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PACIFIC HERRING, *CLUPEA HARENGUS PALLASI*, STUDIES IN SAN FRANCISCO BAY, MONTEREY BAY, AND THE GULF OF THE FARALLONES, JULY 1982 TO MARCH 1983

by

Paul N. Reilly
and
Thomas O. Moore

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ABSTRACT

Herring stocks were hydroacoustically surveyed and sampled in San Francisco Bay from November 1982 to March 1983. Twelve discrete herring schools were identified, all of which spawned between November 7 and February 23. One additional school was found in the Bay in March but showed no evidence of spawning. Total biomass estimate from hydroacoustic surveys was 67 040 tons. Based on MRR biomass estimates from spawned egg counts, an additional 10 000 tons may have spawned in November and December without being detected hydroacoustically. The largest schools occurred in January and February. Hydroacoustic estimates of biomass for individual schools during the season ranged from 270 to 22 300 tons.

Sixty-seven samples, containing a total of 12 232 herring, were collected with variable mesh gill net and midwater trawl or obtained from the commercial roundhaul and gill net fisheries. In general, a trend was observed of decreasing mean size and age as the season progressed.

Schools spawning in November and December consisted primarily of 4-, 5-, 6-, and 7-yr-old fish. Schools sampled from January to March were predominantly 2-, 3-, 4-, and 5-yr-old herring. The 1978, 1979, and 1980 yr classes (ages 5, 4, and 3 yr) were strong, comprising up to 90% of the samples. The 1981 yr class (2-yr olds) was relatively weak.

Abundant rainfall and resultant low salinity in San Francisco Bay surface waters apparently delayed or prevented herring from spawning in February and March.

A relationship may exist between relative abundance of young-of-the-year fish, as noted from midwater trawl samples collected by the Department's Bay-Delta Study, and the resultant year class strength of newly recruited 2-yr-old herring in San Francisco Bay's spawning stocks.

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2/ Marine Resources Branch, 411 Burgess Drive, Menlo Park, California, 94025.

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Susan Hatfield and her colleagues at the Department's Bay-Delta Project collected samples of juvenile herring in San Francisco Bay and allowed us access to their data base. Additional field support was provided by Bob Wright, Keith Long, and the vessel MINNOW from Region 3.

Finally, the commercial herring fleet is to be thanked for their continued cooperation. Frank and Mike Gross were particularly helpful in deciphering echograms and supplying us with herring samples.

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INTRODUCTION

The Pacific Herring Research Project has two major annual objectives: 1) estimate size (area) and biomass of each school of adult herring in San Francisco Bay using hydroacoustic methods; 2) determine size and age composition of each school. Additional research during the 1982-83 herring season included obtaining temperature and salinity profiles at a known spawning area, analyzing catch data of juvenile herring from the Department's Bay-Delta Project, attempting to locate schools of adult herring in the Gulf of the Farallones, and sampling the summer herring fishery in Monterey Bay.

METHODS

Pre-season Field Sampling

The summer herring fishery in Monterey Bay (Figure 1) was sampled by Marine Resources Region (MRR) personnel on four occasions from July 14 to September 28, 1982. Samples were frozen and delivered to the Menlo Park laboratory where they were thawed, measured, sexed, and aged using otoliths.

From October 24 to 26, 1982, acoustic transects were conducted on R/V KELP BASS in central San Francisco Bay and in the Gulf of the Farallones north to Pt. Reyes, south to Half Moon Bay (Figure 1), and out to 35 fm, in an attempt to locate adult herring schools. Four tows with a 43-ft mouth diameter otter trawl were completed in areas where positive acoustic activity was observed. Two otter trawls were made in areas of no acoustic activity. A 1-h night set with a 50-ft long, variable mesh gill net was made in Drakes Bay (Figure 1) in an area of acoustic activity.

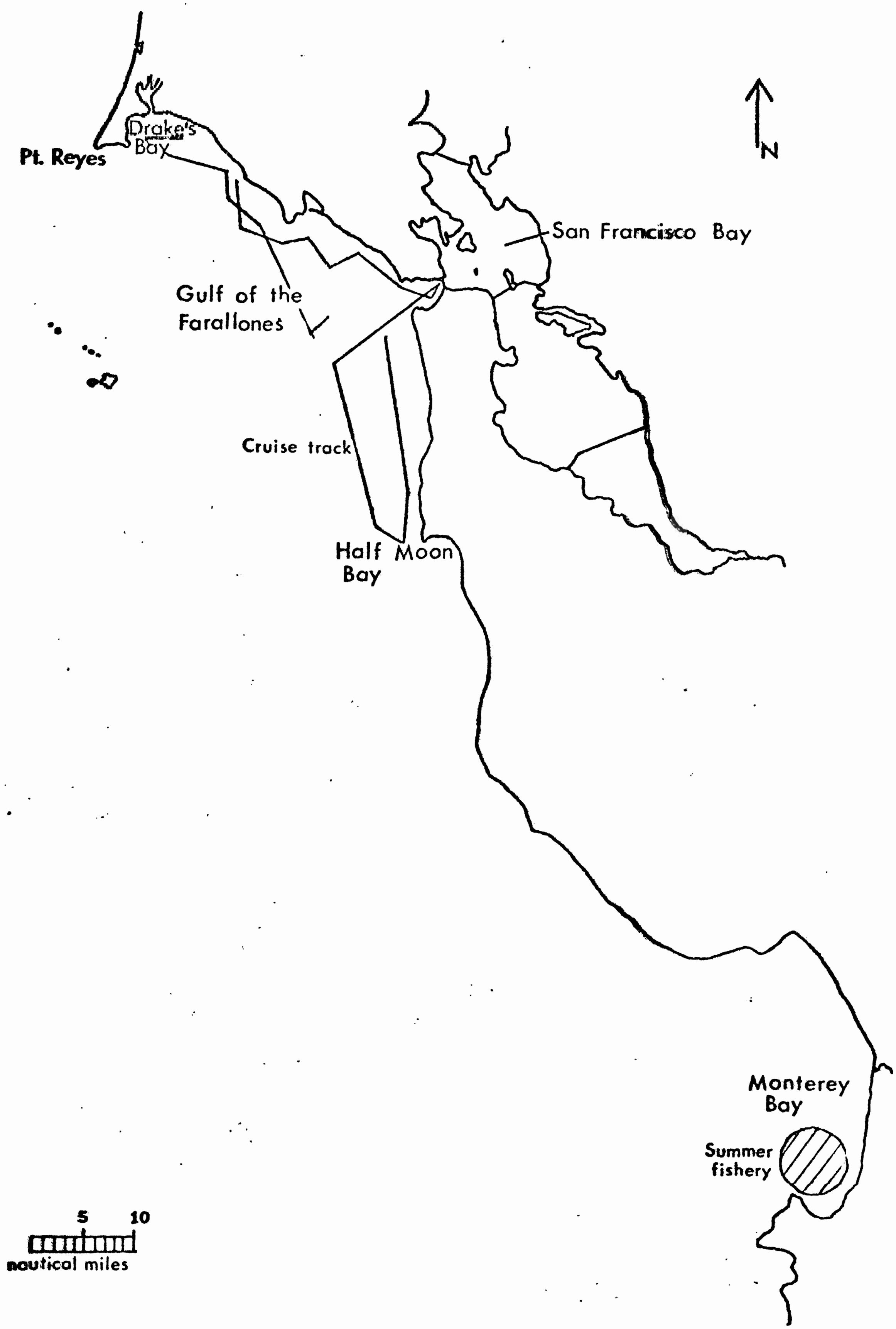

Figure 1. Location of summer herring fishery, Monterey Bay, and pre-season research cruise, Gulf of the Farallones.

Spawning Season Field Work

Research Vessels

A variety of vessels was used to locate and sample herring schools in San Francisco Bay. The project vessel PANDALUS was in service from November 9 to 17, 1982, November 27 to December 13, 1982, and January 31, to April 4, 1983, the last field day of the season. Between the first field day on November 5 and January 31, MRR's KAZUNOKO I and Region 3's MINNOW were borrowed on numerous occasions.

Acoustic Monitoring

Hydroacoustic surveys were conducted approximately 3 days each week using a Raytheon model DE-719B recording fathometer depth sounder. Areas surveyed included central and south San Francisco Bay bounded by the Richmond-San Rafael Bridge, Oyster Point, and the Golden Gate Bridge, and the area between the Golden Gate Bridge and Pt. Diablo (Figure 2). Acoustic monitoring was done at speeds ranging from 6 to 8 kn, calibrated by timing runs between buoys and/or reference points on land at constant engine RPMs.

Herring schools were plotted on charts of San Francisco Bay using a combination of calculated horizontal school dimensions and bottom depths from acoustic tracings, course bearings from a compass, and known landmarks. A planimeter was then 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 tracings. Density estimates (tons/10^6 ft^2) were then assigned to each school or portion of school based on the following methodology.

A commercial purse seine vessel, PACIFIC 2, was chartered in San Francisco Bay on February 17, 21, and 23, 1983, to calibrate densities of acoustic tracings on the Raytheon fathometer. The fathometer transducer was mounted on the side

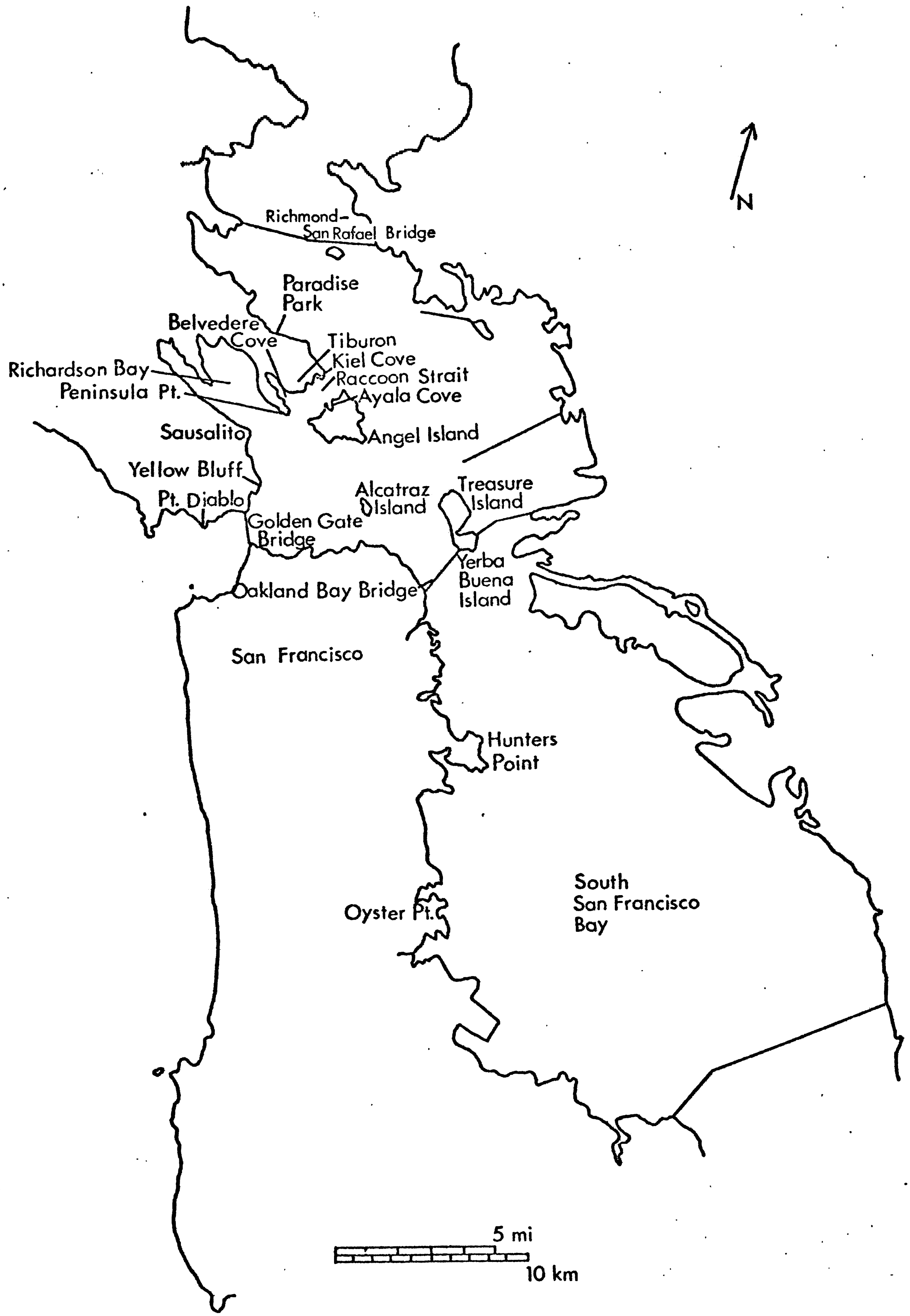

Figure 2. Pacific herring spawning, acoustic survey, and sampling areas in San Francisco Bay, 1982-1983.

of the vessel and used concurrently with the vessel's Konel-Furuno fathometer. When a herring school was located, it was first surveyed at approximately 6.5 kn, comparable to our normal monitoring speed. All or part of the purse seine was then set around a portion of the school, and the catch was brought on board and weighed. Five sets were made in this manner, but only three appeared to catch "what was there", based on the vessel captain's evaluation from past experience. Surface area of the enclosed catch was calculated from the amount of purse seine placed in the water, and catch was converted to density values of tons/10^6 ft^2. This density estimate is biased by unknown changes in school density as the fish react to the presence of the net.

