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The Resources Agency
DEPARTMENT OF FISH AND GAME

PACIFIC HERRING, *CLUPEA HARENGUS PALLASI*, EXPERIMENTAL ROE-ON-KELP OPEN POUND FISHERY STUDIES IN SAN FRANCISCO BAY, DECEMBER 1987 TO FEBRUARY 1988

by

Thomas O. Moore
and
Paul N. Reilly

MARINE RESOURCES DIVISION

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ABSTRACT

The experimental open pound herring roe-on-kelp (ROK) fishery was studied in San Francisco Bay from mid December 1987 to mid February 1988. Five different harvests were observed and sampled. A total of 19.7 tons of *Macrocystis sp.* kelp covered with herring eggs was processed during this period.

Kelp harvested from the Santa Barbara Channel Islands was transported to San Francisco Bay for hanging on the pounds. Weather conditions at the channel islands affected the condition and dimensions of the harvested kelp. Once suspended on the pounds in bay waters, the cut kelp deteriorated in 8 to 10 d. Based on our sampling, an average of 0.98 tons of kelp with a total blade surface area of 3031 m^2 was suspended from each pound.

ROK was sampled at the shoreside processing facility. Densities of attached eggs ranged from light (less than three layers) to heavy (more than six layers) for the five different spawns. Egg coverage on each pound also varied; kelp towards the middle portion of the pound received heavier deposition of eggs. Average weight increase from egg deposition, per blade, was 780% with the kelp weighing an average of 12.2% of the total. An average 13.2% by weight was trimmed during processing. A multiplication factor of 0.206 should be used to convert individual roe herring allotments to ROK allotments.

Standard plastic totes containing processed ROK averaged 1783 lb total gross weight. Totes contained an average of 49.7% ROK by weight. Samples of roe-on-kelp increased an average of 10.9% in weight after brining during processing.

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INTRODUCTION

This was the first year in which field work by the California Department of Fish and Game (CDFG) Pacific Herring Research Project included sampling the experimental herring open pound (unenclosed floating raft with suspended kelp) roe-on-kelp (ROK) fishery in San Francisco Bay (Figure 1).

Additional requests for experimental gear permits for the ROK fishery were submitted to California's Fish and Game Commission in 1987. The Commission recognized the need for additional information on this developing fishery and withheld any additional permits until CDFG could assess the fishery's biological impact and management needs.

The major objectives of this study were: 1) to determine the tonnage of adult herring required to produce 1 ton of ROK; 2) to collect data to assess biological and management needs for a continuing fishery; and 3) to determine future sampling and monitoring needs for the ROK fishery.

History of the Herring Roe-On-Kelp Fishery

In 1965 Japan began importing herring roe-on-seaweed from Tomales Bay, California (Figure 1). In 1966 the Fish and Game Commission accepted sealed bids for the opportunity to take 5 tons of egg-on-seaweed in San Francisco Bay (Spratt 1981). The amount of the bid was a royalty per ton paid to the Department after harvesting took place. The 5-ton quota was split into two 2.5-ton allotments. Eggs-on-seaweed were harvested by divers, with Gracilaria sp. and

