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BIOMASS ESTIMATES OF PACIFIC HERRING,  
*CLUPEA HARENGUS PALLASI*, IN CALIFORNIA  
FROM THE 1980-81 SPAWNING GROUND SURVEYS

by

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ABSTRACT

The spawning biomass of Pacific herring in San Francisco Bay and Tomales Bay was estimated to be 65,441 tons and 5,583 tons, respectively during the 1980-81 season. This is the highest estimate to date for San Francisco and continues a rising trend in abundance. The Tomales Bay population has fluctuated around an annual mean of 6,000 tons since 1973.

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1/ Marine Resources Region, Administrative Report No. 82-2

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## ACKNOWLEDGEMENTS

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## INTRODUCTION

In 1973, the California Department of Fish and Game began estimating the annual spawning biomass of Pacific herring (*Clupea harengus pallasii*) in Tomales and San Francisco Bays (Spratt, 1981). Biomass is derived from estimates of eggs deposited during each season. Both bays are relatively small in area and are well suited for intensive spawning ground surveys. Tomales Bay biomass estimates have fluctuated around a mean of 6,000 tons. The San Francisco Bay estimates began to increase in 1978, as sampling techniques were improved. In 1979-80 the spawning biomass was estimated to be nearly 53,000 tons (Spratt, 1981).

This report includes spawning biomass estimates for Tomales Bay and San Francisco Bay during the 1980-81 spawning season and it provides continuous series of annual herring spawning biomass estimates from 1973-74 onward. These data are the basis of the herring roe fishery management plan.

## DESCRIPTION OF STUDY AREA

### Tomales Bay

Tomales Bay 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) mapped the distribution and abundance of marine flora in Tomales Bay and found that eel grass *Zostera marina*, comprised 75 percent by weight of all vegetation in the bay. The distribution of eel grass in Tomales Bay has changed slightly each year (Spratt, 1981). The present distribution (Figure 1)

was determined during March of 1981. Other species of marine flora are utilized as spawning substrate in Tomales Bay, but eel grass is the only spawning substrate included in my surveys.

#### San Francisco

The regular survey area in San Francisco Bay includes all shoreline and shallow subtidal areas to a depth of 4.6 m (15 ft.) bounded by the Golden Gate Bridge, Richmond Bridge and the San Francisco-Oakland Bridge (Figure 2). While most spawns are subtidal in San Francisco Bay, there is also considerable intertidal spawning activity. Intertidal spawns in San Francisco Bay literally cover all available substrate in the area; including, bare rocks, sand, pier pilings and marina flora. The two major subtidal spawning areas are Richardson Bay and the east bay between Richmond and Oakland. They consist of sparse beds of *Gracilaria* spp. interspersed with *Ulva* sp. and some eel grass. The only areas consistently not utilized for spawning are broad mud flats with no vegetation.

#### METHODS

##### Tomales Bay Sampling Techniques

This season's spawning ground surveys were conducted from December 1, 1980 to March 20, 1981. Spawn sampling techniques have remained relatively unchanged since 1973 (Spratt, 1981). Every eel grass bed (Figure 1) was sampled daily from a 4.6-m (15-ft.) boat by towing a vegetation sampler through the bed.

The distribution of eel grass changes yearly; new beds are discovered, old ones disappear, and the area of some beds change significantly.

Every year in March after spawning has nearly stopped, the area of all eel grass beds is remeasured and this new data is used to calculate all of the season's spawns. Previous estimates of eel grass density ranging from 0.5-4.0 kg/m<sup>2</sup> (Spratt, 1981) were applied this season to each bed by subjective, on site inspections.

#### San Francisco Bay Sampling Techniques

Techniques used in San Francisco Bay to estimate spawning biomass have evolved over the years. Before 1978, spawning biomass estimates for San Francisco Bay were determined by sampling intertidal (shoreline) spawns only. In January of 1979, a major subtidal spawn was located in Richardson Bay, and the following season, seven subtidal spawns were located which accounted for 79 percent of the season's spawning activity (Spratt, 1981). In order to compute biomass from subtidal spawns, it is necessary to determine the weight (kg/m<sup>2</sup>) of vegetation present in the spawning area. In the fall of 1979, Department divers collected quantitative samples of vegetation from Richardson Bay. This vegetation survey was expanded in the fall of 1980 to include Belvedere Cove, Tiburon, Kiel Cove (Figure 3) and the east bay between Richmond and Oakland (Figure 4). The boundaries of known vegetation beds were determined by dragging a vegetation sampler through them. Sampling stations were selected randomly by placing a grid over the beds, and numbering points where grid lines intersected. In the east bay, 15 stations were selected and in the Richardson Bay area 20 stations were selected. Divers removed all vegetation from three 0.25-m<sup>2</sup> quadrats at each station. The vegetation was damp dried and weighed to the nearest gram immediately after collection. When a subtidal spawn occurs, the vegetation sampler is used to collect samples and determine spawning area (m<sup>2</sup>). The number

of eggs/kg of vegetation were determined using techniques developed in the 1979-80 season (Spratt, 1981). The estimate of egg deposition is the product of number of eggs/kg vegetation, kg vegetation/m<sup>2</sup>, and spawn area (m<sup>2</sup>).

