State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

BIOMASS ESTIMATES OF PACIFIC HERRING, *CLUPEA HARENGUS PALLASI*, IN CALIFORNIA FROM THE 1987-88 SPAWNING-GROUND SURVEYS

by

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MARINE RESOURCES DIVISION

Administrative Report No. 88-7

JUNE 1988

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ABSTRACT

The 1987-88 spawning biomass estimate of Pacific herring, *Clupea harengus pallasi*, in San Francisco Bay is nearly 69,000 tons. This is the fourth consecutive year that the San Francisco Bay population has increased, after reaching a low point of 40,000 tons in 1984.

In Tomales Bay the 1987-88 herring spawning biomass was estimated at 2,061 tons. During the past five seasons, the Tomales Bay spawning biomass has been low in even years and high in odd years, indicating that spawning herring are not returning to Tomales Bay consistently.

In San Francisco Bay, over 42,000 tons of herring spawned in January. Similarly, 90% of Tomales Bay herring spawned in January. No spawns were found during March in either bay.

For the first time, in San Francisco Bay, no herring spawned in the Belvedere, Tiburon, or Angel Island areas. In addition, herring spawning was found in the Oakland-Alameda area for the first time and over 95% of all spawning occurred in the southern part of San Francisco Bay.

During the past six seasons in San Francisco Bay, over 70% of all spawning escapement has been in the southern part of the bay. For the nine seasons prior to that, 94% of all spawning escapement was in the northern part of the bay.

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[1] Marine Resources Administrative Report No. 88-7.

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ACKNOWLEDGMENTS

I wish to thank Margaret Graham, Walter Earle, Jennifer Hallet, and Fred Smith for collecting samples of spawn deposition in San Francisco Bay and Tomales Bay, and their diligence in processing said samples.

Subtidal vegetation samples in San Francisco Bay were collected by Department divers Paul Reilly, and Bob Wright.

Phil Law, of the Department's Biometrics Unit at Menlo Park, performed the multiple regression analysis of eelgrass density data.

INTRODUCTION

In 1973, the California Department of Fish and Game began estimating the annual spawning biomass of Pacific herring, *Clupea harengus pallasi*, in Tomales and San Francisco Bays (Spratt 1981). Biomass is derived from estimates of eggs deposited during the season. Both bays are relatively small and well suited for intensive spawning-ground surveys.

This report includes spawning biomass estimates for Tomales Bay and San Francisco Bay during the 1987-88 season, and it provides a continuous series of annual herring spawning biomass estimates from 1973-74 onward. These data provide the basis for managing the herring roe fishery.

DESCRIPTION OF STUDY AREA

Tomales Bay

Tomales Bay (Figure 1) lies in Marin County, a short distance north of San Francisco. It is 20 km (12.4 miles) long and averages more than 1.5 km (0.9 miles) wide. Hardwick (1973) determined that eelgrass, *Zostera marina*, was the predominant marine flora in the bay. The present distribution of eelgrass (Figure 1) is unchanged from the previous season. There are other species of marine flora in Tomales Bay, but eelgrass is the only one used to determine herring biomass.

San Francisco Bay

The portion of San Francisco Bay where regular daily (Mon. - Fri.) surveys are attempted includes all shoreline and shallow subtidal areas to a depth of 4.6 m (15 ft), bounded by the Golden Gate Bridge on the west, the Richmond Bridge on the north, Hunters Point on the south, and the east bay shorelines between Richmond and Oakland (Figure 2). Other areas of the bay were surveyed as needed.

Spawning in San Francisco Bay is both intertidal (partly exposed at low tide) and subtidal (never exposed at low tide). Intertidal spawns are on the shoreline and cover all suitable substrate in the area, including bare rocks, sand, pier pilings, and marine flora. Subtidal spawns generally occur in areas of the bay shallower than 4.6 m (15 ft), where vegetation beds such as *Zostera marina*, *Gracilaria* sp., and *Ulva* sp. are found, but may also occur in shallow rocky or hard bottom areas. Broad shallow mud flats with no vegetation are not utilized by herring as spawning areas.

METHODS

Tomales Bay Sampling Techniques

This season's spawning-ground surveys were conducted from December 2, 1987 to March 11, 1988. Every eelgrass bed (Figure 1) was sampled daily (Mon.-Fri.), as the weather permitted, from the project's 4.6-m (15-ft) boat.

This season was similar to the 1985-86 season, when no large herring spawns were found. Instead of using cohort analysis, as in 1985-86, spawn survey methods were used this season to estimate biomass. Those herring that returned to Tomales Bay this season spawned in areas that allowed traditional sampling techniques to be used. Spawn deposition was determined by dragging a vegetation sampler (rake) through the eelgrass beds at random locations. The area (m^2) of each spawn was also determined with the vegetation sampler. Processing of samples was unchanged from previous seasons (Spratt 1981).

Density of eelgrass (kg/m^2) on spawning grounds was estimated using a multiple linear regression between density and eelgrass measurements that was developed in the 1986-87 season (Spratt, in press). The multiple regression model is represented by the following equation:

$$Y = a_l \text{ (length} + a_w \text{ (width)} + a_{pc} \text{ (percent cover)} + B$$

where:

Y = kg eelgrass per m^2

a_l = slope of regression for length variable

a_w = slope of regression for width variable

a_{pc} = slope of regression for percent bottom coverage variable

B = Y intercept

In December 1987 five or six eelgrass data sets were taken from all beds frequently spawned on by herring. Data sets included acoustical transects with a recording fathometer to determine percent bottom coverage, and eelgrass blade length and width measurements. Acoustics were used to measure eelgrass blade length where applicable. The 1987-88 eelgrass density values were computed by substituting this eelgrass data in the regression formula.

San Francisco Bay Sampling Techniques

This season's spawning-ground surveys were conducted from November 17, 1987 until March 11, 1988. The techniques used to sample both subtidal and intertidal spawns in San Francisco Bay were unchanged from the previous season (Spratt 1987).

Preseason subtidal vegetation densities were determined by collecting quantitative samples with SCUBA from permanent stations in Richardson Bay, Belvedere Cove, Kiel Cove, Angel Island, and Brooks Island near Richmond (Figures 3 and 4). In addition, south bay collecting stations were added between Hunters Point and Oyster Point, and near Alameda (Figure 5).

Biomass Computation

In San Francisco Bay, the method used to convert the number of herring eggs spawned to tons of spawners incorporates sex ratio estimates for each spawning run individually (Reilly and Moore 1988).

Fecundity of herring in San Francisco Bay does not change significantly from year to year (Reilly and Moore 1986). Fecundity is also not significantly different between Tomales Bay and San Francisco Bay. A fecundity of 226 eggs per gram was used in calculating this year's biomass estimates. Factors used to convert number of eggs to tons of herring in both Tomales and San Francisco Bays changed during the season based on the sex ratio of each run in San Francisco Bay.

RESULTS

Tomales Bay

There are a total of 36 eelgrass beds utilized by herring in Tomales Bay (Figure 1). Eelgrass beds were not remeasured this season and March 1987 eelgrass bed area (m^2) measurements (Table 1) were used this season in biomass calculations.

