4	3
190	5	2
192	6	2
194	4	1
196	1	2
198	1	1
200	2	4
202	2	4
204	2	3
206	2	1
208	2	5
210	1	2
212	2	2
214	2	2
216	2	2
222	1	1
224		1
N	820	691
Mean	162.0	163.0

TABLE 5. 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 February 1988.

Body length (mm)	Assigned School Number 7	8	9	10	11	12
130-139					17	14
140-141			1		12	10
142	1			3	14	7
144			1	4	19	15
146			3	4	48	35
148		1	6	3	42	31
150		2	4	16	47	35
152		4	4	15	110	68
154		2	11	17	79	62
156	1	3	9	34	176	97
158	1	9	8	16	125	84
160	4	5	18	21	82	84
162	2	6	19	40	161	140
164	2	5	18	15	93	68
166	1	6	11	22	140	94
168	4	11	8	21	83	75
170	5	8	15	22	44	60
172	4	12	11	30	71	77
174	4	9	6	14	35	43
176	7	9	17	22	54	25
178	3	10	9	16	24	13
180	6	9	13	18	23	15
182	8	18	15	27	35	13
184	5	9	17	16	16	10
186	11	15	13	21	40	6
188	10	7	15	12	26	5
190	5	19	14	13	18	6
192	9	20	10	19	32	
194	3	9	11	11	15	3
196	3	16	10	11	11	2
198	3	13	4	14	7	2
200	3	10	5	1	6	
202	1	10		6	8	
204	5	3	3	4	4	2
206	1	4	2		6	3
208	1	1		3	8	2
210			2	1	2	1
212	2	1	1	4	4	
214	3		2	2	2	1
216		1	1			1
218	2	2	1			
220				2		
222			2		1	
224		1				
N	120	270	320	520	1740	1209
Mean	185.0	182.9	176.1	173.4	165.1	162.9

TABLE 6. Number of Pacific Herring by Body Length (2-mm Intervals) from Roundhaul Samples, 1981-82 to 1987-88.

Body length (mm)	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88
130-139	2	9	247	27	16	24	31
140-141	4	4	84	6	3	8	23
142	6	6	130	10	2	23	25
144	7	3	146	8	6	16	39
146	12	6	223	20	8	26	90
148	3	9	187	26	7	33	83
150	6	7	274	38	15	31	104
152	21	17	399	82	40	67	201
154	27	29	334	103	28	72	171
156	26	55	522	154	57	147	320
158	33	42	428	178	88	135	243
160	27	76	441*	180	113	152	214
162	56	136	498	344	218	265	368
164	56	120	345	312	213	231	201*
166	68	178	302	309*	276	359	274
168	79	157	235	238	256	255	202
170	89	196	121	210	260	263*	154
172	115	267	145	234	353	386	205
174	103*	173	82	159	281	207	111
176	105	261	94	139	309	253	134
178	88	252	92	109	268*	145	75
180	74	241*	79	78	228	111	84
182	91	340	147	107	313	140	116
184	51	238	128	83	243	96	73
186	53	310	129	83	253	89	106
188	60	186	81	64	181	72	75
190	50	205	93	47	166	57	75
192	41	236	90	54	207	92	90
194	22	124	68	28	120	57	52
196	22	166	51	34	136	69	53
198	20	106	34	24	100	54	43
200	12	64	20	16	84	48	25
202	9	77	14	19	70	50	25
204	5	52	7	15	57	27	21
206	3	42	5	8	43	24	16
208	4	13	2	7	26	14	15
210	2	17	3	3	16	18	6
212	3	11	3	5	18	7	12
214		7		3	7	5	10
216	1	4		2	6	4	3
218	1	3			3	1	5
220		3			2	3	2
222	1		1	1	2		3
224	1	2			1		1
226						1	
N	1459	4452	6294	3566	5099	4137	4179
Mean	175.2	180.8	162.4	169.3	178.5	172.6	168.2
% < 150 mm	2.3	0.8	16.2	2.7	0.8	3.1	7.0

* Median Body Length

the 1983-84 season affected by El Niño conditions. This season, above average recruitment of the 1986 year class resulted in the second smallest annual mean BL in seven seasons. In addition, based on the percentage of herring less than 150 mm BL, it appears that growth of this strong year class may have been below average.

Comparison of Length Composition by Gear Type. In previous reports (Reilly and Moore 1982, 1983, 1984, 1985, 1986, and 1987) we have found biases inherent in the variable-mesh gill net (towards larger fish) and midwater trawl (towards smaller fish). In the absence of unbiased roundhaul samples, a combination of gill net and trawl samples from a particular school may be the most accurate representation of the size composition of those herring spawning before or after the roundhaul fishery. During the past seven seasons 19 schools have been adequately sampled by each of the three gears (Table 7). Differences between mean BL from roundhaul samples and the combined mean BL from gill net and trawl samples ranged from 0.1 to 4.4 mm and averaged only 1.2 mm.

Sex Ratios

The usual trend of an increasing percentage of females in herring schools as the season progressed was again apparent this season (Table 8). In general, herring schools from late October to mid-December are composed of more males than females, those from late December until the end of January have a sex ratio of approximately 1.0, and those in February and March have more females than males.

Data from this season are consistent with those of previous years in demonstrating a trend of increasing percentage of female herring with increasing mesh size in variable-mesh gill net samples (Table 9). Earlier maturation and selective mortality of 2-yr old males (Reilly

TABLE 7. Comparison of Gill Net, Midwater Trawl, Combined Gill Net and Trawl, and Roundhaul Samples, San Francisco Bay, 1981-82 to 1987-88.

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
1987-88	7	189.6	179.2	184.4	185.0	0.6
	9	181.9	170.9	176.4	176.1	0.3
					mean=	1.2

TABLE 8. Composition of Pacific Herring Samples from San Francisco Bay, by School and Sex, Gears[1] Combined, November 1987 to March 1988.

School	Month	N	Percentage by number Male	Female
1	Nov	49	55	45
2	Nov	300	55	45
3	Nov	208	56	44
4	Dec	1059	56	44
5	Dec	164	60	40
6	Dec	1817	52	48
7	Jan	1924	50	50
8	Jan	709	52	48
9	Jan	1676	49	51
10	Jan	2234	50	50
11	Feb	2980	45	55
12	Feb	2032	42	58
13	Mar	691	36	64

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

TABLE 9. Percent Female Herring by Number from Variable-mesh Gill Net Samples from San Francisco Bay.

Mesh size (in.)	1981-1982	1982-1983	1983-1984	1984-1985	1985-1986	1986-1987[1]	1987-1988	mean
1.5	37	36	38	36	30	42	32	35.9
1.75	53	42	52	43	37	45	47	45.6
2.0	57	52	64	48	49	55	53	54.0
2.25	79	65	73	62	63	67	66	67.9
2.5	-[2]	-[2]	-[2]	-[2]	80	83	-	81.5

[1] excludes October 1986 sample

[2] insufficient sample size

and Moore 1985) result in a higher proportion of females among older herring. In addition, female herring have a higher girth/length ratio and thus are caught more frequently in larger meshes.