After the charter we acquired the vessel's acoustic tracings from the entire commercial roundhaul season. Tonnage estimates were provided by the captain for 42 discrete density tracings, each of an area that would be encircled by the 240-fm long purse seine.

School biomass was then calculated for each major school surveyed, based on school size estimates, visual comparisons of density tracings from the Raytheon and Konel-Furuno fathometers, and density calibrations obtained during the charter cruise. This is not a precise, systematic, or easily reproduced method of biomass estimation, but it should function as a first approximation which can be refined in subsequent years.

Sampling Gear types

Gill Nets. Throughout the season a 50-ft long by 6-ft high nylon, multifilament, variable mesh gill net was used to sample herring in depths from 6 to 60 ft. The mesh array consisted of five 10-ft long 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 5 min to 17 h. Nets usually were set and retrieved from a boat, but frequently, all during spawning events, they were deployed from shore. Locations included Clipper Yacht Harbor in Sausalito, Paradise Park

Pier in Tiburon, Coast Guard dock at Yerba Buena Island, Hunter's Point Shipyard, and Oyster Point Marina (Figure 2).

Midwater Trawl. A 12-ft square (mouth-opening) double warp midwater trawl with an 0.5-in. stretched mesh cod end was used to obtain five samples (n≥10) of herring from February 1 to March 30, 1983. Tow duration ranged from 10 to 47 min and tow speed was 1 to 2 kn.

Ring Net. On January 27, 1983, one sample was obtained with a ring net. This net consists of two concentric metal hoops with small mesh netting attached to them, forming a basket when the net is lowered or raised by a hand-held line.

Commercial Fishery. From January 5 to March 30, 1983, samples were obtained from purse seine and lampara boats in the process of catching herring. Fish were collected with a brail as they were brought to the side of the boat. On several occasions, samples were taken from the top, middle, and bottom portions of a purse seine catch.

From November 29 to January 27, additional samples were obtained infrequently from gill net boats.

Field Processing of Samples

Body length (BL), the Department's standard measurement for herring (Spratt 1981), was determined to the nearest millimeter from the tip of the snout to the end of the pigment underneath the last column of scales on the caudal peduncle. Fish were sexed and assigned a maturity code. Females were classified as either unripe, mature, or spent; males were classified as either mature or spent. Samples were separated by 10-mm size classes and a maximum 17 fish per size class was retained from each sample for aging. In addition, all gill net samples were separated by mesh size.

Temperature and Salinity Profiles

Temperature and salinity profiles were determined approximately three times each week from November 5 until April 4 near the Peninsula Point buoy in San

Francisco Bay (Figure 2). Readings were taken with a Martek Mark VI Water Quality Analyzer at 5-mm intervals from the surface to 25 m, providing a time-series at a known spawning area. Profiles also were obtained infrequently at other Bay locations.

Laboratory Processing of Samples

Length

All herring samples were returned to the Menlo Park laboratory, frozen, and thawed before processing. A correction factor was developed for converting thawed length to fresh length by remeasuring 1090 fish that were measured originally when fresh. Average fresh length for females was 1.0223 times greater than frozen/thawed length; for males, the factor was 1.0205. Fresh or corrected lengths were used in all data analyses.

Otoliths

Otoliths were removed from herring, cleaned in fresh water and then ethanol, and stored dry in gelatin capsules. Otoliths were read in ethanol under a dissecting microscope by two readers independently. When disagreement concerning the age of a fish occurred, the first reader would read the otoliths again. If otoliths were of poor quality, or agreement could not be reached, the age determination was not used.

Assigned Age by Length

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 a discrete school that spawned in San Francisco Bay or, in one case, a school that was present in the Bay, but showed no evidence of spawning behavior. A combination of factors was used to assign each sample of herring a school number: 1) temporal data from MRR's egg deposition surveys; 2) field observations of spawning events and schooling patterns; 3) examination of daily landings of the commercial fishery (gill net landings usually show peaks during spawns); and 4) miscellaneous information from conversations with fishermen.

Computer Processing of Samples

Length and sex data from all herring samples were entered in a Radio Shack TRS-80 microcomputer, Model I, using a program developed by personnel of our Biometrics Unit. Mean, standard deviation, and standard error of BL, by sex, were generated for each sample, certain combined samples, and for each gear type (each mesh size was considered a gear type for gill net samples). Additional files were created for age-length data. Statistical comparisons of samples were done on the Department's PDP-11 computer using the BMDP programs.

Supplementary Data

Local precipitation and barometric pressure data were obtained from the National Weather Service office at San Francisco International Airport for use in determining if a relationship exists with spawning events.

Juvenile herring catch data from the Department's Bay/Delta Study were obtained for 1980, 1981, and 1982 to examine young-of-the-year (YOY) class strength in relation to the occurrence of 2-yr olds in San Francisco Bay spawning runs.

RESULTS AND DISCUSSION

Monterey Bay Summer Herring Fishery

Three of four samples from the Monterey Bay summer fishery consisted of adult fish ranging from 150- to 216-mm BL and from 2+ to 6+ yr (Tables 1 and 2).

TABLE 1. Number of Pacific Herring by Body Length (2-mm Intervals) from Monterey Bay Summer Commercial Roundhaul Fishery, July to September 1982.

Size interval (mm)	Month July	August	September	Size interval (mm)	Month July	August	September
150-151	1			190-191	1		
152				192	1	2	
154				194	1	2	
156	2		2	196		2	
158		1	3	198		1	
160	2	1		200			
162	1			202		1	
164		1	3	204		1	
166	1		2	206		1	
168		1	2	208		1	
170	2		4	210			
172	3	1	3	212			
174	5	1	7	214			
176	6	1	4	216		1	
178		5	5				
180	4	3	1				
182	2	4	4	N	36	48	44
184	4	6	2	Mean	174.7	185.2	172.8
186		5	1	Std. dev.	9.9	11.3	8.1
188		6	1				

TABLE 2. Age Composition of Pacific Herring Samples, Based on Otoliths, from Monterey Bay Summer Commercial Roundhaul Fishery, July to September 1982.

Age (years)	Number July	August	September	Age (years)	Percent July	August	September
2+	12	9	23	2+	33	19	52
3+	19	21	20	3+	53	44	46
4+	5	14	1	4+	14	29	2
5+		1		5+		2	
6+		3		6+		6	

Herring are assigned a birth date of January 1; thus a 2+ fish in the summer will be 3 yr old the following winter. The July and September samples are fairly similar in size and age composition, while the August sample consists of older, larger fish. It is possible that these stocks may spawn in San Francisco Bay in the winter; variable age composition between schools (samples) in Monterey Bay is consistent with that observed in San Francisco Bay, where earlier spawning schools have a greater mean age than those spawning later.

A fourth sample (n = 28) of herring from Monterey Bay on September 28 consisted of YOY fish (age 0+) in the size range 105-120 mm (x = 111.5 mm). Spratt (1981) found that herring sampled during the winters of 1973-74 and 1974-75 in Monterey Bay averaged 113 mm BL (range 94-136 mm). There does not appear to be any mixing of 0+ or 1-yr-old fish with those 2 yr and older.

Gulf of the Farallones Research Cruise

Three days of acoustic monitoring in the Gulf of the Farallones (Figure 1) and central San Francisco Bay yielded large schools of fish only in the area between Pt. Diablo and the Golden Gate Bridge (Figure 2). An otter trawl sample indicated the composition of the schools to be small anchovies. Other acoustic activity in the Gulf turned out to be small schools of large anchovies, juvenile white croaker and large jellyfish, all verified by otter trawl sampling. A gill net set in Drakes Bay (Figure 1) produced only one anchovy. No adult herring were taken during the cruise.

Acoustic Monitoring

General Observations

Sixty-six days were spent conducting acoustic surveys in San Francisco Bay from November 5, 1982 to April 4, 1983. Schools of herring generally were detected in water deeper than 60 ft in central San Francisco Bay within the boundaries of the three major bridges (Figure 2). The most frequently observed schooling activity occurred in Raccoon Strait and along the shelf of

Richardson Bay. For the second consecutive season, large schools were monitored in southern San Francisco Bay between Hunters Pt. and the Oakland-Bay Bridge (Figure 2).

Large schools of anchovies were present in the Bay during early and mid-November. Their acoustic tracings are characterized by a density greater than that of herring and an irregular, spiked vertical distribution. School composition was verified by sampling a commercial lampara bait hauler and with our midwater trawl. Young-of-the-year herring were mixed with the anchovies and comprised 5 to 7% by number of the samples.

Small schools of adult herring were first detected on November 15. Four days of acoustic monitoring before that failed to locate herring, although a spawn in Kiel Cove (Figure 2) was discovered by MRR on November 8. From mid-November, schooling or spawning activity was evident on most field days until the end of March. The largest schools (5×10^7 ft^2) were present in January and February (Table 3). In general, school depth ranged from 40 to 80 ft until just prior to spawning, when schools would break up as fish moved into shallow water. The vertical extent of a school was 20 ft or less. Most schools had one horizontal axis much longer than the other; the longer axis was oriented with the direction of tidal flow. The longest school (February 2) extended 6.8 miles (10.9 km) along the San Francisco waterfront.

Calibration of Acoustic Echograms

The charter cruise on the PACIFIC 2 in San Francisco Bay produced three estimates of herring school density for our acoustic echograms. On the first good set, the entire purse seine (1440 ft long) enclosed herring of a light density on the echogram, and the catch of 1190 lb was equivalent to a density if 3.5 tons/10^6 ft^2. On the second good set, 3/4 of the net was used to enclose a school of moderately high density, and the catch of 13 745 lb was equivalent to 74 tons/10^6 ft^2. However, after the catch was brought on board, the captain remarked that 2-3 times more fish would have been caught if the net had been set in the other direction. On the last good set, 3/4 of the net enclosed a school of moderate to light density, and the catch of 1752 lb was equivalent to 9.4 tons/10^6 ft^2.

Of greater use in the initial estimation of densities of acoustic echograms were the captain's tonnage estimates for schools detected throughout the commercial season and recorded on his fathometer. The captain has participated in the San Francisco commercial herring fishery for seven seasons and is an experienced fisherman. It is unknown to what extent his estimates are biased. Lowest densities of the 42 estimates were equivalent to a biomass of 4.5 to 6 tons/10^6 ft^2, comparable to our light densities. Frequently occurring densities in his acoustic traces were in the range of 50 to 250 tons/10^6 ft^2 It appears that schooling densities greater than 300 tons/10^6 ft^2 are uncommon in San Francisco Bay. During the 3 days of the charter, in which our fathometer and the fishing vessel's fathometer were run simultaneously, a wide range of school densities was recorded on the two fathometers. It is mainly from these comparisons and the captain's 42 estimates that subsequent biomass estimates were made for schools detected in San Francisco Bay.

<u>Herring Schools by Number</u>

We determined that 13 discrete herring schools were present in San Francisco Bay during the 1982-83 season (Table 3). Spawning behavior was typical for the first seven schools, and spawn was discovered by MRR in the intertidal or shallow subtidal zone after each spawn. However, schools eight and ten were unusual in that spawning patterns were observed (break up of school, movement of fish to shallow water, and large catches of ripe fish by commercial gill nets and our research gill net) yet no spawn was detected during MRR surveys.

TABLE 3. Summary of Herring Schools in San Francisco Bay, November 1982 to March 1983.

