NONDESTRUCTIVE NEUTRON ACTIVATION ANALYSIS OF MARINE ORGANISMS COLLECTED FROM OCEAN DUMP SITES OF THE MIDDLE EASTERN UNITED STATES

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The concentrations of eight metals were determined by a nondestructive neutron activation technique for eleven species of fish and shellfish. The marine organisms were collected from ocean dump sites off New York City, off New Haven, Connecticut, and off Delaware Bay.

Antimony was not detected in most of the organisms examined in this study; the detection limit was about 0.02 to 0.05 ppm. Antimony levels ranged from 0.01 to 0.129 ppm in fish that had detectable levels. Cobalt levels were low in all samples with most levels in the range of 0.1 to 0.3 ppm. Chromium concentrations at 0.3 to 1.0 ppm were only roughly quantitated by the procedure employed. Most marine organisms examined had chromium levels at or below these values. Nickel was not detected in any of the organisms examined; the detection limit was in the 3 to 6 ppm range.

Rubidium concentrations were 0.6 to 1.5 ppm for most organisms; only rough quantitative measurement was possible at these levels. Selenium levels ranged from about 0.3 to 3.8 ppm in all samples. Silver concentrations were below 0.3 ppm in most organisms. Silver concentrations as high as 10 to 30 ppm, however, were found in the digestive gland of rock crab. Zinc levels in windowpane flounder liver were about 6 to 9 times greater than the 4 to 10 ppm levels found in muscle. Zinc concentrations in rock crab muscle, on the other hand, were only slightly higher than the 15 to 32 ppm concentration found in the digestive gland. Fish other than windowpane flounder had zinc levels that ranged from 4 to 9 ppm in the muscle and 14 to 42 ppm in the liver. Shellfish other than rock crab had zinc levels of 15 to 30 ppm in muscle and 17 to 40 ppm in the digestive gland.

Neutron activation analysis has been applied frequently for the detection of trace metals in animal tissues, as well as numerous other materials. Two techniques often applied with neutron activation are nondestructive and destructive analyses. In nondestructive analysis the sample is bombarded with neutrons for various periods, ranging from a few seconds to days. The sample is set aside for a time to allow the

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activity from any interfering, short-lived radionuclides to decay to a negligible amount. The activity of the radionuclide of interest is then counted with the appropriate instrumentation. In destructive analysis the sample is bombarded with neutrons and a chemical separation is performed on the sample to isolate the radionuclide(s) of interest. Chemical separations have been a necessity until the last several years when new instrumentation was developed to handle the analysis of complex gamma-ray spectra.

Robertson *et al.* (1968) applied nondestructive neutron activation analysis techniques to sea water, marine organisms, and sediments. They were able to determine the concentrations of antimony, cobalt, cesium, silver, scandium, and zinc in marine organisms. In addition to these, six other elements were determined in sediments and sea water. Merlini *et al.* (1967) examined water, sediment, plants, and animals from Italian rivers, employing a nondestructive neutron activation technique, and were able to determine arsenic, cobalt, cesium, copper, manganese, and iron in these samples.

In the present study, nondestructive neutron activation analysis was applied to marine organisms collected primarily from ocean dumping grounds in the New York Bight, Long Island Sound, and off Delaware Bay. The purpose of the study was to develop base line data for trace metals in fish and shellfish for these locations and, possibly, to determine any differences in metal concentrations related to geographical location.

Table I. *Descriptions of station locations referred to in Tables 6 to 9*

Station	Description	Latitude	Longitude
73BB	Barnegat Bay	39°50.30′	74°02.20′
1-70	Center of New York sewage sludge dump site	40°25.10′	73°45.00′
69D5	Center of Delaware Bay dump site	38°46.00′	74°46.55′
Chinc.	Off Chincoteague, Virginia	37°50′	75°15′
Lg. Is. Sd.			
Area 1	New Haven dump site	41°09′	72°53′
Area 2	3 miles west of New Haven dump site	41°09′	73°01′
1-47	8 miles from station 1-70 near Long Beach, New York	41°33.30′	73°43.40′
1-106	7 miles from station 1-70 between mouth of Hudson River and station 1-70	40°31.10′	73°50.30′
BA buoy	Off Long Branch, New Jersey	40°20.70′	73°47.55′

Experimental methods

Sample collection and preparation. Samples of fish and shellfish were collected from ocean dump sites in the New York Bight, Long Island Sound, and off Delaware Bay. A list of the areas sampled and their corresponding latitude and longitude is presented in Table I, while Table II lists the common and scientific names of the organisms collected. Tissues from 6 to 10 animals per station were dissected and frozen in plastic bags aboard research vessels.