Weight and Length

Weights and lengths for 1643 herring collected from October 1987 to March 1988 were used to generate the following equations using natural logarithms:

For unripe males

$$\ln W = -12.26 + 3.22 \ln L \qquad r = .98,\ n = 80$$

For unripe females

$$\ln W = -13.12 + 3.38 \ln L \qquad r = .99,\ n = 478$$

For ripe males

$$\ln W = -12.75 + 3.31 \ln L \qquad r = .99,\ n = 602$$

For ripe females

$$\ln W = -13.31 + 3.43 \ln L \qquad r = .99,\ n = 483$$

For all ripe herring

$$\ln W = -13.14 + 3.39 \ln L \qquad r = .99,\ n = 1085$$

Estimated weights for ripe male herring from 130 to 238 mm BL (Appendix E) ranged from 5 to 2% less, respectively, than those from the 1986-87 season. Estimated weights for ripe female herring from 130 to 238 mm BL (Appendix E) ranged from 8 to 2% less, respectively, than those for 1986-87. Last season, the weight/length regression for ripe herring was:

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

An overall test between the two regressions for all ripe herring showed that the slopes were not significantly different at the 99% level of significance ($F = 4.35$, $p = 0.037$, d.f. = 2340).

The weight/length regression for ripe herring bagged individually this season was:

$$\ln W = -13.04 + 3.37 \ln L \qquad r = .98,\ n = 248$$

An overall test between this regression and the 1987-88 regression for all ripe herring was not significant at the 99% level (F = 3.98, p = 0.019, d.f. = 1332). This indicates that weight/length relationships representative of the spawning population may be determined by eliminating partially spent fish from weight determinations in the laboratory. However, some ripe herring lose a significant amount of gonadal material due to stress upon capture.

Length at Age

Mean length at age has shown little variation since the El Nino-influenced 1983-84 season (Table 10). The 1982 year class (shown as 3-yr olds in 1984-85 and 6-yr olds in 1987-88) continues to demonstrate above average growth.

Weight at Age

Mean weights at age for 2- to 7-yr-old herring showed small declines from the previous season (Table 10) but are well above the El Nino season weights of 1983-84 and continue to indicate a healthy population. As 6-yr olds, the 1982 year class averaged only 3.7 g less than 7-yr olds this season. Nine-yr olds have been sampled too infrequently to include with the weight, length, and age data.

Age Composition

Pairs of otoliths were aged for 1892 herring from stratified random samples from variable-mesh gill nets, midwater trawl, and purse seine and lampara nets. Slight differences in mean BL at age presented in Table 10 and Table 11 are due to the pooling of data in Table 11 into 2-mm intervals and the exclusion of partially spent fish in Table 10 for 1987-88 herring.

TABLE 10. Mean Body Length (mm) and Weight (g) of San Francisco Bay Herring by Age and Season, 1983-84 to 1987-88.

Age (yr)	1983-84		1984-85		1985-86		1986-87		1987-88	
	BL	Wt.	BL	Wt.	BL	Wt.	BL	Wt.	BL	Wt.
2	153	47.3	161	64.1	162	63.5	160	61.5	159	58.0
3	172	68.3	182	96.5	178	88.6	179	89.7	176	81.0
4	182	81.6	190	111.2	194	118.5	190	112.8	191	106.8
5	194	99.7	198	126.0	199	127.4	204	140.2	202	130.8
6	201	111.4	204	138.1	206	141.5	209	152.3	211	151.7
7	210	127.8	210	148.8	211	155.4	215	160.5	215	155.4
8	214	135.6	213	156.1	217	166.3	218	166.7	217	167.7

TABLE 11. Number of Pacific Herring at Age by Body Length (2-mm Intervals) from San Francisco Bay, October 1987 to March 1988.

Size interval (mm)	Age (yr) 2	3	4	5	6	7	8	9
130-139	1							
140-149	26							
150-151	13							
152	43	3						
154	39	2						
156	54	12						
158	44	17						
160	26	10						
162	40	25						
164	35	15						
166	38	39						
168	18	37						
170	12	28	1					
172	22	66	6					
174	4	27	6					
176	2	43	6	2				
178	3	44	19					
180	1	20	9					
182		46	31	1	1			
184		34	18	2				
186		31	43	7				
188		18	25	6				
190		16	23	9	1			
192		17	37	17	2			
194		11	28	7	2			
196		9	20	18	3			
198		2	21	21	5			
200		4	19	32	20	2		
202		1	20	33	15	1		
204			14	18	7	2		
206			10	16	17			
208			1	12	10	2		
210			6	15	31	3	4	
212			4	21	24	4	1	
214				5	21	4	1	
216				6	21	3	2	
218				9	10	3	4	
220				3	7	2	2	
222				1	13	5	1	
224					4		1	
226					3			
228								1
232							1	
N	421	577	367	261	217	31	17	1
Mean	159.4	175.6	190.8	201.9	210.0	213.3	216.9	228.0
Std.dev.	7.3	10.2	8.9	8.6	8.6	6.6	5.9	0.0

The percentage of 3-yr olds less than 170 mm increased from 19.5 last season to 27.7% this season. Two otolith patterns were evident for the 1985 year class; one showed robust growth and was characteristic of most 3-yr olds >180 mm BL, while the other, found in most 3-yr olds <170 mm BL, had considerably smaller but still well defined annual growth zones. Six-yr-old herring dominated all length groups >208 mm BL. The weak 1981 year class was poorly represented as 7-yr olds. Seven- to 9-yr-old herring comprised only 2.6% of all fish aged, the lowest percentage we have found during the past 7 seasons.

An additional 209 large herring were selected for aging (Appendix F) for use in the construction of an age-length key. Again, the dominance of the 1982 year class (as 6-yr olds) was apparent. Otoliths from these herring have been of high quality each season and have been aged with a minimum of disagreement.

Variable-mesh Gill Net Samples. Samples for age composition with N>25 were obtained only from schools 1, 4, 7-9, and 11 (Table 12). Percentage of 3-yr olds was fairly constant, while 2-yr olds began to increase with school 11 in late January. Ages 7 to 9 yr were poorly represented. The bias of the gill net towards larger, older fish is apparent when age composition is compared among gear types (Table 12).

Midwater Trawl Samples. All schools were adequately sampled with the exception of number 1, the smallest of the season. Results demonstrate the gradual shift in age composition towards younger fish as the season progressed (Table 12). Two-yr olds became the most abundant year class in trawl samples beginning with school 9 in mid-January. The last three schools of the season contained approximately 90% 2- and 3-yr-old herring by number. Throughout the season, 7-, 8-, and 9-yr olds each comprised no more than 1% by number of any school

TABLE 12. Percent Age Composition by Number of Pacific Herring Samples, by School Number, Based on Otolith Aging and Age Assignments by Length, from San Francisco Bay, October 1987 to March 1988.

School number	Age (yr) 2	3	4	5	6	7	8	9	Otolith aged (n)	Assigned by length (n)
variable-mesh gill net samples										
1	16	35	21	14	10	4			48	1
4	10	35	28	17	9	1	T		19	265
7	10	32	29	14	15	T	T		18	160
8	3	29	32	22	9	1	4		11	93
9	15	33	36	10	6			T	5	144
11	30	30	11	16	13				5	71
midwater trawl samples.										
2	6	39	35	15	5	T			109	191
3	.8	35	38	16	3	T	T		95	113
4	12	37	31	13	6	1	T		211	400
5	19	40	29	7	5	T			92	72
6	15	38	27	13	7	T	T		342	1475
7	24	39	21	10	5	1	T	T	147	1479
8	19	33	27	13	7	T	1		12	323
9	41	37	14	5	3	T	T		115	1092
10	45	35	14	4	2	T			100	1589
11	56	33	6	3	2	T			206	1598
12	64	30	4	1	1	T			75	745
13	63	30	3	2	2	T	T		90	601
roundhaul samples										
7	8	45	23	14	6	2	2		7	113
8	15	37	29	13	6	T			104	166
9	32	40	18	7	2	T	T		9	311
10	34	41	16	7	2	T	T		7	513
11	56	33	7	3	1	T	T		107	1633
12	59	35	4	1	1	T			6	1203

*T-trace, less than 0.5%

sampled by trawl.