<u>Eelgrass Density Estimates From Regression</u>

Previously, density of eelgrass (kg/m^2) was assigned subjectively by on-site visual inspections from 1977 through 1986, based on quantitative samples collected in 1976 (Spratt 1981).

Eelgrass density was estimated for all beds spawned in this season by substituting December 1987 eelgrass variables (Table 2) in the regression formula:

$$\text{Density } kg/m^2 = .0022(l) + .0775(w) + .0029(pc) - .9394, \quad r = .78$$

The computed eelgrass density for each bed (Table 2) is the average of individual estimates from variable data sets. Using bed no. 1A as an example:

solving with variable set 1 (Table 2) in regression formula

$$\text{Density } kg/m^2 = .0022\ (660) + .0775\ (8) + .0029\ (85) - .9394$$

$$= 1.37\ (kg/m^2)$$

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average density computed from six data sets is 1.34 kg/m^2 for bed no 1A.

Spawning Escapement

Herring spawning started on December 17, 1988. There were only 15 individual spawn sites found and only one large spawning run occurred this season. On January 18-21, a total of 880 tons of herring spawned that accounted for 67% of this season's spawning escapement (Table 3). There were no spawning runs in Tomales Bay during February or March.

This season's spawning escapement estimate is 1,311 tons (Table 3). The spawning biomass, which includes the catch of pre-spawning herring, is 2,061 tons (Table 4).

San Francisco Bay

Vegetation Density

Quantitative samples of subtidal vegetation were collected by Department divers on October 29, November 13, and November 23, 1987. Vegetation density increased slightly at Brooks Island and Angel Island, but overall the vegetation density remains low at all permanent stations (Figures 3 and 4). No vegetation was found between Hunter's Point and Oyster Point in south bay (Figure 5). This area had been considered potential spawning area.

The density of eelgrass beds off Alameda (Figure 5) averaged only .092 kg/m^2. The Alameda beds were expected to have eelgrass densities over 1.0 kg/m^2 or similar to Tomales Bay. During the season, our vegetation sampling device was used in other areas of the Bay with very little success.

Spawning Escapement

The season's first spawn was found November 24, 1987, at Sausalito (Table 5). As many as 12 spawning runs may have occurred this season, but two of them were 20 tons or less. All spawning was intertidal this season except for one small run near Alameda that extended into nearby eelgrass beds.

There were seven intertidal spawns along the San Francisco waterfront (Table 5, Figures 6a and 6b), and 75% of this season's spawning escapement occurred in this area. For the first time, there were no spawns at Belvedere, Tiburon, or Angel Island (Figure 7). Herring spawning was also recorded in the Oakland-Alameda area for the first time (Figures 6a and 6b).

Spawning escapement was estimated at 60,155 tons of herring (Table 5). Including the catch of pre-spawning herring from the roe fishery, the spawning biomass for the 1987-88 season is 68,881 tons (Table 6). This represents the fourth consecutive year that the San Francisco Bay population has increased.

Spawning By Area 1973 to 1987

San Francisco Bay

Spawning-ground surveys have been conducted in San Francisco Bay for 15 seasons. During this time, there has been a major change in the distribution of herring spawning. From the 1973-74 to 1981-82 seasons, Richardson Bay, Sausalito, and Richmond were the major spawning areas. Since the 1982-83 season, the San Francisco waterfront has accounted for 63% of all spawning escapement, while Richardson Bay, Sausalito, and Richmond have accounted for only 10.4% of spawning escapement (Table 7). This current trend is expected to continue unless the subtidal vegetation densities in San Francisco Bay increase.

Tomales Bay

Spawning-ground surveys have been conducted in Tomales Bay from 1973-74 to 1987-88, with the exception of the 1978-79 season. The distribution of herring spawning within Tomales Bay over the seasons surveyed has not changed significantly. The larger eelgrass beds near Walker Creek (Figure 1) account for over 50% of spawning escapement (Table 8).

Although herring that return to Tomales Bay are spawning normally, a significant part of the population is not returning regularly and instead spawn either in Bodega Bay or some unknown location. This pattern started with the El Nino season of 1983-84, when herring did not return to Tomales Bay as expected (Spratt 1984). Since then, the even seasons have been characterized by abnormal distribution of spawning herring. In the 1985-86 season, spawning escapement set an all-time low of only 435 tons (Spratt 1986), and this season spawning escapement was 1,311 tons. During the odd seasons of 1984-85 and 1986-87, herring returned in normal numbers to Tomales Bay (Table 4).

Confidence Limits

In Tomales Bay the confidence limits of herring spawning escapement estimates were calculated from variation in the density of egg deposits. Each run usually encompasses several small spawning sites and total spawning escapement is the sum of the estimates for each site (Table 3). The confidence intervals calculated for many sites were again unsatisfactory, even though minimum sampling levels were increased from three to five per spawning site this season. The number of samples that would be statistically required from many small spawning sites becomes prohibitive due to the density range of egg deposits. In large spawns, egg deposition is often uniformly dense, but for small spawning areas egg distribution is often very patchy and may range from 1×10^3 eggs/m^2 to over 1×10^6 eggs/m^2. Sampling itself could decimate small eelgrass beds. A stratified random sampling plan for small sites would also be detrimental to the eelgrass beds because of the number of samples needed to determine strata boundaries within a bed.

This sampling problem will persist when spawn escapement is low or spawn densities are highly variable, but it is generally not a problem in normal years or with large spawning runs. This being a low biomass year, the confidence intervals were calculated by combining the samples from each spawning run or samples from nearby spawning sites with similar egg densities. This results in higher average spawn densities, but an estimate of total spawning escapement that is only 5% higher than the original estimate (Table 3). Using this method, the 95% confidence interval for the two larger spawns, which accounted for over 60% of the spawning escapement, was less than 45% of the estimate (Table 9).

Confidence limits of San Francisco Bay spawns were also calculated for each spawn individually from variation in the density of egg deposits. Six of this season's spawning runs (76% of total escapement) had 95% confidence intervals less than 35% of the estimate (Table 10). Inclement weather prohibited taking more samples from spawning runs at San Francisco (Dec. 26-27) and Hunters Point (Jan. 16-18).

DISCUSSION

Tomales Bay

There have been three unusually low herring spawning biomass estimates in Tomales Bay over the past five seasons. It is believed that El Nino altered the migratory pattern of herring in 1983 and that herring did not return to Tomales Bay as expected, resulting in a low escapement estimate (Spratt 1984). In the 1985-86 season, herring may have returned, but did not spawn in eelgrass beds, and spawning biomass was estimated by cohort analysis (Spratt 1986). This season spawning escapement is again below normal.

A major unanswered question remains. Where are Tomales Bay herring spawning and what effect will this have on the Tomales Bay herring population and the future of the fishery?

San Francisco Bay

Factors that are causing the fluctuation of Tomales Bay herring are not affecting San Francisco Bay herring. The San Francisco Bay herring biomass has increased the past four seasons and is currently 69,000 tons, the highest level since the 1981-82 season.

