Trace Metals in Sea Scallops, *Placopecten magellanicus*, from Eastern United States

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Scallops have been shown to contain remarkably high concentrations of some metals in certain organs. For example, high levels of both manganese and zinc are found in the kidneys (BROOKS and RUMSBY 1965) and cadmium is concentrated in the digestive gland (MULLIN and RILEY 1956; BRYAN 1973). Since the scallops examined by these investigators came from the United Kingdom and New Zealand, it was deemed desirable to examine the sea scallop from U. S. Atlantic waters for both comparative purposes and to establish baseline data for metal concentrations in this mollusk.

The sea scallop, Placopecten magellanicus, is widely distributed off the eastern coast of the United States, from Maine to North Carolina, where it supports a significant commercial fishery. In 1975 the species ranked fifth in importance in terms of total weight of shellfish species landed in the United States, ranking after the surf clam, Spisula solidissima, oyster, Crassostrea virginica, hard clam, Mercenaria mercenaria, and soft clam, Mya arenaria. During the five-year period, 1971-75, total annual landings averaged 2.9 million kg and were valued at an average of 11.1 million dollars (U.S. Dept. Commerce).

Research surveys are conducted periodically by the National Marine Fisheries Service to assess the distribution and abundance of sea scallop resources and provide a basis for anticipated future production (MERRILL 1962). The two principal stocks of sea scallops occur on Georges Bank, off Massachusetts, where they grow on hard sand-gravel-rock bottoms under 40 to 95 m of water, and south of Long Island and east of New Jersey where they grow on sand and sand-gravel bottoms under 35 to 75 m of water (POSGAY in press). In the late 1970's, landings are expected to increase somewhat because of widespread recruitment of young scallops in 1972.

MATERIALS AND METHODS

A standard 3.05-m (10-ft) sea scallop dredge and bag with 5.01-cm (2-in) rings was the sampling gear used throughout the surveys. It was towed for 15 min at each of 42 stations to collect scallops for heavy metals analyses. On Georges Bank, stations were occupied in areas which correspond to historical commercial fishing areas (Fig. 1). Along the middle Atlantic

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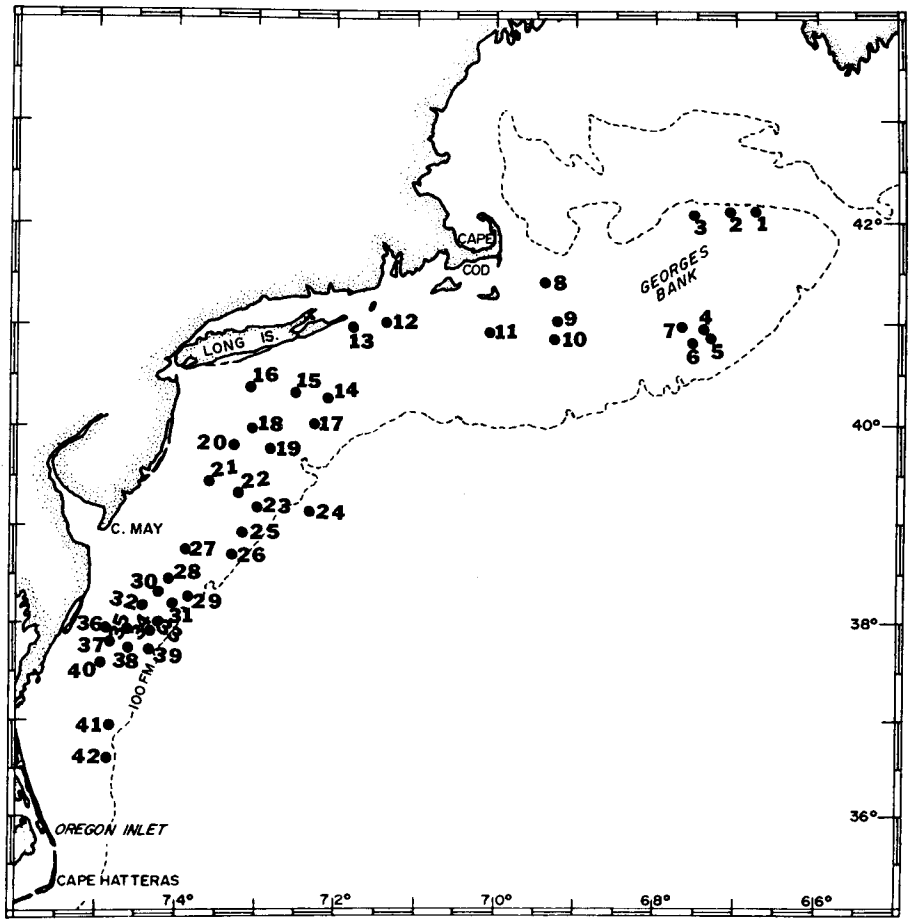

