MERCURY IN FISH AND SHELLFISH OF THE NORTHEAST PACIFIC. II. SABLEFISH, *ANOPLOPOMA FIMBRIA*

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ABSTRACT

Sablefish, *Anoplopoma fimbria*, collected from several locations in Alaska, Washington, Oregon, and California were analyzed for their mercury content. Mean mercury level in this species varied with the geographical location of catch, showing a gradual increase in magnitude from north to south; the average size of the specimens decreased in the same pattern, north to south. Of the 692 specimens analyzed in this study, approximately 30% exceeded the U.S. Food and Drug Administration action level of 0.50 ppm mercury. Significant relationships between the size of the fish and mercury content were observed.

Following the Canadian disclosure in March 1970 of high mercury levels in fish caught in Lake St. Clair (Hearnden 1970), the National Marine Fisheries Service (NMFS) initiated studies to determine the distribution and level of mercury in our marine resources. Since that time, the Pacific Utilization Research Center, NMFS, has been conducting extensive screening studies of fish and shellfish of the northeast Pacific in order to evluate the mercury problem as it relates to those species taken by both commercial and sport fisheries. The main objectives were to determine which species contained mercury in excess of the Food and Drug Administration (FDA) action level of 0.50 ppm (Schmidt 1974) and the severity of the problem.

During our preliminary screening of Pacific species, we found that the edible muscle tissue of a number of sablefish contained mercury in excess of the FDA action level. This species ranges from southern California to the Bering Sea (Clemens and Wilby 1961:240). Domestic landings in 1971 were about 6 million pounds (2.7×10^6 kg) (Thompson 1971) but its high value as a smoked product and the availability to the fishermen of additional supplies of this species suggests that landings will increase.

This paper is the second in a series and reports our findings on mercury in the edible muscle tissue of sablefish, *Anoplopoma fimbria* (Pallas). The first paper in the series is on the Pacific halibut, *Hippoglossus stenolepis* Schmidt (Hall et al. 1976).

EXPERIMENTAL PROCEDURE AND METHODS

Most of the sablefish used in this study were obtained by NMFS personnel aboard National Oceanic and Atmospheric Administration (NOAA) research vessels. Some samples were obtained from commercial lots through the cooperation of fish processors in order to cover the range of this species. Samples were obtained from the waters off Alaska, Washington, Oregon, and California. Date and location of catch were recorded for all specimens.

Weights and lengths are reported for heads-off eviscerated fish because this is the standard practice for landing sablefish. Round weights and lengths were converted to the heads-off eviscerated values using conversion tables. Where possible, sex was determined by physical examination when the specimens were eviscerated. Age was determined from the otoliths which were removed at the same time.

Analytical samples consisted of the entire fillets of each fish. The edible muscle tissue was ground in a Hobart grinder[2] equipped with a stainless steel plate perforated with holes ⅛ inch (3.2 mm) in diameter. The comminuted flesh was mixed thoroughly; subsamples were removed, packaged, and stored at -29°C until analysis.

Total mercury was determined by either the FDA method of Munns and Holland (1971) or Malaiyandi and Barrette (1970) as modified by

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[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

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Munns (1972). Final quantitation was by flameless spectroscopy using a Perkin-Elmer Model 403 Atomic Absorption Spectrophotometer.

Results are stated in parts per million wet weight. All samples were analyzed in duplicate and where the deviation for replicates exceeded ± 0.05 ppm, the analyses were repeated. Control samples of known value were analyzed routinely to verify both accuracy and precision of the method.

RESULTS AND DISCUSSION

A total of 692 sablefish taken from the Bering Sea and coastal waters of the Pacific Ocean from Kodiak Island, Alaska, to San Diego, Calif., were analyzed for individual mercury content. The specific locations of catch and the mean mercury levels by area are shown in Figure 1. The mean mercury levels show a general increase from north to south, as does the percentage of fish that exceed the FDA action level of 0.50 ppm (Table 1).

TABLE 1.–Summary of mercury concentration in sablefish.