At the laboratory, frozen samples were lyophilized for 48 hr and ground into a fine powder with a Teflon mortar and pestle. Organ samples were lyophilized as received and muscle samples were ground into a homogenous sample with an electric blendor, employing glass jars and stainless steel blades, prior to lyophilization. The tissues or organs of the 6 to 10 animals per station were pooled for analysis.

Chemical analysis. The dried material (about 0.4 to 0.8 g) was loaded into quartz tubing which was sealed by heat. A 0.5 ml standard solution was placed in similar quartz tubing, and one tube of standard was wired to two tubes containing test samples. The bundles of samples and standards were bombarded with neutrons for 10 hr at a neutron flux of about 2×10^{13} n/cm^2-sec, then set aside for 5 weeks to allow decay of short-lived radioisotopes. The quartz tubes were smashed and the sample transferred to a counting vial with 1 *M* sulfuric acid. The final volume for sample and standard in the counting vial was kept the same. Samples and standards

Table II. *List of common and scientific names of fish and shellfish referred to in this publication*

Common name	Scientific name
Channeled whelk	*Busycon canaliculatum*
Fluke (summer flounder)	*Paralichthys dentatus*
Ling (white hake)	*Urophycis tenuis*
Lobster	*Homarus americanus*
Red hake	*Urophycis chuss*
Rock crab	*Cancer irroratus*
Spiny dogfish	*Squalus acanthias*
Surf clam	*Spisula solidissima*
Windowpane flounder	*Scophthalmus aquosus*
Winter flounder	*Pseudopleuronectes americanus*
Yellowtail flounder	*Limanda ferruginea*

that were irradiated together were counted within a few hours of one another so that no correction for decay time was necessary. The counting was done on a lithium-drifted germanium detector coupled to a 4000 channel pulse height analyzer. After subtraction of background counts, the areas of the gamma ray photo peaks of samples were compared to those of the standard for quantification. The following metals could be determined by this procedure: selenium, chromium, antimony, silver, nickel, rubidium, zinc, and cobalt.

Results and discussion

Evaluation of neutron activation technique. *Detection limits*. The term "detection limit" is used quite often to define the smallest mass of an element or compound that can be detected by a particular analytical technique. The method of calculating the value that represents the detection limit, however, is not standardized and varies with investigators and with analytical techniques. In the work reported here, the detection limit value was taken as the mass of metal that would produce gamma ray counts equal to 4 times the standard deviation of the background counts (at the proper photo peak energy for the metal) of the marine organism sample.

Table III. *Detection limits for metals in marine organisms employing a nondestructive activation technique*

Metals	Detection limits[a] (ppm, wet wt.)
Antimony	0.02-0.05
Cobalt	0.02-0.05
Chromium	0.2 -0.4
Nickel	3-6
Rubidium	0.3 -0.7
Selenium	0.1 -0.3
Silver	0.05-0.2
Zinc	1-4

[a]Detection limits were calculated from the following:

$$\frac{C_1}{C_2} = \frac{M_1}{M_2}$$

where, C_1 is count of metal standard
$^1C_2$ is count of organism
M_1 is mass of metal standard
M_2 is mass of organism sample.

$^1C_2$ was calculated as equal to the standard deviation of background count times 4.

The detection limits for these samples are shown in Table III. The detection limit for nickel was quite poor and this metal was included in the study only for the purpose of screening for very high levels. Chromium and rubidium also presented problems in this work; most samples did not have sufficient quantities of these metals to allow good quantitative measurements.

Precision. The precision of the neutron activation technique was examined as follows: Analyses of several samples were replicated 3 to 6 times with each group analyzed in June, September, and November, 1971. As a measure of precision, the relative standard deviation was calculated for each set of these replicate determinations. The results show that the precision of this technique was acceptable for zinc, selenium, and silver (Table IV). The relative standard deviations for these metals averaged about 20%, 20%, and 25%, respectively. Most of the selenium and silver concentrations encountered were only 2 to 3 times greater than the detection limits for these metals, thus the precision data are quite good under these conditions. The concentrations of rubidium, cobalt, and chromium were quite close to the detection limit for the method, which may account for the large relative standard deviations encountered with the analysis of these metals.

