the samples taken should not be presented as measurements of the forms that emerged from the underlying substrata.

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EDMUND S. HOBSON
JAMES R. CHESS

Southwest Fisheries Center Tiburon Laboratory
National Marine Fisheries Service, NOAA
3150 Paradise Drive
Tiburon, CA 94920

A SURVEY OF HEAVY METALS IN THE SURF CLAM, *SPISULA SOLIDISSIMA*, AND THE OCEAN QUAHOG, *ARCTICA ISLANDICA*, OF THE MID-ATLANTIC COAST OF THE UNITED STATES

Since the mid-1940's, two varieties of clams have become increasingly important to the seafood industry, the surf clam, *Spisula solidissima* , and the ocean quahog, *Arctica islandica*. Surf clams and ocean quahogs are marketed primarily by the canning industry in chowders or as minced clams, as well as in a number of specialty products, such as cakes, patties, and dips. Prior to World War II, however, these clams had been used only as animal feed or fertilizer. A commercial surf clam fishery developed rapidly with an annual harvest of 51.4 million pounds of meats in 1977 (Hutchison[1]) and a peak harvest of 96.1 million pounds of meats in 1974 (Bell and Fitz Gibbon 1977). The ocean quahog fishery developed more slowly. It was not until the 1970's that a vigorous commercial ocean quahog fishery developed, primarily to supplement the dwindling supplies of more desirable clams, in particular, the hard clam, *Mercenaria mercenaria*; the soft-shell clam, *Mya arenaria*; and the surf clam (Anonymous 1971). The ocean quahog harvest in 1977 of 16.4 million

[1]Roger Hutchison, U.S. Department of Commerce, Economic and Marketing Research Division. Washington, D.C., pers. commun. February 1978.

pounds of meats (Hutchison see footnote 1), however, represents a small fraction of an estimated sustained yield of 86 million pounds of meats annually (Rinaldo[2]).

Since surf clams and ocean quahogs have replaced many traditional species, studies are needed that reflect their economic importance. It is well documented that many molluscs, including surf clams and ocean quahogs, concentrate heavy metals (Brooks and Rumsby 1965; Pringle et al. 1968; Waldichuk 1974). Boyden (1973) stated that one of the nutritious qualities of shellfish may be their high metal content. However, heavy metals exhibit toxic effects that affect all life stages of shellfish, especially development stages (Calabrese et al. 1973; Calabrese and Nelson 1974; Thurberg et al. 1975). Considerable research has been done on effects of heavy metals on more popular species of bivalve molluscs, especially the American oyster, *Crassostrea virginica*, hard clams, and soft-shell clams (Calabrese et al. 1973; Calabrese and Nelson 1974; Thurberg et al. 1974). However, until recently, there has been little interest in surf clams or ocean quahogs. Concentrations and concentration factors for a number of metals, including cadmium, chromium, copper, lead, nickel, and zinc, have been given by Pringle et al. (1968) and Pringle and Shuster[3] for surf clams taken from Atlantic coast waters (Maine through North Carolina). Thurberg et al. (1975) exposed larval, juvenile, and adult surf clams to sublethal doses of silver and measured both physiological responses and bioaccumulation. Researchers at the U.S. Environmental Protection Agency (EPA), Narragansett, R.I., have exposed ocean quahogs to low concentrations of cadmium and monitored toxicological, biological, and histopathological effects, as well as bioaccumulation (Zaroogian[4]). Bioaccumulation distribution patterns associated with industrial and sewage sludge dumpsites southeast of Delaware Bay have been monitored in ocean quahogs by scientists at the EPA, Annapolis, Md. (Lear and Pesch 1975). Awareness, then, of the importance of these species is developing, but clearly more research is needed for such an important commercial shellfishery.

Nine metals were chosen for analysis: arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc. Based upon estimates of global metal production and oceanic sedimentation rates, Bowen (1966) divided 38 metals into their pollution potentials. He categorized cadmium, chromium, copper, lead, mercury, silver, and zinc as very high potential pollutants and arsenic and nickel as moderate. Goldberg (1972) emphasized the need for measurement in benthic organisms of the most potentially hazardous trace metals.

