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Heavy Metals in *Mercenaria mercenaria* and Sediments from the New Bedford Harbor Region of Buzzard's Bay, Massachusetts

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Considerable information has been accumulated on the distribution and concentrations of a wide variety of metals in the marine environment (EISLER 1973; EISLER & WAPNER 1975; 1978). Although the concentrations of heavy metals may be extremely variable, some marine ecosystems contain metal levels indicative of contamination from anthropogenic sources (FOWLER & OREGIONI 1976; PHILLIPS 1977; VINOGRADOV 1953).

The presence of manufacturing facilities engaged in the use of heavy metals combined with the existence of a local fishery suggested the importance of studying the distribution and accumulation of metals in bivalves in the New Bedford, Massachusetts area. This study employed one of the edible clams, Mercenaria mercenaria(L), as an indicator for the following reasons: 1) molluscs are one of the most reliable indicators for heavy metal assessment (PHILLIPS 1977), and together with sediment data, can provide regional profiles for global comparisons, 2) this bivalve is sessile and thus indicative of local metal distribution, 3) they inhabit benthic sediments which accumulate heavy metals (PHILLIPS 1977), 4) they are microphageous and ingest sediment containing metals (PRINGLE et al. 1968), and 5) they are significant in both commercial and recreational fisheries.

M. mercenaria and sediments from the New Bedford region were therefore analyzed for cadmium, copper, iron, lead and zinc to investigate some of the relationships between environmental and organismal levels.

MATERIALS AND METHODS

Six individuals of the common Quahog, M. mercenaria and one sediment sample of the top few millimeters of substratum were collected at each of three sites. Collections were conducted the first weekend of every month from April 1978 through March 1979, at the following locations: Angelica Point, Mattapoisett (41°39'N, 70°46'W); Mattapoisett Neck (41°39'N, 70°49'W); and West Island, Fairhaven (41° 36'N, 70°50'W). All sites were located east (in the direction of the net tidal flow) of New Bedford Harbor, Buzzard's Bay, Ma.

Shucked whole clams with mantle cavity water and sediment samples were prepared for atomic absorption spectrophotometric assay

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using the techniques of ROGERSON & GALLOWAY (1979) modified by extending "cold digestion" to 48 h, and by using 25 mL as the final volume. Values reported are corrected for extraction efficiency determined from prepared standard samples.

RESULTS

The annual means for tissue and sediment metal concentrations are presented in Table 1.

TABLE 1. Annual mean of metal concentrations in M. mercenaria and sediment samples (in μg/g dry weight)

		Mean	S.D.	Range	Extraction Efficiency
Cd	tissue	1.16	0.72	nd -2.82	95%
	sediment	0.23	0.39	nd -2.24	
Cu	tissue	17.4	2.62	6.50-33.5	55%
	sediment	2.59	1.06	nd -8.81	
Fe	tissue	151	36.7	59.1-390	49%
	sediment	4990	1820	1240-23100	
Pb	tissue	1.86	1.77	nd -8.56	95%
	sediment	3.30	1.67	nd -7.69	
Zn	tissue	126	39.9	1.89-309	60%
	sediment	18.2	8.07	nd -44.6	