From the 1978-79 to 1981-82 seasons, the increases in San Francisco Bay herring biomass estimates (Table 6) were attributed, in part, to the discovery of subtidal spawning areas which had previously not contributed to biomass estimates. The current increasing trend in San Francisco Bay herring spawning biomass the past four seasons has been accomplished without the benefit of subtidal spawning. Vegetation densities of known subtidal spawning areas have declined to the point that herring are not utilizing those areas. The current increase in biomass agrees well with acoustical biomass estimates from an independent study (Reilly and Moore 1988).

It is probable that the San Francisco Bay herring population will continue to increase because of good recruitment of the 1986 yr class (Reilly and Moore 1988), which follows four strong year classes.

CONCLUSION

Because of the low spawning escapement three out of the last five years, the future of the Tomales Bay herring fishery is uncertain. This cyclical pattern indicates a movement of herring to and from Tomales Bay. While the population may remain healthy, a change in distribution of the population could be devastating to the Tomales Bay herring fishery. The San Francisco Bay herring population is in excellent condition and the current increasing trend in abundance is expected to continue.

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TABLE 1. Tomales Bay Eelgrass Bed Measurements in March 1987.

Bed number	Area m^2	Bed number	Area m^2
1	4,400	12	1,800
1A	33,000	13	100
1B	21,000	14	1,000
1C	1,500	15	100
2	2,800	16	42,000
2A	2,000	16A	14,600
3	3,800	17	2,200
3A	0	18	0
4	1,000	19	116,600
5	12,000	20	235,500
6	7,400	20A	55,900
7	6,000	21	1,488,000
8	9,100	22	140,000
9 North	13,900	23	1,209,000
9 South	21,000	24	20,900
10	4,100	25	200,000
11 North	17,400	26	190,000
11 Middle	5,000	27	21,000
11 South	1,600	28	0
		28A	11,800

Total area 3,915,700 m^2

TABLE 2. December 1987 Eelgrass Measurements from Tomales Bay and Estimates of eelgrass Density from Multiple Regression.

Bed no.	Data set	(pc) % bottom cover	(l) blade length m	(w) blade width mm	Eelgrass density kg/m^2	Average density kg/m^2
1	1	100	610	7	1.23	
	2	100	610	6	1.15	
	3	100	610	10	1.47	
	4	100	610	5	1.08	
	5	100	610	7	1.23	1.23
1A	1	85	660	8	1.37	
	2	85	660	8	1.37	
	3	95	660	8	1.41	
	4	95	660	6	1.24	
	5	100	660	5	1.22	
	6	100	660	8	1.42	1.34
6	1	85	450	7	0.83	
	2	85	385	5	0.52	
	3	85	490	7	0.92	
	4	85	315	6	0.45	
	5	85	470	6	0.79	0.70
7	1	85	490	7	0.91	
	2	85	480	7	0.89	
	3	85	560	7	1.07	
	4	85	590	7	1.13	
	5	85	540	8	1.10	1.02
9	1	100	620	9	1.43	
	2	100	625	9	1.44	
	3	95	610	8	1.29	
	4	95	610	8	1.29	
	5	95	610	5	1.05	
	6	95	610	9	1.36	1.31
11	1	100	750	10	1.77	
	2	100	880	9	1.98	
	3	100	780	7	1.61	
	4	100	820	10	1.93	
	5	100	800	7	1.65	
	6	100	640	9	1.45	1.73
21	1	100	1,100	10	2.54	
	2	100	1,550	9	3.45	
	3	100	1,130	10	2.61	2.86

TABLE 2. (continued)

Bed no.	Data set	(pc) % bottom cover	(l) blade length m	(w) blade width mm	Eelgrass density kg/m^2	Average density kg/m^2
25	1	90	180	4	0.27	
	2	90	400	5	0.59	
	3	90	310	5	0.39	
	4	90	325	4	0.35	
	5	90	310	4	0.31	
	6	90	410	5	0.61	0.38
27	1	100	800	7	1.65	
	2	100	800	7	1.65	
	3	100	800	7	1.65	
	4	100	800	5	1.49	
	5	100	800	7	1.65	1.61

TABLE 3. **Tomales Bay Herring Spawn Data, 1987-88 Season.**

Date	Location*	Area m^2	Eggs per kg	Kg veg per m^2	Eggs per m^2	Million eggs	Conversion factor x 10^{-6}	Tons
17 Dec 87	1A	33,000	351,000	1.3	456,300	15,058	.0107	160
4 Jan 88	6	7,400	16,000	.7	11,200	83	.0097	1
4 Jan 88	25	225,000	101,000	.4	40,400	9,090	.0097	90
4 Jan 88	27	21,000	246,000	1.6	393,600	8,266	.0097	80
4 Jan 88	29	20,000	528,000	.2	106,000	2,120	.0097	20
6 Jan 88	7	6,000	69,000	1	69,000	414	.0097	4
18 Jan 88	27	5,000	750,000	1.6	1,200,000	6,000	.0088	50
18 Jan 88	29	20,000	1,500,000	.2	300,000	6,000	.0088	50
19 Jan 88	7	6,000	390,000	1	390,000	2,340	.0088	20
21 Jan 88	9	10,000	275,000	1.3	357,500	3,575	.0088	30
21 Jan 88	21	175,000	170,000	2.8	476,000	83,300	.0088	730
26 Jan 88	9	11,000	185,000	1.3	240,500	2,646	.0088	20
26 Jan 88	11	600	200,000	1.7	340,000	204	.0088	2
31 Jan 88	1	4,400	720,000	1.2	864,000	3,802	.0097	40
31 Jan 88	27	5,000	185,000	1.6	296,000	1,480	.0097	14
Total		549,400				132,476		1,311

*See Figure 1

TABLE 4. Tomales Bay Pacific Herring Biomass Estimates 1973-74 through 1987-88 Seasons.

Season	Spawn estimate (tons)	Catch (tons)	Spawning biomass (tons)
1973-74	6,041	521	6,562
1974-75	4,210	518	4,728
1975-76	7,769	144	7,913
1976-77	4,739	344	5,083
1977-78	21,513	646	22,163
1978-79	--	448	--
1979-80	5,420	603	6,023
1980-81	5,128	448	5,576
1981-82	6,298	851	7,149
1982-83	10,218	822	11,040
1983-84	1,170	110	1,280
1984-85	6,156	430	6,586
1985-86	435	771	6,000*
1986-87	4,931	867	5,798
1987-88	1,311	750	2,061

*Biomass estimated by cohort analysis; for all other years biomass was estimated from spawning-ground surveys.

Table 5. San Francisco Bay Herring Spawn Data, 1987-88 Season.

