ENVIRONMENTAL MONITORING SURVEY OF THE MAFLA LEASE AREA

TRACE METALS IN BENTHIC MACROFAUNA (1975-3976)

University of South Florida, Department of Marine Science

Principal Investigator:
Susan B. Betzer

Associate Investigator:
Robert R. Sims, Jr.

ABSTRACT

Seasonal collections of dominant macroinvertebrates were made three times during the year. These included sponges, corals, moll.uses, crustaceans, and echinoderms. A total of 226 samples were collected from 26 stations on the Florida shelf by diving, dredging, and trawling.

A combination of dry and wet oxidations was performed on all samples. Samples were ashed in a low–temperature asher, followed by a further oxidation using HNO_3 in a teflon bomb. The samples were then analyzed for their concentrations of the following elements: cadmium, chromium, copper, iron, lead, nickel, and vanadium. All elements were determined by atomic absorption spectrophotometry.

Sponges generally show the greatest variation in their trace metal content; also, the average concentrations of trace elements in sponges are higher than they are in most other groups. In contrast, corals are not only more uniform in their metal concentrations but also exhibit the lowest concentrations for all trace metals when compared to" other phyla.

Trends are limited, due to the number of samples collected. However, sponges and echinoderms display some geographical trends. Most groups show at least some seasonal trends.

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INTRODUCTION

Concern over trace metal contamination in the marine environment is well-founded (Kobayashi, 1970; Roskam, 1965; Tatsumoto and Patterson, 1963). Increased industrial activity (both land and sea) has resulted in an accelerated mobilization of a number of trace metals such as: cadmium, chromium, copper, iron, lead, nickel, and vanadium. Some of these metals are known to be highly toxic to biological systems (Oehme, 1972), while others are necessary in trace amounts for normal growth and development (Bowen, 1966).

In the marine environment, these elements may enter the biosphere through a number of pathways. One such pathway that has come about, with the increased demand for energy, is the possible introduction of potentially toxic metals via offshore oil drilling and production. It has long been known, that it is the sediments which represent the reservoir of trace metals in the sea (Riley and Chester, 1971). Under reducing conditions in the sediment, the Eh and pH are lowered and the possibility of bringing normally Insoluble metals into solution exists. Under normal conditions, the diffusion of these metals into the water column would be minimal. However, under conditions where the sediment is greatly disturbed, as in drilling, the possibility exists of significantly increasing the dissolved and/or particulate metal content of the water column. Trace elements may enter the marine environment, due to offshore drilling, in another manner. Yen (1975) has shown that certain crude oils contain significant concentrations of the metals previously mentioned. In fact, Yen (1975) has shown nickel and vanadium concentrations in some crude oil to be as great as 300 ppm.

Trace metal concentrations in benthic invertebrates can provide a sensitive measure to these changes in environmental conditions. Since benthic invertebrates are normally confined to the same general geographical locations during their entire lives, they have the potential of being seasonal as well as geographical indicators of environmental contamination.

The main purpose of this study was to provide background information on the levels of the seven metals studied in benthic macroinvertebrates from the MAFLA lease area. Secondary objectives arose from this. These included: (1) baseline metal concentrations in organisms from a relatively unpolluted environment, (2) trends, both geographical and seasonal in metal concentrations among the dominant groups sampled, and (3) variations and the. degree of "scatter" of trace metal concentrations among species within a phyla and samples within a species.

METHODS

Sampling

Collections of dominant macrofauna were made seasonally a three times during the year. Collections were made during the summer 1975, fall 1975, and winter, 1976. During each sampling period, samples were collected by dredging and trawling (18 stations) and diving (eight stations), for a total of 78 stations sampled per year (see Figure 1). A total of 226 different samples including: sponges, corals, molluscs, crustaceans, and echinoderms were analyzed for their content of cadmium, copper, iron, lead, nickel, and vanadium. In addition 60 other samples were analyzed in replicate during the course of the year, making the total number of samples analyzed 286.

Analysis

After collection, all samples were immediately frozen in polyethylene bags. On returning to the laboratory, the samples were thawed, weighed, dried to a constant weight at 60°C and reweighed. The drying process normally took

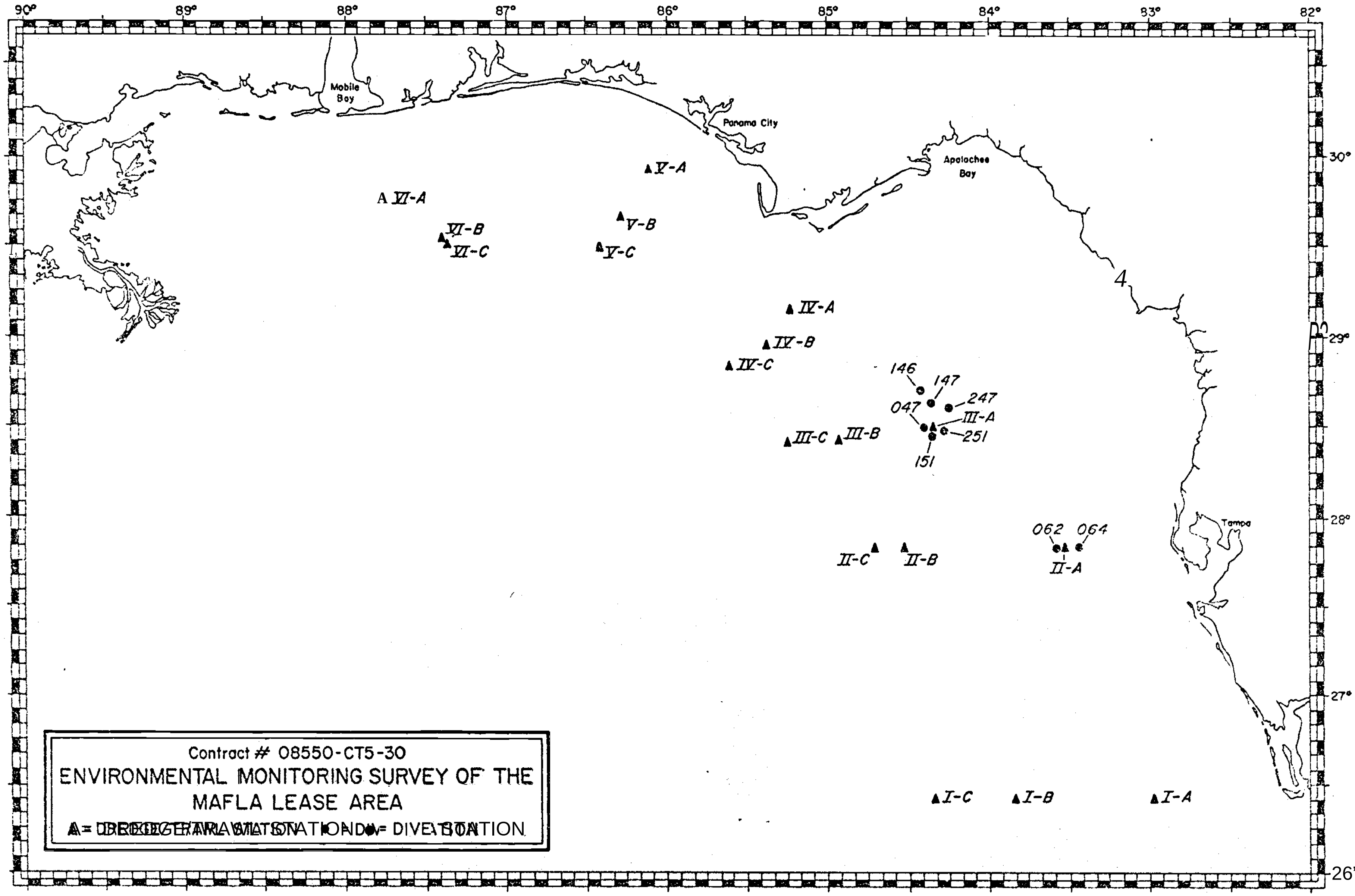

Figure 1. Location of sampling sites

four to five days. All samples, excluding corals, were then ground to a homogeneous powder using a porcelain-lined Spex mixer-mill. In some cases (especially for those samples analyzed in quintuplicate) several individuals from a sample were homogenized together. This was necessary in order to obtain enough material for analysis. Approximately 0.5-0.75 g of sample was then weighed onto a pyrex watch glass and placed in an International Plasma Corp. low temperature asher (LTA) for approximately five. hours. In the case of corals, small pieces were used which had been "semi-ground" using a mortar and pestle. After ashing, the sample was oxidized further, using a modification of a technique developed by Eggimann and Betzer (1976). The ashed sample was placed in a TFE teflon bomb to which three milliliters of concentrated Ultrex nitric acid were subsequently added. The bomb was then placed in a hot water bath (≈85°C) for five hours.