Purse Seine and Lampara Net Samples. Roundhaul samples were obtained from schools 7 to 12 from early January to late February. Similar to trawl results, a trend is apparent of an increasing percentage of 2-yr olds with each new school (Table 12). As reported previously (Reilly and Moore 1987), midwater trawl samples slightly overestimate percentage of 2-yr olds, compared to unbiased roundhaul samples. This occurred for all schools this season with the exception of number 7; one small roundhaul sample was obtained and, based on a comparison with trawl and gill net samples, we believe that it underestimates the percentage of 2-yr olds. No other gill net samples have contained a higher percentage of 2-yr olds than roundhaul samples from the same school.

Total Age Composition for Spawning Season

The 1982 through 1986 year classes contributed 98-99% by number and 97-98% by weight to the total 1987-88 spawning biomass in San Francisco Bay (Table 13). Good recruitment has occurred during the past five seasons. The weak 1981 year class has become insignificant along with 8- and 9-yr olds.

Catches of YOY Herring and Recruitment

During spring and summer, 1983 to 1986, CDFG's Bay-Delta Project, Stockton, collected YOY herring incidentally in San Francisco Bay from approximately 270-400 midwater tows annually (Table 14). Their catch-per-tow increased significantly from 1983 to 1985 and in 1986 was similar to the previous year. We calculated recruitment of 2-yr olds based on our hydroacoustic biomass estimates and age composition by school for the 1984-85 through 1987-88 spawning seasons. A trend is

TABLE 13. Percent Age Composition for 1983-84 through 1987-88 Spawning Seasons in San Francisco Bay.

Season	Age (yr) 2	3	4	5	6	7	8&9
percent by number							
based on spawn escapement-plus-catch biomass estimates							
1983-84	56.6	11.9	15.8	12.6	2.9	0.2	0.0
1984-85	38.7	40.0	9.8	4.6	5.4	1.4	0.1
1985-86	32.5	32.1	25.3	5.3	3.2	1.5	0.1
1986-87[1]	29.2	33.6	23.1	11.2	1.6	1.1	0.2
1987-88	30.6	38.3	17.9	8.7	3.3	0.7	0.5
based on hydroacoustic biomass estimates							
1983-84	51.1	11.7	16.5	15.8	4.3	0.5	0.1
1984-85	36.9	40.7	9.9	4.9	5.8	1.6	0.2
1985-86	31.6	31.7	25.9	5.5	3.4	1.7	0.2
1986-87[1]	33.4	33.7	20.6	9.7	1.5	0.9	0.1
1987-88	27.7	37.6	19.3	9.8	4.2	0.8	0.7
percent by weight							
based on spawn escapement-plus-catch							
1983-84	42.1	12.7	20.1	19.6	5.1	0.4	0.0
1984-85	27.6	42.9	12.1	6.5	8.3	2.3	0.3
1985-86	22.1	30.6	32.2	7.3	4.9	2.6	0.3
1986-87[1]	19.0	31.9	27.8	16.6	2.6	1.8	0.3
1987-88	20.6	36.0	22.2	13.2	5.8	1.2	1.0
based on hydroacoustic biomass estimates							
1983-84	36.2	12.0	20.1	23.5	7.1	1.0	0.1
1984-85	26.1	43.4	12.1	6.7	8.8	2.6	0.3
1985-86	21.6	30.0	32.8	7.4	5.2	2.7	0.3
1986-87[1]	22.4	33.0	25.4	14.9	2.5	1.5	0.4
1987-88	18.1	34.4	23.2	14.4	7.1	1.4	1.3

[1] Data from 1986-87 have been revised subsequent to publication of previous administrative report (Reilly and Moore 1987).

TABLE 14. Monthly Average Catch per Tow of Young-of-the-Year Pacific Herring in San Francisco Bay[1], April to June, 1983 to 1986, and Recruitment Estimates 1985 to 1988.

	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
Weighted mean		239.9		820.6		1372.5		1398.3
Recruitment of 2-yr olds (1000s)		113,543		135,352		198,316		208,308

[1] data from Bay-Delta Project

apparent similar to that of YOYs, although the magnitude of the increase is less for adult recruits.

However, if the recruitment of 2-yr olds, based on escapement-plus-catch estimates, is examined (Table 15), the relationship with YOY catches is not as clear. Year class abundance estimates for the 1981 through 1986 year classes (Table 15) indicate that for some year classes the number of 2-yr olds may be less than the number of 3-yr olds the following season; this indicates that recruitment of a year class may not always be complete by the time it has reached 2 yr of age. For three year classes, using hydroacoustic estimates, and for two year classes, using spawn escapement-plus-catch estimates, number of 3-yr olds was greater than number of 2-yr olds from the previous season. In all cases, number of 4-yr olds was less than number of 3-yr olds from the previous season, indicating complete recruitment by age 3 yr.

For both acoustic and escapement biomass estimates, the number of 3-yr olds has increased during the past three seasons (Table 15), in agreement with average catch-per-tow of YOYs for the respective year classes. Data indicate that the 1986 year class, as 3-yr olds, will be as strong as the previous one.

Relationship Between Unripe Herring and Spawning Events

Sufficient midwater trawl samples were collected this season to examine the relationship between the percentage of unripe females and the number of days before the next spawn. While a wide variation was observed (Figure 4), a linear relationship was derived with a correlation coefficient of 0.77:

Days before spawn = -0.7 + 0.149 Percentage unripe females.

TABLE 15. Number of 2-, 3-, and 4-yr Old Herring (x 1000) in San Francisco Bay Spawning Population, 1981 to 1986.

	Age (yr)		
Year class	2	3	4
based on hydroacoustic biomass estimates			
1981	88,921	39,248	30,143
1982	170,899	124,036	110,941
1983	113,543	135,796	122,204
1984	135,352	200,093	144,960
1985	198,316	283,013	-
1986	208,308	-	-
based on spawn escapement-plus-catch biomass estimates			
1981	87,908	69,654	46,613
1982	332,699	190,998	126,535
1983	185,742	160,613	134,528
1984	162,422	194,365	136,604
1985	168,962	292,508	-
1986	233,193	-	-