Figure 1. Station locations for collection of scallops for trace metal analyses from U. S. North Atlantic waters.

Table I. Metal concentrations in muscle from sea scallops collected from North Atlantic waters.

Station Number	Metals (ppm, wet weight) Ag	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	<0.11	<0.11	0.64	<0.42	*	<0.42	<2.1	3.7
2	<0.09	<0.09	0.61	<0.41	*	<0.41	<2.1	2.7
3	0.13	<0.09	0.56	0.29	*	<0.68	<2.4	3.6
4	0.15	<0.15	0.49	<0.40	*	<0.40	<2.1	3.5
5	0.18	<0.08	0.47	<0.37	*	<0.37	<1.9	3.0
6	<0.09	<0.09	<0.37	<0.41	*	<0.47	<2.1	3.2
7	0.13	<0.09	0.57	0.38	*	<0.42	<2.1	6.5
8	<0.10	<0.10	<0.41	<0.41	*	<0.41	<2.1	4.0
9	0.14	<0.10	0.39	<0.37	*	<0.42	<2.1	6.7
10	<0.10	<0.10	0.52	0.35	*	<0.41	<2.1	3.4
11	<0.09	<0.09	0.27	0.27	*	<0.39	<2.0	4.2
12	<0.11	<0.11	<0.43	0.71	*	<0.43	1.7	7.5
13	<0.09	<0.09	0.33	0.29	*	<0.39	<2.0	7.2
14	<0.11	<0.11	<0.45	1.1	*	<0.45	<0.9	4.7
15	<0.12	<0.12	<0.49	<0.49	*	<0.49	<1.0	3.6
16	<0.12	<0.12	<0.47	<0.47	*	<0.47	<1.0	2.8
17	<0.10	<0.11	<0.41	<0.40	*	<0.41	<0.90	8.1
18	<0.11	<0.11	<0.43	<0.37	*	<0.43	<2.1	2.7
19	0.15	<0.10	<0.40	<0.35	*	<0.40	<2.1	3.4
20	<0.09	<0.09	<0.36	<0.36	*	<0.36	<1.8	2.3
22	<0.17	<0.11	<0.44	<0.44	*	<0.44	0.90	4.0
23	<0.12	<0.12	<0.48	<0.45	*	<0.48	<0.97	5.2
24	<0.11	<0.11	<0.45	0.59	*	<0.45	<2.2	5.7
25	0.17	<0.12	<0.48	<0.48	*	<0.48	<0.97	3.8
26	<0.11	<0.11	<0.49	1.0	*	<0.47	<0.95	3.7
27	<0.09	<0.09	<0.41	<0.41	*	<0.41	<2.1	2.7
28	0.20	<0.08	<0.34	<0.34	*	<0.34	<0.52	2.0
29	<0.11	<0.11	<0.47	<0.47	*	<0.47	<0.94	3.2
30	<0.10	<0.10	<0.43	<0.43	*	<0.43	<0.65	7.4
31	<0.09	<0.09	<0.38	0.40	*	<0.38	<0.57	2.8
32	<0.20	<0.12	<0.48	0.58	*	<0.48	<0.96	5.7
34	0.15	<0.09	<0.38	<0.38	*	<0.38	<0.57	3.5
35	0.24	<0.10	<0.41	<0.41	*	<0.41	<0.62	2.6
36	<0.11	<0.11	<0.45	<0.48	*	<0.45	<0.67	3.7
37	0.12	<0.10	<0.41	0.66	*	<0.41	<0.62	2.5
38	0.08	<0.06	<0.26	0.38	*	<0.26	<0.40	2.4
39	<0.07	<0.09	<0.36	<0.40	*	<0.36	<0.55	2.4
40	<0.12	<0.11	<0.46	<0.55	*	<0.46	<0.70	3.6
41	<0.08	<0.10	<0.40	<0.40	*	<0.40	<0.60	3.2
42	<0.12	<0.12	<0.50	<0.50	*	<0.50	<0.75	3.6