After digestion, the sample was washed into a 50 ml polypropylene volumetric flask and brought to volume using deionized water.

Copper and iron were determined directly on a Perkin-Elmer model 503 atomic absorption spectrophotometer using an air/acetylene flame. When necessary, appropriate dilutions were made using 1 N HNO_3.

For the other metals (because of their lower concentrations) it was necessary to use an HGA-2100 graphite furnace (flameless atomizer). A deuterium arc background corrector was used to subtract interferences due to ~on-specific causes. Aqueous standards were prepared using Fisher standard reference solutions.

Precision and accuracies for all elements determined are presented on Table 1. The organic standard used in this study was N.B.S. bovine liver. The results of our quality control samples are listed on Appendix A.

RESULTS

The cumulative raw data for all three sampling periods is summarized in

Appendix B. As one can see the metal concentrations arc extremely variable, not only among the various groups but also among most of the species within a group.

Table 1

Accuracy and Precision of Tissue Samples
(concentrations in ppm dry weight)

Element	Bovine liver (NBS)	Bovine liver (determined)*
Cd	0.27±0.04	0.32±0.03
Cu	193±10	187±8
Fe	270±20	252±12
Pb	0.3410.08	0.35±0.1

* Mean values obtained from 20 separate analyses.

Overall, sponges vary more than any other phyla. Most metal values vary at lease ten times among species and at least five times within a species (Appendix B).

During the first sampling period Guitarra sp. appears to concentrate cadmium and chromium to higher levels than other sponges. This is also true of iron and vanadium, to a lesser degree. An unidentified Sponge "B" also is high in chromium. Copper is fairly consistent within the entire group. Iron and lead values show a high degree of "scatter" both within the group and also within a species. Nickel and vanadium concentrations vary less than most of the other metals.

A greater number of species and samples of sponges were analyzed during the second sampling period. however, some of the species collected in the first period were not collected during the second. As in the first period, Guitarra sp. concentrates cadmium to the greatest degree. The exception to this is Anthosigmella varians, which, due to the high cadmium, iron, and nickel values, is probably contaminated. Cliona celata, Ircinia campana, and Neofibularia nolitangere oxeata also contain elevated concentrations of chromium and iron. Copper and vanadium values are consistent with the first period. Nickel concentrations vary a great deal.

During the third sampling period Guitarra sp. again has relatively high values for cadmium and iron. Copper and lead are somewhat consistent among all sponges. Vanadium is non-detectable in many of the sponges during this period.

Corals tend to be quite consistent in their metal concentrations. In fact, the values for trace elements in corals are remarkably uniform for all species during the three sampling periods. The only exception to this are Millepora alcicornis and Phyllangia americana.

Only one species of mollusc of any dominance was analyzed. Cadmium appears to be the only element in which the concentrations are above normal.

Crustaceans are the most diverse group of benthic macrofauna that were collected. This is true not only because of the various feeding habits, but also because some species have a great deal more mobility than others (i.e. Sicyiona brevirostris).

During the first period five species were collected, all. of which are somewhat dominant. Multi-samples were analyzed for each species. Cadmium, chromium, copper, lead, nickel, and vanadium values are similar in most samples. Stenorhynchus seticornis exhibits lower iron concentrations during the first period. Crustaceans collected in periods two and three show the same trends as those collected in period one.

The number of echinoderms analyzed during the first sampling period is too limited to show many trends. Copper concentrations do not vary much among samples. The other metal values appear to show a great deal of “scatter”. The samples collected during period two represent mainly one genus. Metal. values in the third period are similar to those of the first.

DISCUSSION

In order to fulfill the objectives listed in the introduction, this section will. be presented by phyla (group) rather than by element.

Sponges

As was mentioned earlier, the variation among samples in this group of organisms is extremely high for all metals. As one can see (Table 2) iron concentrations range over two orders of magnitued. The reasons for such large variations are not known. It is possible that these large variations are due to a number of factors, including the number of different species and geological location. Out of 68 samples there were 26 species. This high percentage of different species certainly lends itself to variations in trace metal concentrations. Also, if the samples are collected in areas where the suspended load is high, and dominated by alumino-silicate material, the possibility exists of significantly increased values for certain trace metals. If one integrates all three sampling periods, the sponges exhibit greater variation in every metal than most other groups. This is surpassed only by the molluscs and crustaceans with reference to cadmium. and copper.

In general., the sponges contained significantly higher concentrations of chromium, iron, and nickel (Table 2). Although Table 2 indicates a great deal of "scatter" in the concentration of these elements in sponges, it is somewhat misleading in the case of nickel.. Looking at Appendix B, one can see that a majority (60%) of the sponge samples have nickel concentrations greater than 10 ppm. Thus nickel values are consistently high in most of the sponges. While a few of the sponges may contain elevated nickel values as a result of sediment contamination (due to increased chromium and iron), it is not felt that this is true for other sponges (i.e. *Cinachyra sp.* and *Pseudoceratina crassa*). Bowen and Sutton (1951) attributed the high nickel values in many sponges to the microflora associated with them.

Table 2

Comparison of the Average Trace Metal Concentrations among the Various Phyla of Benthic Macrofauna from the MAFLA Lease Areas (concentrations in ppm dry weight)

Group Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
Sponges	68	Range	0.058– .670	0.06– 9.80	3.0– 20.5	30.0– 4500	0.4– 372	<0.01– 8.82	<0.4– 8.8
		Mean	2.367	3.11	7.7	516	22.7	<1.17	<1.6
		Std. Dev.	2.540	5.75	3.9	835	52.0	1.50	1.7
Corals	55	Range	0.020– 1.610	<0.01– 0.59	3.7– 10.1	17.0– 123	<0.2– 9.6	0.07– 2.72	<0.4– 6.0
		Mean	0.214	<0.23	7.1	39.3	<1.0	0.29	<1.9
		Std. Dev.	0.317	0.43	1.2	19.0	2.2	0.41	1.4
Molluscs	14	Range	0.660– 35.0	0.32– 9.52	1.5– 44.2	19.3– 308	1.3– 70.3	0.15– 1.66	<0.4– 6.0
		Mean	13.65	4.38	7.9	89.4	22.1	0.94	<3.1
		Std. Dev.	11.33	3.14	10.8	67.8	17.6	0.43	2.0
Crustaceans	59	Range	0.050– 12.120	<0.01– 1.46	12.7– 110	11.0– 773	<0.2– [illegible]9	<0.01– .94	<0.[illegible]– [illegible]9
		Mean	1.807	<0.38	50.7	125	<0.[illegible]	<0.82	<[illegible]
		Std. Dev.	2.141	0.28	24.1	144	0.[illegible]	1.46	[illegible]
Echinoderms	30	Range	0.056– 1.190	<0.01– 1.53	5.1– 21.3	19.3– 1832	<0.2– 6.2	0.27 .96	<0.[illegible]– 8.3
		Mean	0.320	<0.73	7.8	267	<0.9	1.26	<1.9
		Std. Dev.	0.274	0.52	3.2	355	1.2	1.75	1.9

* For some metals, the number of samples analyzed is one less than that given.

