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BIOMASS ESTIMATES OF PACIFIC HERRING,  
*CLUPEA HARENGUS PALLASI*, IN CALIFORNIA  
FROM THE 1981-82 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 99,495 tons and 7,149 tons, respectively during the 1981-82 season. This is the highest estimate to date for San Francisco Bay and continues a rising trend in abundance. The Tomales Bay population increased to the highest level in 4 years.

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## ACKNOWLEDGEMENT

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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 1980-81 the spawning biomass was estimated to be over 65,000 tons (Spratt, 1982).

This report includes spawning biomass estimates for Tomales Bay and San Francisco Bay during the 1981-82 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 1982. 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). The first major spawn outside the regular survey area occurred this season in south San Francisco Bay between Coyote Point and China Basin (Figure 6). This area will be incorporated into future spawn surveys. 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 marine flora. The two major subtidal spawning areas are Richardson Bay and the east bay between Richmond and Oakland. They consists of sparse beds of *Gracilaria* spp. interspersed with *Ulva* sp. and some eel grass. The only shallow 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, 1981 to March 19, 1982. 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 areas of some beds change significantly.

Every year in March, after spawning has nearly stopped, the areas of all eel grass beds are remeasured and these new data are 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

This season's spawning ground surveys were conducted from November 17, 1981 until March 12, 1982. Techniques used in San Francisco Bay to estimate spawning biomass have evolved over the years (Spratt, 1981) and currently the major sampling effort is on subtidal spawns, although intertidal (shore-line) spawns still account for a significant part of each season's spawning activity. In order to compute biomass from subtidal spawns, it is necessary to determine the weight ( $\text{kg/m}^2$ ) of vegetation present in the spawning area. Each fall, Department divers collect quantitative samples of vegetation from Richardson Bay, Belvedere Cove, Tiburon, Kiel Cove and the east bay between Richmond and Oakland. The boundaries of known vegetation beds were determined by dragging a vegetation sampler through them. Permanent sampling stations were selected randomly by placing a grid over the beds, the numbering points where grid lines intersected. In the east bay 27 stations were selected, and in the Richardson Bay area 24 stations were selected. Divers removed all vegetation from three  $0.25\text{-m}^2$  quadrats at each station. The vegetation was damp dried and weighed to the nearest gram immediately after collection.

When a subtidal spawn occurred, the vegetation sampler was used to collect samples and determine spawning area ( $\text{m}^2$ ). The number of eggs/km of vegetation was determined using techniques developed in the 1979-80 season (Spratt, 1981). The estimate of egg deposition is the product of number of eggs/km vegetation,  $\text{kg vegetation/m}^2$ , and spawn area ( $\text{m}^2$ ).

#### Biomass Computation

The techniques used to estimate total number of eggs deposited during a season differ 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 multiplying by  $.966 \times 10^{-8}$ , the reciprocal of fecundity per ton of adult herring.

## RESULTS

### Tomales Bay

Another eel grass bed was discovered this season: bed 28A near the south end of the bay. This bed was found when large numbers of gulls were observed circling in the area as herring were spawning. This bed may not have been newly formed but I believe it was the first time it was utilized for spawning since our survey began. There is now a total of 32 known eel grass beds in Tomales Bay (Figure 1). Bed measurements in March, 1982 revealed that the total amount of eel grass available for spawning declined slightly to 3.9 million  $m^2$  (Table 1).

The first spawn located this season occurred on November 30, 1981, and a total of nine spawning runs occurred utilizing 23 individual spawning sites (Table 2).

I estimate a minimum spawning escapement of 6,298 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 1981-82 season to 7,149 tons of herring.

### San Francisco Bay

The known subtidal spawning areas of the bay were surveyed by Department divers in November of 1981 to estimate the density of vegetation. Vegetation densities were highest in Richardson Bay ( $.480 \text{ kg/m}^2$ ) and Kiel Cove ( $.579 \text{ kg/m}^2$ ) (Figure 3). The vegetation survey of the east bay revealed a much lower mean density of  $.009 \text{ kg/m}^2$  with 78 percent of the stations barren (Figure 4).

The first spawn of the season was located on November 5, 1981 near Tiburon. There were at least 11 spawning runs during the season (Table 3), and spawn was deposited at six locations in the Bay (Figures 5, 6 and 7) including the first major spawn to occur in south San Francisco Bay. Subtidal spawns accounted for 77 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 less suitable to herring because of the low vegetation densities.

I estimated spawning escapement at 89,080 tons of herring. The commercial herring roe fishery catch of pre-spawners was 10,415 tons. Including the catch, the spawning biomass for the 1981-82 season was 99,495 tons, the highest estimate to date. Two spawns near Tiburon on March 13 and April 11 occurred after our surveys terminated and were not included in estimates.

#### DISCUSSION

##### Tomales Bay

Spawning ground surveys in Tomales Bay are begun on December first each season. Since 1973, January and February have combined for 88 percent of all spawning activity. Within this time frame, there has been a shift in the time of peak spawning. In the past 3 years, 92 percent of the spawning has occurred in January.