Date	Location	Area m^2	No. eggs per kg. veg.	Kg veg. per m^2	No. eggs per m^2	Million of eggs	Conversion factor $\times 10^{-6}$	Tons
24-29 Nov 87	Sausalito	5,800	*		2,100,000	12,180	.0107	130
29-30 Nov 87	San Francisco	120,000	*		1,610,000	193,200	.0121	2,350
6-11 Dec 87	San Francisco	290,000	*		1,260,000	365,400	.0107	3,900
26-27 Dec 87	Hunters Point	120,000	*		1,580,000	189,600	.0097	1,850
26-27 Dec 87	Alameda	5,000	*		300,000	1,500	.0097	15
4-5 Jan 88	Treasure Island	50,000	*		2,300,000	115,000	.0097	1,100
4-6 Jan 88	Oakland	330,000	*		4,040,000	1,333,200	.0088	11,750
5-7 Jan 88	San Francisco	320,000	*		1,030,000	329,600	.0097	3,200
8 Jan 88	Sausalito	60,000	*		3,620,000	217,200	.0097	2,100
16-18 Jan 88	Hunters Point	140,000	*		1,700,000	238,000	.0088	2,100
18 Jan 88	Candlestick Point	8,000	*		2,000,000	16,000	.0088	140
25 Jan 88	Sausalito	1,600	*		1,260,000	2,016	.0097	20
25-26 Jan 88	San Francisco	167,000	*		1,450,000	242,150	.0097	2,350
26-28 Jan 88	San Francisco	720,000	*		2,900,000	2,088,000	.0097	20,250
8-13 Feb 88	San Francisco	520,000	*		2,150,000	1,118,000	.008	8,900
Total		2,857,400				6,461,046		60,155

*Intertidal spawn and vegetation parameters were not used to calculate biomass

TABLE 6. San Francisco Bay Pacific Herring Biomass Estimates 1973-74 through 1987-88 Seasons.

Season	Spawn estimate (tons)	Catch (tons)	Spawning biomass (tons)
1973-74	4,300	1,938	6,238
1974-75	26,730	514	27,244
1975-76	25,360	1,719	27,079
1976-77	22,670	4,201	26,871
1977-78	3,750	4,987	8,737
1978-79	32,590	4,121	36,711*
1979-80	46,590	6,430	53,020
1980-81	59,615	5,826	65,441
1981-82	89,220	10,415	99,635
1982-83	49,518	9,695	59,213
1983-84	37,987	2,838	40,825
1984-85	39,130	7,740	46,870
1985-86	41,770	7,298	49,068
1986-87	48,721	8,098	56,819
1987-88	60,155	8,726	68,881

*Subtidal spawning areas were discovered in 1979. Biomass prior to 1979 was probably underestimated.

TABLE 7. Herring Spawning Escapement by Area for San Francisco Bay.

1973-74 to 1981-82

Spawning area	Average % of seasonal biomass	Average escapement (tons)
Richardson Bay	38.6	13,334
Sausalito	16.3	5,616
Richmond	12.7	4,393
Tiburon	9.8	3,389
Angel Island	6.8	2,344
Treasure Island	3.7	1,275
Kiel Cove	3.5	1,205
Belvedere-Tiburon	3.0	1,038
Belvedere	1.9	655
San Francisco	1.5	533
South Bay	0.8	288
Belvedere Cove	0.7	244
Berkeley	0.6	211
Coyote Point	<0.1	11
Oakland-Alameda	0.0	--
Total	100.0	34,536

1982-83 to 1987-88

Spawning area	Average % of seasonal biomass	Average escapement (tons)
San Francisco	63.3	29,246
Sausalito	10.1	4,650
Belvedere-Tiburon	6.0	2,750
Angel Island	4.8	2,198
Oakland-Alameda	4.2	1,960
South Bay	4.1	1,886
Treasure Island	2.1	971
Belvedere Cove	1.4	640
Kiel Cove	1.2	571
Tiburon	1.2	562
Richardson Bay	0.7	303
Richmond	0.6	278
Belvedere	0.3	153
Coyote Point	<0.1	31
Berkeley	0.0	--
Total	100.0	46,199

TABLE 8. Herring Escapement by Area for Tomales Bay, 1973-74 through 1987-88 Seasons.

Eelgrass bed no.	Average escapement (tons)	Average % of annual biomass
1	57	0.87
1A	186	2.85
1B	5	0.08
2	260	3.98
2A	3	0.04
3	69	1.05
3A	1	0.02
4	2	0.03
5	34	0.54
6	61	0.93
7	78	1.20
8	67	1.02
9	650	9.97
10	44	0.67
11	217	3.33
12	6	0.10
13	<1	<0.01
14	1	0.02
15	<1	<0.01
16	157	2.41
16A	29	0.46
17	<1	0.01
18	<1	<0.01
19	64	0.98
20	153	2.35
20A	28	0.44
21	1,442	22.10
22	1,303	19.98
23	926	14.20
24	44	0.68
25	255	3.91
26	256	3.93
27	38	0.58
28	27	0.27
28A	25	0.38
29	6	0.10
Intertidal	30	0.47
*Total	6,531	99.99

*Thirteen years of data; does notinclude 1978-79 or 85-86 season.

TABLE 9. Confidence Limits of the Tomales Bay Herring Spawn Estimates During the 1987-88 Season.

Spawn date	Location	Standard error eggs per m	D.F. N-1	Estimated tons	95% Conf. int.
12/17	1A	79,000	4	170	±77
1/4-6	6, 7, and 25	40,000	13	90	±60
1/4	27, 29	113,000	4	100	±100
1/18	27, 29	223,000	6	150	±120
1/19	7	84,000	3	20	±10
1/19	9	35,000	3	30	±7
1/21	21	29,000	4	730	±125
1/26	9, 11	64,000	7	30	±15
1/31	1, 27	202,000	6	60	±40
Total				1,380	

TABLE 10. Confidence Limits of the San Francisco Bay Herring Spawn Estimates During the 1987-88 Season.

Spawn date	Location	Standard error eggs per m^2	D.F. N-1	Estimated (tons)	95% Conf. int.
11/24-29	Sausalito	200,000	6	130	±30
11/29-30	San Francisco	270,000	6	2,350	±950
12/6-11	San Francisco	270,000	11	3,900	±1,800
12/26-27	San Francisco	420,000	3	1,850	±1,500
12/26-27	Alameda	--	--	15	--*
1/4-5	Treasure Island	600,000	8	1,100	±660
1/4-6	Oakland-Alameda	350,000	20	11,700	±2,100
1/5-7	San Francisco	180,000	7	3,200	±1,300
1/7-8	Sausalito	190,000	3	2,100	±350
1/16-18	Hunters Point	500,000	3	2,100	±2,100
1/16	Candlestick Pt.	--	--	140	--*
1/25	Sausalito	350,000	3	20	±17
1/25-26	San Francisco	80,000	6	2,350	±300
1/26-28	San Francisco	220,000	8	20,200	±3,500
2/8-13	Hunters Point	350,000	11	9,000	±3,200
Total				60,155	

*Quantitative samples were not taken and confidence limits could not be calculated.