Appendix C shows the metal concentrations and variations within a species among the dominant macrofauna. Only two species of sponges display any dominance, Cinachyra and sP. crassa. The only consistency in metal concentrations within each of these species is in copper and nickel., This trend continues throughout all the sampling periods.

Geological trends in trace metal concentrations are not readily apparent among the sponges. This is probably due, in part, to the lack of sufficient numbers of samples, of the same species, at all stations. Therefore, only those stations where samples were collected during at least two of the three sampling periods will be considered in the geographical trends. Also, because of the lack of sufficient data, any geographical trends should be viewed only as possible indicators and not proven facts.

Sponges collected at Stations I–B, II-A, 062, and 064 are consistently lower in their nickel concentrations than those from other stations (Appendix B). A reason for this is not known. Those sponges from Stations VI-B and V-A are consistently higher in chromium and iron. They are also somewhat elevated in their concentrations of vanadium and nickel, respectively. However, these values may be biased somewhat in the case of Station VI-A, since Guitarra sp. is dominant (high chromium and iron values may be characteristic of this sponge). This situation does not exist at Station V-A. Becuase of the location of Station V-A (Figure 1) which is near areas where the suspended loads are sometimes greater than areas further to the south, the elevated chromium, iron, and nickel values may be due, in part, to sediment contamination. Brooks and Rumsby (1965) have demonstrated similar correlations between these elemental concentrations and sediment content of organisms. Within a sampling period, Cinachyra sp. is noticeably higher in cadmium, iron, lead, and vanadium at Stations II-A, 062, and 064 than it is at other stations. The reason for this is not known, except that these. stations are close to the Tampa-St. Petersburg area, a region which is somewhat industrialized.

Seasonal trends in sponges are almost impossible to interpret within a time frame of one year. Because Cinachyra sp. and P. crassa were the only sponges collected in sufficient quantities at the same station locations during all three sampling periods, they are the only sponges used for seasonal trends. Both sponges show a steady decrease in every metal., excluding copper and nickel, as one proceeds from the first to the third sampling period (Appendix C).

Although the range of values for metals in sponges appears quite large, other studies indicate that our values certainly are within the ranges of those found by other investigators (Bowen, 1966; I.D.O,E. , 1972; Vinogradov, 1953).

Corals

Corals exhibit the greatest consistency in their concentrations of trace metals (Table J?). The ranges in nickel and vanadium appear to contradict this stateliest; however, only seven samples out of 55 have values greater than the mean for nickel, and only 17 samples show values greater than the mean for vanadium values are below the detection limit (Appendix B). This lack of "scatter" in values may be due partly to the similar metabolism and feeding habits of the group as a whole; also, only seven species were collected and most of the stations are located quite near one another (Figure 1). Other authors have noted this same uniformity in trace element concentrations (Livingston and Thompson, 1971).

In addition to the consistency in their trace metal concentrations, corals also have the lowest values for the metals when compared to other phyla. They average from five to ten times lower in their values than most of the other groups (Table 2).

The lack of variation in trace element concentrations within species of corals is even more remarkable than the lack of variation within the group (Appendix C). Since all coral samples were collected in a localized area, it is impossible to conclude any geographical trends. However, one seasonal trend was observed. Both dominant corals, Madracis decactis and Porites divaricata, show decreasing values in their cadmium, chromium, and nickel values as one goes from the first sampling period to the third. It is possible, however, that this trend may not be completely due to environmental conditions. Our laboratory was working at or near the detection limit for the above-mentioned metals during the three sampling periods. Our analytical techniques were improved with time; thus, our ability to distinguish. between slight variations in instrumental results was refined and our detection ability improved. Since our analytical ability improved slightly during the course of the year, the slight differences in the metal concentrations in corals may not be significant.

Data concerning trace metal concentrations in corals is very scarce. The few studies that have been done used neutron activation analysis (N.A.A.) to obtain their results (Livingston and Thompson, 1971; Forster et al., 1972). One of the problems with N.A.A. is the poor detection limits for many of the elements of interest. Thus our values are significantly lower for many of the metals in corals than those reported in the literature.

Molluscs

The results on the data obtained on molluscs is so scanty (only 14 samples were collected and analyzed) that data interpretation is difficult, if not impossible. Essentially only one species was collected, Spondylus americanus.

Molluscs vary a great deal in their concentrations of cadmium, chromium, and copper. This is quite surprising, when one considers that S. americanus comprised 11 of the 14 samples and that most samples were collected from one area (Table 2). Cadmium, chromium, and nickel values are greater than those of most of the other groups.

S. americanus exhibits no trends in its trace metal concentrations with one exception: cadmium values decrease rapidly toward the third sampling period.

Comparative values of the molluscs analyzed in this study are almost non-existent in the literature, except for a few values (I.D.O.E. , 1.972).

Crustaceans

As a whole, crustaceans vary to a lesser degree in their trace metal concentrations than most other groups. This is somewhat surprising since crustaceans are the most diverse and mobile group of organisms sampled. They exhibit many types of feeding habits (filter feeders, detrital feeders, and carnivores) . Also crustaceans were collected from stations covering the entire MAFLA lease area. Thus, if there were any differences in trace metal concentrations due to geography, the range in trace metal concentrations would be influenced accordingly. Other than cadmium and copper, metal values are not significantly higher in crustaceans. Nickel and vanadium are near the detection limit in many cases (Table 2).

Variations in trace element concentrations amont the dominant species are again shown in Appendix C. In all three sampling periods, Stenorhynchus seticornis shows the least variation for all elements. Since all S. seticornis samples were collected from one area (Appendix B, Figure 2), that may be a possible reason why the trace element concentrations are so uniform.

No geographical trends were encountered; at best, seasonal trends are very limited. S. seticornis was the only crustacean collected in sufficient quantities at the same location during the three sampling periods that can be used to show any seasonal trends. Cadmium, nickel, and vanadium decrease slightly in concentration as one proceeds from the first to the third sampling period. Iron values show a slight increase (Appendix C).

A number of the crustacean species analyzed in this study are not cited elsewhere in the literature. So in order to make any comparisons to the trace element concentrations of other studies, it was necessary to integrate the various crustacean species together. In general, the trace metal values in crustaceans from this study compare favorably with those of other investigators (Bryan, 1968; I.D.O.E. , 1972; Martin, 1974; Sims and Presley, 1976).

· Echinoderms

Except for iron and lead, the echinoderms are second only to corals in their degree of consistency concerning the various trace elements. Again, this is somewhat surprising, considering that out of the 29 samples analyzed there were 11 species. Brissopsis elongata, from the third sampling period, is not included in this group because the values are so much greater for chromium and iron. Furthermore, the samples were collected from stations encompassing most of the MAFLA lease area, As is the case with most other groups, nickel and vanadium values are quite low.

Because of the lack of sufficient data, any trends in this phylum are also limited. Samples at Transect VI (especially VI-C) contain significantly higher iron values than the rest of the samples (Appendix A, Figure 1). A possible explanation for this may be the input of terrigenous material in this area (see Sponge section). No seasonal trends were observed.

When comparing trace metal values in echinoderms from this study to others, the same problem was encountered as that with the crustaceans: the same species have not been analyzed by others. Therefore, it was again necessary to group all echinoderms together. Our data is quite similar to those of Riley and Segar (1970). I.D.O.E. (1972) data is quite scarce. Vinogradov's (1953) values are close to ours, except that his copper values are much greater (>100 ppm).