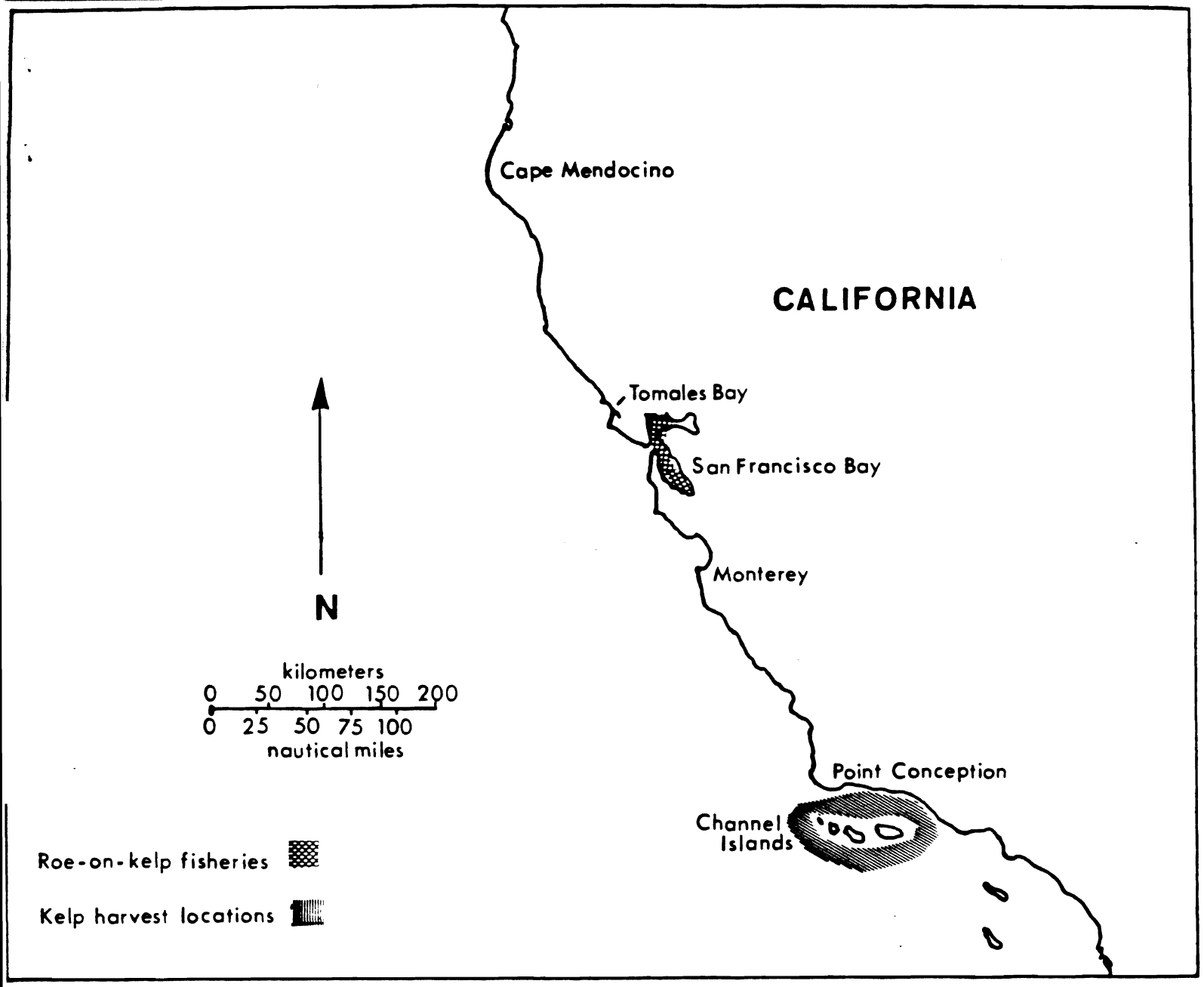

FIGURE 1. Roe-on-kelp fisheries and Macrocystis kelp harvest locations in California.

Laminaria sp. being preferred by the Japanese. From 1966 to 1986 the 5-ton quota was never reached using native vegetation in the bay. During the 1985-86 herring season, the two allotments were harvested using giant kelp, Macrocystis pyrifera (from Monterey Bay, California (Figure 1)), suspended from a log raft. Giant kelp from the Channel Islands, California (Figure 1), was used in both the 1986-87 and 1987-88 season. In the 1987-88 season, the quotas for the two San Francisco Bay allotments were filled for the first time.

The 1985-86 herring season was the first time open pounding was used commercially in San Francisco Bay. In addition to the permit fishery for roe-on-seaweed, an experimental gear permit for an open pound ROK harvest of 7.5 tons was issued in 1986 in lieu of the permittee's equivalent 60-ton purse seine quota. In the 1986-87 herring season, fabricated rectangular aluminum rafts were used instead of the previous log rafts. Giant kelp from the Channel Islands was used instead of kelp from Monterey Bay because the blades were larger and resulted in a better grade of product. Also, they suffered less damage from storms. Two species of Macrocystis, M. pyrifera and M. angustifolia, are found south of Pt. Conception, with rocky bottoms preferred by M. pyrifera and sandy bottoms by M. angustifolia. The main drawback was the 30-h combined truck and boat roundtrip travel time to acquire the kelp.

In 1987 the open pound ROK quota was increased to 165 tons based on two factors: 1) a Canadian study (Shields et al. 1985), which showed a 54% weight gain due to hydration after the spawning of the eggs on kelp; 2) an increase in the individual purse seine quota for

