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CORRELATION OF TRACE ELEMENT CONCENTRATIONS IN MARINE BENTHONIC POLYCHAETES WITH THEIR HOST SEDIMENT

By

Gary W. Hill
U.S. Geological Survey
345 Middlefield Road
Menlo Park, California 94025

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INTRODUCTION

In the past, several investigations have determined uptake rates and concentrations of trace elements in marine organisms. Such studies enabled investigators to use specific species as *in situ* monitors of pollution levels. All these studies to date have at least two aspects in common. First, they make use of large filter feeders, (e.g., oysters) that live above the sediment-water interface. Secondly, these studies have been concerned only with the uptake and concentration of trace elements found in the water column.

Recently, a study by Holmes, *et al*. (1974) has shown that significant quantities of metals precipitate in the reducing environment of bottom water near their source during the summer. Redistribution of these metals occurs during the winter when the metals are resuspended by wave and current action, washed over a larger area and then absorbed by particles settling to the bottom. The net effect of this process is the concentration of metals in bottom sediments several magnitudes higher than trace element concentrations found in the water column. Because many trace elements do become concentrated in the marine food chain and in some cases pose a hazard to aquatic life (IDOE, 1972; Pettyjohn, 1972), the pathways by which trace elements become available to aquatic life are important. Because trace element concentrations are much greater in bottom sediments than in the water column, those organisms which live and feed within bottom sediments take on a new importance with regard to trace element concentration in the marine food chain and possibly as *in situ* monitors of pollution levels. This report describes an investigation conducted on marine benthonic polychaetes and lists some observations of the correlation between trace-element concentrations in the polychaetes and their host sediment. While literature is available on trace element concentration in aquatic organisms *or* bottom sediments, it does not exist for the correlation of trace elements in aquatic organisms *and* host bottom sediments.

REGIONAL AND LOCAL SETTING

The polychaetes and their host sediments used in this study were collected from a 340 km^2 area extending from the beach to 19 km offshore (water depth approximately 28 m) and extending 9.5 km north along St. Joseph Island and south along Mustang Island from Port Aransas, Texas (fig. 1). Bottom sediments consist of fine grained sand in the nearshore and inner continental shelf zones and become increasingly finer seaward. Muddy substrates are closer to shore in the southern part (5-7 km) of the study area than in the northern sections (12-14 km).

Tidal fluctuations along northern Mustang Island are of the diurnal and mixed diurnal types with a mean diurnal range at Aransas Pass of about 0.5 m. Wave height normally is one meter or less and water temperature varies seasonally between 10° C and 30° C (Marmer, 1954).

Aransas Pass serves as a point source for sediment and for many of the trace metals flowing into the Gulf of Mexico within the study area. Sediments are carried down the rivers after heavy rains inland while additional metals are dumped daily into Corpus Christi harbor by industrial plants. The Corpus Christi ship channel funnels both sediments and trace metals out from Aransas Pass into the Gulf of Mexico (Holmes, personal commun.).

METHODS

Field work was done aboard the R/V LONGHORN, an 83 foot research vessel belonging to the University of Texas Marine Science Institution located in Port Aransas, Texas. Loran A and radar were used for navigation. Laboratory work, including sample preparation and analysis, was conducted in the facilities of the United States Geological Survey in Corpus Christi, Texas, and Denver, Colorado.

A sediment sample was collected within each square mile of the study area by means of a grab sampler designed to take 0.1 m^3 sample. For each of the 120 grab samples, subsamples were taken aboard ship for textural and geochemical analyses. Polychaetes were collected by washing the remaining sediment sample through a 1 mm mesh sieve. Immediately after collection, polychaetes were put into numbered "conditioned" test tubes (refluxed with boiling nitric acid for two hours and washed several times in deionized water) and placed in a freezer. Preservatives such as formalin could not be used because of possible trace metal contamination to the polychaetes. Organic samples remained frozen until the day that sample preparation for trace metal analysis was initiated.

