Review of metal concentrations in Southern African coastal waters, sediments and organisms

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SYNOPSIS

Background levels and levels of metal accumulation in water, sediments and fauna were determined using a typical data set from South Africa. This was done to establish the extent and reliability of the available data and to identify any possible anomalies. A comparative study such as this contrasts regional metal values between various areas around South Africa and also allows international comparison.

It is an extension of the philosophy behind the international Mussel Watch Programme and also serves as reference document for future studies. It demonstrates that in South Africa samples are usually taken from polluted areas ("hot spots") and huge gaps exist in the monitoring of coastal areas. Furthermore, the accumulation of metals by different animals does not necessarily depend on current environmental conditions. For instance, different species of limpets accumulated various metals at different rates even at the same geographical position (for example "spread of graphs" presented). Furthermore extrapolation of results from one region to another is not valid, even when working with the same species.

The study also showed that no single indicator species should be used for all metals. Accumulation of specific metals may be highly correlated in one species, while other metals are not. For example in this review bivalves show no clear accumulation trend when one is attempting to establish baseline levels for zinc. Whelk species on the other hand show less inter-organism variation.

OPSOMMING

Agtergrondvlakke en vlakke van die akkumulasie van metale in water, sedimente en fauna is bepaal aan die hand van 'n tipiese stel Suid-Afrikaanse data met die doel om die omvang en betroubaarheid van die beskikbare data te kontroleer en ook om enige moontlike anomalieë te identifiseer. In hierdie vergelykende studie is regionale metaalwaardes van verskillende gebiede om Suid-Afrika teenoor mekaar gestel en voorsiening ook gemaak vir internasionale vergelyking.

Hierdie bydrae bou voort op die filosofie agter die internasionale Mossel-waakprogram en dien ook as verwysingsdokument vir toekomstige studies. Dit toon hoedat in Suid-Afrika monsters gewoonlik van besoedelde gebiede ("hot spots") geneem word en dat groot leemtes bestaan in die monitering van kusgebiede. Hierbenewens is die akkumulasie van metale deur verskillende diere nie noodwendig afhanklik van heersende omgewingsomstandighede nie. Verskillende klipmosselspesies akkumuleer byvoorbeeld verskillende metale teen verskillende tempos, selfs in dieselfde geografiese posisie (soos deur die "verspreiding van grafieke" aangetoon word). Ook is die ekstrapolering van resultate van een gebied na 'n ander nie geldig nie, selfs al word dieselfde spesie ondersoek.

Dit blyk ook uit die studie dat geen enkele indikatorspesie vir alle metale gebruik behoort te word nie. Akkumulasie van spesifieke metale kan in 'n hoë mate in een spesie gekorreleer wees, terwyl dit nie die geval met ander metale is nie. In hierdie oorsig word byvoorbeeld daarop gewys dat tweekleppige skaaldiere geen duidelike akkumulasietendens toon wanneer daar gepoog word om basislynvlakke vir sink vas te stel nie. Aan die ander kant toon wulkspesies minder inter-organismiese variasie.

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1. INTRODUCTION

How serious is chemical pollution of coastal areas? Where are the most polluted areas? Is chemical pollution increasing or decreasing? How rapidly? What are background concentrations? Where is such information to be found? These questions have been asked more and more frequently in the last five to seven years. This has led to the formation of several marine pollution monitoring groups at the major centres around the coast of South Africa, which have reported and made recommendations on the major impact areas to the National Programme for Environmental Sciences and more recently to the South African National Committee for Oceanographic Research (SANCOR). Most of these recommendations were included in a Pollutant Workshop held at Plettenberg Bay in 1979 (Cloete, 1979). For the purpose of the discussion at the workshop the GESAMP definition of marine pollution was used (GESAMP, 1976) which established toxic elements as the most important pollutants.

At the Plettenberg Bay Workshop it was decided that oil was the most serious pollution problem on the southern African coast. Furthermore, based on current knowledge, the South African marine environment was thought to be still relatively unpolluted, apart from a few specific areas, and provided an excellent opportunity for baseline investigations of pollutant transfer (Cloete, 1979).

The US Mussel Watch Program which began in 1976 (Goldberg et al., 1983 and Farrington, 1983) provided strategies for pollutant monitoring. Mussels and oysters from 85 different locations along the US coast were analysed. A similar project was not within the resources of South Africa. Nevertheless, it was hoped that if all available information was gathered a baseline for metals could be established for the southern coastal environment. Unfortunately, such data were in unpublished or confidential reports and therefore were not easily accessible. Darracott and Brown (1980) included in their bibliography the titles of publications on pollution which appeared before the end of 1977, but could not include internal reports with restricted distribution or reports to committees.

In this study, data from publications, university theses, reports and minutes of internal meetings have been summarised, recalculated and redrawn. It was surprising and gratifying to realize how much information was available. When put together these, often unrelated, reports establish the distribution and relative abundance of toxic elements in the South African coastal environment. This study has also shown that even with limited resources, a pooling of all available information can establish a fairly comprehensive metal pollution profile and baseline for coastal environments. This is a lesson which is worthwhile remembering when dealing with other pollutants, for example, halogenated hydrocarbons or radioactive materials, in other resource limited areas and in third-world countries.

1.1 Methodology

The sediments, water and biological material were collected and analysed by many different investigators since 1972. This often made evaluation and direct comparison impossible, and so means (x) of nearly all data sets were calculated. This introduced several errors, as was pointed out by Hennig and Orren (1983) particularly as the older references give no indication of the size or sex of the animals, nor of detailed methods. Thus, taking the mean values gave some uniformity within these studies and was thought to be the best approach.

In 1981 a manual of methods for the Marine Pollution Monitoring Programme appeared (Watling, 1981). This should have standardised the methods for the preparation and analysis of water, sediment and biological samples. Unfortunately no recommendations were given on the preparation of data. This meant that some investigators reported their findings in terms of "wet weight", while others gave their data in terms of "dry weight". In most cases it was not possible to unify and recalculate the data to one set of conditions. **Hence special attention must be given to legends of tables and figures in this report as both sets of units have been used.** Evaluation of the methods of different investigations will be discussed as they appear within the framework of this study. Often an unrealistically high accuracy has been reported. This may well have been due to the use of calculators and not to the high sensitivity of the instruments. Watling (1981, in Table 1) has put the sensitivity at various wavelengths of atomic absorption spectrophotometers into a proper perspective.

Another problem which arose in the compilation of this paper was the repetition of data presented in different publications. For instance, some findings reported in internal memoranda were later published in established journals. It was decided that identical data could be represented only once and that the more accessible reference would be given. When there were differences between data sets in reports and in other publications, it was assumed the authors had additional information, and both sources of information are given here. The nomenclature and spelling of several species has been changed in recent years, for uniformity the names and spelling of the original study have been used in this report.

It is hoped that in future reports and publications a more uniform approach will be used. It is proposed that all sediment and biological data should be expressed in terms of dry mass to eliminate differences arising from different water contents in tissues, shells and carapace.

In this report, the data are divided into five different sections, arranged geographically, as follows:

- I Kosi Bay to Port Shepstone - a sector including most of the Zululand and Natal coasts;
- II Port Shepstone to East London - including the Transkei coast;
- III East London to Cape Agulhas - a sector in which the coastal shelf broadens into the Agulhas Bank;
- IV Cape Agulhas to Cape Columbine;
- V Cape Columbine to the Orange River.

This division was based on South African coastal water movements as described by Harris (1978). Since the metal concentrations in sediment and biological samples are closely linked to concentrations in the associated water masses, these divisions are convenient, though perhaps an over-simplification. Each section has been divided into regions as considered suitable, depending mainly on the amount of data available. The sections are shown in Figure 1.

The coastal data originated from material collected along the beach, in the surf zone, and estuaries in which the salinity was higher than 2.5 x 10^{-3}. Water and sediment data from offshore stations are available from the South African Data Centre for Oceanography (SADCO), but have not been included in this report. Fish and plankton may not be strictly surf zone animals, but data on them have been included for the sake of completeness and in an attempt to establish some baseline criteria.

At several locations data from water (W), sediment (S) and biological material (B) were not all available. A more detailed location of these materials is given in Figure 2. In Table 1 the sampling points are given in order along the South African coast, starting at the eastern border and continuing clockwise around to the west coast.

Water and sediment have been treated as single components, compared with the many "components" (species) of the biological material. It was also decided that the metal concentrations of the water should be described first, since it is the more important, followed by the chemical data for the sediment and finally the distribution of metals in the various biological species.

2. SURVEY OF TRACE METAL ABUNDANCE IN COASTAL WATERS

Treating coastal waters as a single component is an oversimplification. Trace metals exist in water partly in solution and partly in suspension, adsorbed to organic or inorganic particulate matter. In addition a certain amount of metal exists in colloids or chelates which may be difficult to categorize as either soluble or particulate fractions. This categorization is, in any case somewhat arbitrary. In coastal areas and near rivers or estuaries, the proportions and absolute amounts of metal in each fraction may vary according to the metal, the particulate content and its nature and the time and site of sampling (Phillips, 1977).

Direct comparisons of metal concentrations are complicated by the large natural variations which exist. Factors such as differences in season, time of day, the extent of freshwater run-off, depth of sampling, the intermittent flow of industrial effluent and hydrological factors such as tides and currents, all influence trace metal concentrations in both particulate and dissolved forms. Other difficulties in the determinaton of metal concentrations in coastal waters arise from the method of analysis. The low metal concentrations found in South African waters often require first the pre-concentration of large volumes of water by solvent extraction and errors may arise during these procedures.

All these limitations should be borne in mind when comparing and interpreting the metal concentrations in South African waters as summarised in Table 2.

Samples have been taken at 25 sites around South Africa over a period of nine years. The results are reported by ten different workers. Most reported results are on Cd, Co, Cu, Fe, Hg, Mn, Ni, Zn; only very limited information is available for Cr, Sb and Nb.

The only time series was carried out at Saldanha Bay by the Sea Fisheries Research Institute (J Henry, personal communication). This showed a substantial increase in Cu, Fe and Zn concentrations over a period of four years.

Trends in metal concentrations can be observed in Figure 3 and these are discussed below. It should be noted that the data have been log-transformed to accommodate the large ranges of metal concentration (see for example, Figure 3, Fe concentration).

2.1 Cadmium

The concentrations of cadmium ranges from "none detectable" (n.d.) to 3.5 $\mu g\ \ell^{-1}$ at the Swartkops River mouth. Most values are low and compare favourably with the cadmium concentration reported elsewhere, for example 0.01 to 0.62 $\mu g\ \ell^{-1}$ in nearshore water (Phillips, 1977) and 0.11 $\mu g\ \ell^{-1}$ in coastal waters (Waldichuk, 1977).

Three anomalies were observed. Higher concentrations of cadmium were found off Umbogintwini and Fynnlands. Both locations are close to pipelines carrying industrial effluent. High concentrations were also found at Port Elizabeth (Swartkops River) and at Knysna estuary. At Swartkops River the source of enrichment could be industrial effluent. Knysna on the other hand has only limited industry. Here the source could be due to geochemical factors (Watling and Watling, 1980).

2.2 Cobalt

The cobalt concentrations were higher than in comparable Californian nearshore waters (Phillips, 1977) or the value of 0.05 $\mu g\ \ell^{-1}$ quoted by Waldichuck (1977). Anomalies were observed at Richards Bay, Durban Bay and the Umgababa Estuary.

2.3 Copper

The reported values in other parts of the world range from 0.18 to 4.0 $\mu g\ \ell^{-1}$ and were also observed at most South African locations. High values were measured at St Lucia, Durban Bay and vicinity, Bashee River and Swartkops River.

2.4 Iron

The iron concentration was very high at most of the sampling points. The only exceptions were in the vicinity of Melkbos and Saldanha Bay. Because of industrialisation at Saldanha Bay the iron concentration in the water there has been increasing but was still several orders of magnitude less than the average reported for the rest of South Africa.

2.5 Mercury

The mercury concentrations in South African coastal water were usually less than literature values, with the exception of St Lucia and Umgababa.

2.6 Manganese

This metal has been measured only in the waters of the south and west coasts. Values were high at Jeffreys Bay and Arniston, but interestingly both are unpolluted beaches used for "reference" purpose by the Marine Pollution Programme (Orren et al., 1981).

2.7 Nickel

Nickel concentrations were low compared to those from northern hemisphere locations (Phillips, 1977; Waldichuk, 1977). Anomalies were observed at St Lucia, Richards Bay, and particularly at Durban Bay and Arniston.

2.8 Lead

Lead concentrations are very difficult to measure, and values given in the literature range from 0.05 to 1.2 $\mu g\,\ell^{-1}$ (Phillips, 1977), while a mean of 0.03 $\mu g\,\ell^{-1}$ is quoted by Waldichuk (1977). Lead concentrations in the South African coastal waters were comparable, and lay in a range similar to that above, with high concentrations at St Lucia, Durban Bay, Bashee River and Swartkops River.

2.9 Zinc

The distribution of zinc in the South African coastal waters can really serve as a summary and identification of "hot spots". The elevated or polluted areas are St Lucia, Richards Bay, Durban and vicinity, Port Elizabeth (Swartkops River) and possibly Saldanha Bay. All these areas are highly industrialised.

2.10 Chromium, Niobium, Antimony

Chromium concentrations at Melkbos were low compared with those reported in the available literature (Phillips, 1977). Niobium and antimony were reported by Cloete (1979) but no other reference could be found for the two metals.

2.11 Metal concentrations in Table Bay waters, Cape Town

A detailed study has been done by Eagle *et al*. (1982) on the behaviour of sewage from the Green Point outfall and its effect on Table Bay. The results are given in Figures 4 to 7.

The conclusion from this study was "that the shape of the plume is dependent on the current, and hence wind, conditions prevailing at the time. At this stage there is no conclusive evidence that these metals originate from the sewage. Calculations indicate that the trace metal addition to the bay via the sewage is probably insignificant, except perhaps for zinc".

2.12 Conclusions

The drawbacks and difficulties of interpreting metal concentrations in coastal waters have been pointed out. Within these limitations, the data show that the South African coastal waters are largely unpolluted. The enrichment in about four areas is due mainly to industrial effluent. It should be noted that the pollution programme has concentrated on impact areas and only very few samples were taken at non-industrial areas, away from the major cities. However, if elevated levels were to be found at these remote locations, these are likely to be of natural origin and therefore would not fit into the GESAMP definition of pollution.

Unfortunately nearly nothing is known about "normal" or "before pollution" concentrations of metals in South African coastal waters.

This has produced the rather unsatisfactorily situation: there is no reference point or range of metal concentrations by which to judge any pollution or enrichment of the environment.

3. SURVEY OF TRACE METAL ABUNDANCE IN COASTAL SEDIMENTS

Three major problems exist in the interpretation of data concerning the concentrations of trace metals in sediments.

(1) The concentration of a metal in sediments is not only a function of the quantity of metal deposited, but is also a function of the ratio of metal deposited over a given period of time.

(2) The concentration of a metal found in sediments depends on the organic content of the sediment. In general, metal concentrations increase approximately linearly with increase in organic content, measured as total carbon (Halcrow et al., 1973).

(3) Other variables such as particle nature, form and size may also affect the concentrations of metals in sediments. The presence of certain ionic groups and the surface area-to-volume ratio of particulates is important in the process of metal adsorption. In addition, differences in mobilisation rates (biological or physical) may lead to erronious conclusions concerning the rate of metal input.

The available data on metal concentrations in sediments are summarised in Table 3. Sediments were sampled at 29 sites over a period of nine years. The main metals reported are Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn. A small amount of information is available for Ag, Al, Ba, Bi, Br, Mo, Nb, Rb, Sr, Th, Ti, V, Y, and Zr.

Although sampling was repeated at some sites, no trend in metal level with time could be observed. The data in Table 3 have been log-transformed and graphically presented in Figure 8.

3.1 Cadmium

The cadmium concentrations in coastal sediments range from not detectable (b.d.) to 27 $\mu g\ g^{-1}$ (dry) at Port Elizabeth. Most of the reported concentrations are similar to those found in other parts of the world (Phillips, 1977; Gilmour and Kay, 1979; Cloete, 1979). High metal concentrations occurred at Richards Bay, Durban, Bashee River and Port Elizabeth.

3.2 Cobalt

Cobalt concentrations are all low and even the high values at St Lucia (27 $\mu g\ g^{-1}$ dry) cannot be considered high in comparison with other areas (Phillips, 1977). In South Africa sediment anomalies were observed at the industrial centres.

3.3 Chromium

No trend could be observed in the distribution of chromium in the coastal sediments. Values in the range 2.6 to 388 $\mu g\ g^{-1}$ (dry) compare well with Phillips' review (Phillips, 1977), which showed that chromium ranges from 35 to 307 $\mu g\ g^{-1}$ (dry) in many parts of the world.

3.4 Copper

The copper levels in sediments around South Africa range from 0.5 to 74 $\mu g\ g^{-1}$ (dry). Phillips (1977) quotes 1 to 60 $\mu g\ g^{-1}$ (dry) for most parts of the world. It is possible that slightly higher levels are observed at industrialised areas.

3.5 Iron

In reviews, iron concentrations in sediment are usually given in percent by weight. The values are similar in range to those found in South Africa. Iron concentrations in the sediment along the east coast appear to be higher while lower levels occur along the south coast.

3.6 Mercury

There appears to be very little mercury in South African coastal sediments. A "British Control" area (see Halcrow *et al.*, 1972 in Phillips, 1977) contained 0.04 to 0.15 $\mu g\ g^{-1}$ of mercury. In two areas in South Africa, Durban Bay and Buffalo River, mercury levels were higher.

3.7 Manganese

This metal was found in only small concentrations in South African coastal sediment. In control areas elsewhere (Phillips, 1977) concentrations usually range from 240 to 700 $\mu g\ g^{-1}$ (dry). In South Africa higher levels were found at Durban Bay and in the Buffalo River.

3.8 Nickel

High levels of nickel in South Africa lay within the control ranges given in most published reports (Phillips, 1977). Higher nickel concentrations in South Africa occurred around Richards Bay and Durban, Knysna, Green Point and the Olifants River. The higher levels of nickel at the Olifants River were somewhat unusual but may be related to the fresh water run-off and organic matter since higher copper concentrations have also been found in sediments in this region. These minerals originate from the Namaqualand mining area and hence could have a geochemical source.

3.9 Lead

The lead concentrations in the sediment around the South African coast range from 0.4 to 117 $\mu g\ g^{-1}$ (dry). Again these values are low compared with values elsewhere in the world (Phillips, 1977). Higher concentrations have been observed at the industrial areas around the coast.

3.10 Zinc

The pattern of zinc concentrations in the coastal sediments is not very clear. This could partly be due to the relatively low concentrations compared with those in other countries. Again the industrialised areas show higher concentrations.

Concentrations of Ag, Al, Ba, Bi, Br, Mo, Nb, Rb, Sr, Th, Ti, V, Y, Zr have been reported from only two unpolluted areas: Knysna Estuary and the Olifants River. Most of these values may be the natural levels of the trace metals in the sediment of those areas, and may not be derived from the activities of man. Hence they can be assumed to be baseline values.

3.11 Metal concentration in Table Bay sediments, Cape Town

Eagle *et al*. (1982) have analysed selected trace metals in sediments in Table Bay (Figures 9 and 10). The conclusion drawn was that in the sediments there was a sharp increase in the concentrations of all the metals studied in a small area between the Green Point outfall and the harbour.

3.12 Conclusion

The use of sediments in the determination of metal baselines is also subject to some errors. It appears that the enrichment of sediments by metal pollutants has not yet taken place around the coast of South Africa. Comparable areas elsewhere usually contain higher metal concentrations. Against these low background values, it is possible to recognize the industrialised impact areas. Together with the water data this confirmation can be used to indicate those selected places which can be considered "polluted" or "enriched" above the baseline values found in non-industrialised regions.

In this context it is interesting to speculate whether pollution control authorities should act now and focus on enriched areas and hot spots or whether they should adopt the attitude that metal concentration in South Africa's hot spots lie well below those found in other countries and by comparison could not be called "polluted".

4. SURVEY OF TRACE METAL ABUNDANCE IN MARINE ORGANISMS

The gathering of data on metal concentrations in marine organisms was done to establish a baseline for as many organisms as possible and to arrive at approximately the "right" order of magnitude when considering any specific metal. Often baseline studies are not only of academic interest, but are used in predicting the possible effects of proposed industrialisation or sewage disposal (see Hennig *et al*., 1982).

Measurements of physical and chemical variables in sediment and water samples represent only one specific value at one specific time, season or water current pattern. Measurements of chemical variables in animals, on the other hand, represent the mean of metal concentrations integrated over the life-span of the organism, different seasons and water currents. They also represent a permanent record of the relative biological availability of metals to an individual or organism at each location studied.

Some animals accumulate metals more readily than others. These biological indicator species have been identified by Watling (1978) on the South African coast. Fortunately, enough information was available from samples of some organisms (limpets and mussels) taken from many different sections of the coast, so that a type of "Mussel Watch" study could be produced, similar to that of Goldberg *et al*. (1983) in the United States of America.

Therefore the biological data have been presented in two different formats: concentration of metals in the same species at different locations, and metal accumulation in different species at one point along the coast.

The data have been arranged in geographic sequence and are summarized in Table 4. This is especially useful to management and pipeline planners, since they are interested in man-made impact at a specific point.

Methods for the metal determination of biological samples are given for each author. Usually this has been done at the first described geographical area (see Table 4) and are not repeated for subsequent locations to avoid unnecessary repetition.

4.1 Section I - Kosi Bay to Port Shepstone

There were 12 sampling points (Table 1) and most of the data are for Kosi Bay. The main trace elements determined were Cd, Co, Cr, Cu, Fe, Hg, Pb and Zn.

4.1.1 Kosi Bay (Figure 11)

These data were drawn from Oliff and Turner (1976). There were no details of analytical methods for the various tissues. The data were given as $\mu g\ g^{-1}$ of dry weight, and fish length but not sex, was given. The other animals were analysed as "whole" organisms. Nearly half of the 20 species were fish. In these the liver usually had a considerably higher metal content than the muscle tissue. No trends could be observed because of the wide variety of organisms, but in each case the plankton samples showed the highest metal concentrations (Figure 11).

The only other data were from Watling (1978), who quoted Oliff and Turner (1976) and assumed that *Perna* sp. was in fact *Perna perna*. Her data were derived from wet tissue data, assuming 85 per cent water content. The accuracy is presented as in the original report and the concentrations of eight metals were determined.

4.1.2 St Lucia (Figure 12)

Only one reference (Oliff and Turner, 1976) for St Lucia was found. *Loligo* sp. does not seem to be affected by the enriched water and sediment of St Lucia.

4.1.3 Richards Bay (Figure 13)

Four metals were determined (Oliff and Turner, 1976). Most of the samples taken at Richards Bay were fish. These had similar metal concentrations, the highest being in the liver. Since the data are mainly for fish they are not representative of the bioavailability of metals to the fauna at Richards Bay and no "baseline" can be established for Richards Bay. This is especially unfortunate since high metal concentrations in water and sediment were reported here.

4.1.4 Port Durnford Point (Figure 14)

These data were drawn from Connell *et al*. (1975). Methods of analysis were not given. The data are given as $\mu g\ g^{-1}$ of wet weight and no mention is made of size or sex of the sample. Accuracy is as stated in the original report. In all cases, the livers had higher metal content than the muscle tissues.

4.1.5 Umgeni Estuary (Figure 15)

These data were drawn from Connell et al. (1975) and again methods were not given. Two fish species were analysed and both had lower metal concentrations than those from Richards Bay.

4.1.6 Umhlanga Rocks (Figure 16)

Darracott and Watling (1975) presented their data in terms of wet weight. No method, size or sex were quoted, the reference is "Watling, unpublished data". In Watling and Watling (1974) the reference is again "Watling, unpublished data" but more metals were presented and the results are given in terms of dry weight.

Finally Watling (1978) also quoted "Watling, unpublished data" and gave results in terms of wet weight. It is possible that all three references refer to the same 30 animals sampled at Umhlanga Rocks in June 1974.

Connell et al. (1975) measured only mercury and expressed the results in terms of wet weight. No details of method, sex, weight or size were given.

The large variation in concentration range (Figure 16) arises from the different methods of reporting. Watling (1978) assumed a water content of 85 per cent in expressing her data in terms of dry weight. Although this is a very good average figure, data in this report have not been converted as no water content is known for some of the animals mentioned. It also would only have introduced errors into this study.

4.1.7 Durban Bay (Figure 17)

Only mercury levels were reported by Connell et al. (1975).

4.1.8 Umbogintwini (Figure 18)

Only mercury levels were reported by Connell et al. (1975).

4.1.9 Fynnlands (Figure 19)

It is unfortunate that only mercury levels have been recorded in these three areas (Figures 17, 18, 19) in view of the high water and sediment levels recorded. It is surprising that more data are not available for this major industrial and urban centre.

4.1.10 Umhlatuzana (Figure 20)

Connell et al. (1975) reported on three fish species. It is noticeable that copper and zinc levels vary greatly as seen in the two sets of data for Mugil sp.

4.1.11 Umzimkulu Estuary (Figure 21)

The values are reported by Connell et al. (1975).

4.1.12 Umgababa Estuary (Figure 22)

Oliff and Turner (1976) sampled the animals on 30 June 1976. No methods were reported, but sizes are given for P. homarus. Whole animals were used in the case of C. margaritacea and U. africana. The results were reported in terms of dry weight. Watling (1978) converted these data to wet tissue mass assuming 85 per cent water content.

4.1.13 Conclusion for Section I

Although high metal concentrations are reported for water and sediments, no baseline study has been done for this region. Most of the animals studied were fish, which are known to be poor metal pollution indicator species. It is possible that some of the metal concentrations referred to may originate from the same set of animals, which would reduce the metal concentrations coverage for this section even further.

4.2 **Section II - Port Shepstone to East London**

This section along the Transkei coast is very poorly represented. Only references to metal concentrations in the Bashee Estuary have been found.

4.2.1 Bashee Estuary (Figure 23)

Oliff and Turner (1976) reported the average sizes or masses of all their organisms. The results were expressed as wet weights. No description of the method for the determination of metal concentrations was given. Accuracy is given as reported in the original report. The fish were caught in the estuary and had low concentrations of metals. C. margaritacea could have been an old specimen (see high zinc levels).

4.2.2 Conclusion for Section II

Very little is known about this region in terms of metal concentrations. As it lacks heavy industry, this section could provide data which would be a valuable contribution to our metal baseline knowledge.

4.3 **Section III - East London to Cape Agulhas**

This is the section of the coast for which most data were available (Figure 24). Extensive studies were made around Port Elizabeth, Francis Bay, Knysna and Mossel Bay. The animals sampled were a good cross-section of the fauna commonly found in these regions. These surveys can truly be referred to as baseline studies.

4.3.1 Algoa Bay (Figure 25)

All authors report their results in terms of wet weight. Watling (1978) reported mean wet tissue masses in Algoa Bay and apart from standard deviation, no sex or size data were reported. The accuracy is as given in the original report. The method for the preparation of samples for analysis was as follows:

Living specimens were suspended in clean sea water for up to five days to allow them to purge their intestinal contents. The wet tissues were then removed from the shells and frozen. The frozen specimens were thawed, weighed into clean dry flasks and oven-dried at 90°C for 24 h. The dried samples were dissolved in 25 ml nitric acid and heated (solution temperature < 100°C) to near dryness. The residue was dissolved in 25 ml of a 4:1 nitric-perchloric acid mixture. This solution was fumed to dryness at about 140°C. The white residue was redissolved in 10 ml 10 per cent nitric acid for atomic absorption analysis.

Watling and Watling (1981a) reported the number of animals used in their metal determination, also wet mass, dry mass, the mean metal concentration (as wet tissue mass) and the standard deviation. The method of preparing the animals consisted of allowing the animals to purge sediments and gut contents for 48 hours.

This was, however, either not done each time or was not reported on occasions. Whole individuals were weighed and then dried at 105°C for 48 h. The dried and weighed tissue was digested with redistilled, Analar grade nitric acid and the solution was evaporated to dryness. The residue was redissolved in a 4:1 nitric-perchloric acid mixture and the solution fumed to dryness at about 250°C. The residue was then dissolved in 10 ml of 0.1 M nitric acid.

This method was the same as that used by Watling and Watling (1983).

The interesting feature of Figure 25 was that it allows comparison of different species of *Patella* from the same areas. Different species accumulate different metals (see cadmium and iron). Since the limpets usually do not compete for the same niche but occupy different habitats, the different metal burden could be due to different food sources, behaviour and/or excretion mechanisms. These findings illustrate the great diversity of metal concentrations within a family of animals and serves as a warning against extrapolating metal levels from one species to another, even if they are very closely related.

It was also interesting to note that oysters concentrated copper and zinc, but that the concentrations of the other metals in oysters differed little from those in the other animals. Thus to use a single indicator species to establish metal pollution is not always appropriate.

4.3.2 St Croix (Figure 26)

All the results are those of Oliff and Turner (1976) and are reported in terms of dry mass. Watling (1978) converted Oliff's (1978) data to a wet mass basis. The method was that used for the Kosi Bay tests, reported above, again the livers of the fish contained higher metal concentrations than did the muscles.

4.3.3 Swartkops Estuary (Figure 27)

Except for the data for pilchards, all data were from Oliff and Turner (1976). For some reason a few metal concentrations are expressed in terms of dry mass, while the rest are expressed in terms of wet mass. The methods were as reported along with length and mass being reported where appropriate. Six metals were determined.

Metal concentrations in the pilchard (Van der Byl, 1980) were determined by the CSIR for 1979 fish. No detail of method, size or sex are given. The results are expressed in terms of dry mass. Except for copper, the testes contained more metal than did the ovaries.

4.3.4 Port Elizabeth (Figure 28)

Data presented are from Oliff and Turner (1976). They are expressed in terms of dry mass. Again, the metal concentrations in the various animals could not be correlated with the higher levels of metal in the water and sediment of this area.

4.3.5 Maitland (Figure 29)

Watling (1978) has reported on only one species. The results are expressed in terms of wet mass.

4.3.6 St Francis Bay (Figure 30)

Watling and Watling (1983) reported data as mean metal concentration in $\mu g\ g^{-1}$ wet tissue. The number of sampling sites and wet mass, as well as dry mass were reported.

As in other locations, the metal concentrations of the seven Patella species differed from one species to the next and seemed not to be related to metal concentrations in the water at that site. These data can serve as a baseline for future monitoring of this area.

4.3.7 Keurboomstrand (Figure 31)

Both mollusc species contained very similar metal concentrations. The results were expressed in terms of wet mass (Watling, 1978).

4.3.8 Cathedral Rock (Figure 32)

Again method and reporting were by Watling (1978). The mussel showed higher concentration of metals than did the oyster.

4.3.9 Noetzie (Figure 33)

Watling (1978) reported metal concentrations in terms of wet mass; the trends in metal levels were as observed at Cathedral Rock.

4.3.10 Knysna East Head (Figure 34)

Watling and Watling (1980) reported on the results in terms of wet mass. The animals were allowed to purge their intestinal contents for up to five days. The wet tissues were removed from shells and frozen. They were later thawed, weighed and dried at 90°C for 24 h. The dried samples were weighed, dissolved in 25 ml redistilled Analar grade nitric acid and evaporated to near dryness. The residue was dissolved in 25 ml of a 4:1 nitric-perchloric acid mixture and fumed to dryness at 140°C. Methods were as in Watling (1978).

The report gave concentrations for both wet mass and dry mass, the number of animals analysed, the mean metal concentration and standard deviation for concentrations of nine metals.

Watling (1978) reported on an earlier sample taken from that area. This differed slightly from the 1978 samples.

The various species of Patella differed greatly in concentrations of cadmium and iron.

4.3.11 Beacon Point (Figure 35)

The same authors, Watling (1978) and Watling and Watling (1980), have reported metal concentrations here. The same trends are observed as noticed for Knysna East Head.

4.3.12 Knysna West Head (Figure 36)

All species were reported in wet mass by Watling and Watling (1980). More cadmium was accumulated at this location.

4.3.13 Featherbed (Figure 37)

Watling and Watling (1980) reported metal levels for these two species in terms of wet tissue mass.

4.3.14 Belvedere (Figure 38)

Belvedere is the point in the Knysna lagoon which is furthest from the sea. There seems to be very little difference between metal concentrations all around the lagoon. The methods used were as in Watling and Watling (1980) and the data are expressed in terms of wet mass.

4.3.15 Leisure Island (Figure 39)

There seems to be little influence of the metal concentration of the water and sediment on the metal burden of various animals (see cadmium). All concentrations were expressed in terms of wet tissue mass. It is not clear if Watling (1978) and Watling and Watling (1980) were reporting on the same animal collection.

4.3.16 Knysna (Figure 40)

Seven sampling points were located in the Knysna area. Hence this geographical position may coincide with any of the others already mentioned. Darracott and Watling (1975) presented their data in terms of wet tissue mass, while Watling and Watling (1976a) report in terms of dry tissue mass. No method was given in Darracott and Watling (1975). The method for Watling and Watling (1976a) is identical to that reported in the Algoa Bay section.

4.3.17 Thesen's Point (Figure 41)

S. capensis was sampled in 1975 and 1980 with no difference observed by Watling and Watling (1980). Lower metal concentrations were found in P. perna by Watling (1978). The data are expressed in terms of wet mass.

4.3.18 Castle Rock (Figure 42)

Watling (1978) reported in terms of wet mass. These samples could be regarded as unpolluted baseline values for the animal analysed.

4.3.19 Buffalo Bay (Figure 43)

Due to the different sampling site's morphology the same species could not be sampled and a comparison was not possible. Still these metal concentrations represent background baseline data, expressed in terms of wet mass.

4.3.20 Walker Point East (Figure 44)

The mean wet tissue mass was reported by Watling (1978) and the standard deviation of the mean metal concentration was given.

4.3.21 Walker Point West (Figure 45)

There seemed to be more iron on this side of Walker Point.

4.3.22 Herold's Bay (Figure 46)

The data from this study (Watling and Watling, 1981b) were collected during a sampling trip which covered the Mossel Bay area. The numbers of animals are given, wet mass, dry mass, mean and standard deviation expressed in terms of wet mass. It is possible that all these results were summarised by Watling and Watling (1983) so that these results have been repeated under the Mossel Bay section.

4.3.23 Glentana (Figure 47)

See Herold's Bay.

4.3.24 Tergniet (Figure 48)

See Herold's Bay.

4.3.25 Little Brak River (Figure 49)

See Herold's Bay.

4.3.26 Hartenbos (Figure 50)

See Herold's Bay.

4.3.27 Diza Beach (Figure 51)

See Herold's Bay. The reason for separating the data given by Watling and Watling (1981b), is that a large section of coastline had been covered by their survey. The area is being industrialised and separation of each location from the others will help to identify and pin-point any future impact areas.

4.3.28 Die Bakke (Figure 52)

See Herold's Bay.

4.3.29 Mossel Bay (Figure 53)

As mentioned under the Herolds Bay section most of these data may have been summarized by Watling and Watling (1983) and should be read in conjunction with the report by Watling and Watling (1981b). The concentrations were expressed in terms of wet mass.

4.3.30 Dana Township (Figure 54)

See Herold's Bay.

4.3.31 Cape St Blaize (Figure 55

See Herold's Bay and Mossel Bay.

4.3.32 Pinnacle Point (Figure 56)

See Herold's Bay and Mossel Bay.

4.3.33 Fish Bay (Figure 57)

See Herold's Bay and Mossel Bay.

4.3.34 Vlees Bay (Figure 58)

See Herold's Bay and Mossel Bay.

4.3.35 Conclusion for Section III

This section has been well studied and samples have been taken not only from impact areas. Many samples from Knysna and along large sections of the coastline have been analysed. The reports on metal concentration are very valuable, because they give data on not only sample sites, numbers of animals analysed, but also wet and dry masses have been published. The method of preparing the organism is well documented. Again it is felt that all the available information should be published in a report such as the present one to eliminate possible duplication of data and for the sake of completeness.

4.4 **Section IV - Cape Agulhas to Cape Columbine**

Data have been obtained mainly from sampling sites around Cape Town and on the west coast up to Saldanha. Some of the older publications report metal concentrations before industrialisation along the west coast. There have been some very detailed studies of metal concentrations in sediment and water in Table Bay without sampling any organisms. Baseline studies and comparisons of metal levels in a wide variety of organisms have been made in this section.

4.4.1 Strandfontein (Figure 59a - e)

A detailed study and comparison of trace metals in *B. digitalis* at three different sites, by Hennig (unpublished), has demonstrated the size-dependence of selected metal burdens (for example, iron and lead). It also demonstrates that while there may be a linear relationship between metal concentrations in terms of wet mass and dry mass, this is not necessarily true for a dry mass/shell length relationship.

The data are expressed as $\mu g\ g^{-1}$ dry mass. In the study, the animals were collected alive and frozen in plastic bags. After thawing, the shell was measured and the whole whelk was removed from the shell. The animals were then dried in pre-weighed, acid-cleaned glass vials to a constant mass at 60°C. Redistilled Analar grade nitric acid (25 ml) was added to the dried whelk and the mixture was allowed to stand at room temperature overnight. Blank determinations were run concurrently.

Samples were heated to dryness to form a grey to white residue. A 4:1 mixture of nitric/perchloric acids (25 ml) was added and the mixture was heated again to dryness. The residue was dissolved in 10 per cent v/v nitric acid and analysed.

4.4.2 Muizenberg (Figures 59 and 60)

Metals in limpets were analyzed as in whelks (see Strandfontein), but no shell measurements were taken. The whole animal was removed from the shell with an acid washed glass knife. The rest of the method was as described in the Strandfontein section. The data were expressed in terms of dry mass.

4.4.3 Cape (Figure 61)

Some data on metal concentrations in the bones of sea birds were given by Orren (1975). No method was given; only two metals were determined. The data were expressed in terms of dry mass. Penguins seem to concentrate lead in their bones.