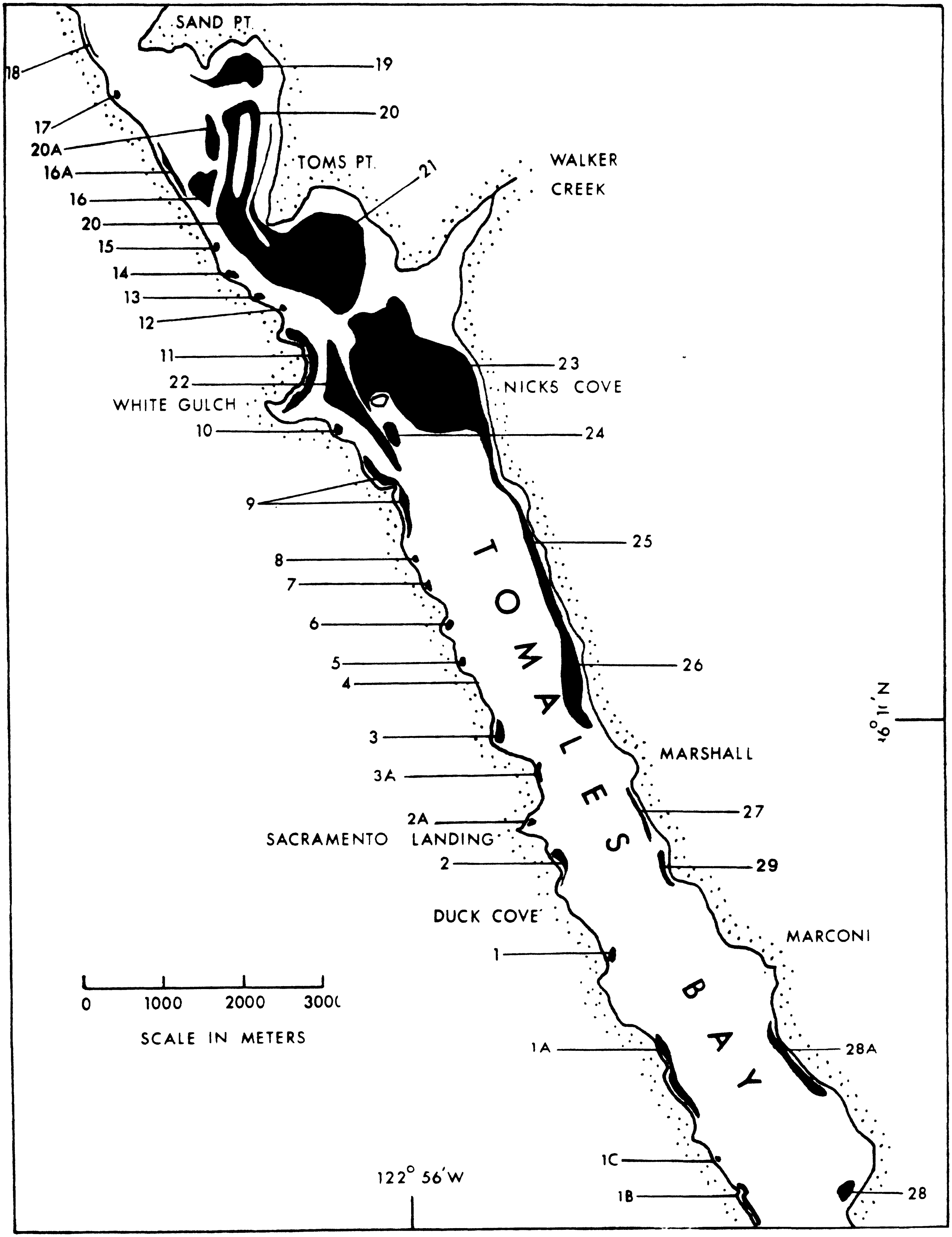

FIGURE 1. Tomales Bay with numbered eelgrass beds.

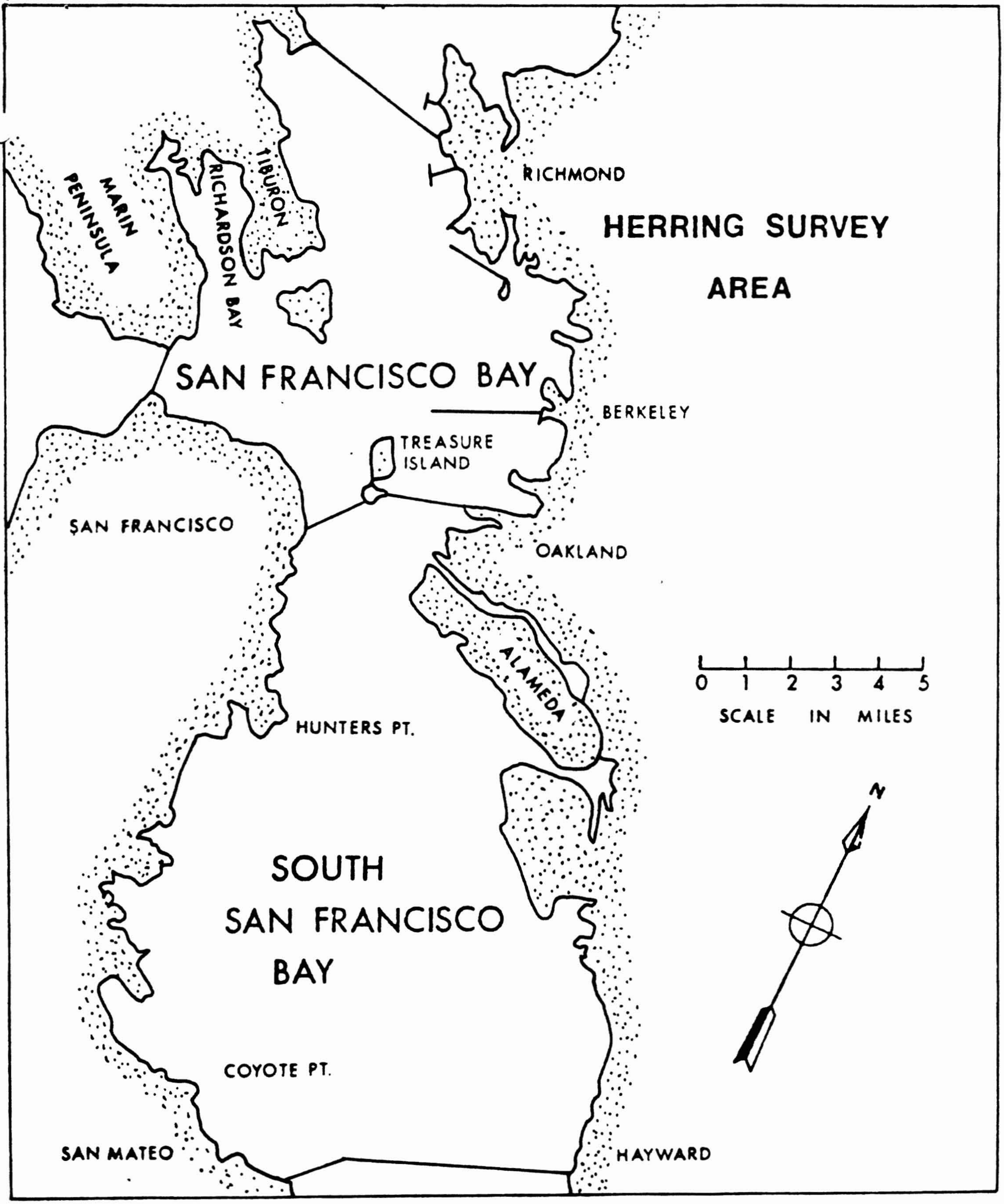

FIGURE 2. San Francisco Bay herring survey area.