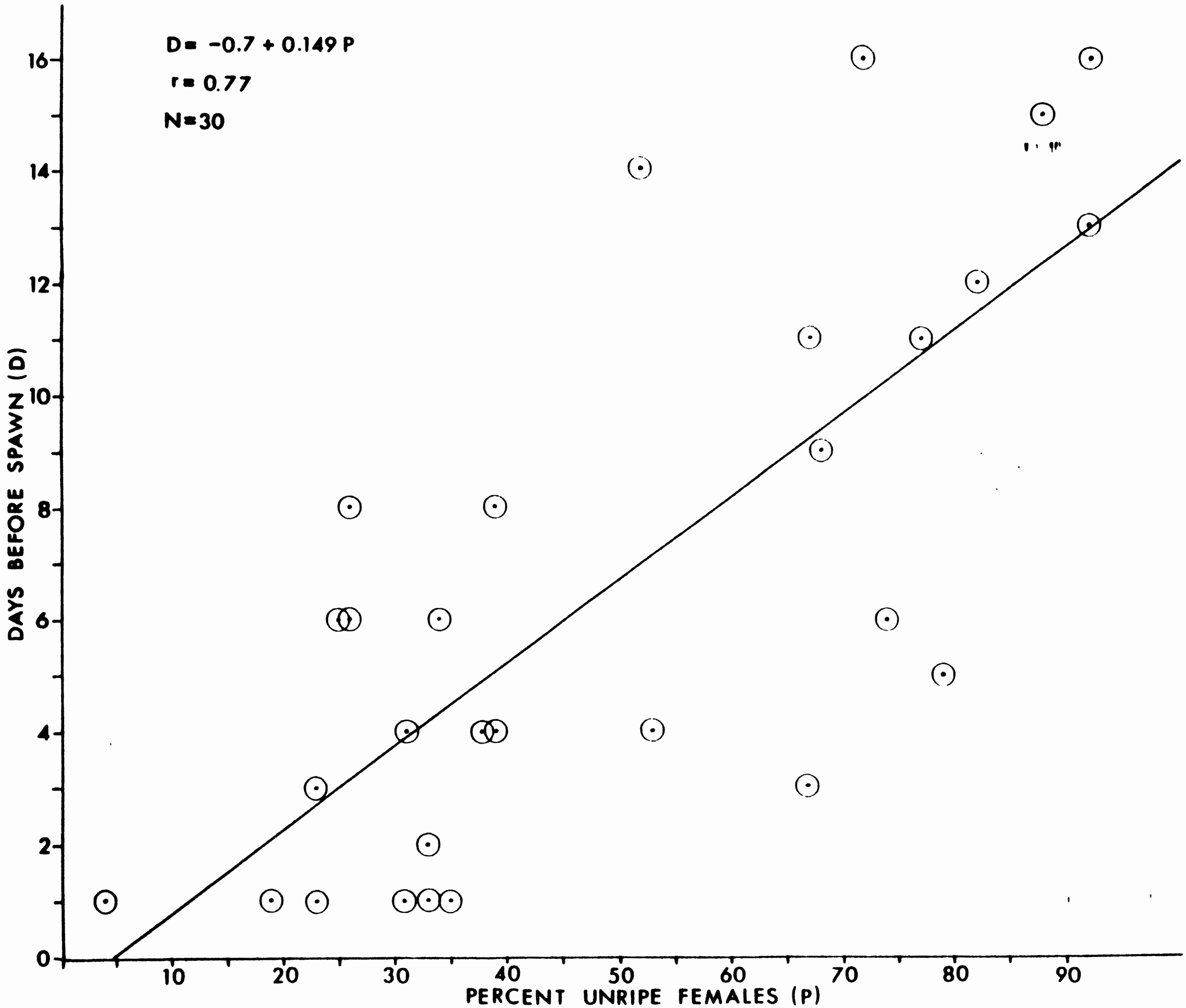

FIGURE 4. Percent unripe females in midwater trawl samples and days before nearest spawn, San Francisco Bay, 1987-88.

This equation predicts that when approximately 50% of female herring are unripe, a spawn is likely within 7 d, while if only 20-25% of females are unripe, a spawn is probable within 3 d.

Tides, Barometric Pressure, Rainfall and Spawning

From October 1987 to March 1988 there were ten tidal cycles in which the highest tide (+5.5 ft or greater) during a 24-hr period occurred at night (sunset to sunrise) (Figure 5). Spawns occurred on five of the 10 cycles within the season. If morning hours are included, then eight of the 10 major spawns are associated with these cycles. Highest tide for the remaining two spawns occurred about midday. However, the high tide at night in both cases was within the tidal range used by spawning herring in a previous year (Reilly and Moore 1987).

Average highest tide height associated with the 10 major spawns was 6.0 ft with a range from +5.3 to +6.7 ft. High tides continue to be a major influence on the timing of spawns in San Francisco Bay.

Periods of falling barometric pressure (Figure 5) appeared to have little correlation with the onset of spawning as was seen in the wet winter of the 1981-82 season.

Total rainfall during the spawning season amounted to 11.4 in with the majority (7.1 in.) falling in the first half of the six-month season. Periods of significant rainfall (> 0.1 in.) began in late October and ended in late February. There appeared to be little correlation between periods of significant rainfall and the onset of spawning (Figure 5). Monthly rainfall totals were highest in December and January and it was during this period that the bulk of the spawning took place in San Francisco Bay. This is the second year in

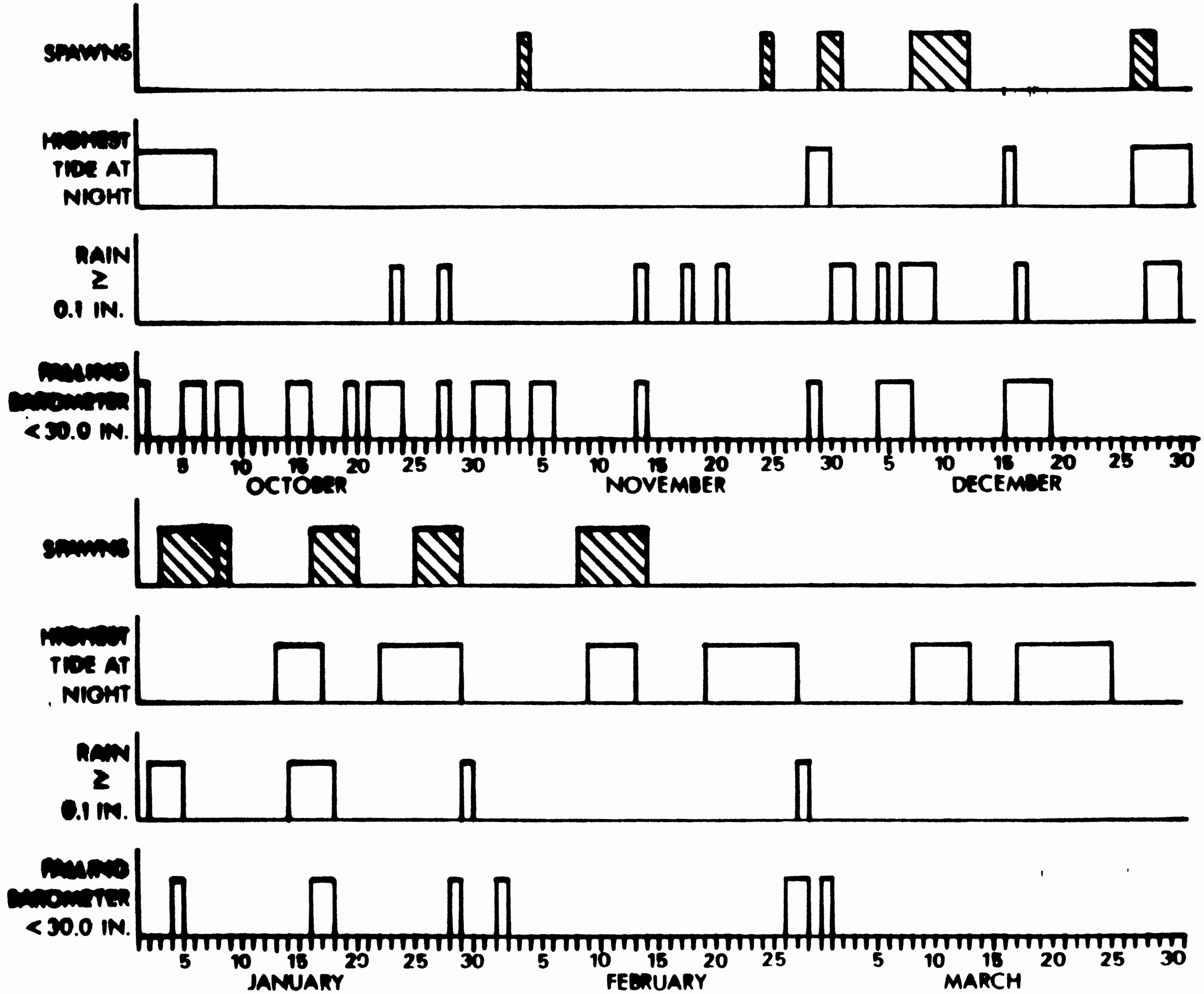

FIGURE 5. Spawning events, tide, rainfall, and barometric pressure data for San Francisco Bay, October 1987 to March 1988.

a row that total rainfall has been less than normal and local rainfall and delta outflows did little to inhibit spawning as was seen in previous years (Reilly and Moore 1983, 1986).