CONCLUSIONS

Because so many different species and phyla were collected with relatively few samples from each, it is somewhat difficult to draw any definite conclusions concerning all the various phyla together. However, some conclusions can be made concerning individual phyla and species within a phylum.

For the most part, the variation in the trace metal concentrations among the various groups is quite high. Variation in the metal concentrations among species within a phylum is also, in most cases, relatively great. This is especially true for the sponges, in which the variation, or "scatter", for trace element values is several orders of magnitude. Reasons for such variability among phyla, *as well* as among species within a phylum, might include: (1) changes in feeding habits, which affect the physiology and metabolism; (2) geographic location, since some organisms are quite mobile and travel into and out of areas where the trace metal concentrations vary in the environment; and (3) seasonal variation of elemental concentrations in organisms.

Corals, contrary to other groups, are very uniform in their trace metal concentrations, This is true not only among the various species but also among individuals within a species.

In spite of the large variation among most species within a phylum, some trends were noted. Sponges and echinoderms are the only groups which display any geographical trends. Although seen in most groups, seasonal trends are minimal. In all cases, these trends should be viewed only as possible indicators.

In general, sponges show the greatest concentrations of chromium, iron and nickel. The high nickel values may be explained partly by a symbiotic relation--ship. In contrast, corals are the lowest in every metal when compared to other groups. In fact, nickel and vanadium concentrations are non-detectable in many of the samples.

The trace metal concentrations in all groups from this study are well within the range of those reported by other investigators. Indeed, as far as trace metals are concerned, the results of the analyses in the organisms from the MAFLA lease area indicate that this area approaches a "pristine" environment.

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A P P E N D I C I E S

Appendix A

Comparison of Quality Control Organisms Samples
(concentrations in ppm dry weight)

Species Name	Station Number	Lab. of Analysis+	Cd	Cr	Cu	Fe	Ni	Pb	V[a]
Zooplankton	1206	USF	5.32	0.39	12.5	118	1.3	0.37	2.9
		TAMU	4.50	1.70	9.8	123	0.9	0.34	- -
Zooplankton	1309	USF	4.66	0.98	19.4	224	3.2	0.94	1.8
		TAMU	4.10	1.20	29.0	257	3.7	0.62	- -
Stenorhynchus seticornis	146	USF	0.40	0.16	25.6	56.4	<0.2	0.22	<0.4
		TAMU	0.53	0.9s	35.6	50.0	<().5	2.7	--
Cinachyra sp.	251	USF	0.36	0.80	6.5	157	10.5	0.55.	3.9
		TAMU	0.30	<0.10	7.0	170	15.0	2.0	- -
Clypeaster raveneli	II-B	USF	0.28	0.77	6.8	148	0.6	0.56	1.0
		TAMU	0.30	0.40	2.2	148	<0.5	2.0	- -

* All samples collected from third sampling period
\+ USF = University of South Florida (Betzer)
TAMU = Texas A&M University (Presley)
a Vanadium values not yet available from TAMU

Appendix B

Concentrations of Trace Elements
in Benthic Macrofauna
(concentrations in ppm dry weight)

1st Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	v
				SPONGES					
Sponge "B"	VI-B	A	1.080	29.80	7.1	217	2.3	3.45	5.8
Sponge "I)"	I-B	A	2.450	0.94	14.5	116	19.5	8.82	1.2
Sponge "G"	III-A	A	0.112	0.51	6.9	561	0.4	1.38	0.6
Geodia gibberosa	V-A	A	1.090	2.70	3.6	1150	25.9	0.11	1.2
Guitarra sp.	VI-B	A	8.270	29.80	7.6	708	5.9	5.13	8.8
Placospongia sp	I-A	A	4.310	3.71	3.0	68.5	1.0	2.07	2.9
Cinachyra sp.	047	A	1.900	0.44	6.9	84.3	27.0	1.0	0.7
	062	A	5.760	5.39	6.2	935	1.5	1.96	2.4
	064	A	4.850	4.06	6.9	883	1.1	1.95	3.8
	146	A	2.160	0.61	4.5	84.2	15.8	0.32	1.5
	147	A	2.110	3.43	5.5	421	18.4	0.36	1.2
	151	A	2.840	1.41	6.3	163	12.5	0.76	1.4
	247	A	2.020	0.43	6.3	65.8	25.1	0.22	0.8
	* 251	A'	3.020	0.61	5.0	80.2	16.7	0.48	1.5

Appendix B (cent'd)

1st Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
Pseudoceratina crassa	047	A	1.220	1.46	7.6	143	23.6	0.72	1.1
	146	A	5.800	2.71	7.1	199	12.8	2.12	5.8
	147	A	0.934	3.15	20.5	312	16.6	3.92	1.0
	151	A	1.300	1.98	8.8	211	5.3	5.39	1.9
	247	A	2.490	0.84	6.4	91.4	16.6	1.03	1.2
	251	A	6.060	0.36	6.5	79.6	18.8	0.46	1.7
CORALS									
Solenastrea hyades	062	A	0.105	2.45	5.3	60.8	0.6	0.55	2.3
Cladocora arbuscula	064	A	0.083	0.40	5.4	321	<0.2	0.24	3.6
	064	A	1.610	1.95	9.3	32.6	0.5	1.74	2.9
Madracis decactis	047	A	0.113	0.40	7.0	24.8	0.3	0.31	1.9
	146	A	0.061	0.28	5.7	22.1	0.5	0.24	1.4
	147	A	0.771	0.17	5.2	17.3	6.5	0.11	1.2
	151	A	0.485	0.21	5.5	16.9	0.22	0.16	1.0
	247	A	0.116	0.38	4.6	22.3	1.5	0.24	2.8
	251	A	1.33	0.38	3.7	18.0	0.3	0.11	1.0

Appendix B (cent'd)

1st Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	v
CORALS									
Porites divaricata*	047	A	0.215	0.26	6.9	21.7	<0.2	0.16	1.9
	147	A	0.461	0.27	6.1	18.3	0.4	0.13	1.2
	151	A	1.110	0.59	6.5	19.1	0.3	2.72	4.9
	247	A	0.251	0.32	6.9	20.6	1.0	0.28	1.5
	251	A	0.438	0.43	5.1	20.8	0.3	0.16	0.4
MOLLUSCS									
Spondylus americanus*	151	A	20.8	2.59	9.2	80.8	20.5	1.42	6.0
	247	A	20.4	1.89	6.9	71.9	5.4	1.04	5.6
Mercenaria campechiensis	V-B	C	2.670	1.88	10.0	308	21.3	1.31	1.5
CRUSTACEANS									
Myropsis quinquespinosa	IV-C	A	2.690	0.50	82.7	132	1.8	0.24	3.9
	v-c	A	3.790	0.51	50.0	150	0.9	0.22	1.5
Sicyiona brevirostris	IV-A	E	0.149	0.44	12.7	11.2	<0.2	0.80	<0.4
	VI-A	B	0.571	0.44	31.0	106	1.2	0.73	1.7

Appendix B (cent'd)

1st Sampling Period

Species Name	Station Number	Part Analyzed*	C d	Cr	Cu	Fe	Ni	Pb	v
Acanthocarpus alexandri	Iv-c	A	1.250	0.65	38.7	276	1.9	0.24	1.2
	V-C	A	1.1.00	1.46	45.0"	773	0.2	0.48	2.4
	*VI-C	A	0.500	0.71	53.7	245	0.8	5.88	1.3
Portunus gibbesi	VI-A	D	12.10	0.61	44.1	54.4	<0.2	1.62	0.8
Portunus spinicarpus	I-B	A	7.120	0.42	61.0	26.4	0.5	6.94	1.0
	II-B	A	4.640	0.42	50.5	50.2	0.4	4.88	().4
	IV-B	A	2.5S0	0.42	57.0	76.2	0.7	6.40	0.4
	V-B	A	2.770	0.81	61.4	235	0.5	0.23	0.8
	VI-A	A	0.936	1.05	.26.2	669	0.6	1.80	1.0
	VI-A	A	0.815	0.33	19.1	89.2	0.6	0.29	<0.4
Stenorhynchus seticornis	047	C	1.610	0.35	23.3	38.1	0.9	0.83	1.8
	146	C	1.160	0.31	19.3	35.2	0.8	0.61	2.4
	147	C	1.830	0.25	21.7	32.1	0.9	0.73	2.2
	151	C	1.890	0.37	24.6	39.2	1.7	0.17	2.5
	247	C	1.070	0.46	29.2	61.9	0.9	0.25	2.0
	251	C	1.720	0.40	34.3	41.9	1.0	0.31	1.4