* Mercury concentrations were below detection limits, which were 0.08 - 0.18 ppm.

Table II. Metal concentrations in gonadal tissue of sea scallops collected from North Atlantic waters.

Station Number	Sex	Metals (ppm, wet weight) Ag	Cd	Cr	Cu	Hg	Ni	Pb	Zn
11	M	<0.14	0.71	0.43	1.3	*	<0.59	<3.0	13.3
	F	<0.19	0.76	<0.76	2.8	*	<0.75	<3.9	53.6
12	M	0.20	0.52	<0.49	1.6	*	<0.49	<1.0	7.5
	F	0.15	0.79	<0.48	4.3	*	<0.48	<1.0	56.1
13	M	<0.16	0.72	<0.70	1.5	*	<0.65	<3.3	10.5
	F	0.23	1.1	<0.67	2.5	*	<0.77	<3.9	40.2
14	M	0.24	0.94	<0.59	2.0	*	<0.59	<1.2	11.6
	F	0.16	1.0	0.48	3.7	*	<0.37	<0.7	39.7
15	M	0.47	0.47	<0.63	2.3	*	<0.63	<1.3	12.7
	F	0.28	1.2	<0.62	4.0	*	<0.62	<1.3	52.8
16	F	0.50	2.3	<0.60	5.8	*	0.66	<1.5	75.4
17	M	0.14	0.58	3.6	10.6	*	<0.58	<1.3	4.7
	F	0.25	2.1	0.37	4.5	*	0.43	<0.64	45.5
18	M	0.23	0.95	<0.54	1.6	*	<0.54	<2.7	11.7
	F	<0.19	0.74	<0.65	3.2	*	<0.63	<3.3	56.5
19	M	0.23	0.63	<0.47	1.6	*	<0.50	<2.5	5.7
	F	0.17	0.59	<0.49	2.1	*	<0.49	<2.5	25.7
20	M	0.35	1.7	1.7	5.6	*	0.39	<1.6	15.3
22	M	0.14	0.58	<0.41	1.7	*	<0.41	<0.83	9.5
	F	0.25	0.58	<0.67	3.0	*	<0.67	<1.4	22.5
23	M	0.23	1.6	<0.51	3.0	*	0.87	<1.0	18.3
	F	0.29	2.9	<0.42	4.1	*	0.66	<0.85	61.1
24	M	0.17	0.48	<0.59	1.1	*	<0.59	<3.0	6.1
	F	0.19	0.95	<0.80	4.0	*	0.60	<3.1	45.1
27	M	0.21	1.0	0.33	1.7	*	<0.38	<1.9	8.3
	F	0.13	1.3	<0.39	1.7	*	<0.39	<2.0	25.8
28	M	0.31	1.4	<0.42	1.2	*	<0.42	<0.63	8.9
	F	0.23	0.52	<0.50	0.71	*	<0.50	<0.75	9.9
29	M	0.51	2.0	<0.47	2.8	*	1.2	<0.90	24.8
	F	0.63	1.9	<0.47	2.9	*	0.84	0.94	29.4
30	M	0.33	1.3	<0.59	1.9	*	0.47	<0.89	16.8
	F	0.24	1.9	<0.59	3.3	*	<0.59	<0.88	55.3
31	M	0.34	2.2	<0.73	1.8	*	<0.73	<1.1	23.8
	F	0.38	2.7	<0.62	5.7	*	0.58	<0.93	38.0
32	M	0.59	2.2	<0.91	3.1	*	0.7	<1.8	28.7
34	M	0.28	3.0	<0.37	2.0	*	0.75	<0.56	28.8
	F	0.30	3.1	<0.62	2.7	*	<0.55	<0.93	43.2
35	M	0.50	1.8	<1.3	2.2	*	<1.3	<1.9	19.8
	F	0.32	1.5	<1.1	2.5	*	<1.1	<1.6	53.8
36	F	0.33	1.1	<0.3	1.6	*	0.27	0.79	24.2
37	M	0.69	1.1	<1.3	1.5	*	<1.3	<1.9	22.4
	F	0.61	1.9	<1.4	2.9	*	<1.4	<2.1	61.8
38	M	0.28	1.1	<0.76	1.7	*	<0.76	<1.1	17.8
	F	0.36	2.7	<0.52	2.7	*	0.60	1.1	62.9
39	M	0.63	1.5	<0.98	2.2	*	2.5	<1.5	19.9
40	M	0.30	1.2	<1.0	1.2	*	<1.0	1.5	16.1
	F	0.44	2.2	<1.8	2.4	*	<1.8	<2.7	47.1
41	M	0.34	3.2	<0.40	2.0	*	0.74	0.80	33.4
	F	0.25	1.6	<0.41	2.1	*	0.45	0.62	38.4
42	M	0.23	0.81	<0.29	1.1	*	0.23	<0.44	15.2
	F	0.25	1.5	<0.55	1.8	*	0.39	<0.82	22.5