After drying, sediment samples were ground to less than 200 mesh, and leached with boiling 16 N HNO_3 (pure of any trace metal to be tested) until NO_2 fumes ceased. The samples were then analyzed for copper and zinc by atomic absorption spectrophotometry. Replicate sediment samples were analyzed for lead by an emission spectrographic method (Grimes and Marranzino, 1968) in the U.S.G.S. laboratory in Denver, Colorado. Polychaete samples were prepared for analysis after a method described by Hill (1979). They were analyzed for copper, lead, and cadmium by anodic stripping voltammetry (ASV). Zinc was determined by atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Sediments

The following range of concentrations of trace metals were found: copper 1-57 ppm; lead, 10-70 ppm; and zinc, 3-68 ppm (fig. 2). Distribution of trace metals over the study area is not random. In every case, lowest concentrations occur mainly along shore at shallow water depths in sandy substrates while the highest concentrations are in very muddy sediments in deeper water depths in the southeastern quadrant of the study area (fig. 2). A small area of high concentrations of trace metals, especially zinc, is located in the northeastern quadrant of the study area (fig. 2). Isolated pockets of high or low trace metal concentrations exist throughout the study area and can be attributed to local accumulations of mud or sand. The average concentrations of copper, lead, and zinc for the entire study area are 6.8 ppm, 27.5 ppm, and 31 ppm, respectively.

Polychaetes

A total of 84 polychaetes representing eight species were collected from 55 stations in the study area (table 1). Polychaetes were identified by Dr. Donald Harper of Texas A&M. *Diopatra cuprea* (Family Onuphidae) and *Nereis sp.* (Family Nereidae) are the most common species. Nineteen stations yielded 26 *Diopatra cuprea* -- a filter feeder, while twenty-seven specimens of *Nereis sp.*, a deposit feeder, were collected from 20 stations. Other species were uncommon, and no further work was done on them.

In *Diopatra*, concentrations of trace metals ranged as follows: copper, 8-2310 ppm; lead, 5-317 ppm; and zinc, 15-366 ppm (table 2). *Nereis* contained copper ranging from 14 ppm to 455 ppm, lead from 7 ppm to 454 ppm, and zinc from 31 ppm to 345 ppm (table 2).

Significant trends in trace metal concentrations in the worms relative to onshore-offshore or north-south directions was not immediately obvious when trace metal concentrations for each polychaete species were plotted on a base map of the study area. When contours representing trace element concentrations in the sediments were superimposed on the concentrations in the organisms, some correlation was apparent. Polychaetes with high concentrations of trace metals seem to occur in sediments with high concentrations of the same trace metals. Scattergraphs were constructed and correlation coefficients and the slope of linear regression lines computed to determine if observed trends were statistically significant (fig. 2). According to Holmes (personal commun.), good correlation between samples of this type exists with correlation coefficients (r) above 0.50 and excellent correlation with correlation coefficients above 0.75.

Very good correlations between copper and lead concentrations in the worms and sediment were observed (fig. 2A, B). Correlation coefficients for copper in the sediment and in Diopatra and Nereis were 0.70 and 0.89, respectively. For lead concentrations in the sediment and in Diopatra and Nereis, the correlation coefficients were 0.69 and 0.77, respectively. In each case, there is better correlation for trace metal concentrations between the deposit feeder (Nereis) and the sediment than the filter feeder (Diopatra) and the sediment.

Correlation of zinc in the worms and sediment was relatively poor (fig. 2C). Correlation coefficients were 0.52 for Nereis and 0.20 for Diopatra. Good correlation might not be expected, however, because Pettyjohn (1972) has shown that zinc is not concentrated in marine food chains.

Correlation coefficients between cadmium in the worms and sediment could not be computed for lack of sediment data. Cadmium concentrations were sufficiently low in the sediment to be undetected by atomic absorption spectophotometry (less than 1 ppm). However, the relatively high cadmium concentrations in the worms, 1-81 ppm (table 2), indicate probable concentration of this element by the polychaetes.

Trace metal concentrations are several times higher in the polychaetes than in the host sediment (fig. 2). Copper concentrations are approximately 30 times higher, lead is 3 to 4 times higher and zinc is 5 times higher in the worms than in the sediment. The deposit feeder (Nereis) had higher concentrations or specific trace metals than the filter feeder (Diopatra). Copper and lead were concentrated in Nereis at higher levels than Diopatra particularly at the low end of the range (fig. 2). Zinc concentrations were about the same in both species of worms.

MAJOR OBSERVATIONS

1. Trace metal concentrations are not randomly distributed over the study area. Low concentrations are found in nearshore sandy substrates in relatively shallow water depths. High concentrations are found in muddy offshore sediments in deeper water depths mainly in the southeastern quadrant of the study area.