#### BIOMASS COMPUTATION

The techniques used to estimate total number of eggs deposited during a season differs between Tomales and San Francisco Bays. However, conversion from numbers of eggs spawned to tons of adults is identical for both bays.

Hardwick's (1973) estimate of fecundity was used to convert numbers of eggs to tons of herring. Hardwick estimated fecundity at 114 eggs/gram of herring (both sexes combined) for Tomales Bay herring, and that 103.5 million eggs would be produced by one ton of adult herring.

The total eggs deposited during the season is the sum of the estimates of each individual spawn. The number of eggs spawned is converted to short tons of spawners by the conversion factor of  $.966 \times 10^{-8}$ , which is the reciprocal of fecundity.

#### RESULTS

##### Tomales Bay

Two more eel grass beds were discovered this season; bed 1A near the south end of the bay and, bed 20A which is west of Tom's Point. These two beds were found when large numbers of gulls were observed circling in the area as herring were spawning. These beds may not be newly formed but I believe this is the first time they were utilized for spawning since our survey began. There is now a total of 31 known eel grass beds

in Tomales Bay (Figure 1). Bed measurements in March, 1981 revealed that the total amount of eel grass available for spawning is over 4 million m<sup>2</sup> (Table 1).

The first spawn located this season occurred on December 15, 1980 and a total of six spawning runs occurred utilizing 24 individual spawning sites (Table 2). The last two spawns of the season on February 2 and February 17, 1981 were much larger than estimates indicated. Part of the February second spawn was on eel grass at bed 1A, but the major part of the spawn utilized a *Gracilaria* sp. bed near Sacramento Landing. On February 17, 1981, herring spawned on an extensive bed of *Gracilaria* sp. near Marshall. Both of these spawns are not included in my estimates because no density (kg/m<sup>2</sup>) estimates of *Gracilaria* were available.

I estimate a minimum spawning escapement of 5,135 tons. The commercial herring roe fishery takes herring just prior to spawning, therefore, the spawning biomass estimate for the season should include the catch. The catch of pre-spawners increases the biomass estimate for the 1980-81 season to 5,583 tons of herring. This should be considered a minimum estimate because two significant spawns are not included.

#### San Francisco Bay

Significant subtidal spawning in San Francisco Bay was first discovered during the 1978-79 season and in the following season (1979-80), 79 percent of the spawning biomass estimate was derived from subtidal spawning (Spratt, 1981). Subtidal spawns are now considered to be more important than intertidal (shoreline) spawns.

The known subtidal spawning areas of the bay were surveyed by



Department divers in November of 1980 to estimate the density of vegetation. Vegetation densities were highest in Richardson Bay (.083 kg/m<sup>2</sup>) and Kiel Cove (.0908 kg/m<sup>2</sup>) (Figure 3). The vegetation survey of the east bay revealed a mean density of .002 kg/m<sup>2</sup> except at one station near Berkeley which had a density of .629 kg/m<sup>2</sup> (Figure 4).

The first spawn of the season was located on November 17, 1980 near Tiburon. There were at least 10 spawning runs during the season (Table 3), and spawn was deposited at six locations in the Bay (Figure 5). Subtidal spawns were less than the 1979-80 season, but still accounted for 56 percent of the estimate.

Richardson Bay, Kiel Cove, and associated shoreline accounted for 90 percent of the season's spawning activity. The east bay was apparently less suitable to herring because of the low vegetation densities.

I estimated spawning escapement at 59,615 tons of herring. The commercial herring roe fishery catch of pre-spawners was 5,826 tons. Including the catch, the spawning biomass for the 1980-81 season is 65,441 tons, the highest estimate to date.

#### DISCUSSION

##### Tomales Bay

Spawning ground surveys in Tomales Bay are begun on December first each season. It is possible that some spawning occurs in November, as was demonstrated in San Francisco Bay the past two seasons. However, surveys are conducted to encompass the time of peak spawning activity in the bay, which is January and February. Since 1973, January and February have combined for 86 percent of all spawning activity (Table 4).

Within this time frame, there has been a shift in the time of peak spawning. In the past three years, 91 percent of the spawning has occurred in January.

This shift to earlier spawning began in the 1976-77 season and now appears to be stabilized in January. The cause of this change is not completely understood, but could be related to rainfall. California has been in the midst of a drought of varying degrees that began in 1976.