4.4.4 Blouberg Strand (Figure 62)

A great number of different organisms were analysed in the early 1970's by Van As et al. (1973 and 1975). The samples were collected by skin-divers, dissected and weighed. The tissues were freeze-dried and again weighed. The dried samples were then ground in an agate pestle and mortar to obtain a homogenous sample. Approximately 1 g of material was soaked in a pure quartz ampoule and irradiated with neutrons in the nuclear reactor. Samples were then analysed for Cr, Co, Cs, Fe, Sb and Zn.

Analyses for Fe, Mn, Zn were carried out by atomic absorption analysis; aliquots (3 g) of the freeze-dried tissue were dissolved by refluxing in a mixture of HNO_3 and $HClO_4$. Blanks were used to determine background contribution. Data thus consist of results of atomic absorption analysis only for Mn, of neutron activation analysis for Cr, Co, Cs and Sb, and of parallel analyses for Fe and Zn. The data were expressed in terms of wet mass, mean and standard deviation were given. No numbers of organisms, size, sex or weight are given.

Watling (1978) reported results for one wet mass sample (February 1977) but gave no further information. Orren et al. (1980) reported on the metal levels in mussels collected in June and November 1979. The mussels had the byssus tracts removed and were allowed to purge for 72 hours. The dry mass was determined after oven drying at 100°C. The rest of the method was as used in the Strandfontein study.

A detailed study was made by Hennig (1981) of metal concentrations in adult (Figure 63) and immature (Figure 64 - notice the different x-axis scale) black mussels, C. meridionalis. There was a decrease of metal concentration with increase in size of animals. Such a trend is often noticeable only if sufficient animals have been sampled. For instance, 17 black mussels analysed for Cu, Fe and Zn (Figure 65), showed no such trend nor was there a difference between male and female. On the other hand, Watling (1978) found a difference between zinc levels in males and females at Knysna (Figure 66). The results have been recalculated to be expressed in terms of dry mass (Hennig and Orren, 1983). The method used by Hennig (1981) was that mentioned above by Orren, et al. (1980).

It should be noted that there are some metal values which have been determined for marine algae and kelp in this section.

4.4.5 Melkbos Strand

Van As et al. (1975) conducted a survey along the littoral zone from Blouberg Strand to Bokbaai. In his report Fourie (1976) calls this Melkbos Strand.

4.4.6 Koeberg (Figure 67)

Cuthbert et al. (1976) reported B. digitalis with exceptionally high cadmium concentrations. This was followed up by later studies and comparisons (Figure 59). At the same time other animals and sediment were analysed to find the source of these high cadmium levels. The results showed a decrease in cadmium concentrations in Bullia and no high levels in sediments or other animals. The source of the high cadmium is still unknown. Cuthbert et al. (1976) did not describe the method but did state wet and dry mass of their sample animals. Wet tissue was digested and dry mass was calculated from previously established wet/dry relationships.

The present study is the first report on the metal concentrations in jellyfish. The jellyfish (2 000 ml) was heated with 10 ml redistilled Analar grade nitric acid. The sample liquified within 5 minutes. The resulting liquid was evaporated to dryness, and treated by the method used in the Strandfontein study.

When comparing these results with the results obtained for jellyfish tentacles (Cimino et al. 1983) it was found that cadmium, copper and nickel accumulated in the umbrella of the jellyfish while iron, manganese and zinc were concentrated in the tentacles. All results are expressed in terms of dry mass.

4.4.7 Langebaan (Figure 68)

Fourie (1976) presented his data on a wet-mass basis. The samples were collected by skin-divers and kept frozen at -20°C until analysed. The samples were sized, but sizes are not given. Tissues were lyophilized and wet-ashed with 30 ml atomic absorption quality (AA) nitric and 5 ml AA perchloric acids. The residues were redissolved in 1 ml concentrated hydrochloric acid and made up to 50 ml with double distilled water. About 300 organisms were sampled between October 1974 and January 1975. The data are presented per site without numbers of individuals, size, sex or mass. Metal concentrations were presented as means and sometimes standard deviation was given. Accuracy is as reported in the original paper.

Watling and Watling (1976a) quote Watling (unpublished data) on metal concentrations in various animals in terms of mean dry tissue mass.

Watling and Watling (1974) reported on the metal concentrations in some oysters which had been transplanted into the lagoon at Langebaan, and which were outside their normal habitat. The method was to dry the animals at 90°C for 48 hours and then digest them with redistilled, Analar grade nitric acid. The solutions were evaporated and the residue redissolved in 10 ml 0.1 M nitric acid. Results were calculated as µg metal per g dried tissue.

Samples for the determination of mecury were digested in redistilled, Analar grade nitric acid at 60°C under reflux. The solutions were diluted to 100 ml with double distilled water and aliquots taken for analysis. Mercury was determined by flameless atomic absorption after reduction by stannous chloride. The number of samples, dry mass, range (min, max) and mean were reported for 15 elements. This is the most complete record of elements determined.

4.4.8 Saldanha (Figure 69)

Most of the determinations were done by Watling and Watling (1974). The method was the same as that used in the Langebaan study. This again is a very comprehensive set of data.

Fourie (1975, 1976) may have repeated his data, but since the concentrations are different it is assumed that more information was available. His method was as that used in the Langebaan study.

John Henry (personal communication) of Sea Fisheries Research Institute, Cape Town, was kind enough to make the results from his January 1979 analyses available.

4.4.9 Noordwesbaai

The concentrations of metals in Jasus lalandii (rock lobster) tail (Figure 70a), green gland (Figure 70b) and gills (Figure 70c) are given as well as rock lobster's food mussel, Aulacomya ater (Figure 71). The results for both species were in terms of dry mass and metal data are given by Hennig, et al. (1982) but the other metals were present in such low concentrations as to show no trend.

Finally, some metal concentrations have been reported (Figure 72) in chemical analysts together with the accepted World Health Organisation's guideline values.

4.4.10 Conclusion for Section IV

The data on organisms in this section show some detail and enable some comparisons to be made. From these the shortcomings of baseline studies have emerged, but more important, the shortcomings of inadequate reporting are highlighted. Data presented here show that metal concentrations without detail of the animal size, weight, sex, dry and wet mass may give misleading baseline values.

Large sections of the coast have not been covered and there are still large gaps in our knowledge of metals in important commercial species.

4.5 **Section V - Cape Columbine to Orange River**

Although water and sediment data are available for this section, no determinations of trace metals in biological specimens have been done. Since there is very little industry along this stretch of coast, very valuable background data about the west coast could be gathered there.

5. METAL BURDENS IN DIFFERENT SPECIES

In some cases the location of an organism is not as important as the type of animal. In this section the metal concentrations in individual species are given as they vary with location.

It is hoped that it will be more useful if organisms were grouped into phyla. The system adopted is the classification system presented by Day (1974), who reported further detail on the distributions of the various animals and plants mentioned in this study.

5.1 **Plankton** (Figure 73)

In some cases samples were a mixture of algae and animals such as copepods. Plankton are known to have high metal concentrations (Hennig, 1981). Some of the data are expressed in terms of wet mass, some as dry mass. However it is still evident that the east coast plankton samples contain very high amounts of metals. This could be due to the metal enriched water around Kosi Bay.

5.2 **Porifera** (sponges) (Figure 74)

Only one sponge species *Tethya aurantia*, has been analysed for metal. This sponge is utilised as food by some of the nudibranchs at Langebaan. The metal concentrations were found to be low and related to the concentration of metals in the water.

5.3 **Cnidaria** (jellyfish) (Figure 75)

Only one jellyfish species *Semaeostomeae* sp. has been analysed. There was no metal accumulation in these jellyfish in relation to their size. More information is provided under the Koeberg location section.

5.4 **Arthropoda**

5.4.1 *Macrura* (lobsters, shrimps and prawns)

Jasus lalandii (Figure 76), *Panulirus homarus* (Figure 77), *Panulirus versicolor* (Figure 78), *Penaeus indicus* (Figure 79), *Penaeus monodon* (Figure 80).

There is a decreasing metal concentration from north to south, with lower metal concentrations on the west coast. Only *J. lalandii* has been studied in detail (see diagrams of Noordwesbaai location).

5.4.2 *Anomura* (hermit crabs and burrowing prawns)

Callianona sp. and *Callianassa kraussi* (Figure 81), *Emerita austroafricana* (Figure 82), *Upogebia africana* (Figure 83).

Animals in the industrialised areas contained higher metal burden.

5.4.3 *Brachyura* (crabs)

Although crabs are common all along the coast of South Africa, only one species *Scylla serrata* (Figure 84) has been analysed.

5.5 **Mollusca**

5.5.1 *Pelecypoda* (bivalves)

These include *Atrina squamifera* (Figure 85), *Crassostrea cucullata* (Figure 86), *Crassostrea gigas* (Figure 87), *Crassostrea margaritacea*

(Figure 88), Choromytilus meridionalis (Figure 89), Donax serra (Figure 90), Mactra glabrata (Figure 91), Ostrea atherstonei (Figure 92), Ostrea edulis (Figure 93), Perna perna (Figure 94), Solen capensis (Figure 95), Venus verrucosa (Figure 96).

Bivalves exhibit several characteristics of ideal indicator species (Eisler, 1981). In general, the highest concentrations are in the gut and digestive gland, with moderate enrichment in mantle, gills and gonads, and lowest residuals in muscle.

C. margaritacea (Figure 88) gives the best sampling distribution pattern. Not all metals exhibit the same trends and it would be expected that impact areas would be easily identifiable. This is, unfortunately, not the case. There seems to be a local "hot spot" between Pinnacle Point and Fish Bay. The distribution of zinc is very varied and there appear to be factors other than environment which influence the accumulation of zinc.

C. meridionalis has been studied in detail regarding local differences in metal accumulation (see Figures 63 to 65) but little is known about metal accumulation at different locations.

D. serra was sampled at many locations. Again a more varied zinc content was found. Copper seems to decrease and lead to increase from east to west. There is little difference between concentrations of the other metals with geographical distribution.

The other well represented species is P. perna (Figure 94). At the industrial impact areas there was a greater variation in metal body burden, but the concentrations are much more consistent throughout the region when compared with the metal burdens in the oysters. Of the unpolluted areas, Fish Bay seems to induce the accumulation of more metals in molluscs.

For baseline metal concentration data, three species C. margaritacea, D. serra and P. perna provide the most complete record of metal accumulation in South Africa. When the results for C. margaritacea and P. perna are compared with those of the Mussel Watch (Goldberg et al., 1983) it is found that cadmium, copper, nickel concentrations were lower in South Africa, while lead and zinc levels are similar, on average, in both countries.

5.5.2 Gastropoda (whelks, limpets and slugs)

5.5.2.1 Whelks

Bullia digitalis (Figure 97, see also Figure 59), Bullia natalensis (Figure 98), Bullia rhodostoma (Figure 99), Bullia sp. (Figure 100), Burnupena cincta (Figure 101), Haliotis midae (Figure 102).

5.5.2.2 Limpets

Patella argenvillei (Figure 103), P. barbara (Figure 104), P. cochlear (Figure 105), P. granularis (Figure 106), P. longicosta (Figure 107), P. miniata (Figure 108), P. oculus (Figure 109), P. tabularis (Figure 110).

5.5.3 Slugs

Doris verrucosa (Figure 111), Iorunna tomentosa (Figure 112).

Some comparisons of metal levels in Bullia have been done (Figure 59a-e) and no reason could be found for the high cadmium concentration in the animals from Koeberg, although the problem is still receiving attention. B. rhodostoma has been sampled over a wide enough region to be of value as a baseline study. The data from Port Elizabeth (Figure 99) show that Bullia makes a good indicator species for Cd, Cr, Cu, Fe, Pb and Zn. The trend lines are more uniform as in the case of mussels and oysters. This is somewhat surprising as Bullia is a scavenger.

H. midae (Figure 102) has been dissected and the different organs analysed separately; this showed that different organs accumulate different metals.

The metal burden in limpets (Figures 103 to 110) was studied in eight closely related species sampled over a wide region. Although not all figures are as complete as Figures 104 and 105, it is obvious that limpets accumulate different metals at different rates. More details are given in the Algoa Bay section and in Figure 25. Higher burdens were reported from St Francis Bay, Herold's Bay and Pinnacle Point for Cd and Cr, but Cu and Zn did not follow this trend. Data such as these should make it possible to group together those metals which display similar trends and which, therefore, may be taken up by certain animals, by the same mechanisms. The data may also be used to show that some ions (for example, Cd) may compete with others (for example, Zn).

The metal concentrations in the two nudibranchs have been used to compare the concentrations in apparently unpolluted nudibranchs from Gough Island with those in animals from coastal regions (Hennig, 1984). These appear to be background levels.

5.5.4 Cephalopoda (squids)

Loligo (Figure 113) from St Lucia is the only reference animal from this class. Since squids are an important food source, more information should perhaps be gathered.

5.6 **Echinodermata**

5.6.1 Echinoidea (sea-urchins)

Parechinus (Figure 114) is the only representative of this large phylum. Unfortunately no details of the method were given by Van As et al. (1975); hence it is not known which part of the sea-urchins were used. Hennig (in preparation) analysed gonads and soft parts only of sea-urchins from Gough Island and found very little metal accumulation.

5.7 **Chordata**

5.7.1 Tunicata (sea-squirts or red bait)

Pyura stolonifera (Figure 115)

Although red bait is very common on rocky shores and piers, very few metal data were available. If compared with other filter feeders the metal body-burden of red bait is very low. Unfortunately, due to lack of information it is not known if the data represent concentrations in only the fleshy part or whole animal.

5.7.2 Aves (birds)

The bones of three species of birds were analysed for cadmium and lead (Figure 116). Penguins accumulate surprisingly high levels of lead in their bones, while cormorants showed a wide range of cadmium concentrations.

5.7.3 Pisces (fish)

All the fish analysed were bony fish. They have been arranged alphabetically: Acanthopagrus berda (Figure 117), Argyrosomus hololepidotus (Figure 118), Argyrozona argyrozona (Figure 119), Atractoscion aequidens (Figure 120), Cheimerius nufar (Figure 121), Chrysoblephus gibbiceps (Figure 122),Chrysoblephus puniceus (Figure 123), Diplodus sargus (Figure 124), Elops machnata (Figure 125), Hypacanthus sp. (Figure 126), Hypacanthus amia (Figure 127), Johnius hololepidotus (Figure 128) Lithognathus lithognathus (Figure 129), Lophius piscatorius (Figure 130), Lutianus argentimaculatus (Figure 131), Merluccius capensis (Figure 132), Mugil canaliculatus (Figure 133), Mugil cephalus (Figure 134), Mugil richardsoni (Figure 135), Mugil sp. (Figure 136), Oplegnathus conwayi (Figure 137), Otolithes ruber (Figure 138), Pomadasys commersonni (Figure 139), Pachymetopon grande (Figure 140), Rhabdosargus holubi (Figure 141), Rhabdosargus sp. (Figure 142), Sardinops ocellata (Figure 143), Sarotheradon mossambicus (Figure 144), Scomber japonicus (Figure 145), Scombrops dubius (Figure 146), Seriola pappe (Figure 147), Synaptura marginata (Figure 148), Therapon jarbua (Figure 149), Thunnus sp. (Figure 150), Tilapia sp. (Figure 151), Trachinotus russellii (Figure 152), Trachurus trachurus (Figure 153), Trigla capensis (Figure 154), Xiphiurus capensis (Figure 155).

More species of fish than of any other animals have been analysed, but these come from very different habitats and prefer different types of food. The range and accumulation were very varied and no trend can be observed. In all animals, the liver contained a higher metal concentration than did the muscle tissues. The data should not be considered as representative, although they give the correct magnitudes of metal concentration.

5.7.4 Human (Figures 156 to 157)

As a matter of interest, metal concentrations in the people who analysed trace metals are included. Data are given for blood (Figure 156) and hair (Figure 157, mercury only).

5.8 **Algae** (including seaweeds)

This is a loose collection of algae and seaweeds, so they have been arranged alphabetically.

Ecklonia maxima (Figure 158), Gigartina radula (Figure 159), Gracilaria verrucosa (Figure 160), Porphyra capensis (Figure 161), Suhria vittata (Figure 162), Ulva sp. (Figure 163).

Most species in the section had low metal concentrations. Hence the very high levels (7 647 $\mu g\ g^{-1}$ dry) in Ulva sp. were surprising. If these are background values and some limpets eat algae, then there is no biomagnification of metals via the food chain. This may be due to the non-bioavalibility of the metals to the grazers in the algae.

6. CONCLUSION

Metal distributions in water and sediment samples outlined impact areas and established baseline values with which future values can be compared. Although a fairly large number of samples were taken, these were unfortunately concentrated around impact areas and it is suggested that more baseline studies should be done on unpolluted reference beaches in Section I (Natal).

The value of trace metal reports would be enhanced if water, sediment and biological samples were taken simultaneously. In several locations only water or sediment samples were taken. This diminished the value of the data with respect to monitoring strategies for metals, because it is more important to know how much metal is bioavailable to animals than to know merely the total amount.

A huge gap in our knowledge still exists in data for Section IV (north part of west coast). Nearly every data point from this area would be a baseline data point.

With regard to metals in biological samples it is surprising how much data is available. For Bullia (Figure 99), C. margaritacea (Figure 88), P. barbara (Figure 104), P. longicosta (Figure 107) and P. perna (Figure 94) there were enough data to establish national and regional baselines for metal concentrations in organisms in unpolluted waters. The data emphasized that certain metal anomalies could have been identified only by analysis of the data for different locations in a review such as this. This became apparent from the consistently high concentrations in organisms from Pinnacle Point.

This review has identified "hot spots" and areas which should be watched. It has shown which organisms accumulate particular metals and that data for one particular location or organism cannot always be used for comparison of metal concentrations in other locations or other animals, even if closely related.

For instance, the question why Patella accumulate metals differently at the same location, could be investigated. As a conjecture this may be due to food differences. It may also enable us to speculate on the mechanisms of uptake and the extent to which metals are similar or dissimilar in bioavailability (see section on gastropoda).

Finally, it makes it possible to answer questions on metal concentrations asked by planners and coastal management about a vast variety of species and to be able to supply an answer which is correct to the right order of magnitude.

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LIST OF TABLES

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TABLE I: SAMPLE LOCATIONS AS THEY APPEAR ALONG THE SOUTH AFRICAN COAST AND IN FIGURE 1 (B = biological samples, W = water samples, S = sediment samples)

SECTION I –	1.	Kosi Bay	BW
	2.	St Lucia	BWS
	3.	Richards Bay	BWS
	4.	Port Durnford Point	B
	5.	Umhlanga Rocks	B
	6.	Umgeni	B
	7.	Durban Bay	BWS
	8.	Umbogintwini	BW
	9.	Fynnlands	W
	10.	Umhlatuzana	B
	11.	Umgababa	BWS
	12.	Umzimkulu	BWS
	13.	Umzimvubu	WS
	14.	Mngazana	WS
SECTION II –	15.	Bashee	BWS
	16.	Buffalo	WS
SECTION III	17.	Algoa Bay	BWS
	18.	St Croix	B
	19.	Swartkops	BWS
	20.	Port Elizabeth	BS
	21.	Maitland	B
	22.	Jeffreys Bay	WS
	23.	Cape St Francis	BWS
	24.	Keurboomstrand	BWS
	25.	Cathedral Rock	B
	26.	Noetzie	B
	27.	Knysna East Head	BW
	28.	Beacon Point	B
	29.	Knysna West Head	B
	30.	Featherbed	B
	31.	Belvedere	B
	32.	Leisure Island	B
	33.	Knysna	BS

	34.	Thesen's Point	B
	35.	Castle Rock	B
	36.	Buffalo Bay	B
	37.	Walker Point East	B
	38.	Walker Point West	B
	39.	Herold's Bay	B
	40.	Glentana	B
	41.	Tergniet	B
	42.	Little Brak River	B
	43.	Hartenbos	B
	44.	Diaz Head	B
	45.	Die Bakke	B
	46.	Mossel Bay	BWS
	47.	Dana Township	B
	48.	Cape St Blaize	B
	49.	Pinnacle Point	B
	50.	Fish Bay	B
	51.	Vlees Bay	B
	52.	Arniston	WS
SECTION IV -	53.	False Bay	B
	54.	Eerste River	S
	55.	AECI	S
	56.	Swartklip	S
	57.	Strandfontein	B
	58.	Muizenberg	B
	59.	Cape	B
	60.	Hout Bay	S
	61.	Camps Bay	S
	62.	Green Point	S
	63.	Salt River	S
	64.	Blouberg Strand	B
	65.	Melkbos	WB
	66.	Koeberg	BS
	67.	Langebaan	WB
	68.	Saldanha	WBS
	69.	Noordwesbaai	B
	70.	Berg Rivier	WS
	71.	Olifants River	WS

TABLE II: SUMMARY OF METAL CONCENTRATIONS OF COASTAL WATER AROUND SOUTH AFRICA ($\mu g\ \ell^{-1}$)

Location	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Sb	Zn	Nb	Reference
Kosi River	1976	0.14	1.1		na		0.019		1.1	0.33		3.31		Oliff & Turner, 1976
Kosi Bay	1976	na 0.4	na 0.8		na 1.1		0.05 0.08		0.7 1.9	0.4 1.0		na 5.7		Cloete (ed), 1979
St Lucia E.	1976	0.187	1.534		3.329	68.81	3.949			39.15		2.312		Oliff & Turner, 1976
St Lucia E.	1978	0.03 0.25	0.08 2.4		1.2 17	460 2 000	0.03 0.13		1.2 6.1			1.4 11.7		Cloete (ed), 1979
Richards Bay	1976	0.09	2.4		0.64		0.60		2.2	1.8		1.8		Oliff & Turner, 1976
Richards Bay	1974	<0.04			4.79		0.011			10.5		12.5		Connell *et al.*, 1975
Richards Bay	1974	<0.04			1.55		0.006			<0.4		<0.4		Connell *et al.*, 1975
Richards Bay	1974	0.015			1.70		0.174			1.87				Connell *et al.*, 1975
Richards Bay	1974	0.001 0.025			0.25 3.1		0.01 0.38			3,9			0.53	Cloete (ed), 1979
Richards Bay	1976	0.804 0.17	0.4 4.0		0.1 4.0		0.45 1.92		nd 13.0	nd 4.2		nd 3.8		Cloete (ed), 1979
Durban	1974	0.306			0.773	11.70	0.383			0.25		28.1		Oliff & Turner, 1976
Durban	1978	na 0.82	na 3.2		0.57 27	15 800	0.17 0.37		7 26	18 117		26 287		Cloete (ed), 1979
Umbogintwini R.	1974	1.39			31.29		0.097			0.6		43.0		Connell *et* al., 1975
Fynnlands	1974	1.07			12.14		0.023			1.52		20.7		Connell *et al.*, 1975

TABLE II (continued)

Location	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Sb	Zn	Nb	Reference
Umzimkulu River	1974	0.015			1.45		0.065			2.93		7.78		Connell *et al.*, 1975
Umzimkulu River	1974	0.04 0.015			0.90 2.21		0.05 0.13			0.38 3.5		7.5 8.9		Cloete (ed), 1979
Umzimvubu River	1977	0.13 0.24	1.5 1.6		1.1 1.9	390 460	0.33 0.40			2.2 2.9		11.5 20.1		Cloete (ed), 1979
Umgababa River	1977	0.075	9.80		1.957	64.5	0.871			2.891		1.454		Oliff & Turner, 1976
Umgababa River	?	0.06	7.9		2.8	684	1.0							Cloete (ed), 1979
Mngazana River	1977	nd	nd		2.4	211	0.3			2.7		5.7		Cloete (ed), 1979
Bashee River	1975	0.159			8.730		0.11			6.009		11.429		Oliff & Turner, 1976
Bashee River	1975	0.20			8.3	120	0.14			5.71		28.6		Cloete (ed), 1979
Buffalo River	1977	na 0.035	0.7 1.5		1.5 1.7	72 122	0.16 0.23			na 0.02		0.094		Cloete (ed), 1979
Algoa Bay	1978	0.2	0.1		1.9	81	0.009	5.6	0.6	0.9		22		Watling & Watling, 1983
Swartkops River	1975	0.312			7.059		0.13			11.320		10.092		Oliff & Turner, 1976
Swartkops River	1975	0.05			2.62							3.0		Oliff & Turner, 1976
Swartkops River	1975	0.01 0.03			2.63 2.75					2.5 2.8		2.0 3.8		Cloete (ed), 1979
Swartkops River	1975	2.8 3.5			0.21 0.22		0.06			7 8.7				Cloete (ed),1979

TABLE II (continued)

Location	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Sb	Zn	Nb	Reference
St Francis Bay	1979	0.3	0.3		1.3	275	0.010	4.2	0.2	0.3		1.4		Watling & Watling, 1983
Jeffreys Bay	1977	0.15			0.9	40.6		24.0	1.3	0.073		5.5		NRIO, 1981; Orren *et al*., 1981
Keurboomstrand	1977	0.41			1.7	15.7		11.9	0.8	0.65		3.8		NRIO, 1981; Orren *et al*., 1981
Knysna E	1977	0.4	0.6		1.1	192.0	0.1	3.1	0.3	1.3		1.5		Watling & Watling, 1980
Knysna E	1977	1.0	1.0		0.8	101.7	0.100	8.2	0.2	1.4		3.8		Watling & Watling, 1980
Mossel Bay	1979	0.6	0.5		1.8	45	0.037	2.1	0.16	0.3		1.7		Watling & Watling, 1983
Arniston	1977	0.27			1.0	7.9		50.5	3.2	0.68		5.9		NRIO, 1981; Orren *et al*., 1981
Table Bay	1980	see separate Figures												Eagle *et al*., 1982
Melkbos	?		0.02	0.08		1.7		0.7			0.7	1.2		Van As *et al*., 1975
Saldanha	1976				0.98	2.49						2.10		Henry (pers. com.)
Saldanha	1977				0.98	3.68		1.20				3.38		Henry (pers. com.)
Saldanha	1978				1.00	3.40		1.73				4.98		Henry (pers. com.)
Saldanha	1979				1.39	3.92		0.80				6.85		Henry (pers. com.)
Berg River	1976	0.08			1.3	71.3		17.2	0.9	1.5		3.7		NRIO, 1979
Olifants River	1980	0.08			0.3	170.7	0.286	11.9	0.44	0.71		6.1		NRIO, 1981

TABLE III: SUMMARY OF METAL CONCENTRATIONS OF COASTAL SEDIMENTS AROUND SOUTH AFRICA ($\mu g\ g^{-1}$ dry)

Location	Date	Al	Ag	Bi	Cd	Co	Cr	Cu	Fe	Hg	Mn	Mo	Ni	Pb	Ti	V	Zn	Reference
St Lucia E	1978				0.08 0.4	1 27	7 150	2 61	3 000 60 000	0.007 0.04			2.9	0.8 19			3.4 72	Cloete (ed), 1979
Richards Bay	1974				0.57			9.9	23 640	0.022			84	24			98	Connell *et al.*, 1975
Richards Bay	1974				0.46 0.76			8.3 12.0	19 000 29 000	0.017 0.029				20 32			66 175	Cloete (ed), 1979
Richards Bay	1976				0.07	16.13	74.80	24.04	5 814	0.014			27.24	17.47			87.16	Oliff & Turner, 1976
Richards Bay	1976				0.6 1.6	1.5 23.5		1.1 40.0	800 11 000	0.007 0.039			2.2 73	5.5 33.0			14 179	Cloete (ed), 1979
Durban Bay	1978				0.7 1.9	4.2 13	10 388	5.5 57	3 000 40 000	0.07 0.87	23 303		7 26	18 117			26 287	Cloete (ed), 1979
Umzimkulu E	1974				0.7			9	13 057	0.005				10			162	Connell *et al.*, 1975
Umzimkulu E	1974				0.4 0.6			4 10	9 000 11 000	0.001 0.005				5 9			33 649	Cloete (ed), 1979
Umzimvubu R	1977				0.008 0.07	0.83 0.95	26 27	2.6 4.8	1 420 1 540	0.03 0.05			13 17	0.16 0.35			12.1 16.4	Cloete (ed), 1979
Umgababa	1976				0.28	6	15	3.7	7 016	0.014				4.6			7.8	Oliff & Turner, 1976
Umgababa	1976				0.52	12	21	9.6	12 330	0.02				9			21	Cloete (ed), 1979
Umgababa	1977				0.35		7.0	1.4	4 302	0.095			5.01	4.3			4.9	Oliff & Turner, 1976
Umgababa	1977				0.35		7.6	2.2	5 192	0.04			5.1	4.0			10.2	Cloete (ed), 1979
Mngazana R	1977				0.09	3.9	126	15	4 990	0.09			35	1.4			71	Cloete (ed), 1979

TABLE III (continued)

Location	Date	Al	Ag	Bi	Cd	Co	Cr	Cu	Fe	Hg	Mn	Mo	Ni	Pb	Ti	V	Zn	Reference
Bashee River	1975				0.82			10.03	11 810	0.007				21.3			17.8	Oliff & Turner,1976
Bashee River	1975				0.23		5.0	2.7	4 780	0.001				5.3			8.4	Cloete (ed), 1979
Buffalo River	1977				0.04 0.06	9 11	35 40	16.2 18.6	25 000 36 000	0.05 0.16	150 470		17 21	8.8 9.5			52 69	Cloete (ed), 1979
Algoa Bay	1978				0.338	0.2	3.7	1.8	2 539	0.063	112.6		0,09	2.7			5.6	Watling & Watling, 1983
Swartkops R.	1975				1.42		44.4	5.97	5 133	0.0576				28.4			19.7	Oliff & Turner, 1976
Swartkops R.	1975				0.45		40	8.9	7 320	0.035				13.1			21	Cloete (ed), 1979
Port Elizabeth	1975				27		8	2	2 378	0.004				18			7	Oliff & Turner, 1976
St Francis Bay	1978				0.072	0.4	33	3	1 451	0.004	31		0,6	3			3	Watling & Watling, 1983
Jeffreys Bay	1977				0.05	<0.5		<0.5	2 810		18.4		< 1	2.0			3.1	NRIO, 1979; Orren _et al._, 1981
Keurboom-strand	1977				0.002	<0.5		0.5	3 596		19.9		< 1	2.0			2.8	NRIO, 1979
Keurboom-strand	1977				0.07	<0.5		<0.5	960		11.3		< 1	2.0			1.5	Orren _et al._, 1981
Knysna E	1975	0,77	0,06	18	0.6	3	21	5	0,8%		40	4,7	7	14	370	9	17	Watling & Watling, 1977
Knysna E	1976				0.2			3.1		0.003			5,2	12			17.8	Watling & Watling, 1980
Knysna E	1977	7,76	0,06	17,84	0.72	3.43	20.5	5.16	7 551		40.40	4,79	7,41	13.94	373	8.67	16.08	Watling & Watling, 1977
Mossel Bay	1979				<0.05	< 0.5		0.8	2 794		30.6		1,3	1.7			6.1	NRIO, 1980

TABLE III (continued)

Location	Date	Al	Ag	Bi	Cd	Co	Cr	Cu	Fe	Hg	Mn	Mo	Ni	Pb	Ti	V	Zn	Reference
Mossel Bay	1978				0.021	0.4	2.7	1.9	2 574	0.001	24		0,9	4.3			4.1	Watling & Watling, 1983
Arniston	1977				0.07	0.5		< 0.5	956		11.3		< 1	2.0			1.5	NRIO, 1979; Orren *et al.*, 1981
Eerste River	1980				0.04			0.5	535		7.00		bd	1.1			1.2	NRIO, 1981
AECI	1976				0.3	< 0.5		2.1	494		4.5		< 1	2.4			2.8	NRIO, 1979
AECI	1979				< 0.03	< 0.5		1.5	706		4.5		< 1	3.2			2.3	NRIO, 1980
Swartklip	1978				0.05	< 0.5		< 0.5	1 208		7.7		< 1	2.5			1.9	NRIO, 1979; Orren *et al.*, 1981
Hout Bay	1977				0.18	< 0.8		0.4	510		8.0		< 0.1	1.5			2.8	NRIO, 1979
Hout Bay	1979				0.6	< 0.5		0.5	198		3.4		< 1	0.4			1.1	NRIO, 1980
Hout Bay	1980				0.06			0.5	590		7.3		bd	1.0			1.5	NRIO, 1981
Camps Bay	1978				< 0.1	< 0.5		0.3	383		7.5		< 1	1.1			1.2	NRIO, 1980
Green Point	1977				0.6	1.2		9.1	3 523		19.5		3.5	14.2			25.7	NRIO, 1979
Green Point	1980				0.1			5.4	3 055	0.014	21.5		1.3	7.4			10.9	NRIO, 1981
Green Point	1980				0.1			4.5	1 904		17.5		1.4	9.3			11.8	NRIO, 1981
Salt River	1980				bd			bd	519	bd	8.0		bd	1.3			1.4	NRIO, 1981; Orren *et al.*, 1981b
Koeberg	1981				0.05			< 0.3	268		4.35		< 0.4	0.4			0.41	This study
Saldanha	1976				0.7	3		3.3			12		6	17			8.7	Watling & Watling, 1976

TABLE III (continued)

Location	Date	Ba	Br	Co	Cr	Cu	Nb	Ni	Rb	Sr	V	Y	Zn	Zr		Pb	Th	Reference
Olifants R.	1976	553 585	8 10	29 31	105 116	65 74	11 13	46 51	138 149	154 161	127 143	32	110 122	152 192				Cloete (ed), 1979
Olifants R.	1977			nd 23	15 82	3 61	nd 13	5 46	14 141	26 137	14 114	5 32	8 107	49 143		nd 28	nd 17	Cloete (ed), 1979
Berg River	1975				0.3	0.8		0.8	2 611		26		1.3	3.0			5.3	NRIO, 1979
Berg River	1975				0.3	1.6		5.3	5 152		50.9		4.6	6.0			26.9	NRIO, 1979
Berg River	?				0.67			5.23						5.99			29.6	Cloete (ed), 1979
Berg River	?				0.42			5.34						10.9			22.2	Cloete (ed), 1979
Olifants R.	19				0.21			13.2						7.9			32.7	
Olifants R.	?				0.14			23.7						7.95			44.1	Cloete (ed), 1979
Olifants R.	1980				0.7			8.9	13 435		284.3		7.67	17.8			23.73	NRIO 1981

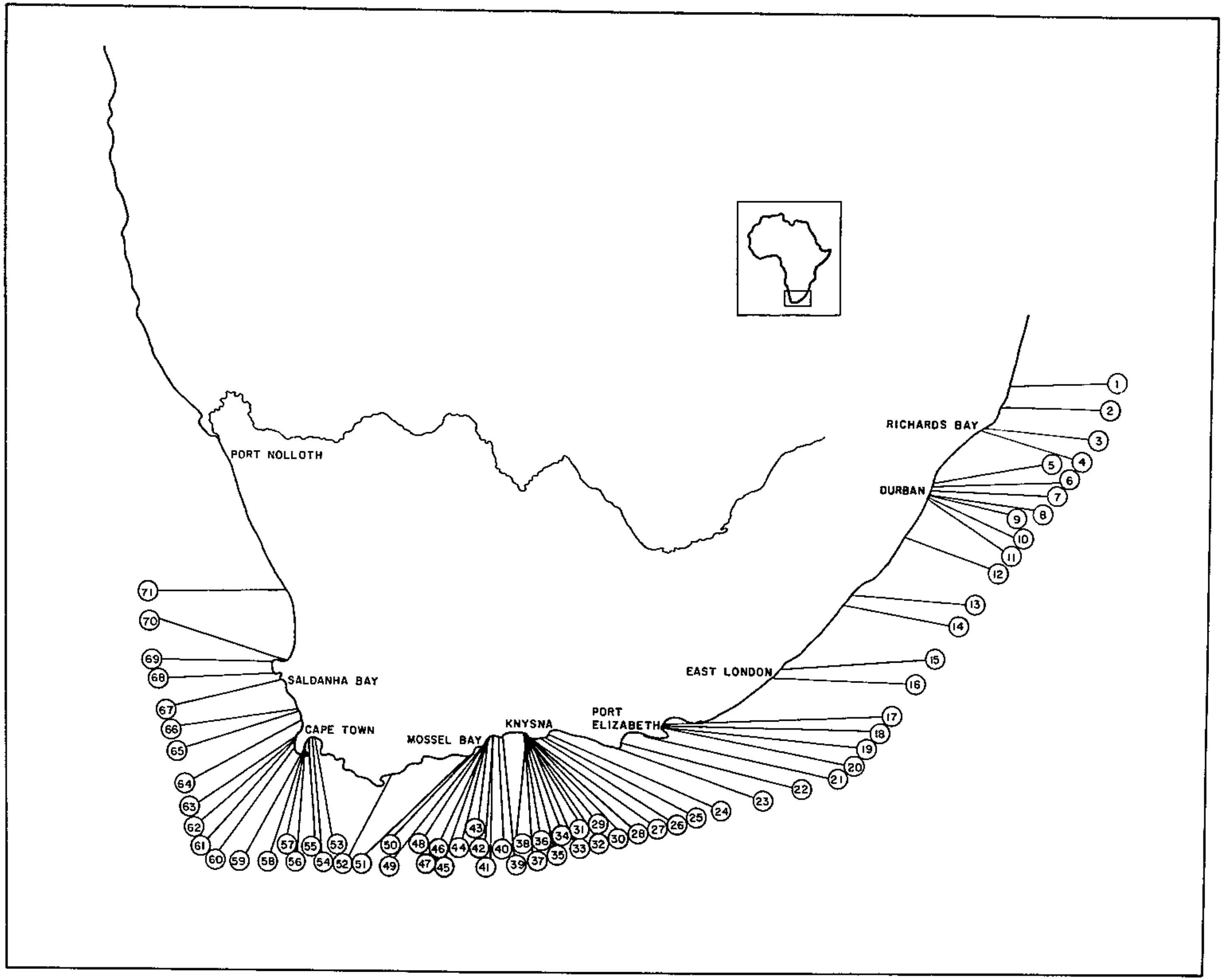


Figure 2 Location of sampling points for biological material (B), water (W) and sediment (S)