* Mercury concentrations were below detection limits, which were 0.08 - 0.18 ppm.

Coast, stations were occupied from eastern Long Island to Cape Hatteras, North Carolina, many of which were in commercial fishing areas (Fig. 1). The catch from each tow was emptied on deck, sorted, and sea scallops separated for measurements and processing. For trace metal analysis, specimens were immediately processed into muscle, gonad and total visceral mass (material left after removal of shell, muscle and gonad) portions, then frozen for shipment to the laboratory.

Metal analyses were conducted by two different methods: one for mercury, and another for seven other metals examined in this study (Tables I-III). Mercury analyses were made by the method described By GREIG et al. (1975a) and the remaining metals by the method of GREIG et al. (1975b). Data are reported on a wet weight basis.

RESULTS AND DISCUSSION

Most metal concentrations, except zinc, in muscle tissue of scallops were below detection limits of the methodology employed (Table I). Zinc levels ranged from about 2-8 ppm, but geographic differences in these concentrations were not evident. Comparisons of the present data with those obtained on scallop muscle from the United Kingdom and New Zealand are shown in Table IV. Zinc levels in the present study are substantially lower than the 14-22 ppm found by the three other investigators. Differences in species could account for this observation; however, differences in analytical results for zinc, as well as all other metals, could be important. Mercury was not determined by any of the other investigators; it was below a mean of 0.18 ppm in scallops from the U.S., which is well below the "action limit" of 0.5 ppm established for fishery products by the U.S. Food and Drug Administration.

In contrast to muscle, Ag, Cd, Cu, and Zn were present in detectable concentrations in gonads of scallops (Table II). Levels of Cr, Hg, Ni, and Pb were below detection limits in most gonad samples (Table II). Male and female gonads were examined and differences in Cu and Zn levels related to sex were observed. Concentrations of these metals generally were greater in the female gonad; however, in several instances levels in male gonad exceeded those in the female. Copper and zinc have important biochemical functions, in particular, as enzyme activators (BROOKS and RUMSBY 1965); thus, it probably is not surprising to find greater concentrations of these metals in the female gonad since a portion probably has to be transmitted to the progeny. Even though these scallops were collected over a very wide geographic area (Fig. 1), there is no evidence that metal concentrations in gonads differ as a function of geographic location. Data by other investigators are available from the United Kingdom and New Zealand (Table IV). Differences in metal concentrations among investigators are evident but, as stated earlier, they cannot be attributed to any one parameter, such as species or analytical differences.