Table IV. *Precision of neutron activation analysis as measured by relative standard deviations.*

Metals	Metal concentration (ppm, range)	Batch[a]	N[b]	Relative standard deviation	
				Range	Average
Chromium	0.5 -1.3	1	4	5.3-97.6	56.3%
	0.3 -0.8	2	6	11.4-49.3	27.2%
	3.8	3	1	3.1	3.1%
Cobalt	0.08-0.4	1	4	14.8-78.1	34.6%
	0.08-0.14	2	8	11.5-71.0	29.2%
	0.11-0.43	3	3	3.5-14.0	10.3%
Rubidium	0.4 -1.2	1	6	12.7-32.6	25.3%
	0.3 -0.7	2	3	24.1-28.9	26.8%
	0.6 -1.8	3	5	27.5-62.9	40.0%
Selenium	0.3 -2.9	1	11	12.5-42.6	23.6%
	0.3 -5.1	2	8	5.8-30.8	19.8%
	0.30-3.4	3	8	1.7-50.7	21.2%
Silver	0.1 -4.3	1	5	12.4-39.8	24.8%
	0.1 -1.3	2	6	10.9-45.8	26.4%
	0.81	3	1	12.5	12.5%
Zinc	4 -72	1	10	1.0-39.6	19.7%
	4 -54	2	8	9.4-32.0	18.3%
	4 -592	3	6	11.9-42.7	23.3%

[a]Batch—Represents groups of samples that were analyzed in June, September, and November, 1971 (for 1, 2, 3, respectively).
[b]N—Number of samples that were replicated 3 to 6 times.

Metal concentrations in marine organisms. *Antimony.* Antimony was not detected in most of the organisms examined in this study. The detection limit for this metal was about 0.02 to 0.05 ppm. Some samples, however, were favorable for the determination of antimony and the results are presented in Table V. Seventeen samples of windowpane flounder from various catch locations and seasons were examined and only 6 muscle and 2 liver samples had measurable antimony concentrations. The levels in these and other samples examined were quite low and were expressed as ppb rather than ppm. Muscle samples of windowpane flounder averaged 28 ppb antimony, while liver averaged 24.5 ppb. Eleven samples of rock crab were examined, with 4 muscle, 1 gill, and 1 digestive gland samples having measurable antimony concentrations; the average antimony levels were 16, 129, and 58 ppb, respectively. Seven samples of channeled whelk were examined and antimony was detected in only one sample of muscle; the concentration was 10 ppb. Single samples of ling, red hake, and yellowtail flounder were analyzed and antimony levels in muscle tissue were 40, 22.5, and 10 ppb, respectively. Winter flounder liver had 20 ppb antimony, while none was found in the muscle.

Cobalt. Cobalt concentrations were low in all samples; surf clam digestive gland at 0.4 ppm (wet wt.) had the highest concentration (Table IX). In most other samples the cobalt level was 0.1 to 0.3 ppm (Tables VI to IX). The data revealed no substantial differences in cobalt concentrations that could be related to geographical areas. The concentrations of cobalt found in these organisms were similar to those reported by Pringle *et al.* (1968) for various shellfish. Pringle found cobalt levels from 0.06 to 0.2 ppm in oysters, soft shell clams, and northern quahogs. Robertson *et al.* (1968), however, examined 47 samples of zooplankton, shrimp, and various fish and found cobalt concentrations ranging from 0.003 to 0.01 ppm. These levels

Table V. *Antimony concentrations in various species of marine organisms*

Species	Tissue	Antimony concentration (ppb)		
		Range	Average	N
Windowpane flounder	Muscle	19-36	28.0	6
Windowpane flounder	Liver	16-33	24.5	2
Rock crab	Muscle	13-22	16.0	4
Rock crab	Gills	129.0	129.0	1
Rock crab	Digestive gland	58.0	58.0	1
Channeled whelk	Muscle	10.0	10.0	1
Ling	Muscle	40.0	40.0	1
Red hake	Muscle	23.0	23.0	1
Yellowtail flounder	Muscle	10.0	10.0	1
Winter flounder	Liver	20.0	20.0	1

Table VI. *Metal concentrations in windowpane flounder collected from six locations at inshore marine waters of the Middle Atlantic Bight and Long Island Sound, U.S.A.*