Area of catch	No. of fish	Mean weight Pounds (kg)	Mercury (ppm) Low	High	Mean	% samples over 0.50 ppm
Bering Sea-Kodiak Island	30	2.02 (0.92)	0.02	0.11	0.04	0
Southeast Alaska	120	5.22 (2.37)	0.06	0.77	0.28	5
Washington	121	5.27 (2.39)	0.06	1.28	0.37	23
Oregon	174	4.33 (1.96)	0.06	1.23	0.40	29
Northern California	98	3.14 (1.42)	0.03	0.95	0.26	21
Central California	30	5.68 (2.58)	0.08	0.79	0.47	43
Southern California	119	2.93 (1.33)	0.04	2.11	0.60	72

Effect of the Geographical Location

The fish caught in the Bering Sea and in the vicinity of Kodiak Island were all small (less than 3 pounds [1.4 kg]) and contained very low levels of

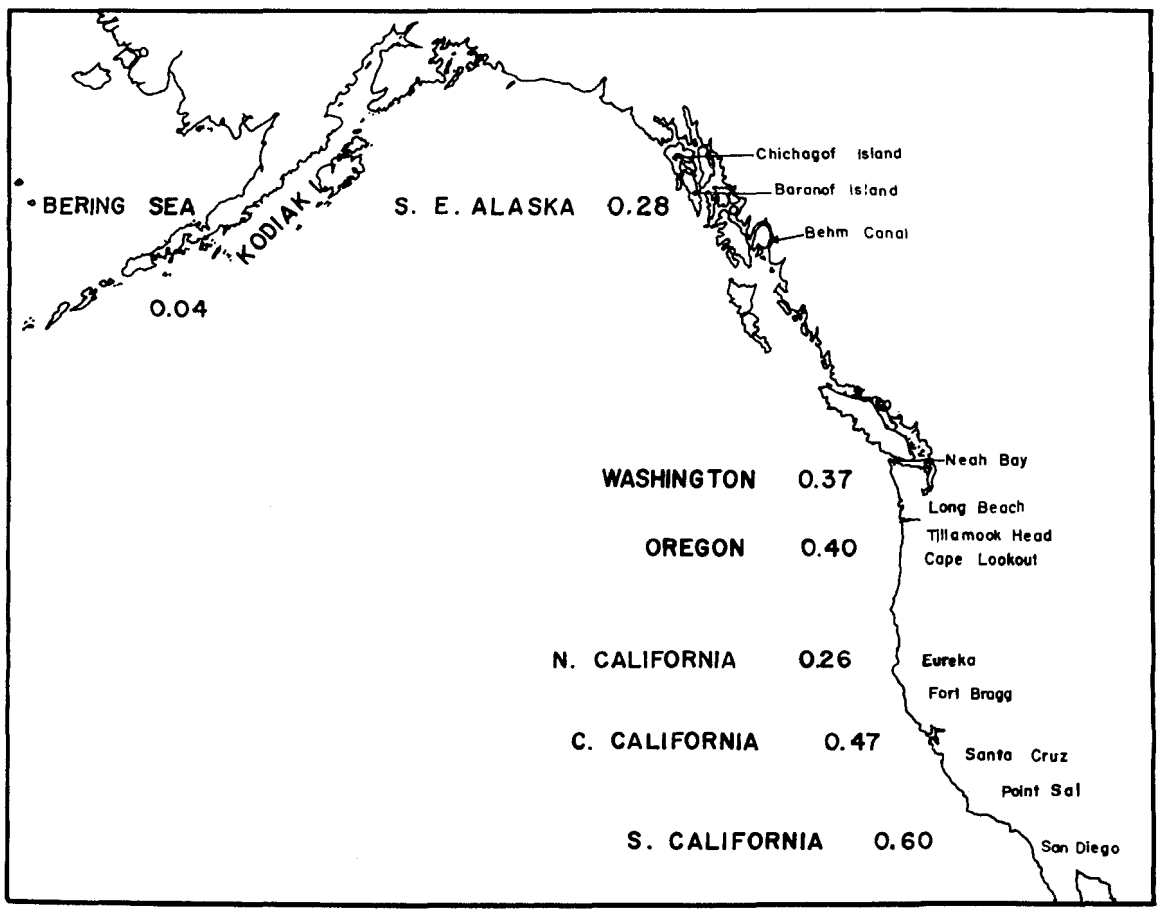

FIGURE 1.–Mean mercury levels (parts per million) in sablefish by area and the specific locations of the catches.

mercury (0.02-0.11, $\bar{x}$ 0.04 ppm). The data for the specimens from these two areas were combined since the samples were relatively few in number, and there was no evidence of any significant differences based on area (Table 1).

