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JOSEPH G. LOESCH

Virginia Institute of Marine Science
Gloucester Point, VA 23062

MERCURY IN FISH AND SHELLFISH OF THE NORTHEAST PACIFIC. III. SPINY DOGFISH, *SQUALUS ACANTHIAS*

The spiny dogfish, *Squalus acanthias* Linnaeus, is a small shark that is abundant in the northeast Pacific and has been utilized both as a food fish and as a source of industrial fishery products. This species was heavily harvested in the 1940's for the high vitamin A content in the liver oil until the population was significantly reduced (Alverson and Stansby 1963). The declining resource, along with the availability and low cost of synthetic vitamin A, led to the collapse of the fishery in the early 1950's. Since that time the dogfish population has significantly increased, but the low economic value of the species precluded development of any substantial fishery.

Another limiting factor in commercial handling of dogfish is its rather rapid deterioration. Stansby et al. (1968) found that rancidity, not bacterial spoilage, was the principal factor limiting the ice-storage life of dogfish. If dogfish are properly iced and handled quickly, off flavors due to rancidity and the breakdown products of urea are minimized, and they can be used as food.

Recently there has been a renewed interest in commercial exploitation of this species in Puget Sound, primarily because of the export demand and increased price for frozen dogfish fillets and bellyflaps in Europe. In 1975 only 0.43 million lb of dogfish were landed in the State of Washington for both food and reduction purposes, in contrast to 4.9 million lb landed during 1976 in Puget Sound ports[1] and processed for export to Great Britain and West Germany. As a result of the current interest in the use of Puget Sound dogfish as food and the mercury levels in relation to import regulations of various countries, this investigation was undertaken to determine the mercury levels in dogfish from inland waters of the State of Washington. This report summarizes our findings.

Materials and Methods

The specimens were obtained from commercial gill net and longline catches through the cooperation of the industry and the State of Washington Department of Fisheries. They were collected from the Strait of Georgia near Blaine, Wash. (Figure 1), and from five locations in Puget Sound: Port Townsend, Port Susan, Seabeck (Hood Canal), Seattle (Elliott Bay), and Tacoma (Tacoma Narrows to Carr Inlet). Date and location of capture, round weight, length, and sex were recorded for each fish. Commercial buyers had established a minimum acceptable length of 32 in (81.3 cm) for food processing; therefore, the size distribution of most samples reflected this market practice rather than the normal range of lengths in the dogfish population.

[1]Preliminary landings data, State of Washington Department of Fisheries.

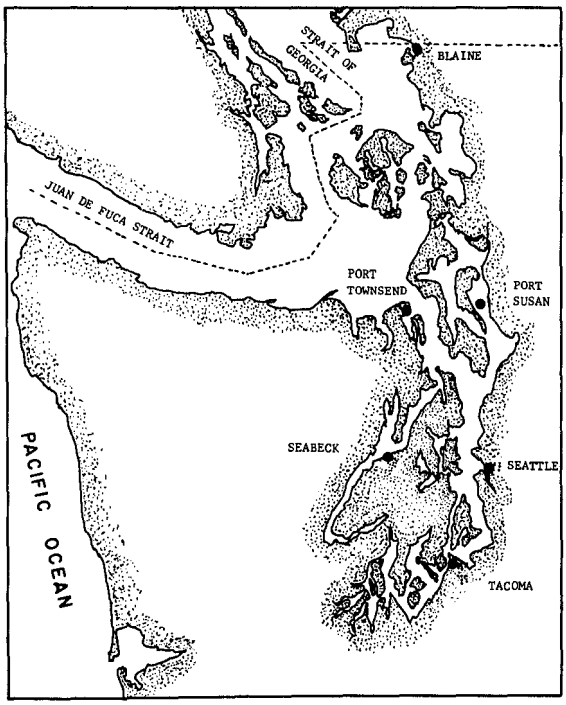

FIGURE 1.—General points of collection of spiny dogfish in Puget Sound and the Strait of Georgia.

Analytical samples were prepared at this laboratory and consisted of the skinned and deboned edible muscle tissue from both fillets and bellyflaps. Since the bellyflaps are marketed as a separate product, they were removed and analyzed separately. Each sample was ground and thoroughly mixed prior to subsampling for analysis.

Total mercury was determined by the U.S. Food and Drug Administration's Vanadium Pentoxide Method (Munns 1972), which uses a nitric-sulfuric acid digestion with vanadium pentoxide as a catalyst. Final determination was by flameless atomic absorption spectroscopy with results stated in parts per million (ppm) of mercury on a wet-weight basis. All samples were subjected to single analysis, and those exceeding 0.40 ppm were repeated. Differences between replicates did not exceed 0.05 ppm. A standard fish sample was analyzed routinely as an internal control.