Appendix B (cent'd)

1st Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
				ECHINODERMS					
Astroporpa annulata	VI-B	A	1.19	1.51	5.2	641	1.4	1.74	2.2
Comactina echinoptera	I-B	B	0.350	0.59	7.0	41.0	0.6	7.96	0.9
Echinaster sp.	V-A	A	0.569	0.49	21.3	108	6.2	0.38	2.0
Encope michelini	IV-A	A	0.079	1.23	6.5	235	<0.2	6.4	7.9
Brissopsis elongata *	IV-C	F	0.072	0.95	7.2	523	0.8	1.87	0.9
*	VI-C	F	0.089	2.44	7.2	1300	1.5	2.04	8.3
Stylocidaris affinis	V-A	A	0.842	0.28	5.1	19.3	0.8	0.27	2.2
	VI-B	A	0.924	0.64	6.7	196	0.8	0.82	1.9
Clypeaster raveneli	IV-B	A	0.162	0.79	7.6	81.4	0.6	0.35	1.9
Clypeaster durandi	VI-A	A	0.210	0.78	7.2	229	0.8	0.54	1.8

Appendix B (cent'd)

2nd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
				SPONGES					
Sponge "B"	IV-A	A	6.580	2.45	3.1	492	141	1.01	0.7
Sponge "C"	III-B	A	0.475	0.06	3.4	30.0	12.9	0.05	<0.4
Anthosigmella varians	I-A	A	64.500	0.77	12.1	2260	2320	0.27	1.0
Axinella polycapella	II-A	A	5.48(')	1.37	4.2	85.2	1.2	0.15	0.6
Spongosorites sp.	III-B	A	0.226	2.23	4.7	1241	3.8	1.76	2.50
Mycale sp.	II-B	A	9'.670	1.43	8.5	736	7.7	0.50	2.0
Epallax sp.	I-B	A	0.462	6.14	6.1	469	0.5	0.54	2.1
Tethya sp.	I-B	A	2.360	6.75	6.6	520	1.0	1.97	3.4
Cliona celata	064	A	0.158	17.87	6.8	3022	1.1	2,55	4,9
Ircinia campana	V-A	A	0.663	16.2	11.2	2992	13.9	3.78	3.3
Agelas	III-A	A	1.670	0.65	15.6	169	18.2	0.78	1.8
	146	A	2.170	0..91	18.2	64.1	21.6	0.13	0.5
	147	A	5.960	1.03	17.5	61.7	16.1	0.19	1.1
Neofibularia nolitangere oxeata	V-A	A	7.480	11.23	7.3	2685	183	1.86	2.6
Sponge "A"	064	A	2.400	2.79	4.9	256	2.2	0.28	1.0

Appendix B (con'td)

2nd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
Guitarra sp.	VI-B	A	8.580	10.45	7.6	4500	6.3	0.58	6.2
Cinachyra sp.	*II-A	A	5.120	0.88	3.9	200	0.7	0.45	1.2
	247	A	1.500	1.39	4.7	130	16.8	0.16	<0.4
Pseudoceratina crassa	I-A	A	1.550	1.66	19.2	268	33.1	0.07	1.7
	251	A	1.000	0.89	8.1	67.0	31.8	0.23	<0.4

CORALS

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
Solenastrea hyades	II-A	A	0.085	0.15	7.8	78.2	<0.2	0.40	<0.4
	062	A	0.091	0.03	7.5	35.1	<0.2	0.26	<0.4
	064	A	0.089	0.09	7.9	123	<0.2	0.40	1.3
Cladocora arbuscula	062	A	0.060	0.10	7.0	51.1	<0.2	0.24	6.0
	064	A	0.094	0.03	6.8	56.7	<0.2	0.21	2.9
Madracis decactis	III-A	A	0.243	<0.01	7.6	27.0	9.6	0.34	3.0
	047	A	0.045	<0.01	7.1	35.7	<0.2	0.35	1.9
	146	A	0.081	<0.01	6.9	37.4	<0.2	0.17	4.8
	147	A	0.045	<0.01	6.5	31.8	<0.2	0.13	2.5

Appendix B (cent'd)

2nd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
	151	A	0.047	<0.01	6.9	35.1	<0.2	0.17	3.5
	*247	A	0.070	<0.01	6.8	36.5	<0.2	0.16	6.0
	251	A	0.041	<0.01	7.0	35.9	<0.2	0.14	2.1
Porites divaricata	047	A	0.325	---	6.8	35.6	<0.2	0.27	3.8
	146	A	0.330	<0.01	6.8	36.2	<0.2	0.14	2.4
	147	A	0.193	<0.01	6.8	34.2	1.8	0.20	3.7
	151	A	0.108	<0.01	7.0	35.9	<0.2	0.07	2.2
	247	A	0.229	<0.01	6.3	31.6	<0.2	0.18	1.7
	*251	A	0.211	<0.01	6.8	36.1	<0.2	0.08	2.8
Phyllangia sp.	062	A	0.120	0.51	9.0	106	<0.2	0.48	0.5
				MOLLUSCS					
Spondylus americanus	III-A	c	19.4	8.73	5.1	121	31.5	0.63	5.0
	047	c	22.0	4.09	5.0	63.2	70.3	0.82	3.0
	147	c	21.7	9.52	3.2	77.3	27.8	1.66	5.1
	*151	c	11.5	0.44	2.3	69.5	25.8	0.51	3.2
	247	A	35.()	3.3	3.5	79.5	33.7	1.05	4.7
	251	c	26.6	7.72	/3.1	70.2	30.6	1.49	3.4

Appendix B (cont'd)

2nd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
Mercenaria campechiensis	V-B	A	3.150	0.75	8.1	107	0.7	1.07	0.9
CRUSTACEANS									
Calappa angusta	I-C	C	0.895	0.48	27.2	53.6	<0.2	0.195	2.9
Parapenaeus longirostris	II-C	C	1.150	<0.01	106	55.3	0.7	0.16	1.6
Hymenopenaeus tropicalis	VI-B	C	0.809	0.06	67.3	135	1.7	0.49	1.2
	VI-C	B	2.930	0.49	96.1	474	0.46	1.4	1.7
Sicyiona brevirostris	I-A	A	0.424	1.07	29.9	104	0.5	0.15	0.6
	III-A	A	0.317	0.09	76.6	69.1	0.5	0.31	1.5
	IV-A	A	0.228	<0.01	93.4	91.9	0.5	0.67	2.1
	IV-B	A	0.474	<0.01	92.0	49.9	0.8	0.42	1.6
Acanthocarpus alexandri	IV-C	C	0.518	0.03	80.0	124	<0.2	0.28	3.0
	V-C	C	2.680	0.30	71.8	245	0.3	0.66	2.3
Portunus spinicarpus	I-A	C	1.010	0.75	44.2	85.8	0.6	0.13	1.1
	III-A	A	5.870	0.11	36.0	89.3	0.8	0.35	1.8
	III-B	A	2.660	<0.01	79.8	35.9	0.9	0.21	2.2
	III-C	A	3.740	<0.01	58.1	159	0.7	0.25	3.1