Assigned school number	Spawning dates	Spawning location	MRR spawning biomass estimate (tons)	Commercial catch (tons)	Hydroacoustic biomass estimate (tons)	School surface area (ft^2)
1	Nov 7-8	Kiel Cove	1000	0	-	-
2	Nov 22-23	Belvedere Angel Island Tiburon	2150	0	250 5/	5.6×10^6
3	Nov 30	Paradise Park	20	70	270	6.5×10^6
4	Dec 4-7	Richardson Bay Angel Island Belvedere Tiburon	1457	490	160 5/	2.0×10^7
5	Dec 13-16	Treasure Island	1650	1220	3900	2.6×10^7
6	Dec 21-26	Richardson Bay Sausalito	7720	0	960 5/	4.2×10^6
7	Jan 5-12	Treasure Island San Francisco	16 570	1570	11 000	7.1×10^7
8	Jan 20-26 1/	Paradise Park Tiburon (Sausalito) 1/	521	2390	6300	4.1×10^7
9	Jan 27-28	Oyster Point	15	160	-	-
10	Jan 31-Feb 1 2/	Richardson Bay 2/	-	1170	5300	4.0×10^7
11	Feb 1-7	San Francisco	13 040	1220	11 600	1.1×10^8
12	Feb 21-23 3/	Belvedere, Angel Island, Sausalito (South Bay, Treasure Island) 3/	5420	1350	22 300	1.7×10^8
13	(March?) 4/	(Richardson Bay, Sausalito) 4/	-	50	5000	4.1×10^7

1/ Gill netters caught 240 tons of herring January 25-26 along Sausalito shoreline; however, MRR surveys yielded no spawn deposition.

2/ Herring were present in Richardson Bay (515 fish were caught with 50-ft variable mesh gill net in an overnight set); however, subsequent MRR surveys yielded no spawn deposition.

3/ Majority of school detected in South San Francisco Bay on February 14; school moved to Treasure Island and then Angel Island before spawning.

4/ Small- to moderate-sized school was present between Sausalito and Tiburon on many field days from March 3 to 31; no spawning was evident during the month.

5/ Entire school probably was not detected prior to spawning; estimate given is of maximum biomass monitored hydroacoustically, but most likely significantly underestimates total school biomass.

It should be noted that there is no correlation between commercial catch and size of spawning run because of closures and weather.

School 12, the largest of the season, entered San Francisco Bay on February 8, according to commercial fishermen. Between then and February 21, part of the school apparently stayed in the area outside Richardson Bay and was available to the roundhaul fleet; on every fishing day, daily landings ranged from 43 to 112 tons. The majority of the school was detected in south San Francisco Bay on February 14 and covered 1.5 x 10^8 ft^2. Fish remained at depths of 40 to 80 ft, although most were ripe. Gillnetters reported spawn on their anchors after they made sets in the area. However, MRR surveys did not find any evidence of deep subtidal spawning in the south Bay, an area characterized by mud and oyster shell bottom. The gill net fleet followed the herring to Treasure Island and Angel Island before a spawn occurred along Raccoon Strait and the Sausalito shoreline. Gill net landings ranged from 0 to 36 tons per day from February 9 to 21, but on February 22 and 23, during the spawn, a total of 424 tons was landed. Spawning was most likely inhibited for 2 wk by an extensive layer of low-salinity (<10.0 ppt) surface water.

The behavior of school 13 was even more unusual. Herring were present in the Bay on most field days from March 3 to 31, yet no evidence of spawning or spawning behavior was found. Throughout this period a halocline often was present between 5 and 10 m (16 to 33 ft), and herring were never observed in the low salinity water above it.

Acoustic Biomass Estimates

Biomass estimates for herring schools in which we feel the entire school was surveyed ranged from 270 to 22 300 tons (Table 3). We did not acoustically monitor schools 1 and 9, and probably did not monitor the entire school for schools 2, 4, and 6. Schools in November and December appeared to spawn within several days after entering the Bay, and the entire school may not have been present in the typical holding depths, either at any one time or for any length of time. Based on MRR's spawning biomass estimates for these five schools, we feel that our total acoustic biomass estimate of 67 040 tons may have missed an additional 10,000 tons in our surveys.

On only four occasions did we observe schooling densities estimated as greater than 250 tons/10^6 ft^2. Twice in January, the density of part of school 7 was estimated to be 400 tons/10^6 ft^2. In late January, small parts of two separate schools had an estimated density of 500 tons/10^6 ft^2. Densities as low as 3 tons/10^6 ft^2 were observed, but the majority of schooling densities ranged from 10 to 250 tons/10^6 ft^2.

We have no way of calculating confidence intervals of our biomass estimates. Our estimates show some consistency with the sum of MRR spawning biomass estimates and the commercial catch but also differ greatly for some schools. Our method of "visual integration" is not scientifically precise, but will serve as a first approximation until we are able to improve our estimates using better equipment, specifically an acoustic echo integrator. Results from this year show the need to continue both the spawn deposition and acoustic surveys; we feel that, due to the complementary nature of the two, we did not miss any significant herring schools which entered San Francisco Bay this season. Our acoustic estimates revealed large schools which may have spawned in deep subtidal areas, or which did not spawn; these would not have been included in biomass estimates based only on egg deposition surveys. Thus, the best estimate for total spawning biomass in San Francisco Bay for the 1982-83 season lies somewhere between 59 200 tons (MRR's estimate of spawning biomass) and 77 000 tons.

Herring Samples

Sixty-seven samples ($n \geq 10$) were collected in San Francisco Bay from November 18, 1982 to March 30, 1983 (Appendix A); these contained a total of 12 232 fish. Herring were sampled from every school except number 1. Samples from school number 3 were obtained only from the commercial 2.25-in. mesh gill net fishery and are biased due to the exclusion of smaller fish in the catch. Three large samples, numbers 74, 91, and 96, were also biased and relative numbers by age or size class were not used for comparisons between schools. Sample 74 consisted of 800 herring captured with two variable mesh gill nets in 10 min at a boat launch ramp in Sausalito. The positioning of the net was such that the large-mesh end of one net was in water too shallow to fish effectively and the sample contained a disproportionate number of smaller fish. Samples 91 and 96 were obtained with the variable mesh gill net, but in each case the net was inshore of, and in close proximity to, 10-20 commercial 2.125-in. mesh gill nets. Larger fish were caught by the commercial nets, thus biasing our sample. However, data from these samples were used for length-at-age determinations and gill net selectivity curves.

Size Composition

Variable Mesh Gill Net Samples. Our variable mesh gill net was the only type of gear used successfully to obtain samples throughout the season. Thirty-nine samples were obtained (Appendix B), and these were grouped by assigned school number, excluding samples 74, 91, and 96 (Table 4). Mean BL ranged from 202.2 mm (school 2) to 177.6 mm (school 11). Schools spawning in November and December (numbers 2-6) had greater mean lengths than those spawning in January and February. Historically, older and larger San Francisco Bay herring mature and spawn earlier each year than the younger, smaller fish. Schools 8-13 were characterized by a relative scarcity of fish $\geq$ 200 mm BL (7.6%) when compared with schools 2, 4, 5, and 6 (46.4%). School 7 (early January) appeared to be transitional in size composition with 25.7% of the fish $\geq$ 200 mm BL.

TABLE 4. Number of Pacific Herring by Body Length (2-mm Intervals), Combined by Assigned School Number, from 1.5- to 2.5-in. Mesh Array Gill Net Samples, San Francisco Bay, November 1982 to March 1983.

Size	Assigned school number							
interval (mm)	2	4	5	6	7	8	9	10
<150					2		1	
150-151			1		1		1	1
152		1	1	1	3		2	2
154			1	1	4	1	3	3
156		2		1	6	1	3	6
158		1		1	3	2	4	3
160			5	1	10		8	15
162		3	1	1	12	3	10	17
164	1	2	3	2	7	4	7	20
166	2	2	2	3	24	5	9	26
168		1	3	4	16	2	6	23
170		1	3	2	23	1	11	25
172	2	5		1	18	4	15	20
174	1	4	3	6	13	1	15	11
176	1	3	4	5	21	1	11	25
178		10	1	8	17	2	6	21
180	5	13	4	9	27	3	15	23*
182	3	13	6	8	41	8	24*	40
184	9	13	8	16	37	6	20	30
186	6	20	5	20	54	15*	23	31
188	9	15	9	12	59	9	9	27
190	8	14	6	12	61*	5	14	20
192	9	21*	19	26	53	5	17	20
194	12	20	11	26	62		6	14
196	13	28	15	26	56	10	4	11
198	8	9	10	30*	42	2	4	14
200	12	14	18	23	40	3	6	6
202	13*	19	21*	29	39	3	3	8
204	9	10	17	34	28	1	5	6
206	10	7	16	14	44	2		
208	11	4	10	22	18		2	2
210	10	8	14	15	15		3	6
212	4	2	17	7	16	1		4
214	10	4	6	8	11	1		
216	5	2	8	12	2			
218	7	2	3	6	4			1
220	6		7	4	3			1
222	3	2	7	5	3			
224	8	1	5	3	5			
226	2	1	5	2	1			
228	2		2	3				
≥230	5	1	6	4	3			
N	206	278	283	413	904	101	267	482
Mean	202.2	192.5	200.1	197.8	190.2	184.6	180.4	180.5
Std. dev.	14.0	12.5	16.0	13.6	14.2	12.8	12.7	13.0

*Location of median body length

TABLE 4. (continued)

Size interval interval (mm)	Assigned school number 11	12	13
<150			
150-151	6		
152	6		
154	9	1	1
156	14		4
158	10	2	5
160	8	4	1
162	7	2	9
164	14	7	12
166	17	6	13
168	17	7	15
170	12	11	27
172	10	15	28
174	18	8	25
176	15	13	37
178	15*	10	38
180	16	12	35
182	18	17	42*
184	12	14	41
186	16	22*	36
188	12	25	28
190	15	17	27
192	12	24	15
194	11	9	15
196	12	10	12
198	6	5	8
200	4	5	8
202	3	3	11
204	4	3	7
206	3	4	3
208		5	5
210	2		7
212	1	1	1
214			
216	1		
218			
220		1	
222	1		
224	1		
N	328	263	516
Mean	177.6	184.4	182.2
Std. dev.	14.8	11.6	11.2

*Location of median body length

A series of gill net selectivity curves was generated for the 1.5-, 1.75-, 2.0-, and 2.25-in. mesh size by month (Figures 3-6). Selectivity curves for the 2.5-in. mesh were not plotted due to small sample size; mean BL was 218.8 mm in November-December (n = 39) and 211.3 mm in January (n = 29). Although monthly mean lengths varied for a specific mesh size, the catch curves are fairly similar and the means did not overlap those from another mesh (except for the 2.25-in. mesh in November-December and the 2.5-in. mesh in January). There was a consistent trend of decreasing mean BL for each mesh size between the November-December and January samples. With the exception of the 1.5-in. mesh, mean BL either declined slightly or remained constant from January to March for each mesh size, indicating a uniformity in size composition for the later spawning schools. This is consistent with the relatively uniform overall school means (Table 4) for schools 8-13, which occurred in the Bay from mid-January to late March. In general, the catch curve for each mesh size approximates a normal distribution with a range of about 30 mm BL for the majority of the fish.

Commercial Purse Seine and Lampara Samples. Twelve samples were obtained from the commercial roundhaul fishery from January 5 to March 30, 1983 (Appendix C); a total of 4452 herring was measured. Samples 112 and 114 were unusually large due to frequent sampling on the PACIFIC 2 charter cruise. Samples were grouped by assigned school numbers, and five shcools were represented (Table 5). Mean BL for all schools ranged from 178.6 to 184.2 mm. Schools 8, 10, 12, and 13 were similar in size composition and were characterized by a relative scarcity of fish ≥ 200 mm BL (5.9%). School 7 had a greater mean BL with 17.2% of the fish ≥ 200 mm BL. These results are comparable to those from the variable mesh gill net. Samples from the roundhaul fishery are assumed to be unbiased. A comparison with variable mesh gill net samples for the same school numbers indicates the possibility of a bias towards larger fish; mean BL for schools 7, 8,

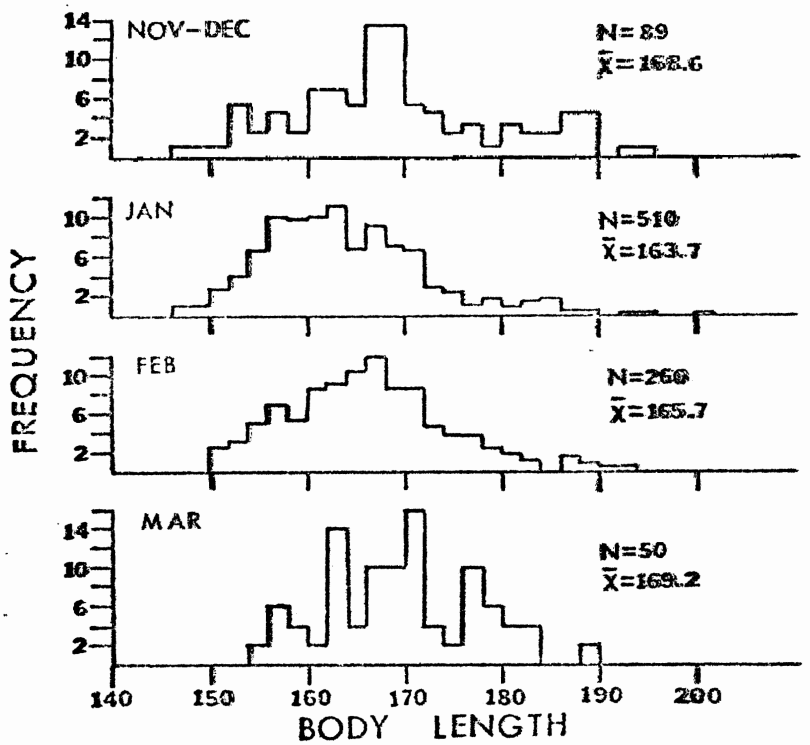

Figure 3. Percent size frequencies (2-mm intervals) from 1.5-in. mesh gill net samples, San Francisco Bay, November 1982 to March 1983.