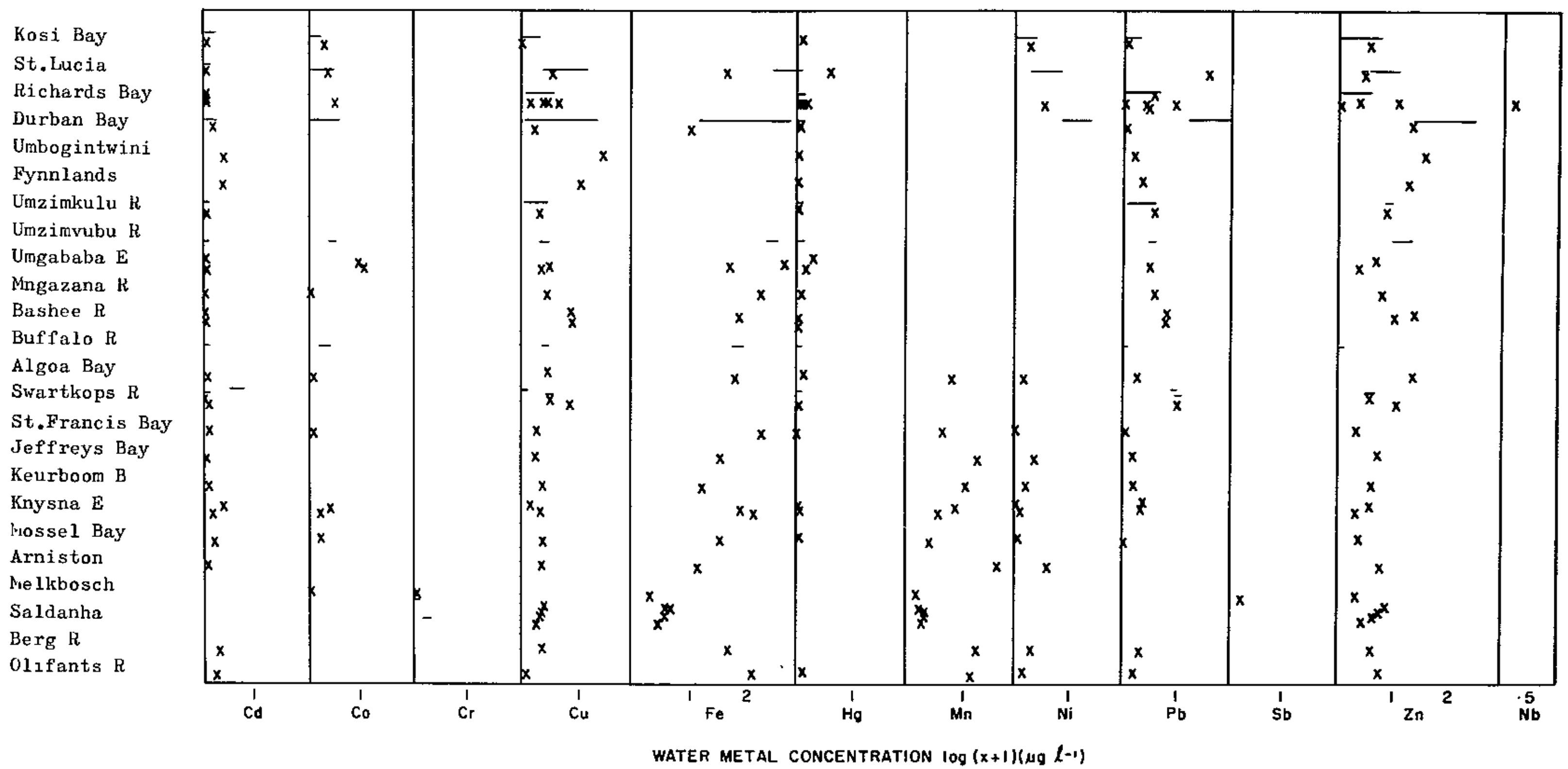


Figure 3 Metal concentrations in water at different locations along the coast of South Africa. All concentrations in $\mu g\ \ell^{-1}$

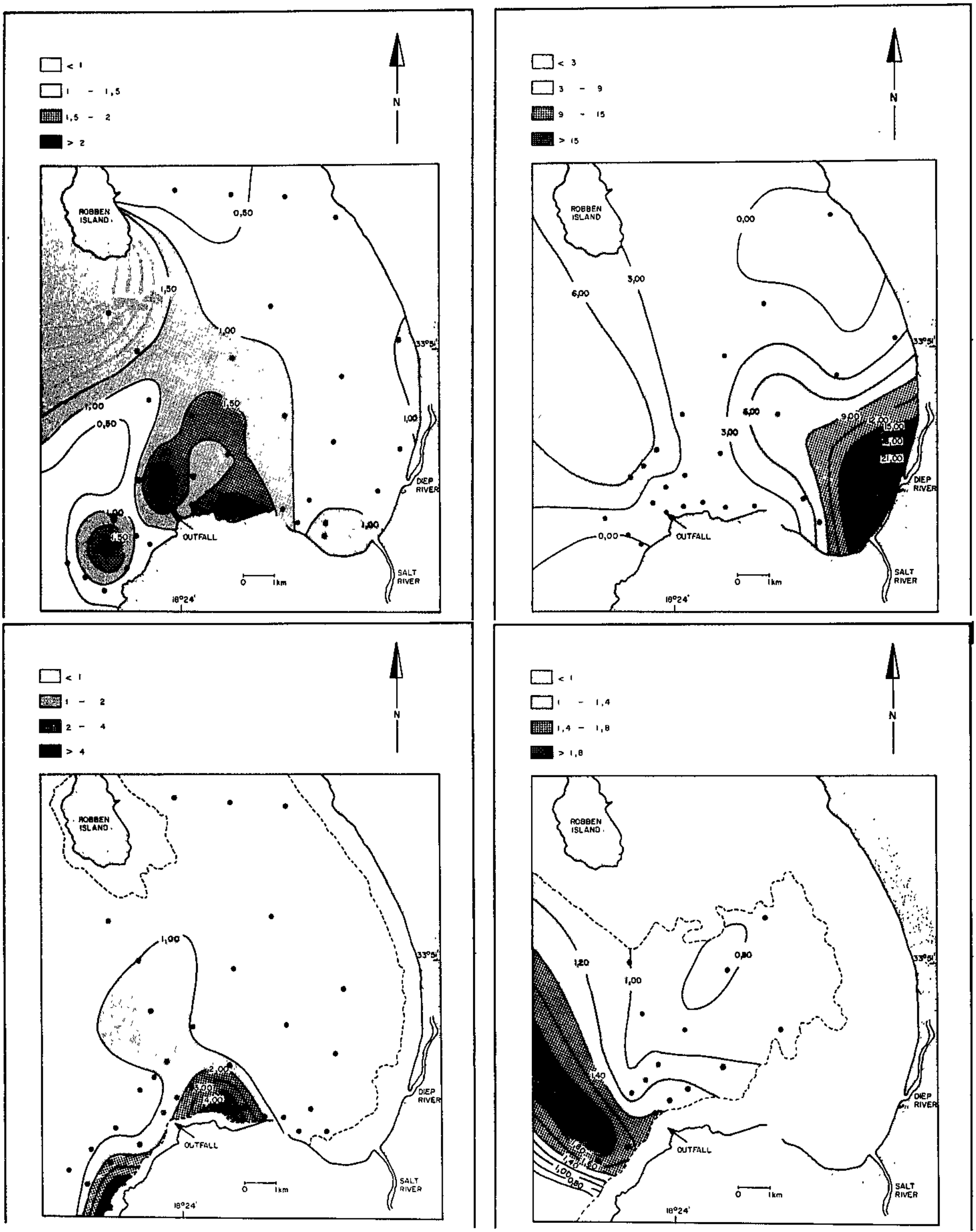


Figure 4 Metal concentrations in Table Bay waters (µg ℓ^{-1})
top left: zinc, surface - spring;
top right: iron, surface - winter;
bottom left: zinc, 10 m - spring;
bottom right: zinc, 20 m - spring

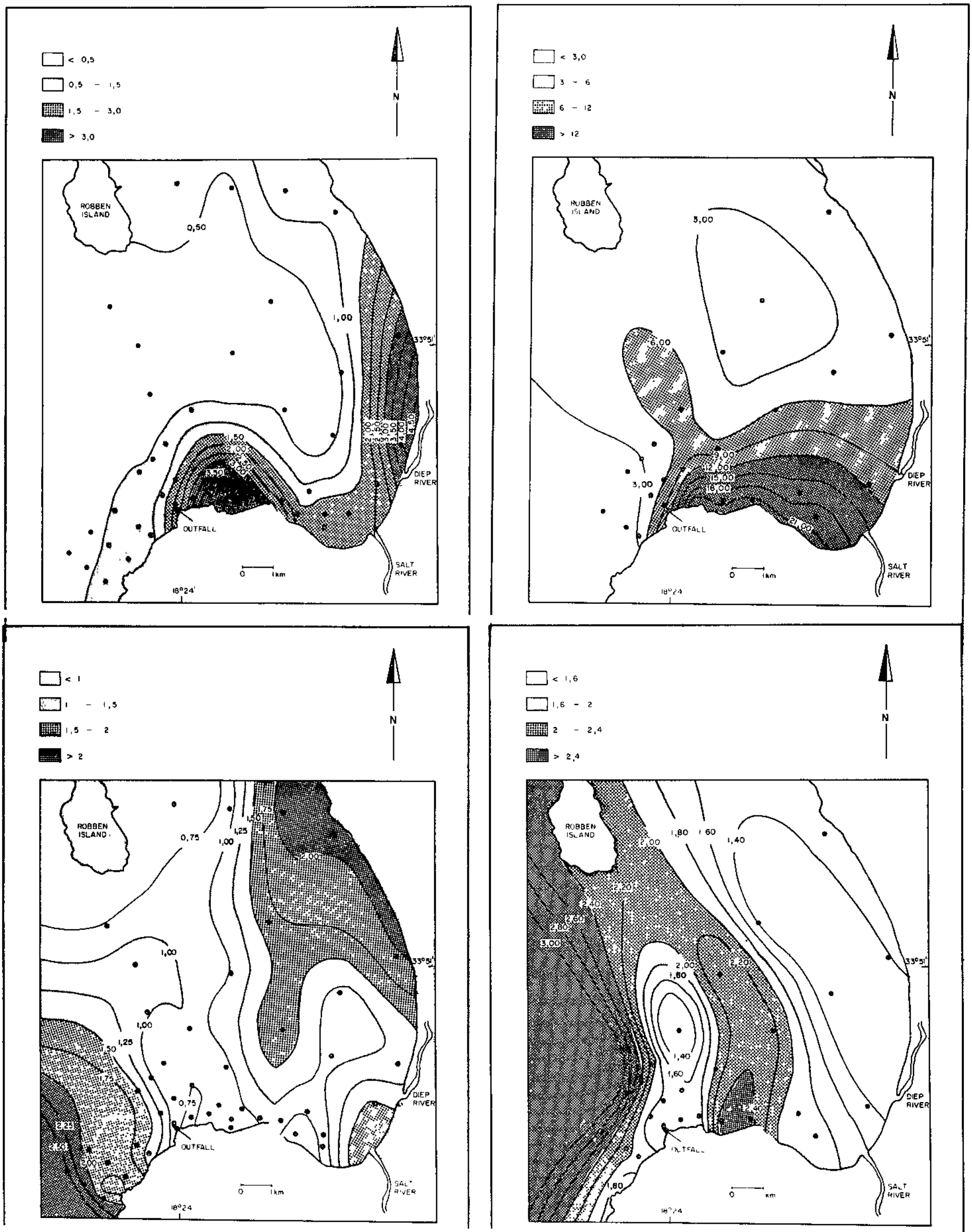


Figure 5 Metal concentrations in Table Bay waters (μg ℓ$^{-1}$)
top left: iron, surface - spring;
top right: iron, surface - winter;
bottom left: lead, surface - spring;
bottom right: lead, surface - winter

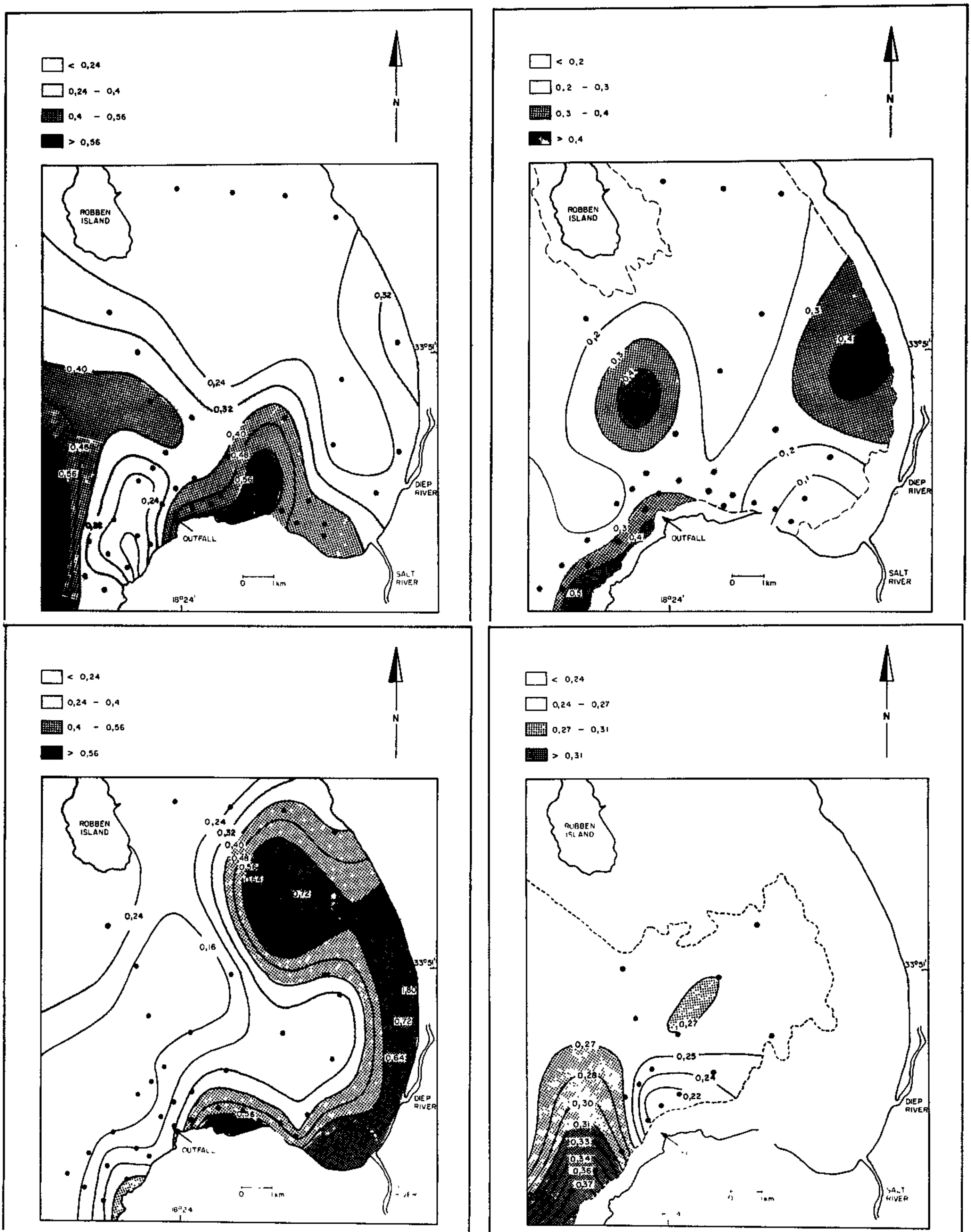


Figure 6 Metal concentrations in Table Bay waters (μg ℓ^{-1})
top left: copper, surface - spring;
top right: copper, 10 m - spring;
bottom left: manganese, surface - spring;
bottom right: manganese, 10 m - spring

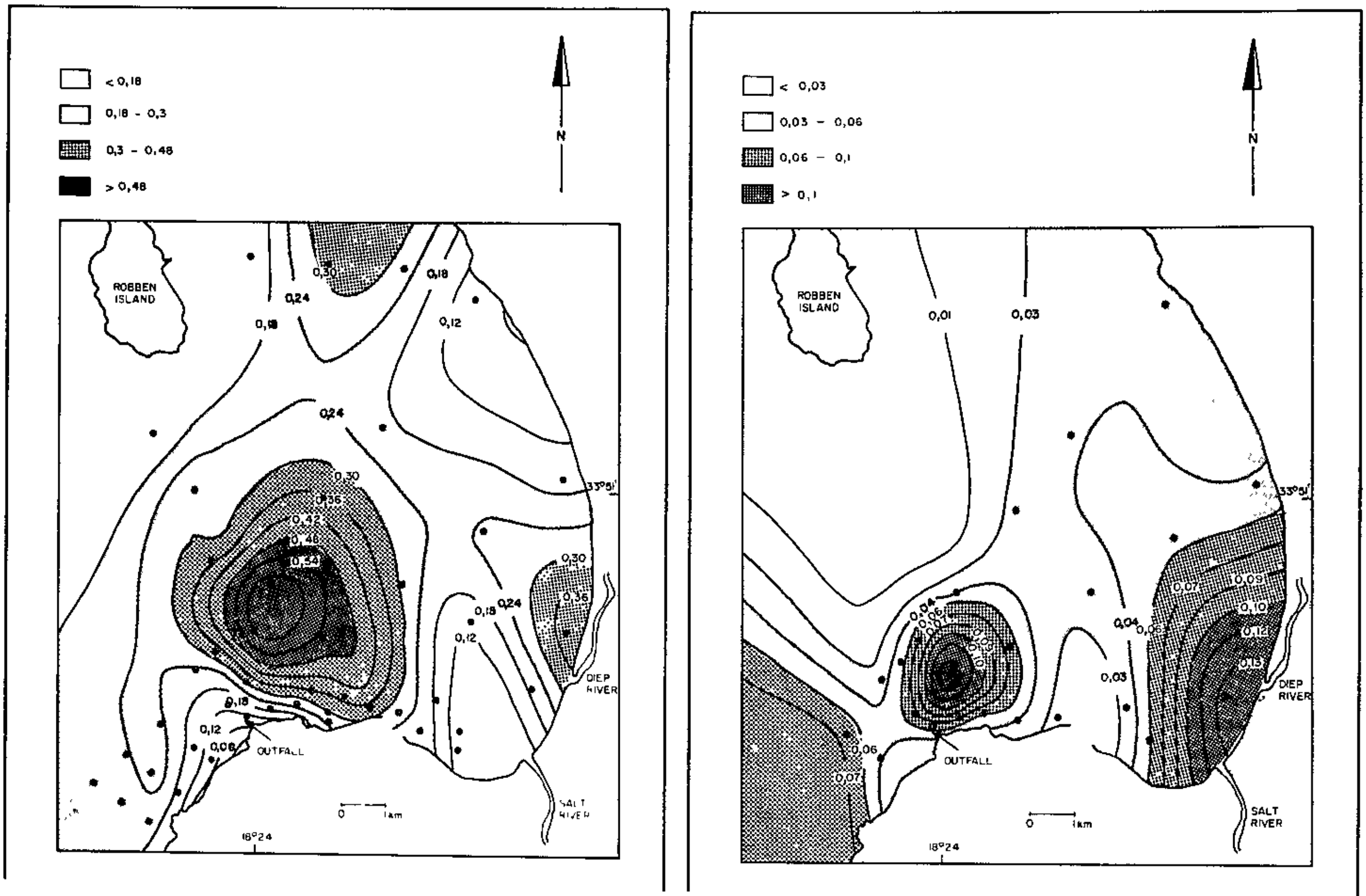


Figure 7 Metal concentrations in Table Bay waters (μg ℓ $^{-1}$)
left: nickel, surface - spring;
right: mercury, surface - winter

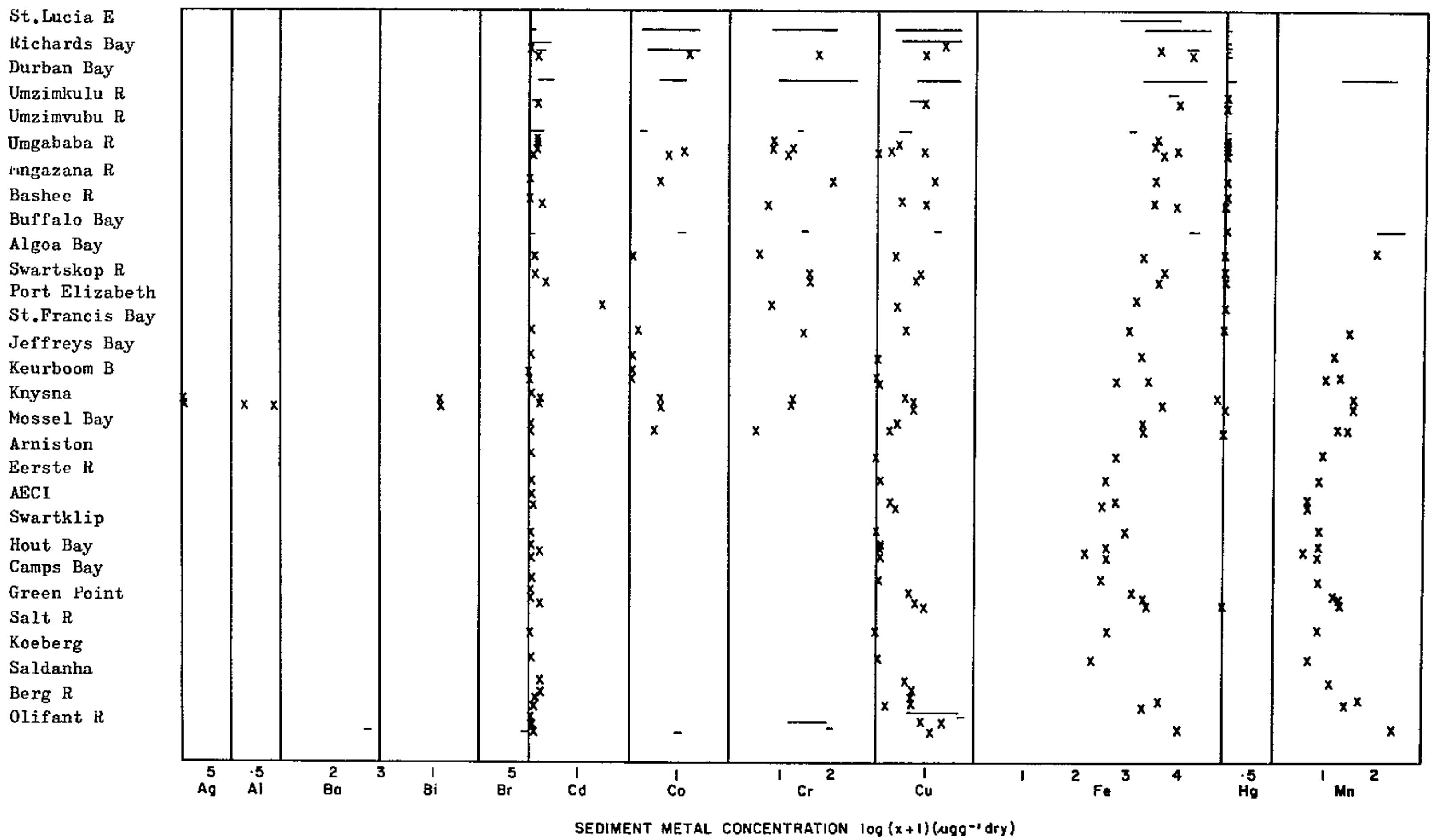
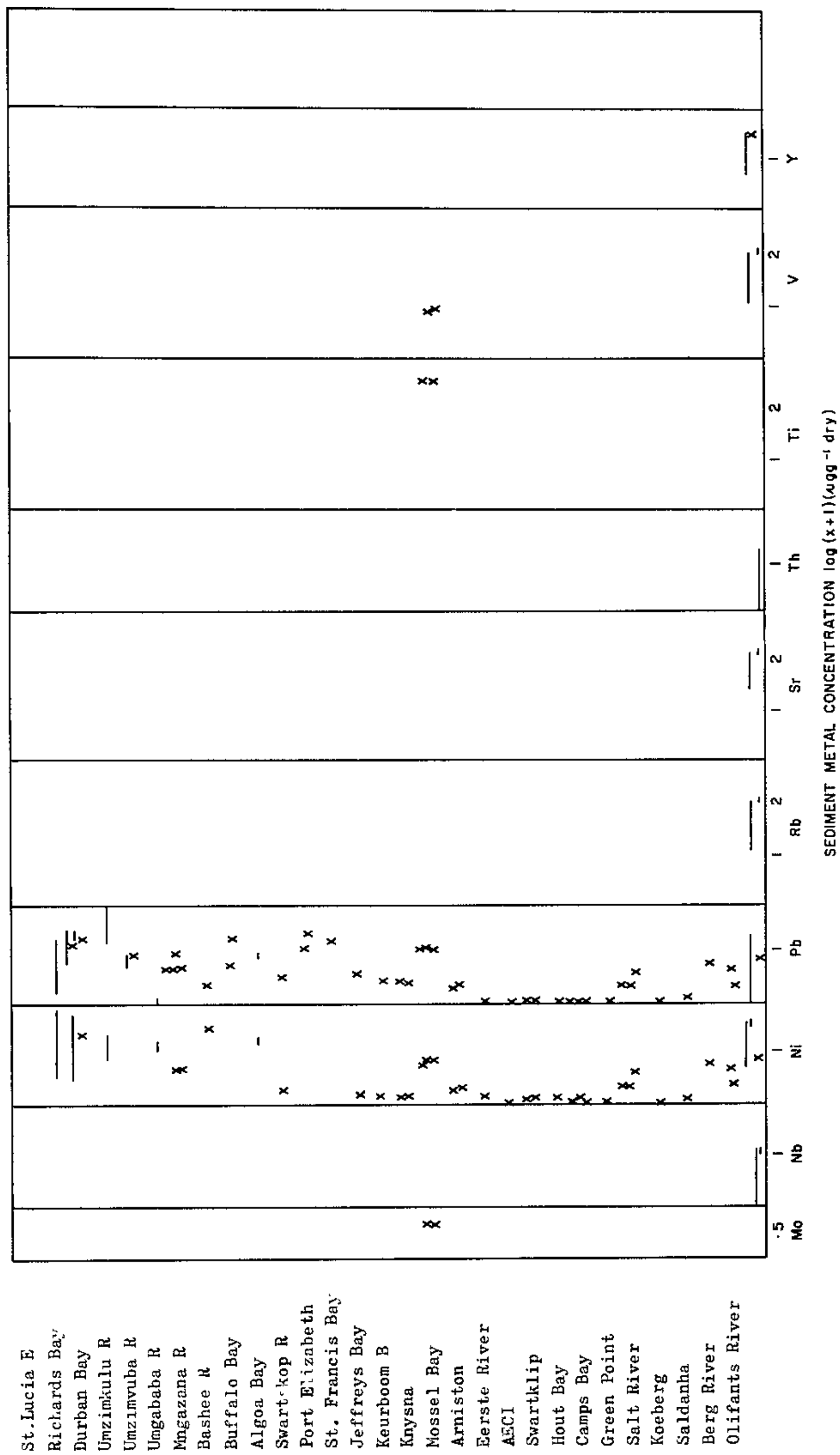
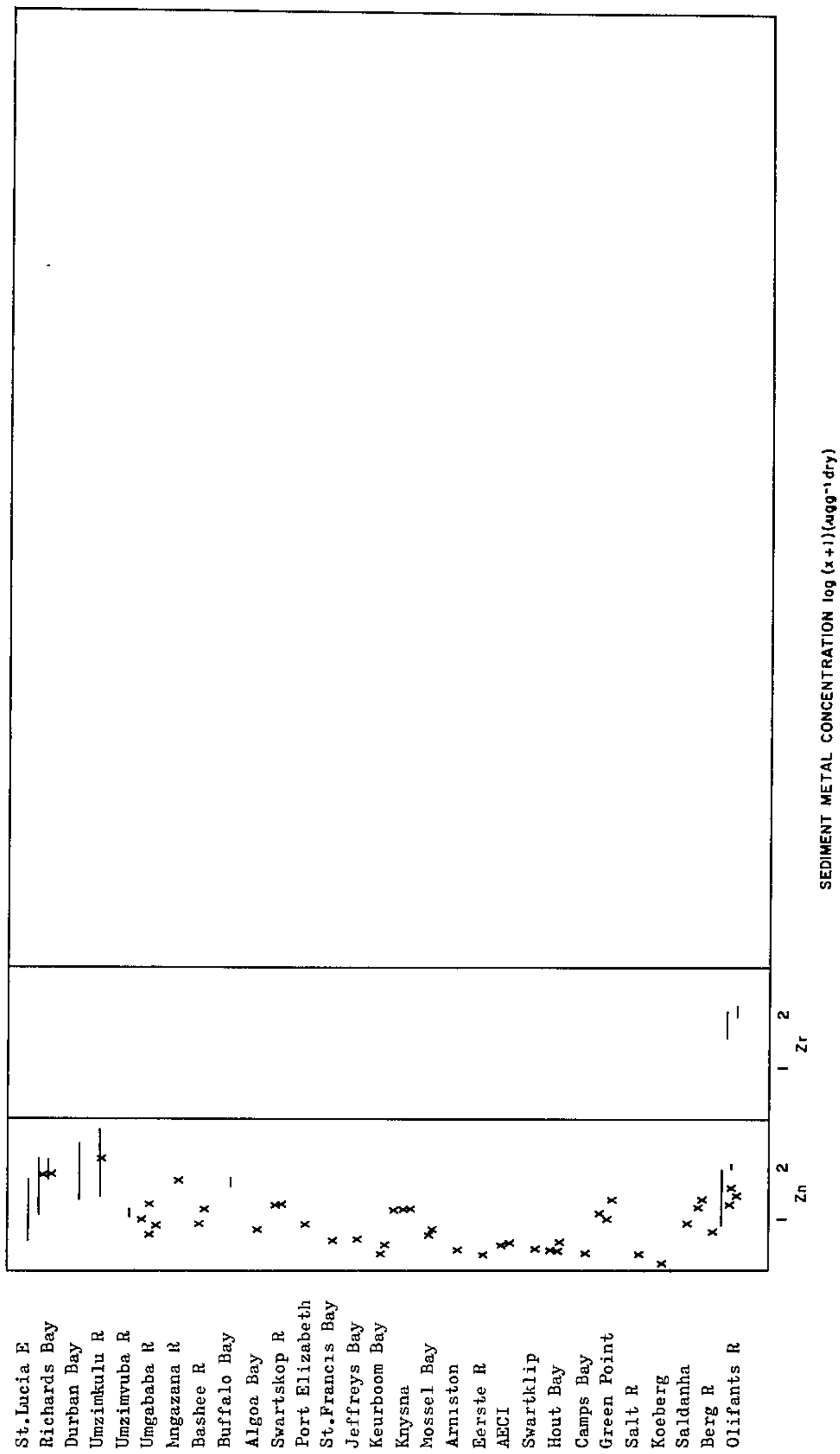


Figure 8 Metal concentrations in sediment at different locations along the coast of South Africa. All figures refer to μg g^{-1} in dry sediment



St.Lucia E
Richards Bay
Durban Bay
Umzimkulu R
Umzimvuba R
Umgababa R
Mngazana R
Bashee R
Buffalo Bay
Algoa Bay
Swartkop R
Port Elizabeth
St. Francis Bay
Jeffreys Bay
Keurboom B
Knysna
Mossel Bay
Arniston
Eerste River
AECI
Swartklip
Hout Bay
Camps Bay
Green Point
Salt River
Koeberg
Saldanha
Berg River
Olifants River
·5 Mo
1 Nb
1 Ni
1 Pb
1 Rb 2
1 Sr 2
1 Th
1 Ti 2
1 V 2
1 Y
SEDIMENT METAL CONCENTRATION log(x+1)(µgg⁻¹ dry)


St.Lucia E
Richards Bay
Durban Bay
Umzinkulu R
Umzimvuba R
Umgababa R
Mngazana R
Bashee R
Buffalo Bay
Algoa Bay
Swartskop R
Port Elizabeth
St.Francis Bay
Jeffreys Bay
Keurboom Bay
Knysna
Mossel Bay
Arniston
Eerste R
AECI
Swartklip
Hout Bay
Camps Bay
Green Point
Salt R
Koeberg
Saldanha
Berg R
Olifants R
1
2
Zn
1
2
Zr
SEDIMENT METAL CONCENTRATION log (x+1)(µgg-1dry)

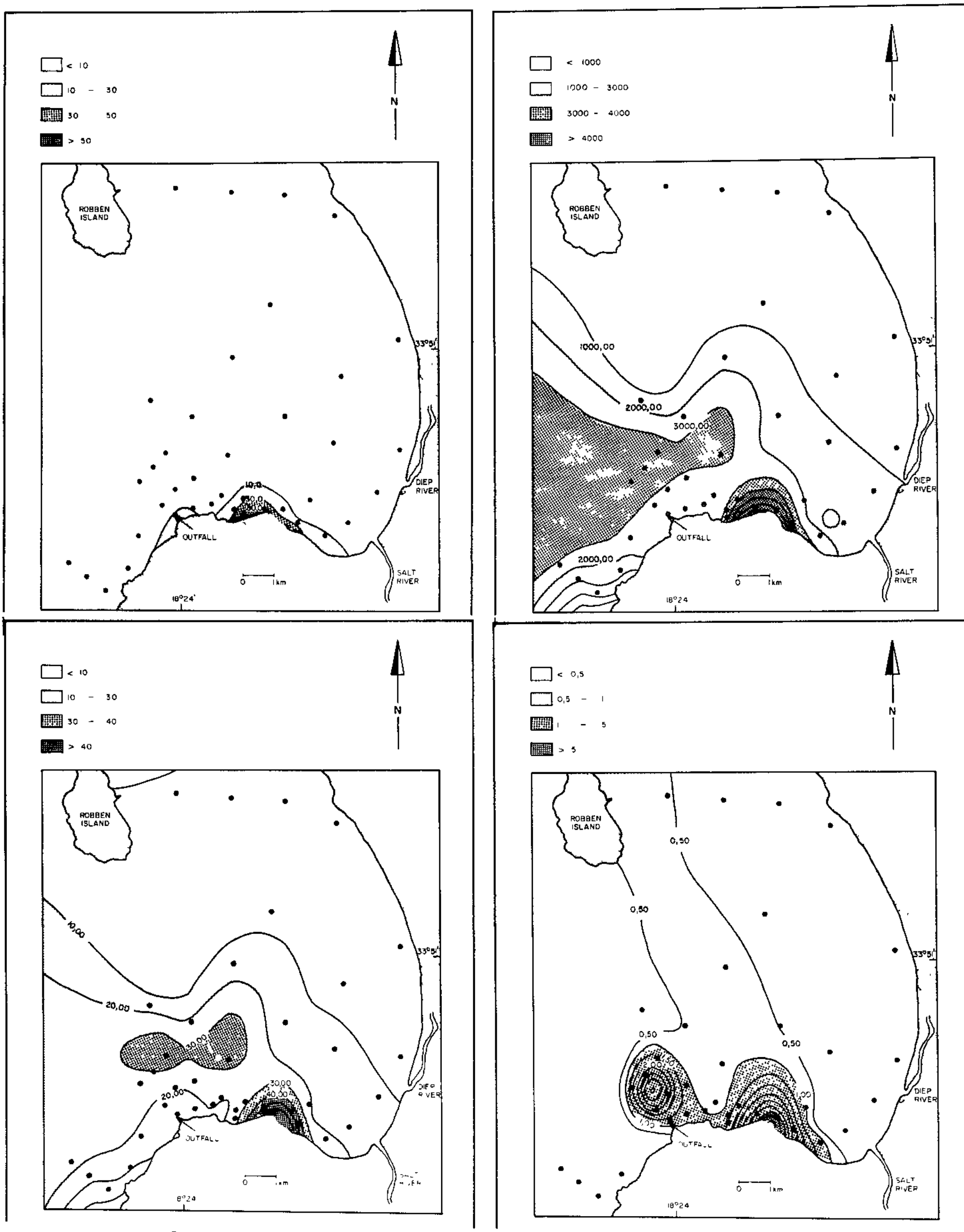


Figure 9 Metal concentrations in Table Bay sediments ($\mu g\ g^{-1}$) top left: copper; top right: iron; bottom left: manganese; bottom right: nickel