Appendix B (cent'd)

2nd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
	IV-B	C	2.180	0.35	66.2	78.2	<0.2	C.34	2.3
	VI-A	A	0.358	0.38	51.0	326	0.7	0.54	2.0
Stenorhynchus seticornis	047	C	0.771	0.72	28.5	43.5	1.4	0.34	1.5
	*146	C	0.849	0.41	36.7	47.8	1.2	0.46	1.4
	147	C	1.260	0.28	57.8	69.7	1.6	0.48	1.9
	151	C	0.635	0.44	59.4	39.4	0.5	0.43	1.7
	247	C	1.240	0.89	37.2	71.4	0.3	0.36	1.8
	251	C	1.000	0.47	40.0	69.9	<0.2	0.56	2.5
			ECHINODERMS						
Astropecten sp.	VI-A	C	0.249	0.37	10.0	318	3.2	0.70	1.5
Clypeaster raveneli	III-B	A	0.326	1.01	7.2	291	1.0	0.81	1.4
	IV-B	A	0.207	0.28	7.2	140	0.3	0.43	2.4
Clypeaster durandi	I-A	A	0.221	1.53	7.4	230	0.4	0.47	0.6
	VI-A	A	0.107	0.74	7.4	704	0.5	1.58	<0.4

Appendix B (cent'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
			SPONGES						
Sponge "C"	I-B	A	0.171	1.72	4.5	261	1.1	1.19	<0.4
	III-B	A	0.208	0.70.	4.0	173	0.9	0.25	<().4
Sponge "F"	I-B	A	4.445	3.16	6.1	422	1.9	1.96	<0.4
Yvesia or Gnayella	II-B	A	4.248	2.03	7.4	526	5.0	1.12	1.8
Xetospongia sp.	III-A	A	0.093	0.49	10.4	86.4	19.0	1.42	1.1
Asteopus sp.	III-B	A	0.126	0.30	4.8	70.7	21.8	<0.01	<0.4
Verongia longissma	I-A	A	3.458	0.50	16.9	166	75.9	0.91	<().4
Tethya sp.	II-A	A	0.362	1.97	4.8	388	1.4	0.52	1.2
Haliclona rubens	I-A	A	0.334	2.84	6.3	476	2.4	0.35	1.7
	I-A	A	8.270	0.95	6.4	127	2.4	0.36	<0.4
Neofibularia nolitangere ixeata	V-A	A	1.633	1.35	7.9	820	372	0.74	1.3
Guitarra sp.	VI-B	A	6.733	2.73	8.7	2030	2.4	2.87	2.1
Placospongia sp.	I-A	A	0.058	0.14	3.2	43.0	0.4	0.08	<0.4
Cinachyra sp.	II-A	A	1.877	1.05	6.4	265	0.8	0.30	<0.4
	047	A	0.623	0.32	5.7	89.9	20.9	0.33	0.9

Appendix B (cont'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
Cinachyra sp.	062	A	1.740	0.64	5.7	222	0.8	0.65	<0.4
	064	A	0.644	3.76	7.1	863	0.8	0.95	2.6
	146	A	0.454	0.27	5.4	105	8.6	0.54	<0.4
	147	A	0.543	0.71	6.4	142	19.1	0.64	<0.4
	151	A	0.371	0.59	5.8	96.4	6.0	0.80	<0.4
	247	A	0.239	0.46	5*O	143	13.9	0.49	<0.4
	*251	A	0.365	0.80	6.5	157	10.5	0..55	3.9
Pseudoceratina crassa	047	A	0.352	0.33	8.6	87.7	39.6	0.33	<().4
	146	A	0.790	0.18	8.9	79.3	27.0	0.33	<0.4
	147	A	0.284	0.50	10.7	106	22.7	0.77	<0.4
	151	A	0.247	1.25	1.1.4	1,26	20.7	1.20	<().4
	247	A	0.216	0.40	10.0	11.7	20.5	0.83	<0.4
	251	A	0.371	0.39	8,3	91.4	20.0	0.40	<().4

Appendix B (cent'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
				CORALS					
Solenastrea hyades	II-A	A	0.021	0.35	7.9	54.1	<0.2	0.22	1.4
	062	A	0.041	0.03	8.6	34.7	<0.2	0.25	0.8
	064	A	0.045	0.16	8.4	51.4	<0.2	0.25	<0.4
Cladocora arbuscula	064	A	0.025	0.14	8.4	63.2	<0.2	0.20	0.7
Madracis decactis	III-A	A	0.030	0.11	7.8	36.8	0.7	0,13	<0.4
	047	A	0.039	0.08	7.7	38.4	0.3	0.13	<0.4
	146	A	0.040	0.07	7.6	36.3	<0.2	0.11	1.4
	147	A	0.038	0.08	7.8	40.4	<0.2	0.12	<0.4
	151	A	0.072	0.05	7.7	41.1	<0.2	0.17	<().4
	247	A	0.020	0.09	8.5	44.9	<0.2	0.22	1.9
	251	A	0.039	<0.01	7.6	38.2	<0.2	0.1.1	1.7
Porites divaricata	*047	A	0.068	0.06	7.6	41.9	<0.2	0.11	1.7
	146	A	0.269	0.18	7.5	46.1	<0.2	0.14	2.6
	147	A	0.127	0.15	7.7	36.0	<0.2	0.13	<0.4
	151	A	0.112	0.20	6.8	32.2	<0.2	0.31	1.5
	247	A	0.070	0.01	8.5	42.3	<0.2	0.17	<0.4

Appendix 3 (cont'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
	251	A	0.280	0.07	7.6	41.4	<0.2	0.15	1.3
Phyllangia americana	062	A	0.073	0.99	10.1	308	0.6	0.70	2.3
Siderastrea radians	064	A	0.020	0.06	8.1	35.7	<0.2	0.12	1.3
Millepora alcicornis	147	A	0.472	0.13	8.3	36.1	8.4	0.52	<0.4
	151	A	0.262	0.01	8.5	39.9	7.6	0.17	<0.4
	247	A	0.339	0.07	8.2	35.0	6.9	0.09	1.6
MOLLUSCS									
Spondylus americanus	147	A	2.038	6.31	1.7	33.0	9.2	0.65	<0.4
	*151	A	3.875	4.33	3.3	66.1	17.1	0.71	3.9
	247	A	1.525	1.76	1.5	19.3	5.9	0.15	1.4
Murex beauii	II-C	A	0.660	0.32	⊂4.2	84.2	1.3	0.61	<0.4
CRUSTACEANS									
Calappa angusta	I-C	B	0.699	0.22	32.7	103	0.4	0.40	<0.4
Myropsis quinques-perforata	II-C	A	6.540	0.32	95.3	175	0.9	0.65	<0.4

Appendix B (cent'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	v
Hymenopenaeus tropicalis	I-A	C	0.692	0.35	69.1	69.2	1.1	<0.01	<0.4
Sicyiona brevirostris	I-A	A	0.179	0.51	37.5	84.2	0.8	0.26	<0.4
	III-A	A	0.050	0.32	45.7	51.4	0.4	0.28	<0.4
	IV-A	D	0.827	0.20	110	71.3	0.7	0.35	<0.4
	V-A	A	0.073	0.26	84.7	82.4	0.6	0.39	<0.4
Acanthocarpus alexandri	III-C	B	0.445	0.42	39.1	383	0.7	0.33	0.9
Portunus spinicarpus	I-B	A	5.466	0.19	60.4	51.5	0.3	0.25	<0.4
	III-A	A	3.201	0.22	39.4	57.3	0.7	0.45	<().4
	IV-B	A	3.354	0.35	67.8	172	0.9	0.36	1.4
Stenorhynchus seticornis	047	c	0.661	0.09	29.5	69*9	0.7	0.30	3.0
	*146	C	0.397	0.16	25.6	56.4	<0.4	0.22	<0.4
	147	C	0.417	0.28	35.9	80.4	0.6	0.73	<0.4
	151	C	0.430	0.01	32.3	52.4	<0.2	0.47	<0.4
	247	C	0.430	0.23	39.1	86.3	<0.2	0.52	<0.4
	251	C	0.461	0.21	27.7	71.4	<0.2	0.47	<().4