Materials and Methods

Sampling

The area of this survey extended from approximately Montauk Point, N.Y., to Cape Hatteras, N.C., and seaward to approximately the 20-fathom contour. The survey encompassed the southern distribution of both surf clams and ocean quahogs in the United States. Samples were collected at 151 stations for chemical analysis (Figure 1) in June and August 1974, aboard the NOAA ship *Delaware II* (MARMAP[5]). A small hydraulic surf clam dredge, modeled closely after larger commercial dredges, was used throughout the survey. At each station 4-6 clams of marketable size were dissected, using stainless steel equipment. The foot was removed from each animal, drained, then combined and frozen in plastic bags. At the laboratory the tissues were homogenized in an electric blender equipped with a glass jar and stainless steel blades then stored for analysis in plastic ointment jars. All containers and equipment were acid-washed prior to use.

Analysis

Mercury analysis was performed on a Perkin-Elmer Model 305[6] atomic absorption spectrophotometer fitted with a 25 × 150 mm absorption cell with silica end windows, using the flameless method of Greig et al. (1975).

Arsenic analysis, performed on a Perkin-Elmer Model 403 atomic absorption spectrophotometer,

[2]Rinaldo, R. G. 1977. Atlantic clam fishery management plan. Environmental impact statement: Mid-Atlantic and New England Regional Fisheries Management Councils. Available Fisheries Management Division, National Marine Fisheries Service, NOAA, State Fisheries Pier, Gloucester, MA 01930.

[3]Pringle, B. H., and C. N. Shuster, Jr. 1967. A guide to trace metal levels in shellfish. USDHEW, Public Health Serv., Shellfish Sanit. Tech. Rep., 18 p.

[4]Gerald E. Zaroogian, U.S. Environmental Protection Agency, Environmental Research Laboratory, Narragansett, RI 02882, pers. commun. February 1976.

[5]MARMAP 1974. Surf clam survey, cruise report, NOAA ship *Delaware II*, 13-28 June 1974 and 5-10 August 1974, 9 p.