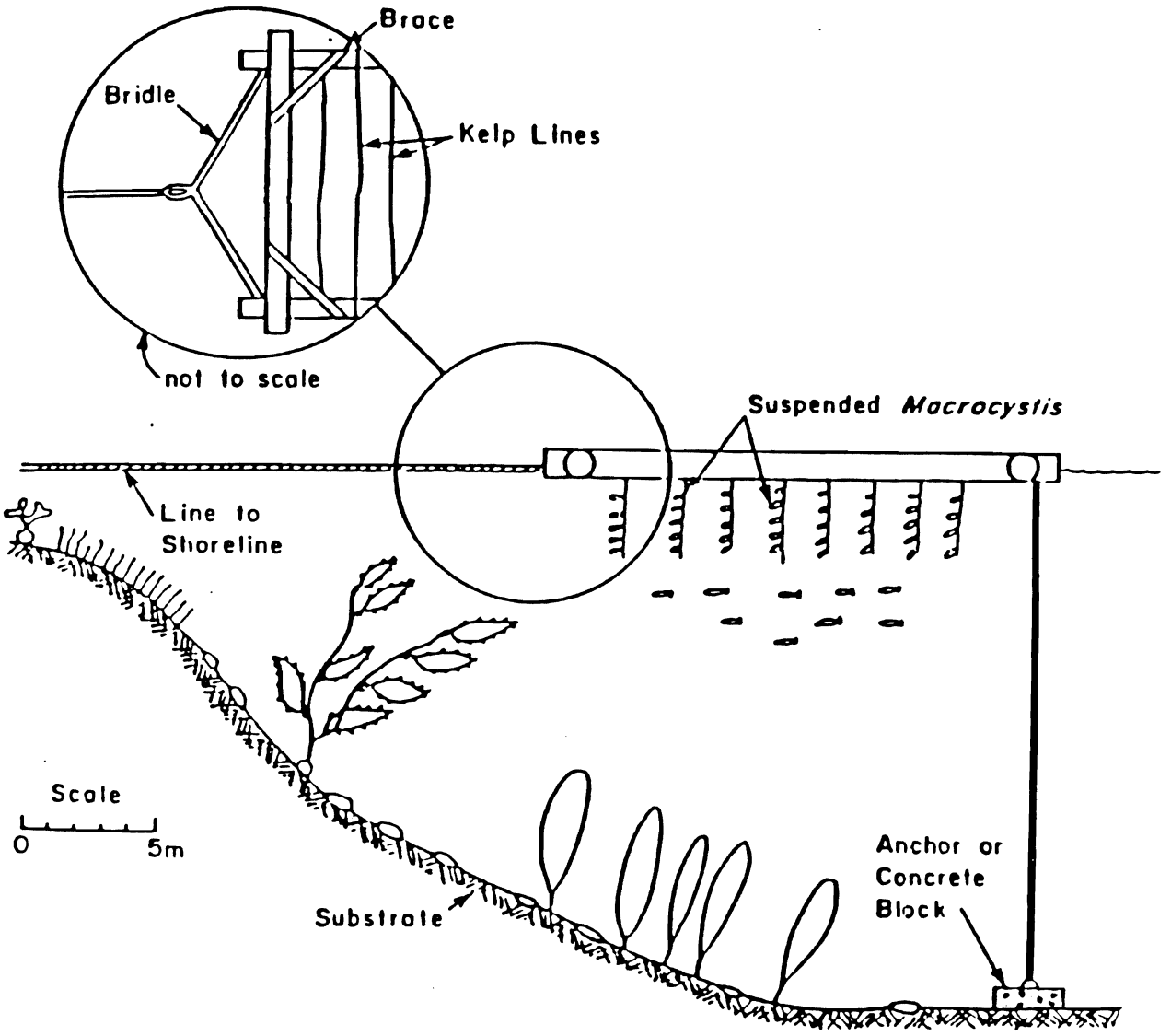

FIGURE 2. Illustration of a typical open pound (Shields et al. 1985).

roe herring from 60 to 78 tons. In the 1987-88 herring season, the experimental gear permittee was also the successful bidder for the two 2.5-ton native roe-on-seaweed allotments and harvested nearly 20 tons of ROK in San Francisco Bay. The quotas for the San Francisco Bay allotments were filled for the first time in the 1987-88 season.

Description Of The Current Roe-On-Kelp Fishery

Rafts Used For Open Pound Fishery

Welded aluminum rafts, approximately 60 ft x 45 ft outside dimensions, are hung with lengths of kelp equally spaced on suspension lines (Figure 2).

Obtaining Macrocystis For Pounds

Empty large (4 x 4 x 3 ft) plastic boxes or totes are trucked to Santa Barbara where they are loaded on a chartered vessel which transports kelp harvest workers and totes to the Channel Islands. Kelp stipes floating on the surface of the water are cut off and trimmed of young growing tips and older ragged and epiphytized lower blades so that a 12- to 14-ft portion is obtained (Figure 3). These are stacked in covered totes to prevent dehydration. Immediately upon return to shore, the kelp is trucked back to San Francisco and cut into approximately 6-ft lengths, weighted, and hung on kelp suspension lines on the rafts (Figure 4). Timing is critical because cut kelp only lasts 8 to 10 d in San Francisco Bay waters before it begins to deteriorate. This will occur with or without eggs covering it.

Placement Of Pounds For Spawning

The movement and maturity of herring schools that enter the bay during the spawning season are monitored continually. Once a