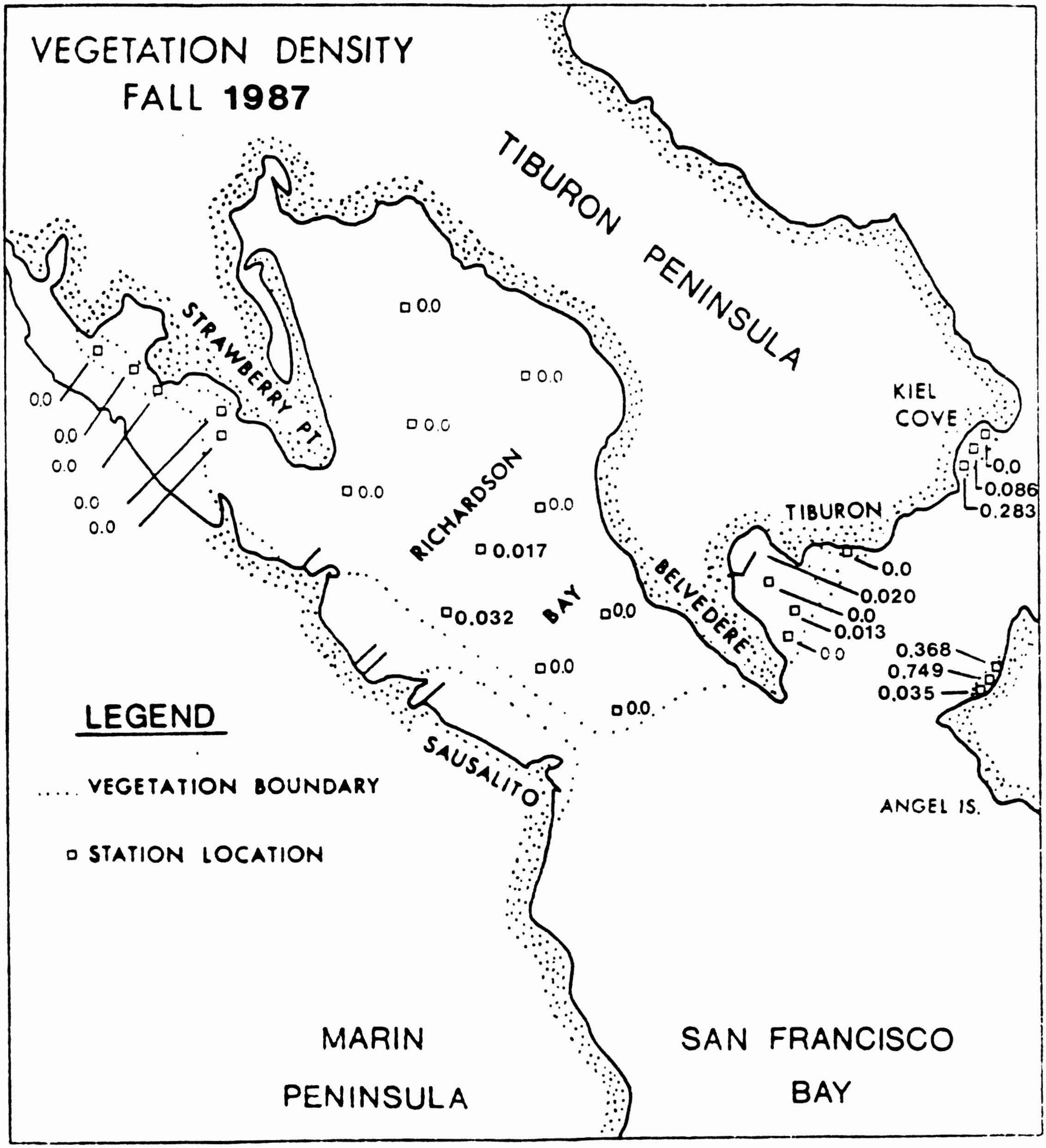

FIGURE 3. **Vegetation densities kg/m^2 in San Francisco Bay in the fall of 1987.**

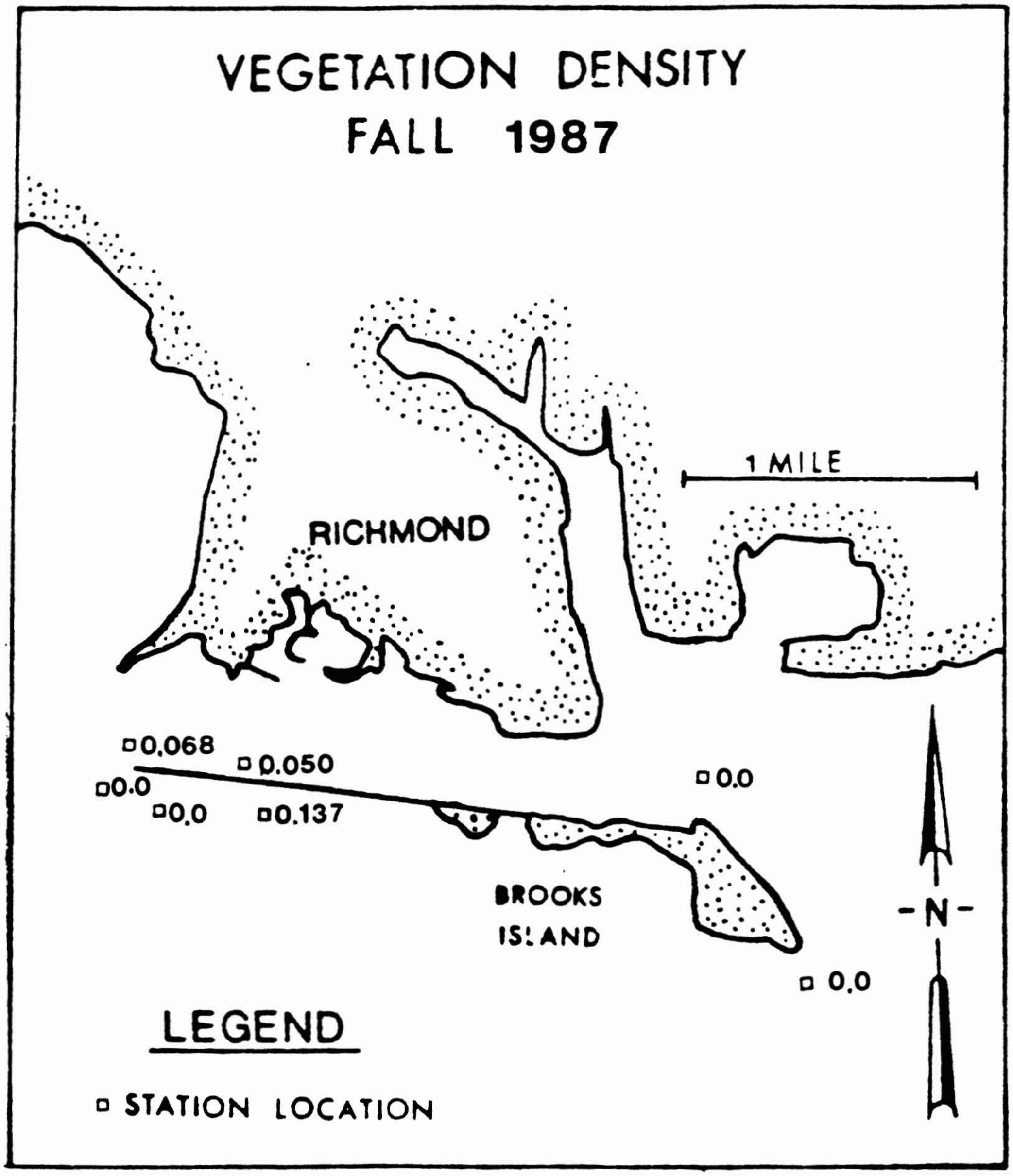

FIGURE 4. Vegetation densities kg/m^2 near Brooks Island San Francisco Bay in the fall of 1987.