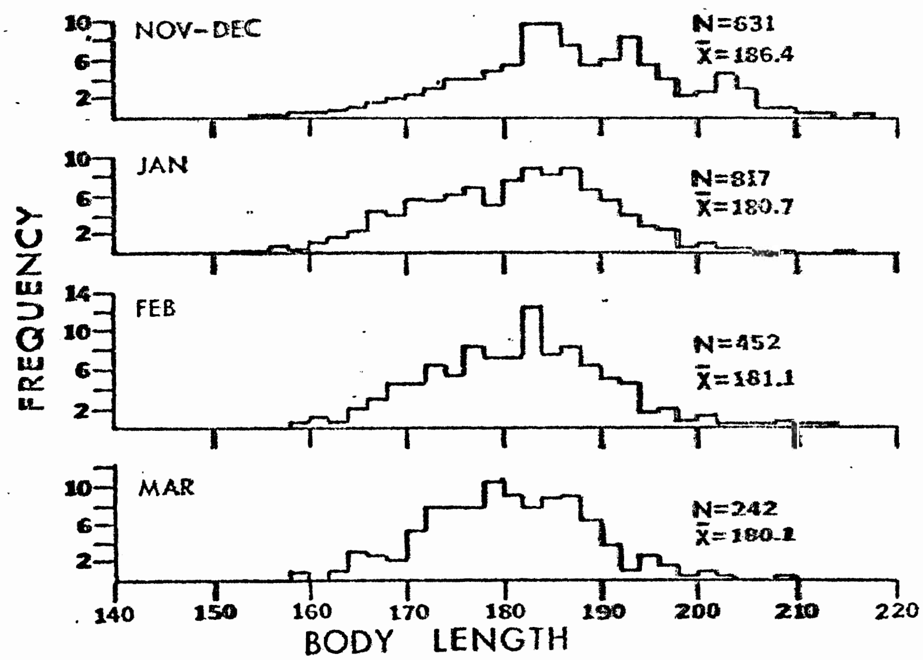

Figure 4. Percent size frequencies (2-mm intervals) from 1.75-in. mesh gill net samples, San Francisco Bay, November 1982 to March 1983.

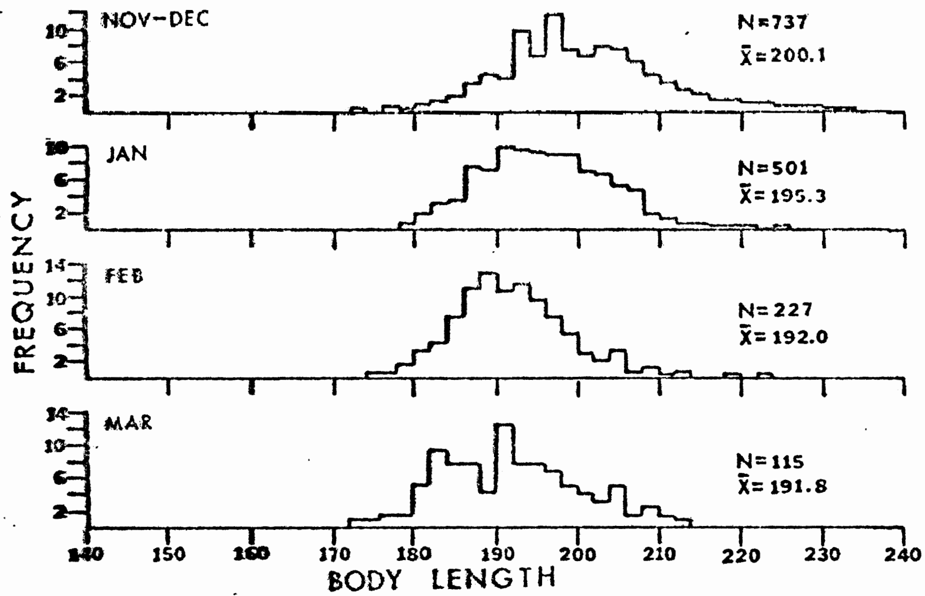

Figure 5. Percent size frequencies (2-mm intervals) from 2.0-in. mesh gill net samples, San Francisco Bay, November 1982 to March 1983.

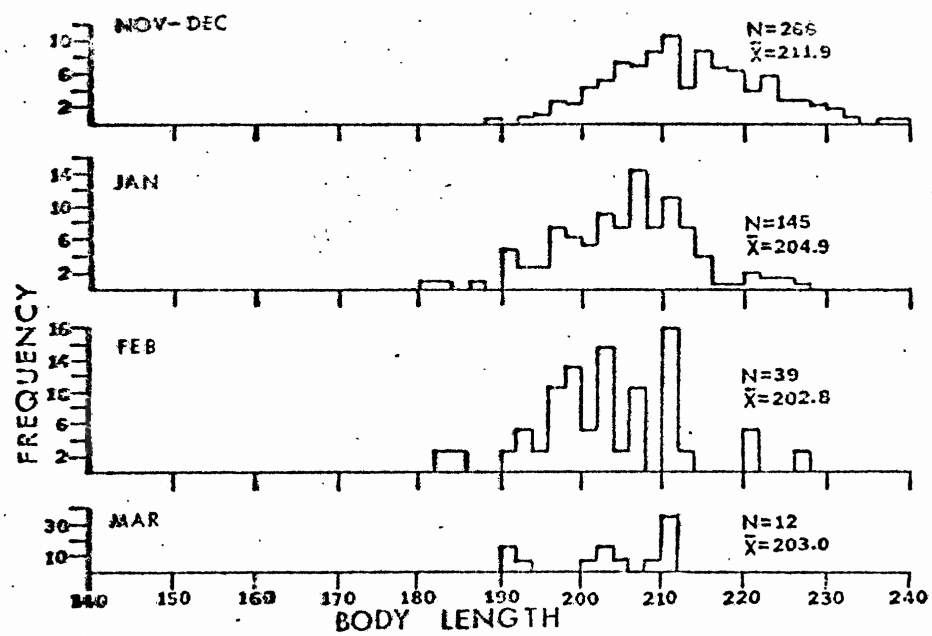

Figure 6. Percent size frequencies (2-mm intervals) from 2.25-in. mesh gill net samples, San Francisco Bay, November 1982 to March 1983.

TABLE 5. Number of Pacific Herring by Body Length (2-mm Intervals), Combined by Assigned School Number, from Commercial Purse Seine and Lampara Net (Roundhaul) and Midwater Trawl Samples, San Francisco Bay, January to March 1983.

Size interval	Roundhaul: Assigned school number 7	8	10	12	13	Midwater trawl: Assigned school number 11	12	13
<150	5	5	4	19	4	11	1	1
150-151	1			5	1	2	1	1
152	5	3	1	8		5	1	1
154	1	8	8	12		8		2
156	4	9	9	28	5	10	3	2
158	2	8	9	21	2	10	1	1
160	3	21	15	34	3	14	1	4
162	16	23	12	77	8	11	1	6
164	7	20	19	65	9	17	2	2
166	14	23	30	103	8	24	1	7
168	9	20	18	97	15	16	1	3
170	14	29	33	102	18	12	1*	4
172	8	24	44	166	25	14		6
174	10	29	23	91	20	14	2	8
176	8	35	30	165	23	13*	2	7*
178	4	23	28	164	33*	17	1	8
180	7	33	32	149*	20	19	1	6
182	12	32*	50*	220	26	16	1	3
184	9	17	34	154	24	19		6
186	16*	46	45	181	22	18	1	8
188	9	20	34	116	7	10		3
190	15	39	48	97	6	17	1	3
192	25	28	31	140	12	13		2
194	14	21	26	56	7	9	1	1
196	13	45	40	64	4	5	1	
198	14	15	18	56	3	5		
200	8	13	14	28	1	3	2	3
202	11	10	21	35		2		2
204	5	8	15	22	2	4		
206	8	10	10	12	2	2		
208	5	2	2	2	2			
210	6	3	2	6				
212	2	2	3	4				
214	2	1	2	1	1			
216		1	2		1			
218	1			2				
220	2			1				
222								
224	1			1				
N	296	626	712	2504	314	340	28	100
Mean	184.2	181.0	182.5	180.1	178.6	175.1	171.1	175.7
Std. dev.	16.3	13.9	13.3	11.9	11.4	14.5	16.2	12.8

*Location of median body length

12, and 13 was 4-6 mm greater than the roundhaul samples. However, mean BL for school 10 was smaller from the gill net sample.

Analysis of variance showed highly significant differences ($P<0.001$) in mean BL due to gear type for all schools sampled by gill net and roundhaul. Subsequently, pairwise comparisons ($\alpha = 0.05$) were performed. When adjusted for multiple comparisons (Bonferroni inequality), all tests showed highly significant differences ($P<0.01$). However, a difference of 2-6 mm in mean BL of a school may be statistically significant, due to large sample sizes, but not biologically significant. Other treatments were applied to age composition data for the same schools and are presented later.

Samples were obtained from the catch of a purse seine vessel on January 25 (school 8) and February 17 and 21 (school 12). Samples were brailed from the top, middle (February 17 only), and bottom of the school as the fish were loaded onto the vessel from the purse seine. Sample size ranged from 88 to 230, and sample means ranged from 177.8 to 182.2 mm BL. Paired t-tests, when alpha levels were adjusted for multiple testing, showed no significant differences ($\alpha = 0.05$). Analysis of variance showed no significant differences in mean BL among all samples combined ($P = 0.23$), but there was a significant difference among the the 3 d ($P = 0.03$). Each of three top samples from February 17 had a greater mean BL than that of the corresponding bottom sample. Again, differences were small (1.2-2.6 mm) and may not be biologically significant. In general, we concluded that, within a school on a particular day, size composition of a sample will not be affected by the sample's location within the purse seine.

Midwater Trawl Samples. Due to the lack of an appropriate vessel, the midwater trawl was used only in February and March. One large and four small samples were obtained (Table 5, and Appendix D). Comparison of sample 103 with gill net sample 102, taken 1 d apart in south San Francisco Bay, showed that the mean for the gill net sample (177.6 mm) was significantly greater than that of the trawl sample (175.1 mm) at the 95% level. However, exclusion of four fish less than 140 mm BL from the trawl sample eliminates that significant difference. This indicates that large samples from the midwater trawl and variable mesh gill net can be compatible (i.e. no significant difference in sample means) from the same school.

Commercial Gill Net Samples. Eight samples from 2.25-in. commercial gill nets obtained from November 29, 1982 to January 13, 1983 show a gradually decreasing mean BL from 211 to 199 mm (Appendix E). Samples 93 and 94 were taken after the fishery changed to 2.125-in. mesh on January 17; both sample means are less than 200 mm. These data are consistent with other samples, showing a shift towards smaller fish as the season progressed.

Ring Net Sample. One sample was collected at Oyster Point Marina concurrently with a variable mesh gill net sample (96). It appears that larger fish are able to avoid the ring net. Only one fish (2.4%) was greater than 195 mm BL, while 6.8% of the gill-netted fish were greater than 195 mm BL.

Sex Ratios

Samples from the 1.5- to 2.5-in. mesh array gill net show a decreasing proportion of male herring with increasing mesh size for all months (Table 6), similar to results from the 1981-1982 season. For all meshes combined, a shift in sex ratio occurred as the season progressed. Males comprised 62.1% of the samples in November-December, 48.5% in January, 56.3% in February, and 34.8% in March. Percentage of males in roundhaul samples decreased from 51.6% in January to 41.6% in February, then rose to 44.1% in March.