The Tomales Bay biomass estimate has ranged between 4,728 tons in 1975 and 22,163 tons in 1978 (Table 5). Excluding the anomalous 1978 season, the Tomales Bay estimate averaged nearly 6,000 tons per year. The spawning population in the bay currently appears stable and fluctuates normally from year to year.

#### San Francisco Bay

The months of peak spawning activity in San Francisco Bay are December, January and February (Table 6). However, in the past four seasons there has been a shift in spawning activity to December and January, with over 90 percent of spawning activity completed by the end of January. This same phenomena occurred in Tomales Bay over the past four seasons.

The estimate of herring spawning biomass in San Francisco Bay has more than doubled since the 1976-77 season (Table 7). There is little reason to believe that the population has actually increased. The estimate of spawning biomass has increased due to the following changes in methodology:

(i) extensive subtidal spawning areas were included in surveys beginning with the 1979-80 season, (ii) the month of November was included in surveys beginning with the 1980-81 season.

The estimated herring spawning biomass in San Francisco Bay for the 1980-81 season is 65,441 tons, the highest estimate to date. Fine tuning of methodology, particularly the vegetation surveys, will improve our estimates again next season, but this is not expected to result in a significant increase in the population estimate. Assuming that all the major spawning areas in the bay have been discovered, the population can be expected to fluctuate normally in the future, as the Tomales Bay population does. Herring are noted for natural cycles in abundance and decreases in population size in the future can be expected to occur.

#### REFERENCES

- Hardwick, James E. 1973. Biomass estimates of spawning herring, *Clupea harengus pallasii*, herring eggs, and associated vegetation in Tomales Bay. Calif. Fish and Game, 59(1):36-61.
- Spratt, J. D. 1981. Status of the Pacific herring, *Clupea harengus pallasii*, in California to 1980. California Fish and Game, Fish. Bull., (171):1-104.

TABLE 1. Tomales Bay Eel Grass Beds as Measured in March 1981.

Bed Number	Area (m <sup>2</sup> )	Bed Number	Area (m <sup>2</sup> )
1	5,900	14	1,800
1A	13,500	15	100
2	10,500	16	37,200
3	12,500	16A	11,400
4	100	17	2,200
5	6,150	18	0
6	17,900	19	116,600
7	19,400	20	235,500
8	2,700	20A	55,900
9 North	16,000	21	1,488,000
9 South	19,400	22	140,000
10	4,100	23	1,209,000
11 North	23,000	24	20,900
11 Middle	5,200	25	207,000
11 South	9,900	26	270,000
12	2,400	27	12,400
13	100	28	24,000
TOTAL AREA			4,000,750

Table 2. Herring Spawn Data for Tomales Bay, 1980-81 Season.

<u>Date</u>	<u>Location*</u>	<u>Area (m<sup>2</sup>)</u>	<u>No. eggs per kg eel grass</u>	<u>Kg. eel grass per m<sup>2</sup></u>	<u>No. eggs per m<sup>2</sup></u>	<u>Millions eggs</u>	<u>Tons</u>
15 Dec 80	2	10,500	694,000	1.9	1,318,000	13,839	130
16 Dec 80	11	23,000	5,000	1.9	9,500	218	2
17 Dec 80	21	29,000	40,000	1.5	59,500	1,725	20
18 Dec 80	1A	13,500	155,000	1.9	295,900	3,982	40
4 Jan 81	10	4,100	219,000	1.9	416,000	1,706	20
4 Jan 81	11	33,000	284,000	1.9	540,000	17,820	170
4 Jan 81	21	84,000	37,000	1.5	55,500	4,662	40
4 Jan 81	22	140,000	261,000	1.9	496,000	69,426	670
6 Jan 81	6	18,000	360,300	1.9	684,600	12,312	120
6 Jan 81	7	19,400	335,000	1.9	636,000	12,338	120
6 Jan 81	9	35,400	510,000	1.9	969,000	34,302	330
6 Jan 81	16	37,200	484,000	4.0	1,936,000	72,019	700
6 Jan 81	20	2,900	69,000	1.5	103,000	299	3
6 Jan 81	20A	56,000	454,000	1.5	681,000	38,136	370
6 Jan 81	21	84,000	66,000	1.5	99,000	8,316	80
24 Jan 81	1A	13,500	1,337,000	1.9	2,540,000	34,290	330
24 Jan 81	1	5,900	1,109,000	1.9	2,108,000	12,437	120
25 Jan 81	3	12,500	89,500	1.9	170,000	2,125	20
25 Jan 81	11	11,500	70,500	1.9	134,000	1,541	10
25 Jan 81	21	150,000	462,000	1.5	693,000	103,950	1,000
25 Jan 81	22	110,000	374,000	1.9	711,000	78,210	760
25 Jan 81	23	103,000	39,300	1.5	59,000	6,077	60
2 Feb 81	1A						Trace
17 Feb 81	9	19,400	43,000	1.9	81,700	1,585	20
TOTAL		1,015,800				531,315	5,135

\*See Figure 1

Table 3. Herring Spawn Data for San Francisco Bay, 1980-81 Season.