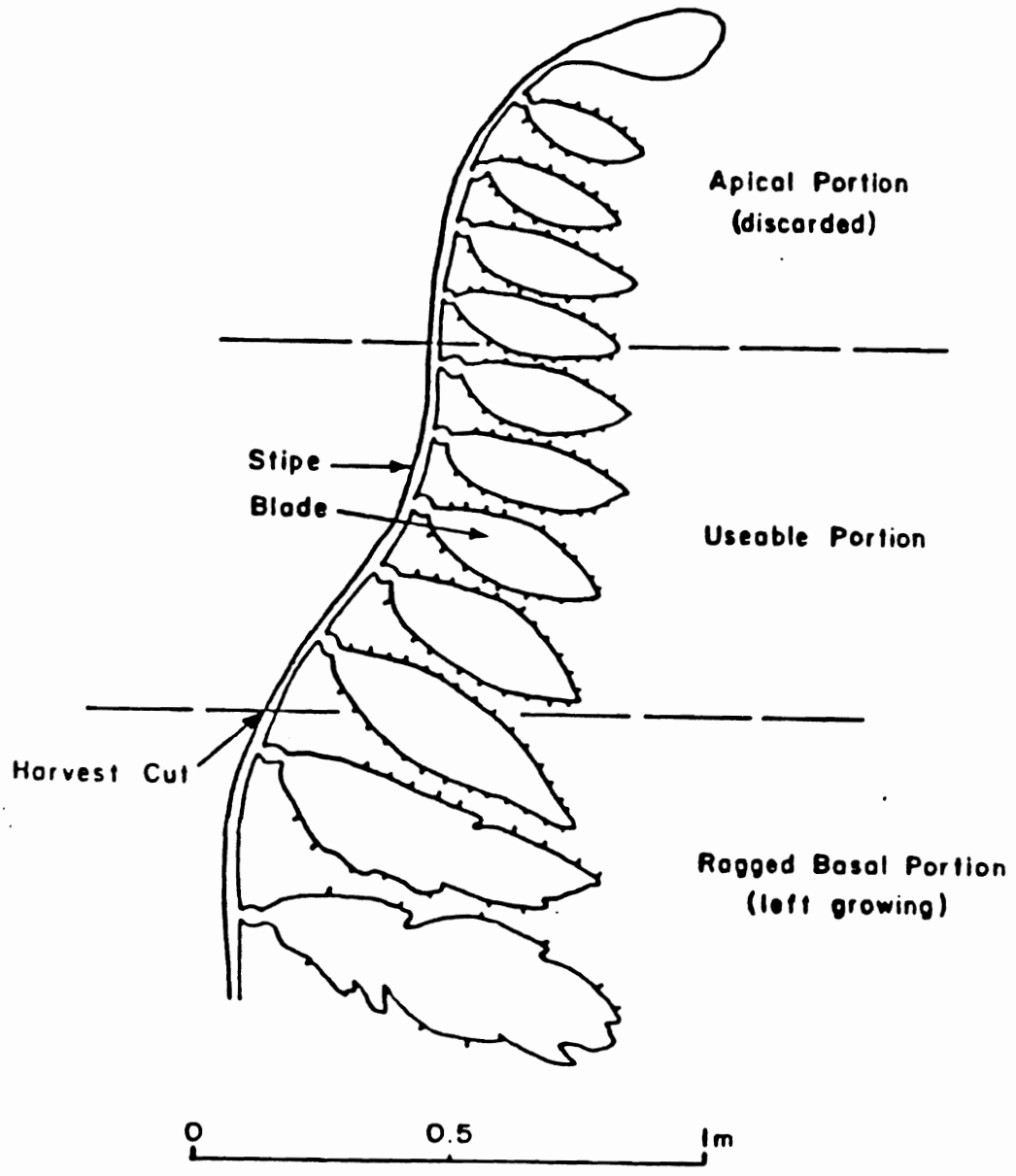

FIGURE 3. The portion of a Macrocystis kelp plant utilized by the herring roe-on-kelp fishery (Shields et al. 1985).

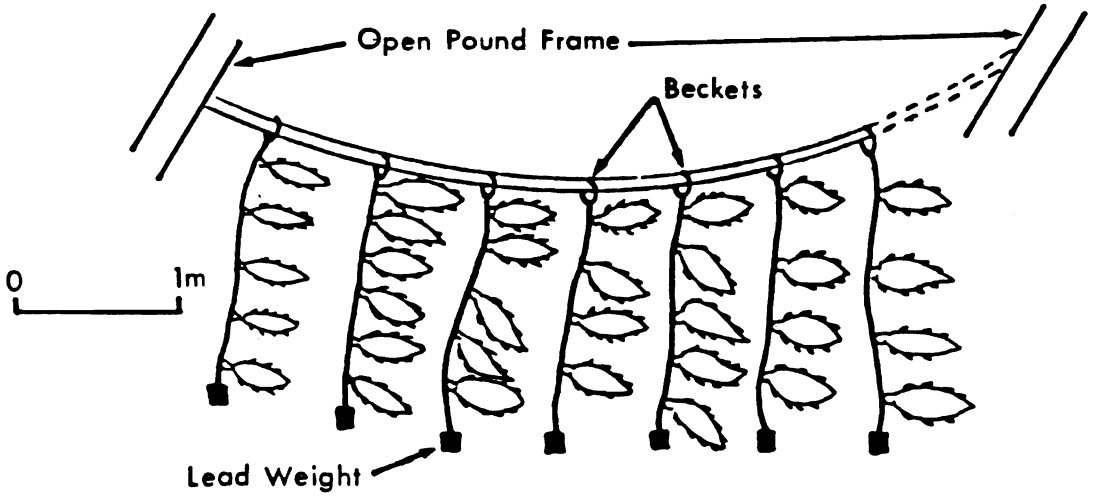

FIGURE 4. Diagram illustrating a typical attachment method of Macrocystis to kelp lines (Shields et al. 1985).

probable spawn location is determined, a pound is towed by a vessel to the site and anchored. Once spawning begins, the herring tend to move in a seaward direction and the pounds need to be moved to nsure as many eggs as possible are deposited on kelp. Towing is done at slack tide and at a speed of 1 kn to prevent tattering and tearing of kelp blades.