Results and Discussion

A total of 141 dogfish (127 females, 14 males) were analyzed for mercury content. Mean mercury levels in specimens from each area (Table 1) were at or above the action level of 0.50 ppm set by the U.S. Food and Drug Administration (FDA) (Schmidt 1974). Specimens taken from the west side of Puget Sound (Port Townsend and Seabeck) contained lower levels of mercury than did those taken from the east side of Puget Sound (including Blaine). The mercury levels appeared to increase from north to south on each side of the Sound. This phenomenon may be due to the absence of industry at points of collection on the west side of the Sound and an increase of industrial activity from north to south along the east side of the Sound; however, these observations on the effect of catch area may not be representative of the total Puget Sound dogfish population.

The mean mercury level for the 127 female dogfish fillets was 0.92 ppm, which is almost twice the FDA action level. The mercury level in 91 females (72%) exceeded 0.50 ppm and 48 (38%) exceeded 1.0 ppm. Regression analysis showed a positive correlation between mercury content of

TABLE 1.—Mercury concentration in spiny dogfish from the State of Washington.

						Mercury (ppm)									
						Fillets					Bellyflaps				
	No. of	Weight (g)		Length (cm)		No. of			>0.5 ppm		No. of			>0.5 ppm	
Location	fish	Range	Mean	Range	Mean	fish	Range	Mean	No.	%	fish	Range	Mean	No.	%
						Females									
Port Townsend	22	2,190–4,160	3,194	85–102	93.9	22	0.16–1.28	0.50	9	40.9	20	0.14–1.18	0.41	5	25.0
Seabeck	12	2,465–4,915	3,372	86–106	93.5	12	0.34–1.43	0.63	7	58.3	12	0.29–1.30	0.57	7	58.3
Blaine	20	2,360–5,065	3,469	86–106	94.6	20	0.20–1.38	0.71	15	75.0	20	0.17–1.27	0.62	15	75.0
Port Susan	32	1,340–4,560	3,033	70–106	89.6	32	0.09–2.28	0.89	20	62.5	22	0.17–1.95	1.02	19	86.3
Seattle	8	5,230–7,930	6,706	105–117	109.9	8	0.82–1.94	1.16	8	100.0	—	—	—	—	—
Tacoma	33	700–6,630	3,862	60–113	95.2	33	0.43–2.58	1.41	32	96.9	33	0.38–2.24	1.25	32	96.9
Σ	127	700–7,930	3,608	60–117	94.2	127	0.09–2.58	0.92	91	71.6	107	0.14–2.24	0.85	78	72.9
						Males									
Port Susan	7	1,445–2,645	1,864	75–87	79.4	7	0.21–0.98	0.64	6	85.7	2	0.49–0.95	0.72	1	50.0
Seattle	4	2,025–3,400	2,626	85–93	89.0	4	1.16–1.61	1.38	4	100.0	—	—	—	—	—
Tacoma	3	1,240–2,180	1,728	68–84	77.3	3	0.94–1.27	1.15	3	100.0	3	0.92–1.24	1.08	3	100.0
Σ	14	1,240–3,400	2,052	68–93	81.7	14	0.21–1.61	0.96	13	92.8	5	0.49–1.24	0.93	4	80.0

the fillets and fish weight for the 127 females (Figure 2). The weight of individual fish was evenly distributed in each of the area samples with the exception of the small sample of eight fish from Seattle. Although these were the largest fish collected, they contained less mercury than smaller fish from other areas. The Seattle sample does not appear to be adequate in number and may not be representative of the population. In all areas, except Seattle, the correlation coefficients were significant for the relationship of mercury content to weight (Table 2). The correlations between mercury content and fish length were significant but slightly lower in four of the five groups showing

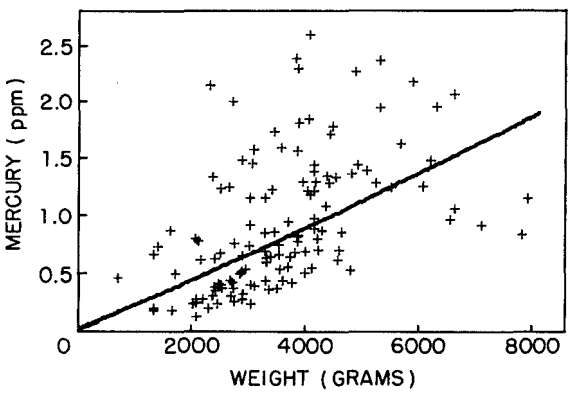

FIGURE 2.—Relationship between weight and mercury concentration in female dogfish fillets.

TABLE 2.—Correlation coefficients (r) and significance level (α) of mercury content to the weight and length of female spiny dogfish fillets from the State of Washington.

Location	No. of fish	Weight vs. mercury		Length vs. mercury	
		r	α	r	α
Port Townsend	22	0.645	0.01	0.507	0.05
Seabeck	12	0.648	0.05	0.616	0.05
Blaine	20	0.768	0.001	0.756	0.001
Port Susan	32	0.699	0.001	0.643	0.001
Seattle	8	−0.501	NS[1]	−0.414	NS
Tacoma	33	0.601	0.001	0.648	0.001
Σ	127	0.576	0.001	0.530	0.001

[1]Not significant.

positive coefficients. We expected a more significant correlation with length, since the weight of the females varied as to whether or not they were pregnant and the length of gestation. Childs et al. (1973) stated that mercury is not concentrated in the fetuses in situ; therefore, the mercury level in the flesh of the female is presumably unaffected by pregnancy.