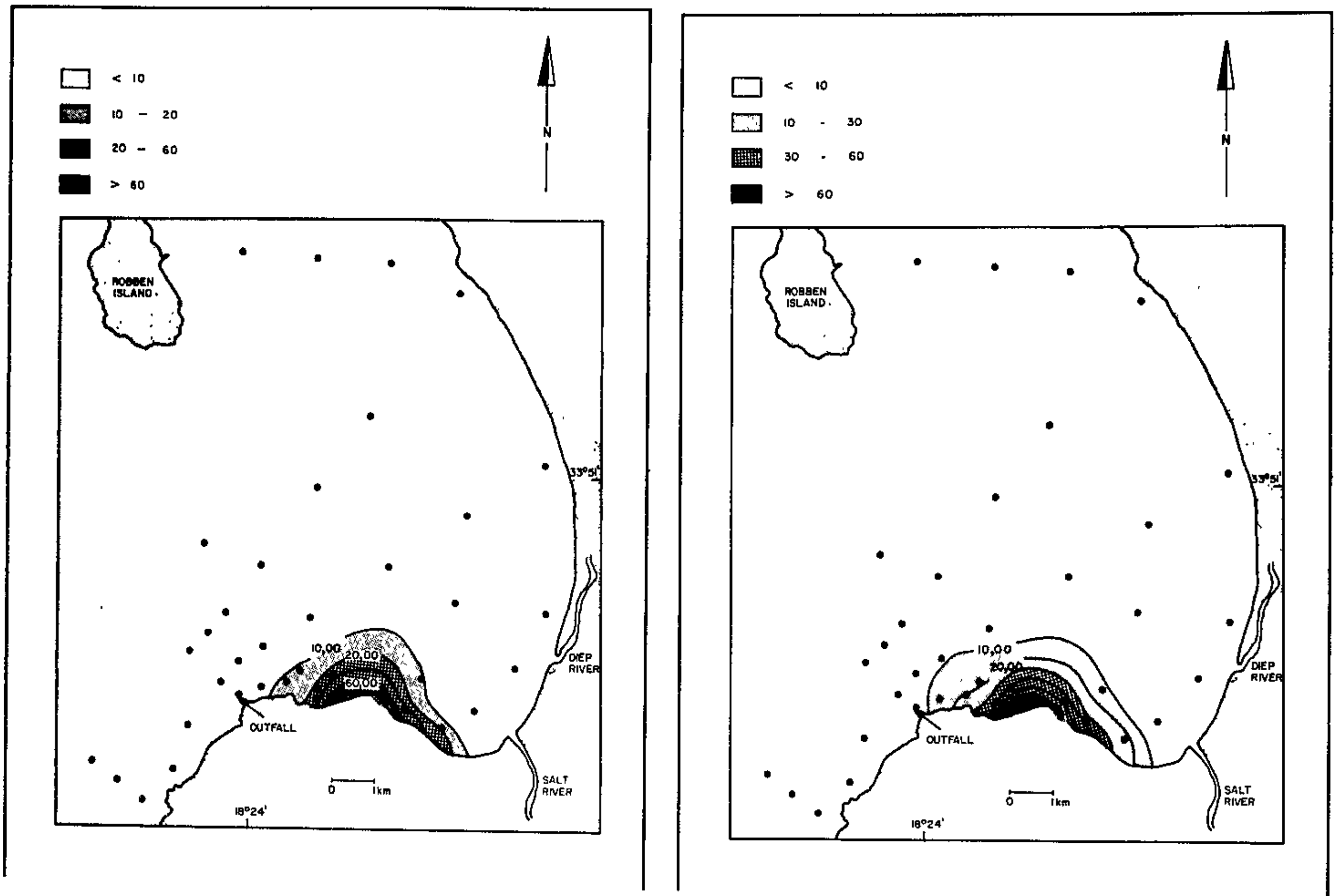


Figure 10 Metal concentrations in Table Bay sediments ($\mu g\ g^{-1}$) left: lead; right: zinc

TABLE IV: SUMMARY OF METAL CONCENTRATION IN MARINE ORGANISMS (d = dry mass; w = wet mass; units = $\mu g\ g^{-1}$)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	Sr	Reference
Kosi Bay																		
d Plankton (E)	1976	12.200	20.806	17.897	884.836	6 920.274	0.152			129.516	1 096.743							Oliff and Turner, 1976
d Plankton (M)	1976	129.664	166.666	192.241	579 921.132	66 774.22	1.130			812.980	21 528.560							Oliff and Turner, 1976
d Plankton (O)	1976	7.205	13.662	6.643	806.78	3 576.571	0.057			66.784	413.393							Oliff and Turner, 1976
d Plankton (F)	1976	15.367	ND	234.240	24.415	20 461.76	3.054			84.078	1 151.88							Oliff and Turner, 1976
d Perna perna	1976	1.20	4.73	7.53	6.60	1 440.0				157.33	44.0							Watling, 1978
d Cheimerius nufar (muscle)	1976	0.519	ND	0.818	0.500	17.968	1.033			2.129	15.626							Oliff and Turner, 1976
d Cheimerius nufar (liver)	1976	15.812	0.830	0.490	28.716	574.713	0.941			1.985	129.581							Oliff and Turner, 1976
d Chrysoblephus puniceus (muscle)	1976	0.109	1.417	0.927	1.745	20.107	0.329			4.360	18.861							Oliff and Turner, 1976
d Thunnus sp. (liver)	1976	55.391	0.795	0.819	18.868	243.228	0.050			0.467	90.846							Oliff and Turner, 1976
d Thunnus sp. (muscle)	1976	0.325	1.684	1.190	1.850	33.381	0.111			0.742	53.381							Oliff and Turner, 1976
d Perna sp.	1976	1.186	4.70	7.51	6.62	1 441.2	0.124			157.00	43.69							Oliff and Turner, 1976
d Bullia natalensis	1976	12.18	11.06	6.11	5.38	226.8	0.026			31.08	50.17							Oliff and Turner, 1976
d Crassostrea margaritacea	1976	7.87	3.81	20.48	10.0	283.63	ND			4.30	646.9							Oliff and Turner, 1976
d Trachinotus russellii (muscle)	1976	0.16	1.71	3.12	1.44	35.56	0.073			6.72	20.92							Oliff and Turner, 1976
d Lutianus argentimaculatus (muscle)	1976	0.573	0.205	3.79	2.15	35.49	0.076			ND	ND							Oliff and Turner, 1976
d Lutianus argentimaculatus (liver)	1976	1.08	2.67	3.19	133.68	1 022.7	0.335			71.12	492.5							Oliff and Turner, 1976
d Johnius hololepidotus (muscle)	1976	0.587	1.27	34.94	6.60	118.55	0.096			3.64	7.87							Oliff and Turner, 1976
d Johnius hololepidotus (liver)	1976	2.72	ND	29.63	36.21	731.9	0.156			10.20	128.5							Oliff and Turner, 1976
d Callianassa sp.	1976	1.48	2.32	ND	290.9	514.19	0.164			6.97	50.45							Oliff and Turner, 1976
d Panulirus homarus (muscle)	1976	0.201	2.63	2.14	34.46	26.13	0.063			2.15	62.51							Oliff and Turner, 1976
d Mugil cephalus (liver)	1976	12.08	3.79	28.22	32.98	2 142.5	0.147			ND	165.24							Oliff and Turner, 1976
d Mugil canaliculatus (liver)	1976	1.52	0.658	62.32	22.98	693.2	0.245			6.97	117.32							Oliff and Turner, 1976
d Mugil cephalus (muscle)	1976	0.59	1.108	13.55	9.78	117.36	0.041			5.06	9.83							Oliff and Turner, 1976
d Mugil canaliculatus (muscle)	1976	1.47	1.61	20.33	3.58	62.80	ND			2.31	5.85							Oliff and Turner, 1976
d Rhabdosargus sp.	1976	0.17	1.03	3.82	2.56	25.85	ND			8.27	13.96							Oliff and Turner, 1976
d Diplodus sargus (muscle)	1976	2.06	2.70	4.04	6.64	25.06	ND			7.48	69.47							Oliff and Turner, 1976
d Acanthopagrus berda (liver)	1976									0.827								Oliff and Turner, 1976
d Acanthopagrus berda (muscle)	1976	0.40	0.63	21.44	3.85	121.4	0.108			4.74	49.45							Oliff and Turner, 1976
d Elops machnata (muscle)	1976	2.47	1.79	19.02	6.34	84.1	0.008			5.45	13.0							Oliff and Turner, 1976
d Pomadasys commersonni (liver)	1976									0.128								Oliff and Turner, 1976
d Pomadasys commersonni (muscle)	1976	0.382	2.75	82.56	6.93	265.99	0.181			3.34	36.19							Oliff and Turner, 1976
St Lucia																		
d Loligo	1976	4.543	0.516	0.848	16.311	31.239	ND			4.370	12.043							Oliff and Turner, 1976

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	V	Reference
Richards Bay																		
d *Penaeus indicus*	1976	0.8			38.1				ND		21.7							Oliff and Turner, 1976
d *Argyrosomus hololepidotus* (muscle)	1976	2.0			7.5				ND		2.4							Oliff and Turner, 1976
d *Argyrosomus hololepidotus* (liver)	1976	3.9			10.3				ND		82.1							Oliff and Turner, 1976
d *Otolithes ruber* (muscle)	1976	1.1			0				ND		32.0							Oliff and Turner, 1976
d *Otolithes ruber* (liver)	1976	2.7			13.4				ND		80.8							Oliff and Turner, 1976
d *Rhabdosargus holubi* (muscle)	1976	1.0			ND				ND		89.1							Oliff and Turner, 1976
d *Rhabdosargus holubi* (liver)	1976	1.8			11.6				ND		173.1							Oliff and Turner, 1976
d *Mugil cephalus* (muscle)	1976	0.4			ND				ND		71.8							Oliff and Turner, 1976
d *Mugil cephalus* (liver)	1976	0.4			169.8				ND		149.5							Oliff and Turner, 1976
d *Elops machnata* (muscle)	1976	0.6			ND				ND		5.0							Oliff and Turner, 1976
d *Elops machnata* (liver)	1976	1.0			39.5				ND		86.9							Oliff and Turner, 1976
d *Pomadasys commersonni* (muscle)	1976	0.6			ND				ND		72.5							Oliff and Turner, 1976
d *Pomadasys commersonni* (liver)	1976	1.9			39.5				ND		148.5							Oliff and Turner, 1976
Port Durnford Point																		
w *Acanthopagrus berda* (muscle)	1974	0.681			0.05		0.045			11.32								Connell *et al.*, 1975
w *Rhabdosargus* sp. (muscle)	1974	0.066			0.3	4	0.029			0.72	56							Connell *et al.*, 1975
w *Emerita austroafricana*	1974	1.040			20.43		0.008			9.07								Connell *et al.*, 1975
w *Penaeus indicus*	1974	0.474			25.15		0.011			4.19	17							Connell *et al.*, 1975
w *Johnius hololepidotus* (muscle)	1974	0.086			0.09	13	0.018			1.19	7							Connell *et al.*, 1975
w *Johnius hololepidotus* (liver)	1974	2.011			2.47	251	0.035			0.35	24							Connell *et al.*, 1975
w *Mugil* sp. (muscle)	1974	0.077			0.75	11	0.015			0.71	52							Connell *et al.*, 1975
w *Pomadasys commersonni* (muscle)	1974	ND			0.25	ND	0.099			ND	ND							Connell *et al.*, 1975
w *Pomadasys commersonni* (liver)	1974	0.620			58.27	657	0.018			0.15	45							Connell *et al.*, 1975
Umgeni Estuary																		
w *Mugil*	1974	ND			0.387		0.17			ND	4.7							Connell *et al.*, 1975
w *Tilapia*	1974	ND			0.42		0.25			ND	15.2							Connell *et al.*, 1976
Umhlanga Rocks																		
w *Perna perna*	1972	0.29			14						0.95							Darracott and Watling, 1975
d *Perna perna*	1974	2	3	2	7	557		7	6	4	93			568		0.3	6	Watling and Watling, 1974
w *Perna perna*	1975	0.27	0.44	0.35	1.01	84		1.04	0.95	0.56	14.0							Watling, 1978
w *Perna perna*	1974						0.016											Connell *et al.*, 1975
Durban Bay																		
w *Panulirus versicolor*	1974						0.079											Connell *et al.*, 1975
w Plankton							0.004											Connell *et al.*, 1975

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	Sr	Mo	Reference
Umbogintwini																			
w Emerita austroafricana	1974						0.237												Connell et al., 1975
w Panulirus homarus	1974						0.199												Connell et al., 1975
Fynnlands																			
w Panulirus homarus	1974						0.383												Connell et al., 1975
Umhlatuzana																			
w Mugil sp.	1974	ND			2.60		0.024			ND	23.2								Connell et al., 1975
w Mugil sp.	1974	ND			0.63		0.026			ND	4.7								Connell et al., 1975
w Therapon jarbua	1974	ND			0.56		0.041			ND	15.1								Connell et al., 1975
w Sarotheradon mossambicus	1974	ND			0.39		0.023			ND	4.3								Connell et al., 1975
Umzimkulu Estuary																			
w Mugil sp.							0.012												Connell et al., 1975
w Acanthopagrus berda	1974						0.207												Connell et al., 1975
Umgababa Estuary																			
d Panulirus homarus (muscle)	1976	0.52	2.7	1.0	41.7	87	0.481			4	81								Oliff and Turner, 1976
d Crassostrea margaritacea	1976	4.97	4.6	0.8	352.6	453	0.189			4	3 279								Oliff and Turner, 1976
d Upogebia africana	1976	2.90	12.6	0.7	145.0	1 349	0.089			26	207								Oliff and Turner, 1976
d Acanthopagrus berda (muscle)	1976	0.50	3.5	0.2	4.0	167	1.15			4	57								Oliff and Turner, 1976
d Crassostrea margaritacea	1976	1.01	0.63	0.03	81.9	46				1.35	600								Watling, 1978
Bashee Estuary																			
w Panulirus homarus	1975	0.06		0.03	4.28	1	0.0171			1.2	8.2								Oliff and Turner, 1976
w Pomadasys commersonni	1975	0.30		0.10	0.53	10	0.0449			4.6	10.2								Oliff and Turner, 1976
w Argyrosomus hololepidotus (muscle)*	1975	0.18		0.05	0.28	5	0.0454			2.5	3.5								Oliff and Turner, 1976
w Acanthopagrus berda (muscle)**	1975	0.13		0.04	0.34	5	0.4158			2.1	6.9								Oliff and Turner, 1976
w Hypacanthus amia (muscle)***	1975	0.15		0.03	0.34	5	0.2407			2.6	4.8								Oliff and Turner, 1976
w Argyrosomus (liver)*	1975	0.57		0.04	3.03	257	0.0263			5.0	20.0								Oliff and Turner, 1976
w Acanthopagrus (liver)**	1975	0.69		ND	4.05	180	0.3448			2.0	33.3								Oliff and Turner, 1976
w Hypacanthus (liver)***	1975	0.20		0.02	5.46	116	0.0646			1.2	17.4								Oliff and Turner, 1976
w Pachymetopon grande (muscle)	1975	0.32		0.40	0.60	12	0,0111			4.9	11.4								Oliff and Turner, 1976
w Pachymetopon grande (liver)	1975	21.62		0.12	18.02	808	0.0511			1.9	879.4								Oliff and Turner, 1976
w Upogebia africana	1975	0.23		0.33	15.90	208	0.0096			3.9	8.48								Oliff and Turner, 1976
w Crassostrea margaritacea	1975	0.76		0.22	9.55	38	0.0068			5.2	688.5								Oliff and Turner, 1976
w Bullia	1975	4.04		1.78	3.56	80	0.0079			17.1	23.8								Oliff and Turner, 1976
w Plankton (river)	1975	0.14		0.12	3.63	58	0.0060			1.8	10.0								Oliff and Turner, 1976
w Penaeus monodon	1975	0.37		0.22	25.46	95	0.0097			6.1	16.3								Oliff and Turner, 1976
w Perna perna	1975	0.39		0.12	1.38	54	0.0060			2.1	10.2								Oliff and Turner, 1976

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	Sr	Mo	Reference
Algoa Bay																			
w Crassostrea margaritacea	1977	0.21	0.02	0.23	7.7	39		1.18	0.06	0.15	574								Watling, 1978
w Patella longicosta		2.71	0.19	1.06	1.09	212.09		1.57	0.39	0.24	14.89								Watling and Watling, 1981a
w Perna perna		0.23	0.15	0.83	1.40	75.52		2.24	1.51	0.46	22.29								Watling and Watling, 1981a
w Crassostrea margaritacea		0.59	0.06	1.37	5.29	34.65		1.59	0.17	0.39	669.03								Watling and Watling, 1981a
w Patella oculus		1.13	0.011	1.03	0.87	463.95		1.70	0.47	0.24	13.57								Watling and Watling, 1981a
w Bullia rhodostoma		3.40	0.10	2.07	1.73	47.44		1.53	0.15	0.13	46.38								Watling and Watling, 1981a
w Crassostrea margaritacea	78/79	0.24	0.06	2.5	7.9	50		1.6	0.16	0.69	1 054								Watling and Watling, 1983
w Crassostrea margaritacea	78/79	0.99	0.07	0.04	2.7	21		1.7	0.17	0.13	249								Watling and Watling, 1983
w Perna perna	78/79	0.23	0.12	0.8	1.4	88		2.4	1.52	0.62	24.6								Watling and Watling, 1983
w Perna perna	78/79	0.22	0.21	0.9	1.3	107		2.2	1.36	0.20	17.8								Watling and Watling, 1983
w Patella granularis	78/79	3.1	0.07	3.3	2.0	403		2.4	1.15	0.23	13.9								Watling and Watling, 1983
w Patella oculus	78/79	1.2	0.13	1.4	1.2	581		2.2	0.64	0.35	15.9								Watling and Watling, 1983
w Patella oculus	78/79	1.7	0.12	1.6	1.1	574		2.0	0.99	0.04	10.7								Watling and Watling, 1983
w Patella barbara	78/79	2.5	0.10	1.7	1.0	255		2.4	0.77	0.40	267								Watling and Watling, 1983
w Patella barbara	78/79	4.0	0.24	1.5	0.9	380		1.9	0.78	0.32	24.9								Watling and Watling, 1983
w Patella longicosta	78/79	2.6	0.18	1.1	1.1	215		1.6	0.40	0.27	15.0								Watling and Watling, 1983
w Patella longicosta	78/79	2.9	0.09	1.3	1.9	268		1.6	0.68	0.36	16.2								Watling and Watling, 1983
w Patella miniata	78/79	3.7	0.04	0.6	0.8	177		0.9	0.31	0.07	9.6								Watling and Watling, 1983
w Patella miniata	78/79	3.3	0.05	1.6	1.3	675		3.0	0.87	0.12	10.3								Watling and Watling, 1983
w Patella cochlear	78/79	6.3	0.10	0.7	0.9	99		0.6	0.75	0.08	10.2								Watling and Watling, 1983
w Patella tabularis	78/79	1.40	0.08	0.4	1.1	145		1.0	0.28	0.39	17.0								Watling and Watling, 1983
w Donax serra	78/79	0.05	0.03	0.6	0.9	81		1.5	0.28	0.03	10.9								Watling and Watling, 1983
w Bullia rhodostoma	78/79	4.2	0.13	0.8	2.0	50		1.5	0.19	0.10	36.9								Watling and Watling, 1983
w Bullia rhodostoma	78/79	3.1	0.10	2.3	1.7	48		1.5	0.16	0.12	46.3								Watling and Watling, 1983
St Croix																			
d Patella cochlear	1975	16.604		3.391	6.525	403.130	0.066			40.332	36								Oliff and Turner, 1976
d Perna perna	1975	3.323		4.106	11.167	422.691	0.150			26.346	60								Oliff and Turner, 1976
w Perna perna	1975	0.50		0.62	1.68	63				3.95	9								Watling, 1978
d Oplegnathus conwayi (muscle)	1975	0.500		2.357	2.621	18.408	0.199			26.412	22								Oliff and Turner, 1976
d Oplegnathus conwayi (liver)	1975	13.650		5.868	26.555	737.211	1.034			5.648	116								Oliff and Turner, 1976
Swartkops Estuary																			
d Rhabdosargus holubi	1975	0.782		1.789	2.926	20.972	0.310			18.104	36								Oliff and Turner, 1976
d Callianassa kraussi	1975	3.468		6.526	70.128	792.228	0.571			53.514	69								Oliff and Turner, 1976
w Callianassa kraussi	1975	0.75			69.4	225.5	0.042			10.93	25.08								Oliff and Turner, 1976
w Scylla serrata	1975	0.26			28.6	6.21	0.115			3.42	40.96								Oliff and Turner, 1976

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	Sr	Mo	Reference
w *Upogebia africana*	1975	0.56			44.5	163.6	0.049			8.59	19.18								Oliff and Turner, 1976
w *Crassostrea margaritacea*	1975	0.26			79.3	27.0	0.042			3.01	333.1								Oliff and Turner, 1976
w *Striliza canaliculatus*	1975	0.09			0.42	4.07	0.042			1.58	6.28								Oliff and Turner, 1976
w *Mugil cephalus*	1975	0.06			0.28	3.89	0.017			1.32	4.43								Oliff and Turner, 1976
w *Argyrosomus hololepidotus* (muscle)	1975	0.04			0.15	1.05	0.152			1.02	5.04								Oliff and Turner, 1976
w *Argyrosomus hololepidotus* (liver)	1975	0.09			3.44	151.3	0.156			4.49	22.52								Oliff and Turner, 1976
w *Hypacanthus amia*	1975	0.16			0.60	2.75	0.114			1.18	7.26								Oliff and Turner, 1976
w *Pomadasys commersonni* (muscle)	1975	0.14			0.33	3.20	0.190			2.04	6.91								Oliff and Turner, 1976
w *Pomadasys commersonni* (liver)	1975	0.23			42.9	209.0	0.410			4.08	32.16								Oliff and Turner, 1976
w *Rhabdosargus holubi*	1975	0.13			0.35	3.36	0.146			1.93	7.84								Oliff and Turner, 1976
d *Sardinops ocellata* (muscle)	1979	0.405	0.2	6.958	5.560	69.160	0.018	2.414	1.539	0.2	22.320								Van der Byl, 1980
d *Sardinops ocellata* (liver)	1979	0.712	0.2	0.314	10.916	1 110.000	0.013	5.148	0.873	0.2	74.200								Van der Byl, 1980
d *Sardinops ocellata* (ovaries)	1979	0.807	0.2	6.468	4.236	117.540	0.158	6.300	0.322	0.2	224.400								Van der Byl, 1980
d *Sardinops ocellata* (testes	1979	0.426	0.2	2.118	4.984	111.740	ND	2.204	0.556	0.2	52.420								Van der Byl, 1980
Port Elizabeth																			
d *Bullia rhodostoma*	1975	12.191		9.923	33.297	257.602	0.237			86.191	198								Oliff and Turner, 1976
d *Perna perna*	1975	1.761		4.968	10.614	471.846	0.170			27.620	80								Oliff and Turner, 1976
d *Choromytilus meridionalis*	1975	3.448		4.046	18.470	376.477	10.282			26.919	102								Oliff and Turner, 1976
d *Burnupena cincta*	1975	16.454		8.500	102.136	236.503	0.680			19.510	1 223								Oliff and Turner, 1976
Maitland																			
w *Donax serra*	1975	0.04			1.6	72		1.93		0.03	28								Watling, 1978
St Francis Bay																			
w *Crassostrea margaritacea*	78/79	1.57	0.11	0.8	4.4	39		1.0	0.10	0.04	114								Watling and Watling, 1983
w *Perna perna*	78/79	0.58	0.17	0.5	1.2	94		1.5	2.02	0.10	19.0								Watling and Watling, 1983
w *Patella granularis*	78/79	8.9	0.06	1.6	1.3	518		1.4	1.14	0.09	12.0								Watling and Watling, 1983
w *Patella oculus*	78/79	3.8	0.12	0.8	0.7	466		1.0	0.51	0.06	11.2								Watling and Watling, 1983
w *Patella barbara*	78/79	5.9	0.10	1.4	0.8	208		1.1	0.79	0.11	14.4								Watling and Watling, 1983
w *Patella longicosta*	78/79	14.3	0.08	1.2	0.8	149		0.9	0.44	0.05	13.7								Watling and Watling, 1983
w *Patella miniata*	78/79	6.3	0.04	1.2	1.0	286		1.5	0.70	0.05	10.3								Watling and Watling, 1983
w *Patella argenvillei*	78/79	10.5	0.05	0.5	0.7	85		0.7	0.53	0.01	10.1								Watling and Watling, 1983
w *Patella cochlear*	78/79	9.6	0.06	1.6	1.4	86		0.6	0.64	0.04	9.7								Watling and Watling, 1983
w *Patella tabularis*	78/79	9.9	0.04	0.7	0.8	40		0.6	0.17	0.03	8.9								Watling and Watling, 1983
w *Donax serra*	78/79	0.04	0.07	0.8	1.0	231		2.2	0.33	0.06	13.2								Watling and Watling, 1983
w *Bullia rhodostoma*	78/79	5.9	0.08	1.8	1.7	39		1.6	0.18	0.10	42.4								Watling and Watling, 1983

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	Sr	Mo	Reference
Keurboom																			
w *Donax serra*	1975	0.14	0.04	0.16	1.18	84		1.15	0.43	0.03	15.6								Watling, 1978
w *Solen capensis*	1975	0.27	0.22	0.21	0.52	56		1.01	0.26	0.36	8.7								Watling, 1978
Cathedral Rock																			
w *Perna perna*	1975	0.37	0.04	0.46	0.70	37		0.56	0.66	0.11	7.8								Watling, 1978
w *Crassostrea margaritacea*	1975	2.28	0.03	1.02	4.7	36		1.30	0.79	0.37	50								Watling, 1978
Noetzie																			
w *Perna perna*	1975	1.07	0.24	0.16	0.84	41		0.70	1.37	0.40	12.0								Watling, 1978
w *Crassostrea margaritacea*	1975	2.49	0.31	0.40	4.1	23		1.20	0.54	0.69	156								Watling, 1978
Knysna East Head																			
w *Patella oculus*	1978	3.8	0.03	0.83	0.61	177		0.71	0.23	0.05	8.8								Watling and Watling, 1980
w *Patella longicosta*	1978	11.1	0.06	1.01	0.61	89		0.83	0.25	0.09	12.1								Watling and Watling, 1980
w *Patella miniata*	1978	5.1	0.02	1.04	0.72	230		1.21	0.30	0.04	9.0								Watling and Watling, 1980
w *Patella argenvillei*	1978	5.8	0.04	0.56	0.70	68		0.84	0.33	0.02	10.3								Watling and Watling, 1980
w *Patella cochlear*	1978	7.2	0.07	1.40	0.75	106		1.05	0.41	0.05	10.0								Watling and Watling, 1980
w *Patella barbara*	1978	4.2	0.06	1.26	0.94	247		1.88	0.44	0.31	13.1								Watling and Watling, 1980
w *Perna perna*	1975	0.61	0.17	0.35	1.4	105		1.01	1.41	0.08	18.4								Watling, 1978
w *Perna perna*	1978	0.55	0.07	0.76	0.94	64		0.73	1.21	0.04	12.8								Watling and Watling, 1980
Beacon Point																			
w *Perna perna*	1975	0.30	0.02	0.32	0.43	36		0.40	0.30	0.15	6.8								Watling, 1978
w *Crassostrea margaritacea*	1975	1.34	0.06	2.96	2.5	47		0.74	1.45	0.44	332								Watling, 1978
w *Patella granularis*	1978	3.3	0.05	0.39	1.1	377		1.3	0.74	0.14	11.9								Watling and Watling, 1980
w *Patella barbara*	1978	3.7	0.13	0.59	0.82	258		1.10	0.68	0.19	17.9								Watling and Watling, 1980
w *Patella oculus*	1978	2.39	0.09	0.62	0.71	379		1.07	0.56	0.15	10.8								Watling and Watling, 1980
w *Patella longicosta*	1978	7.09	0.09	0.74	0.65	121		1.07	0.34	0.15	11.2								Watling and Watling, 1980
w *Patella miniata*	1978	4.02	0.06	0.69	0.93	334		8.50	0.38	0.12	9.9								Watling and Watling, 1980
w *Patella cochlear*	1978	3.9	0.09	0.71	0.88	123		1.66	1.01	0.09	7.1								Watling and Watling, 1980
w *Perna perna*	1976	0.30	0.02	0.32	0.43	36		0.40	0.30	0.15	6.8								Watling and Watling, 1980
w *Perna perna*	1978	0.99	0.12	0.63	1.20	66		1.05	1.51	0.09	15.5								Watling and Watling, 1980
Knysna West Head																			
w *Perna perna*	1975	1.00	0.08	1.25	1.09	87		0.87	1.17	0.11	11.3								Watling and Watling, 1980
w *Perna perna*	1978	0.70	0.10	0.74	0.90	77		0.80	1.13	0.05	11.6								Watling and Watling, 1980
w *Patella cochlear*	1978	7.5	0.06	1.29	0.52	91		0.56	0.28	0.03	8.1								Watling and Watling, 1980
w *Patella argenvillei*	1978	10.8	0.12	0.28	0.95	86		1.53	0.35	0.04	10.5								Watling and Watling, 1980

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	Sr	Mo	Reference
w *Patella miniata*	1978	9.80	0.03	0.82	0.61	87		0.60	0.26	0.04	7.9								Watling and Watling, 1980
w *Patella longicosta*	1978	11.9	0.08	1.07	0.50	53		0.57	0.15	0.06	10.7								Watling and Watling, 1980
w *Patella oculus*	1978	4.5	0.10	0.73	0.47	143		0.80	0.18	0.07	8.6								Watling and Watling, 1980
Featherbed																			
w *Crassostrea margaritacea*	1975	1.73	0.32	0.34	1.1	22		0.97	0.44	0.82	95								Watling, 1978
w *Perna perna*	1976	0.52	0.08	0.69	1.15	99		0.78	0.98	0.13	13.1								Watling and Watling, 1980
Bellvedere																			
w *Crassostrea gigas*	1975	0.56	0.15	0.11	5.7	20		2.1	0.26	0.21	69								Watling, 1978
w *Crassostra margaritacea*	1975	0.49	0.22	0.40	3.6	11		0.46	0.38	0.33	197								Watling, 1978
w *Ostrea atherstonei*	1975	0.75			14.2	81		0.70		0.31	692								Watling, 1978
w *Crassostrea cucullata*	1978	0.67	0.06	1.18	15	46		0.63	0.33	0.10	105								Watling and Watling, 1980
w *Crassostrea cucullata*	1978	0.61	0.04	0.16	13	21		0.40	0.05	0.04	123								Watling and Watling, 1980
w *Crassostrea margaritacea*	1977	1.09	0.02	0.33	2.6	13		0.6	0.04	0.07	121								Watling and Watling, 1980
Leisure Island																			
w *Perna perna*	1975	0.93	0.19	1.4	1.57	93		0.91	3.2	0.17	138								Watling, 1978
w *Venus verrucosa*	1975	0.55	0.56	0.87	1.15	52		0.71	1.08	0.63	7.6								Watling, 1978
w *Atrina squamifera*	1975	2.6	0.38	0.20	0.74	45		0.54	0.59	0.13	70								Watling, 1978
w *Atrina squamifera*	1978	3.8	0.22	0.97	1.48	131		0.85	0.66	0.12	206								Watling and Watling, 1980
w *Venus verrucosa*	1975	0.47	0.21	0.23	1.13	56		0.66	0.74	0.19	7.5								Watling and Watling, 1980
w *Venus verrucosa*	1976	0.79			2.80	63		1.13		0.29	11.0								Watling and Watling, 1980
w *Venus verrucosa*	1978	0.79	0.34	0.84	1.81	123		0.98	0.66	0.20	8.9								Watling and Watling, 1980
w *Mactra glabrata*	1975	1.27			1.07	111		1.10		0.34	12.0								Watling and Watling, 1980
Knysna																			
w *Crassostrea gigas*	1972	1.3			4.4						69								Darracott and Watling, 1975
w *Crassostrea margaritacea*	1972	1.3			3.6														Darracott and Watling, 1975
d *Ostrea edulis*	1975	3.1			38	167		6	1.7	66.0	1.7								Watling and Watling, 1976a
d *Crassostrea gigas*	1975	3.7			32	138		16	1.6	396	1.9								Watling and Watling, 1976a
d *Crassostrea margaritacea*	1975	2.5			17	57		2	1.6	886	2.6								Watling and Watling, 1976a
Thesens Point																			
w *Solen capensis*	1975	0.58			1.09	105		1.21		0.62	16.3								Watling and Watling, 1980
w *Solen capensis*	1978	0.46	0.09	0.84	0.80	260		1.50	0.14	0.10	10.10								Watling and Watling, 1980
w *Perna perna*	1975	0.12	0.04	0.11	0.38	39		0.28	0.40	0.06	5.0								Watling, 1978

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	Sr	Mo	Reference
Castle Rock																			
w *Perna perna*	1975	0.86	0.32	0.37	1.02	44		0.97	1.98	0.50	15.6								Watling, 1978
w *Crassostrea margaritacea*	1975	2.39	0.24	0.42	3.8	15		1.35	0.46	0.85	107								Watling, 1978
Buffalo Bay																			
w *Donax serra*	1975	0.12			1.29	79		1.39		0.76	19.3								Watling, 1978
Walker Point East																			
w *Crassostrea margaritacea*	1975	1.61	0.22	0.38	3.1	11		1.50	0.34	0.73	60								Watling, 1978
Walker Point West																			
w *Perna perna*	1975	0.54	0.13	0.70	1.9	107		1.43	1.45	0.25	21.4								Watling, 1978
w *Crassostrea margaritacea*	1975	1.30	0.04	0.68	2.9	50		0.79	0.62	0.32	249								Watling, 1978
Herolds Bay																			
w *Perna perna*	197?	0.53	0.08	0.29	1.29	61		1.16	0.96	0.08	12.7								Watling and Watling, 1981b
w *Patella oculus*	197?	2.8	0.24	0.48	0.82	907		6.38	0.51	0.12	8.6								Watling and Watling, 1981b
w *Patella longicosta*	197?	13.0	0.13	0.23	0.78	143		1.37	0.30	0.09	14.2								Watling and Watling, 1981b
w *Patella barbara*	197?	4.5	0.12	0.37	0.83	353		2.03	0.38	0.22	8.8								Watling and Watling, 1981b
w *Bullia rhodostoma*	197?	4.1	0.06	2.5	1.42	63		1.31	0.17	0.11	26.5								Watling and Watling, 1981b
Glentana																			
w *Perna perna*	197?	0.95	0.13	0.33	1.27	49		1.08	1.18	0.07	16.4								Watling and Watling, 1981b
w *Crassostrea margaritacea*	197?	1.64	0.01	0.23	3.68	17		1.12	0.08	0.02	143								Watling and Watling, 1981b
w *Patella oculus*	197?	2.6	0.04	2.95	0.72	490		1.72	0.82	0.86	11								Watling and Watling, 1981b
w *Patella longicosta*	197?	10.3	0.08	5.00	1.86	121		1.43	1.10	0.17	8.8								Watling and Watling, 1981b
w *Patella barbara*	197?	3.6	0.07	0.47	0.67	320		1.79	0.30	0.14	8.4								Watling and Watling, 1981b
w *Donax serra*	197?	0.14	0.04	0.26	1.18	84		1.15	0.43	0.03	15.6								Watling and Watling, 1981b
w *Bullia rhodostoma*	197?	8.5	0.11	3.7	2.23	80		1.78	0.19	0.26	46.6								Watling and Watling, 1981b
Tergniet																			
w *Perna perna*	197?	0.46	0.06	0.86	1.20	65		1.43	0.67	0.10	13.7								Watling and Watling, 1981b
w *Patella barbara*	197?	3.8	0.13	0.96	0.83	544		2.17	0.39	0.12	9.4								Watling and Watling, 1981b
w *Patella longicosta*	197?	5.9	0.16	0.98	0.65	391		1.39	0.48	0.06	11.6								Watling and Watling, 1981b
w *Bullia rhodostoma*	197?	3.7	0.08	2.80	1.41	49		1.33	0.19	0.06	31.3								Watling and Watling, 1981b
Little Brak River																			
w *Perna perna*	197?	0.42	0.07	1.76	1.14	110		1.70	0.85	0.15	14.1								Watling and Watling, 1981b
w *Patella longicosta*	197?	4.70	0.16	1.15	1.02	347		1.24	0.42	0.11	10.17								Watling and Watling, 1981b

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	Sr	Mo	Reference
Hartenbos																			
w Perna perna	197?	0.92	0.07	0.24	1.15	83		1.65	0.66	0.10	14.7								Watling and Watling, 1981b
w Patella longicosta	197?	2.40	0.13	0.36	0.74	337		1.41	0.50	0.04	14.9								Watling and Watling, 1981b
w Bullia rhodostoma	197?	3.60	0.11	1.6	1.28	72		1.56	0.22	0.12	50.0								Watling and Watling, 1981b
Diaz Beach																			
w Bullia rhodostoma	197?	2.4	0.08	1.9	0.90	24		1.24	0.13	0.11	26.0								Watling and Watling, 1981b
w Donxa serra	197?	0.12	0.09	0.82	1.20	79		1.39	0.23	0.06	19.3								Watling and Watling, 1981b
Die Bakke																			
w Perna perna	197?	0.37	0.05	0.20	1.08	63		1.03	0.58	0.09	13.8								Watling and Watling, 1981b
w Patella longicosta	197?	4.84	0.06	0.17	0.66	96		1.03	0.21	0.08	17.5								Watling and Watling, 1981b
w Patella barbara	197?	3.9	0.13	0.34	1.00	217		1.38	0.47	0.21	18.4								Watling and Watling, 1981b
Mossel Bay																			
w Perna perna	197?	0.60	0.04	1.18	1.33	59		1.30	0.85	0.35	16.5								Watling and Watling, 1981b
w Perna perna	78/79	0.65	0.09	0.7	1.2	68		1.3	0.90	0.11	14.1								Watling and Watling, 1983
w Crassostrea margaritacea	78/79	1.72	0.01	0.3	5.4	18		0.9	0.05	0.01	178								Watling and Watling, 1983
w Patella granularis	78/79	7.6	0.04	2.2	1.2	427		2.1	0.97	0.42	13.6								Watling and Watling, 1983
w Patella oculus	197?	1.58	0.05	0.28	0.87	275		1.35	0.31	0.11	10.7								Watling and Watling, 1981b
w Patella oculus	78/79	2.8	0.11	1.0	0.8	517		2.8	0.53	0.27	9.9								Watling and Watling, 1983
w Patella barbara	197?	1.94	0.04	0.14	0.80	147		0.81	0.19	0.43	24.1								Watling and Watling, 1981b
w Patella barbara	78/79	3.9	0.17	0.5	0.8	380		2.3	0.42	0.29	13.4								Watling and Watling, 1983
w Patella longicosta	197?	0.55	0.05	0.36	1.16	174		1.24	0.30	0.31	13.5								Watling and Watling, 1981b
w Patella longicosta	78/79	9.0	0.12	1.1	1.0	213		1.3	0.46	0.13	12.6								Watling and Watling, 1983
w Patella miniata	78/79	6.6	0.10	1.0	0.7	440		2.0	0.36	0.11	7.8								Watling and Watling, 1983
w Patella argenvillei	78/79	5.7	0.16	0.6	0.8	121		1.1	0.42	0.07	14.6								Watling and Watling, 1983
w Patella cochlear	78/79	5.5	0.09	0.7	0.9	197		1.5	0.50	0.09	10.6								Watling and Watling, 1983
w Patella tabularis	78/79	1.8	0.02	0.1	0.7	107		0.5	0.11	0.27	11.5								Watling and Watling, 1983
w Donax serra	78/79	0.11	0.11	0.6	1.1	81		1.3	0.38	0.14	16.0								Watling and Watling, 1983
w Bullia rhodostoma	78/79	4.5	0.10	2.7	1.5	66		1.5	0.18	0.14	35.5								Watling and Watling, 1983
Dana Township																			
w Donax serra	197?	0.07	0.19	0.65	0.82	81		1.33	0.47	0.34	13.0								Watling and Watling, 1981b
w Bullia rhodostoma	197?	5.1	0.09	2.4	1.89	93		1.66	0.20	0.13	36.3								Watling and Watling, 1981b
Cape St Blaize																			
w Perna perna	197?	0.50	0.09	0.56	0.88	79		1.08	0.85	0.06	12.1								Watling and Watling, 1981b
w Patella oculus	197?	2.74	0.08	1.06	0.73	443		1.87	0.56	0.07	8.8								Watling and Watling, 1981b
w Patella longicosta	197?	16.2	0.10	0.86	0.58	71		0.97	0.37	0.08	11.3								Watling and Watling, 1981b
w Patella barbara	197?	2.2	0.03	0.13	0.82	130		0.49	0.16	0.38	17.4								Watling and Watling, 1981b