Processing Of Roe-on-Kelp At Pound Location

After the spawn is over or a suitable density of spawn is deposited on the suspended kelp, individual lengths of kelp are removed and blades are separated from the stipe and stacked in totes for transfer to the shoreside processing facility. Stipes and cysts (trim) are put back into the water at the raft location to allow attached eggs to hatch.

Processing Of Roe-on-Kelp at Shoreside Location

Workers at the shoreside processing facility remove kelp blades from totes and place them in small plastic baskets. Workers then trim the kelp blades (Figure 5), discard trim into large totes for return to the bay later, and place trimmed blades into other small plastic baskets, which are left to drain prior to official weighing. After weighing, other workers then stack the trimmed blades in a criss-cross pattern in large totes. Salt is added to entirely cover each layer of kelp. When the tote is full, a 100% brine solution is added until the contents are covered. Totes are then covered with lids and placed in cold storage until they are transported out of state for reprocessing.

Reprocessing Of Roe-on-Kelp Out Of State

The product is removed from cold storage, trimmed again, if

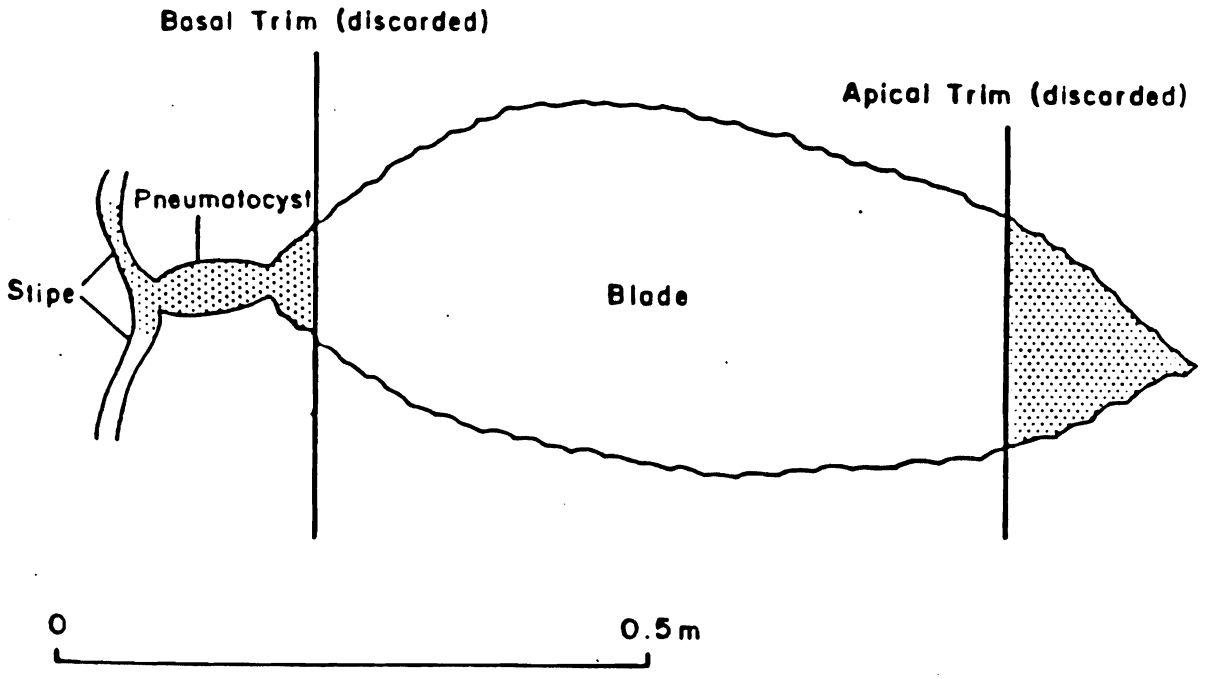

FIGURE 5. The portion of a kelp blade removed by trimming (Shields et al. 1985).

necessary, graded according to the buyer's standards, stacked on side, allowed to air dry 1 h, and then weighed.

METHODS

Field Sampling

Sampling was opportunistic; it was done when time permitted and conflict with other project goals was minimized. A good working relationship with the permittee was established, and communications were such that we were generally informed 24 h in advance of most operations.

Kelp Sampling

Samples of kelp were obtained from the permittee prior to suspension on the pounds. Random samples of 6- to 7-ft cut lengths were measured to the nearest mm and the total number of blades was counted. A total of 29 lines per pound with 43 beckets per line was used to suspend the kelp stipes. The produce of these two numbers gives a total of 1247 stipes per pound. Multiplying this number by the average number of blades per stipe produced the total number of blades per pound.

Weight of 6- to 7-ft lengths of kelp (stipe, cysts and blades) in the field was obtained to the nearest 5 g. Average weight multiplied by total number of lengths of kelp per pound
equals total weight of kelp per pound.

Standard rectangular subsamples (11.9 x 7.0 cm) were used to estimate weight per unit area of kelp blades 10, 20, and 30 cm from the basal tip of a blade. Samples were placed in airtight plastic bags.

Kelp blade surface area was calculated using a Housten Instrument HI-PAD digitizer.

The Man-Whitney U Test was used to compare mean values of various kelp parameters obtained from different samples.