The Tomales Bay biomass estimate has ranged between 4,728 tons in 1975 and 22,163 tons in 1978 (Table 4). Excluding the anomalous 1978 season, the Tomales Bay estimate has 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. However, from the 1977-78 to 1980-81 seasons over 90 percent of spawning activity was completed by the end of January (Spratt, 1982). In the 1981-82 season there were more large spawnings and more late



season spawnings reflecting the season's larger spawning biomass. February and March accounted for 40 percent of the season's spawning activity.

The estimate of herring spawning biomass in San Francisco Bay has increased since the 1976-77 season (Table 5). Until this season, increases in the estimate of spawning biomass have been attributed to the following changes in methodology: (i) extensive subtidal spawning areas were included in surveys beginning with the 1979-80 season, and (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 1981-82 season is 99,495 tons, the highest estimate to date, and an increase of 50 percent over the 1980-81 estimate of 65,441 tons. There were no changes in methodology this season. The population increased due to excellent survival rates of the 1978, 1979 and 1980 year classes. Herring are noted for natural cycles in abundance and the San Francisco Bay population may continue to increase or may stabilize at a high level for several years. However, at some point in the future the population is likely to decline due to unfavorable environmental conditions.

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. Calif. Fish and Game, Fish. Bull., (171):1-104.

\_\_\_\_\_. 1982. Biomass estimates of Pacific herring, *Clupea harengus pallasii*, in California from the 1980-81 spawning ground surveys. Calif. Dept. Fish and Game, Mar. Resource Admin. Rept. 82-2:1-21.

TABLE 1. Tomales Bay Eel Grass Beds as Measured in March 1982.

Bed number	Area (m <sup>2</sup> )	Bed number	Area (m <sup>2</sup> )
1	4,800	14	1,400
1A	24,900	15	100
2	7,150	16	42,200
3	2,100	16A	14,600
4	100	17	2,200
5	8,400	18	0
6	9,400	19	116,600
7	8,100	20	235,500
8	11,000	20A	55,900
9 North	19,800	21	1,488,000
9 South	18,200	22	140,000
10	4,100	23	1,209,000
11 North	15,400	24	20,900
11 Middle	7,500	25	165,000
11 South	2,600	26	160,000
12	2,400	27	52,000
13	100	28	21,000
		28A	11,800
TOTAL AREA			3,882,250

TABLE 2. Herring Spawn Data for Tomales Bay, 1981-82 Season.

Date	Location*	area (m <sup>2</sup> )	No. eggs per kg eel grass	Kg eel grass per m <sup>2</sup>	No. eggs per m <sup>2</sup>	Millions of eggs	Tons
30 Nov 81	1A	24,900	118,000	1.9	224,000	5,578	54
15 Dec 81	1A	13,500	7,400	1.9	14,000	5,578	2
22 Dec 81	6	9,400	237,000	1.9	450,000	4,230	41
22 Dec 81	7	8,100	91,000	1.9	173,000	1,401	14
22 Dec 81	8	11,000	245,000	1.9	465,000	5,115	49
22 Dec 81	23	94,000	28,000	1.9	53,000	4,982	48
22 Dec 81	24	20,900	21,000	1.9	40,000	836	8
6 Jan 82	7	8,100	38,700	1.9	735,000	5,953	57
6 Jan 82	8	11,000	162,000	1.9	308,000	3,388	33
6 Jan 82	9	38,000	74,000	1.9	141,000	5,358	52
6 Jan 82	21	150,000	64,000	1.5	96,000	14,400	139
6 Jan 82	22	144,000	333,000	1.9	633,000	91,152	880
19 Jan 82	3	2,100	2,600	1.9	5,000	10	Trace
24 Jan 82	23	232,000	327,000	1.5	490,000	113,680	1,098
25 Jan 82	11	22,900	173,000	1.9	329,000	7,543	73
25 Jan 82	21	167,000	252,000	1.5	378,000	63,126	610
25 Jan 82	22	144,000	1,039,000	1.9	1,975,000	284,400	2,747
7 Feb 82	1	4,800	4,600	1.9	8,700	42	trace
7 Feb 82	28A	11,800	180,000	1.9	343,000	4,047	39
17 Feb 82	1	4,800	124,000	1.9	236,000	1,132	11
18 Feb 82	1A	13,500	71,000	1.9	135,000	1,822	18
28 Feb 82	1	4,800	666,000	1.9	1,265,000	6,072	59
28 Feb 82	1A	24,900	583,000	1.9	1,108,000	27,589	266
<b>Total</b>		<b>1,165,500</b>				<b>652,045</b>	<b>6,298</b>

\* See Figure 1.

TABLE 3. San Francisco Bay Herring Spawn Data, 1981-82 Season.