<u>Date</u>	<u>Location</u>	<u>Area (m<sup>2</sup>)</u>	<u>No. eggs per kg vegetation</u>	<u>kg vegetation per m<sup>2</sup></u>	<u>No. eggs per m<sup>2</sup></u>	<u>Millions eggs</u>	<u>Tons</u>
16-19 Nov. 80	Belvedere Tiburon	180,000	*	*	713,000	128,340	1,200
17 Nov 80	Kiel Cove	67,000	2,827,000	.900	2,544,000	170,448	1,600
17 Nov 80	Pt. Tiburon	5,000	259,000	.170	44,000	220	2
1-4 Dec 80	Richmond	117,000	*	*	1,321,000	154,557	1,500
1-4 Dec 80	Richmond	2,600,000	953,000	.043	41,000	106,600	1,000
7-9 Dec 80	Belvedere Tiburon	128,000	*	*	1,543,000	197,504	1,900
7-9 Dec 80	Pt. Tiburon	5,000	14,100,000	.170	2,397,000	11,985	100
7-9 Dec 80	Kiel Cove	67,000	650,000	.900	585,000	39,195	400
21-22 Dec 80	Richardson Bay	1,463,000	3,042,000	.240	730,000	1,067,990	10,300
21-22 Dec 80	Sausalito	163,000	*	*	3,000,000	489,000	4,700
21-22 Dec 80	Belvedere	71,000	*	*	2,223,000	157,833	1,500
6-8 Jan 81	Richardson Bay	6,900,000	2,709,000	.093	252,000	1,741,392	16,800
7-10 Jan 81	Sausalito	54,000	*	*	2,398,000	129,492	1,300
7-10 Jan 81	Belvedere Tiburon	29,000	*	*	1,091,000	31,639	300
7-10 Jan 81	Kiel Cove	67,000	5,781,000	.900	5,203,000	348,601	3,400
8-9 Jan 81	Angel Island	150,000	*	*	2,456,500	368,400	3,600
15 Jan 81	Treasure Island	71,000	*	*	3,761,000	267,031	2,600
27 Jan 81	Angel Island	63,000	*	*	1,576,000	99,288	1,000
6-7 Jan 81	Sausalito	134,000	*	*	1,338,000	179,292	1,700
6-7 Jan 81	Richardson Bay	3,470,000	70,000	.010	700	2,429	20

Table 3. (Cont'd)

<u>Date</u>	<u>Location</u>	<u>Area (m<sup>2</sup>)</u>	<u>No. eggs per kg vegetation</u>	<u>kg vegetation per m<sup>2</sup></u>	<u>No. eggs per m<sup>2</sup></u>	<u>Millions eggs</u>	<u>Tons</u>
16 Feb 81	P. Diablo		Not sampled				
23 Feb 81	Richardson Bay	209,000	160,000	.010	1,600	334	3
24 Feb 81	Kiel Cove	67,000	4,348,000	.900	3,913,000	262,171	2,500
24-25 Feb 81	Tiburon	81,000	*	*	2,718,000	220,158	2,100
5 Mar 81	Richmond	8,400	*	*	1,084,000	9,106	90
Total		16,169,400				6,183,005	59,615

\* These are intertidal spawns and vegetation parameters are not used.

TABLE 4. Tomales Bay Monthly Herring Spawning Biomass, Expressed as a Percent of Season Total.

<u>Season</u>	<u>Month</u>			
	<u>Dec</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>
1973-74	9	36	55	-
1974-75	10	65	22	3
1975-76	6	68	25	1
1976-77	42	49	5	4
1977-78	5	93	2	-
1978-79	No Survey was conducted			
1979-80	12	86	2	-
1980-81	4	95	1	-
Monthly Average	13	70	16	1



TABLE 5. Tomales Bay Pacific Herring Spawning Biomass Estimates, 1973-74 through 1980-81 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	21,517	646	22,163
1978-79	-	448	-
1979-80	5,420	603	6,023
1980-81	5,135	448	5,583

**TABLE 6.** San Francisco Bay Monthly Herring Spawning Biomass, Expressed as a Percent of Seasonal Total.

<u>Season</u>	<u>Month</u>				
	<u>Nov*</u>	<u>Dec</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>
1973-74	-	8	-	45	47
1974-75	-	1	66	33	-
1975-76	-	12	62	21	5
1976-77	-	18	33	49	-
1977-78	-	52	44	4	-
1978-79	-	14	76	10	-
1979-80	5	72	14	9	-
1980-81	5	36	48	10	1
Monthly Average	1	27	43	23	6

\*November was not surveyed prior to the 1979-80 season.

TABLE 7. San Francisco Bay Pacific Herring Spawning Biomass Estimates, 1973-74 through 1980-81 Seasons.