Differences in time and length of the maturation period of herring most likely are responsible for the above trends. Apparently, a higher proportion of small males (2-yr olds) than small females achieves first maturity and enters the spawning population. For example, 186 fish less than 160 mm BL were taken from commercial roundhaul samples; 113, or 60.8%, were males. This would

TABLE 6. Sex Ratios of Pacific Herring Samples by Gear Type from San Francisco Bay, November 1982 to March 1983.

Month	Gear type	Males Number	Males Percent	Females Number	Females Percent
Nov-Dec	1.5-in. mesh	70	78.7	19	21.3
	1.75-in. mesh	457	72.4	174	27.6
(School numbers 2,3,4, 5,6)	2.0-in. mesh	442	60.0	295	40.0
	2.25-in. mesh	110	41.4	156	58.6
	2.25-in. mesh (commercial)	297	39.6	453	60.4
	2.5-in. mesh	15	38.5	24	61.5
	all meshes (excluding commercial)	1094	62.1	668	37.9
Jan	1.5-in. mesh	293	57.5	217	42.5
	1.75-in. mesh	435	53.2	382	46.8
(School numbers 7,8,9)	2.0-in. mesh	196	39.1	305	60.9
	2.25-in. mesh	44	30.3	101	69.7
	2.25-in. mesh (commercial)	142	32.9	289	67.1
	2.5-in. mesh	3	10.3	29	89.7
	all meshes (excluding commercial)	971	48.5	1031	51.5
	commercial purse seine	380	52.0	351	48.0
	commercial lampara	96	50.3	95	49.7
	combined roundhaul	476	51.6	446	48.4
Feb	1.5-in. mesh	191	73.5	69	26.5
	1.75-in. mesh	264	58.4	188	41.6
(School numbers 10,11, 12)	2.0-in. mesh	88	38.6	139	61.4
	2.25-in. mesh	8	20.5	31	79.5
	all meshes	551	56.3	427	43.7
	commercial purse seine	1045	41.0	1506	59.0
	commercial lampara	294	44.2	371	55.8
	combined roundhaul	1339	41.6	1877	58.4
	midwater trawl	205	55.7	163	44.3
Mar	1.5-in. mesh	24	48.0	26	53.0
	1.75-in. mesh	93	38.8	147	61.2
	2.0-in. mesh	27	23.5	88	76.5
	2.25-in. mesh	1	8.3	11	91.7
	all meshes	145	34.8	272	65.2
	commercial purse seine	154	44.1	195	55.9
	midwater trawl	39	42.9	52	57.1

explain the selectivity of the 1.5-in. mesh toward males. It appears that, in general, large males mature earlier than females and enter the Bay sooner; large males were a dominant component of the November-December samples and were relatively scarce afterwards. For example, of 295 fish $\geq$ 200 mm BL taken from roundhaul samples (January to March), only 89, or 30.2%, were males.

Age Composition

Pairs of otoliths were removed from 2321 herring; of these, 2260 were aged (Table 7, Appendix F). Ten fish, ranging from 117 to 133 mm BL ($\bar{x}$ = 124.6) were aged as 1 yr old and are not included in the table. All other fish ranged in age from 2 to 10 yr. The single occurrence of a 10-yr-old herring from a commercial gill net sample is the first one recorded from San Francisco Bay. Commercial gill net samples primarily were used to fill out upper size classes in our stratified random sampling procedures for age composition. Four- and 5-yr-old fish from these commercial samples were not used to assign ages to lengths of fish not aged. Due to selectivity of the gear, only the largest 4- and 5-yr olds are caught (Appendix F), and age-at-length data are biased.

A regression was calculated for age at length with values of age transformed into natural logarithms. For 2212 herring from San Francisco Bay samples:

$$\ln \text{age (years)} = -1.7644 + 0.01698\text{BL (mm)}.$$

The standard regression coefficient is 0.925.

Variable Mesh Gill Net Samples. Herring schools sampled by variable mesh gill net in November and December (schools 2, 4, 5, and 6) primarily consisted of 4-, 5-, 6-, and 7-yr-old fish (Table 8); these year classes comprised 83.6% of the samples. As the season progressed, proportion of 2- and 3-yr-old herring increased, and herring aged 6 yr and older became relatively scarce. The percentage of 8- and 9-year-old fish decreased from 4.8% in November-December to

TABLE 7. Number of Pacific Herring at Age by Body Length (2-mm Intervals) from All San Francisco Bay Samples (Excluding Commercial Gill Net), November 1982 to March 1983.

Size interval (mm)	Age (years) 2	3	4	5	6	7	8	9
<140	4							
140-141	4							
142	3							
144	2							
146	12	1						
148	14							
150	9	2						
152	24	4						
154	24	3						
156	48	6						
158	33	11						
160	24	10						
162	27	15						
164	25	25						
166	30	39						
168	18	36	1					
170	12	39	1					
172	4	43	3					
174	4	36	6					
176	2	42	17	1				
178		31	19	2				
180		17	25	4				
182		17	58	8				
184		3	45	13	1			
186		6	65	14				
188		5	59	19				
190		4	34	27	1			
192		1	36	39	2			
194			28	31	5			
196			33	44	7			
198			21	30	6			
200			15	46	7	3		
202			15	60	17	6		
204			8	33	19	5		
206			4	25	19	5		
208			3	20	21	7		
210			2	36	33	19	1	
212			1	14	18	14		
214				6	14	16	2	
216				5	5	11	5	
218					7	11	6	
220				1	3	18	8	2
222				1	1	11	9	1
224					2	10	9	2
226						5	9	2
228						1	6	2
230						4	7	3
232							4	
234							2	
236							1	
N	323	399	499	479	188	146	69	12
Mean	158.3	171.1	188.3	198.7	207.2	215.0	223.8	225.7
Std. dev.	7.6	7.7	7.6	8.3	6.7	7.0	5.5	3.5

TABLE 8. Age Composition of Pacific Herring Samples, Combined by Assigned School Number, Based on Otolith Aging and Subsequent Age Assignments by Length, from 1.5- to 2.5-in. Mesh Array Gill Net in San Francisco Bay, November 1982 to March 1983.

School number	Number at age (years) 2	3	4	5	6	7	8	9	Total	Percent at age (years) 2	3	4	5	6	7	8	9	Number aged	Number assigned
2	1	6	52	60	35	33	17	2	206	1	3	25	29	17	16	8	1	120	86
4	12	29	100	98	24	12	2	1	278	4	11	36	35	9	4	1	T*	97	181
5	7	20	67	89	44	40	13	3	283	2	7	24	31	16	14	5	1	119	164
6	24	47	156	149	63	37	20	3	499	5	9	31	30	13	7	4	1	262	237
7	52	139	301	285	82	36	7	2	904	6	15	33	32	9	4	1	T*	507	397
8	6	27	37	23	6	2			101	6	27	36	23	6	2			24	77
9	37	84	89	45	10	2			267	14	31	33	17	4	1			4	263
10	69	146	165	83	14	4	1		482	15	30	34	17	3	1	T*		10	472
11	75	103	97	43	6	2	2		328	23	31	30	13	2	T*	T*		106	222
12	21	71	102	58	7	4			263	8	27	39	22	3	1			115	148
13	35	174	194	98	13	2			516	7	34	37	19	3	T*			92	424

*T = trace, less than 1%.

TABLE 9. Age Composition of Pacific Herring Samples, Combined by Assigned School Number, Based on Otolith Aging and Subsequent Age Assignments by Length, From Midwater Trawl and Commercial Purse Seine and Lampara Net Vessels in San Francisco Bay, January to March 1983.

School number	Number at age (years) 2	3	4	5	6	7	8	Total	Percent at age (years) 2	3	4	5	6	7	8	Number aged	Number assigned
7	37	72	95	67	15	7	3	296	13	24	32	23	5	2	1	115	181
8	98	165	220	116	26			625	16	26	35	19	4			39	586
10	90	183	251	157	26	4	1	712	12	26	35	22	4	1	T*	113	599
11	81	112	89	45	6	3		336	24	33	27	13	2	1		0	336
12	311	856	896	410	43	10	1	2527	12	34	35	16	2	1	T*	164	2363
13	57	169	124	59	3	2		414	14	41	30	14	1	T*		25	389

*T = trace, less than 1%.

0.15% after mid-January (schools 8-13). The 1978, 1979, and 1980 yr classes (ages 5, 4, and 3 yr) were strong, comprising up to 90% of the samples (school 13). Last year these three year classes contributed 86% by number to samples in February and March. This year the same cohorts comprised 83.7% of samples from late January to March. The 1981 yr class (2-yr olds) was relatively weak. Last year 2-yr-old fish comprised 25 to 35% of samples in February and March; this year they made up 7 to 23% of samples for the same months.

Roundhaul and Midwater Trawl Samples. Three-, 4-, and 5-yr-old fish made up from 73 to 85% of samples by number. With the exception of school 11, 2-yr-old fish were poorly represented. Last year 2-yr-old fish contributed 29% by number in roundhaul samples. During the same time period this year, only 14% were 2-yr-old herring. All roundhaul and midwater trawl samples are from January to March during or after the transition to a younger age composition. Only 0.1% of samples consisted of 8-yr-old fish and 6- and 7-yr olds were relatively scarce.

A comparison of age composition by gear type was performed for schools 7, 8, 10, 11, 12, and 13, all of which were sampled by variable mesh gill net and either commercial roundhaul net or midwater trawl. Chi Square tests at $\alpha=0.05$ showed that age composition was not significantly different between gear types for schools 8, 10, and 11 and was significantly different for schools 7, 12, and 13. Age composition tests are less sensitive than size composition tests. However, a bias still exists in some variable mesh gill net samples in which older year classes are over-represented and younger year classes are under-represented.

Spawning and Physical Factors

Temperature

Temperature between the surface and 25 m at Peninsula Pt., San Francisco Bay, ranged from 9.6 to 15.3°C during the 1982-83 herring spawning season (Figure 7, Appendix G). Temperature declined steadily from early November to early January and gradually increased during the rest of the survey period.

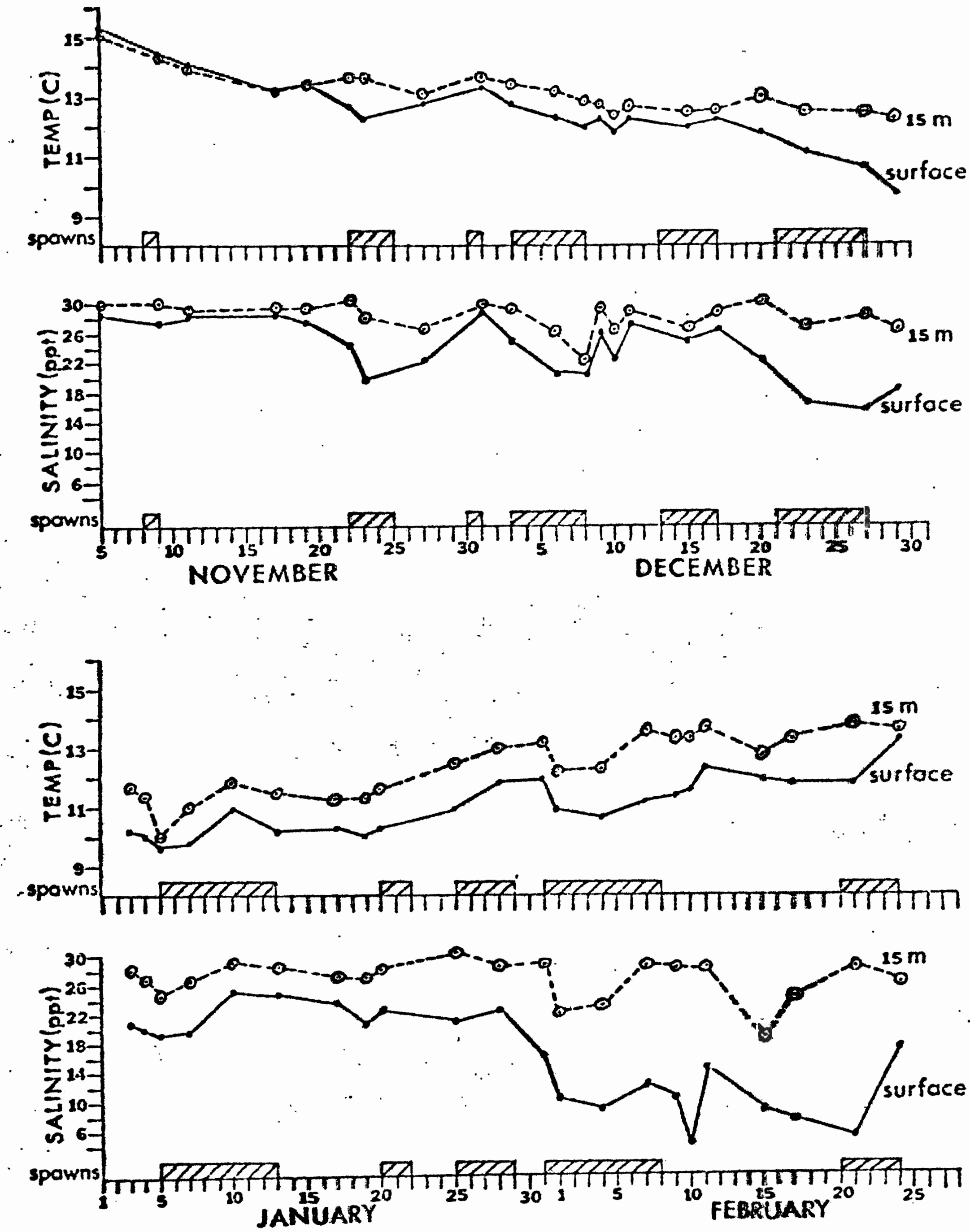

Figure 7. Surface and 15-m temperature and salinity at Peninsula Point, San Francisco Bay, November 5, 1982 to February 28, 1983, and occurrence of herring spawns.