Table III. Metal concentrations in the total visceral mass of sea scallops collected North Atlantic waters.

Station Number*	Metals (ppm, wet weight) Ag	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1	0.46	10.8	1.2	1.8	**	<0.48	<2.0	12.5
2	0.27	6.5	1.7	1.7	**	0.37	<1.9	15.6
3	0.31	5.7	1.3	1.5	**	<0.68	<2.1	15.2
4	0.23	7.7	0.87	1.8	**	0.46	<1.3	15.3
5	0.31	14.1	1.5	4.7	**	0.47	<2.1	16.2
6	0.47	9.5	0.95	1.9	**	0.49	<1.8	13.6
7	0.22	3.7	1.1	1.3	**	0.37	<1.3	7.4
8	0.51	8.9	0.91	1.9	**	<0.39	<2.0	16.2
9	0.37	7.9	0.51	1.7	**	<0.43	<2.2	15.9
10	0.26	7.9	1.1	1.8	**	<0.45	<2.0	20.1
11	0.46	4.5	2.7	2.1	**	1.1	<2.2	16.6
12	0.29	10.1	1.5	3.7	**	1.0	<0.98	14.9
13	0.31	5.0	2.1	2.4	**	0.86	<1.9	15.2
14	0.35	9.6	1.2	2.5	**	0.50	<1.0	14.2
15	0.69	5.5	1.1	2.3	**	0.62	<1.1	14.7
16	0.68	5.1	0.69	2.7	**	<0.49	<1.0	17.5
17	0.38	11.4	4.0	2.8	**	1.3	1.6	13.7
18	0.37	8.0	0.43	2.5	**	0.57	<2.1	15.9
19	0.34	12.1	1.3	3.1	**	0.81	<2.2	15.2
20	0.62	7.5	0.69	3.7	**	0.42	<4.9	14.6
22	0.40	8.5	2.0	2.6	**	0.70	<1.4	13.4
23	0.44	13.1	0.69	2.9	**	0.34	<0.9	12.9
24	0.31	6.4	0.47	1.8	**	0.43	<1.1	11.7
25	0.45	18.0	1.2	4.1	**	0.70	<1.1	13.9
26	0.51	27.0	0.71	5.0	**	1.3	<0.95	16.1
27	0.41	18.9	0.45	2.7	**	0.63	<1.9	17.5
28	0.54	10.8	<0.50	2.2	**	0.72	0.88	19.1
29	0.46	13.1	<0.48	2.9	**	0.49	<0.92	13.4
30	0.52	8.4	1.4	5.6	**	0.50	1.0	15.4
31	0.37	16.9	<0.49	2.9	**	0.47	<0.74	13.7
32	1.1	2.7	0.57	1.5	**	0.55	<0.68	13.1
34	0.29	9.6	0.37	1.6	**	0.31	<0.45	12.5
35	1.3	4.5	1.3	2.1	**	0.59	0.85	16.5
36	0.41	12.4	<0.41	1.8	**	0.35	<0.62	16.9
37	1.9	5.5	1.5	2.3	**	0.67	1.2	22.5
38	0.54	12.7	<0.47	2.6	**	<0.48	<0.71	16.5
39	0.49	17.1	0.46	3.1	**	0.86	<0.71	14.5
40	0.90	5.1	<0.50	2.6	**	1.6	<0.87	14.4
41	0.82	14.4	<0.47	2.7	**	1.3	<0.70	17.1
42	0.48	14.7	0.75	2.2	**	0.55	1.0	15.5

* Stations 1-10 - total visceral mass material includes gonads; at all other stations gonads were removed.

** Mercury concentrations were below detection limits, which were 0.08 - 0.18 ppm.

Table 4. Metal concentrations in muscle and gonad of scallops obtained from various countries.