Season	Spawn estimate (tons)	Catch (tons)	Spawning biomass (tons)
1973-74	4,241	1,938	6,179
1974-75	26,820	514	27,334
1975-76	25,318	1,719	27,037
1976-77	22,375	4,201	26,576
1977-78	3,682	4,987	8,669
1978-79	32,580	4,121	36,701
1979-80	46,439	6,430	52,869
1980-81	59,615	5,826	65,441

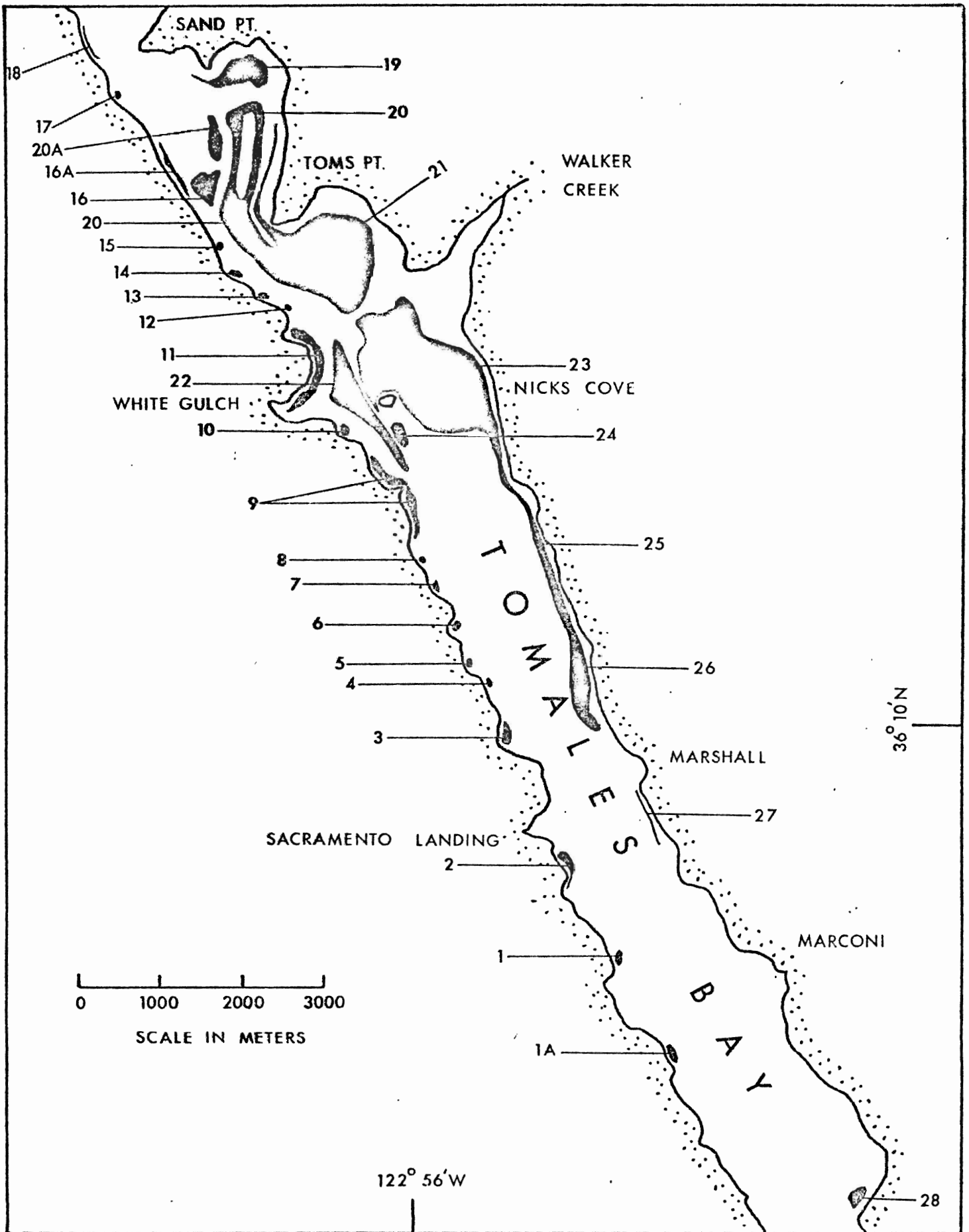


FIGURE 1. Tomales Bay with numbered eel grass beds.