2. There is a positive correlation between trace metal concentrations in benthonic polychaetes and their host sediment. As trace element concentrations increase in the sediment, an increase in trace metal concentration occurs in the polychaetes.

3. Deposit feeders (e.g., *Nereis*) exhibit a better correlation of trace metal concentrations with their host sediment than do filter feeders (e.g., *Diopatra*). Concentrations of trace metals tend to be higher in deposit feeders than filter feeders.

4. Copper and lead are concentrated in *Nereis* and *Diopatra* in relation to the trace metal content of the sediment. Zinc has a relatively poor organic-sediment trace metal concentration relationship in deposit feeders and no apparent relationship in filter feeders.

5. Trace metal concentrations in benthonic polychaetes are several times higher than trace metal concentrations in the host sediment.

ACKNOWLEDGEMENTS

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PERSONAL COMMUNICATIONS

Henry Berryhill, Geologist, U.S. Geological Survey, P.O. Box 6732, Corpus Christi, Texas, 78411

Charles W. Holmes, Geochemist, U.S. Geological Survey, P.O. Box 6732, Corpus Christi, Texas, 78411.

Table 1. Species and number of individuals of each species listed by stations.

Table 1

Number of Individuals

Sta. No.	Species *							
	1	2	3	4	5	6	7	8
1	1							
2								
3		3						
4			1					
5				2				
6		1						
7			2					
8		2						
9				1				
10			3					
11								
12								
13		2						
14								
15								
16		1						
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27			2					
28								
29			1					
30			3					
31				1		1		
32			2					
33					1			
34		2			1			
35								
36			1		1			
37			1					
38						1		
39				1			1	1
40								

Sta. No.	Species *							
	1	2	3	4	5	6	7	8
41								
42		2						
43								
44								
45								
46								
47								
48								
49								
50								
51								
52				1				
53								
54								
55			1					
56								
57								
58		2						
59			1					
60								
61								
62				1				
63								
64								
65								
66								
67								
68								
69								
70			1					
71								
72			1					
73		1						
74								1
75				1				
76								
77		1						
78				1				
79			1		1			
80		1						

* 1. *Ninoe sp.*
2. *Diopatra cuprea*
3. *Nereis sp.*
4. Unidentified
5. *Glycera sp.*
6. *Lepidonotus sublevis*
7. Unidentified
8. Unidentified

Table 1

Number of Individuals

Sta. No.	Species * 1	2	3	4	5	6	7	8
1	1							
2								
3		3						
4			1					
5				2				
6		1						
7			2					
8		2						
9				1				
10			3					
11								
12								
13		2						
14								
15								
16		1						
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27			2					
28								
29			1					
30			3					
31				1		1		
32			2					
33					1			
34		2			1			
35								
36			1		1			
37			1					
38						1		
39				1			1	1
40								

Sta. No.	Species * 1	2	3	4	5	6	7	8
41								
42		2						
43								
44								
45								
46								
47								
48								
49								
50								
51								
52				1				
53								
54								
55			1					
56								
57								
58		2						
59			1					
60								
61								
62				1				
63								
64								
65								
66								
67								
68								
69								
70			1					
71								
72			1					
73		1						
74								1
75				1				
76								
77		1						
78				1				
79			1		1			
80		1						

* 1. *Ninoe sp.*
2. *Diopatra cuprea*
3. *Nereis sp.*
4. Unidentified
5. *Glycera sp.*
6. *Lepidonotus sublevis*
7. Unidentified
8. Unidentified

Table 1

Number of Individuals

Sta. No.	Species * 1	2	3	4	5	6	7	8
81								
82							1	
83				1				
84		2	1					
85			1					
86								
87								
88								
89								
90						1		
91					1	1		
92		3						
93			1					
94			1					
95		2						
96								
97								
98								
99								
100								
101					1			
102				1				
103								
104		1						
105		1			1			
106								
107		1						
108								
109								
110								
111								
112								
113								
114		2						
115				1			1	
116					1			
117							1	
118								1
119		1						
120								

Sta. No.	Species * 1	2	3	4	5	6	7	8

* 1. *Ninoe sp.*
2. *Diopatra cuprea*
3. *Nereis sp.*
4. Unidentified
5. *Glycera sp.*
6. *Lepidonotus sublevis*
7. Unidentified
8. Unidentified

Table 2. Trace element concentrations (Zn, Cd, Pb, Cu) for _Diopatra cuprea_ and _Nereis sp_. listed by station, number of individuals, and sample weight. ASV and AA raw instrument readings listed for each analytical sample tested.