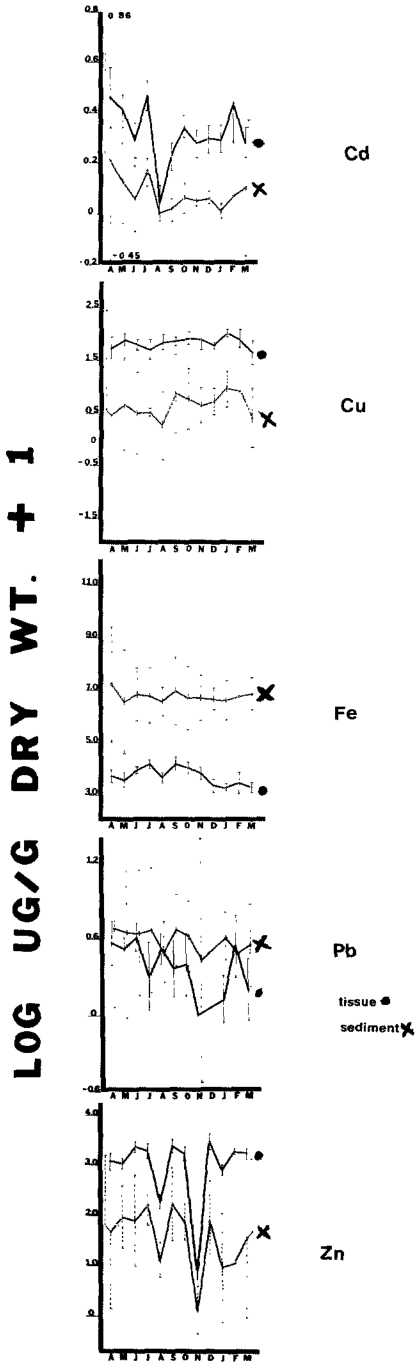
nd - not detectable (nd < .01 ppm)

Cadmium content of the sediments did not vary significantly with either season or site (Oneway ANOVA). Although copper, iron, and lead concentrations in the sediments did not vary throughout the year, they were site dependent (Cu, $P<0.08$; Fe and Pb, $P<0.005$). Zinc concentrations were both site dependent ($P<0.007$) and seasonal ($P<0.006$) (Figure 1). All five metal levels in the sediments were correlated using a Pearson Correlation as follows:

	Copper	Iron	Lead	Zinc
Cadmium	0.519(0.002)	0.857(0.001)	0.581(0.001)	0.467(0.005)
Copper		0.709(0.001)	0.601(0.001)	0.415(0.015)
Iron			0.613(0.001)	0.528(0.001)
Lead				0.635(0.001)

All tissue metal concentrations varied significantly with season (Twoway ANOVA; Cd, Fe, Pb, Zn $P<0.001$; Cu $P<0.008$). Cadmium and copper showed no differences according to site, however interaction between season and site for tissue cadmium was significant ($P<0.001$). Tissue iron concentrations varied slightly between sites ($P<0.08$), while lead content was significantly site dependent ($P<0.02$). Zinc values were erratic, site related ($P<0.001$), and had significant interaction between season and site ($P<0.001$).

FIGURE I MEAN MONTHLY METAL CONCENTRATIONS



Correlation between the tissue concentrations of several metals was observed. Tissue cadmium, iron, and lead concentrations were correlated with zinc tissue levels as follows: 0.216 ($P<0.03$); 0.209 ($P<0.04$); and 0.279 ($P<0.007$) respectively. Tissue iron and lead concentrations were also correlated, 0.268 ($P<0.009$). The correlation between metal levels for tissue and sediment concentrations were as follows: cadmium, 0.673 ($P<0.001$); copper, 0.238 ($P<0.016$); lead, 0.188 ($P<0.071$); and zinc, 0.474 ($P<0.001$). After a Naparian logarithmic transformation of the data, there was an apparent correlation (0.207, $P<0.04$) between tissue and sediment iron concentrations

DISCUSSION

With the exception of iron, metal concentrations reported herein were generally lower than those reported for other marine sediments (AYLING 1974; FRAZIER 1976; PHILLIPS 1977). The metal concentrations in the sediments at each site showed little variation over time, supporting the observations of AYLING (1974) and FRAZIER (1976) who suggested that sediments may be reliable indicators of heavy metal contamination. This is in contrast to the variability of sediment metal concentrations reported by PHILLIPS (1977) who therefore supported the use of biological indicator organisms to assess heavy metal contamination.

The high degree of correlation between all metals in the sediments suggests that the source of these metals (either natural, industrial, or municipal) are closely related. SUMMERHAYES et al. (1978) reported high correlations for copper and cadmium (0.734) and for copper and lead (0.850) in other areas near New Bedford Harbor. These high correlations between heavy metal concentrations in the sediments in both the present study and that of SUMMERHAYES et al. (1978) and the fact that both studies reported sediment metal values of the same order of magnitude suggest the industrialized region surrounding New Bedford Harbor as a major source of these heavy metals.