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

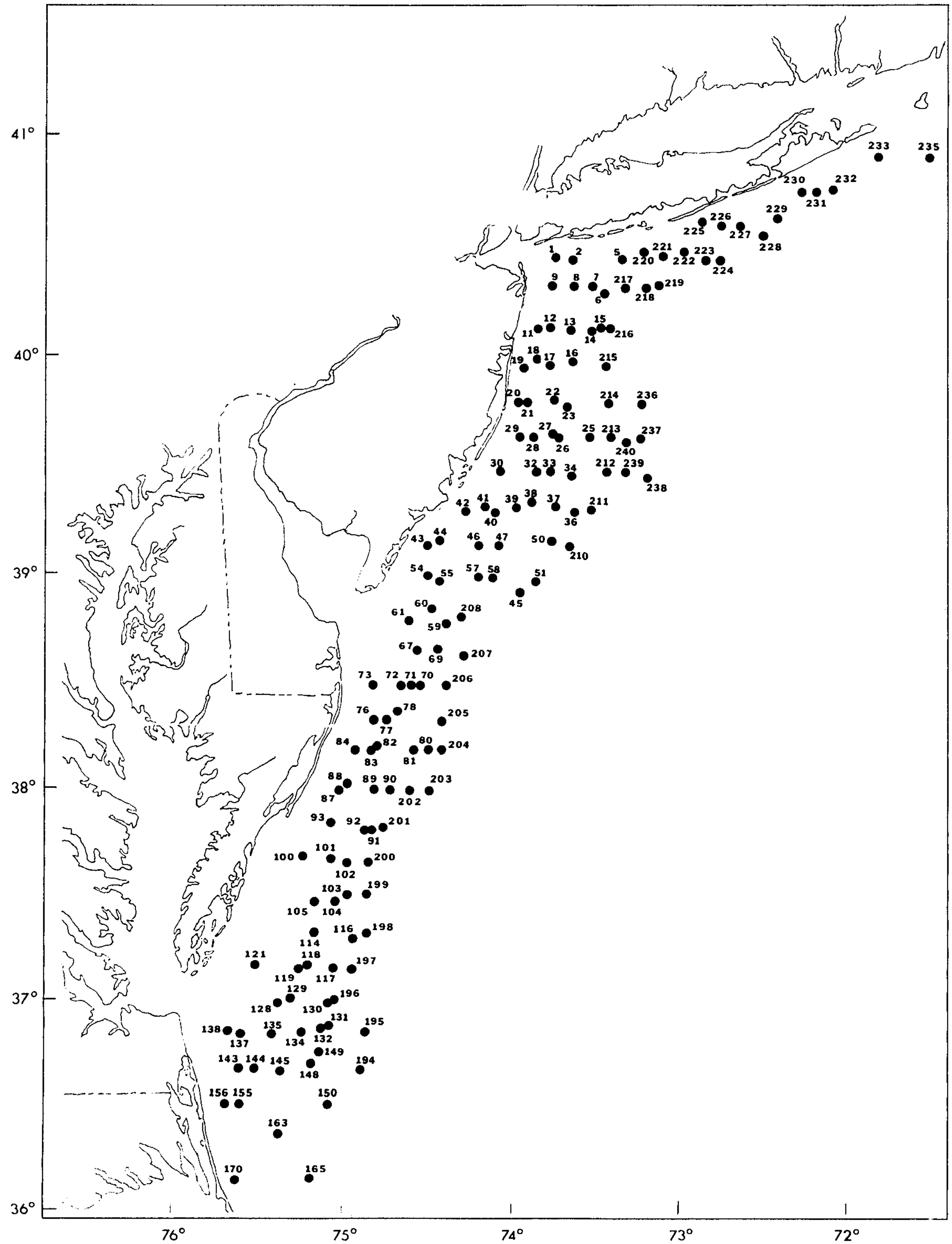

FIGURE 1.—Station location and number relative to the mid-Atlantic coast of the United States.

using a nitrogen/hydrogen flame, required an improvisation of two simple interconnecting adapters. The first, attached directly to the instrument, consisted of the female portion of a polyethylene quick disconnect (Nalgene 6150) and a nylon elbow hose connector threaded to fit the auxiliary inlet of the burner assembly. The second consisted of the male portion of the quick disconnect and a gas outlet adapter (Kontes K-183000). Both adapters were assembled with minimum length and bore of Nalgene tubing. The following procedure was used: A 5-g sample of tissue was placed into a 250-ml beaker to which 10 ml $Mg(NO_3)_2 \cdot 6H_2O$ (200 g/l) and 10 ml concentrated HNO_3 (Baker 9603) were added. The mixture was covered with a watchglass and evaporated to dryness on a hot plate (130°-140°C). It was then placed into a cool muffile furnace and the temperature raised in steps, first to 250°C for 3 h, then to 400°C for 3 h, and finally to 550°C for approximately 15 h. After the beaker was completely cool, 15 ml of concentrated HCL (reagent grade) were added and the resulting solution transferred to a 25-ml volumetric container and brought to volume with distilled water. A 10-ml aliquot of this solution was placed into a 24/40 jointed, 50-ml Erlenmeyer reaction flask and 2 ml of 15% (wt/vol) freshly made KI solution and 2 ml of freshly made $StCl_2$ solution (20% [wt/vol] in 1:1 concentrated HCL:water) were added, waiting 2 min after each addition. Then 10 ml of distilled water were added. Five (5.00) grams of granular (20 mesh, no fines) low arsenic zinc (Fisher Z-15) were placed into the elbow of the second adapter, as noted above, and attached to the first adapter. This assembly was quickly inverted while attaching it to the reaction flask. The arsine generated was then analyzed at the instrument, which was equipped with a 3-slot burner and background corrector. Use of a recorder combined with full noise filtration and slow gas evolution contributed to a smooth and reproducible peak upon which calculations were based. The reaction flask and the first adapter can be quickly removed for cleaning and reuse.

Analysis of the remaining metals, also performed on the Perkin-Elmer Model 403, resembled that of Middleton and Stuckey (1954): A sample of tissue (10 g wet weight) was weighed into a 250-ml beaker and 10 ml of concentrated HNO_3 (Baker 9603) were added. The beaker was covered with a watchglass and heated to approximately 130°-140°C on a hot plate until the liquid evaporated. One to two milliliters of concentrated HNO_3 was added and the evaporation repeated. Again, 1-2 ml of acid was added but evaporated at 350°C or more. The hot plate was cooled and the latter acid addition and evaporation was repeated until ashing was complete. The residue was dissolved in and taken up to 25 ml with 10% (wt/vol) reagent grade HNO_3 after filtration through Whatman No. 2 paper. The solution was then analyzed directly in an air/acetylene flame by conventional atomic absorption spectrophotometry.