Roe-On-Kelp

At the shoreside processing facility, samples of trimmed ROK blades were selected at random from different workers who were given baskets of whole blades covered with spawn. Trimmed blades were measured to the nearest millimeter and weighed to the nearest gram. The respective trim from the same basket was weighed to the nearest gram.

Standard rectangular subsamples were excised with a scalpel at either 10, 20, or 30 cm from the basal tip of a blade covered with roe. Samples were then placed in airtight plastic bags.

Trimmed ROK weight, salt weight, and quantity of brine added were obtained from the permittee's official tally sheets.

Laboratory Procedures

Weighing of Standard Kelp Subsamples

Standard rectangular subsamples of kelp and ROK were removed from the bags and immediately weighed to the nearest 0.01 g.

Egg Counts

Egg counts (number of eggs per gram) were done using standard ROK subsamples after preservation in 5% formalin. A subsample was divided into fourths and measured, damp-dried using a paper towel, and weighed. From each fourth subsample a portion of ROK weighing approximately 1.0 g was removed and weighed to the nearest 0.01 g; all eggs were then counted. Total number of eggs for each fourth subsample was then calculated.

Change in Roe-on-Kelp Weight

In order to measure the change in weight of ROK after brining, standard subsamples were weighed, then placed in 100% brine solution for 6 to 7 d. In the first experiment, brined samples were rinsed with fresh water after removal from the brine, damp dried using paper towels, and immediately weighed. In the second experiment, brined samples were rinsed with fresh water, allowed to air-dry for 1 h while standing on edge, and weighed.

Calculation of Total Number Of Eggs Harvested

The total number of eggs harvested for the permittee's 15-ton quota was calculated based on the average number of spawned eggs per gram derived from our laboratory work (Appendix A). Number of eggs per gram was converted to number of eggs per ton and then multiplied by 15 to obtain the number of eggs harvested for the experimental 15-ton quota.

Calculation of Conversion Factors, Eggs and Spawners

To calculate the equivalent weight of herring per quota, the number of eggs per quota was divided by the relative fecundity of San Francisco bay herring (Reilly and Moore 1986) adjusted for sex ratio. The number of grams of herring per quota was converted to equivalent tons of herring per 15 ton ROK quota by dividing by grams per ton.

RESULTS

Raw Kelp

This was the first year that we sampled the Channel Islands kelp used in the open pound ROK fishery. No data are available for a comparison with kelp from the Monterey Bay area which was

used in the previous spawning season. Sampling of raw kelp was limited to two occasions. Blade dimensions and surface area were determined for each sample from the two kelp harvest dates (Table 1). Kelp was harvested from approximately the same location on both occasions. Blade area for the earlier date was significantly larger (Mann-Whitney U, P = 0.0007, alpha = 0.05) than for the later date. High seas following a major winter storm made the second kelp harvest difficult. Workers obtained kelp which had smaller blades and a minimum of storm damage.

A high degree of consistency was seen among samples when the area, determined with the digitizer, was expressed as a percentage of the length-width product (Table 1). The length-width product was not significantly different (Mann-Whitney U, P = 0.4354), nor was the ratio of blade length to blade width significantly different (Mann-Whitney U, P = 0.1514) between sample dates. So, although mean length of blades was different between sample dates, the length and width measurements can be used to calculate surface area by multiplying the length-weight product by 0.712 (Table 1). A summary of raw kelp statistics is presented (Table 2).

Amount of Kelp Per Pound

Total amount of kelp harvested can be obtained from the permittee's kelp harvest permit records, but these numbers do not accurately reflect what is suspended from each pound. However, since 1247 stipes or lengths of kelp are suspended per pound, the estimation of the amount of kelp used per raft is simplified. The standard measure for a length of kelp is a span of two arm

TABLE 1. Kelp Blade Surface Area.

Date of sample	Blade length (mm)	Blade width (mm)	Product of (L)*(W) (mm^2)	Plotted area (mm^2)	Plotted area as % of (L)*(W)
12/16/87	670	113	75,710	52,181	68.9
12/16/87	590	120	70,800	52,637	74.4
12/16/87	640	118	75,520	56,436	74.7
12/16/87	585	109	63,765	47,731	74.8
12/16/87	650	115	74,750	53,251	71.2
12/16/87	840	107	89,880	64,162	71.4
12/16/87	775	116	89,900	61,437	68.3
12/16/87	825	112	92,400	63,240	68.4
12/16/87	765	104	79,560	56,764	71.4
12/16/87	755	118	89,090	62,100	69.8
Average	710	113	80,138	56,994	71.3
std dev	94.0	5.2	9696	5563	0.03
1/8/88	500	105	52,500	38,005	72.4
1/8/88	520	113	58,760	40,265	68.5
1/8/88	505	108	54,540	38,495	70.6
1/8/88	665	94	62,510	45,502	72.8
1/8/88	650	97	63,050	44,606	70.8
1/8/88	650	98	63,700	44,829	70.4
Average	582	103	59,177	41,950	70.9
std. dev.	80.8	7.3	4750	3415	0.02
Combined average	662	109	72,277	51,353	71.2
std. dev.	107.8	7.9	13,183	8890	0.02

TABLE 2. Summary of Channel Islands Kelp Data.