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	Sr	Mo	Reference
Pinnacle Point																			
w *Perna perna*	197?	1.05	0.08	0.87	0.85	58		1.04	1.05	0.06	12.7								Watling and Watling, 1981b
w *Crassostrea margaritacea*	197?	2.11	0.01	0.40	8.50	13		0.66	0.03	0.01	190								Watling and Watling, 1981b
w *Patella oculus*	197?	4.1	0.12	0.29	0.63	473		2.58	0.43	0.18	10.5								Watling and Watling, 1981b
w *Patella longicosta*	197?	16.2	0.14	0.82	0.89	189		1.25	0.38	0.14	11.2								Watling and Watling, 1981b
w *Patella barbara*	197?	5.1	0.31	0.61	0.88	703		5.10	0.76	0.33	8.3								Watling and Watling, 1981b
Fish Bay																			
w *Perna perna*	1975	1.02	0.49	0.85	1.12	52		1.20	2.08	0.64	16.7								Watling, 1978
w *Crassostrea margaritacea*	1975	1.93	0.36	1.39	3.5	28		1.56	1.39	0.92	107								Watling, 1978
w *Donax serra*	1975	0.07	0.19	0.65	0.82	81		1.33	0.47	0.34	13.0								Watling, 1978
Vlees Point																			
w *Perna perna*	197?	0.74	0.20	0.25	1.29	45		1.57	1.38	0.06	14.5								Watling and Watling, 1981b
w *Crassostrea margaritacea*	197?	1.41	0.01	0.18	4.14	25		0.89	0.03	0.01	202								Watling and Watling, 1981b
w *Patella longicosta*	197?	10.7	0.22	0.54	1.39	258		1.42	0.49	0.18	12.2								Watling and Watling, 1981b
w *Patella barbara*	197?	5.8	0.50	0.77	0.90	633		4.80	0.72	0.49	12.0								Watling and Watling, 1981b
w *Bullia rhodostoma*	197?	3.9	0.14	3.9	1.36	84		1.88	0.18	0.17	32.1								Watling and Watling, 1981b
Strandfontein																			
d *Bullia digitalis*	1981																		See diagrams
Muizenberg																			
d *Bullia digitalis*	1981																		See diagrams
d *Patella granularis*	1981	10.6			5.5	510.4		ND	ND	-	17.2						31.3		This study
Cape																			
d Penguin bones	1974	1.2-1.9								3.0-12.1									Orren, 1975
d Gannet bones	1974	0.2-0.9								1.0-1.7									Orren, 1975
d Cormorant bones	1974	1.0-6.0								0.7-1.7									Orren, 1975
Blouberg Strand																			
d *Choromytilus meridionalis*	70/73		2	2		82			8			73							Van As *et al.*, 1973
d *Donax serra*	70/73		0.2	0.7		181			3			62							Van As *et al.*, 1973
w *Choromytilus meridionalis*	1977	0.31	0.07	0.09	1.09	13		1.60	0.13	0.08	12								Watling, 1978
d *Choromytilus meridionalis* (female)	1979	0.28			5.84	21.4		8.5	0.85	0.82	75.3								Orren *et al.*, 1980
d *Choromytilus meridionalis* (male)	1979	0.32			3.21	12.8		3.87	0.71	0.95	38.7								Orren *et al.*, 1980
d *Choromytilus meridionalis* (female)	1979	1.11			7.17	51.0		9.63	1.16	2.57	90.8								Orren *et al.*, 1980
d *Choromytilus meridionalis* (male)	1979	0.94			6.29	69.9		12.1	0.95	2.87	75.7								Orren *et al.*, 1980
d *Choromytilus meridionalis*	1980	*																	See diagrams

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	Sr	Mo	Reference
w Plankton (mixed)	1971		0.089	1.726		578.5		1.47			113.2	0.003	0.664						Van As et al., 1973
w Plankton (mixed)	1972		0.004	0.07		9.26		0.18			9.3	0.001	0.027						Van As et al., 1973
w Plankton (mixed)	1973		0.076	0.43		94.4		0.80			26	0.010	ND						Van As et al., 1973
w Choromytilus meridionalis	70/73		0.038	0.10		20		2.70			16	0.007	0.20						Van As et al., 1973
w Donax serra	70/73		0.038	0.24		59		1.00			18	0.007	0.18						Van As et al., 1973
w Haliotis midae	70/73		0.025	0.50		18		0.17			12	0.001	0.08						Van As et al., 1973
w Jasus lalandii	70/73		0.004	0.08		2.7		0.27			17	0.001	0.12						Van As et al., 1973
w Parechinus	70/73		0.006	0.1		11		ND			9.4	ND	ND						Van As et al., 1973
w Pyura	70/73		0.075	ND		230		ND			12	ND	ND						Van As et al., 1973
w Seriola pappe	70/73		0.008	1.0		14		0.29			6.7	0.040	0.057						Van As et al., 1973
w Argyrozona argyrozona	70/73		0.003	0.1		3.2		0.44			3.2	0.024	0.029						Van As et al., 1973
w Johnius hololepidotus	70/73		0.002	0.72		7.2		0.14			3.8	0.031	0.018						Van As et al., 1973
w Pachymetopon grande	70/73		0.002	3.0		5.2		0.23			3.5	0.018	0.19						Van As et el., 1973
w Atractoscion pequidens	70/73		0.004	ND		7.7		0.26			5.7	0.025	0.059						Van As et al., 1973
w Chrysoblephus gibbiceps	70/73		ND	0.1		5.8		0.16			4.6	0.015	0.002						Van As et al., 1973
w Lithognathus lithognathus	70/73		0.003	0.11		5.0		0.21			4.9	0.044	0.009						Van As et al., 1973
w Merluccius capensis	70/73		0.004	0.26		4.9		0.22			3.7	0.038	0.075						Van As et al., 1973
w Xiphiurus capensis	70/73		0.003	0.92		4.4		0.21			4.8	0.028	0.037						Van As et al., 1973
w Synaptura marginata	70/73		0.003	1.3		4.5		0.17			4.0	0.006	0.14						Van As et al., 1973
w Trachurus trachurus	70/73		0.008	0.14		10		0.11			4.4	0.022	0.028						Van As et al., 1973
w Sardinops ocellata	70/73		0.033	ND		22		0.91			11	0.013	0.26						Van As et al., 1973
w Scomber japanicus	70/73		0.020	0.65		17		0.28			7.2	0.037	0.19						Van As et al., 1973
w Mugil richardsoni	70/73		ND	0.1		6.7		0.19			4.1	0.007	0.024						Van As et al., 1973
w Scombrops dubius	70/73		0.003	ND		3.5		ND			3.6	0.025	0.055						Van As et al., 1973
w Lophius piscatorius	70/73		0.006	0.1		3.0		0.12			3.7	0.014	0.066						Van As et al., 1973
w Trigla capensis	70/73		0.011	0.1		4.5		0.11			3.7	0.032	0.020						Van As et al., 1973
w Gigartina radula	70/73		0.018	0.23		40		2.0			5.6	0.023	0.24						Van As et al., 1973
w Suhria vittata	70/73		0.048	0.87		49		3.70			9.4	0.007	0.23						Van As et al., 1973
w Porphyra capensis	70/73		0.054	0.47		37		6.1			11	0.006	0.21						Van As et al., 1973
w Ulva spp.	70/73		0.038	0.45		39		4.1			5.6	0.011	0.16						Van As et al., 1973
w Ecklonia maxima	70/73		0.0064	0.13		3.3		0.25			1.2	0.010	0.082						Van As et al., 1973
Melkbos Strand						Same as Blouberg in Van As et al., 1973													Fourie, 1976
Koeberg																			
d Bullia digitalis (whole)	1975	164.9																	Cuthbert et al., 1976
d Bullia digitalis (viseral)	1975	235.5																	Cuthbert et al., 1976

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Sb	Al	Bi	Ag	Sr	Mo	V	Reference
d Bullia digitalis	1981	*																	See diagram
d Patella granularis	1981	9.6			2.4	282.2		3.60	10.9	ND	66								This study
d Choromytilus meridionalis	1981	3.4			4.1	81.7		1.60	3.4	3.6	124.4								This study
d Donax serra	1981	ND			0.7	18.3		0.1	0.9	ND	14.1								This study
d Semaeostomeae	1981	ND			3.0	14.9		0.05	4.8	ND	0.4								This study
Langebaan																			
w Choromytilus meridionalis	1974	0.31		1.08	1.2	14.3		2.2	0.16	0.1	15	1.0	9.4	0.44					Fourie, 1976
w Crassostrea margaritacea	1974	0.88		0.50	1.9	4.7		0.55	0.20	0.42	120	1.8	ND	0.68					Fourie, 1976
w Crassostrea gigas	1974	0.87		0.54	3.7	17		1.3	0.25	0.34	21	1.4	ND	0.49					Fourie, 1976
w Haliotis midae	1974	0.14		0.6	3.6	24		0.21	1.20	0.29	9.3	1.3	4.5	0.87					Fourie, 1976
w Jasus lalandii	1974	0.12		0.02	3.9	1.1		0.34	0.19	0.55	16	3.0	1.0	0.82					Fourie, 1976
w Mactra glabrata	1974	0.19		0.54	0.22	41		0.34	ND	ND	7.9	ND	29	ND					Fourie, 1976
w Pyura stolonifera	1974	0.13		0.30	0.52	42		1.49	0.70	0.87	9.0	4.0	61	1.7					Fourie, 1976
w Ulva sp.	1974	0.11		0.095	1.40	30		0.94	0.49	0.62	2.0	1.75	39	0.74					Fourie, 1976
d Crassostrea margaritacea	1974	7			15	45		4	1		957				2				Watling and Watling, 1976a
d Crassostrea gigas	1974	9			29	248		14	2		399				2				Watling and Watling, 1976a
d Doris verrucosa	1982	65.5			50.1	816.9		13.3	2.5	ND	373.6					625.7			This study
d Iorunna tomentosa	1982	11.8			143.5	419.5		4.1	9.0	ND	163.7					127.4			This study
d Tethya aurantia	1982	1.8			14.6	215.9		7.7	2.8		52.9					17.7			This study
d Crassostrea margaritacea	1974	7.31	0.79	0.25	10.99	47.45	118	4.06	0.91	2.62	972.3		20.98	4.33	1.09		1.06	0.08	Watling and Watling, 1974
d Crassostrea gigas	1974	5.3	0.7	1.0	9.6	176		7	0.7	1.4	217		205	1.8				0.9	Watling and Watling, 1974
d Crassostrea gigas	1974	9	1		33			12	1	1	424			4					Watling and Watling, 1976
Saldanha																			
w Jasus lalandii	74/75	0.09		0.01	5.34	1.05		0.31	0.21	0.50	14.95	2.69	1.06	0.77					Fourie, 1975
w Mactra glabrata	74/75	0.19		0.54	0.22	41.01		0.34	ND	ND	7.86	ND	29.05	ND					Fourie, 1975
w Pyura stolonifera	74/75	0.16		0.24	0.29	36.65		1.93	0.66	0.77	10.19	3.93	53.47	1.65					Fourie, 1975
w Haliotis midae	74/75	0.17		0.50	2.76	19.16		0.23	1.18	0.27	9.55	1.56	3.59	0.89					Fourie, 1975
w Crassostrea margaritacea	74/75	0.88		ND	1.85	4.65		0.55	0.20	0.42	20.9	1.84	ND	0.68					Fourie, 1975
w Crassostrea gigas	74/75	0.87		0.54	3.65	17.26		1.26	0.25	0.34	21.13	1.42	ND	0.49					Fourie, 1975
w Choromytilus meridionalis	74/75	0.26		1.09	1.13	14.57		1.82	0.26	0.15	12.53	2.28	7.99	0.78					Fourie, 1975
w Ulva sp.	74/75	0.14		0.07	1.39	25.47		0.92	0.38	0.59	1.91	1.31	31.82	0.57					Fourie, 1975
w Jasus lalandii	1974	0.03		ND	3.3	0.89		0.24	0.26	0.40	14	2.2	1.2	0.69					Fourie, 1976
w Pyura stolonifera	1974	0.12		ND	0.21	5		0.65	0.59	0.40	14	3.8	25	1.4					Fourie, 1976
w Haliotis midae	1974	0.24		0.29	1.2	11		0.26	1.2	0.67	10	2.0	17	0.92					Fourie, 1976
w Choromytilus meridionalis	1974	0.34		0.75	0.68	6.9		1.7	0.30	0.04	9.6	1.9	4.5	0.58					Fourie, 1976
w Choromytilus meridionalis	1974	0.09		1.3	1.5	23		1.3	0.41	0.35	12	3.1	9.1	0.88					Fourie, 1976

TABLE IV (continued)

Location/Species	Date	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Cs	Sb	Al	Bi	Ag	Sr	Mo	V	Reference
w *Ulva* spp.	1974	0.18		ND	1.5	12		0.92	0.05	0.50	1.5		1.30	10	0.70					Fourie, 1976
d *Choromytilus meridionalis*	1974	3.72	2.40	0.99	9.75	133.19	0.069	10.41	2.16	3.55	95.66			73.88	5.39	0.17		4.05	0.43	Watling and Watling, 1974
d *Mactra glabrata* (whole)	1974	6.3	2.8	1.3	5.2	376	130	1.4	2.4	2	78			130	2.9	0.17		1.3	0.9	Watling and Watling, 1974
d *Mactra glabrata* (heart)	1974	4.2	24.2	6.11	18.2	1 091	-	6.1	8.8	12.1	76			1 727	9.1	1.52		12.1	-	Watling and Watling, 1974
d *Mactra glabrata* (gonad)	1974	9.7	6.7	10.3	34.8	809	-	3.4	7.2	4.5	74			315	6.7	0.11		7.9	1.0	Watling and Watling, 1974
d *Mactra glabrata* (gill)	1974	34.2	14.5	8.6	21.4	513	-	4.3	12.7	6.8	87			180	7.7	6.41		5.1	0.3	Watling and Watling, 1974
d *Mactra glabrata* (mantle)	1974	2.6	2.3	0.9	3.0	241	-	1.0	1.5	1.5	50			66	3.8	0.11		1.9	0.6	Watling and Watling, 1974
d *Mactra glabrata* (adductor)	1974	3.6	1.5	0.7	1.7	93	-	0.8	0.9	2.0	70			63	3.2	0.08		1.0	0.1	Watling and Watling, 1974
d *Mactra glabrata* (foot)	1974	3.4	1.4	0.3	1.4	50	-	0.6	0.7	1.4	60			6	3.1	0.08		0.9	0.1	Watling and Watling, 1974
d *Mactra glabrata* (remainder)	1974	3.5	4.6	2.7	3.2	671	-	3.2	2.6	3.2	53			954	6.0	0.56		1.9	1.5	Watling and Watling, 1974
d *Donax serra*	1974	0.5	1.7	0.9	3.5	236		3.4	1.2	1.9	95			84	3.8	0.05		3.7	0.3	Watling and Watling, 1974
d *Haliotis midae* (gonad)	1974	5.3	2	0.7	4	798		6	4	2	64			10	3.7	0.06		2.4	0.99	Watling and Watling, 1974
d *Haliotis midae* (kidney)	1974	17.00	2	1.1	6	375		4	3	2	76.2			114	4.2	0.24		4.6	3.19	Watlirg and Watling, 1974
d *Haliotis midae* (gill)	1974	5.0	5	1.5	93	350		6	16	9	100			63	7.9	0.33		10.4	0.71	Watling and Watling, 1974
d *Haliotis midae* (heart)	1974	6.7	5	2.4	15	470		4	9	4	66			300	9.7	0.37		6.9	0.37	Watling and Watling, 1974
d *Haliotis midae* (mantle)	1974	2.0	3	2.5	57	197		1	33	3	105			25	4.2	0.20		2.0	0.58	Watling and Watling, 1974
d *Haliotis midae* (white muscle)	1974	6.00	1	0.2	3	21		1	1	1	33			1	1.9	0.2		0.20	0.01	Watling and Watling, 1974
d *Gracilaria verrucosa*	1974	1.4	4	1.4	2	159	0.047	7	2	3	25			172	7.1	0.08		1.2	0.13	Watling and Watling, 1974
d *Ulva* sp.	1974	0.80	3	10.2	5	1 330	0.094	9	8	5	24			3 647	7.0	0.07		1.5	6.65	Watling and Watling, 1974
w *Choromytilus meridionalis*	1972	0.43																		Darracott, 1975
w *Donax serra*	1975	0.09	0.30	0.17	0.64	42		0.62	0.21	0.34	17									Watling, 1978
w *Crassostrea gigas*	1977	1.10	0.1	0.34	9.3	32		2.2	0.1	0.1	100									Watling, 1978
d *Choromytilus meridionalis* (male)	197?	0.9	1.0	1.4	5.9	54		6		2.1	54				4.0	0.3				Watling and Watling, 1976b
d *Choromytilus meridionalis* (female)	197?	0.9	0.9	1.4	7.7	66		12		1.8	97				3.4	0.3				Watling and Watling, 1976b
w *Choromytilus meridionalis*	1979	0.53		0.09	1.42	41.46		1.32	0.64	0.33	26.4									John Henry (pers. com.)
w *Haliotis midae*	1979	0.53		0.21	0.80	29.65		0.20	0.81	0.43	12.34									John Henry (pers. com.)
w *Pyura stolonifera*	1979	0.14		0.10	0.72	22.0		3.25	0.53	ND	21.3									John Henry (pers. com.)
w *Mactra glabrata*	1979	0.69		0.32	0.67	41.78		0.72	0.49	0.22	8.26									John Henry (pers. com.)
w *Jasus lalandii*	1979	0.09		0.19	7.34	2.49		0.30	0.26	0.34	13.05									John Henry (pers. com.)
Noordwesbaai	1982																			See diagram
Analytical chemists																				
Homo sapiens (blood)	1974	25	25	25	649	384	9.1	25	59	125	6.2			2.5		25	132.4		12.5	Butler and Watling, 1975
Homo sapiens (blood)		7.40	0.30	26	1 070	475.00	6.50	26	38	270	6.5			0.32		24	130.0		17.0	WHO
Homo sapiens (hair)							450-635	ngg^{-1}												Butler and Watling, 1975

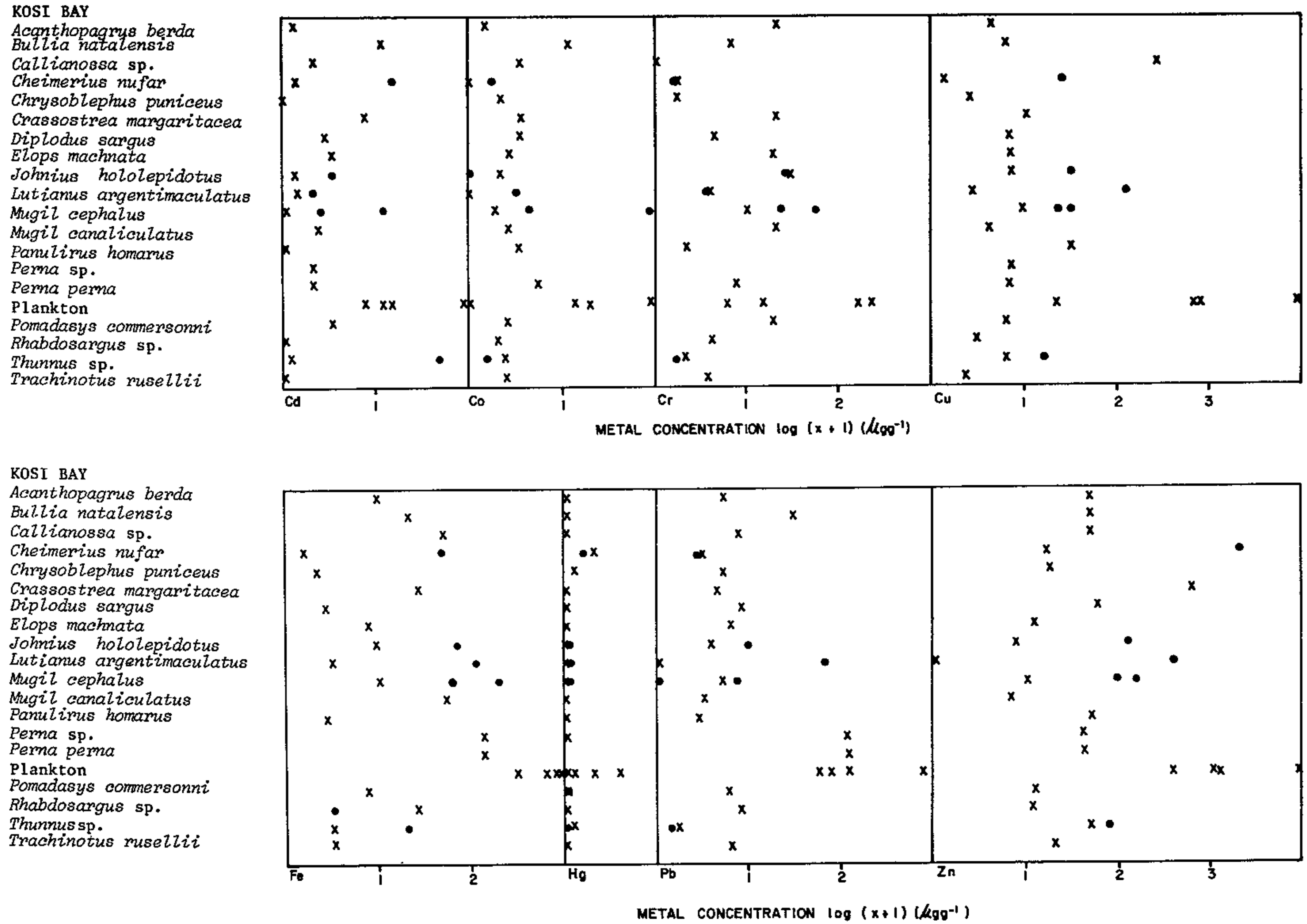


Figure 11 Metal concentrations in marine organisms from Kosi Bay (• = liver)

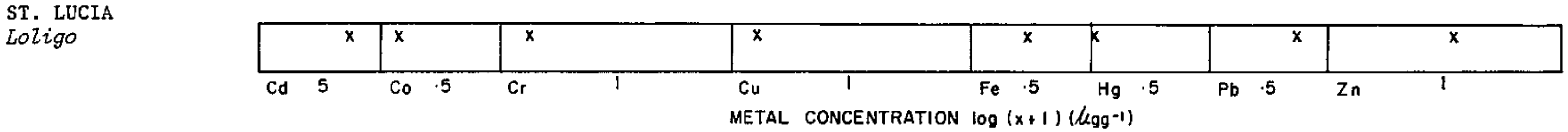


Figure 12 Metal concentrations in marine organisms from St Lucia

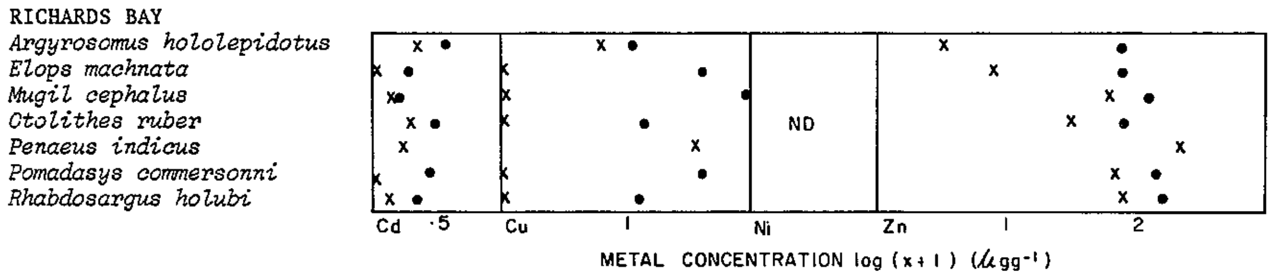


Figure 13 Metal concentrations in marine organisms from Richards Bay (• = liver)

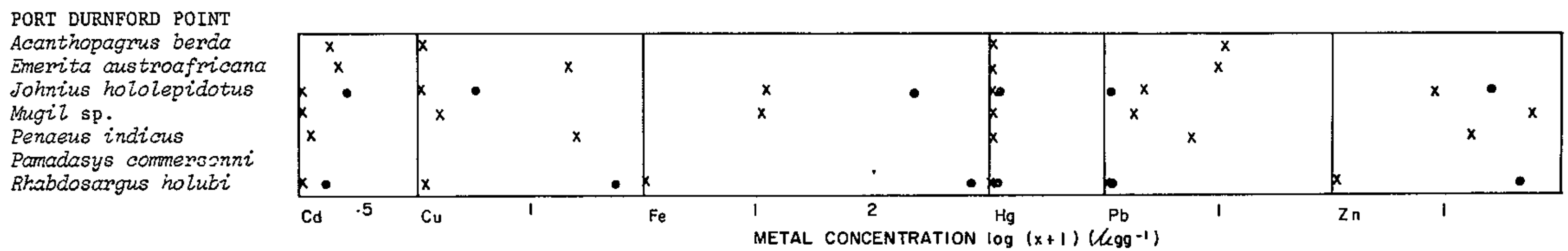


Figure 14 Metal concentrations in marine organisms from Port Durnford Point (• = liver)

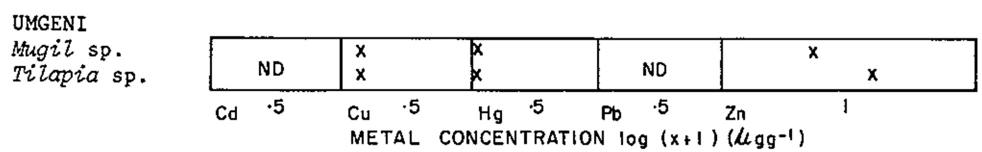


Figure 15 Metal concentrations in marine organisms from Umgeni Estuary

UMHLANGA ROCKS
Perna perna

UMHLANGA ROCKS
Perna perna

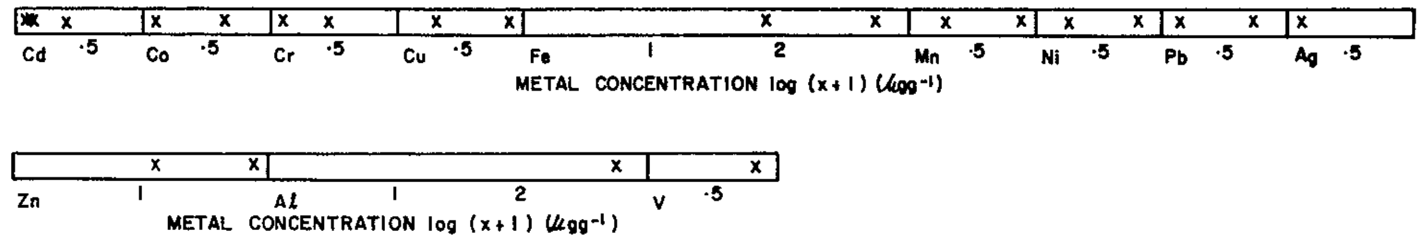


Figure 16 Metal concentrations in marine organisms from Umhlanga Rocks

DURBAN BAY
Panulirus versicolor
Plankton

Figure 17 Metal concentrations in marine organisms from Durban Bay

UMBOGINTWINI
Emerita austroafricana
Panulirus homarus

Figure 18 Metal concentrations in marine organisms from Umbogintwini

FYNNLANDS
Panulirus homarus

Figure 19 Metal concentrations in marine organisms from Fynnlands

UMHLATUZANA
Mugil sp.
Sarotheradon mossambicus
Therapon jarbua

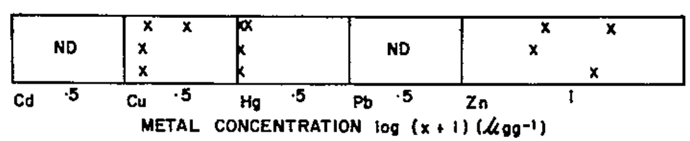


Figure 20 Metal concentrations in marine organisms from Umhlatuzana

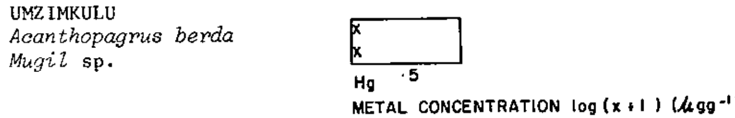


Figure 21 Metal concentrations in marine organisms from Umzimkulu Estuary

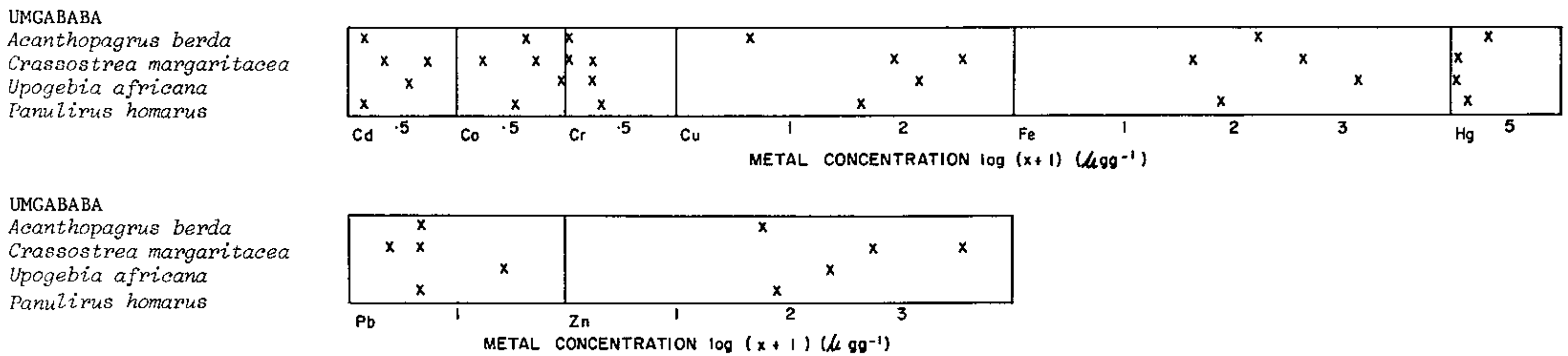


Figure 22 Metal concentrations in marine organisms from Umgababa Estuary

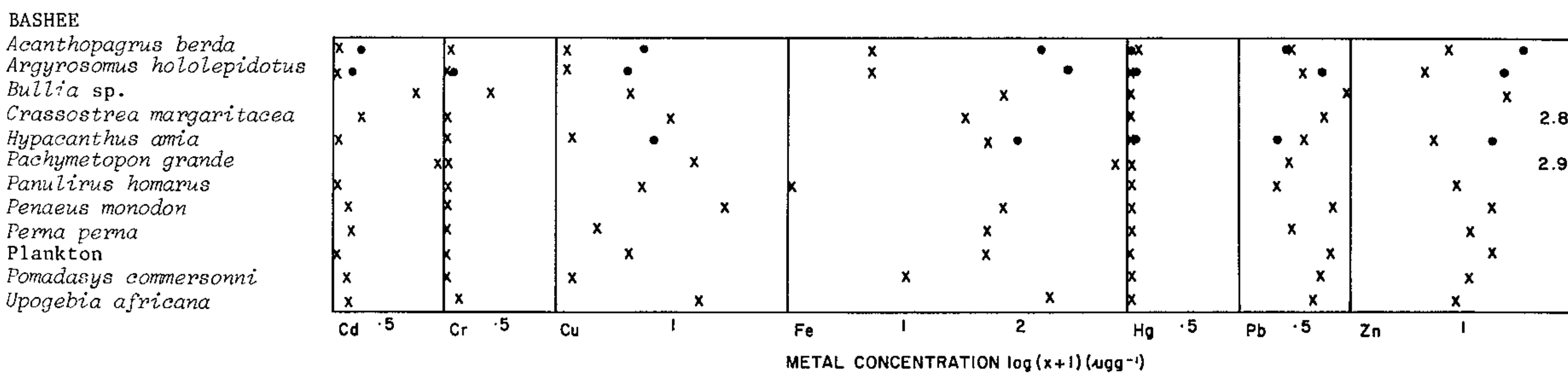


Figure 23 Metal concentrations in marine organisms from Bashee Estuary (• = liver)

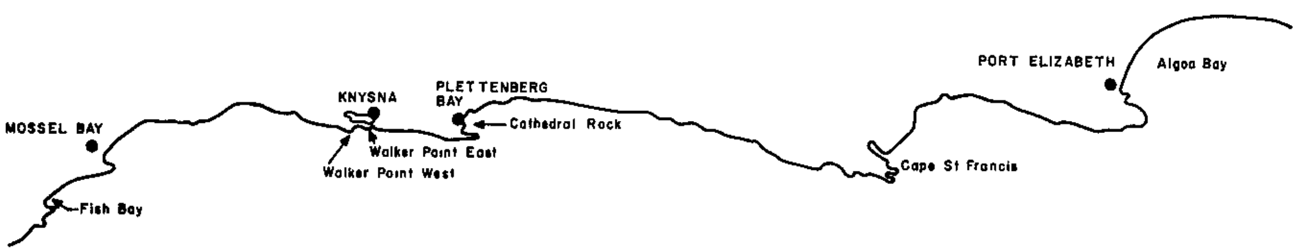


Figure 24 Location map of major sampling areas of Section III

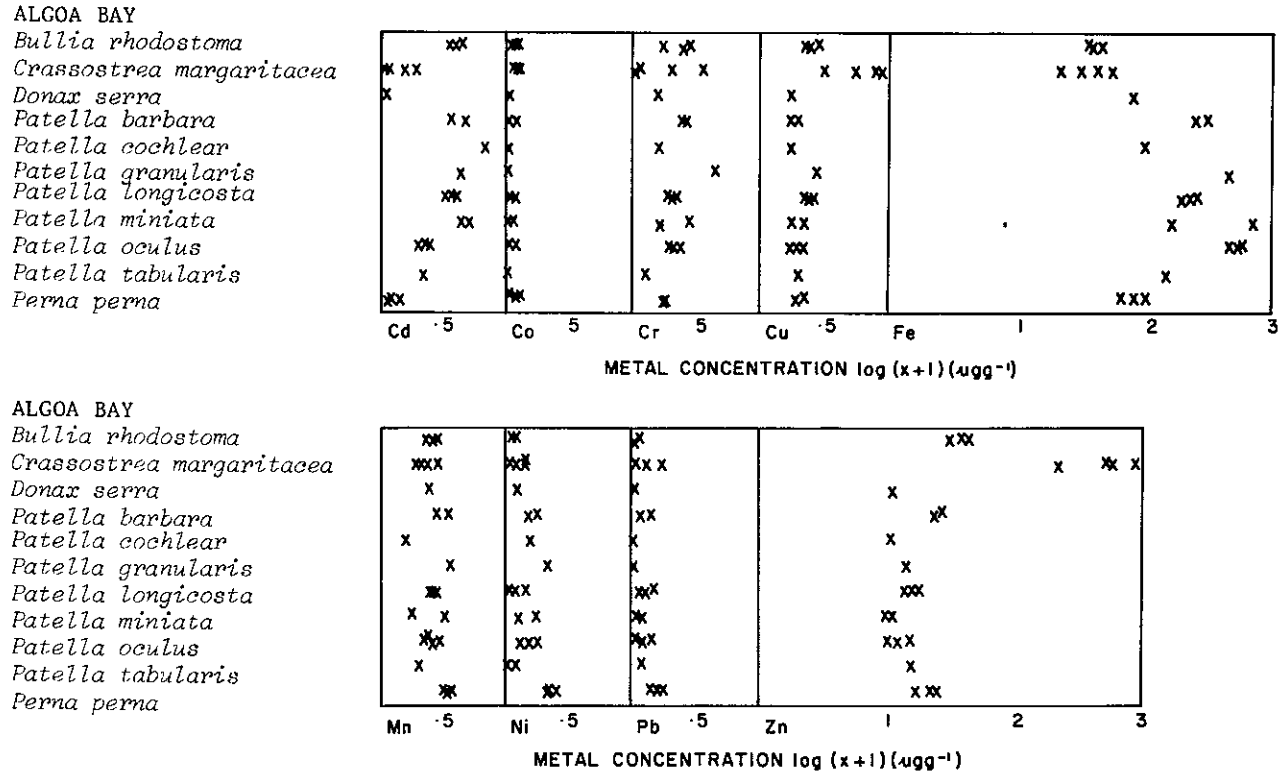


Figure 25 Metal concentrations in marine organisms from Algoa Bay

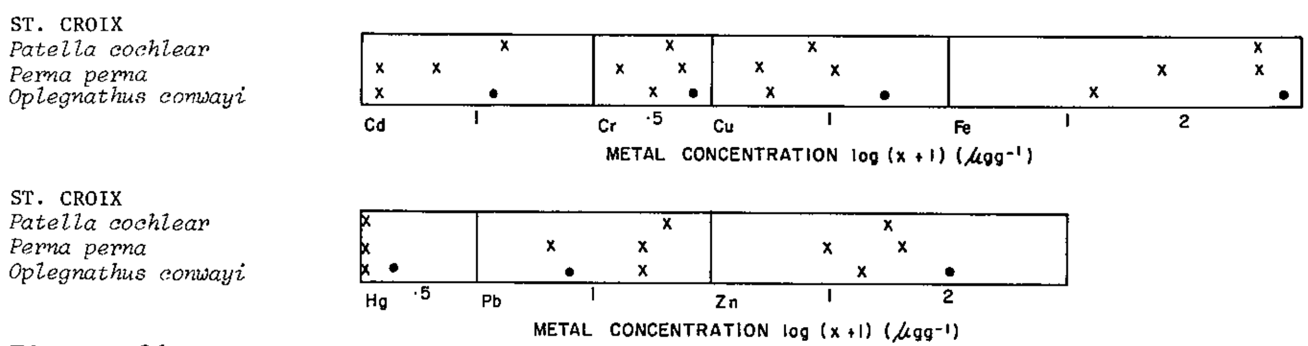


Figure 26 Metal concentrations in marine organisms from St Croix (• = liver)