Results

Greater average concentrations of silver, arsenic, cadmium, copper, and zinc (122, 44.5, >230, 56.0, and 10.9% greater, respectively) were found in ocean quahogs than in surf clams for the entire survey (Table 1). Concentrations of several metals in both clams decreased southward. Concentrations of silver decreased steadily from 2.62 to 0.58 ppm in ocean quahogs and 1.63 to 0.19 ppm in surf clams. This is a 4.5- and 8.6-fold decrease, respectively, from the northernmost range of latitude to the southernmost. Concentrations of arsenic also decreased steadily, 1.6-fold, from 3.90 to 2.41 ppm in ocean quahogs. Although a steady decrease in arsenic concentrations was noted for a full 2.5° of latitude, a distinctive trend for the entire range of latitude was not evidenced. Copper concentrations in ocean quahogs decreased 2.5-fold from 7.16 to 2.84 ppm and zinc concentrations in surf clams decreased 2.0-fold from 18.5 to 9.1 ppm. Concentrations of cadmium and zinc in the ocean quahog and copper in the surf clam did not exhibit any statistically significant trends, while the data for the remaining metal-clam combinations were insufficient for statistical analysis (Table 2).

The results of Pringle and Shuster (see footnote 3) for cadmium and zinc (<0.20, 12.39 ppm, wet weight, respectively) in surf clams are in general agreement with the mean results of our study. Their result for copper (2.39 ppm) was lower, while chromium and nickel (2.57, 1.22 ppm, respectively) were higher. The collection area of the former study was defined only as Maine through North Carolina; hence, geographic variations might be expected. In addition, neither the number of stations nor of surf clams analyzed was stated.

Conclusions

While the Food and Drug Administration (FDA)

TABLE 1.—Average[1] heavy metal concentrations (parts per million, wet weight) found in surf clams and ocean quahogs by latitude.

Range of lat. N	n	Ag $\bar{x}$	Ag SE	As $\bar{x}$	As SE	Cd $\bar{x}$	Cd SE	Cu $\bar{x}$	Cu SE	Zn $\bar{x}$	Zn SE
Surf clams											
41°00′-40°30′	3	1.63	1.11	2.38	0.146	<0.12		3.83	0.786	9.7	0.674
40°30′-40°00′	6	1.42	.329	2.63	.234	0.13	0.008	2.87	.216	18.5	.481
40°00′-39°30′	11	1.18	.140	2.39	.120	0.13	.010	2.96	.348	18.3	1.14
39°30′-39°00′	11	1.05	.130	2.17	.200	0.15	.015	3.45	.226	14.8	1.11
39°00′-38°00′	13	0.94	.120	1.91	.131	<0.13		3.38	.211	11.3	.485
38°30′-38°00′	13	0.50	.082	1.57	.082	<0.11		2.97	.259	10.6	.188
38°00′-37°30′	8	0.51	.081	2.08	.145	<0.12		3.54	.360	9.1	.253
37°30′-37°00′	11	0.44	.071	2.22	.122	<0.12		3.48	.478	9.4	.228
37°00′-36°30′	14	0.32	.046	2.17	.233	<0.14		3.08	.228	9.3	.260
36°30′-36°00′	3	0.19	.053	1.46	.082	<0.14		2.88	.262	9.6	.153
41°00′-36°00′	93	0.76		2.08		<0.13		3.23		11.9	
Ocean quahogs											
41°00′-40°30′	8	2.62	0.400	3.90	0.374	0.54	0.069	7.16	0.837	12.6	0.518
40°30′-40°00′	15	2.49	.376	3.36	.293	0.42	.034	5.33	.401	14.5	1.04
40°00′-39°30′	9	1.53	.296	2.97	.171	0.42	.035	4.71	.348	13.9	.741
39°30′-39°00′	9	1.29	.138	2.68	.236	0.39	.035	4.41	.280	12.4	.991
39°00′-38°30′	5	1.21	.371	2.65	.114	0.42	.059	5.10	.727	13.2	.806
38°30′-36°30′	6	0.58	.120	2.41	.326	0.39	.051	2.84	.434	10.4	1.38
41°00′-36°30′	52	1.69		3.01		0.43		5.04		13.2	

[1]Average of n samples with 4-6 clams per sample.

TABLE 2.—Average[1] heavy metal concentrations (parts per million, wet weight) found in surf clams and ocean quahogs by latitude.