Appendix B (cent'cl)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
				ECHINODERMS					
Coelopleurus floridanus	VI-C	A	0.119	1.45	8.0	1832	1.9	2.51	<0.4
Astrophyton muricatum	247	A	0.505	0.35	5.9	40.0	0.5	0.44	<0.4
Astropecten sp.	I-C	c	0.463	0.01	11.5	64.1	<0.2	0.35	<0.4
	IV-A	A	0.294	0.01	15.2	70.7	<0.2	0.44	1.7
Astroporpa annulata	III-B	A	0.293	0.39	6.1	54.3	0.8	0.56	0.9
	V-B	B	0.647	0.36	6.0	52.2	0.4	0.55	<0.4
	VI-B	A	0.207	0.25	7.0	151	0.6	0.56	1.9
Comactina echinoptera	I-B	A	0.268	0.65	6.8	110	0.6	0.74	<0.4
Brissopsis elongata	VI-C	A	0.117	9.41	11.8	9794	8.5	7.74	9.3
Stylocidaris affinis	V-A	A	0.239	0.80	6.8	369	0.4	0.55	2.1
	VI-B	A	0.100	0.36	7.6	580	0.6	1.51	0.8
Clypeaster raveneli	*11-B	A	0.278	0.77	6.8	148	0.6	0.56	1.0
	IV-B	A	0.234	0.91	6.6	278	0.3	0,47	4.6
Clypeaster durandi	VI-A	A	0.056-	0.36	5.9	94.2	0.2	0.67	2.0

Appendix B (cent'd)

3rd Sampling Period

Species Name	Station Number	Part Analyzed*	Cd	Cr	Cu	Fe	Ni	Pb	V
	062	A	0.187	0.90	7.0	140	<0.2	0.39	1.0

* = Averaged from 5 replicated samples

+A = Representative sample from one whole organism

B = One whole organism

C = Several whole organisms

D = Head section (internal organs)

E = Tail section (mostly muscle tissue)

F = One whole organism which contained sediment

Appendix C

Intraspecies Variability of Trace Metals
among the Dominant' Macrofauna
(concentrations in ppm dry weight)

Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
			SPONGES						
			1st Sampling Period						
Cinachyra sp.	8	Range	1.900-5.850	0.43-5.39	4.5-6.9	65.8-935	1.1-26.9	0.10-1.96	0.8-3.8
		Mean	3.080	2.05	6.0	339	14.7	0.77	1.6
		Std. Dev.	1.450	2.00	0.9	370	9.6	0.76	1.0
Pseudoceratina crassa	6	Range	1.220-5.800	0.36-3.15	6.4-20.5	79.6-312	5.3-23.6	0.72-5.39	1.0-5.8
		Mean	2.967	1.75	9.4	172	15.6	2.27	2.1
		Std. Dev.	2.357	1.07	5.5	87.0	6.2	1.98	1.8
			2nd Sampling Period						
Cinachyra sp.	2	Range	1.500-5.100	0.58-1.39	3.9-4.7	130-200	0.8-16.8	0.16-0.45	<o.4-1.2
		Mean	3.310	0.98	4*3	165	8.8	0.30	<0.8
		Std. Dev.	2.600	0.57	0.6	49	11.3	0.20	0.6
Pseuodoceratina crassa	2	Range	1.000-1.550	0.89-1.66	8.1-19.2	67.0-268	31.8-33.1	0.07-0.23	<cl.4-1.7
		Mean	1.275	1.27	13.6	137	32.4	0.15	<1.0
		Std. Dev.	0.389	0.54	7.8	185	0.9	0.11	<0.9
			3rd Sampling Period						
Cinachyra sp.	9	Range	0.239-1.877	0.32-1.05	5.0-7.1	86.9-863	0.8-20.9	0.30-0.95	<().4-3.9
		Mean	0.785	0.96	5.9	231	9.0	0.58	<0.8
		Std. Dev.	0.570	1.02	0.7	230	7.3	0.20	1.4

Appendix C
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Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
Pseudoceratina crassa	2	Range	1.000-1.550	0.89-1.66	8.1-19.2	67.0-268	31.8-33.1	0.07-0.23	<0.4-1.7
		Mean	1.275	1.27	13.6	137	32.4	0.15	<1.0
		Std. Dev.	0.389	0.54	7.8	185	0.9	0.11	<0.9
			3rd Sampling Period						
Cinachyra sp.	9	Range	0.239-1.877	0.32-1.05	5.0-7.1	86.9-863	0.8-20.9	0.30-0.95	<0.4-3.9
		Mean	0.785	0.96	5.9	231	9.0	0.58	<0.8
		Std. Dev.	0.570	1.02	0.7	230	7.3	0.20	1.4
Pseudoceratina crassa	6	Range	0.216-0.790	0.18-1.25	8.3-11.4	79.3-126	20.0-39.6	0.33-1.20	--- ---
		Mean	0.377	0.51	9.6	101	25.1	0.64	<0.4
		Std. Dev.	0.200	0.32	1.2	18.1	7.5	0.35	---
			CORALS						
			1st Sampling Period						
Madracis decactis	6	Range	0.061-1,330	0.17-0.40	3.7-7.0	17.3-24.8	0.3-1.5	0.11-0.31	1.o-2.8
		Mean	0.479	O*32	5.3	20.0	0.6	0.19	1.5
		Std. Dev.	0.500	0.12	1.1	3.0	0.5	0.08	0.7
Porites divaricata	5	Range	0.129-1.110	0.26-0.59	5.1-6.9	18.3-21.7	<o..2-1.0	0.13-0.28	0.4-4.9
		Mean	0.478	0.37	6.3	20.0	<0.4	0.18	2.0
		Std. Dev.	0.379	0.14	0.7	2.0	').3	0.07	1.7
			2nd Sampling Period						
Madracis decactis		Range	0.041-0.081	---- ----	6.5-7.6	27.0-41.8	---- ----	0.13-0.35	1.9-6.0
		Mean	0.055	<0.01	7.0	35.0	<0.2	0.21	3.4
		Std. Dev.	0.016	----	0.3	5.0	----	0.09	1.5

Appendix C
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Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
Porites divaricata	6	Range	0.108-0.325	---- ----	6.3-7.0	'31.6-36.2	---- ----	0.07-0.27	1.7-3.8
		Mean	0.233	0.01	6.7	35.0	< 0.2	0.16	2.7
		Std. Dev.	0.084	----	0.2	2.0	----	0.08	0.8
Madracis decactis	7	Range	0.020-0.072	0.01-0.11	7.6-8.5	36.3-44.9	---- ----	0.11-0.17	< 0.4-1.9
		Mean	0.040	0.07	7.8	39.5	< 0.2	0.14	< 0.7
		Std. Dev.	0.010	0.03	0.3	2.8	----	0.04	0.8
Porites divaricata	6	Range	0.068-0.280	0.01-0.20	6.8-8.5	32.2-42.3	---- ----	0.11.-0.31	<o.4-1.7
		Mean	0.154	0,10	7.6	40.0	< 0.2	0.17	< 1.2
		Std. Dev.	0.090	0.09	0.5	4.6	----	0.07	0.9
MOLLUSCS									
1st Sampling Period									
Spondylus americanus	2	Range	20.4-20.8	1.89-2.59	6.9-9.2	71.9-80.8	5.4-20.5	1.04-1.42	5.6-6.0
		Mean	20.6	2.25	8.0	76.0	13.0	1.23	5.8
		Std. Dev.	0.3	0.49	1.6	6.4	10.6	0.27	0.3
2nd Sampling Period									
Spondylus americanus	6	Range	19.4-35.0	3.31-9.56	2.3-6.1	63.2-79.5	25.8-33.7	0.51-1.66	3.0-5.1
		Mean	22.7	6.92	4.2	72.0	29.9	1.03	4.1
		Std. Dev.	7.8	2.58	1.4	6.0	3.1	0.46	1.0
3rd Sampling Period									
Spondylus americanus		Range	1.525-3.875	1.76-"6.31	1.5-3.3	19.3-66.1.	5.9-17.1	0.15-0.71	<o,4-3.9
		Mean	2.479	4.14	2.2	39.5	10.7	(-).51	<1,8
		Std. Dev.	1.010	1.86	0.8	19.6	4.5	0.25	1.6