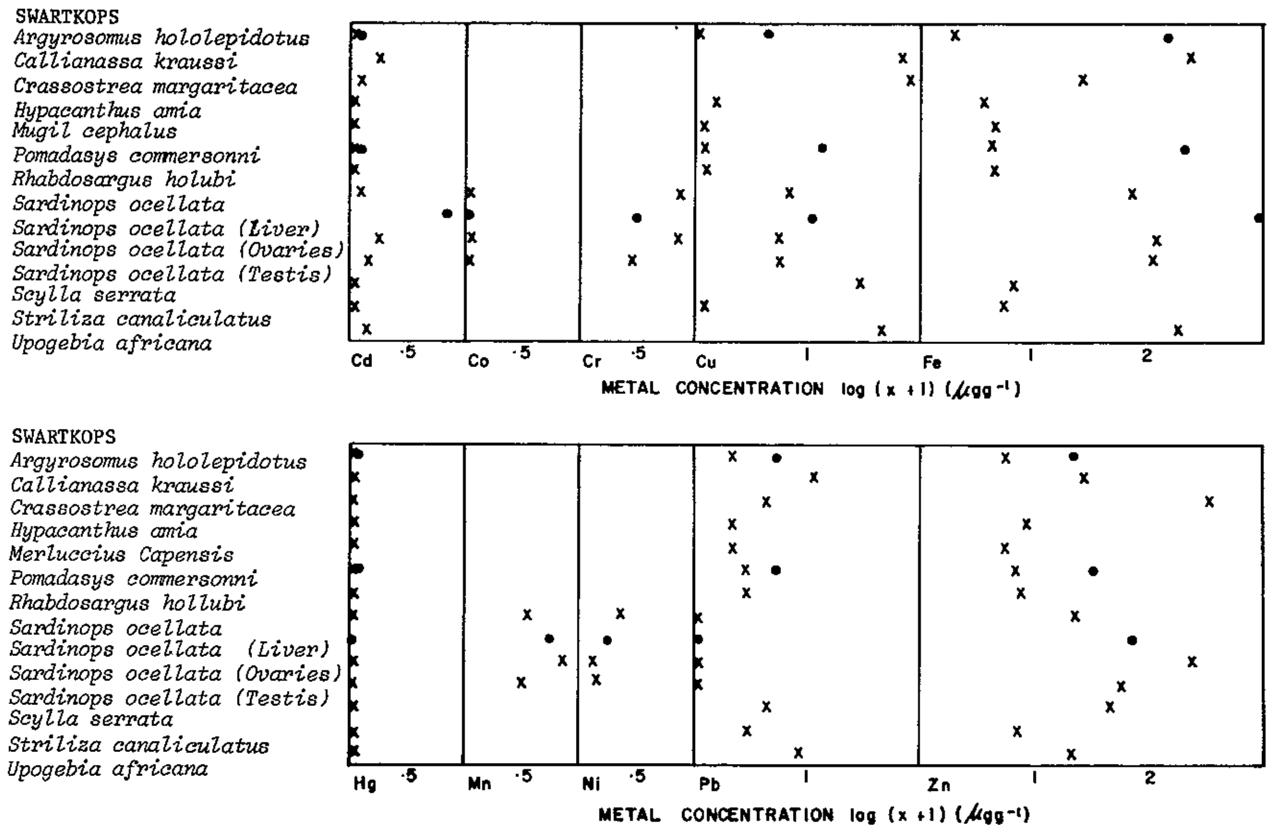


Figure 27 Metal concentrations in marine organisms from Swartkops Estuary (• = liver)

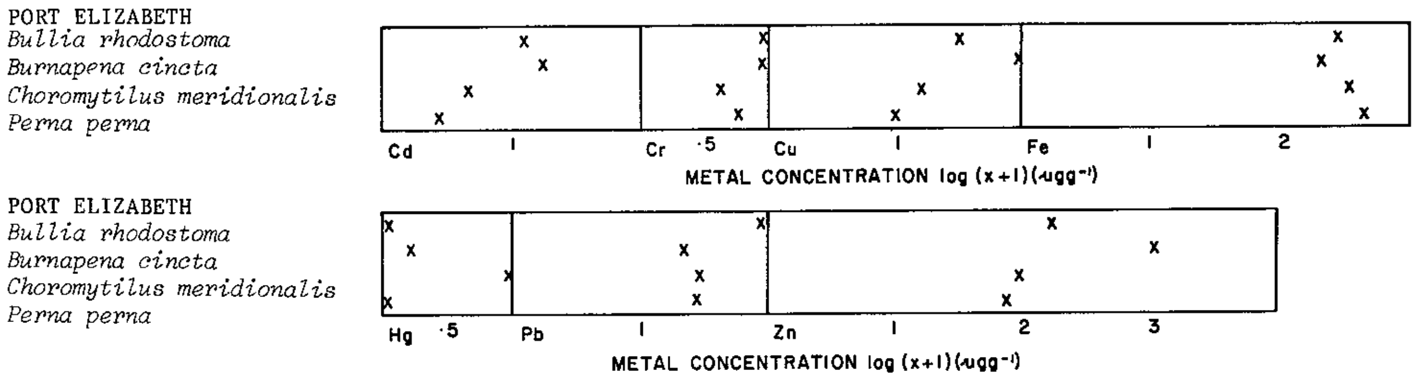


Figure 28 Metal concentrations in marine organisms from Port Elizabeth

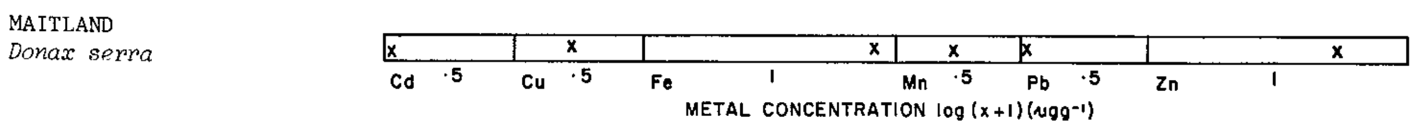


Figure 29 Metal concentrations in marine organisms from Maitland

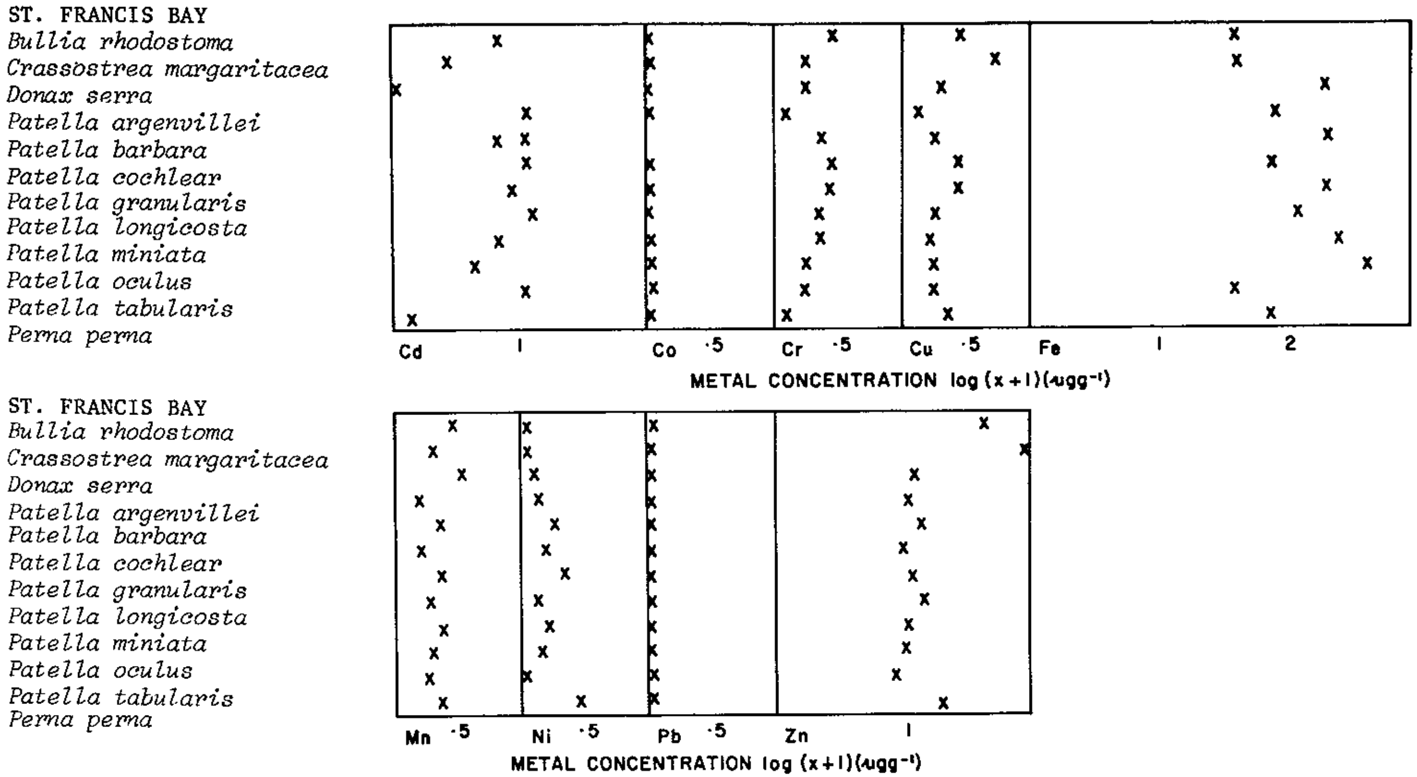


Figure 30 Metal concentrations in marine organisms from St Francis Bay

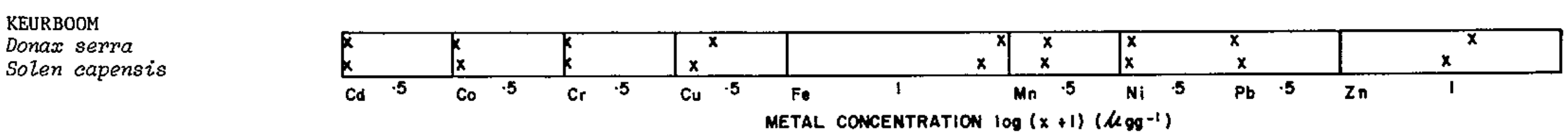


Figure 31 Metal concentrations in marine organisms from Keurboomstrand

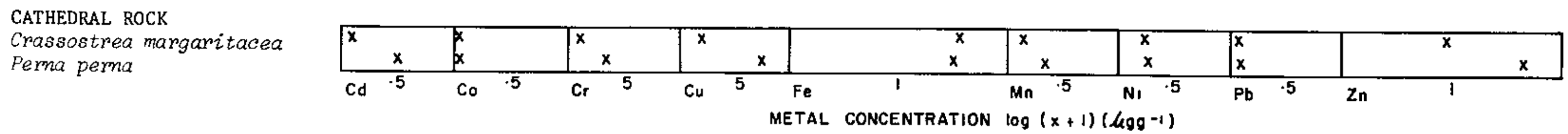


Figure 32 Metal concentrations in marine organisms from Cathedral Rock

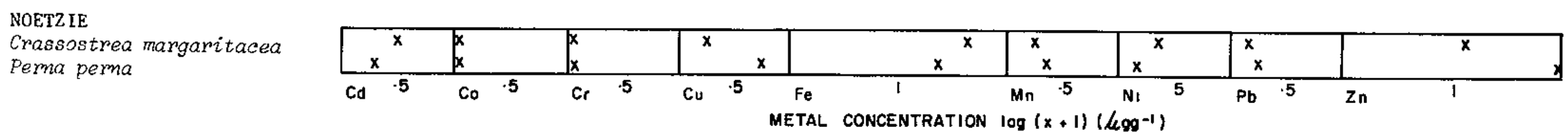


Figure 33 Metal concentrations in marine organisms from Noetzie

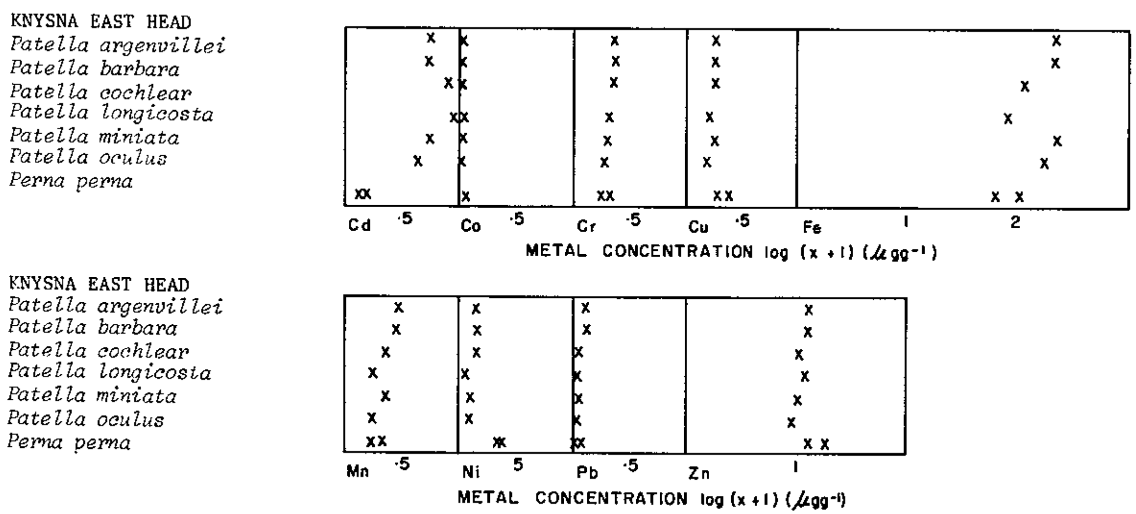


Figure 34 Metal concentrations in marine organisms from Knysna East Head

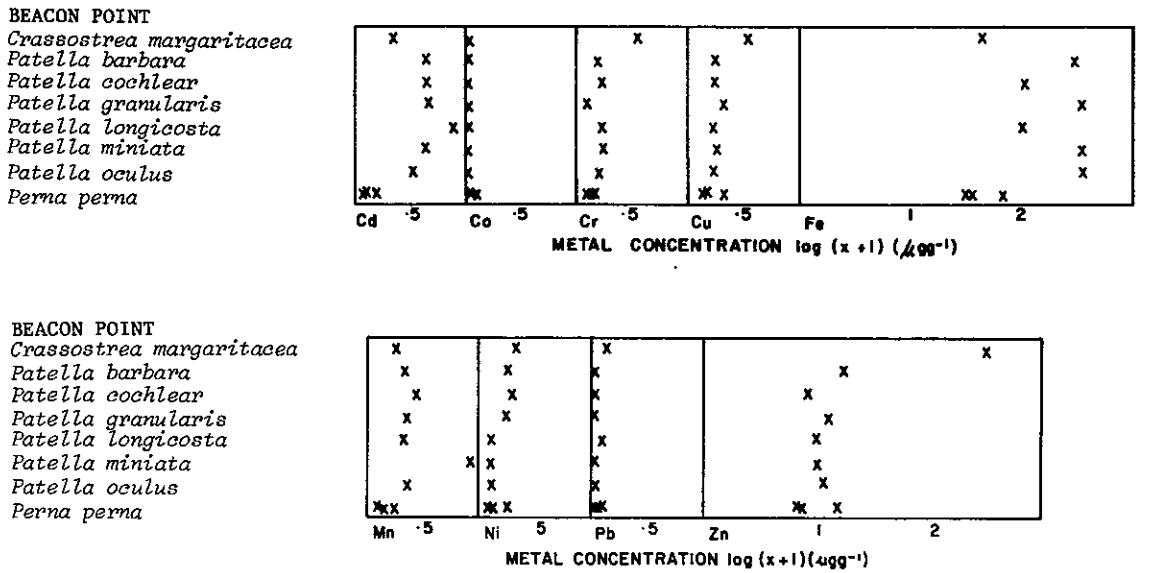


Figure 35 Metal concentrations in marine organisms from Beacon Point

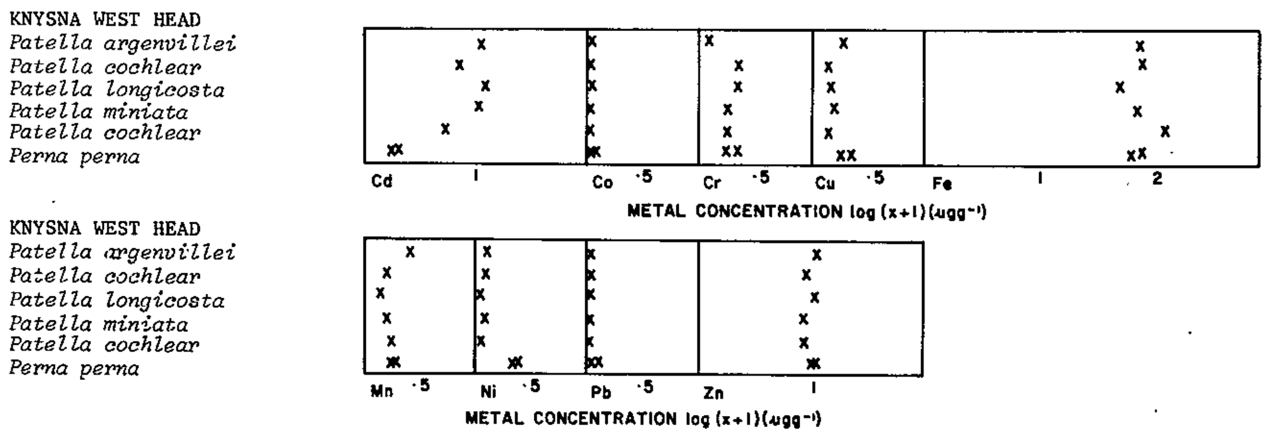


Figure 36 Metal concentrations in marine organisms from Knysna West Head

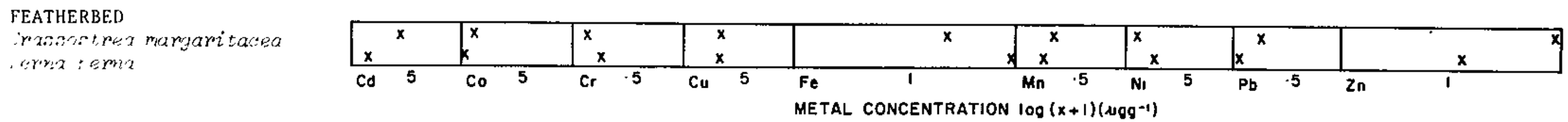


Figure 37 Metal concentrations in marine organisms from Featherbed

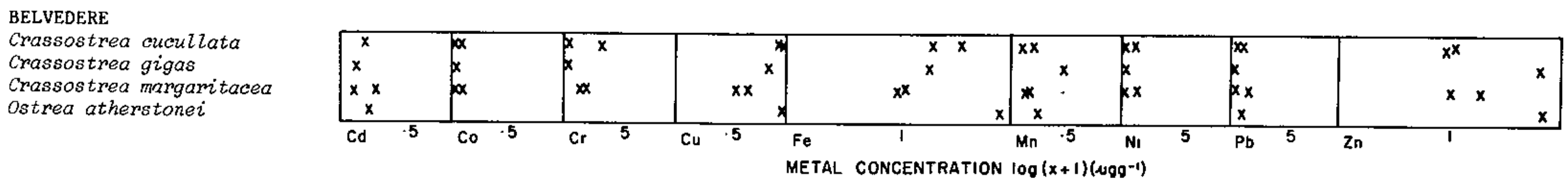


Figure 38 Metal concentrations in marine organisms from Belvedere

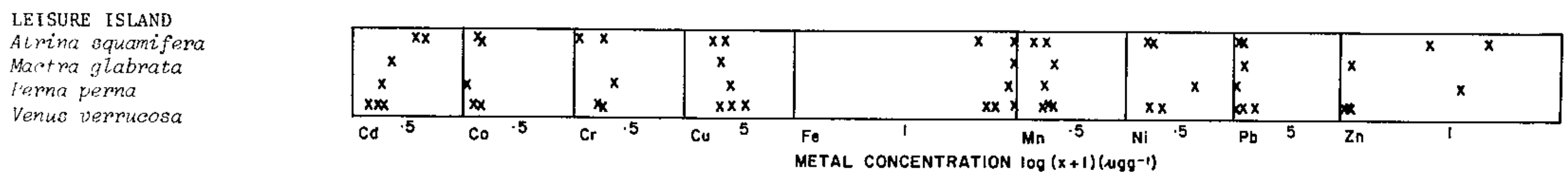


Figure 39 Metal concentrations in marine organisms from Leisure Island

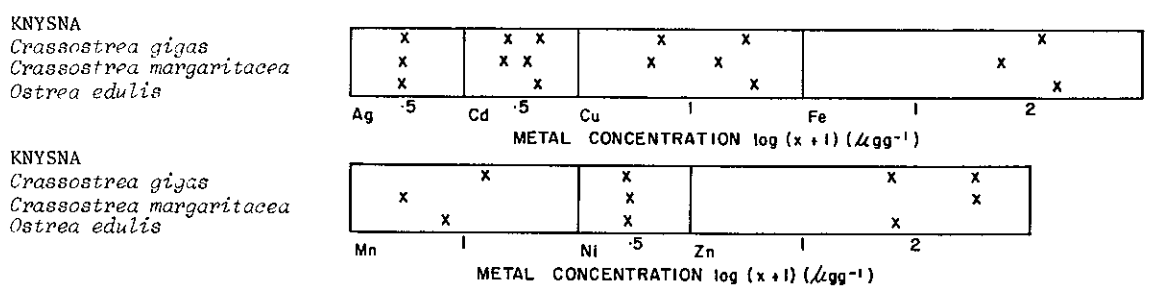


Figure 40 Metal concentrations in marine organisms from Knysna

THESENS POINT
Perna perna
Solen capensis

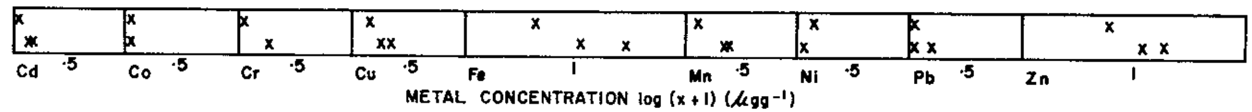


Figure 41 Metal concentrations in marine organisms from Thesen's Point

CASTLE ROCK
Crassostrea margaritacea
Perna perna

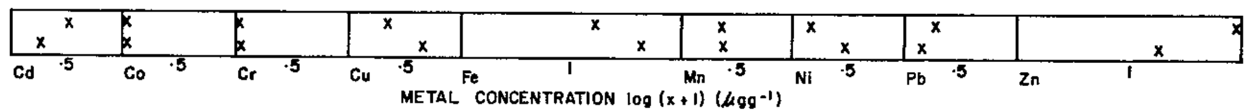


Figure 42 Metal concentrations in marine organisms from Castle Rock

BUFFALO BAY
Donax serra

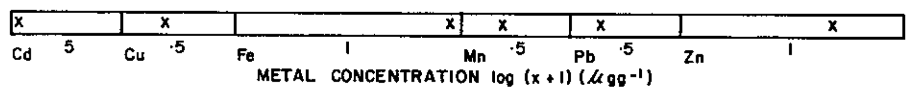


Figure 43 Metal concentrations in marine organisms from Buffalo Bay

WALKER POINT EAST
Crassostrea margaritacea

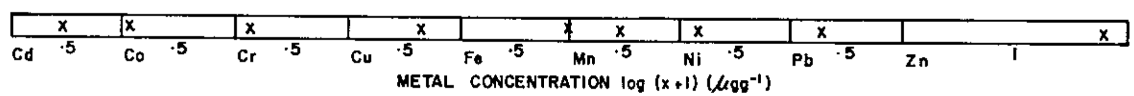


Figure 44 Metal concentrations in marine organisms from Walker Point East

WALKER POINT WEST
Crassostrea margaritacea
Perna perna

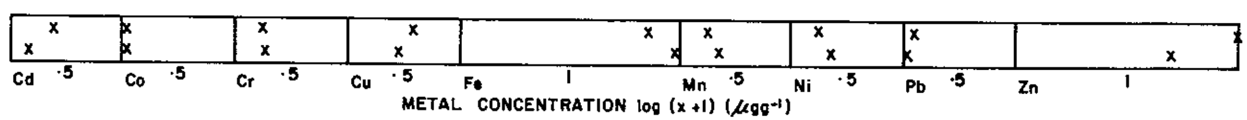


Figure 45 Metal concentrations in marine organisms from Walker Point West

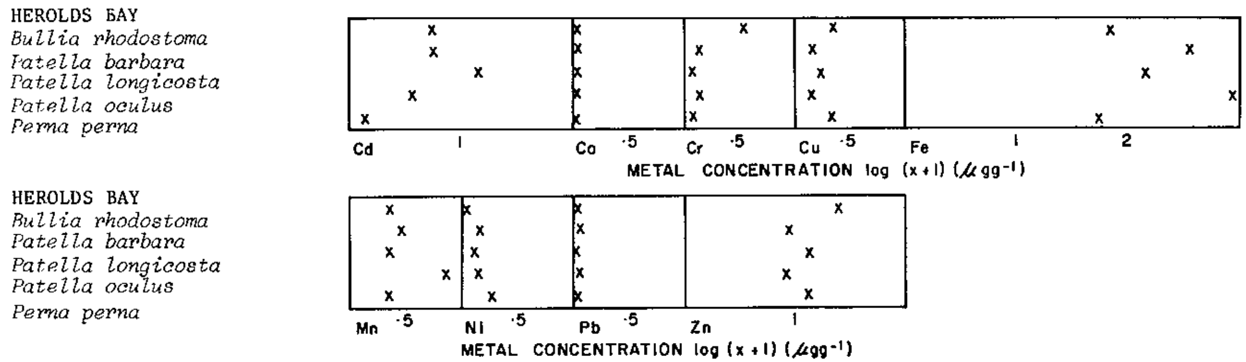


Figure 46 Metal concentrations in marine organisms from Herold's Bay

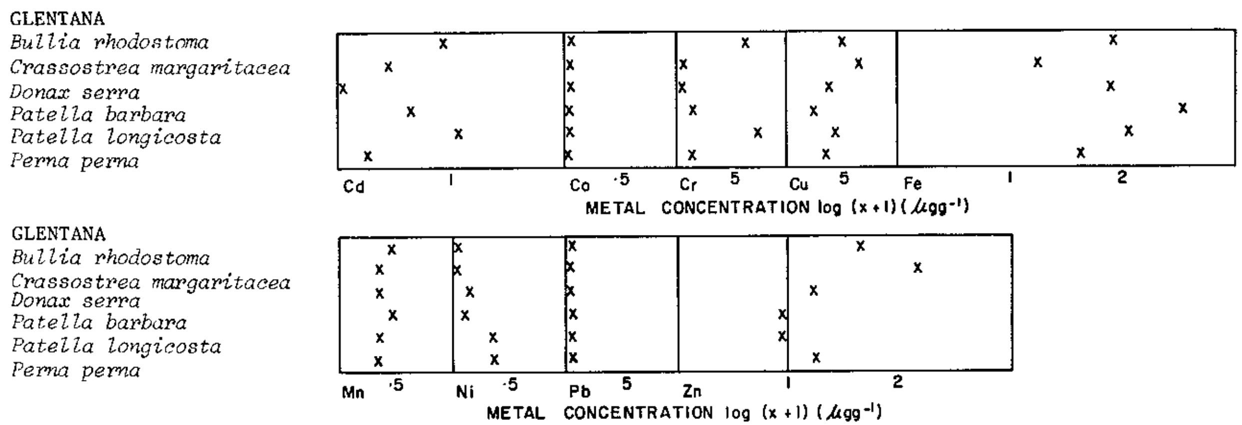


Figure 47 Metal concentrations in marine organisms from Glentana

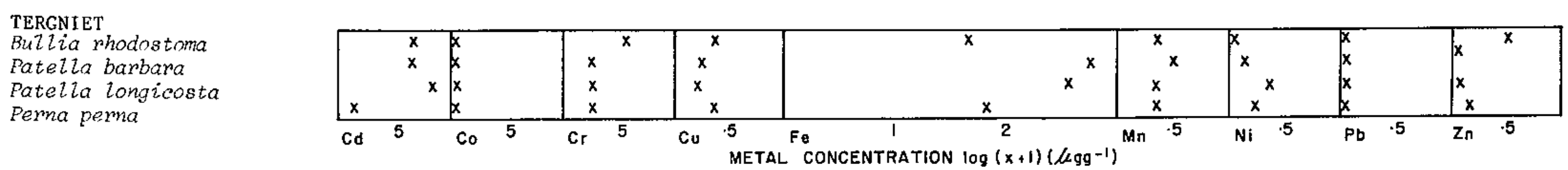


Figure 48 Metal concentrations in marine organisms from Tergniet

LITTLE BRAK RIVER
Patella longicosta
Perna perna

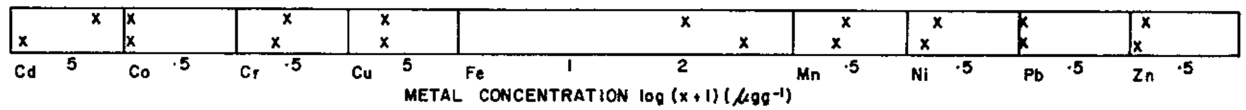


Figure 49 Metal concentrations in marine organisms from Little Brak River

HARTENBOS
Bullia rhodostoma
Patella longicosta
Perna perna

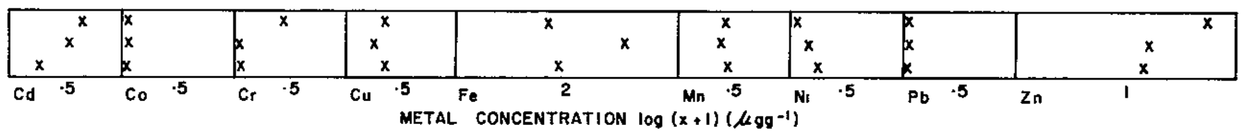


Figure 50 Metal concentrations in marine organisms from Hartenbos

DIZA BEACH
Bullia rhodostoma
Donax serra

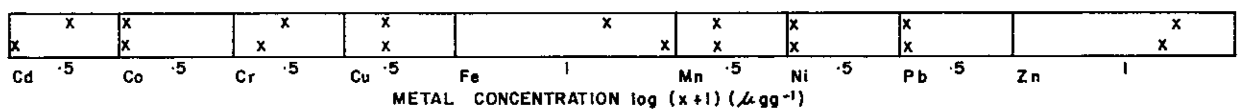


Figure 51 Metal concentrations in marine organisms from Diza Beach

DIE BAKKE
Patella barbara
Patella longicosta
Perna perna

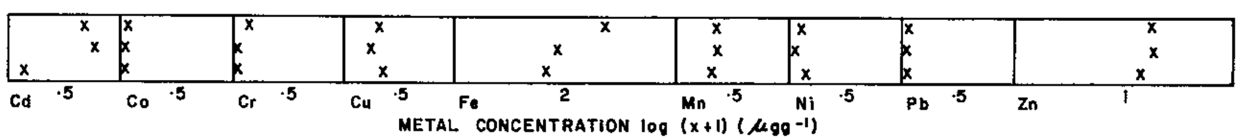


Figure 52 Metal concentrations in marine organisms from Die Bakke

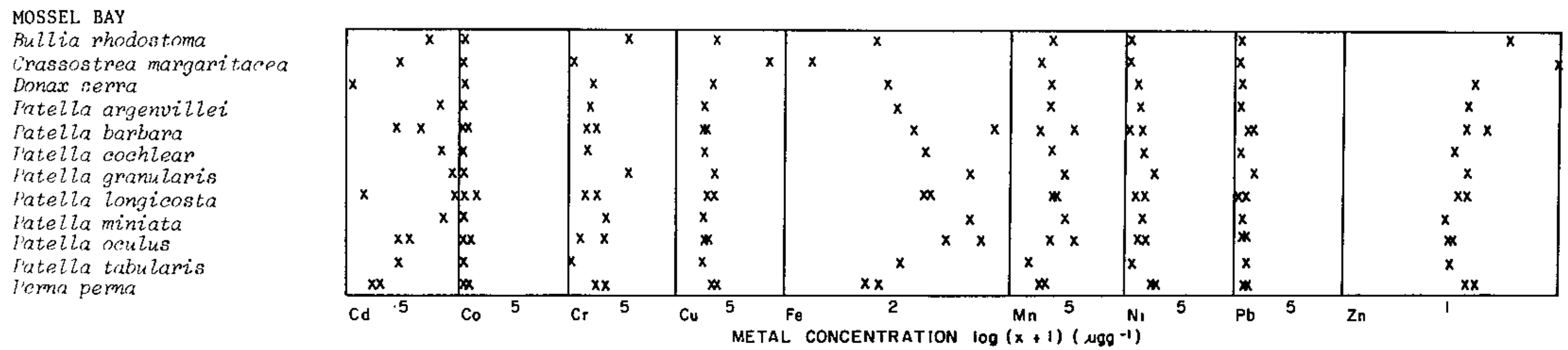


Figure 53 Metal concentrations in marine organisms from Mossel Bay

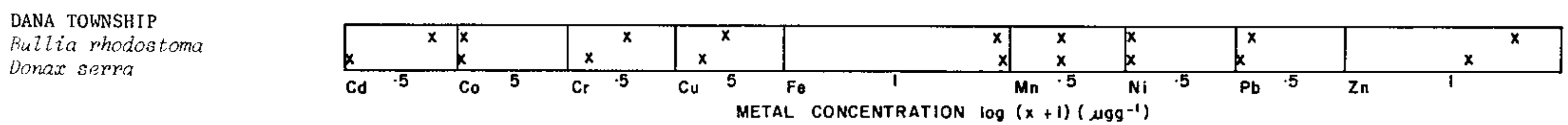


Figure 54 Metal concentrations in marine organisms from Dana Township

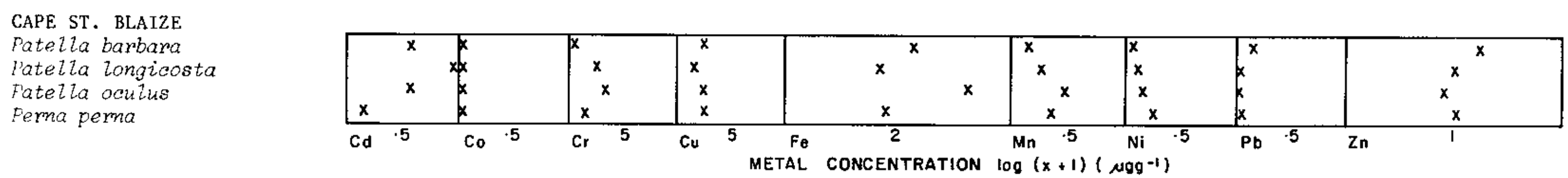


Figure 55 Metal concentrations in marine organisms from Cape St Blaize

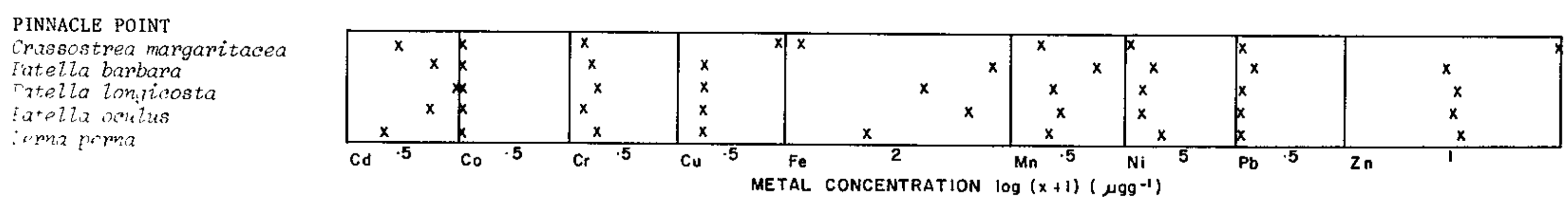


Figure 56 Metal concentrations in marine organisms from Pinnacle Point

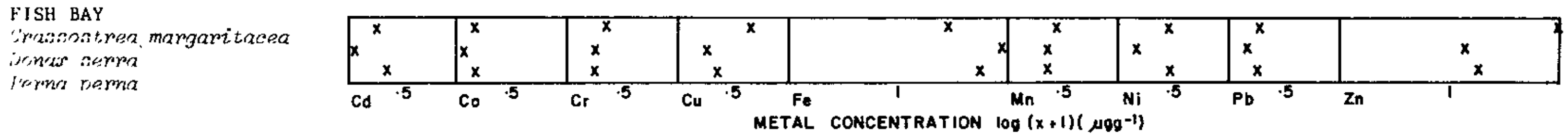


Figure 57 Metal concentrations in marine organisms from Fish Bay

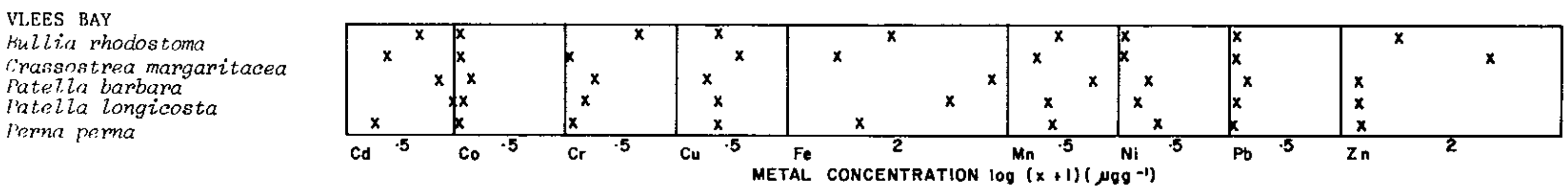


Figure 58 Metal concentrations in marine organisms from Vlees Bay

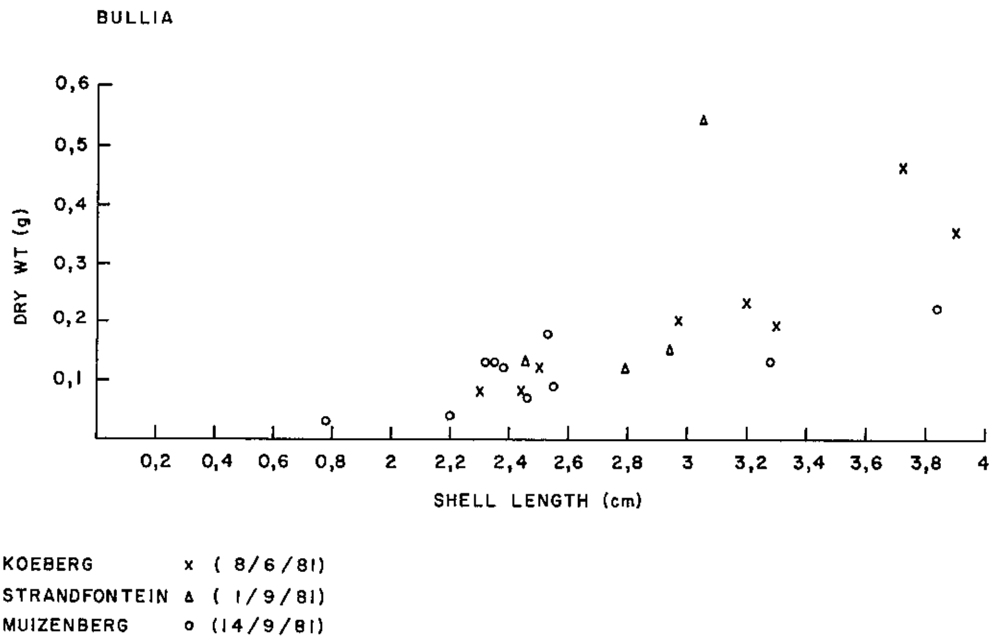


Figure 59 Relationship of shell length and dry mass in Bullia. (This is part of the comparison of metal content of Bullia digitalis from three different sites along the West Coast)