Date	Location	Area (m <sup>2</sup> )	No. eggs per kg vegetation	Kg vegetation per (m <sup>2</sup> )	No. eggs per (m <sup>2</sup> )	Millions of eggs	Tons
5-6 Nov 81	Kiel Cove	67,000	233,000	.580	135,000	9,045	90
18-19 Nov 81	Richardson Bay	2,716,000	205,000	.400	82,000	222,567	2,150
28-29 Nov 81	Richardson Bay	3,971,000	140,000	.450	63,000	250,173	2,420
2-3 Dec 81	Treasure Island	7,300	*	*	771,000	5,628	50
2-3 Dec 81	Treasure Island	41,000	3,688,000	.500	1,844,000	75,604	730
8-9 Dec 81	Angel Island	127,000	*	*	350,000	44,450	430
9-10 Dec 81	Sausalito	38,000	*	*	913,000	34,694	340
22-27 Dec 81	Richardson Bay	5,330,000	1,500,000	.260	390,000	2,078,700	20,080
5-8 Jan 82	Sausalito	238,000	*	*	3,157,000	751,366	7,260
17-22 Jan 82	Richardson Bay	4,284,000	695,000	.400	278,000	1,190,952	11,500
21-22 Jan 82	Sausalito	67,000	*	*	2,871,000	192,357	1,860
25 Jan- 2 Feb	South Bay	290,000	*	*	2,641,000	765,890	7,400
10-12 Feb 82	Richardson Bay	5,120,000	3,418,000	.110	376,000	1,925,120	18,600
16-17 Feb 82	Tiburon	109,000	*	*	1,044,000	113,796	1,100
17 Feb 82	Kiel Cove	67,000	976,000	.580	566,000	37,922	370
28 Feb 82	Richardson Bay	3,761,000	44,000	.240	10,500	39,490	380
5-6 Mar 82	Tiburon	129,000	*	*	1,288,000	166,152	1,600
5-6 Mar 82	Kiel Cove	67,000	4,353,000	.580	2,525,000	169,175	1,630
7-8 Mar 82	Richardson Bay	<u>4,284,000</u>	1,117,000	.240	268,000	<u>1,148,112</u>	<u>11,090</u>
TOTAL		30,713,300 .				9,221,193	89,080

\* This is an intertidal spawn (shoreline) and vegetation parameters are not used.

TABLE 4. Tomales Bay Pacific Herring Spawning Biomass Estimates 1973-74 through 1981-82 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	5,128	448	5,576
1981-82	6,298	851	7,149

TABLE 5. San Francisco Bay Pacific Herring Spawning Biomass Estimates 1973-74 through 1981-82 Seasons.

<u>Season</u>	<u>Spawn estimate (tons)</u>	<u>Catch (tons)</u>	<u>Spawning biomass (tons)</u>
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
1981-82	89,080	10,415	99,495