Species	Country	Metals (ppm, wet weight[a]) Ag	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Authors
					MUSCLE					
Placopecten magellanicus	United States	<0.1-0.2	<0.15	<0.3-0.6	<0.3-1.1	<0.18	<0.5	<2.0	2-8	This paper
Pecten maximus	United Kingdom	---	----	---	0.24	----	0.008	0.04	16	Bryan, 1973
Pecten maximus	United Kingdom	---	0.38	---	0.24	----	0.34	3.4	14	Segar et al., 1971
Pecten maximus	United Kingdom	---	0.38	---	----	----	----	---	--	Mullin & Riley, 1956
P. novae-zelandiae	New Zealand	<0.02	<4	<0.6	0.2	----	0.4	<1	22	Brooks & Rumsby, 1965
					GONAD					
Placopecten magellanicus	United States	<0.1-0.7	0.4-3.2	<0.3-3.6	1-11	<0.18	<0.4-1.2	<0.4-1.5	8-75	This paper
Pecten maximus	United Kingdom	---	---	---	3.5[b]	----	0.05	0.34	39	Bryan, 1973
Pecten maximus	United Kingdom	---	0.5	---	2.6	----	0.09	6.2	72	Segar et al., 1971
Pecten maximus	United Kingdom	---	0.16	---	---	----	----	---	--	Mullin & Riley, 1956
P. novae-zelandiae	New Zealand	0.04	<4	<0.6	1.8	----	<0.4	15.6	51	Brooks & Rumsby, 1965

a - Data by all authors except this paper were converted from a dry weight basis to wet weight basis by dividing by 5 (this assumes 80% water content of tissue).

b - Data by Bryan was for gonad plus foot.

Metal concentrations were also determined for the total visceral mass of the scallop (Table III). Only Hg and Pb concentrations were generally below detection limits. Except for Cd and Zn, the other metal concentrations were similar to those found in the gonads. Zinc levels were similar to those in the male gonad, but were at the low end of the levels found in the female gonad. Cadmium concentrations varied greatly between scallops in the total visceral mass (range 2.7-27.0 ppm), but in most they were several orders of magnitude greater than in gonad or muscle. Again, no evidence of geographic difference in metal concentrations was found. The investigators in Table IV did not examine the total visceral mass of scallops. However, they did examine the digestive gland, which probably makes up a significant part of the total visceral mass portion examined here. Because Cd was the only unusual metal for the total visceral mass compared to muscle and gonad, it alone will be compared to other investigators' results on digestive glands. BRYAN (1973) found 64 ppm of Cd in the digestive gland, MULLIN and RILEY (1956) 106 ppm, SEGAR et al. (1971) 19 ppm, and in the present study a range of 2.7 to 27.0 ppm. The SEGAR et al. data were for gut and digestive gland together. The BRYAN and MULLIN and RILEY data are astonishingly high in comparison to our data and those of SEGAR et al. The latter two sets of data are comparable in magnitude but differences in sample type prevent exact comparison.

Recently WENZLOFF et al. (unpublished manuscript available at National Marine Fisheries Service, Milford, Connecticut) determined the concentrations of 9 metals in the surf clam (Spisula solidissima) and the ocean quahog (Arctica islandica). Data on these clams and the sea scallops examined in the present study provide some interesting comparisons. Whole body meats were examined for the clams, whereas muscle, gonad, and total visceral mass were examined for sea scallops making direct comparison difficult. However, we believe that the best comparison is between the total visceral mass of the scallop and the whole body meat of the clam. With the exception of silver and cadmium the metal concentrations found in the clams were very similar to those found in the total visceral mass of the scallop (data presented in Table III). Sea scallops are generally found further offshore than the clams and thus one would expect them to contain lower concentrations of metals than the clams, thus finding similar concentrations of metals is somewhat surprising. Silver, on the other hand, was as expected with the surf clams and quahogs having about 2-5 times more silver than the total visceral mass of the sea scallop. Cadmium, however, was very different in that the total visceral mass of the sea scallop contained 2.7 to 27.0 ppm, whereas surf clams contained less than 0.13 ppm and quahogs contained about 0.4 ppm.

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