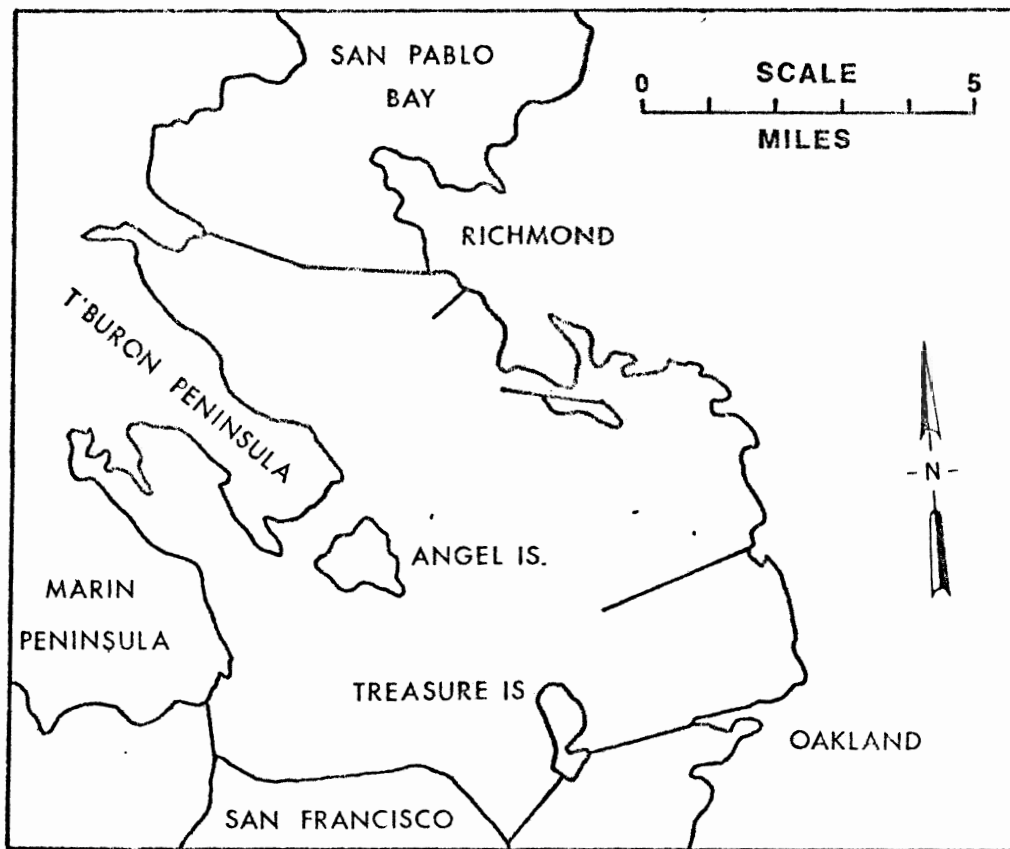


FIGURE 2. Herring spawn survey area in San Francisco Bay.