A much better weight distribution is seen in the 120 fish from southeast Alaska (Table 2). The fish taken from several locations around Baranof and Chichagof islands (45 specimens) contained a significantly lower mean level of mercury (0.19 ppm) than did the 75 fish taken from the Behm Canal area (0.34 ppm). The only fish (5% of the total sample) from southeast Alaska that exceeded 0.50 ppm mercury were caught off Betton Island, which is in the north arm of Behm Canal. This would indicate a higher level of mercury contamination in the inland waters than in the offshore waters around the outer islands.

Analyses of 121 fish from Washington showed that 23% (28 fish) of the sample exceeded the action level (Table 2). The fish taken from the northern coast off Neah Bay and those taken from the southern coast off Long Beach showed little difference in mercury content.

Of the 174 fish from Oregon, 51 or 29% exceeded the action level (Table 2), which is an increase over that observed in previously discussed areas. A significant part of the total sample (39%) consisted of fish weighing less than 3 pounds (1.4 kg) and of these small fish we observed an increase in the percentage that exceeded 0.50 ppm mercury.

The sampling from northern California (Table 3) consisted of 98 fish of which 62% (61 fish) weighed less than 3 pounds (1.4 kg) and contained low levels of mercury. Only one of these small fish exceeded 0.50 ppm mercury. Of the remaining 37 larger fish, the mercury level of 20 fish exceeded 0.50 ppm. The mean mercury level of the total lot of 98 fish was 0.26 ppm, and 21 fish or 21% exceeded the action level. Considering that this lot represented an atypical weight distribution, it seems likely that both the mean and the percentage of fish exceeding the action level would be higher in a sampling where the number of fish are more uniformly distributed over the weight range.

The 30 fish collected in central California were well distributed over the weight range (Table 3) and 43% of these fish exceeded the action level.

Analytical data on 119 fish from the southern California area showed that 72% (86 fish) exceeded the action level (Table 3). Of this group, 47% weighed less than 3 pounds (1.4 kg). Here, as in Oregon, we saw that smaller fish contained high levels of mercury in comparison to other areas. The weight range of the fish from southern California was small (from 0.5 to 5.5 pounds [0.2-2.5 kg]), but the mercury levels were higher than were observed in any other area.

Effect of Size of Fish

The observations on mercury levels and size of

TABLE 2.—Mercury concentration in heads-off eviscerated sablefish from southeast Alaska, Washington, and Oregon.

Weight range	Southeast Alaska					Washington					Oregon				
	Fish		Mercury (ppm)			Fish		Mercury (ppm)			Fish		Mercury (ppm)		
Pounds (kg)	No.	% over 0.5 ppm	Low	High	Mean	No.	% over 0.5 ppm	Low	High	Mean	No.	% over 0.5 ppm	Low	High	Mean
0.5-2.99 (0.23-1.36)	31	0	0.06	0.23	0.12	23	4	0.07	0.52	0.27	68	7	0.06	0.69	0.25
3.0-3.99 (1.36-1.81)	17	0	0.07	0.48	0.29	21	14	0.12	0.82	0.35	29	24	0.20	0.63	0.43
4.0-4.99 (1.82-2.26)	15	0	0.12	0.40	0.27	22	4	0.06	0.52	0.29	14	43	0.22	0.71	0.48
5.0-5.99 (2.27-2.72)	17	0	0.19	0.46	0.33	14	29	0.26	0.61	0.41	14	21	0.18	0.72	0.45
6.0-6.99 (2.72-3.17)	9	11	0.23	0.61	0.39	11	18	0.12	0.62	0.33	20	55	0.06	1.23	0.51
7.0-7.99 (3.18-3.63)	13	15	0.18	0.66	0.36	14	36	0.08	0.72	0.41	11	64	0.33	0.84	0.55
8.0-8.99 (3.63-4.09)	8	0	0.20	0.47	0.35	3	67	0.48	0.65	0.58	12	58	0.33	0.72	0.52
9.0-9.99 (4.09-4.54)	4	0	0.24	0.48	0.37	7	57	0.15	1.28	0.61	5	80	0.44	1.02	0.68
10.0-10.99 (4.54-4.99)	3	67	0.46	0.77	0.61	3	100	0.52	0.90	0.72	0	—	—	—	—
11.0-11.99 (4.99-5.44)	1	100	0.56	0.56	0.56	3	100	0.50	0.67	0.58	1	100	1.15	1.15	1.15
12.0-12.99 (5.45-5.90)	2	0	0.38	0.48	0.43	—	—	—	—	—	—	—	—	—	—

TABLE 3.—Mercury concentration in heads-off eviscerated sablefish from California.