Temperature at the surface, indicative of spawning conditions, was usually 1-2^{o}C lower than at 15 m, indicative of pre-spawning schooling conditions. There is little evidence to suggest that spawning events were triggered by temperature change.

Salinity

Salinity at Peninsula Pt. during the survey period ranged from 3.1 to 29.1 ppt at the surface and from 12.1 to 30.6 ppt at 15 m (Figure 7, Appendix H). Abundant rainfall during the winter kept surface salinities below 20 ppt during February and March. Spawning behavior during these months was atypical and probably influenced by the tremendous fresh water outflow through the Bay system. This established a strong halocline between 5 and 10 m. Schooling fish would enter the Bay and remain below the halocline for extended periods. School 12 was first detected February 9 and spawning did not occur until February 20; during this time surface salinities were depressed and 15-m salinity dropped below 20 ppt. School 13 was present in the Bay as early as March 9. For the next 3 weeks, at least part of the school was acoustically monitored during every field day, yet no spawning occurred. Surface salinity generally was less than 10 ppt. Evidently, extended periods of reduced salinity may inhibit herring from spawning in San Francisco Bay.

Tides, Barometric Pressure, and Rainfall

From November 1982 to February 1983, there were seven tidal cycles in which the highest tide during a 24-h period occurred at night (Figure 8); spawning occurred on some or all of the days during each of these cycles, although not all spawning occurred during nocturnal high tides.

During the 1981-82 season, a statistical correlation was found between the onset of spawning events and periods of falling barometric pressure with average pressure less than 30.0 in. This relationship was not apparent during the 1982-83 season (Figure 8), particularly in March (not displayed in figure) when low

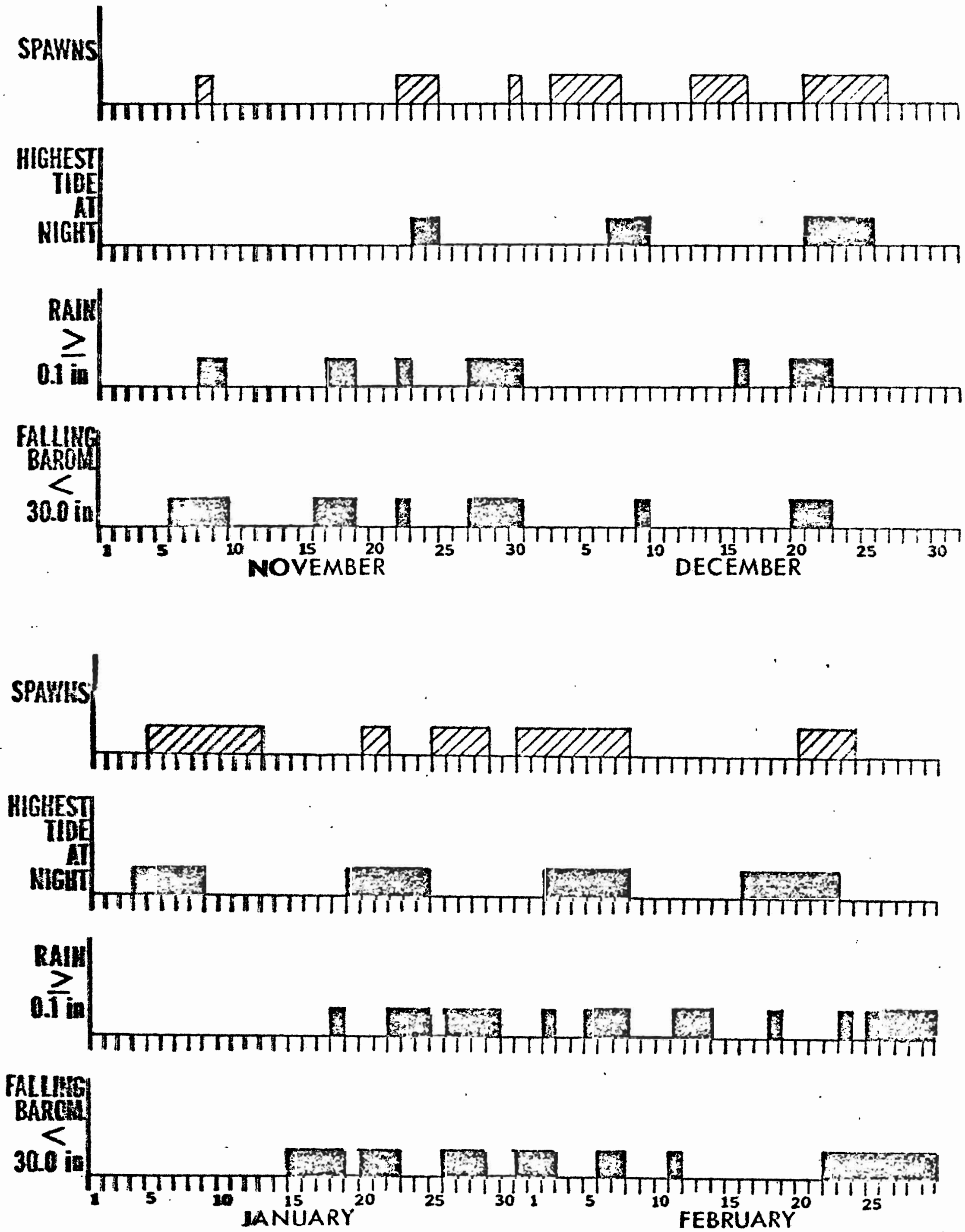

Figure 8. Spawning events, tide, rainfall, and barometric pressure data for San Francisco Bay, November 1, 1982 to February 28, 1983.

pressure storm fronts were numerous and no spawning occurred. Periods of significant rainfall (at least 0.1 in./day) followed the general pattern of low barometric pressures and did not appear to be related to spawning events (Figure 8). Because rainfall is directly related to reduced salinities from freshwater runoff and Delta outflow, abundant rainfall probably inhibited spawning during the latter part of the season. San Francisco airport recorded 10.8 in. of rain from February 25 to March 30, 1983; no spawning was evident during this period.

Young-of-the-Year Herring

Young-of-the-year herring commonly are found in San Francisco Bay during spring and summer and less frequently during fall. The Department's Bay/Delta Project has conducted midwater trawls monthly since 1980 at approximately 35 Bay stations. An examination of monthly average catch for April to August, 1980 to 1982 shows differences of about one order of magnitude between years (Table 10). Catches of these 0-yr-class herring may be indicators of the relative magnitude of year class strength when they first enter the fishery. During January and February 1982, 2-yr olds (1980 yr class) comprised 29% by number of herring sampled from the roundhaul fishery and with our variable mesh gill net. During the same period in 1983, 2-yr olds (1981 yr class) comprised only 10 to 14% of herring sampled with the above gear types. The 1980 yr class had a much greater average catch than the 1981 yr class in the Bay/Delta Study tows.

Several samples of YOY fish were obtained during the fall of 1982. The September sample from the Monterey Bay bait fishery consisted of 28 fish from 105 to 120 mm BL ($\bar{x}$ = 11.5 mm). The first annulus had not yet formed on the otoliths, but otolith radius, measured from the nucleus to the outer margin, was approaching that of the first annulus of older fish.

In October, during the Gulf of the Farallones research cruise, approximately 400 YOY herring in the size range 63-82 mm BL ($\bar{x}$ = 69.7 mm) were collected 1 mile west of San Francisco. It is likely that these fish hatched in San

TABLE 10. Monthly Average Catch per Tow of Young-of-the-Year Pacific Herring in San Francisco Bay, April to August, 1980 to 1982.[1/]

	Year					
	1980		1981		1982	
Month	Number of tows	Catch per tow	Number of tows	Catch per tow	Number of tows	Catch per tow
April	33	33.1	34	11.8	35	19.3
May	35	51.3	33	1.6	35	162.8
June	36	26.3	35	3.4	35	100.9
July	36	134.8	34	9.7	35	127.1
August	32	16.0	35	3.3	35	43.3

1/ Data from Bay-Delta Study, Department of Fish and Game, Stockton.

Francisco Bay. However, it is not known if the Monterey Bay fish were hatched earlier in the spawning season in San Francisco Bay or if they came from a different area, such as Tomales Bay, where higher growth rates have been reported (Spratt 1981).

Two small samples (n = 14 and 17) of YOY fish from San Francisco Bay ranged in size from 60 to 116 mm BL. It is likely that the variation in length is the result of different hatching times.

LITERATURE CITED

Spratt, Jerome D. 1981. Status of the Pacific herring, *Clupea harengus pallasii*, resource in California 1972 to 1980. Calif. Dept. Fish and Game, Fish. Bull., (171):1-107.

APPENDIX A. Summary of Adult Herring Samples (n ≥ 10) from San Francisco Bay, November 1982 to March 1983.

Sample number	Date	Location[1/]	Gear[2/]	Number measured	Number aged	Assigned school number
52-55	Nov 18-22	BELV	GN	21	15	2
56	Nov 22	BELV	GN	89	40	2
57	Nov 22	TIB	GN	96	65	2
60	Nov 29	TI	CGN	108	54	3
61	Nov 29	PPARK	CGN	56	18	3
64	Dec 3	SAUS	CGN	164	15	4
66	Dec 3	PP	GN	278	97	4
67	Dec 6	SAUS	CGN	122	5	4
68	Dec 10	TI	CGN	146	17	5
69	Dec 11	AY	GN	283	119	5
70	Dec 15	AY	GN	136	74	6
71	Dec 15	TI	CGN	154	12	5
72	Dec 20	AY	GN	53	51	6
73	Dec 23	RICH	GN	224	51	6
74	Dec 23	RICH	GN	800	85	6*
75	Dec 29	AY	GN	70	58	7
76	Dec 30	AY	GN	109	42	7
77	Jan 3	AY	GN	88	80	7
78	Jan 5	HP	GN	88	64	7
79	Jan 5	SAUS	RH	126	96	7
80	Jan 5	SAUS	RH	170	19	7
81	Jan 5	AY	GN	68	9	7
82	Jan 7	TI	CGN	254	19	7
83	Jan 7	TI	GN	44	5	7
84	Jan 9	YBI	GN	138	92	7
85	Jan 12	HP	GN	82	66	7
86	Jan 13	SB	GN	217	91	7
87	Jan 13	SB	CGN	177	15	7
88	Jan 17	AY	GN	11	0	8
89	Jan 19	SAUS	RH	353	36	8
90	Jan 20	PP	GN	90	24	8
91	Jan 21	PPARK	GN	521	69	8*
92	Jan 25	PP	RH	273	4	8
93	Jan 26	SAUS	CGN*	111	0	8
94	Jan 27	OP	CGN*	111	0	9
95	Jan 27	SAUS	RH	197	0	10
96	Jan 27	OP	GN	515	105	9*
97	Jan 27	OP	RN	41	0	9
98	Jan 28	AY	GN	82	0	10
99	Jan 28	OP	GN	267	4	9
100	Jan 31	SAUS	RH	515	113	10
101	Feb 1	PP	GN	400	10	10
102	Feb 1	HP	GN	328	106	11
103	Feb 2	HP	MT	340	4	11
105	Feb 9	SAUS	RH	304	90	12
106	Feb 9-10	AY	GN	27	23	12

APPENDIX A. (continued)

Sample number	Date	Location[1/]	Gear[2/]	Number measured	Number aged	Assigned school number
107	Feb 11	SAUS	RH	246	17	12
108	Feb 11	AY	GN	59	5	12
109	Feb 14	SB	GN	116	67	12
110	Feb 14	SB	MT	28	16	12
111	Feb 15	SB	GN	31	6	12
112	Feb 17	SAUS	RH	1198	36	12
113	Feb 21	PP	GN	16	0	12
114	Feb 21	SAUS	RH	756	10	12
115	Feb 24	PP	GN	14	14	12
116-117	Mar 3-4	PP	GN	117	74	13
118	Mar 9	PP	GN	36	7	13
119	Mar 9	PP	MT	46	17	13
120	Mar 11	WANG-SAUS	GN	44	6	13
121	Mar 14	BELV-SAUS	GN	46	4	13
122	Mar 18	SAUS	GN	26	0	13
123	Mar 25	SAUS	GN	98	3	13
124	Mar 25	SAUS	MT	16	1	13
125	Mar 28	BELV-SAUS	GN	149	0	13
126	Mar 28	BELV	MT	29	0	13
127	Mar 28	PP	RH	227	4	13
128	Mar 30	PP	RH	87	1	13

1/ Legend: AY- Ayala Cove, Angel Island; BELV- Belvedere Cove; HP- Hunter's Point, South Bay; OP- Oyster Point, South Bay; PP- Peninsula Point; PPARK- Paradise Park, Tiburon; RICH- Richardson Bay; SAUS- Sausalito to Yellow Bluff; SB- South San Francisco Bay; TI- Treasure Island; TIB- Tiburon shoreline, Raccoon Strait; WANG- western shoreline, Angel Island; YBI- Yerba Buena Island.