The heavy metal concentrations found in the clam tissues are compared with the maximum permissible limits set for Australia (as limits have not yet been established for the United States) in order to indicate the relative environmental safety of these concentrations. The tissue concentrations of the two most toxic metals studied, cadmium and lead, were consistently lower than the maximum permissible limits (EISLER et al. 1978; MACKAY et al. 1975; TALBOT et al. 1976; THROWER & EUSTACE 1973a, b). Tissue zinc levels were below these limits, but at times copper values approached or exceeded these limits.

Tissue iron concentrations were one or two orders of magnitude lower than the sediments, even though the sediment concentrations were relatively high. The low tissue iron concentrations corroborate the concept of metabolic regulation of iron by marine molluscs previously reported (DIXON & WEBB 1964; GHIRETTI-MAGALDI et al. 1958; PRINGLE et al. 1968; WINTER 1972). Cadmium and lead concentrations in sediments and tissues were of similar magnitude, suggesting that they are not regulated by the organism. These metals have not been demonstrated to be utilized in metabolism (PRINGLE et al. 1968). Tissue copper and zinc concentrations were higher than the sediments indicating that these metals are probably taken up actively from the environment, possibly reflecting their use in metabolism (BRERETON et al. 1973; COOMBS 1972; DIXON & WEBB 1964; LEHNINGER 1970; NOEL-LAMBERT 1976; PRINGLE et al. 1968).

The seasonal fluctuations of tissue metal observed correspond with those reported by other authors (BETZER & PILSON 1974; BROOKS & RUMSBY 1967; BRYAN 1973; FRAZIER 1975, 1976; FOWLER & OREGIONI 1976; HILL & HELZ 1973; PRINGLE et al. 1968; ROMERIL 1974). Significant interaction between season and site suggests that tissue levels are affected by monthly variations in environmental factors affecting the organisms' metabolism. The significant correlations for tissue cadmium, iron, and lead with zinc concentrations; and iron with lead concentrations suggest that these metals are related by detoxification mechanisms, storage compounds, uptake mechanisms, or through physical-chemical relationships in the surrounding sediments. The strong relationships present between sediment and tissue metal concentrations further support the use of sediments and indicator organisms for heavy metal pollution assessment, and indicate that for *M. mercenaria* tissue levels are at least partially dependent on sediment metal concentrations. Similar associations have been previously reported in only a few studies (HUTCHINSON et al. 1976; ROMERIL 1974). By coupling the clam data with the sediment data, a reliable assessment of heavy metal contamination of the test areas has been provided for these five metals.

M. mercenaria tissue levels of the five metals studied appear to be within safe limits in terms of public health even though copper approached the permissible levels established for Australia. It is likely, however, that additional inputs or increases in existing inputs may raise metal concentrations to toxic levels. Also, any dredging activities in the study areas or their vicinity are likely to increase the amount of metals available to the local biota due to increased sediment suspension (EISLER 1977).

It appears that at present there is no major contamination of clams or sediments in the areas studied. However, since levels of some metals approached the permissible limits at times, it would obviously be beneficial if all sources of pollution to the area could be identified and regulated. It is suggested that harvesting of clams could be managed seasonally so that tissue contaminants are at their periodic minima. For these metals late summer, fall and winter appear to be favorable times. It is also suggested that clams harvested in the vicinity of recently dredged areas be monitored for heavy metal levels. The need for a continuous monitoring program for heavy metals and other toxic substances for New Bedford and surrounding areas to insure public safety is recommended.