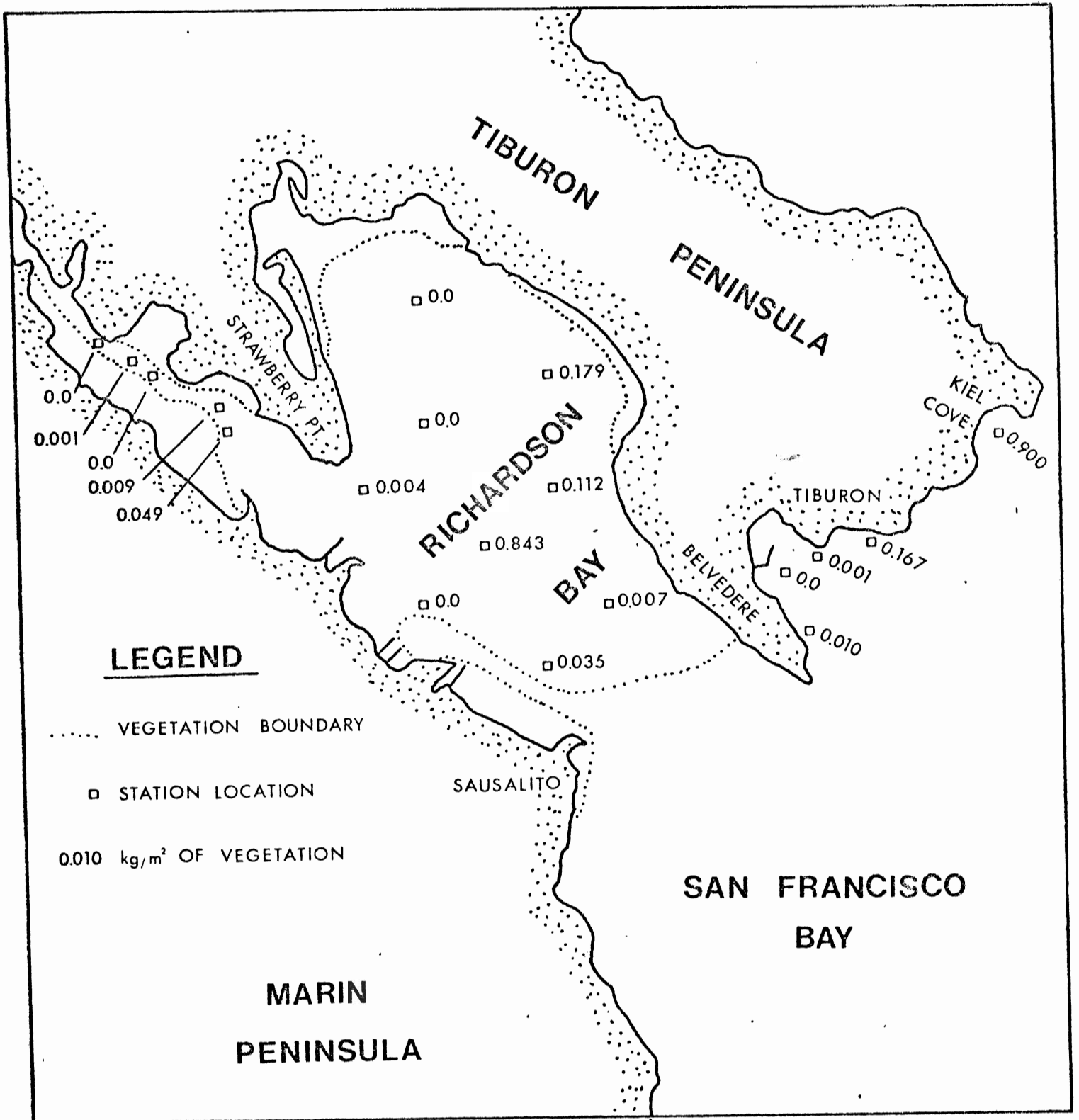


FIGURE 3. Richardson Bay vegetation density (kg/m<sup>2</sup>) in the fall of 1980.