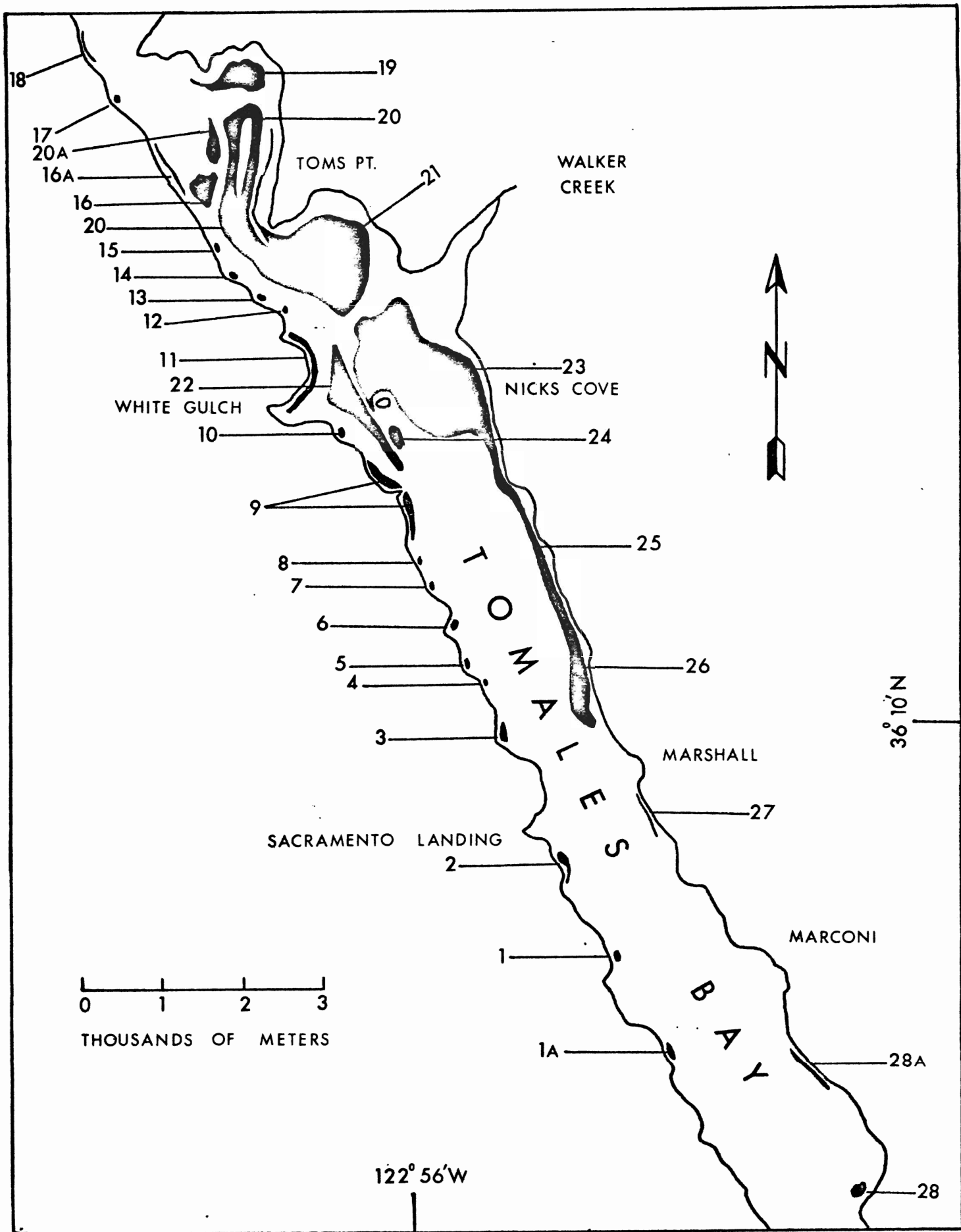


FIGURE 1. Tomales Bay with numbered eel grass beds.



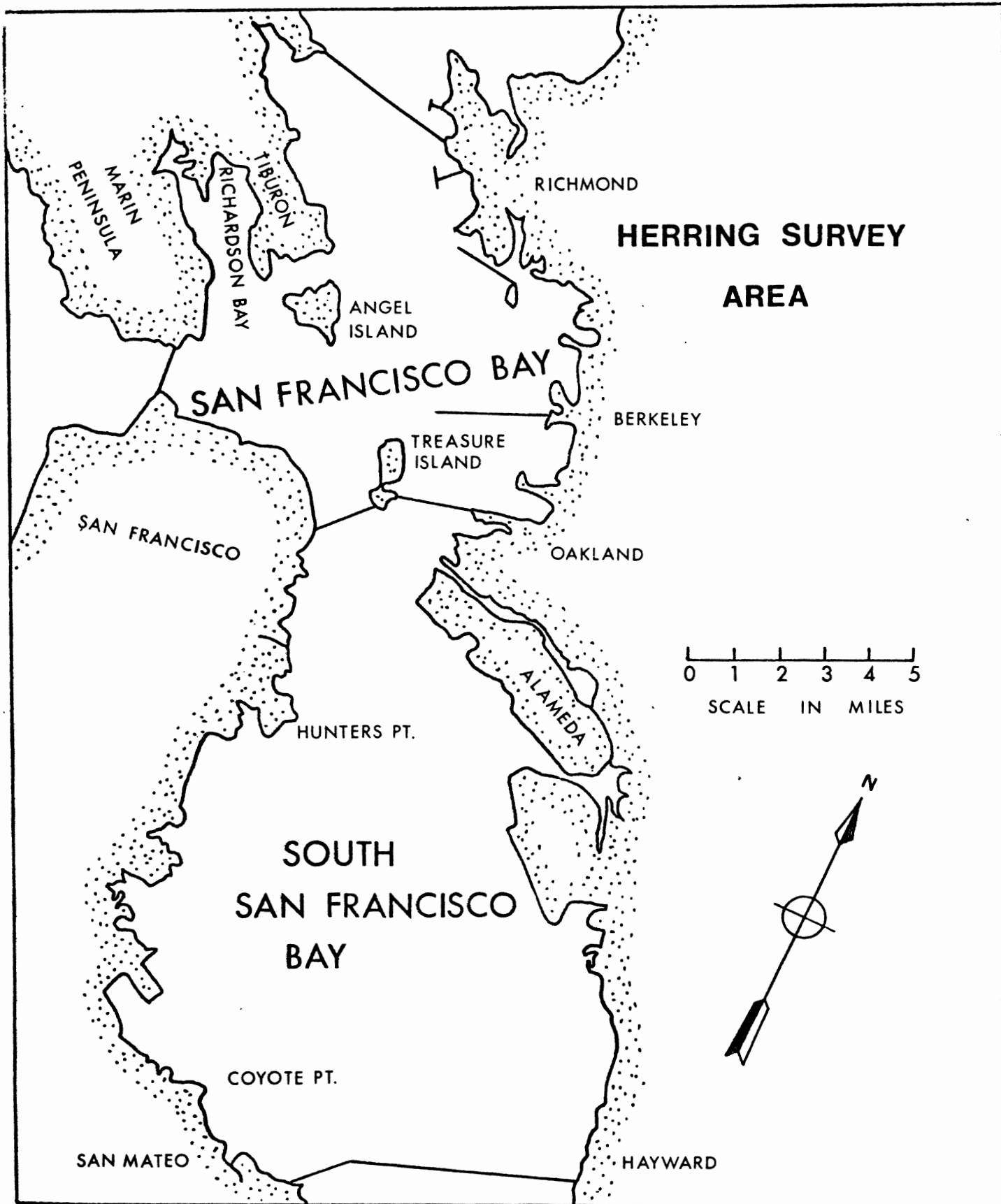


FIGURE 2. Herring spawning ground survey area in San Francisco Bay.