Non-Spawning Season Sampling of YOY Herring

Samples of YOY herring were obtained from semi-monthly midwater trawls in San Francisco Bay from April, May, July, and August 1987. Mean BL increased from 44.6 mm in April to 61.5 mm in August (Table 16). Data from the first 2 months are consistent with an approximately 10 mm per month growth rate reported by Reilly (1988), but July and August mean BLs are much less than expected. Since there are many YOY cohorts from different spawns each season, it is likely that YOYs in August represent the cohort from the last major spawn (late February 1987). Mean BL of YOYs in May 1987 was similar to that of 3 out of 4 yr previously studied by Reilly (1988) and indicates normal growth.

DISCUSSION

Improvement in the accuracy of calibration parameters for our echo integration equipment has resulted in close agreement between acoustic and escapement-plus-catch (EC) biomass estimates for San Francisco Bay herring during the past 2 seasons. Confidence limits cannot be obtained for acoustic estimates because time constraints in the survey design prohibit replicate sampling; each school is integrated during the period of minimal tidal flow (approximately 2 h) and the assumption is made that each transect integrates a unique part of a school.

Significant discrepancies exist for acoustic and EC biomass

TABLE 16. Number of Young-of-the-Year Pacific Herring by Body Length (2-mm Intervals) from Midwater Trawl Samples, San Francisco Bay, April to August 1987.

Body length	April	May	July	August
34-35	1			
36	8			
38	13			
40	19			
42	36		1	1
44	47			
46	38	2		
48	19	14		2
50	12	37		1
52	4	51	3	2
54	1	58	6	4
56	1	23	1	3
58	1	13	4	7
60		4		7
62		2	2	6
64			1	5
66				7
68				3
70				1
72				1
74				1
76			1	1
78				1
N	200	205	19	53
Mean	44.5	53.5	56.5	61.5

estimates for schools 6, 7, and 10. When acoustic estimates exceed EC estimates, it may be due to the fact that all fish detected acoustically on a particular day may not spawn as a unit; part of a school may spawn while the remaining fish may wait and join another school entering the bay. In addition, spawn deposition sometimes is not located for a school that has been detected acoustically and EC estimates are not possible. When EC estimates exceed acoustic estimates, it may be due to part of a school entering the bay and spawning shortly thereafter. These fish will then avoid detection by acoustic surveys which cannot be conducted on a daily basis due to weather and personnel limitations. The important conclusion to draw is that the two biomass survey methods are complementary and, when used together, provide a more accurate estimate of the spawning population than either method alone.

Boat avoidance by herring may result in an underestimation of acoustic biomass. Target strength data collected this season are directly related to the orientation in the water column of fish in the path of the transducer beam during normal survey operations (i.e. responding to boat noise). However, it is not known if herring simply change their orientation in response to noise, such as by sounding, or move horizontally out of the path of the beam, thus avoiding acoustic detection. The latter scenario will of course result in underestimation of biomass. Experiments are planned next season to investigate this problem.

Frequent sampling throughout each October to March spawning season during the 7 yr of this research project has revealed patterns for San Francisco Bay herring. Mean BL and mean age for each school gradually decrease as the season progresses, and 2-yr olds do not become a significant part of the spawning biomass until late December or January. Two-, 3-, and 4-yr-old herring typically comprise 80-90% by number of each school in February and March. Sex ratios favor male herring from October to December, while females generally are more abundant in February and March.

Total age composition for the spawning season is heavily influenced by the relative abundance of 2- and 3-yr-old herring when they first enter the fishery. The 1981 year class has consistently been poorly represented in samples since the 1982-83 season. Fortunately, this is the only weak year class that has entered the fishery in the past 10 yr.

The 1982 year class was above average in strength: mean BL of 2-yr olds was well below average due to the effects of El Niño and poor growth as YOYs in San Francisco Bay (Reilly 1988). However, a dramatic recovery in growth rate resulted in these fish being larger at each subsequent age than any other year class we have seen since the project in 1981. We have not collected any herring greater than 240 mm BL in San Francisco Bay since 1982 but we anticipate that in 2 yr some of the 1982 year class may reach that size.

The 1985 year class appears to be of greater relative abundance than previously thought due to additional recruitment of 3-yr olds this season. Recruitment patterns have been inconsistent in that not all herring may be present on the spawning grounds when they reach 2 yr. Studies of growth patterns of YOY and juvenile herring may offer an explanation. Reilly (1988) reported that the 1985 year class had the smallest mean BL as YOYs in June of four year classes studied (1983 to 1986). As juveniles the following spring (1986), a significant proportion sampled in San Francisco Bay ranged from 90 to

120 mm BL, compared with a normal size range of 120 to 150 mm BL. It is likely that these herring did not mature until their third year. This may also explain the relatively high abundance of 3-yr olds in the 156-168 mm BL range this season.

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APPENDIX A. Summary of Adult Herring Samples from San Francisco Bay, October 1987 to March 1988.

Sample number	Date	Location[1/]	Gear[2/]	Number measured	Number aged	Assigned school number
543	Oct 26	BE	GN	49	48	1
544	Nov 18	SA	MT	85	85	2
545	Nov 23	SA	MT	215	24	2
546	Nov 29	AL	MT	208	95	3
547	Dec 2	SB	MT	188	97	4
548	Dec 3	SA	MT	164	92	5
549	Dec 8	SB	MT	357	107	4
550	Dec 9	SA	GN	141	12	4
551	Dec 9	PP	MT	66	7	4
552	Dec 11	SB	GN	143	7	4
553	Dec 11	AL	MT	380	116	6
554	Dec 14	TB	MT	331	103	6
555	Dec 17	SB	MT	597	12	6
556	Dec 18	AL	MT	509	111	6
557	Dec 28	SB	MT	228	2	7
558	Dec 30	SB	MT	347	9	7
559	Dec 30	AL	MT	378	111	7
560	Dec 31	TB	MT	334	11	7
561	Jan 2	SB	MT	339	14	7
562	Jan 5	OA	GN	178	18	7
563	Jan 5	SA	GN	25	3	8
564	Jan 5	SA	RH	128	8	8
565	Jan 5	SA	RH	142	96	8
566	Jan 5	AI	RH	120	7	7
567	Jan 6	SA	GN	79	8	8
568	Jan 6	SA	MT	335	12	8
569	Jan 8	SB	MT	331	5	9
570	Jan 11	SB	MT	60	26	9
571	Jan 13	SB	MT	383	79	9
572	Jan 13	HP	MT	433	5	9
573	Jan 13	HP	GN	149	5	9
574	Jan 13	SB	RH	165	3	9
575	Jan 13	SB	RH	155	6	9
576	Jan 14	SA	MT	71	47	10
577	Jan 14	SA	GN	25	10	10
578	Jan 15	SB	MT	434	2	10
579	Jan 19	SB	RH	130	0	10
580	Jan 20	SB	RH	135	4	10
581	Jan 20	SB	MT	437	6	10
582	Jan 22	SA	MT	353	44	10
583	Jan 25	SB	MT	156	0	11
584	Jan 25	TI	RH	124	2	11
585	Jan 25	GG	RH	126	0	10
586	Jan 25	GG	RH	129	3	10
587	Jan 25	GG	MT	394	1	10
588	Jan 27	AL	RH	100	0	11
589	Jan 27	AL	RH	66	0	11
590	Jan 27	AL	RH	77	0	11
591	Jan 27	AL	RH	118	0	11
592	Feb 1	SB	RH	120	1	11