Weight range	Northern California					Central California					Southern California				
	Fish		Mercury (ppm)			Fish		Mercury (ppm)			Fish		Mercury (ppm)		
Pounds (kg)	No.	% over 0.5 ppm	Low	High	Mean	No.	% over 0.5 ppm	Low	High	Mean	No.	% over 0.5 ppm	Low	High	Mean
0.5-2.99 (0.23-1.36)	61	2	0.03	0.65	0.12	4	0	0.08	0.18	0.13	68	59	0.04	1.74	0.50
3.0-3.99 (1.36-1.81)	8	50	0.20	0.85	0.45	5	40	0.36	0.54	0.46	35	86	0.38	2.11	0.73
4.0-4.99 (1.82-2.26)	14	50	0.22	0.73	0.47	7	29	0.42	0.79	0.53	12	100	0.53	0.88	0.72
5.0-5.99 (2.27-2.72)	9	44	0.22	0.75	0.49	4	25	0.13	0.57	0.40	4	100	0.54	0.83	0.71
6.0-6.99 (2.72-3.17)	2	100	0.70	0.75	0.73	2	0	0.31	0.44	0.37	—	—	—	—	—
7.0-7.99 (3.18-3.63)	2	50	0.32	0.89	0.61	1	100	0.58	0.58	0.58	—	—	—	—	—
8.0-8.99 (3.63-4.09)	1	100	0.95	0.95	0.95	3	100	0.62	0.69	0.66	—	—	—	—	—
9.0-9.99 (4.09-4.54)	1	100	0.53	0.53	0.53	2	100	0.61	0.68	0.64	—	—	—	—	—
12.0-12.99 (5.45-5.90)	—	—	—	—	—	1	100	0.71	0.71	0.71	—	—	—	—	—
13.0-13.99 (5.90-6.35)	—	—	—	—	—	1	100	0.61	0.61	0.61	—	—	—	—	—

sablefish are analogous to what was found in Pacific halibut (Hall et al. 1976); i.e., mercury levels increased from north to south until at the southern part of the range even small fish exhibited high mercury levels. Anas (1974) observed a similar pattern in the harbor seal, *Phoca vitulina richardi*.

There appears to be a direct relationship between the size of the sablefish and the mercury level found in the muscle. Comparisons between weight and mercury level for fish from each area are given in Figures 2-8. The exponential function, $y = ax^b$, was used for the statistical evaluation of the data. Length-to-mercury relationships are very similar to those for weight-to-mercury and are not shown for this reason. Correlation coefficients (r values) are shown on each plot, and the relationship between weight and mercury was highly significant (0.1% level) in all areas except in the Bering Sea-Kodiak Island area where the relationship was not significant.

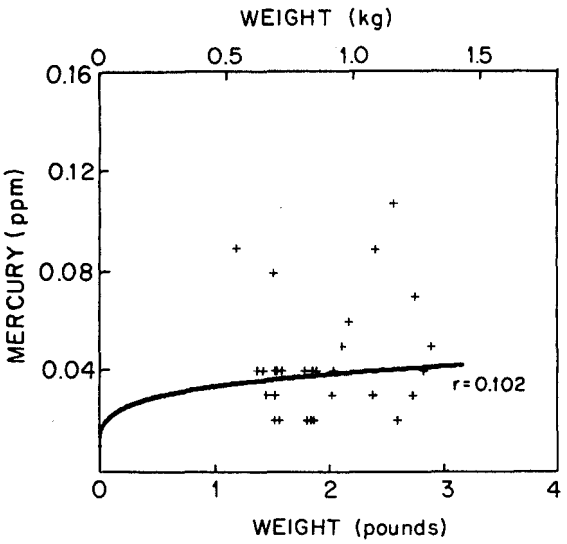

FIGURE 2.—Relationship between heads-off eviscerated weight and mercury concentration in muscle tissue of sablefish from the Bering Sea-Kodiak Island, Alaska.

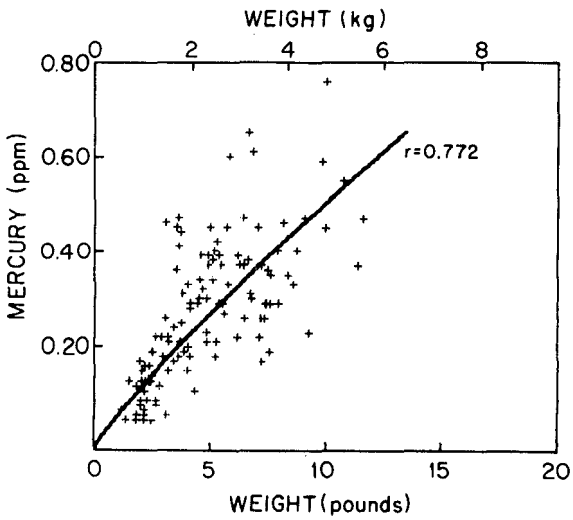

FIGURE 3.—Relationship between heads-off eviscerated weight and mercury concentration in muscle tissue of sablefish from southeast Alaska.