Appendix C
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Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
					CRUSTACEANS				
					1st Sampling Period				
Sicyiona brevirostris	2	Range	0.149–0.571	0.44-0.44	12.7-31.0	11.2–106	<o.2-1.2	0.73-0.80	<0.4–1.7
		Mean	0.360	0.44	21.8	58.6	<0.8	0.76	<1.1
		Std. Dev.	0.298	0.00	12.9	67.0	0.5	0.05	0.9
Acanthocarpus alexandri	3	Range	0.500-1..250	0.65-1.46	38.7-53.7	245-773	0.8-1.9	0.24-5.88	1.2-2.4
		Mean	0.950	0.94	45.8	431	0.9	2.20	1.6
		Std. Dev.	0.397	0.45	7.5	296	0.8	3.19	0.7
Portunus spinicarpus		Range	0.815-7.120	0.33-1.05	19.1-61.4	26.5–669	0.3-1.4	().~9-6.94	<(I.4-1.4
		Mean	3.143	0.54	45.7	190	0.9	3.42	<0.9
		Std. Dev.	2.400	0.27	18.5	245	0.5	3.03	0.5
Stenorhynchus seticornis	6	Range	1.070-1.890	0.25-0.46	19.3-34.3	32.1–61.9	0.9-1.7	().17-0.83	1.4-2.5
		Mean	1.547	0.36	25.4	41.0	1.0	0.48	2.0
		Std. Dev.	0.349	0.07	5.5	7.0	0.3	0.28	0.4
					2nd Sampling Period				
Sicyiona brevirostris	4	Range	0.228–0.474	<0.01–1.07	29.9-92.0	49.9-104	0.5-0.8	0.15-0.67	0.6-2.1
		Mean	0.361	0.29	73.0	79.0	0.6	0.41	1.4
		Std. Dev.	0.110	0.52	29.7	24.0	0.1	0.26	0.6
Acanthocarpus alexandri	2	Range	0.518–2.68	<0.01–0.49	71.8-80.0	124-245	<0.2–0.6	0.28–0.66	2.3-3.0
		Mean	1.600	<0.19	75.9	184	<0.4	0.47	2.6
		Std. Dev.	1.529	0.26	5.8	85	().3	0.26	0.5

Appendix C
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Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
Portunus spinicarpus	6	Range	0.358-5.870	<0.01-0.75	36.0-79.8	35.9-326	<0.2-0.9	0.15-0.67	1.1-3.1
		Mean	2.636	0.21	55.9	129	<0.6	0.30	2.1
		Std. Dev.	1.986	0.30	15.7	104	0.2	0.14	0.6
Stenorhynchus secticornis	6	Range	0.635-1,250	0.28-0.89	28.5-57.8	39.4-71.4	<0.2-1.6	0.34-0.56	1.4-2.5
		Mean	0.959	0.53	39.9	56.9	<0.9	0.44	1.8
		Std. Dev.	0.254	0.22	9.7	14.9	0.6	0.08	0.4
					3rd Sampling Period				
Sicyiona brevirostris	4	Range	0.050-0.827	0.20-0.51	37.5-110	51.4-84.2	0.4-0.8	0.26-0.32	---- ----
		Mean	0.282	0.32	69.6	72.3	0.6	0.32	<0.4
		Std. Dev.	0.320	0.12	29.5	13.1	0.1	0.05	----
Acanthocarpus alexandri	1	Range	---- ----	---- ----	---- ----	---- ----	---- ----	---- ----	---- ----
		Mean	0.445	0.42	39.1	383	0.7	0.33	0.9
		Std. Dev.	----	----	----	----	----	----	----
Portunus spinicarpus	3	Range	3.201-5.466	0.19-0.35	39.4-67.8	51.5-172	0.3-0.9	0.25-0.45	<0.4-1.4
		Mean	4.007	0.25	55.9	93.6	0.6	0.35	<0.7
		Std. Dev.	1.030	0.07	12.0	55.4	0.2	0.08	0.6
Stenorhynchus seticornis	6	Range	0.397-0.661	0.09-0.28	25.6-39.1	52.4-86.3	<0.2-0.7	0.22-0.73	<0.4-3.0
		Mean	0.466	0.17	31.7	69.5	<0.2	0.45	<0.5
		Std. Dev.	0.090	0.09	4.7	12.0	0.3	0.16	1.1

Appendix C
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Species Name	No. of samples* analyzed		Cd	Cr	Cu	Fe	Ni	Pb	V
ECHINODERMS									
1st Sampling Period									
Stylocidaris affinis	2	Range	0.842-0.924	0.28-0.64'	5.1-6.7	19.3-196	0.8-0.8	0.27-0.82	1.9-2.2
		Mean	0.883	0.46	5.9	107	0.8	0.54	2.0
		Std. Dev.	0.058	0.25	1.1	125	0.0	0.39	0.2
Clypeaster sp.	2	Range	0.162-0.210	0.78-0.79	7.2-7.6	81.4-229	0.6-0.8	0.35-0.54	1.8-1.9
		Mean	0.186	0.78	7.4	155	0.7	0.44	1.8
		Std. Dev.	0.040	0.01	0.3	105	0.1	0.13	0.0
2nd Sampling Period									
Clypeaster sp.	4	Range	0.107-0.326	0.28-1.53	7.2-10.9	140-704	0.3-3.2	0.43-1.58	<o.4-2.4
		Mean	0.222	0.79	7.8	337	1.1	0.80	<1.3
		Std. Dev.	0.079	0.51	1.2	216	1.2	0.46	0.8
3rd Sampling Period									
Stylocidaris affinis	2	Range	0.100-0.239	0.36-0.80	6.8-7.6	369-580	0.4-0.6	o.55-1.51	0.8-2.1
		Mean	0.167	0.58	7.2	474	0.5	1.03	1.5
		Std. Dev.	0.070	0.22	0.4	106	0.1	0.48	0.6
Clypeaster sp.	4	Range	0.056-0.278	0.36-0.91	5.9-7.0	94.2-278	<o.2-0.6	0.39-0.67	1.o-4.6
		Mean	0.191	0.73	6.6	165	<0.3	0.52	2.2
		Std. Dev.	0.090	0.22	0.4	68	0.2	0.10	1.5

*For some elements, the number of samples analyzed is one less than that given.

Appendix D

Recommendations for Future Study

1) In order to obtain reliable statistics concerning trace metal variations within a species, several samples of the same species from a station should be collected.

2) Geographical trends have more significance when many samples of the same species are collected from many geographical locations.

3) Better seasonal trends can be observed when several samples of the same species arc collected from the same locations, throughout all seasons.

4) Perhaps more emphasis should be placed on corals in future studies. They are not only the lowest in their trace metal concentrations, but also show the least variation. This is especially signifi.tact in the case of nickel and vanadium, which are non detectable in many instances. Therefore, even slight elevations in the concentrations of these elements, in corals, may be indicative of imput by man (i.e. contamination from petroleum).