*D = _Diopatra cuprea_   N = _Nereis sp_.

[1]RR = Raw instrument reading

[2]CC = Conversion to ppm based on standards

Station Number	Species*	No. of Individuals	Test Tube Number	Test Tube Weight (g)	Test Tube + Sample Weight (g)	Sample Weight (g)	Instrument Readings					Trace Element Concentration in Samples (ppm)			
							ASV			AA (Zinc)					
							Cd	Pb	Cu	RR[1]	CC[2]	Zn	Cd	Pb	Cu
3	D	3	5	11.2368	11.4762	0.2394	8	21	31	282	1.5	31	3	7	52
4	N	1	4	11.2173	11.2394	0.0221	11	2	7	160	0.5	113	40	7	127
6	D	1	42	11.4439	11.6350	0.1911	6	12	5	293	1.1	29	3	5	11
7	N	2	43	11.3275	11.3440	0.0165	2	9	3	211	.75	227	8	44	14
8	D	2	41	11.3994	11.5756	0.1762	7	19	4	426	1.8	51	4	9	9
10	N	3	9	11.3866	11.4221	0.0355	7	25	28	189	.65	92	17	56	316
13	D	2	6	11.1758	11.3596	0.1838	7	17	12	167	.55	15	3	7	25
16	D	1	3	11.2254	11.3812	0.1558	19	16	46	169	.55	18	10	8	117
27	N	2	51	11.3431	11.4000	0.0569	6	27	32	290	1.1	97	9	38	221
29	N	1	48	11.2175	11.2443	0.0263	4	32	6	448	1.9	120	13	99	84
30	N	3	56	11.3858	11.4157	0.0299	2	19	11	311	1.2	263	4	52	180
32	N	2	8	11.2199	11.2513	0.0314	7	42	28	132	0.4	64	17	109	361
34	D	2	7	11.3057	11.5510	0.2453	26	20	27	302	1.15	23	9	43	113
36	N	1	44	11.1281	11.2074	0.0793	2	10	3	247	0.9	57	3	10	111
37	N	1	40	11.4028	11.4202	0.0174	2	14	5	316	1.2	345	10	63	103
42	N	2	28	11.0616	11.1088	0.0472	5	23	7	341	1.3	138	9	34	58
55	N	1	46	11.3557	11.4142	0.0585	12	59	5	288	1.05	90	16	81	34
58	D	2	61	11.2696	11.3004	0.0308	1	29	2	417	1.75	284	3	77	26
59	N	1	53	11.4273	11.4339	0.0066	4	36	8	350	1.35	61	43	454	455
70	N	1	31	11.1610	11.1700	0.0090	4	29	7	172	.55	31	32	82	289
72	N	1	30	11.2721	11.3491	0.0770	6	24	5	312	1.2	78	6	25	23
73	D	1	29	11.2156	11.2430	0.0274	4	20	4	189	.65	119	12	58	51
77	D	1	39	11.1915	11.1977	0.0062	3	24	58	420	1.95	157	39	317	608
79	N	1	32	11.2315	11.2415	0.0100	4	20	4	237	.85	43	33	158	210
80	D	1	38	11.4496	11.4612	0.0116	1	17	67	243	.85	366	7	119	2310
84	D	2	34	11.3370	11.6874	0.3504	17	22	7	408	1.7	24	4	5	8
84	N	1	35	11.2632	11.3813	0.1181	2	20	12	457	1.95	83	1	60	40
85	N	1	36	11.2975	11.3118	0.0143	1	11	5	138	0.4	140	5	13	135
92	D	3	24	11.2679	11.6062	0.3381	15	25	9	333	1.3	19	4	6	10
93	N	1	25	11.2165	11.2311	0.0146	6	19	4	90	.25	86	35	107	112
94	N	1	26	11.2514	11.2650	0.0136	2	27	5	96	.30	110	12	158	147
95	D	2	27	11.0991	11.3016	0.2025	12	37	22	296	1.1	27	5	15	44
104	D	1	12	11.2707	11.2810	0.0103	10	12	14	123	.35	170	81	93	524
105	D	1	13	11.3135	11.3711	0.0576	8	18	8	233	0.8	69	11	25	56
107	D	1	14	11.3753	11.5398	0.1645	10	27	37	383	1.45	90	5	13	90