Station	N[a]	Range and average metal concentrations (ppm, wet wt.)					
		Cobalt	Chromium	Selenium	Silver	Rubidium	Zinc
				MUSCLE			
73BB	2	*	*	0.73-0.75	*	0.7	4.3- 5.5
				0.74		0.7	4.9
1-70	2	*	*	0.59	*	*-0.6	4.0- 4.5
						<0.6	4.3
69D5	4	*	*	0.5-0.7	*	0.7-1.0	3.7-10
				0.6		0.8	6.1
Chinc.	2	*	*-0.3	0.3-0.55	*	*-0.5	4.1- 8.5
			>0.3	0.43		<0.5	6.3
Lg.Is.Sd.	5	*	*	*-0.5	*-3.4	*-0.8	3.9- 8.2
Area 1				<0.5	<1.2	>0.8	5.5
Lg.Is.Sd.	2	*	*-0.3	*-0.3	*	0.6-0.9	4.5- 5.5
Area 2			<0.3	<0.3		0.75	5.0

LIVER

73BB	2	0.13-0.14	0.4	2.4-5.1	0.5-1.4	1.5	34.3-54.2
		0.14	0.4	3.8	1.0	1.5	44.2
1-70	2	0.13	*-0.4	2.1-2.5	*-1.3	*-1.1	37.0-39.3
		0.13	<0.4	2.3	<1.3	<1.1	38.0
69D5	4	0.04-0.16	*-0.8	1.1-2.8	*	*-1.8	23.7-39.2
		0.12	<0.8	1.6	*	<1.8	32.3
Chinc.	2	0.07-0.20	*-0.3	1.1-2.5	*	*-0.9	24.5-46.0
		0.13	<0.3	1.8	*	<0.9	35.3
Lg.Is.Sd.	5	0.11-0.25	*-1.3	1.6-2.0	*-0.2	*-1.1	34.3-40.6
Area 1		0.17	<0.7	1.8	<0.2	<1.1	36.5
Lg.Is.Sd.	2	0.04-0.1	0.3-0.5	1.1-2.0	*	*-1.5	32.0-36.3
Area 2		0.07	0.4	1.5	*	<1.5	34.1

*Not detected—see discussion for detection limits.

[a]N = Number of composites of 6 to 10 fish tissues analyzed. Samples were collected April to June and September to December, 1971.

Table VII. *Metal concentrations in rock crab collected from five locations at inshore marine waters of the Middle Atlantic Bight and Long Island Sound, U.S.A.*

Station	N[a]	Range and average metal concentrations (ppm, wet wt.)					
		Cobalt	Chromium	Selenium	Silver	Rubidium	Zinc
				MUSCLE			
73BB	1	0.2	*	1.0	1.9	*	35.0
		0.2	*	1.0	1.9	*	35.0
1-70	4	*-0.04	*-0.8	1.0-2.2	*-0.8	*-1.5	24.7-48.4
		<0.03	<0.5	1.4	<0.5	<1.3	31.4
69D5	2	*-0.10	*-0.2	1.0	0.5-0.9	*-1.0	28.0-36.5
		<0.1	<0.2	1.0	0.7	<1.0	32.2
Chinc.	2	*-0.10	*-0.5	1.0-1.6	0.2	*-1.0	29.5-45.0
		<0.1	<0.5	1.3	0.2	<1.0	37.2
Lg.Is.Sd.	2	0.04-0.10	0.3-0.6	2.8-5.5	0.1-0.2	0.7-1.3	25.5-77.9
Area 2		0.06	0.5	3.6	0.15	1.0	52.8

DIGESTIVE GLAND							
73BB	1	0.2	*	3.7	29.5	*	25.0
		0.2	*	3.7	29.5	*	25.0
1-70	4	*-0.22	*-0.8	1.3-1.7	*-10.0	*-1.5	13.0-24.5
		<0.16	<0.8	1.5	<4	<1.2	18.2
69D5	2	*	*-0.6	1.5-3.3	2.5-16.5	*-0.6	16.0-27.4
		*	<0.3	2.4	9.5	<0.3	21.7
Chinc.	2	0.21-0.25	*-0.6	1.4-2.1	2.4-3.2	0.9-1.7	28.1-34.9
		0.23	<0.4	1.7	2.8	1.3	31.5
Lg.Is.Sd	2	0.05-0.20	0.3-1.0	1.7-2.4	2.3-4.4	0.1-2.1	21.0-45.8
Area 2		0.14	0.6	2.0	3.8	1.1	32.4
GILLS							
Lg.Is.Sd.	2	0.3-0.4	3.8-3.9	0.6-0.9	0.5-0.8	0.4-2.5	< 4-13.3
Area 2		0.35	3.85	0.7	0.7	1.2	<8.6