2/ Legend: CGN- commercial gill net, 2.25-in mesh
CGN*- commercial gill net, 2.125-in mesh
GN- 5-panel gill net, mesh sizes 1.5, 1.75, 2.0, 2.25, 2.5 in.
MT- 12-by 12-ft (mouth opening) midwater trawl
RH- commercial purse seine or lampara net
RN- hand-held ring net

*Biased sample; not used for comparisons between schools.

APPENDIX B. Number of Pacific Herring by Body Length (2-mm Intervals) from 1.5 - to 2.5-in. Mesh Array Gill Net Samples (n ≥ 10) in San Francisco Bay, November 18, 1982 to March 28, 1983.

Size interval (mm)	Sample number 52-55	56	57	66	69	70	72	73	74[1/]	75
<150									2	
150-151					1					
152				1	1			1	2	
154					1		1		2	
156				2				1	3	
158				1				1	3	
160					5	1			2	
162				3	1		1		7	
164	1			2	3	1		1	5	
166			2	2	2		1	2	14	2
168				1	3	1	1	2	16	1
170				1	3			2	15	1
172	1		1	5		1			16	2
174		1		4	3	1	2	3	20	1
176		1		3	4	1	1	3	21	1
178				10	1	2	1	5	17	
180		4	1	13	4	3	1	5	18	
182		3		13	6	1	1	6	50	2
184		5	4	13	8	1	3	12	40	1
186	1	2	3	20	5	5	2	13	35	1
188	1	5	3	15	9	4	4	4	38	5
190	2	2	4	14	6	5		7	38	5
192	1	5	3	21*	19	9	1	16	64*	1
194		3	9	20	11	8	3	15	30	3
196	3	5	5	28	15	14	4*	8	51	8
198		3	5	9	10	9	1	20*	32	4*
200		6*	6	14	18	8*	2	13	26	6
202	1*	7	5*	19	21*	12	3	14	38	6
204		3	6	10	17	17	3	14	39	3
206		4	6	7	16	4	3	7	32	7
208	3	2	6	4	10	6	6	10	31	3
210	2	4	4	8	14	4	2	9	20	2
212		3	1	2	17	3		4	11	
214	1	4	5	4	6	5	1	2	13	2
216	1	3	1	2	8	3	2	7	9	
218		3	4	2	3	1		5	8	1
220	1	4	1		7	2		2	4	1
222		2	1	2	7	3		2	9	1
224	2	1	5	1	5		1	2	2	
226		1	1	1	5			2	7	
228		1	1		2	1	1	1	4	
230		2	1	1	4		1	3	2	
≥232			2		2				4	
N	21	89	96	278	283	136	53	224	800	70
Mean	200.7	201.2	202.4	192.5	200.1	199.2	196.2	197.3	192.7	196.5
Std. dev.	15.6	13.8	13.7	12.5	16.0	11.7	16.0	14.0	15.1	12.5

*Location of median body length

APPENDIX B. (continued)

Size interval (mm)	Sample number 76	77	78	81	83	84	85	86	88	90
<150							2			
150-151								1		
152						2		1		
154					1		1	2		1
156					1	1	2	2		1
158		1		1				1	1	1
160		2		1	1	2		4		
162	1	2		1		5		3		3
164	2					3		2		4
166	3	2	1		1	3		12	2	3
168		5	1	1	1	2		5	1	1
170	2	2	2		1	5	2	9		1
172		2	2			3	1	8		4
174	2	1	1			3	1	5		1
176	2	1	2	1	1	3	2	7		1
178	1	1	2	1		3	2	7		2
180	1	1	3	2	2	4	4	9		3
182	5	3	2	2	1	8	7	12		8
184	3	5	6	3	1	4	1	13		6
186	3	6	5	4	2	9	5	18*		14*
188	7	5	5	6	4	7	4	19	1	9
190	9	7*	4	3	5*	11*	3	16		5
192	6	2	5	6	3	10	3	14	1*	4
194	12*	2	10*	7*		6	9*	11		
196	7	4	4	5	7	8	3	11	2	8
198	5	3	7	3	3	7	7	5	1	1
200	8	7	2	4	3	3	3	5		3
202	6	3	4	2		6	4	7	1	2
204	2	2	4	2	3	5	3	1		1
206	10	6	5	4	1	3	5	2		2
208	1	3	4	1		5	2	1		
210	4	4		2		1	3			
212	2	2	1	4	1	2	1	1	1	
214		1	2	2	1	1	1	2		1
216	1									
218		2	1							
220	1						1			
222			2					1		
224	2					2				
226			1							
228										
230										
232	1	1								
N	109	88	88	68	44	138	82	217	11	90
Mean	194.5	191.4	193.9	193.7	189.9	188.4	190.9	184.1	186.0	184.4
Std. dev.	13.0	15.6	16.3	12.1	13.4	15.1	14.7	12.8	17.1	12.2

*Location of median body length

APPENDIX B. (continued)

Size interval (mm)	Sample number 91[2/]	96[2/]	98	99	101	102	106	108	109	111
<150	3	5		1						
150	6	7		1	1	6				
152	3	15		2	2	6				
154	9	18		3	3	9			1	
156	19	27		3	6	14				
158	26	26		4	3	10			1	
160	24	27		8	15	8	1	1	1	
162	26	34		10	17	7		1	1	
164	19	22	2	7	18	14		2	2	2
166	26	26	3	9	23	17		2	2	1
168	24	28	1	6	22	17	2	1	2	2
170	28	27*	4	11	21	12	1	3	7	
172	12	13	1	15	19	10		4	4	3
174	17	25	3	15	8	18		1	4	1
176	19*	21	1	11	24	15	1	2	5	4
178	15	20	4	6	17	15*	3	1	4	
180	24	21	3	15	20*	16	3	2	6	
182	24	21	6	24*	34	18	4*	2	9	1
184	30	25	7	20	23	12	1		8	2*
186	18	20	10*	23	21	16	1	6	11*	3
188	19	14	9	9	18	12		7*	16	1
190	16	16	5	14	15	15	4	4	6	3
192	11	14	4	17	16	12	3	6	9	4
194	8	8	5	6	9	11		2	5	
196	8	12	4	4	7	12	1	2	4	1
198	17	3	5	4	9	6	2		1	
200	11	4	2	6	4	4		1	2	
202	7	5	2	3	6	3		1	1	1
204	16	2		5	6	4				
206	6	3				3		3	1	2
208	9	1		2	2			1	2	
210	9	2	1	3	5	2		3		
212	2	2			4	1				
214	2							1		
216	1					1				
218	1				1					
220	3	1			1				1	
222	2					1				
224						1				
226	1									
N	521	515	82	267	400	328	27	59	116	31
Mean	178.7	173.2	185.9	180.4	179.4	177.6	183.4	186.4	184.2	183.5
Std. dev.	16.6	14.1	9.9	12.7	13.3	14.8	9.3	13.5	10.9	11.6

*Location of median body length

APPENDIX B. (continued)

Size interval (mm)	Sample number 113	115	116-117	118	120	121	122	123	125
<150									
150-151									
152									
154									1
156			1						3
158		1			1			1	3
160		1							1
162			3			4			2
164		1	5		2	1	1	2	1
166	1		2		1	1		4	5
168			3		1	1	1	2	7
170			8	1	4	1	1	6	6
172	2	2	7	2	2	2	2	5	8
174	1	1	5	1	2	2	1	5	9
176		1*	9	2	2	4	3	8	9
178	2		13	2	1	5	2	6	9
180		1	9*	3	1	4*	2*	5	11*
182		1	9	2	6*	2	1	11*	11
184	2*	1	6	3	3	5	1	5	18
186	1		7	1	3	3	5	7	10
188	1		6	2*	1	3	2	10	4
190			4	4	4	2	1	7	5
192	1	1	4	3	2			1	5
194	1	1	3	1	2	1	1	1	6
196	2		4	2	1			1	4
198	1	1	3			1	1	2	1
200	1	1	3		2	1	1		1
202			2	3	2	1		1	2
204				1		1		2	3
206				1				2	
208			1		1	1			2
210				2				3	2
212								1	
N	16	14	117	36	44	46	26	98	149
Mean	185.4	179.3	181.1	188.7	182.9	181.2	181.8	183.0	181.1
Std. dev.	10.1	13.0	10.3	10.8	11.7	11.0	8.7	11.3	11.6

*Location of median body length

1/ Biased sample; two nets were fished simultaneously from boat launch ramp. Large-mesh end of one net was two shallow, resulting in over-representation of smaller fish. Sample not used in comparisons between schools.

2/ Biased sample; net was surrounded by commercial gill nets, resulting in under-representation of larger fish. Sample not used in comparisons between schools.

APPENDIX C. Number of Pacific Herring by Body Length (2-mm Intervals) from Commercial Purse Seine and Lampara Net Samples in San Francisco Bay, January 5 to March 30, 1983.

Size interval (mm)	Sample number 79	80	89	92	95	100	105	107
<150	1	4	3	2	2	2		
150-151	1							1
152	1	4	2	1		1	1	
154		1	3	5	2	6		2
156	2	2	5	4	1	8	2	
158	1	1	5	3	4	5	3	1
160	2	1	9	12	4	11	1	1
162	4	12	14	9	2	10	5	2
164	4	3	8	12	5	14		6
166	6	8	11	12	8	22	10	8
168	5	4	12	8	5	13	11	7
170	4	10	14	15	14	19	8	6
172	5	3	11	13	14	30	20	7
174	6	4	12	17	7	16	12	10
176	2	6	18	17	9	21	21	13
178	1	3	12	11*	10	18	19	19
180	2	5	19	14	17*	15	19	17
182	6	6	17	15	12	38	30*	19
184	2	7	12*	5	8	26*	13	23*
186	4	12*	32	14	7	38	25	19
188	6*	3	11	9	4	30	14	12
190	5	10	24	15	25	23	11	13
192	11	14	15	13	7	24	29	16
194	6	8	8	13	7	19	13	8
196	6	7	35	10	7	33	11	7
198	9	5	12	3	1	17	8	6
200	4	4	9	4	7	7	5	7
202	3	8	6	4	2	19	4	7
204	3	2	3	5	4	11	2	7
206	3	5	7	3	2	8	1	1
208	3	2		2		2		
210	3	3	2	1		2	1	1
212	2		1	1		3	3	
214	1	1	1			2	1	
216				1		2		
218		1						
220	2							
222								
224		1					1	
N	126	170	353	273	197	515	304	246
Mean	185.8	183.1	182.3	179.4	180.8	183.1	183.2	183.8
Std. dev.	16.3	16.3	13.7	14.0	12.3	13.6	11.1	11.0

*Location of median body length

APPENDIX C. (continued)

Size interval (mm)	Sample number 112	114	127	128
<150	10	9	4	
150-151	2	2	1	
152	4	3		
154	2	8		
156	15	11	3	2
158	8	9	2	
160	22	10	2	1
162	43	27	6	2
164	38	21	7	2
166	51	34	5	3
168	48	31	13	2
170	45	43	13	5
172	81	58	18	7
174	46	23	16	4
176	74	57	18	5
178	83	43*	21*	12*
180	76*	37	17	3
182	106	65	18	8
184	71	47	20	4
186	76	61	13	9
188	52	38	6	1
190	46	27	6	
192	58	37	4	8
194	26	9	5	2
196	29	17	3	1
198	30	12	2	1
200	11	5	1	
202	17	7		
204	12	1	1	1
206	8	2		2
208	1	1	1	1
210	4			
212		1		
214			1	
216				1
218	2			
220	1			
N	1198	756	227	87
Mean	179.8	178.2	177.9	180.7
Std. dev.	12.0	11.9	11.3	11.5

*Location of median body length

APPENDIX D. Number of Pacific Herring by Body Length (2-mm Intervals) from Midwater Trawl Samples in San Francisco Bay, February 2 to March 28, 1983.