	Mean	Standard deviation	Sample number
Blade length	595.6 mm	140.2	495
Blade width	104.0 mm	13.5	495
Blade area	0.051 m^2		16
Blade weight	22.9 g	3.9	52
Length of stipe (suspended on pound)	2.18 m	0.3	12
Weight of stipe (stipes,cysts and blades)	713.1 g	121.6	15
Blade weight as percentage of total weight	76.4%	0.6%	2
Number of blades per stipe	23.6	4.7	16

lengths, and this results in some variation when different crew members hang kelp. Physical differences in kelp from different harvests probably account for the greatest variation in weight. Using an average 713.1 g per stipe, a total of 0.98 tons (889.3 kg) of kelp is used per pound. The stipe and cyst portion of each length account for approximatly 24% of the total weight (Table 2). Based on this percentage, 0.74 tons of kelp blades can be used by spawning herring in each open pound. Using a calculated total of 29,429 blades per open pound and an average surface area of 0.103 m^2 (both sides), a total surface area of 3031m^2 is available for spawning.

Equivalent Tons Of Herring For a 15-Ton Quota

Two separate ROK harvests were sampled to obtain estimates of the number of herring eggs per gram (Table 3). Egg coverage on each pound varied somewhat, with kelp towards the middle portion of the pound receiving a heavier deposition of eggs. Egg coverage was classed as medium (between 3 and 6 layers) on the earlier date and heavy (>6 layers) on the later date. Average number of eggs per gram was significantly different at the 90% level among the two dates (Mann-Whitney U, two tailed P= 0.06), with the earlier date having a larger number of eggs per gram. However, larger herring tend to have larger egg size (Kingston 1982, as cited by Hay and Brett 1988), and larger females spawn earlier than smaller females (Hay 1985). Consequently, a smaller number of eggs per gram would have been expected at the earlier spawning. In light of these findings, it is possible that the effect of different egg coverage may have caused egg weights to differ on the two separate dates. Using an average of 551 eggs

TABLE 3. Number Of Spawned Herring Eggs Per Gram (Unbrined).

Date	Sample number	Calculated total no. of eggs	Total wt of eggs	Calculated number of eggs/gram
12/28/87	1	5024	8.62	583
	2	4485	8.00	561
	3	4858	8.78	553
	4	4903	8.08	607
2/18/88	1	10,405	19.68	529
	2	9428	16.91	558
	3	13,128	25.78	509
	4	11,092	21.79	509
			Mean	551
			std. dev.	34.49

TABLE 4. Summary of Roe-On-Kelp Data.

	Average value	Standard deviation	Total number sampled
Blade length (trimmed)	365.8 mm	129.0	547
Blade width	111.5 mm	35.2	547
Blade weight	155.8 g	113.9	547

TABLE 5. Average Percentage Trim Weight Per Blade.

Processing date	Spawn location/ intensity	Number of samples	Mean % trim	Comments
12/28/87	Hunters Pt. medium	3	9.8	
1/08/88	South Bay light	7	12.4	
1/10/88	Ft. Baker heavy	2*	2.3	did not trim basal portion of blade
1/29/88	Ft. Mason heavy	3	17.3	
2/11/88	Hunters Pt.	5	28.3	maximum trim and discard for quality

* Failure to trim basal portion was a mistake and was not done on future processing dates.

per gram as our best estimate, an equivalent of 72.8 tons of herring produce 15 tons of ROK (Appendix A). The upper 95% confidence limit estimate of 76.1 tons is close to the 78-ton purse seine quota that was traded for the 15-ton ROK equivalent. For management purposes a multiplication factor of 0.206 should be used to convert individual roe herring allotments to ROK allotments.

Roe-On-Kelp-Statistics

All five of the ROK harvests by the permittee were sampled this spawning season. Data on blade length, width, and weight were pooled and summarized (Table 4). Egg coverage on kelp varied with the different spawns (Table 5) and ranged from light (< 3 layers per side) to heave (>6 layers per side). All spawns, with the exception of some of the ROK sampled on January 8, 1988, produced number-one grade produce (minimum 12-in. length, 4-in. width and 6+ layers of eggs, 3+ per side). ROK averaged 12.2% kelp overall and is the same as that reported for the British Columbia ROK fishery (Shields et al. 1985). Average percent trim varied with egg coverage and procedure (table 5). Minimum and maximum averages are not representative of normal trimming procedures. If these trim values are excluded, an average of 13.2% of the produce was trimmed. This compares closely to the 11% trimmed in British Columbia (Shields et al. 1985).

Using an average trim value of 13%, kelp blades were 780% heavier with roe (Appendix B). This value falls within the range of 540% to 920% of the raw kelp weight gain for giant kelp in the ROK fishery in Alaska (Brady 1985).

TABLE 6. Pre-Brine And Post-Brine Roe-On-Kelp Weights.