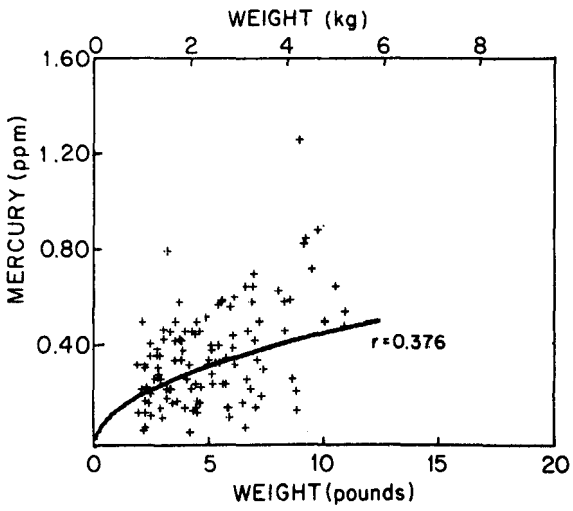

FIGURE 4.—Relationship between heads-off eviscerated weight and mercury concentration in muscle tissue of sablefish from Washington.

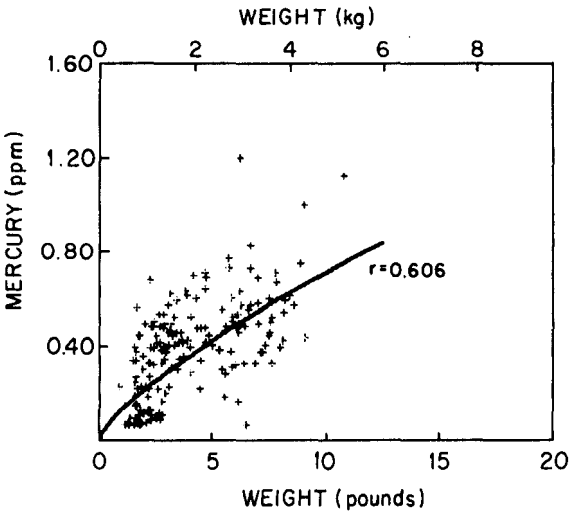

FIGURE 5.—Relationship between heads-off eviscerated weight and mercury concentration in muscle tissue of sablefish from Oregon.

Effect of Age

Since the female sablefish grows faster and attains a larger size than the male (Clemens and Wilby 1961), it would seem logical to assume that the correlation between age and mercury level might be better than that of weight and mercury level. However, higher correlation coefficients exist between weight and mercury than between age and mercury in all areas except Oregon.

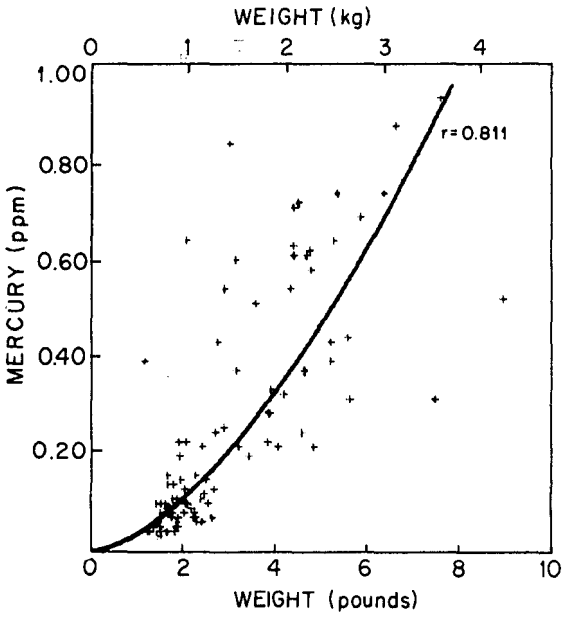

FIGURE 6.—Relationship between heads-off eviscerated weight and mercury concentration in muscle tissue of sablefish from northern California.