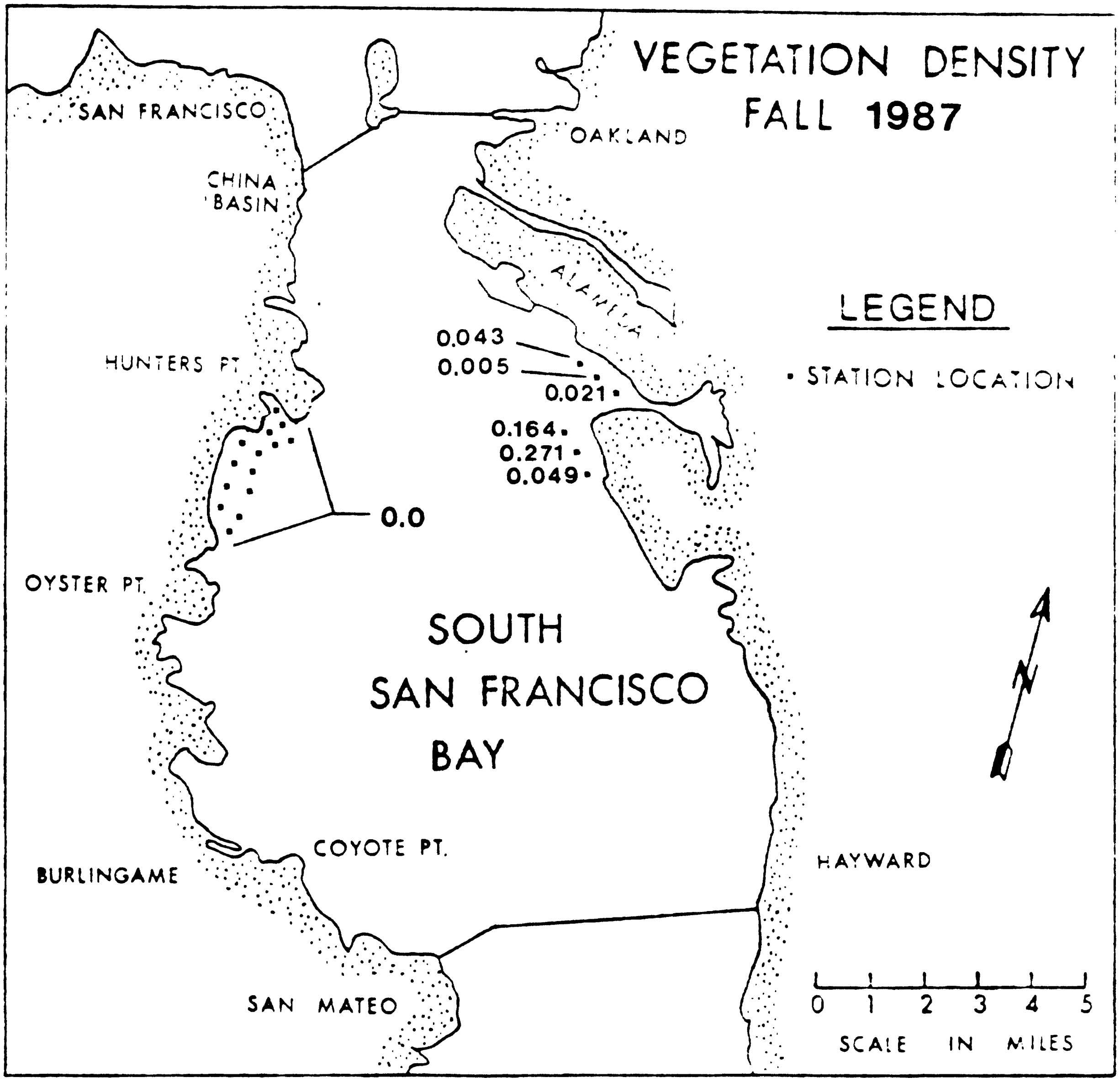

FIGURE 5. Vegetation densities kg/m^2 in south San Francisco Bay in the fall of 1987.