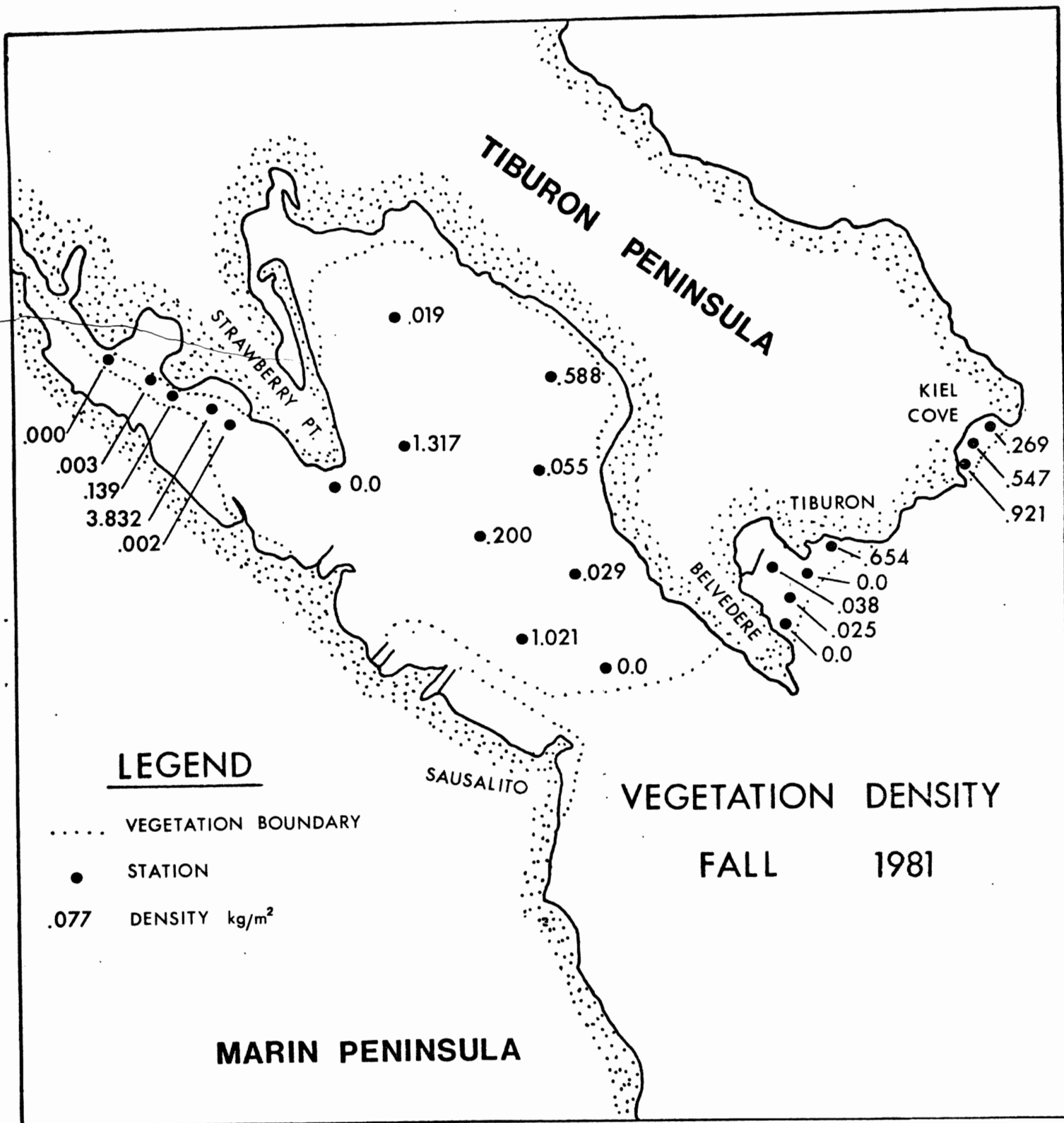


FIGURE 3. Vegetation density kg/m<sup>2</sup> in the Richardson Bay area in the fall of 1981.