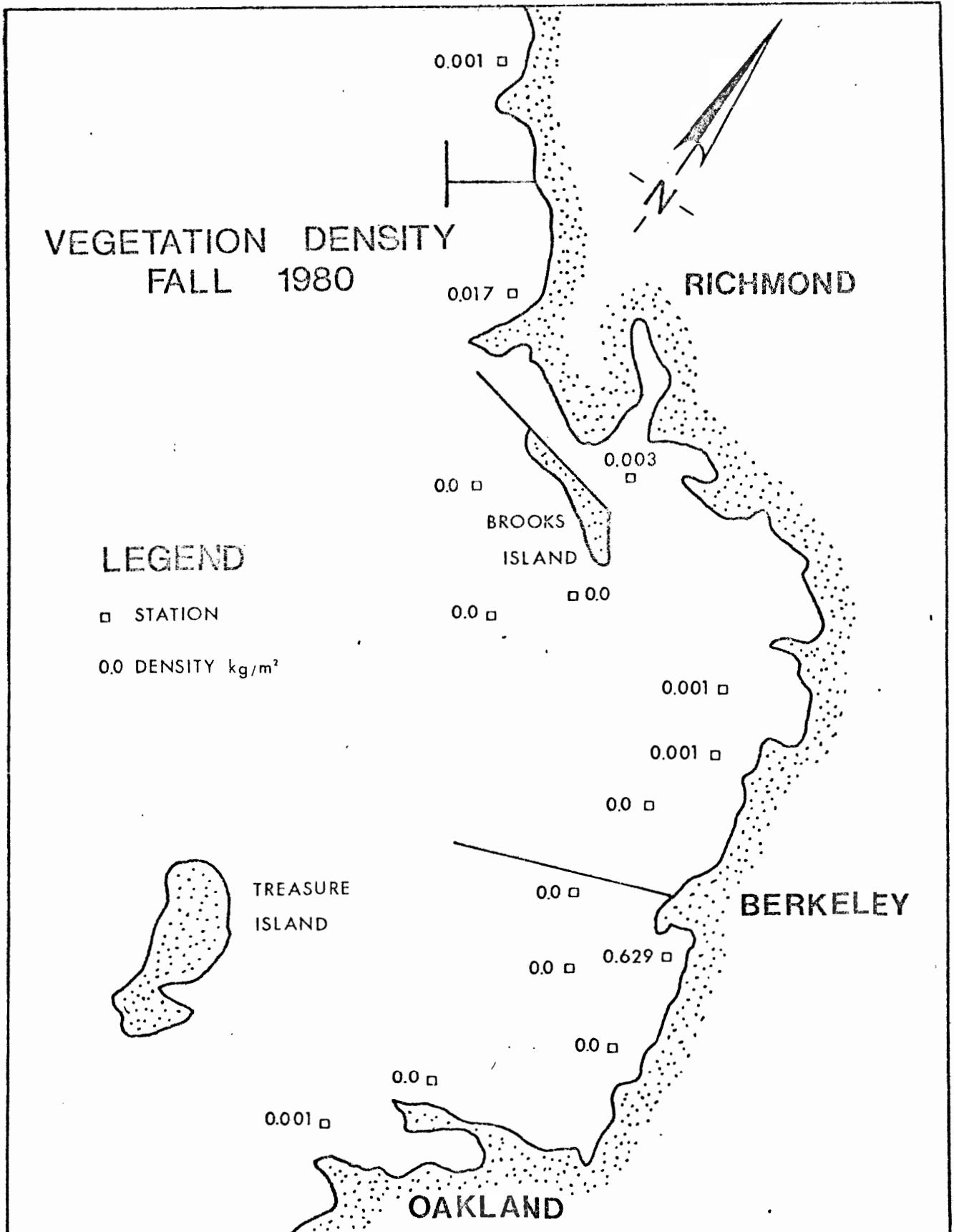


FIGURE 4. East San Francisco Bay vegetation density (kg/m<sup>2</sup>) in the fall of 1980.

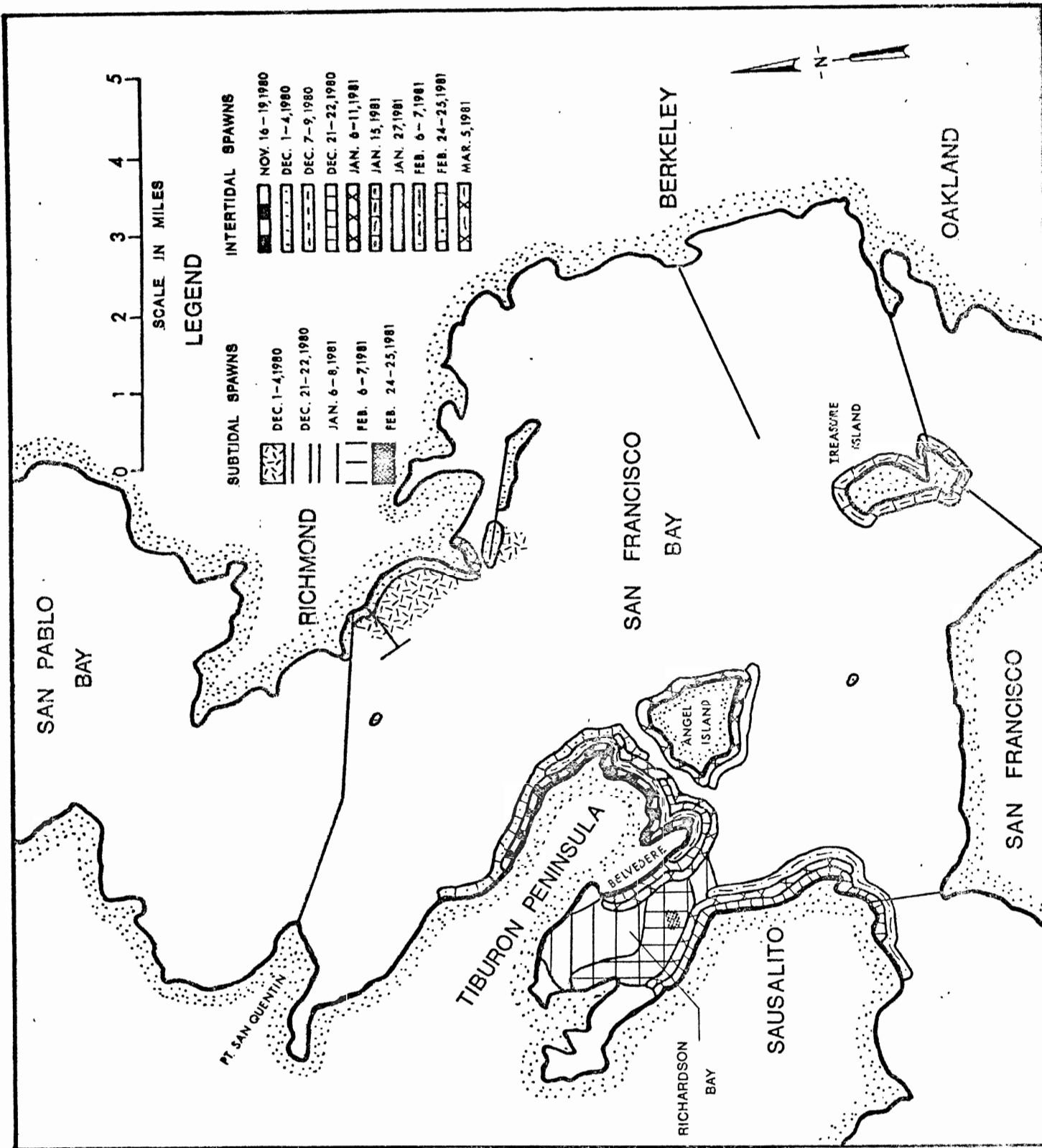


FIGURE 5. Dates and locations of San Francisco Bay herring spawns during the 1980-81 season.