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Station Number	Species *	No. of Individuals	Test Tube Number	Test Tube Weight (g)	Test Tube + Sample Weight (g)	Sample Weight (g)	Instrument Readings					Trace Element Concentration in Samples (ppm)			
							ASV			AA (Zinc)					
							Cd	Pb	Cu	RR[1]	CC[2]	Zn	Cd	Pb	Cu
114	D	2	16	11.1732	11.2794	0.1062	30	23	15	490	2.15	101	23	18	57
118	N	1	1	11.2690	11.3112	0.0422	11	7	10	138	0.4	84	20	14	90
119	D	1	21	11.2881	11.3243	0.0362	5	56	38	475	2.05	283	12	125	420

TABLE 2 CON'T

Figure 1. Index map of study area and station locations

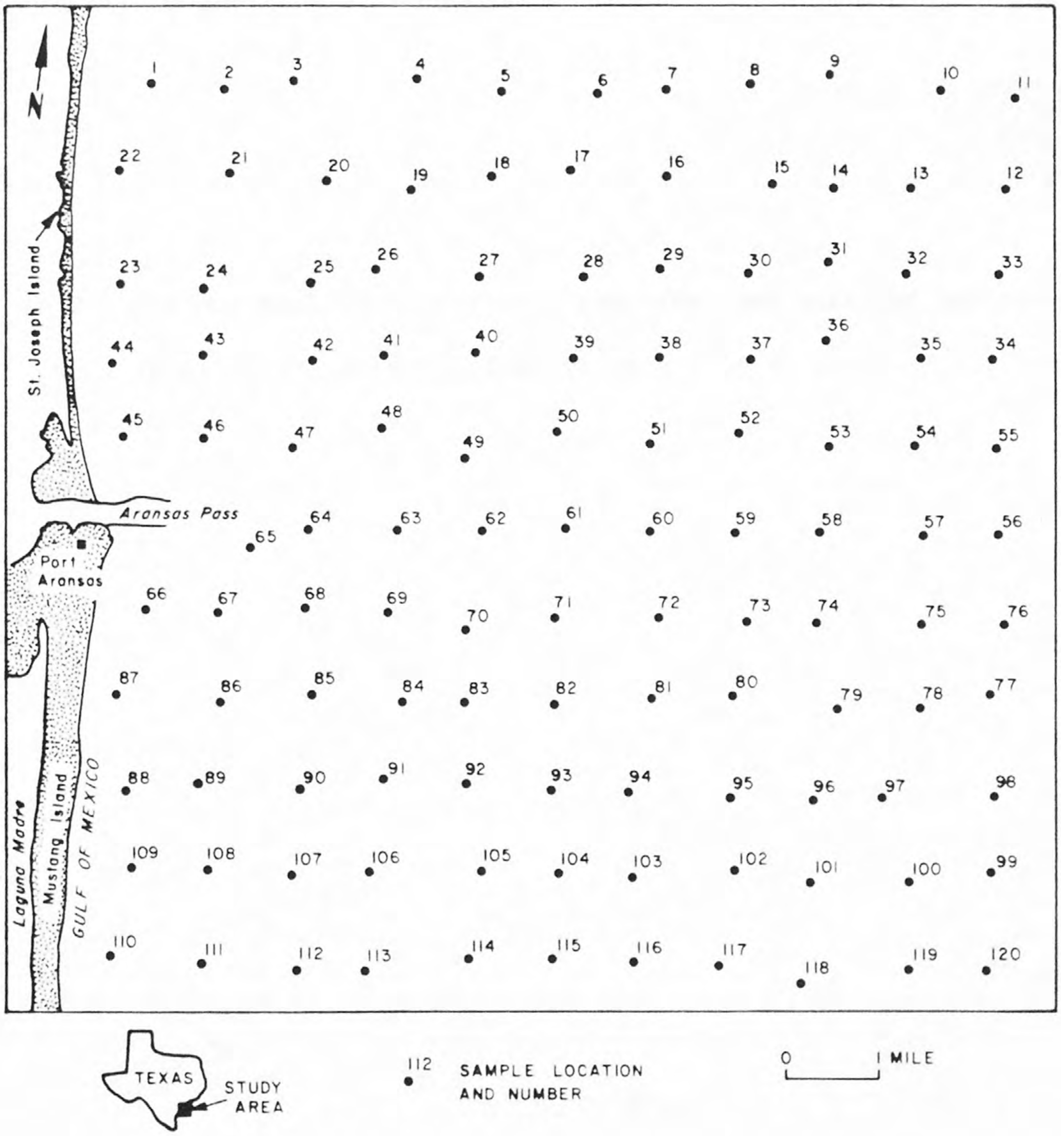

N
St. Joseph Island
Aransas Pass
Port Aransos
Laguna Madre
Mustang Island
GULF OF MEXICO
TEXAS
STUDY AREA
112
SAMPLE LOCATION AND NUMBER
0
1 MILE

Figure 2. Contour maps of copper (A), lead (B), and zinc (C) concentrations (ppm) in the bottom sediments of the study area.