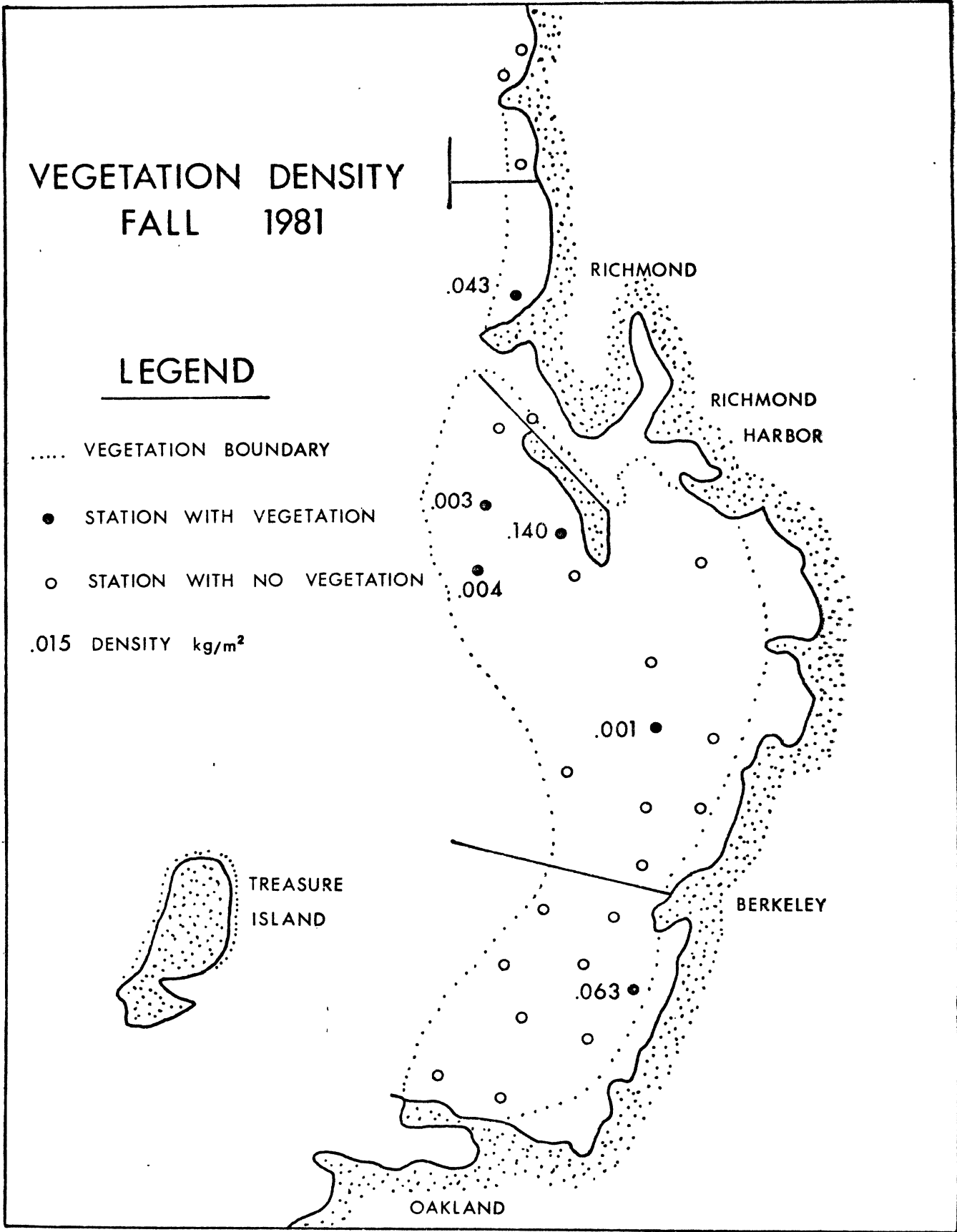


FIGURE 4. Vegetation density kg/m<sup>2</sup> in the eastern part of San Francisco Bay in the fall of 1981.