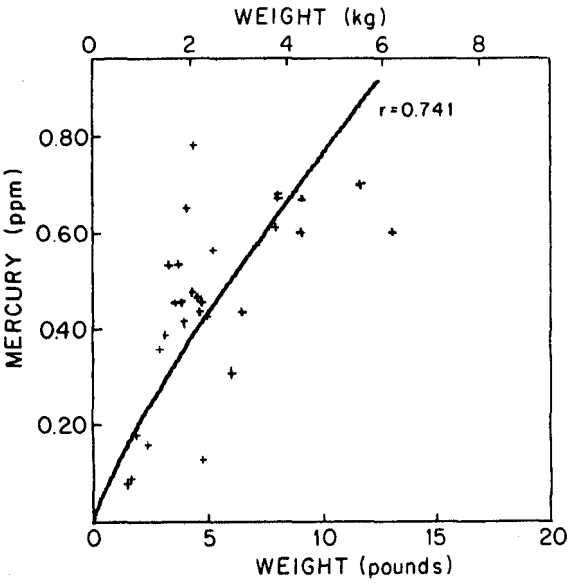

FIGURE 7.—Relationship between heads-off eviscerated weight and mercury concentration in muscle tissue of sablefish from central California.

Relationships between age and mercury are significant in all areas except Washington (Table 4). Age was not obtained on fish from the Bering Sea-Kodiak Island area.

TABLE 4.—Correlation coefficients for relationship of mercury level in the edible flesh to weight, age, and sex of sablefish.[1]

Area of catch	Number of fish	Weight to mercury	Number of fish	Age to mercury	Number of females	Weight to mercury	Number of males	Weight to mercury
Bering Sea-Kodiak Island	30	[2]0.102	—	—	—	—	—	—
Southeast Alaska	120	0.772	103	0.684	71	0.868	43	0.762
Washington	121	0.376	38	[2]0.179	30	0.731	10	[2]0.349
Oregon	174	0.606	80	0.693	116	0.657	53	0.480
Northern California	98	0.811	63	0.558	—	—	—	—
Central California	30	0.741	28	[3]0.430	17	[4]0.630	12	[4]0.758
Southern California	119	0.748	97	0.439	30	0.661	11	[2]0.203

[1]Correlation coefficients significant at the 0.1% level unless otherwise indicated.
[2]Not significant.
[3]Significant at 5% level.
[4]Significant at 1% level.

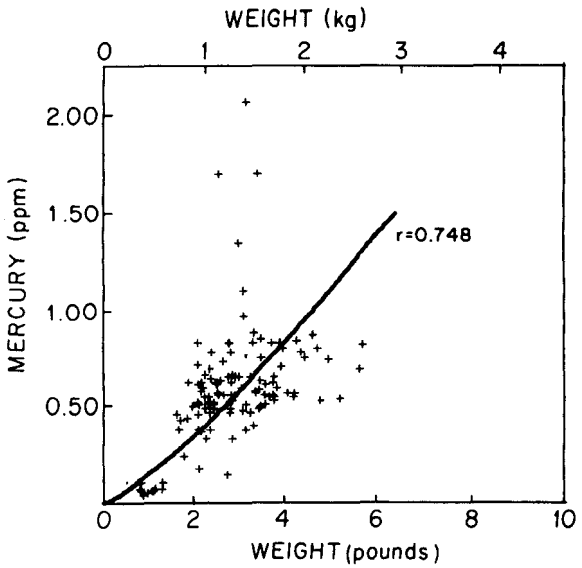

FIGURE 8.—Relationship between heads-off eviscerated weight and mercury concentration in muscle tissue of sablefish from southern California.

Effect of Sex

The females show better correlation between weight and mercury than do the males, and correlation coefficients are significant for females from all areas (Table 4). Correlation coefficients for weight to mercury are also significant for males in all areas except Washington and southern California. Sex was not obtained on fish from the Bering Sea-Kodiak Island or northern California.

Effect on Utilization of Sablefish

It is apparent that sablefish can accumulate mercury in amounts that exceed the maximum level permitted in fish by the FDA. Spinelli et al. (1973) noted that fish withheld from food use due to high mercury levels constitute a significant loss to the industry and showed that such losses could be reduced by using a cysteine treatment to lower the mercury content of the fish during processing. Teeny et al. (1974) conducted a similar study on the reduction of mercury in sablefish, and found that up to 80% of the mercury present in the edible tissue could be removed. Processing techniques of this type could result in all sablefish being acceptable for human consumption.

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