*Not detected——see discussion for detection limits.
[a]N = Number of composites of 6 to 10 fish tissues analyzed. Samples were collected April to June and September to December, 1971

Table VIII. *Metal concentrations in fish collected from various inshore marine areas of the Middle Atlantic Bight, U.S.A.*

Species	Tissue	Station	Catch date	N[a]	Metal concentrations, ppm, wet wt.					
					Cobalt	Chromium	Selenium	Silver	Rubidium	Zinc
Fluke	Muscle	69D5	Sept. '71	1	*	0.7	0.7	*	*	4.0
Ling	Muscle	1-70	Sept. '71	1	*	*	0.3	*	0.8	2.9
Ling	Liver	1-70	Sept. '71	1	*	0.6	1.7	*	0.4	19.7
Red hake	Muscle	BA Buoy	Jan. '72	1	*	*	0.42	*	0.8	3.3
Red hake	Liver	BA Buoy	Jan. '72	1	*	*	1.9	0.06	*	29.5
Spiny dogfish	Muscle	69D5	Jan. '72	1	*	0.5	0.94	0.26	0.7	7.6
Yellowtail flounder	Muscle	73BB	Apr. '71	1	*	*	0.70	*	*	9.0
Yellowtail flounder	Muscle	1-70	Sept. '71	1	*	*	0.50	*	0.5	4.2
Winter flounder	Muscle	1-70	Sept. '71	1	*	*	0.40	*	0.5	—
Winter flounder	Liver	1-70	Sept. '71	1	*	0.4	2.8	0.1	5.2	42.0

*Not detected—see discussion for detection limits.
[a]N = Number of composites of 6 to 10 fish tissues analyzed.

Table IX. *Metal concentrations in shellfish collected from various inshore marine areas of the Middle Atlantic Bight and Long Island Sound, U.S.A.*

Species	Tissue	Station	Catch date	N[a]	Metal concentrations, ppm, wet wt.					
					Cobalt	Chromium	Selenium	Silver	Rubidium	Zinc
Surf clam	Muscle	Chinc.	Spr. '71	1	0.20	*	0.7	*	*	22.5
Surf clam	Digestive gland	Chinc.	Apr. '71	1	0.40	*	1.1	3.7	*	17.0
Surf clam	Muscle	69D5	Apr. '71	1	0.30	1.3	0.7	0.7	1.5	15.2
Surf clam	Muscle	1-47	June '71	1	0.16	0.7	0.8	1.3	1.2	15.6
Surf clam	Muscle	1-106	June '71	1	0.35	2.7	0.8	1.0	2.3	—
Lobster	Muscle	1-70	June '71	1	*	*	2.0	0.5	1.0	30.2
Lobster	Digestive gland	1-70	June '71	1	0.11	*	2.9	*	*	39.0
Channeled whelk	Muscle	Lg.Is.Sd.	Sept.-Dec.	5	*-*	*-0.7	*-0.4	*-0.3	*-1.7	23.5-35
		Area 1	'71		*	<0.3	<0.2	<0.2	<1.3	27.4
Channeled whelk	Muscle	Lg.Is.Sd.	Sept.-Dec.	2	*-*	*-0.4	*-0.4	*	*-1.1	22.8-25
		Area 2	'71		*	<0.4	<0.4	*	<1.1	23.9
Channeled whelk	Soft parts[b]									

*Not detected—see discussion for detection limits.

[a]N = Number of composites of 6 to 10 fish tissues analyzed.

[b]The metal concentrations of the soft parts of channeled whelk varied too greatly amongst replicate determinations to average the results. See discussion for results.

of cobalt in marine organisms are considerably lower than those reported above. A possible reason for the differences is that the marine organisms examined by Robertson *et al.* came from waters 350 miles offshore (samples taken off Portland, Oregon), whereas the data by Pringle *et al.* and the present study were on organisms from inshore waters.

Chromium. The measurement of chromium in these samples provided only rough quantitation for concentrations of about 0.3 to 1.0 ppm (wet weight basis). Most of the marine organisms examined in this study had chromium levels that were in this range or less (Tables VI to IX)). The highest levels of chromium were 3.9 ppm in gills of rock crab obtained from Long Island Sound and 2.7 ppm in muscle of surf clam obtained from station 1-106.