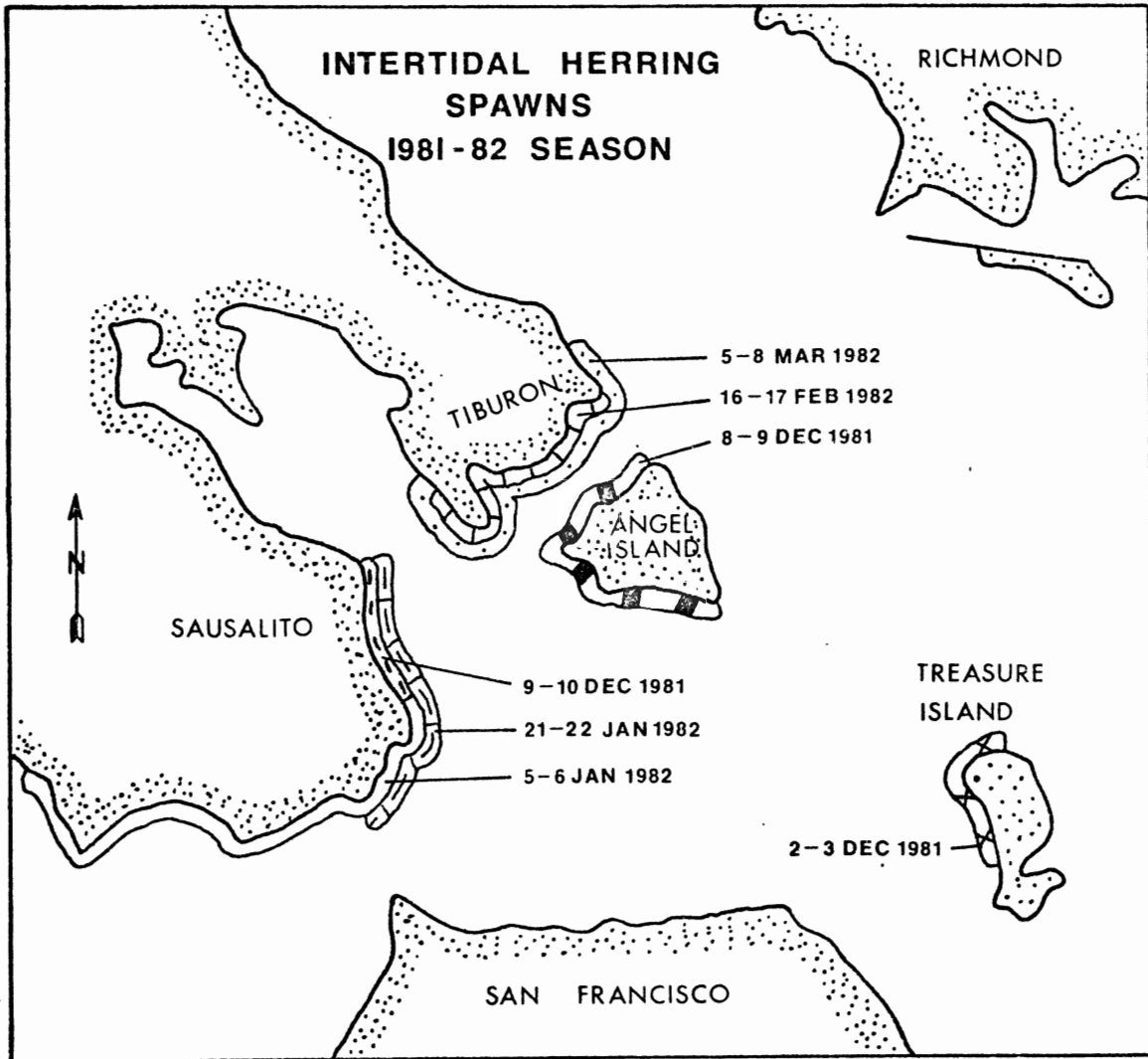


FIGURE 5. Intertidal herring spawnings and dates of occurrence in San Francisco Bay during the 1981-82 season.