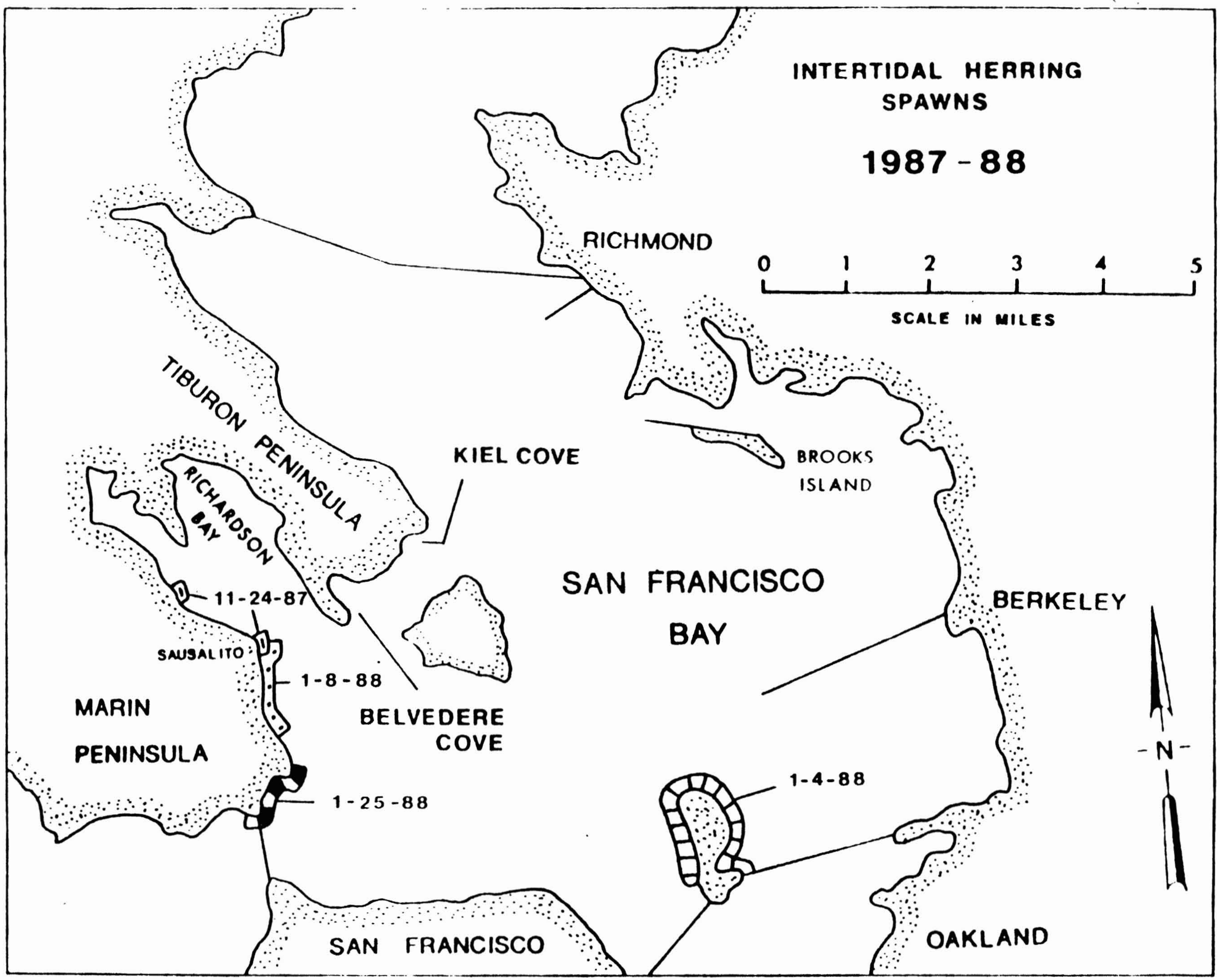

FIGURE 7. Intertidal herring spawning and dates of occurrence in San Francisco Bay during the 1987-88 season.

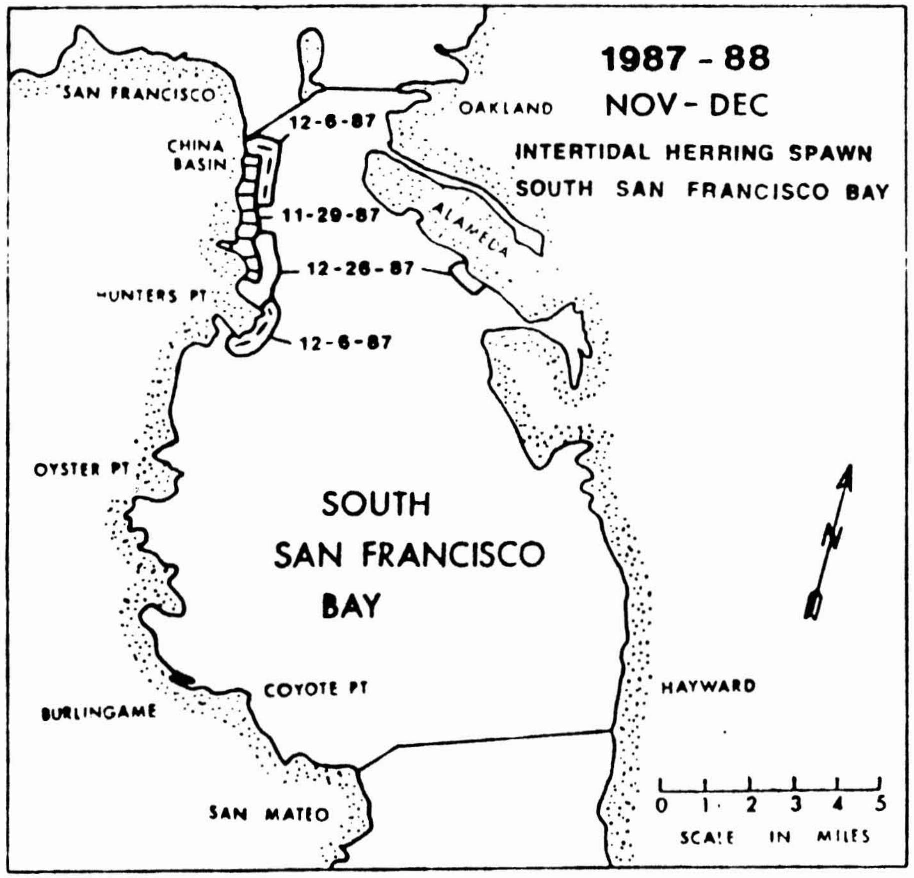

FIGURE 6a. South San Francisco Bay herring spawning during November and December 1987.

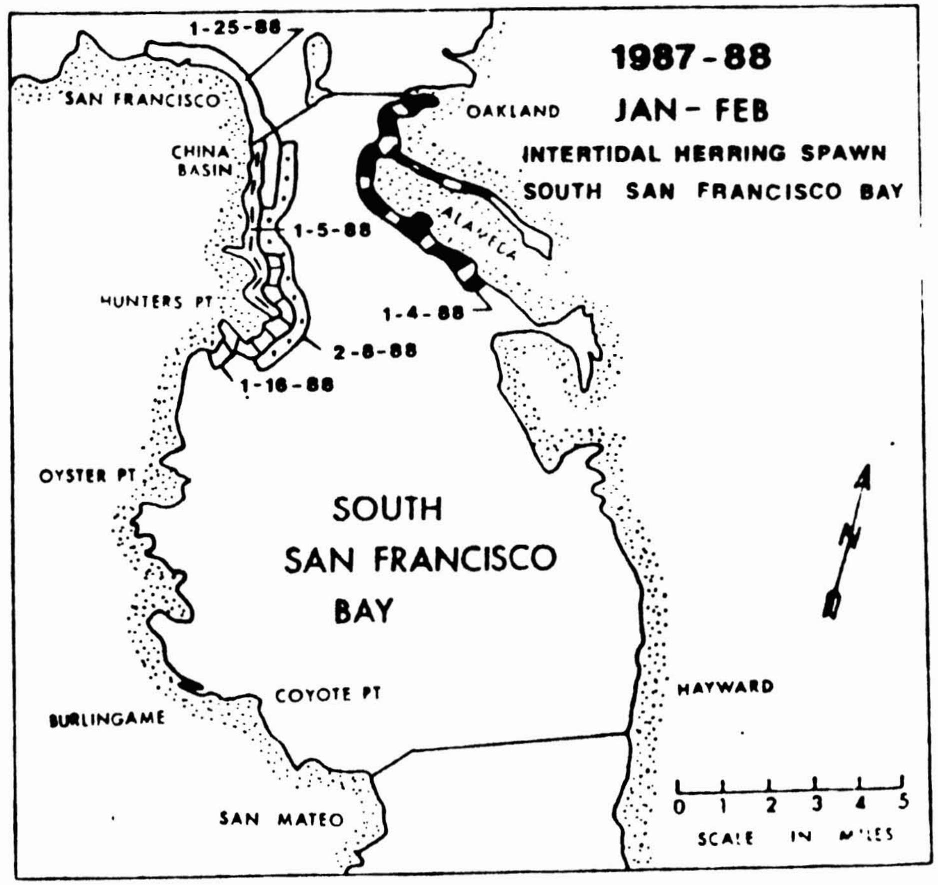

FIGURE 6b. South San Francisco Bay herring spawning during January and February 1988.