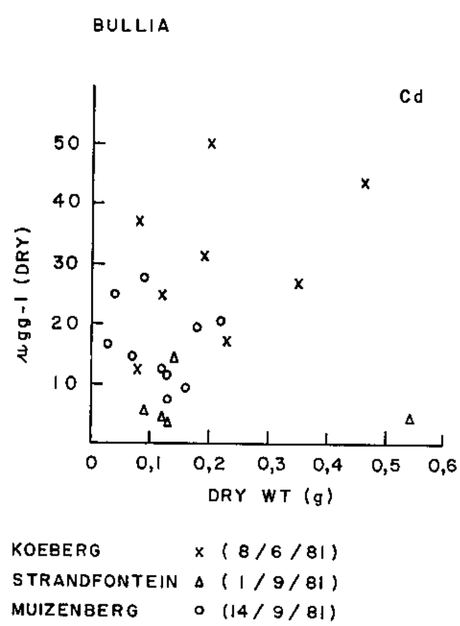
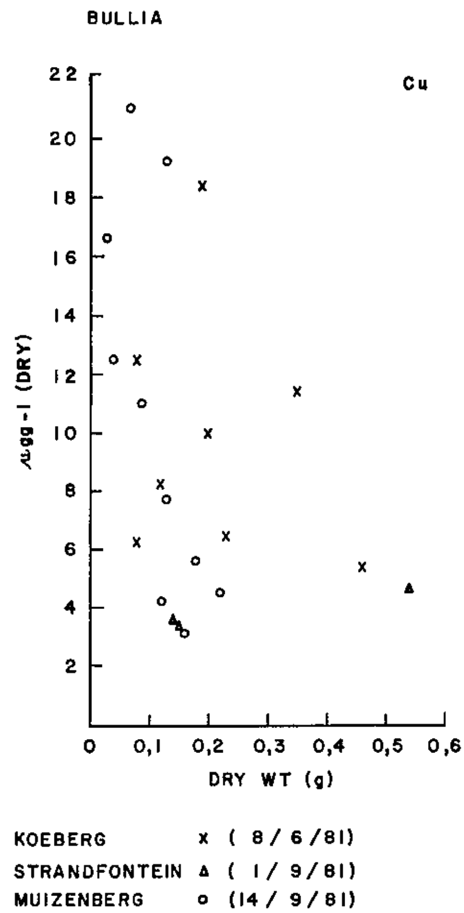


Figure 59a Cadmium concentrations in Bullia



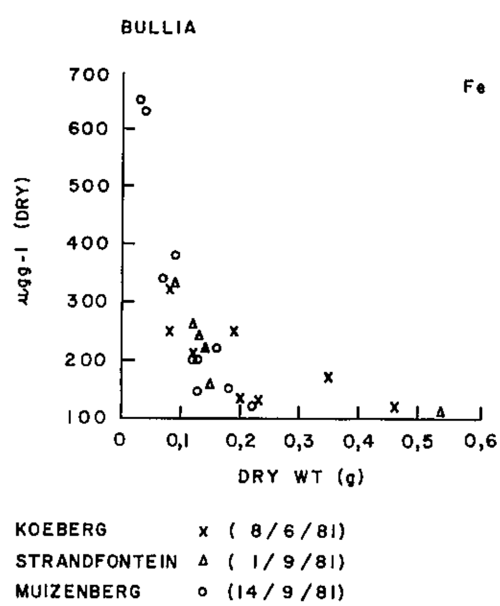


Figure 59b Copper and iron concentrations in <u>Bullia</u>

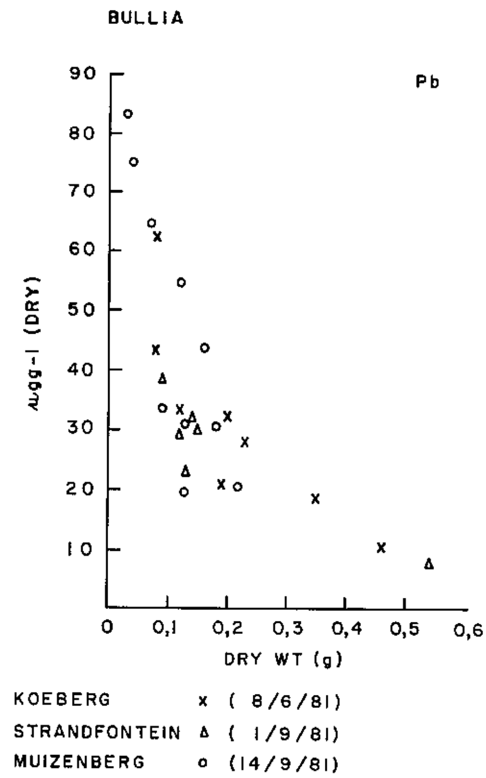


Figure 59c Lead concentrations in <u>Bullia</u>

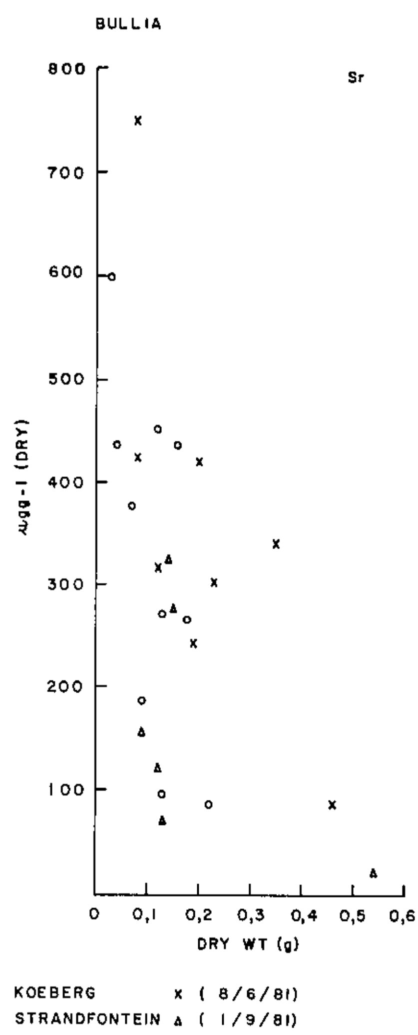


Figure 59d Strontium concentrations in <u>Bullia</u>

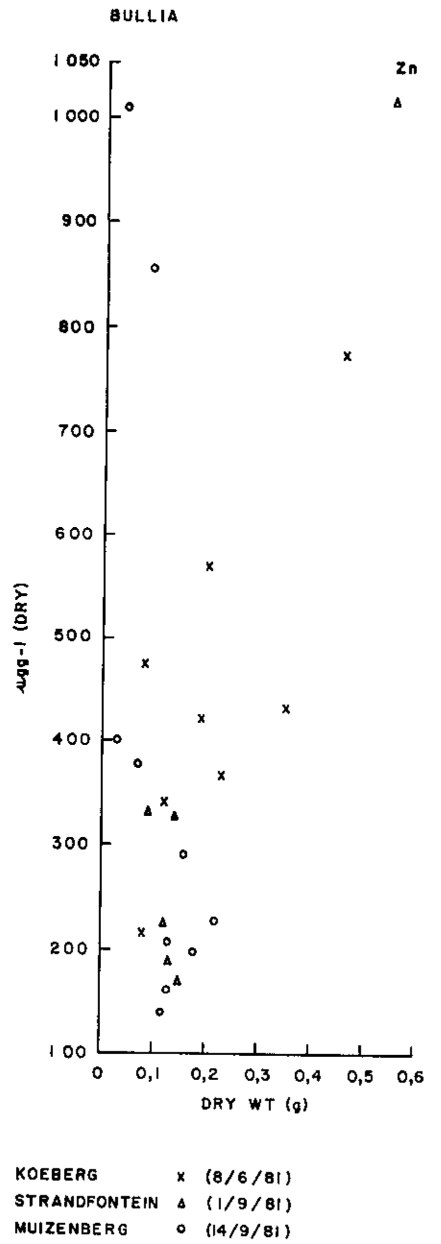


Figure 59e Zinc concentrations in Bullia

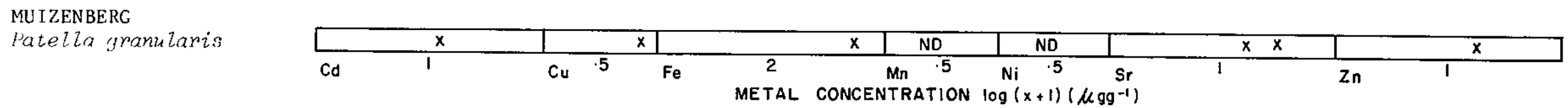


Figure 60 Metal concentrations in marine organisms from Muizenberg

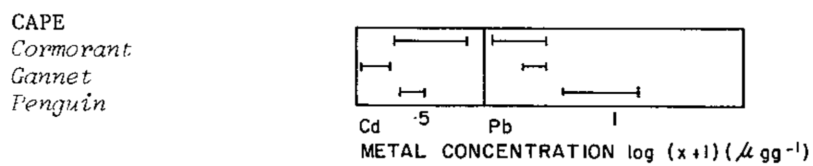


Figure 61 Metal concentrations in marine organisms from Cape

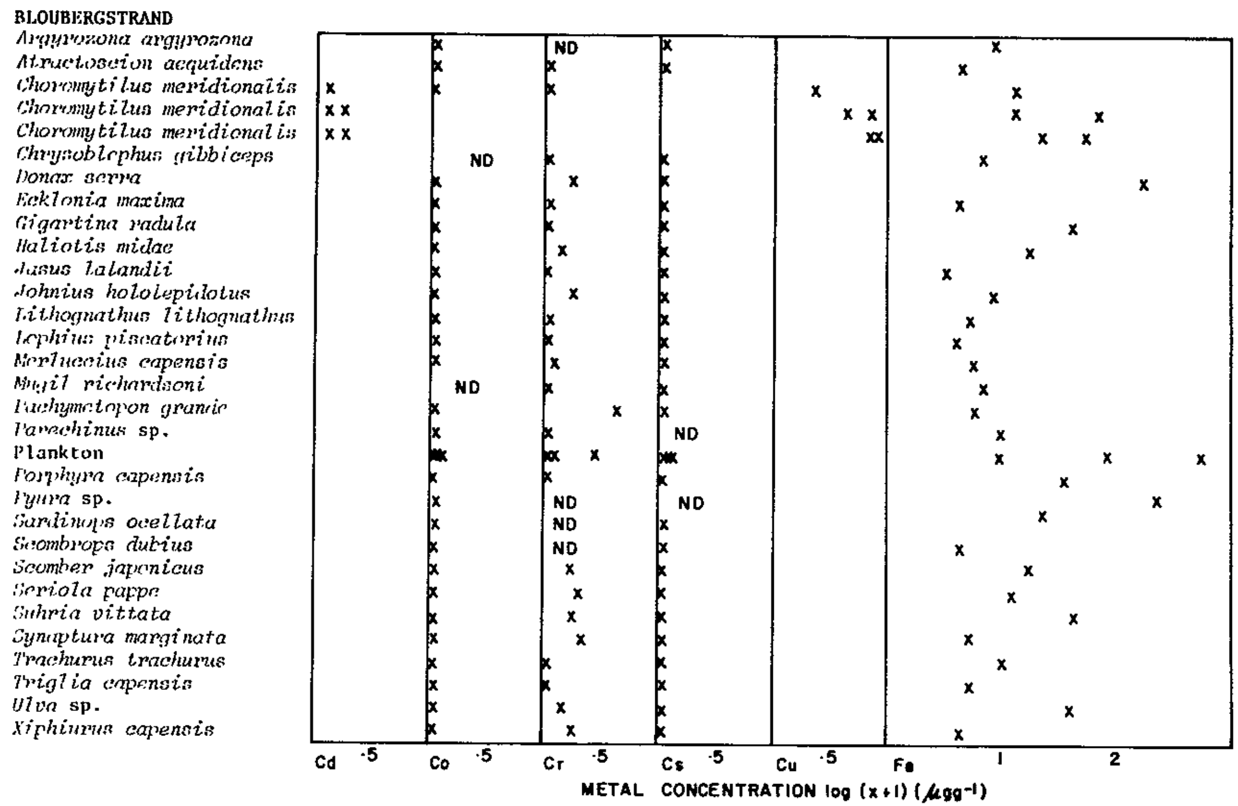
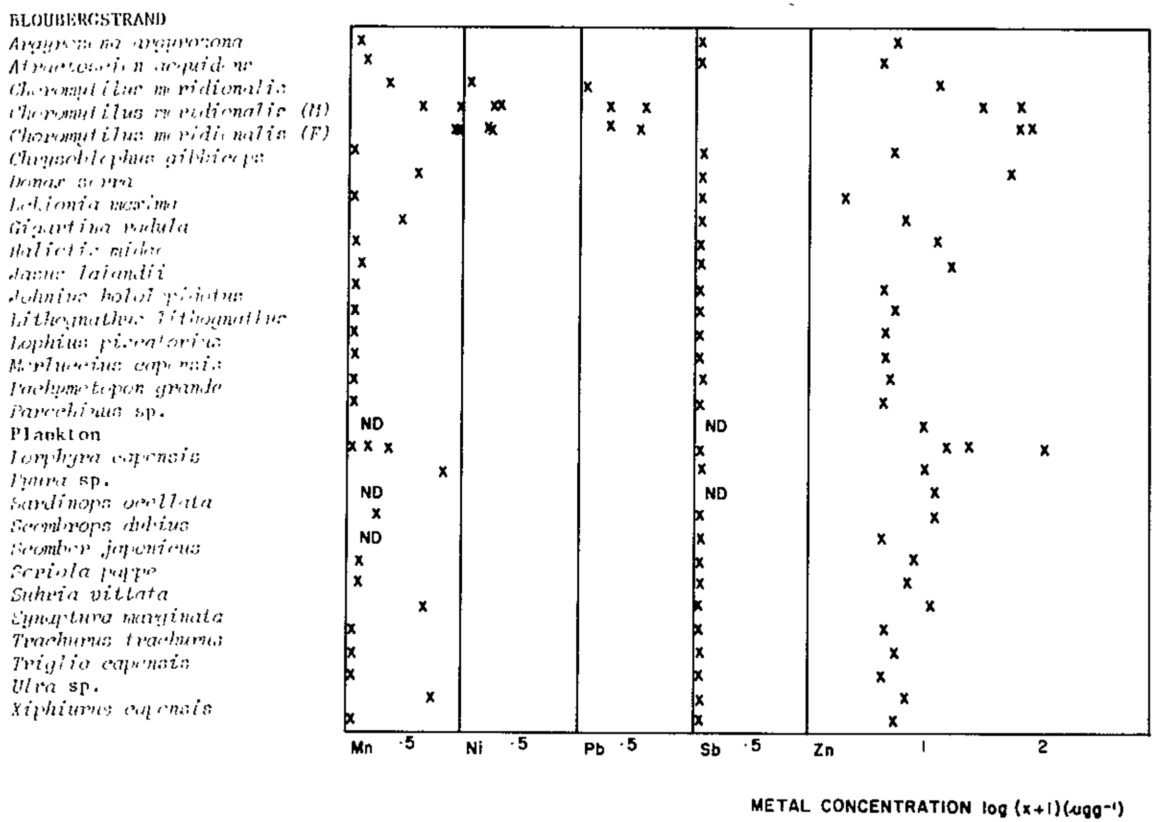


Figure 62 Metal concentrations in marine organisms from Blouberg Strand


BLOUBERGSTRAND
Argyrosoma argyrozona
Atractoscion aequidens
Choromytilus meridionalis
Choromytilus meridionalis (M)
Choromytilus meridionalis (F)
Chrysoblephus gibbiceps
Donax serra
Ecklonia maxima
Gigartina radula
Haliotis midae
Jasus lalandii
Johnius hololepidotus
Lithognathus lithognathus
Lophius piscatorius
Merluccius capensis
Pachymetopon grande
Parechinus sp.
Plankton
Porphyra capensis
Pyura sp.
Sardinops ocellata
Scombrops dubius
Scomber japonicus
Seriola pappe
Sufflamen vittata
Synaptura marginata
Trachurus trachurus
Triglia capensis
Ulva sp.
Xiphiurus capensis
ND
Mn ·5
Ni ·5
Pb ·5
Sb ·5
Zn 1 2
METAL CONCENTRATION log (x+1)(µgg⁻¹)

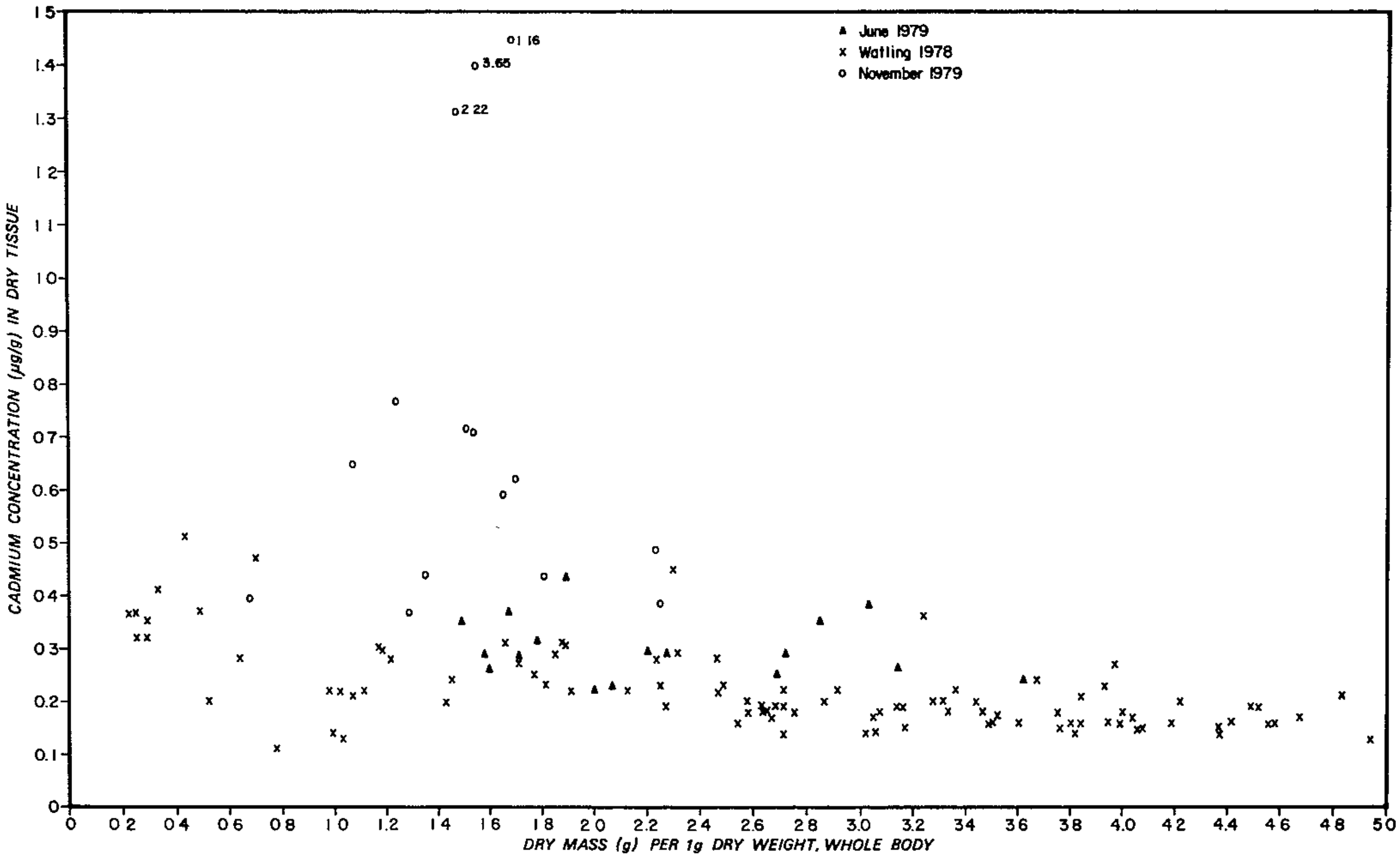


Figure 63 Cadmium content in mature C. meridionalis from Blouberg Strand

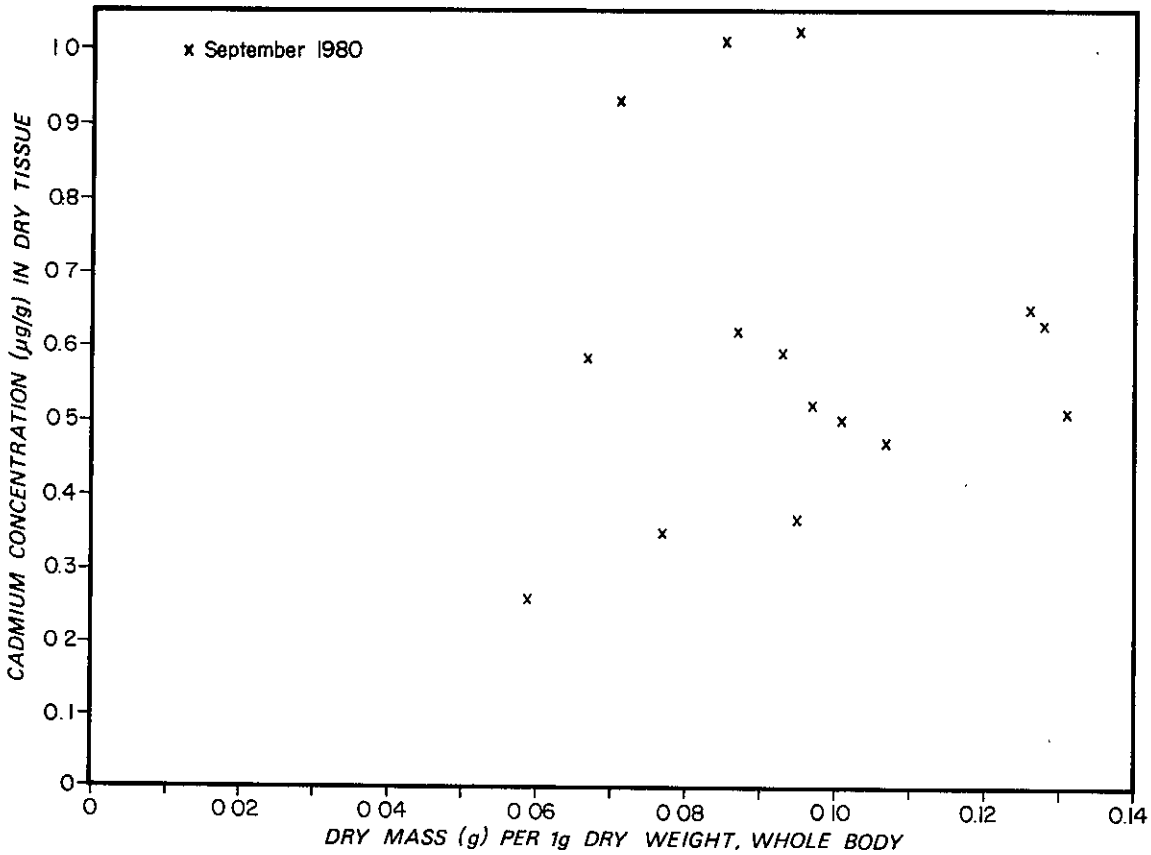


Figure 64 Cadmium content in immature C. meridionalis from Blouberg Strand

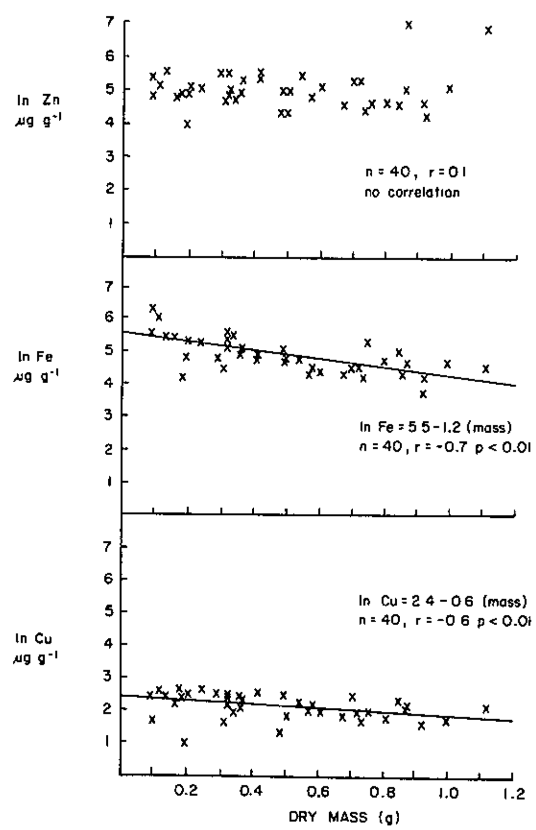


Figure 65 Metal concentrations in C. meridionalis

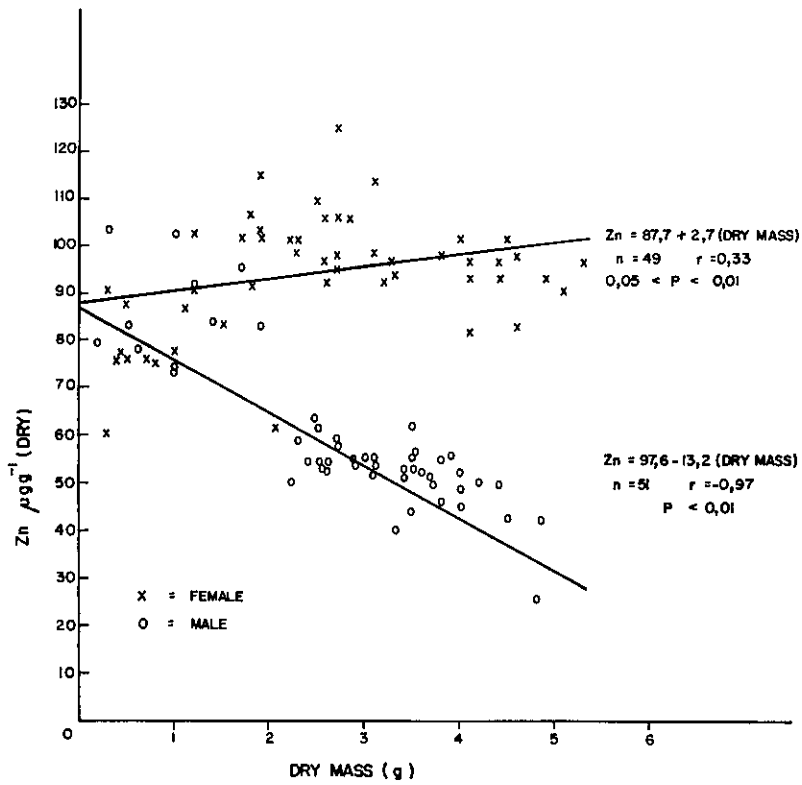


Figure 66 Zinc concentrations in black mussel (after Watling, 1978)