APPENDIX A. (continued)

Sample number	Date	Location	Gear	Number measured	Number aged	Assigned school number
593	Feb 1	SB	RH	100	1	11
594	Feb 1	SB	RH	99	2	11
595	Feb 1	SB	MT	420	99	11
596	Feb 2	SA	RH	173	4	11
597	Feb 3	GG	RH	86	2	11
598	Feb 3	GG	RH	198	90	11
599	Feb 3	GG	RH	97	4	11
600	Feb 3	SA	MT	151	4	11
601	Feb 5	YB	GN	76	5	11
602	Feb 5	SB	MT	435	8	11
603	Feb 8	SB	MT	417	18	11
604	Feb 9	HP	RH	148	0	11
605	Feb 10	PP	MT	225	77	11
606	Feb 11	SM	RH	234	1	11
607	Feb 16	SB	MT	40	3	12
608	Feb 16	HP	RH	113	2	12
609	Feb 16	HP	RH	130	0	12
610	Feb 17	SB	MT	450	12	12
611	Feb 19	GG	RH	99	0	12
612	Feb 19	GG	RH	151	2	12
613	Feb 19	GG	RH	125	1	12
614	Feb 22	GG	RH	116	1	12
615	Feb 22	GG	RH	114	0	12
616	Feb 22	GG	RH	98	0	12
617	Feb 22	SB	MT	131	2	12
618	Feb 24	BB	MT	199	58	12
619	Feb 24	GG	RH	115	0	12
620	Feb 26	GG	RH	148	0	12
621	Feb 29	GG	MT	249	4	13
622	Mar 4	GG	MT	313	82	13
623	Mar 7	GG	MT	40	3	13
624	Mar 14	SA	MT	89	1	13

1/ Legend: AI-Angel Island; AL-Alcatraz; BB-Oakland-Bay Bridge; BE-Belvedere; GG-Golden Gate Bridge; HP-Hunters Point; OA-Oakland; PP-Peninsula Point; SA-Sausalito; SB-South San Francisco Bay between Oakland-Bay Bridge and Hunters Point; SM-San Mateo Bridge; TB-Tiburon; TI-Treasure Island; YB-Yerba Buena Island.

2/ Legend: GN-variable-mesh gill net; MT-midwater trawl; RH-purse seine or lampara net.

APPENDIX B. Number of Pacific Herring by Body Length (2-mm Intervals) from Variable-mesh Gill Net Samples, San Francisco Bay, October 26, 1987 to February 5, 1988.

Body length (mm)	Sample Number 543	550	552	562	563	567	573	577	601
144-145							1	1	
146							1		
148							1		
150							1	1	
152		1	1	1				2	1
154				2					3
156			1	1			1	1	3
158		1	4	1			5	2	1
160		1	1				5		2
162		4	1	4		1	4	3	4
164		1	2	6			2	1	7
166		5	5	5	1	3	5	4	2
168		4	2	2		3	5		4
170		5	2	2			4		4
172	2	4	3	5		1	4	1	3
174		3	1	3	1		8		1
176	1	3	3	6	1	1	9	1	
178	2	4	1	7	4	2	5		4
180	1	3	6	3		4	4		3
182	1	8	7	9	4	5	12		3
184	5	10	9	4		5	3		3
186	1	12	15	14	1	7	11	3	2
188	6	11	10	5	1	9	13	1	2
190	3	4	10	11		1	8	1	3
192	2	11	14	15		7	13	1	4
194	3	6	5	9	2	4	3		1
196	1	11	7	8	1	5	5		1
198	1	7	3	8	1	1	4		2
200	3	4	6	4	1	2	2	1	4
202	2	3	5	13	2	4	2	1	
204		2	5	1		3	2		
206	2	2	5	5		3			3
208	1	1	2	5	2		1		
210	5	2	2	6	1				1
212	3	2	2	5	1		2		2
214		2		3		1			
216	2	2	1		1	2	1		1
218	2	2	1	2		1	1		
220				1		1			
222			1			2			2
224						1			
226				1			1		
N	**49**	**141**	**143**	**178**	**25**	**79**	**149**	**25**	**76**
Mean	**196.0**	**187.5**	**188.5**	**189.6**	**191.3**	**191.4**	**181.9**	**170.8**	**180.3**

APPENDIX C. Number of Pacific Herring by Body Length (2-mm Intervals) from Midwater Trawl Samples, San Francisco Bay, November 18, 1987 to March 14, 1988.

Body length (mm)	Sample Number 544	545	546	547	548	549	551	553	554	555	556
144-145											1
146								1	1		
148						1		1			1
150				1			1	1		4	1
152		1	1			2	1	3	2	3	5
154		1	4	1	3			6	3	3	2
156		1	3	1	6	4	2	3	3	7	9
158			1	2	4	8	2	7	6	10	9
160		3	1	3	9	10		13	7	19	5
162	1	5	1	4	3	11	4	10	18	21	15
164	2	3	3	3	5	11	1	7	6	9	16
166	1	5	7	7	6	12	3	14	10	29	24
168	3	8	4		3	10	2	7	11	15	12
170		10	3	1	7	7	2	10	10	14	18
172	3	10	5	10	10	16	2	14	15	24	27
174	1	5	5	2	7	11		10	2	23	14
176	4	11	13	5	8	17	2	11	11	31	27
178	6	6	10	7	4	14	2	17	20	27	17
180	3	14	12	13	6	20	2	13	9	22	22
182	5	25	21	12	15	15	1	29	23	23	30
184	6	15	11	9	8	14	1	18	13	26	22
186	12	23	14	14	6	25	2	19	20	43	33
188	4	8	13	10	8	18	3	14	21	24	19
190	6	13	13	10	8	19	4	22	20	29	18
192	6	11	15	13	6	20	8	27	22	30	34
194	7	5	12	12	7	19	4	17	12	24	20
196	4	10	11	7	5	17	2	9	15	33	26
198	1	7	4	7	9	10	3	16	9	16	8
200	1	3	7	8	3	14		13	10	15	12
202	5	6	4	10		10	4	13	10	18	17
204	1		2	3	3	8	1	3	8	18	17
206	2	2	4	2	1	4	2	15	7	15	14
208		1	1	1		3	1	2	1	9	5
210	1			2		4	1	2	2	3	5
212		1		6	1	1	1	4	1	3	1
214		1			1	1	1	2		2	
216		1				1		6	1	2	1
218			2	1	2		1	1	1	1	1
220									1	1	
222			1	1							1
232										1	
N	85	215	208	188	164	357	66	380	331	597	509
Mean	186.7	183.3	184.8	187.0	180.4	183.4	184.9	184.2	183.3	183.6	183.1

APPENDIX C. (continued)