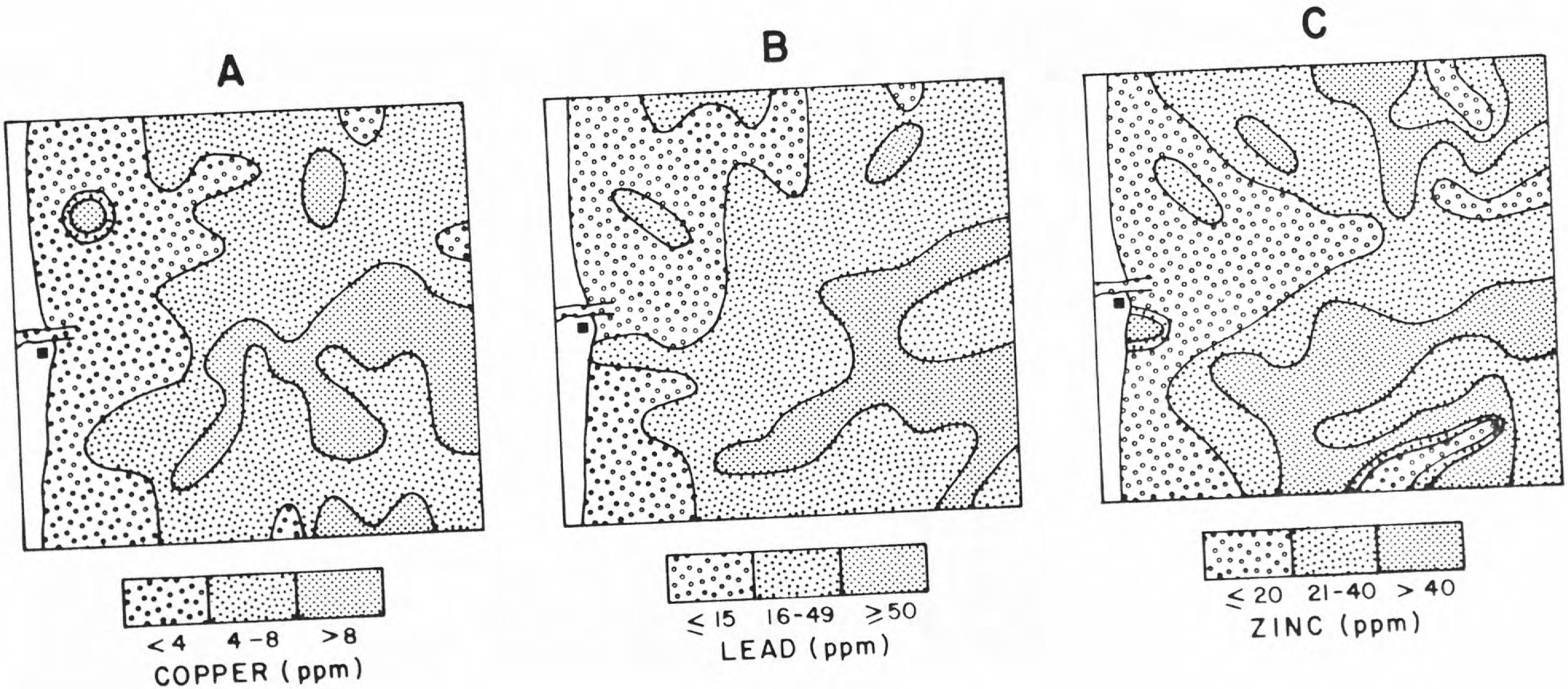
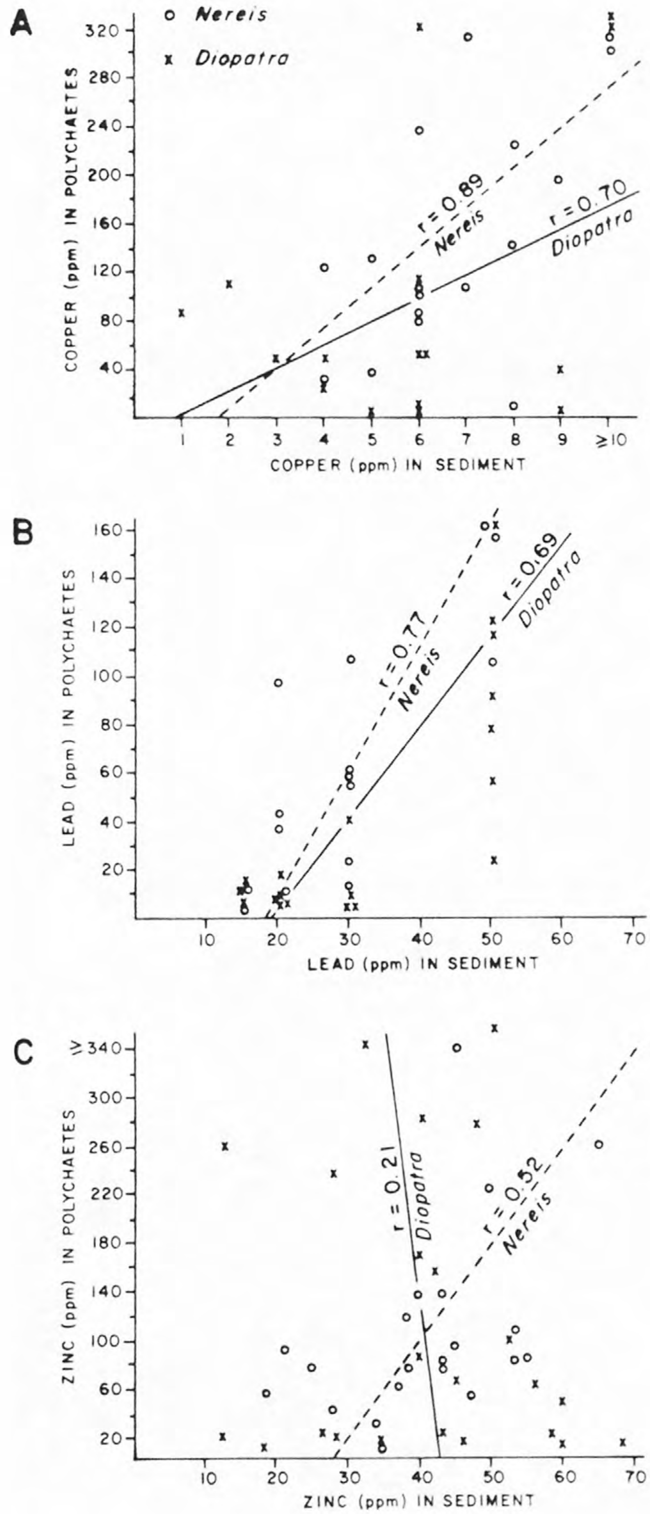

A
< 4 4 -8 > 8
COPPER (ppm)
B
≤ 15 16-49 ≥ 50
LEAD (ppm)
C
≤ 20 21-40 > 40
ZINC (ppm)

Figure 3. Scattergraphs of copper (A), lead (B), and zinc (C) in polychaetes versus host sediment (correlation coefficients r, and linear regression lines shown).


A
o Nereis
x Diopatra
COPPER (ppm) IN POLYCHAETES
COPPER (ppm) IN SEDIMENT
r = 0.89 Nereis
r = 0.70 Diopatra
B
LEAD (ppm) IN POLYCHAETES
LEAD (ppm) IN SEDIMENT
r = 0.77 Nereis
r = 0.69 Diopatra
C
ZINC (ppm) IN POLYCHAETES
ZINC (ppm) IN SEDIMENT
r = 0.21 Diopatra
r = 0.52 Nereis