Size interval (mm)	Sample number 103	110	119	124	126
<150	11	1	1	1	
150-151	2	1			
152	5	1	1		
154	8		2		
156	10	3	2		
158	10	1		1	
160	14	1	2	1	
162	11	1	1	3	2
164	17	2	2		
166	24	1	3	1	2
168	16	1	1	1	1
170	12	1*	2	1*	1
172	14		2	1	2
174	14	2	5*		1
176	13*	2	4		2
178	17	1	4		3
180	19	1	3	2	
182	16	1	1		2*
184	19		1	1	4
186	18	1	2	1	4
188	10		1	1	1
190	17	1	2		1
192	13		1		1
194	9	1	1		
196	5	1			
198	5				
200	3	2	1		2
202	2				
204	4		1	1	
206	2				
N	340	28	46	16	29
Mean	175.1	171.1	174.3	171.4	180.2
Std. dev.	14.5	16.2	12.6	15.7	9.8

*Location of median body length

APPENDIX E. Number of Pacific Herring by Body Length (2-mm Intervals) from Commercial Gill Net Samples in San Francisco Bay, November 30, 1982 to January 27, 1983.

Size interval (mm)	Sample number 60	61	64	67	68	71	82	87	93	94
174-175										1
176										1
178										
180								2	1	1
182					1		1	1	1	1
184				1					3	7
186			1	1			3	4	3	4
188				2	1	1	1	4	1	5
190		1	2	1	1	1	4	14	12	9
192			7	3	6	3	9	13	7	15
194	3	2	5	5	3	6	20	15	9	13*
196		3	7	7	7	6	14	20	10	7
198	5	4	11	10	10	11	22	20*	9*	8
200	10	1	13	15	10	10	28	14	17	12
202	4	1	11	10	13	18	27*	23	17	11
204	10	7	16	16*	15	13	29	20	2	7
206	15	6	11*	8	13*	13*	20	6	5	1
208	5	2	14	9	8	9	18	7	4	2
210	14*	3*	14	6	15	13	19	4	4	2
212	10	2	6	7	8	14	10	6	3	3
214	8	3	14	6	5	9	8	2	1	
216	7	6	6	5	10	7	6	2		
218	5	3	8	2	3	5	4			
220	2	1	6	4	5	6	4		1	
222	4	5	2	1	4	3	3			1
224	3		4	2	1	5	1			
226		3	4		3		1			
228	1	2			2					
230	1		1		1					
232	1	1		1			1			
234			1							
236					1					
238						1	1			
N	108	56	164	122	146	154	254	177	111	111
Mean	209.9	210.8	207.6	205.1	207.5	207.5	204.0	199.2	198.9	196.1
Std. dev.	7.9	10.2	9.2	8.6	9.4	8.5	8.1	7.0	7.6	8.0

*Location of median body length

APPENDIX F. Number of Pacific Herring at Age by Body Length (2-mm Intervals) from Commercial Gill Net Samples, San Francisco Bay, November 1982 to January 1983.

Size interval (mm)	Age (years) 4	5	6	7	8	9	10
190–191	1						
192							
194	1	3	1				
196		2					
198	1	5	3				
200		2					
202		2	2				
204	1	2					
206		1	5				
208		1	1	1			
210	1	3	1				
212		3	2	2	1		
214		2	1	6	1		
216		2		3	1		
218			1	2			
220		1	1	10	6	1	
222			3	8	5		
224			1	7	3	1	
226				3	5		
228				3	1		
230				2	1		
232					2	1	
234					1		
236							1
N	5	30	22	47	27	3	1
Mean	199.2	204.9	209.4	220.6	223.3	225.3	236.0
Std. dev.	7.1	7.6	8.8	5.0	5.1	5.0	-

APPENDIX G. Temperature (C) Profiles of San Francisco Bay at Peninsula Point, November 5, 1982 to April 4, 1983.

				Depth		
Date	Surface	5 m	10 m	15 m	20 m	25 m
Nov 5	15.3	15.1	-	15.1	-	.15.0
9	14.4	14.5	-	14.4	-	14.4
11	14.1	14.1	14.0	14.0	13.9	13.9
17	13.2	13.2	13.2	13.2	13.2	13.2
19	13.4	13.3	13.3	13.4	13.4	13.4
22	12.7	13.4	13.5	13.6	13.6	13.6
23	12.3	12.7	13.2	13.3	13.6	13.6
27	12.9	12.7	12.8	13.0	13.0	13.0
Dec 1	13.4	13.5	13.6	13.6	13.6	13.6
3	12.8	13.3	13.4	13.4	13.4	13.4
6	12.4	12.4	12.9	13.1	13.1	13.2
8	12.0	11.9	11.9	12.0	12.3	12.8
9	12.3	12.6	12.7	12.7	12.7	12.8
10	11.8	12.3	12.4	12.4	12.4	12.4
11	12.3	12.6	12.7	12.7	12.7	12.7
15	12.0	12.2	12.2	12.3	12.3	12.5
17	12.3	12.5	12.6	12.6	12.6	12.6
20	11.8	12.6	12.7	12.8	13.0	13.0
23	11.1	11.7	12.3	12.5	12.5	12.5
27	10.6	12.2	12.4	12.4	12.5	12.5
29	9.8	11.6	11.8	12.1	12.4	12.3
Jan 3	10.2	10.9	10.9	11.7	11.8	11.8
4	10.0	10.7	11.0	11.4	11.6	11.6
5	9.6	9.7	9.7	10.0	11.3	11.4
7	9.8	9.8	9.8	11.0	11.3	11.4
10	11.0	11.5	11.9	11.9	11.9	11.9
13	10.2	10.3	11.1	11.5	11.5	11.5
17	10.4	10.7	11.1	11.3	11.4	11.5
19	10.0	10.7	11.0	11.3	11.3	11.4
20	10.3	10.4	11.4	11.6	11.7	11.7
25	10.9	12.4	12.5	12.5	12.5	12.5
28	11.8	12.6	12.8	13.0	13.0	13.1
31	12.0	12.8	13.2	13.2	13.3	13.3
Feb 1	10.9	11.1	11.8	12.3	12.6	12.6
4	10.7	10.8	11.2	12.4	13.1	13.1
7	11.2	12.3	13.4	13.5	13.5	13.5
9	11.4	12.9	13.3	13.4	13.5	13.5
10	11.6	12.0	13.1	13.4	13.4	13.4
11	12.5	13.0	13.3	13.6	13.6	13.6
15	11.9	12.1	12.4	12.8	13.5	13.5
17	11.9	12.1	12.2	13.4	13.5	13.5
21	11.8	12.4	13.7	13.8	13.9	13.8
24	13.3	13.5	13.6	13.6	13.6	13.6
Mar 3	12.6	12.5	12.9	13.0	13.2	13.3
4	12.0	12.1	12.6	12.9	13.2	13.3
7	12.2	12.3	12.5	13.3	13.7	13.9
9	12.7	13.0	13.9	14.1	14.1	14.1
11	13.4	13.7	14.1	14.1	14.2	14.2
14	14.3	14.1	14.2	14.2	14.2	14.3
18	13.3	13.4	13.8	13.9	13.9	13.9
21	12.3	12.5	12.7	12.9	13.6	13.7
25	12.2	13.2	13.3	13.4	13.5	13.5
28	13.2	13.2	13.4	13.4	13.4	13.4
30	13.0	12.8	13.0	13.1	13.3	13.3
Apr 4	13.3	13.3	13.4	13.3	13.2	13.2

APPENDIX H. Salinity (ppt) Profiles of San Francisco Bay at Peninsula Point, November 5, 1982 to April 4, 1983.

				Depth			
Date	Surface	5 m	10 m	15 m	20 m	25 m	Tidal state
Nov 5	28.2	29.9	-	29.9	-	29.9	Flood
9	27.8	29.3	-	29.9	-	29.8	Flood
11	28.5	28.6	29.1	29.2	29.4	29.1	Ebb
17	29.1	29.2	29.5	29.7	30.0	30.1	High slack
19	27.8	28.5	29.0	29.6	30.1	30.0	Ebb
22	24.4	29.3	29.8	30.6	30.8	30.9	High slack
23	19.8	23.5	27.6	28.2	30.1	30.0	Flood
27	22.3	23.5	25.5	26.7	27.3	28.1	Low
Dec 1	29.0	30.1	30.3	30.0	30.3	30.3	High
3	25.1	29.1	29.7	29.7	29.8	29.8	Flood
6	20.6	21.5	24.4	26.5	26.9	27.4	Flood
8	20.6	21.1	21.5	22.8	25.8	27.3	Low slack
9	26.1	28.2	29.2	29.5	29.5	29.4	Ebb
10	22.5	25.5	26.7	26.5	27.6	28.2	Ebb
11	27.5	28.6	29.1	29.2	29.3	29.3	High
15	25.1	26.5	26.6	26.7	27.6	28.5	Flood
17	26.5	28.7	29.3	29.4	29.5	29.5	High
20	22.9	29.0	29.4	30.3	30.8	30.8	High
23	16.9	23.4	26.5	27.3	27.8	27.5	Flood
27	15.7	26.5	28.0	28.6	28.9	28.7	Ebb
29	18.5	25.3	25.6	26.9	28.8	28.5	Flood
Jan 3	20.9	24.1	24.6	28.1	28.5	28.5	Flood
4	19.6	23.6	24.6	26.8	27.9	27.9	Flood
5	19.0	20.0	20.8	24.3	26.8	26.5	Low
7	19.4	19.9	20.2	26.3	27.1	27.0	Low slack
10	25.1	27.5	29.1	29.2	29.2	28.9	High
13	24.4	25.5	27.3	28.4	28.4	29.0	Flood
17	23.9	25.5	26.8	27.3	27.7	27.6	Low
19	20.4	24.8	26.1	27.0	27.2	27.4	Flood
20	22.6	24.4	27.4	28.1	28.5	28.5	Flood
25	21.3	29.8	30.1	30.1	30.1	30.1	High
28	22.7	26.9	27.7	28.5	28.7	28.9	Flood
31	16.3	26.9	28.7	28.8	28.9	29.0	High
Feb 1	10.3	12.4	18.2	22.0	23.9	24.1	Low
4	9.2	10.0	13.5	23.0	27.5	27.5	Low
7	12.3	21.1	28.1	29.2	29.7	29.7	High
9	10.6	24.9	28.4	28.6	29.0	29.0	High
10	4.4	12.5	25.7	28.0	28.1	28.6	Ebb
11	14.3	23.4	26.1	28.4	28.6	28.7	High slack
15	8.6	10.9	12.6	18.3	25.7	26.0	Low
17	7.6	9.1	10.5	24.8	26.1	26.6	Low
21	5.5	9.7	28.0	28.7	29.5	29.5	Ebb
24	17.9	25.1	25.3	26.7	27.5	27.6	High slack
Mar 3	10.3	12.0	17.1	18.5	20.4	22.1	Low slack
4	5.6	6.3	12.7	17.0	20.6	21.4	Low
7	3.1	4.5	6.3	16.8	24.4	28.3	Ebb
9	3.4	9.5	26.9	28.7	29.3	29.7	Ebb
11	6.5	12.4	27.1	27.6	28.5	28.5	High
14	8.3	19.0	25.7	26.7	27.3	27.8	High
18	7.7	10.5	21.5	24.6	25.2	25.3	Flood
21	4.6	6.4	9.7	12.1	20.8	24.2	Low
25	6.5	16.8	22.5	23.4	24.5	24.9	High
28	16.6	21.2	25.5	25.5	25.6	25.6	High
30	10.4	10.9	13.4	15.0	18.6	19.3	Flood
Apr 4	8.8	14.1	17.6	26.1	27.6	28.8	Low