Range of lat. N	n	Cr	Hg	Ni	Pb
Surf clams					
41°00′-40°30′	3	<0.62	<0.05	—	<0.7
40°30′-40°00′	6	0.95	<0.07	0.71	<0.7
40°00′-39°30′	11	0.70	<0.08	<0.39	<0.7
39°30′-39°00′	11	0.69	<0.08	0.80	<0.7
39°00′-38°30′	13	0.65	<0.08	<0.60	<0.7
38°30′-38°00′	13	<0.61	<0.08	<0.50	<0.6
38°00′-37°30′	8	<0.53	<0.08	—	<0.7
37°30′-37°00′	11	<0.49	<0.07	—	<0.7
37°00′-36°30′	14	<0.48	<0.06	—	<0.7
36°30′-36°00′	3	<0.48	<0.05	—	<0.7
41°00′-36°00′	93	<0.61	<0.07	<0.59	<0.7
Ocean quahogs					
41°00′-40°30′	8	1.03	<0.09	0.91	1.8
40°30′-40°00′	15	<1.23	<0.06	<0.62	1.0
40°00′-39°30′	9	<0.70	<0.06	<0.50	<1.2
39°30′-39°00′	9	<0.80	<0.07	<0.50	<0.9
39°00′-38°30′	5	<1.0	<0.08	<0.55	<1.2
38°30′-36°30′	6	<1.1	<0.06	<0.59	<0.9
40°00′-36°30′	52	<1.0	<0.06	<0.61	<1.1

[1]Average of n samples with 4-6 clams per sample.

has not set standards for heavy metals in U.S. fishery products (except mercury), the National Health and Medical Research Council (NHMRC) of Australia has recommended maximum concentrations for a number of metals in seafoods (Mackay et al. 1975). Concentrations of cadmium, copper, lead, and zinc found in surf clams and ocean quahogs were well under these limits (2.0, 30, 2.0, 1,000 ppm, wet weight, respectively) and far below levels found in American oysters harvested from Atlantic coastal waters (Pringle et al. 1968). The NHMRC recommendation of 1.14 ppm (wet weight) arsenic (1.5 ppm as As_2O_3), however, was exceeded at all but a few sampling stations. Mean arsenic concentrations for all stations were 2.1 ppm in surf clams and 3.0 ppm in ocean quahogs. The distribution of arsenic concentrations did not vary greatly with latitude and may indicate that background levels along the mid-Atlantic coast are higher than those in Australian waters. Concentrations of mercury were found to be well below the action limit set by the FDA (0.50 ppm, wet weight).

Major fishing grounds for the surf clam industry are located off the New Jersey and Virginia coasts. Since data for mercury presented in this study are well within the existing guideline set by the FDA for U.S. fishery products and, with a single exception, within the more extensive NHMRC recommendations for Australia, there should be little concern to consumers for surf clams or ocean quahogs harvested from these areas at present.

The latitudinal cline demonstrated in this study should, however, stimulate further interest in heavy metal inputs along the mid-Atlantic coast of the United States. Data indicate that a large area of our eastern coast may be affected by the presence of heavy metals. The effect on clams is important, particularly since surf clams and ocean quahogs are representative of the important shellfisheries located in this area.

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D. R. WENZLOFF
R. A. GREIG

Northeast Fisheries Center Milford Laboratory
National Marine Fisheries Service, NOAA
Milford, CT 06460

A. S. MERRILL
J. W. ROPES

Northeast Fisheries Center Woods Hole Laboratory
National Marine Fisheries Service, NOAA
Woods Hole, MA 02543

APPARENT FEEDING BY THE FIN WHALE, *BALAENOPTERA PHYSALUS*, AND HUMPBACK WHALE, *MEGAPTERA NOVAENGLIAE*, ON THE AMERICAN SAND LANCE, *AMMODYTES AMERICANUS*, IN THE NORTHWEST ATLANTIC

On 18 May 1977 a large group of fin, *Balaenoptera physalus*, and humpback, *Megaptera novaengliae*, whales was observed on Stellwagen Bank north of Cape Cod (lat. 42°26′N, long. 70°26′W) by Northeast Fisheries Center (NEFC) personnel conducting an annual spring bottom-trawl survey aboard the National Oceanic and Atmospheric Administration RV *Albatross IV*. Nine fin and 14 humpback whales were identified and observed near the vessel. More whales were sighted in the vicinity, but were too far away to identify positively or to observe conveniently. Many great black-back, *Larus marinus*, and herring, *Larus argentatus*, gulls were seen feeding at the surface and circling around the whales. The whales displayed a characteristic feeding behavior described by Gunther (1949) and mentioned in Katona et al. (1975). The animals we observed were circling, spouting often, making short shallow dives, and not moving in any set direction. They behaved in a leisurely manner and were seemingly undisturbed by our presence as noted by Gunther (1949). Echo sounding traces indicated a depth of 40 m in this area and large patches of densely concentrated small fishes throughout the water column, but particularly near the surface. During several 30-min bottom-trawl tows in the area, up to 400 kg of adult American sand lance, *Ammo-*