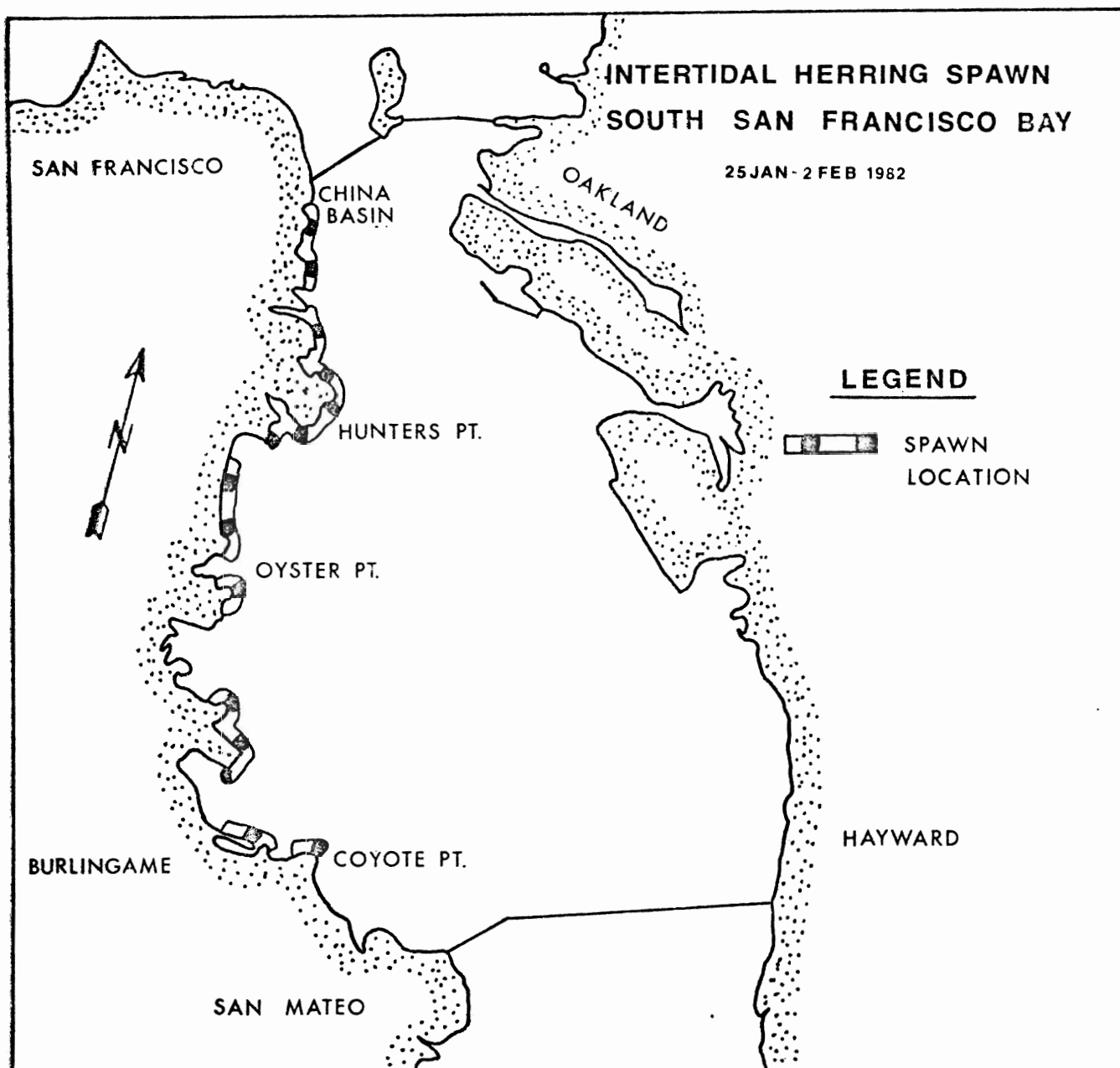


FIGURE 6. Location of intertidal spawning in south San Francisco Bay during the 1981-82 season.

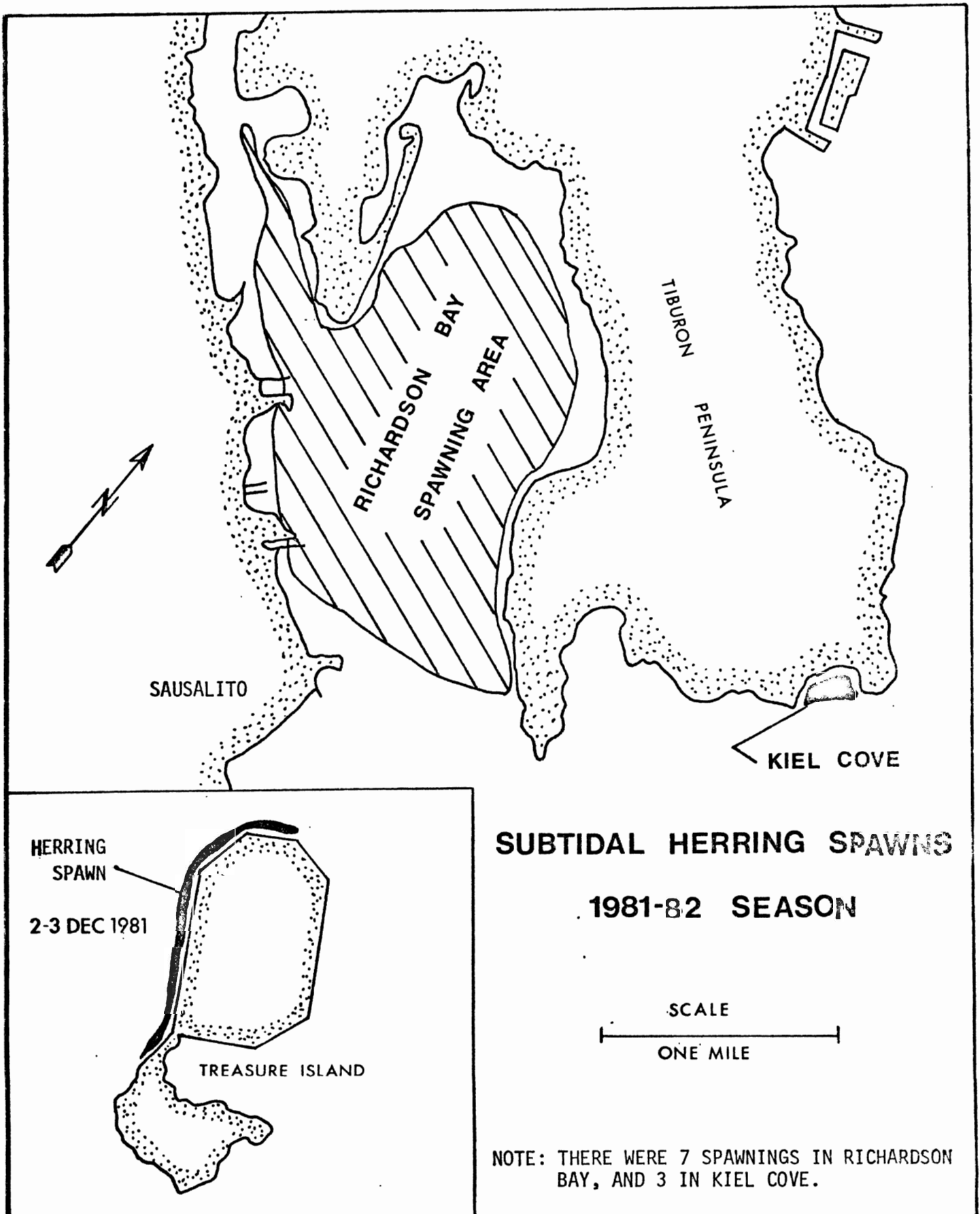


FIGURE 7. Location of subtidal spawning in San Francisco Bay during the 1981-82 season.