Nickel. Nickel was not detected in any of the fish and shellfish examined. The detection limit was in the 3 to 6 ppm range.

Rubidium. Only a rough quantitative measurement was possible for rubidium because the levels were near the detection limit of the method; most samples had levels in the 0.6 to 1.5 ppm range (Tables VI to IX). The highest concentration observed was 2.3 ppm in surf clam muscle from station 1-106 (Table IX).

Selenium. Selenium levels ranged from about 0.3 to 5.5 ppm in all samples. Selenium levels in fish muscle tissue ranged from 0.3 to 0.9 ppm and in liver from 0.5 to 3.8 ppm (Tables VI and VIII). Generally, selenium concentrations were not substantially different in animals from the various locations. Rock crab from Long Island Sound, however, had selenium levels in muscle ranging from 2.8 to 5.5 ppm, as compared to 1.0 to 2.2 ppm in the muscle of rock crab from stations 1-70, 69D5, and Chincoteague Inlet (Table VII). These data suggest that the selenium content of samples from Long Island Sound is substantially greater than that of samples from the other locations. There were not sufficient data, however, to evaluate whether the differences were statistically significant.

Robertson *et al.* (1968) examined silver salmon obtained from the West Coast and found selenium concentrations of 0.7 to 1.0 ppm in muscle tissue and 3.8 ppm in the liver. The levels of selenium found in the present study were in the same range as the salmon data.

Silver. Silver concentrations were below 0.3 ppm in most of the fish examined (Tables VI and VIII). Most shellfish had silver levels from 0.2 to 3.7 ppm (Tables VII and IX). The silver levels in rock crab, however, were quite unusual. The digestive gland samples collected in April had silver levels of 10, 16.5, and 29.5 ppm for stations 1-70, 69D5, and 73BB, respectively (Table VII). The digestive gland of rock crab at station 1-70 in June and September had silver levels in the range of 0.04 to 2.0 ppm, and at station 69D5, the September sample had a level of 2.6 ppm. These data suggest the possibility that high levels of silver accumulate in this animal in the spring and are depleted by summer. The digestive gland of the rock crab,

however, is not a well-defined organ, such as the liver of fish. Samples of this gland may include portions of the digestive tract and might contain undigested material or even sediment deposits. Variability of metal concentrations in this organ, therefore, could be very substantial.

The level of silver in the muscle of the rock crab was considerably less than in the digestive gland for all collections. In April the silver concentration in muscle was in the range of 0.2 to 1.9 ppm and in September to December, the level for muscle was 0.1 to 0.5 ppm.

Zinc. Of the eight metals examined in this study, zinc measurements were probably the most precise and quantitative because of the relatively high levels found.

For windowpane flounder and rock crab, the two species sampled most extensively, the zinc concentrations were quite interesting (Tables VI and VII). The level of zinc in the windowpane flounder liver was about 6 to 9 times that in the muscle, with liver concentrations ranging from 23 to 46 ppm and muscle concentrations ranging from 4 to 10 ppm. Zinc levels in the rock crab muscle (24 to 53 ppm) were slightly higher than in the digestive gland (15 to 32 ppm). Zinc levels in muscle were higher than in the digestive gland for each rock crab sample examined.

Tissues and organs of windowpane flounder and rock crab had zinc levels that were not substantially different for the various geographical locations. The differences that were observed were within the expected variation between animals for one geographical location.

Fish other than windowpane flounder had zinc levels that ranged from 4 to 9 ppm in the muscle and from 14 to 92 ppm in the liver (Table VIII). Zinc levels in shellfish other than rock crab ranged from 15 to 30 ppm in the muscle and 17 to 40 ppm in the digestive gland (Table IX).

Channeled whelk soft parts. The levels of metals found in the soft parts of the channeled whelk collected from Long Island Sound only were exceptional to the discussions presented above. Replicate analyses on this tissue were too variable to be included in the average values (Table IX). Samples of soft parts of this animal may include the gut and therefore the variability could be caused by the presence of sediment material. The levels of metals found in seven different composite samples were (in ranges):
Cobalt, 0.07 to 0.13 ppm; silver, nondetected to 21 ppm; selenium, 0.35 to 1.9 ppm; rubidium, nondetected to 4 ppm; chromium, nondetected to 3.6 ppm; and zinc, 356 to 3,684 ppm.

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