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REFERENCES

AYLING, G.M.: Wat. Res. 8, 729 (1974).
BETZER, S.B. and M.E.Q. PILSON: Biol. Bull. 146, 165 (1974).
BRERETON, A., H. LORD, I. THORTON, J.S. WEBB: Mar. Biol. 19, 96 (1973).
BROOKS, R.R. and M.G. RUMSBY: Austral. J. Mar. Freshwater Res. 18, 53 (1967).
BRYAN, G.W.: J. Mar. Biol. Assn. U.K. 53, 145 (1973).
COOMBS, T.L.: Mar. Biol. 12, 170 (1972).
DIXON, M. and E.C. WEBB: Enzymes. 1 ed. London, Longmans and Green (1964).
EISLER, R.: E.P.A.-R3-73-007 (No. 1-567), Nat. Tech. Inform. Serv., Springfield, Va. (1973).
EISLER, R. and M. WAPNER: E.P.A. 600/3-75-009 (no. 568-1292), Nat. Tech. Inform. Serv., Springfield, Va. (1975).
EISLER, R.: Mar. Biol. 43, 265 (1977).
EISLER, R. and M. WAPNER: E.P.A. 600/3-78-005 (No. 1293-2246), Nat. Tech. Inform. Serv., Springfield, Va. (1978).
EISLER, R., M.M. BARRY, R.L. LAPAN, Jr., G. TELEK, E.W. DAVEY, A.E. SOPER: Mar. Biol. 45, 311 (1978).
FOWLER, S.W. and B. OREGIONI: Mar. Poll. Bull. 7, 26 (1976).
FRAZIER, J.M.: Chesapeake Sci. 16, 162 (1975).
FRAZIER, J.M.: Chesapeake Sci. 17, 188 (1976).
GHIRETTI-MAGALDI, A., A. GIUDITTA, F. GHIRETTI: J. Cell Comp. Physiol. 52, 389 (1958).
HILL, J.M. and G.R. HELZ: Environm. Letters 5, 165 (1973).
HUTCHINSON, T.C., A. FEDERENKO, J. FITCHKO, A. KUJA, J. VANLOON, J. LICHWA: In Nriagu, J.O. ed. Environmental Biogeochemistry. 1 ed. Ann Arbor, Ann Arbor Sci. Publ. (1976).
LEHNINGER, A.L.: Biochemistry. 1 ed. New York: Worth Publ. Inc. (1970).
MACKAY, N.J., R.J. WILLIAMS, J.L. KACPRZAC, M.N. KAZACOS, A.J. COLLINS, E.H. AUTY: Austral. J. Mar. Freshwater Res. 26, 31 (1975).
NOEL-LAMBERT, F.: Experientia 32, 324 (1976).
PHILLIPS, J.H.: Environ. Pollut. 13, 281 (1977).
PRINGLE, B.H., D.E. HISSONG, E.L. KATZ, S.T. MULAWKA: J. Sanitary Engineer. Div. 94, 455 (1968).
ROGERSON, P.F. and W.B. GALLOWAY: In F.S. Jacob ed. Proc. Symp. on State of Marine Environments Research. Wash. D.C., U.S. Gov't Printing Office (1979).
ROMERIL, M.D.: Revue Int. Oceanogr. Medicale 33, 31 (1974).
SUMMERHAYES, C.P., J.P. ELLIS, P. STOFFERS, S.R. BRIGGS, M.G. FITZGERALD: Fine-grained Sediment and Industrial Waste Distribution and Dispersal in New Bedford Harbor and Western Buzzard's Bay, Massachusetts. 1 ed. Wash. D.C., Nat. Oceanic and Atmos. Admin., Office of Sea Grant, 04-6-158-44016 and 04-6-158-44106. (1978).

TALBOT, V.W., R.J. MAGEE, M. HUSSAIN: Mar. Poll. Bull. 7, 84 (1976).
THROWER, S.J. and I.J. EUSTACE: Austral. Fisher. 32, 7 (1973a).
THROWER, S.J. and I.J. EUSTACE: Food Tech. in Australia 25, 546 (1973b).
VINOGRADOV, A.P.: The Elementary Chemical Composition of Marine Organisms. 1 ed. New Haven, Sears Foundation for Marine Research, Yale Univ. (1953).
WINTER, J.E.: In Ruivo, M.ed. Marine Pollution and Sea Life. 1 ed. Surrey, Eng. (1970).