Body length (mm)	557	558	559	560	561	568	569	570	571	572	576
130-139	1	1					2	1	3	2	1
140-141	1					1	1		1	1	1
142		1			1		3		3	4	
144				1			1		4	3	
146	4	4	1	1	2	2	7	1	4	5	1
148	2	2	1	1	2	3	8	3	6	12	2
150	3	5	1	2	2	3	5		10	10	3
152	8	13	2	4	6	7	14	4	20	16	7
154	5	7	3	3	5	2	12	2	17	10	3
156	18	13	12	1	6	10	16	8	27	24	8
158	11	12	5	4	11	3	12	1	22	25	7
160	7	9	3	6	13	5	16	1	15	29	4
162	25	22	23	15	9	12	23	3	27	28	6
164	7	14	8	11	6	9	13	1	15	15	7
166	20	23	18	20	10	12	23	2	17	30	2
168	8	7	13	6	14	10	13	5	17	17	3
170	8	17	10	8	15	4	11	2	9	18	1
172	15	15	21	11	12	13	17	1	12	20	3
174	2	9	6	12	16	11	6		9	14	1
176	10	19	30	16	17	13	14	2	18	15	1
178	3	8	17	16	16	12	12	2	10	10	1
180	2	10	10	8	12	12	9		6	13	1
182	7	18	21	23	22	25	13	4	14	12	2
184	4	11	15	14	15	14	9	3	9	19	
186	11	13	18	24	14	28	14	2	14	20	2
188	5	13	22	18	15	16	11	1	14	9	
190	7	11	13	15	14	17	6	1	7	10	
192	9	17	26	20	11	13	8	1	14	10	1
194	3	6	13	5	11	8	3		3	4	1
196	3	7	5	11	11	10	10	3	7	7	1
198	2	5	10	13	13	8	4		8	7	1
200	6	7	8	8	7	8	3	1	5	2	
202	5	5	9	10	5	15	3	1	4	3	
204	1	4	9	4	4	8		2	6	2	
206	1	7	11	9	6	8	2		2	1	
208	2	3	3	3	2	1	1	1		1	
210	1	2	2	2	5	2	3		2	3	
212		2	2	6	1	1	1			1	
214		2			1	2			1	1	
216		2	1			2	2				
218		1	3		3	2			1		
220			1	2	3			1			
222			1		1	3					
224			1								
226	1										
228				1							
N	228	347	378	334	339	335	331	60	383	433	71
Mean	172.2	176.4	181.9	182.6	180.5	182.4	171.4	172.1	170.9	170.4	163.3

APPENDIX C. (continued)

Body length (mm)	578	581	582	583	587	595	600	602	603	605	607
	Sample Number										
130-139	3	3	4	3	5	4		7	7	3	1
140-141	4	1			5	1	2	1	3	1	
142	3		2	5	5	3	3	9	6	1	1
144	3	5	3	2	2		2	6	4	1	1
146	8	5	6	1	12	12	4	15	11	8	1
148	10	6	6	8	10	14	4	20	18	3	1
150	14	15	5	8	15	14	5	13	16	2	2
152	17	19	20	9	29	26	4	31	28	15	1
154	13	20	13	9	21	18	8	23	26	12	1
156	35	41	25	14	30	36	15	39	35	23	2
158	20	14	14	16	34	25	7	24	23	6	2
160	18	19	9	12	18	26	12	27	37	15	2
162	30	23	17	15	31	39	7	38	38	22	7
164	23	23	10	10	15	18	7	24	31	12	4
166	19	16	15	6	27	22	12	37	17	15	5
168	21	14	11	8	16	7	9	16	16	13	2
170	9	30	5	2	12	9	6	12	23	10	
172	18	17	16	5	14	15	7	15	10	16	
174	14	9	13	3	9	8	4	7	10	5	
176	15	18	11		10	14	3	5	9	6	1
178	13	9	17	3	10	8	6	5	6	3	1
180	8	13	9		3	7	2	12	4	2	
182	17	12	25	2	12	19	2	5	9	5	1
184	17	11	10	1	7	4	3	4	4	4	
186	16	10	18	1	6	8	3	3	3	7	
188	8	10	13	3	5	14	2	4	2	1	
190	12	17	5	2	6	6	1	1	4		1
192	14	6	17	2	6	12		6	3	4	
194	6	5	6	1	6	5	3	4	2	1	
196	8	10	7		3	6	3	3		4	
198	2	10	4		2	4	1	1	3		
200	3	6	4		2	2	2	4	3	1	
202	4	4	5	1	1	4	1	2			
204	1	3	1	2		2		1	1		1
206	4	2			1	1		3		1	1
208	2	3	1	1	3	2		2	1	1	1
210	1	2	3		1	1		1	1		
212			1			2	1	2			
214	1	1						1	2	1	
216		1	1						1		
218		1				1		1			
220			1	1				1		1	
222						1				1	
224		1									
N	434	437	353	156	394	420	151	435	417	226	40
Mean	169.8	171.0	172.7	162.5	164.9	167.8	166.2	163.8	162.9	166.2	164.8

APPENDIX C. (continued)

Body length (mm)	Sample Number 610	617	618	621	622	623	624
130-139	8	1	7	2	1	2	
140-141	1		2	1	1	1	
142	7	2	5	7	2	1	
144	6	3	2	9	2		1
146	13	3	12	10	12		
148	8	3	5	9	7		2
150	11	5	9	11	14		2
152	34	12	15	20	19	2	5
154	16	10	9	20	14	1	5
156	42	8	26	27	23	2	5
158	31	9	10	22	20	3	4
160	27	9	20	19	26	4	10
162	60	19	17	26	28	3	17
164	28	9	11	16	25		7
166	35	9	15	18	17	1	9
168	25	10	11	9	20	2	7
170	18	5	6	4	12	1	3
172	19	5	6	7	13	3	2
174	6	3	1	1	8	1	3
176	10	2	2	5	11	4	3
178	6	1	3		5	1	1
180	1		1		2		
182	4		1		4		
184	4		1		2	1	
186	3				2		1
188	3		1		2	1	
190	3	1		1		1	
192	6				1	1	
194	3		1		1		
196	1			1			1
198	1				1		
200	2			1	3		
202	2				3		1
204	1					3	
206	1				1		
208	1			1	4		
210			1		2		
212	2				2		
214	1	1		1	1		
216	1	1		1	1		
222	1					1	
224					1		
N	452	131	200	249	313	40	89
Mean	163.5	161.4	159.0	159.1	165.1	169.3	163.8

APPENDIX D. Number of Pacific Herring by Body Length (2-mm Intervals) from Purse Seine and Lampara Net Samples, San Francisco Bay, January 5 to February 26, 1988.

Body length (mm)	Sample Number 564	565	566	574	575	579	580	584	585	586	588
130-139								2			
140-141					1						1
142			1			1		2		2	
144				1		3	1	1			
146				2	1			5	3	1	4
148		1		3	3	2	1	2			3
150	1	1		2	2	5	4	7	4	3	5
152	1	3		1	3	2	4	9	3	6	10
154		2		8	3	7	2	3	4	4	2
156	1	2	1	6	3	6	6	15	8	14	9
158	1	8	1	8		4	5	12	2	5	4
160	3	2	4	10	8	7	5	5	4	5	4
162	3	3	2	11	8	5	9	9	13	13	12
164	2	3	2	9	9	6	5	6	2	2	2
166	3	3	1	6	5	7	4	6	5	6	6
168	5	6	4	4	4	6	2	4	10	3	4
170	3	5	5	12	3	10	8	1	2	2	3
172	6	6	4	5	6	6	11	3	7	6	7
174	3	6	4	4	2	5	4	1	3	2	2
176	6	3	7	9	8	8	9	4	4	1	3
178	5	5	3	4	5	5	5	4	5	1	
180	4	5	6	6	7	2	5	2	6	5	1
182	9	9	8	11	4	4	6	2	12	5	2
184	5	4	5	7	10	5	4		3	4	3
186	5	10	11	8	5	4	9	5	3	5	3
188	4	3	10	8	7	3	2	1	4	3	2
190	8	11	5	7	7	3	1	1	3	6	2
192	14	6	9	4	6	2	5	3	6	6	1
194	5	4	3	1	10	4	1	1	3	3	
196	8	8	3	2	8	2	4	1	2	3	1
198	5	8	3	2	2	2	5		2	5	1
200	5	5	3	1	4				1		2
202	6	4	1			1	1	2		4	
204	2	1	5		3		1	1	2	1	
206	3	1	1		2						
208		1	1			1	2	2			1
210				1	1					1	
212		1	2	1		1	2	2		1	
214			3		2		1			1	
216		1			1						
218	2		2		1						
220						1	1				
222				1	1						
224		1									
N	128	142	120	165	155	130	135	124	126	129	100
Mean	185.1	181.7	185.0	173.0	179.4	171.5	175.5	165.5	173.1	173.6	166.0