The bellyflaps of 107 female and 5 male dogfish were analyzed (Table 1). Bellyflaps of the fish from Seattle and 10 small females from Port Susan were not analyzed. The bellyflaps contained slightly less mercury than the corresponding fillets; however, the percentage exceeding the action level (73%) was not significantly different from that for fillets.

The limited data on mercury levels in male dogfish (Table 1) indicated that essentially all male dogfish over the minimum commercial size (81.3 cm) would exceed the FDA action level. Of the 14 males analyzed, 13 (93%) exceeded the action level. The mean weight of the males (2,052 g) was less than the mean weight of the females (3,608 g), yet the mean mercury level was higher (0.96 ppm for males and 0.92 ppm for females). This difference may be attributed to the fact that males are smaller than females of the same age (Jensen 1966). Our findings agree with those of Forrester et al. (1972) on the mercury levels in male and female spiny dogfish from inland waters of British Columbia.

A study by Childs and Gaffke (1973) included 88 dogfish taken off the Oregon coast and showed a similar correlation of mercury level to weight and length but a lower mean level of 0.602 ppm mercury in all muscle samples. This suggests that dogfish taken from the Pacific Ocean off the Oregon coast may contain less mercury than the population sampled in this study of the inland waters of Washington. Tagging studies by Kauffman (1955) and Holland (1957) indicated that offshore dogfish populations may be highly migratory. Jensen (1966) noted that the nature of the dogfish's seasonal migration in offshore coastal waters was not clearly understood. Alverson and Stansby (1963) stated that the dogfish within Puget Sound show less tendency to migrate and that Puget Sound stocks are apparently somewhat independent from the coastal and offshore stocks. They further stated that some movement of dogfish may occur between ocean areas and Puget Sound. The mercury levels found in our study are most probably those of a population indigenous to Puget Sound.

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ALICE S. HALL
FUAD M. TEENY
ERICH J. GAUGLITZ, JR.

Northwest and Alaska Fisheries Center
National Marine Fisheries Service, NOAA
2725 Montlake Boulevard East
Seattle, WA 98112

LOCALIZED MASS MORTALITY OF RED SEA URCHIN, *STRONGYLOCENTROTUS FRANCISCANUS*, NEAR SANTA CRUZ, CALIFORNIA

Johnson (1971) reported on the occurrence of a mass mortality of red sea urchin, *Strongylocentrotus franciscanus* (Stimpson 1857) off Point Loma, San Diego, in the summer of 1970, and she detailed the symptoms of the diseased sea urchins. Large areas of the test, particularly of the interambulacra, were denuded of spines and epidermis. These denuded areas were chalky white with green blotches and often were bordered by a ring of swollen tissue. The test plates of the denuded area were layered and a middle "red-friable" layer with disorganized cellular structure replaced the normal plate tissue and ossicle. In some cases, lesions broke through the denuded tests and these apparently led to the animals' death. The internal organs appeared to be normal. Johnson (1971) was unable to determine the cause of these symptoms, but she suggested that a microorganism, perhaps a fungus, might be responsible.

The area affected in the 1970 mass mortality off Point Loma was limited to a few hectares (Johnson 1971). It was first noted in May 1970, when the center of the area was littered with dying sea urchins while the perimeter had fewer diseased animals with only small patches of denuded tests. The affected area did not spread, and by the middle of summer, many of the surviving urchins were regenerating spines. Diseased animals with partially denuded tests were difficult to find in November 1970.

We report here two other localized mass mortalities of *S. franciscanus* in central California, which seem to be similar to the one documented by Johnson (1971). One was found in 3–5 m of water off the southeast side of Año Nuevo Island (lat. 37°06′25″N, long. 122°19′30″W). It was first observed on 18 July 1976, and revisited on 31 July 1976. Diseased animals with drooping spines and partially denuded tests were found scattered among healthy-appearing individuals. They did not seem to be clumped or segregated, although most diseased animals were in the open while healthy-appearing animals tended to be under ledges or in crevices. Diseased animals did not hold onto the rocks as normal animals usually do, and they were picked up easily by divers. Empty tests of recently dead animals littered portions of the bottom. Red sea urchins were the only animals noted to be affected at the Año Nuevo Island site. Other areas of similar depth to the south and northwest of Año Nuevo Island supported numerous healthy-appearing red sea urchins and none with denuded tests.

The diseased animals collected from Año Nuevo Island were very similar to those described by Johnson (1971) (Figure 1). Portions of the test were denuded of spines while the remainder of the test was covered with normal-appearing spines. The affected test plates were layered with a thin greenish surface layer, a red-friable middle layer