Distance from basal tip (cm)	Pre-brine weight(g)	Post-brine weight (g)*	Percentage increase
10	70.46	77.22	9.6
10	83.67	93.12	11.3
10	82.23	94.81	15.3
20	67.73	74.63	10.2
20	57.43	62.89	9.5
20	117.75	131.46	11.6
20	61.31	66.87	9.1
30	71.52	79.76	11.5
30	66.30	75.53	13.9
30	83.46	88.14	5.6
30	68.91	77.89	13.0
30	73.19	80.25	9.6
		Mean	10.9
		std. dev.	2.54

* Stood on edge, air dried one h, then weighed.

TABLE 7. ROE-ON-KELP TALLY SHEET SUMMARY 1987-88 HERRING SEASON

PROCESSING DATE	SPAWN LOCATION/ INTENSITY	NUMBER OF TOTES	TOTAL GROSS WEIGHT (lbs)	TOTAL NET WEIGHT	NET WEIGHT AS % OF GROSS	AVG GROSS WEIGHT PER TOTE	AVG NET WEIGHT PER TOTE	AVG WEIGHT OF SALT PER TOTE	AVG VOLUME OF BRINE PER TOTE (gal)
12/28/87	HUNTERS PT. MEDIUM	6	10,800	4873	45.12	1800	812.2	663	10.0
1/08/88	SOUTH BAY LIGHT	1.7	2,798	1029	33.61	1619*	544.2*	650*	10.0*
1/10-11/88	FT. BAKER HEAVY	20	34,308	19,170	51.66	1767	912.9	604	10.9
1/29/88	FT. MASON HEAVY	11	20,149	9622	47.75	1832	874.7	698	11.0
2/11/88	HUNTERS PT. HEAVY	5	8747	4486	51.29	1749	897.2	600	10.5
	small totes	3	2608	1289	49.44	869	429.8	---	----
TOTALS/AVERAGES		46.7	79,410	39,440	49.67	1783**	878**	637	10.7

* VALUE BASED ON ONE FULL TOTE

** VALUES FOR SMALL TOTES NOT INCLUDED

Average Increase In Weight Of Eggs After Brining

Two experiments were done to determine if there was an increase in the weight of the ROK due to processing. In both cases there was an increase in weight. The results from the second experiment (Table 6) were obtained using a draining method and drying period used by Japanese buyers. The 10.9% average weight increase found is due to the uptake of salt and water during processing.

Open-Pound Production

An estimate of total ROK production was obtained from the permittee's official tally sheets for the 1987-88 harvest (Table 7). Nearly 20 tons (47 totes) of ROK were harvested from five different spawns. With the exception of three small totes, large standard totes were used at all times. ROK product averaged 49.7% of the average gross weight per large tote, for the entire season, with the remaining approximately 50% consisting of salt and water. This value decreases somewhat for spawn intensities classed as less than heavy, but overall it was a good rough estimate of the amount of product in a tote.

DISCUSSION

Almost 73 tons of herring were required to produce the 15-ton experimental ROK harvest quota set by CDFG for the 1987-88 herring season. The dimensions of the giant kelp used easily met the size requirements for number one grade, and all spawns except one produced egg coverage equivalent to number one grade or

better. Siltation continues to be a problem in San Francisco Bay, but the permittee and his Japanese buyers believe this problem can be resolved.

A comparison of data obtained in the San Fransisco Bay herring ROK fishery with data from open pound fisheries in British Columbia and Alaska indicates a close similarity. Future sampling efforts will include: 1) improving the precision of our estimate of the number of eggs per gram used for calculation of a conversion factor and 2) determining any variation in harvest parameters by other permittees as the fishery expands. However, the potential for possible gear conflicts exists. Given the urban location and multiple fishing methods used in the San Francisco Bay herring fishery, these factors may preclude rapid expansion. Closed pounding (enclosed floating raft with suspended kelp and captured quantity of herring) may be an alternative to these problems, although a greater adult mortality will result from the capture, movement, transfer, and holding of herring in the pounds (Shields et al. 1985).

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APPENDIX A. Conversion of Number of Eggs to Equivalent Weight of Herring.

Number Of Eggs Per Ton

551 eggs per g x 907,200 g per ton = 50.0×10^7 eggs per ton

Number Of Eggs Per 15 Ton Quota

15 tons x 50.0×10^7 eggs per ton = 7.5×10^9 eggs

Equivalent Tons Of Herring Per 15-Ton Quota

-assumes a relative fecundity of 227 eggs per gram and 1:1 sex ratio, giving 113.5 eggs per gram

$$\frac{7.5 \times 10^9 \text{ eggs per quota}}{113.5 \text{ eggs per gram}} = 66.1 \times 10^6 \text{ grams of herring}$$

-then

$$\frac{66.1 \times 10^6 \text{ g of herring}}{9.072 \times 10^5 \text{ g per ton}} = 72.8 \text{ tons of herring}$$

APPENDIX B. Average Percent Weight Increase per Blade

-average trim removed up to 13.2% of the blade

(1.00- 0.132) x 22.9 g untrimmed blade = 19.9 g equivilent weight

$$\frac{\text{155.8 g avg trimmed blade wt (roekelp)}}{\text{19.9 g avg untrimmed blade wt (rawkelp)}} = 7.8 \times 100 = 780\% \text{ increase}$$