APPENDIX D. (continued)

Body length (mm)	Sample Number 589	590	591	592	593	594	596	597	598	599	604
130-139				7	1		1	2			1
140-141				1	3	1	3		2	1	
142	1		3		4	2			1		1
144		3	1		2	1	1	1	2	3	4
146		1	3	5	3	2	6	5	1	5	4
148			2	7	2	3	3	1	3	1	7
150	1		1	3	7	3	5	1	2	3	5
152	7	4	8	7	8	5	8	4	11	10	9
154	2	4	6	11	8	7	9	2	6	5	6
156	5	5	17	8	9	8	22	8	14	12	20
158	5	5	11	4	3	8	9	8	11	10	17
160	3	1	6	6	4	5	7	7	10	3	11
162	10	7	10	18	7	6	13	10	20	2	7
164	4	4	7	2	6	10	10	5	7	7	6
166	8	6	9	8	6	8	17	6	20	6	11
168	1	4	5	5	5	5	4	2	13	3	5
170	1	4	3	2	2	4	5		4	3	5
172	2	4	4	4	2	3	3	2	12	2	6
174	1		1	3	1	2	5	5	3	1	3
176	3	5	1	1	2		9	4	10	2	5
178			3	2	1	3	3		5	2	
180	2	1	2	3	1	2	2	3	1		2
182	1	5	3	3		1	3	2	7	3	1
184	2			1	2	2	2		3	1	
186	2	1	2	3	5	2	6	3	6		
188	2	3	1	2		2	3	1	3	2	2
190		2	1	1		1	1	1	2	4	1
192	3	4	1	2	3		6	1	4	1	2
194		2	2		1	1	1		2		1
196			1		1		1		3	1	1
198			1				1		3		1
200		1				1			1		
202			1			1		1	1	1	1
204							1	1	1		
206			2		1		1			1	1
208		1					1		1	1	1
210									1		1
212				1					1		
214							1		1		
222										1	
N	66	77	118	120	100	99	173	86	198	97	148
Mean	166.2	169.6	164.6	162.0	162.1	164.2	166.2	164.7	169.1	164.6	163.0

APPENDIX D. (continued)

Body length (mm)	Sample Number 606	608	609	611	612	613	614	615	616	619	620
130-139	5	2		1	1	2	2	2		1	3
140-141			1		1	1	3	2	1		1
142		1					2	2		1	1
144		2	1		1		2	3	3	1	2
146	4	4	2	2	6	2	2	10		1	6
148	8	1	2		4	3	2	2	5	5	7
150	4	1	3	2	3	2	7	5	4	1	7
152	10	9	11	3	13	7	4	2	6	8	5
154	8	6	6	1	7	4	7	6	4	5	16
156	24	17	7	9	11	8	7	7	7	12	12
158	18	6	14	8	10	11	3	8	6	8	10
160	10	7	4	8	11	5	6	15	7	9	12
162	30	11	21	14	13	16	15	13	7	10	20
164	17	9	4	10	5	5	11	3	4	7	10
166	23	8	15	7	11	10	8	3	10	10	12
168	23	4	7	6	8	8	12	12	7	7	4
170	7	3	8	4	8	10	6	3	4	6	8
172	17	6	11	9	11	7	4	8	11	6	4
174	7	4	3	1	5	8	5	2	4	6	5
176	5	5	5	5	2	4	1	1	1		1
178	1	1	2	1	3		1	1	2	2	
180	1	1		2	4	2	2	1	2		1
182	2			2	1	4		1	1	3	1
184			1	2	1	2	1		1	2	
186	2				1		1	1		3	
188	2	2				1		1		1	
190	1	1	2	1		1	1				
192	1										
194	4				3						
196	1			1	1						
198					1	1					
200	1										
204		1			1						
206		1			1				1		
208					2						
210					1						
214						1					
216							1				
N	236	113	130	99	151	125	116	114	98	115	148
Mean	163.8	162.5	163.3	165.3	165.0	165.1	162.1	160.2	163.2	163.4	159.6

APPENDIX E. Estimated Weight (g) at Length for Ripe Pacific Herring from San Francisco Bay, 1987-88.

Body length (mm)	Male	Female	Both
130	29.6	28.9	29.0
132	31.1	30.5	30.6
134	32.7	32.1	32.2
136	34.3	33.8	33.8
138	36.0	35.5	35.6
140	37.8	37.3	37.3
142	39.6	39.2	39.2
144	41.5	41.1	41.1
146	43.4	43.1	43.0
148	45.4	45.1	45.1
150	47.5	47.2	47.2
152	49.6	49.4	49.4
154	51.8	51.7	51.6
156	54.1	54.0	53.9
158	56.4	56.4	56.3
160	58.8	58.9	58.7
162	61.3	61.5	61.3
164	63.8	64.1	63.9
166	66.4	66.9	66.5
168	69.1	69.7	69.3
170	71.9	72.5	72.1
172	74.7	75.5	75.1
174	77.7	78.6	78.1
176	80.7	81.7	81.1
178	83.7	84.9	84.3
180	86.9	88.2	87.6
182	90.1	91.6	90.9
184	93.5	95.1	94.3
186	96.9	98.7	97.9
188	100.4	102.4	101.5
190	104.0	106.2	105.2
192	107.6	110.1	109.0
194	111.4	114.0	112.9
196	115.2	118.1	116.9
198	119.2	122.3	121.0
200	123.2	126.6	125.2
202	127.4	131.0	129.5
204	131.6	135.5	133.9
206	135.9	140.1	138.4
208	140.3	144.8	143.0
210	144.9	149.6	147.7
212	149.5	154.6	152.5
214	154.2	159.6	157.5
216	159.0	164.8	162.5
218	164.0	170.1	167.7
220	169.0	175.5	172.9
222	174.2	181.0	178.3
224	179.4	186.6	183.8
226	184.8	192.4	189.5
228	190.3	198.3	195.2
230	195.8	204.3	201.1
232	201.5	210.5	207.1
234	207.4	216.8	213.2
236	213.3	223.2	219.4
238	219.3	229.7	225.8

APPENDIX F. Number of Pacific Herring at Age by Body Length (2-mm Intervals) for Selected Fish from San Francisco Bay, November 1987 to March 1988.

Body length	Age (yr) 4	5	6	7	8	9
210-211	6	14	17	3		
212	3	9	26	3	6	
214	2	10	18	1	1	
216		6	15	1	1	1
218		3	19	2	2	
220		3	6	2	3	
222		2	7	2		
224			10	1		
226			2			
228			2			
N	11	47	122	15	13	1