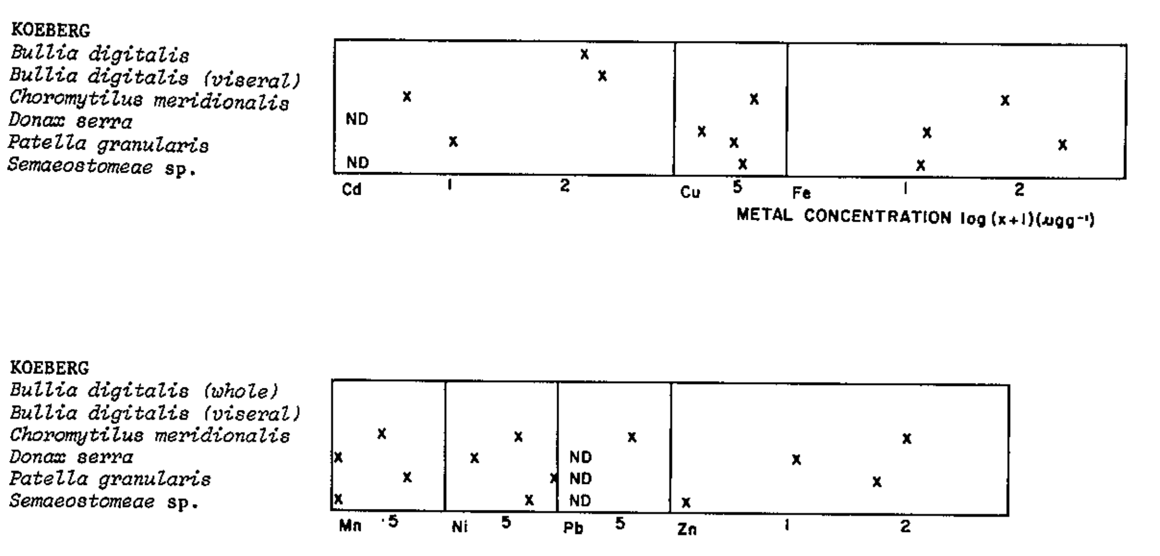


Figure 67 Metal concentrations in marine organisms from Koeberg

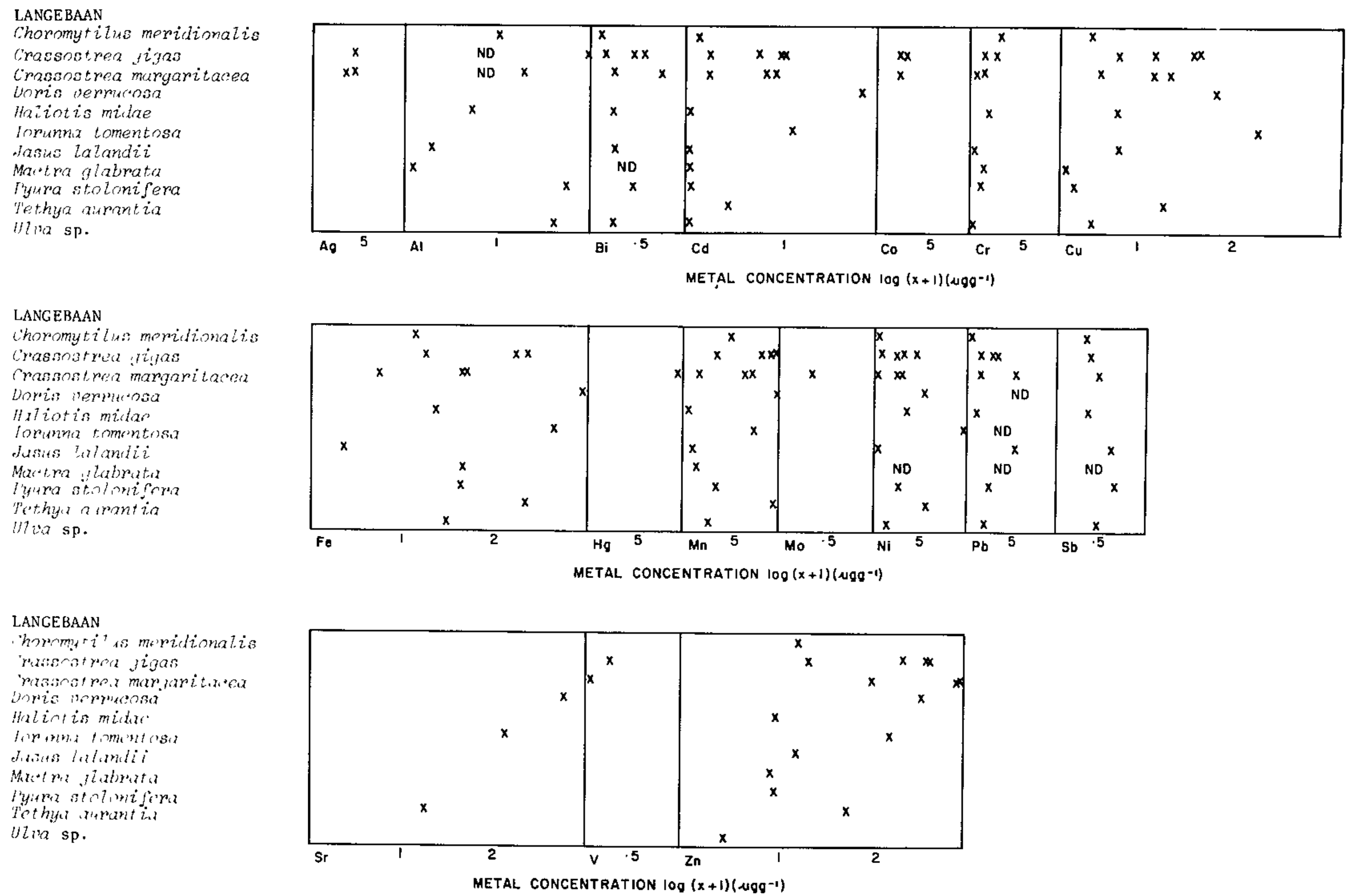


Figure 68 Metal concentrations in marine organisms from Langebaan

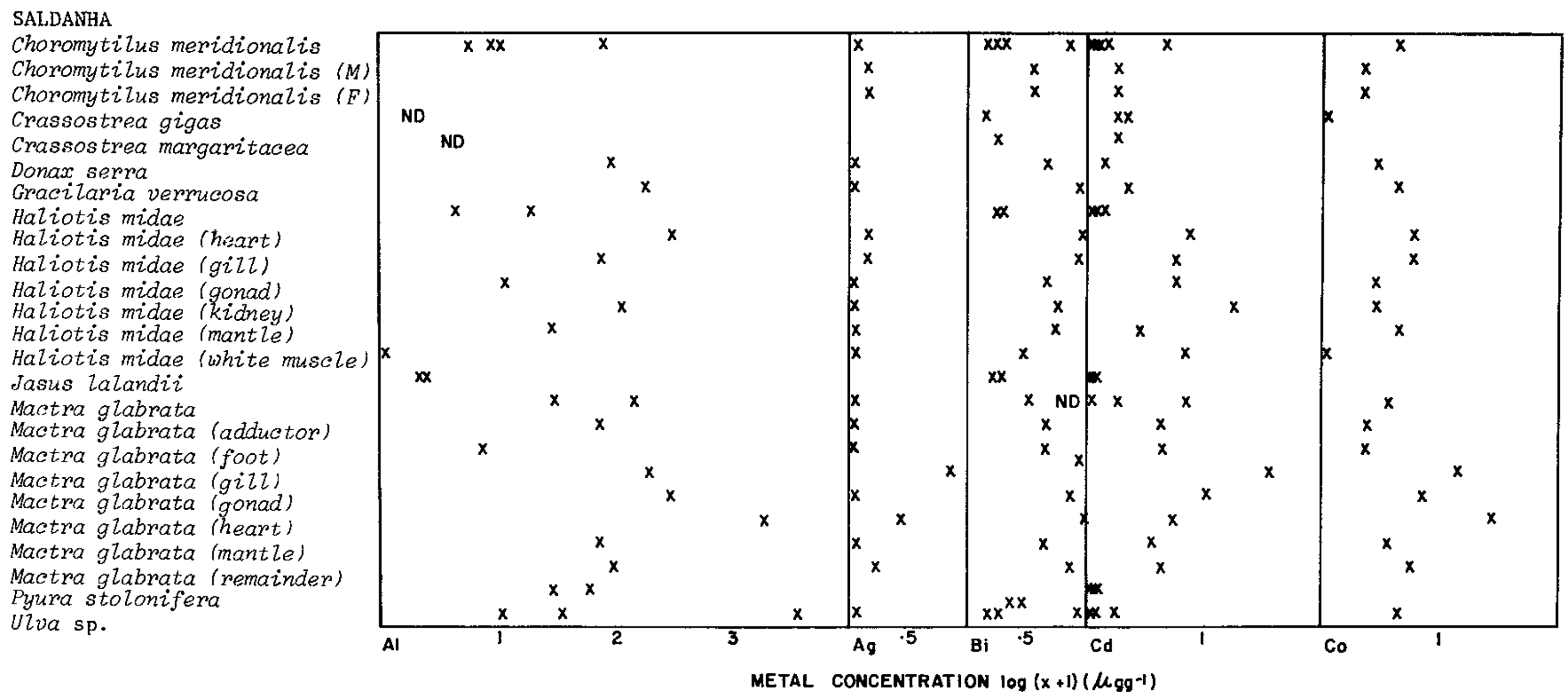
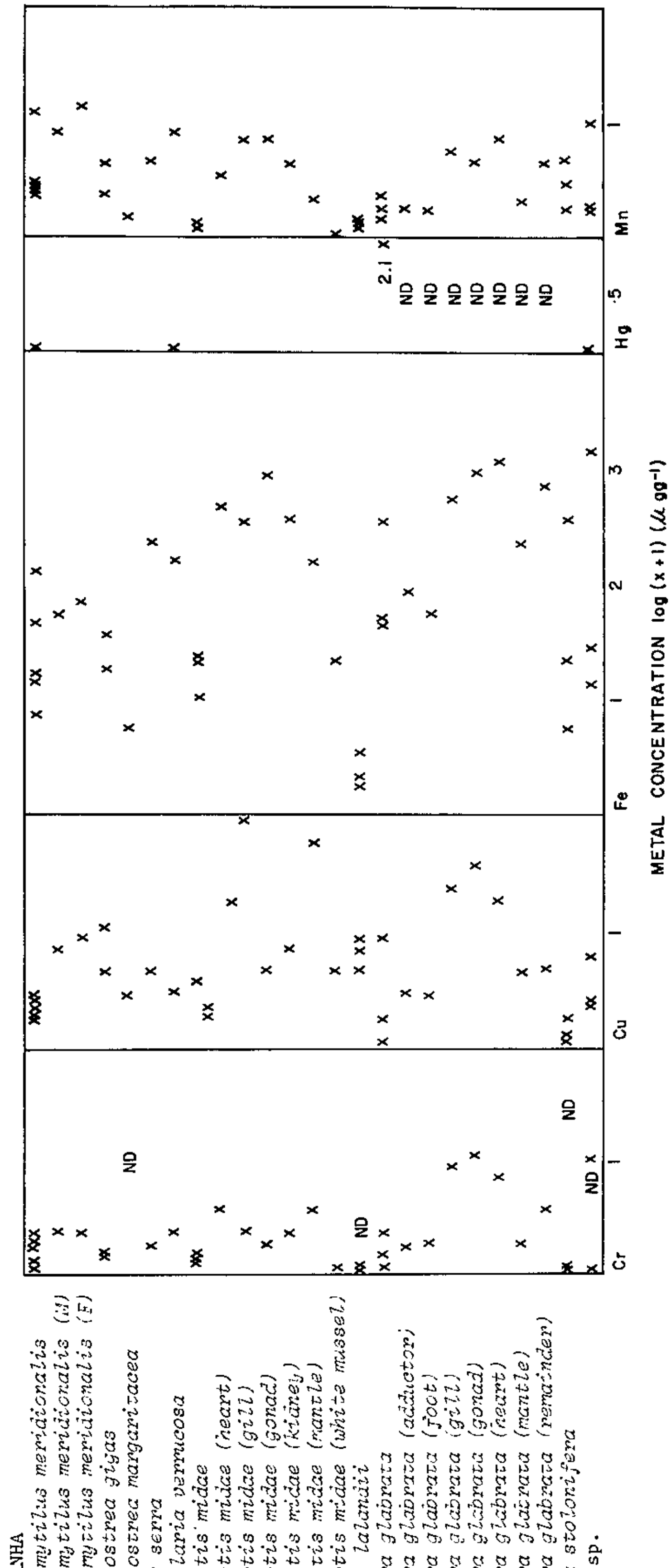
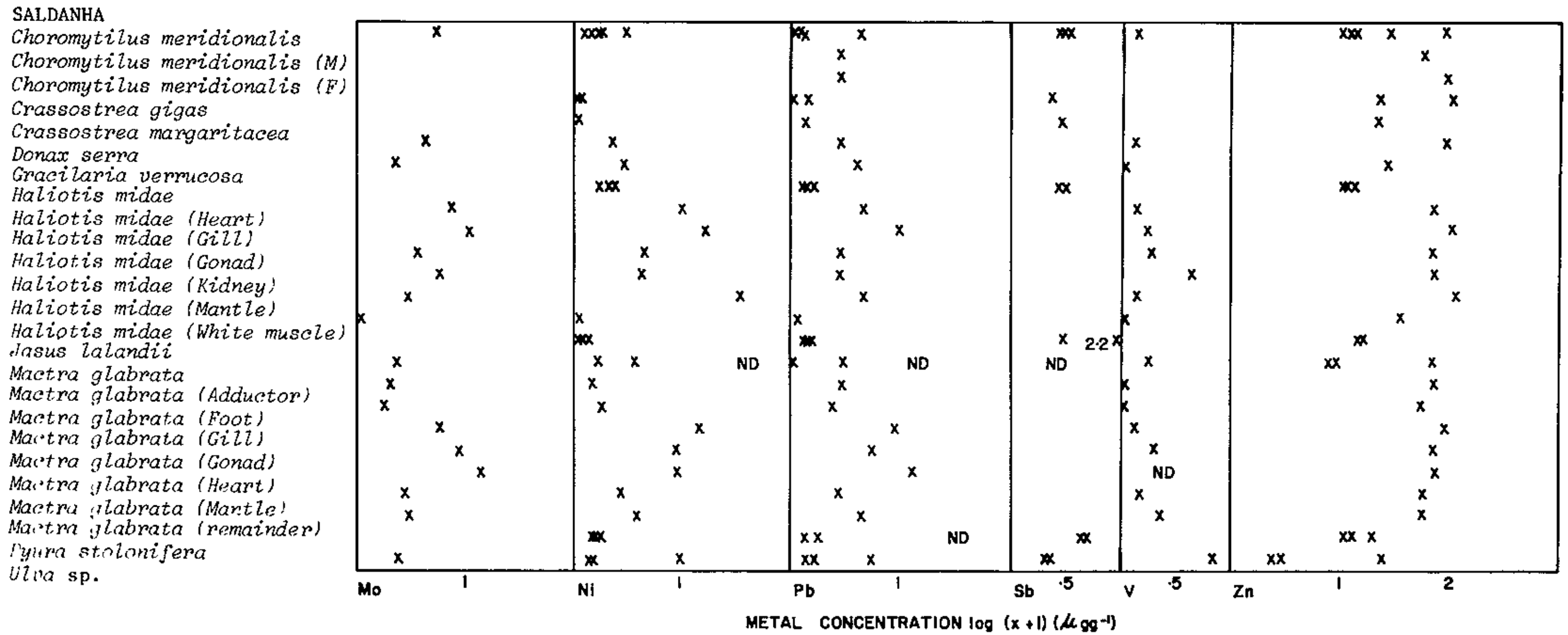


Figure 69 Metal concentrations in marine organisms from Saldanha


SALDANHA
Choromytilus meridionalis
Choromytilus meridionalis (M)
Choromytilus meridionalis (F)
Crassostrea gigas
Crassostrea margaritacea
Donax serra
Gracilaria verrucosa
Haliotis midae
Haliotis midae (heart)
Haliotis midae (gill)
Haliotis midae (gonad)
Haliotis midae (kidney)
Haliotis midae (mantle)
Haliotis midae (white mussel)
Jasus lalandii
Mactra glabrata (adductor)
Mactra glabrata (foot)
Mactra glabrata (gill)
Mactra glabrata (gonad)
Mactra glabrata (heart)
Mactra glabrata (mantle)
Mactra glabrata (remainder)
Pyura stolonifera
Ulva sp.
Cr
Cu
Fe
Hg
Mn
ND
2.1
METAL CONCENTRATION log (x+1) (μ gg⁻¹)


SALDANHA
Choromytilus meridionalis
Choromytilus meridionalis (M)
Choromytilus meridionalis (F)
Crassostrea gigas
Crassostrea margaritacea
Donax serra
Gracilaria verrucosa
Haliotis midae
Haliotis midae (Heart)
Haliotis midae (Gill)
Haliotis midae (Gonad)
Haliotis midae (Kidney)
Haliotis midae (Mantle)
Haliotis midae (White muscle)
Jasus lalandii
Mactra glabrata
Mactra glabrata (Adductor)
Mactra glabrata (Foot)
Mactra glabrata (Gill)
Mactra glabrata (Gonad)
Mactra glabrata (Heart)
Mactra glabrata (Mantle)
Mactra glabrata (remainder)
Pyura stolonifera
Ulva sp.
ND
2·2
Mo
Ni
Pb
Sb
V
Zn
·5
1
2
METAL CONCENTRATION log (x + l) (µg g⁻¹)

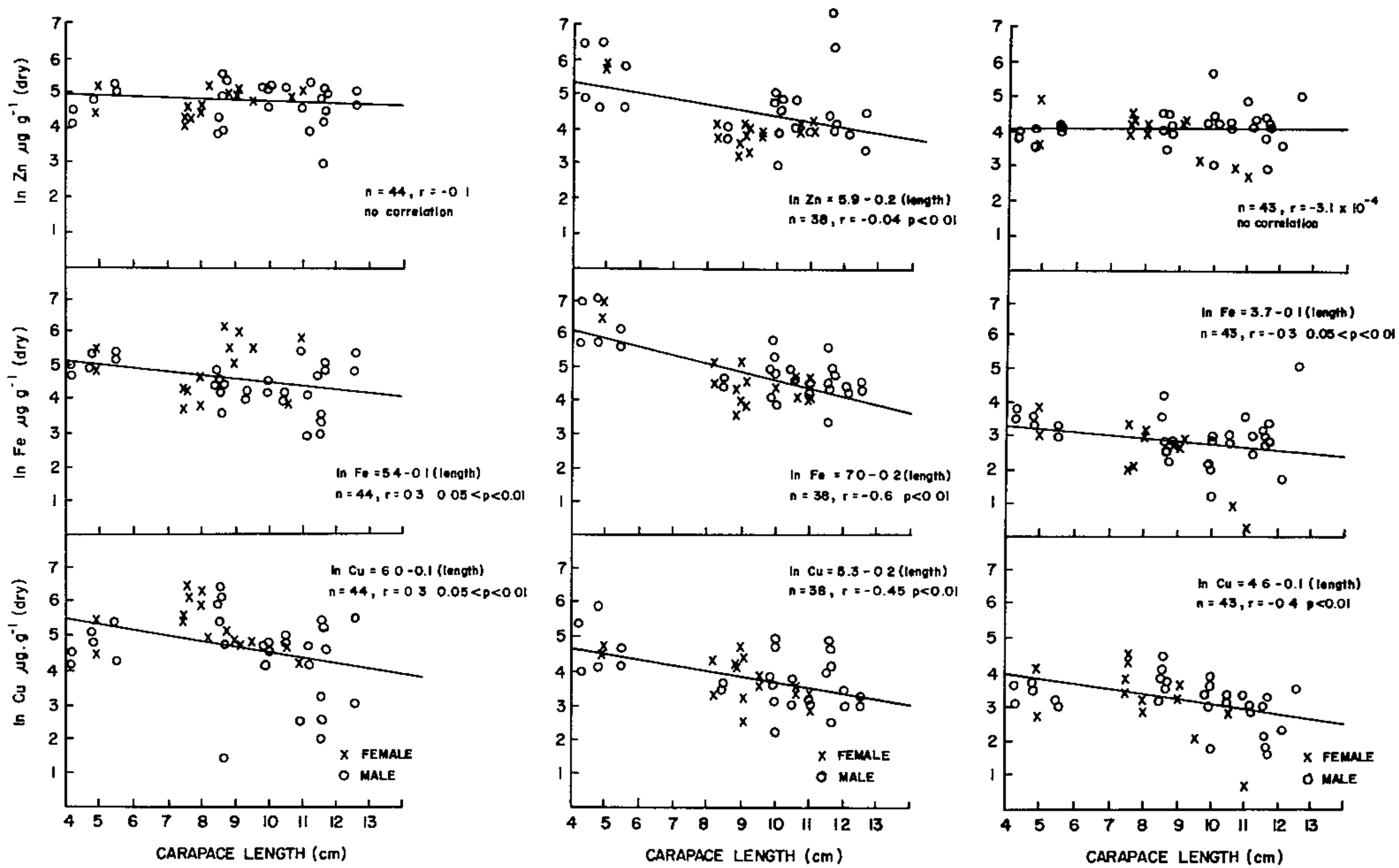


Figure 70a Metal concentrations in rock lobster tails (left)

Figure 70b Metal concentrations in rock lobster green gland (middle)

Figure 70c Metal concentrations in rock lobster gills (right)

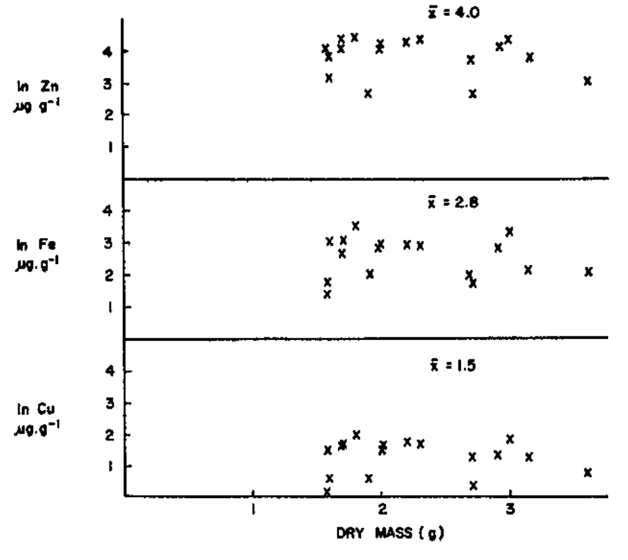


Figure 71 Metal concentrations in ribbed mussels, Aulacomya ater

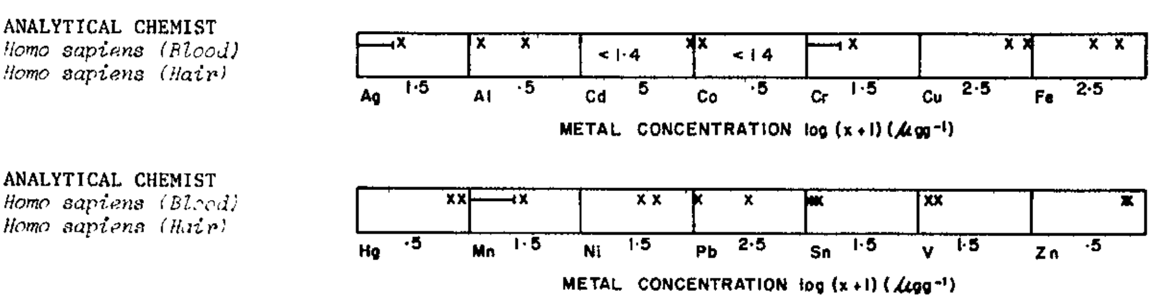


Figure 72 Metal concentrations in chemical analysts

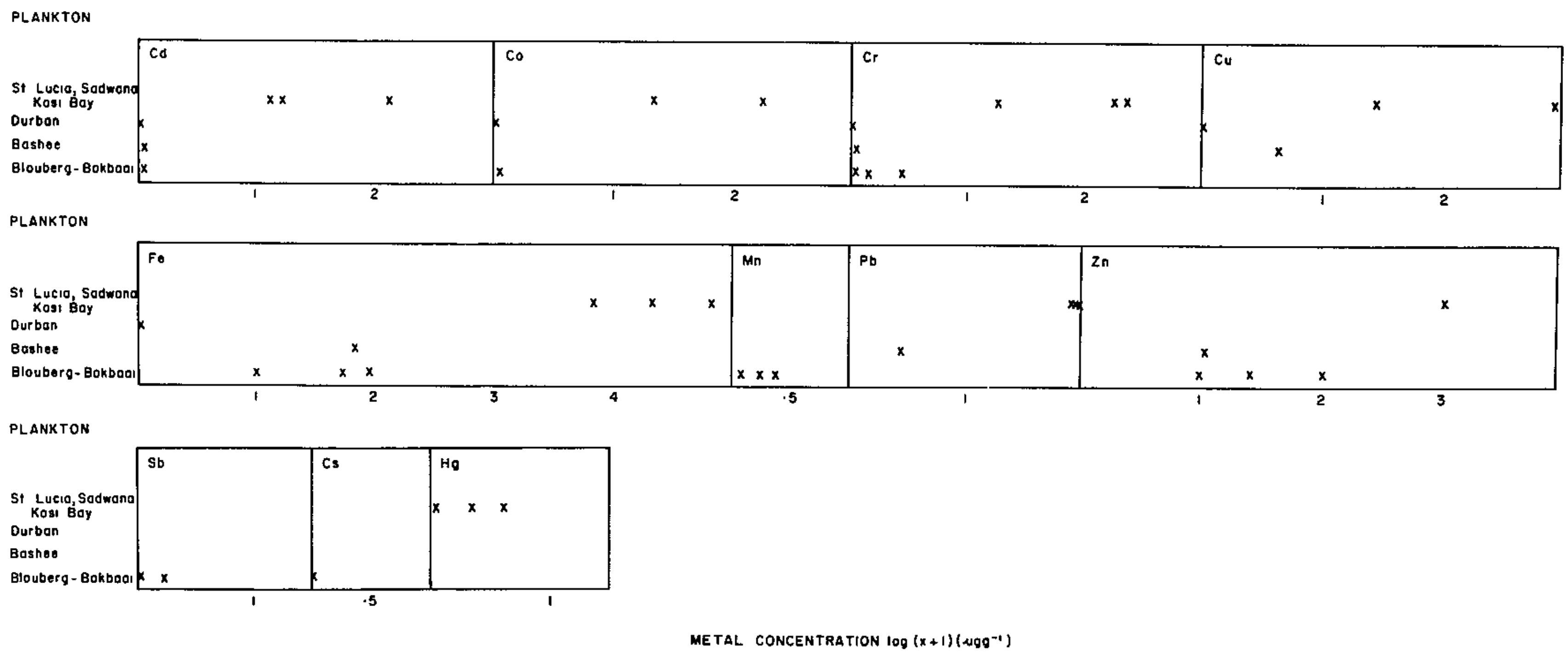


Figure 73 Metal concentrations in plankton

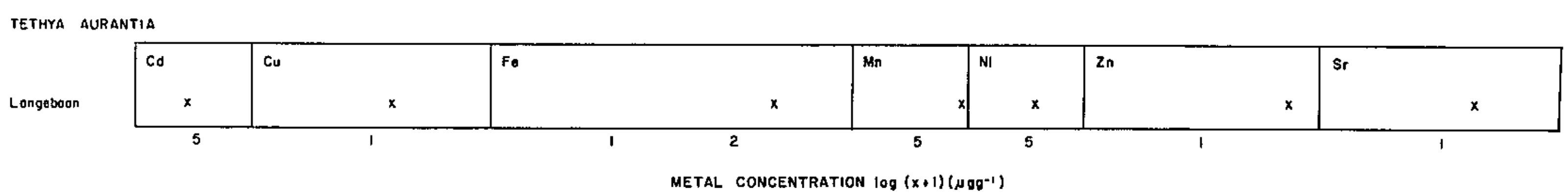


Figure 74 Metal concentrations in <u>Porifera</u> (sponge)

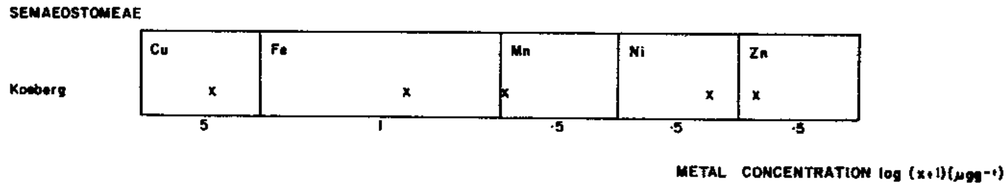


Figure 75 Metal concentrations in <u>Cnidaria</u> (jelly fish)

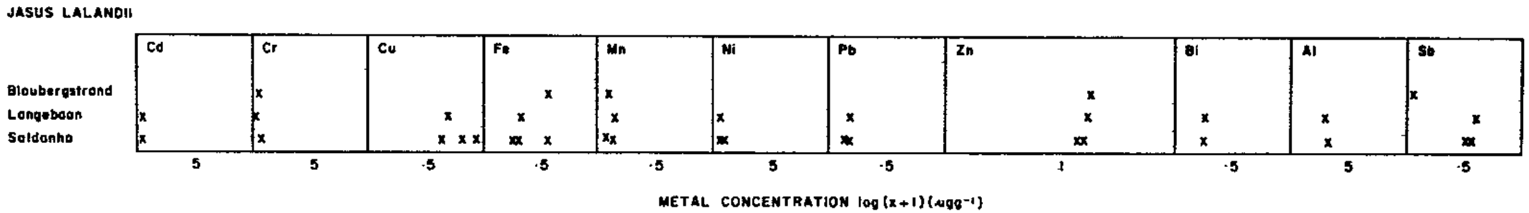


Figure 76 Metal concentrations in <u>Jasus lalandii</u>

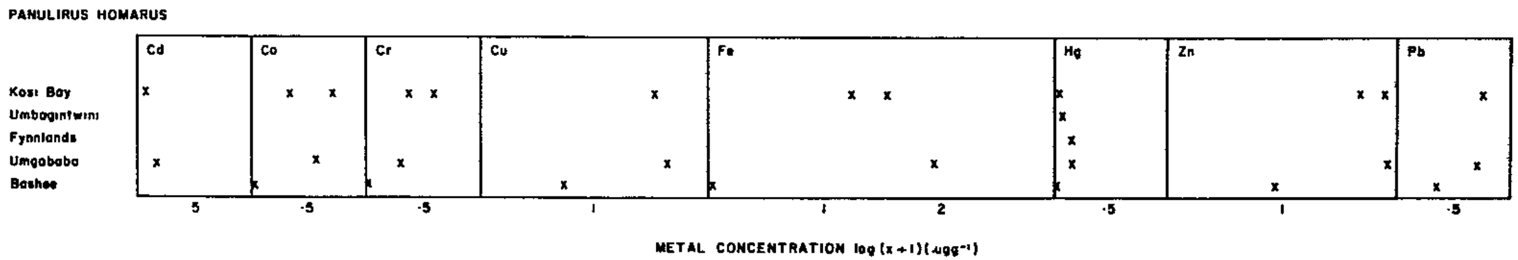


Figure 77 Metal concentrations in <u>Panulirus homarus</u>

Figure 78 Metal concentrations in <u>Panulirus versicolor</u>

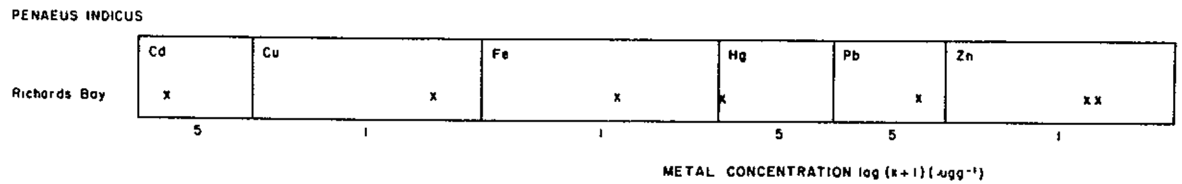


Figure 79 Metal concentrations in <u>Penaeus indicus</u>

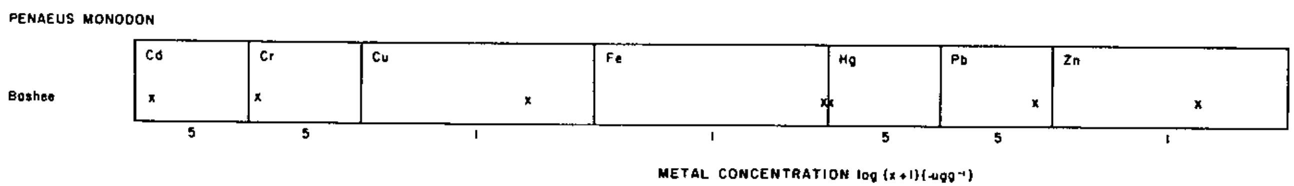


Figure 80 Metal concentrations in <u>Penaeus monodon</u>

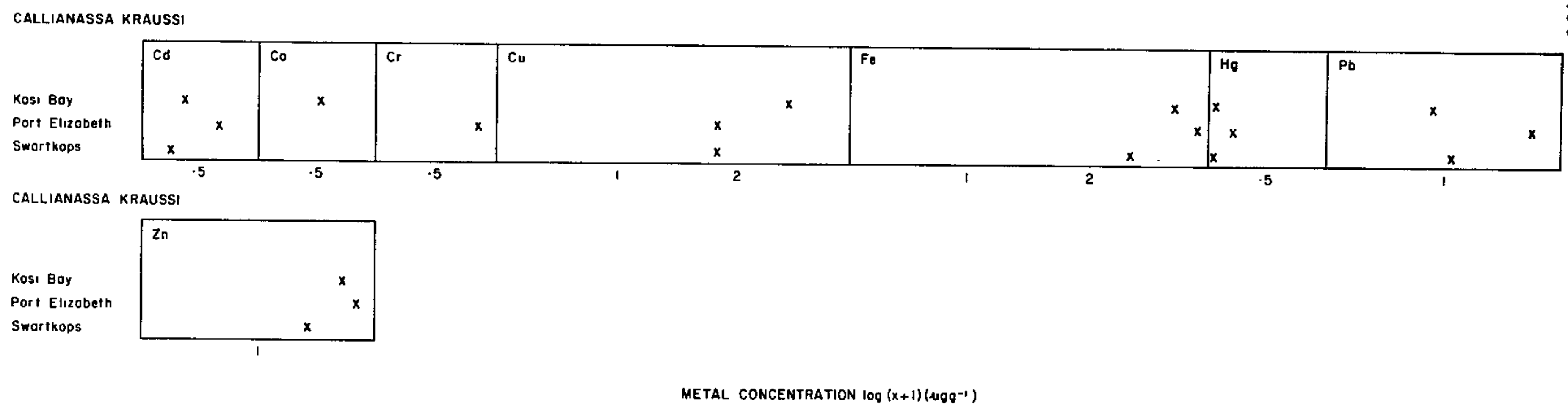


Figure 81 Metal concentrations in <u>Callianassa kraussi</u>

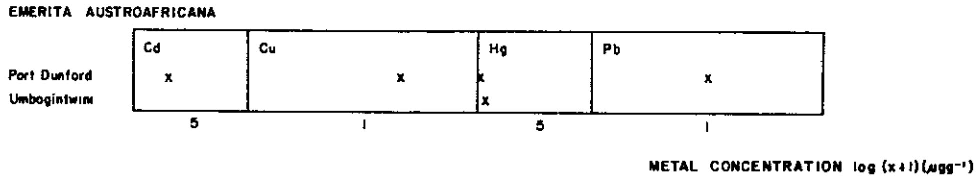


Figure 82 Metal concentrations in Emerita austroafricana

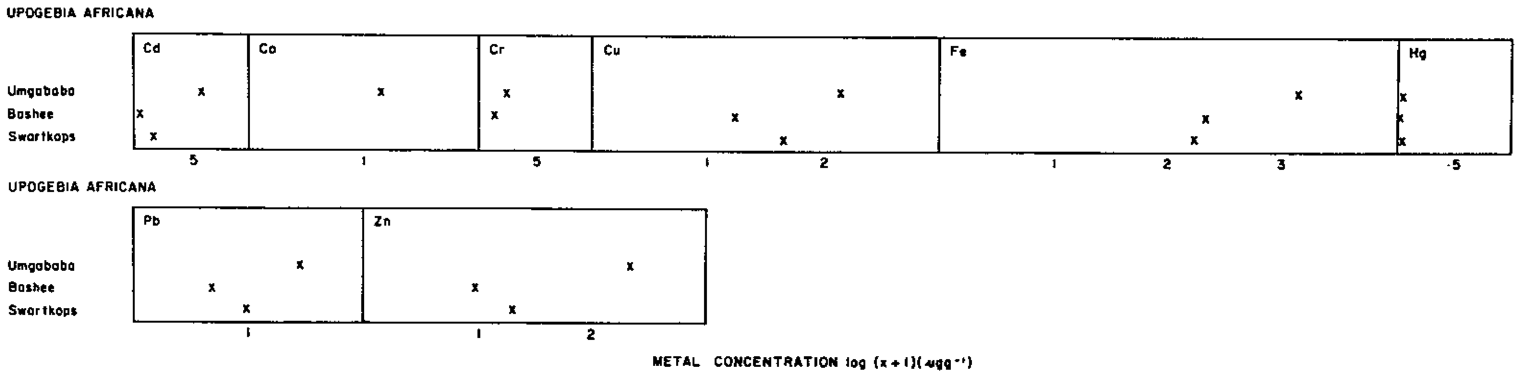


Figure 83 Metal concentrations in Upogebia africana

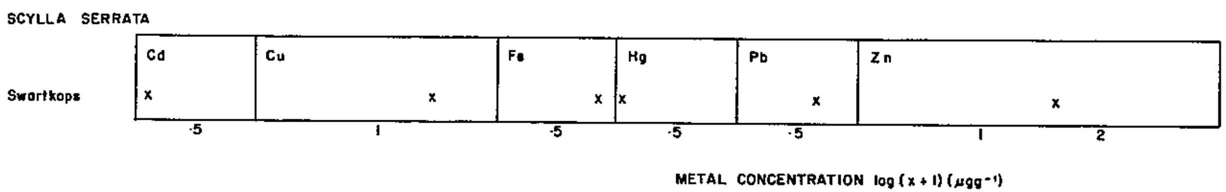


Figure 84 Metal concentrations in Scylla serrata

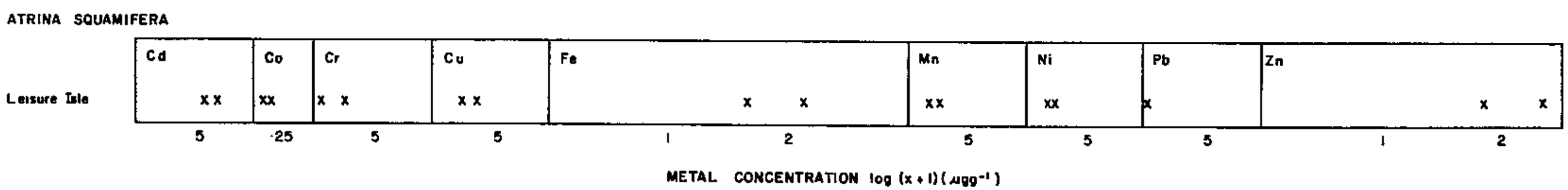


Figure 85 Metal concentrations in Atrina squamifera

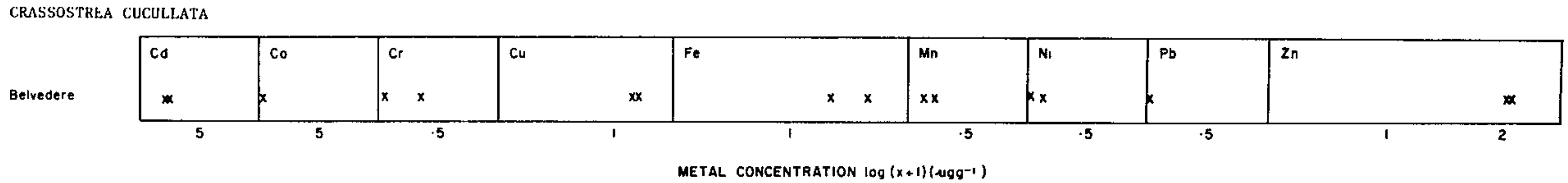


Figure 86 Metal concentrations in Crassostrea cucullata

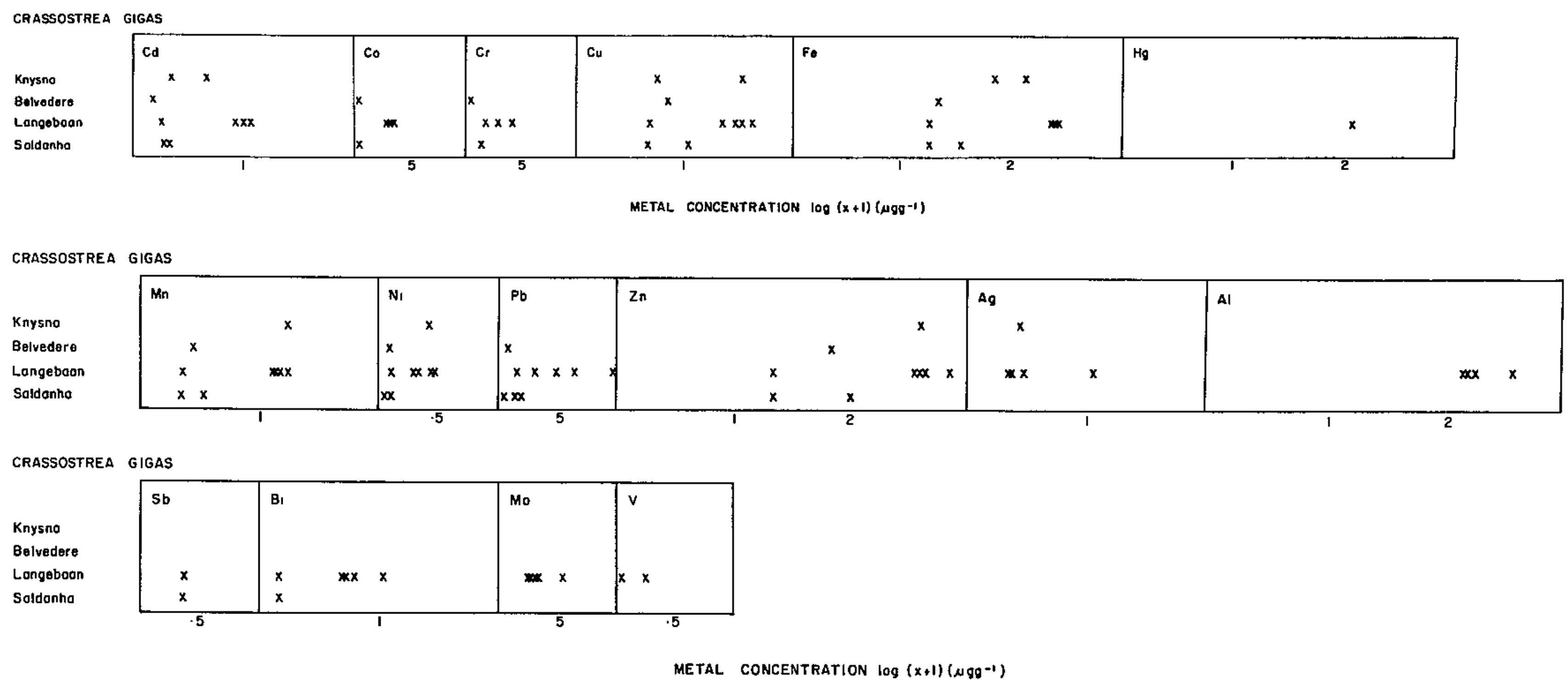


Figure 87 Metal concentrations in Crassostrea gigas

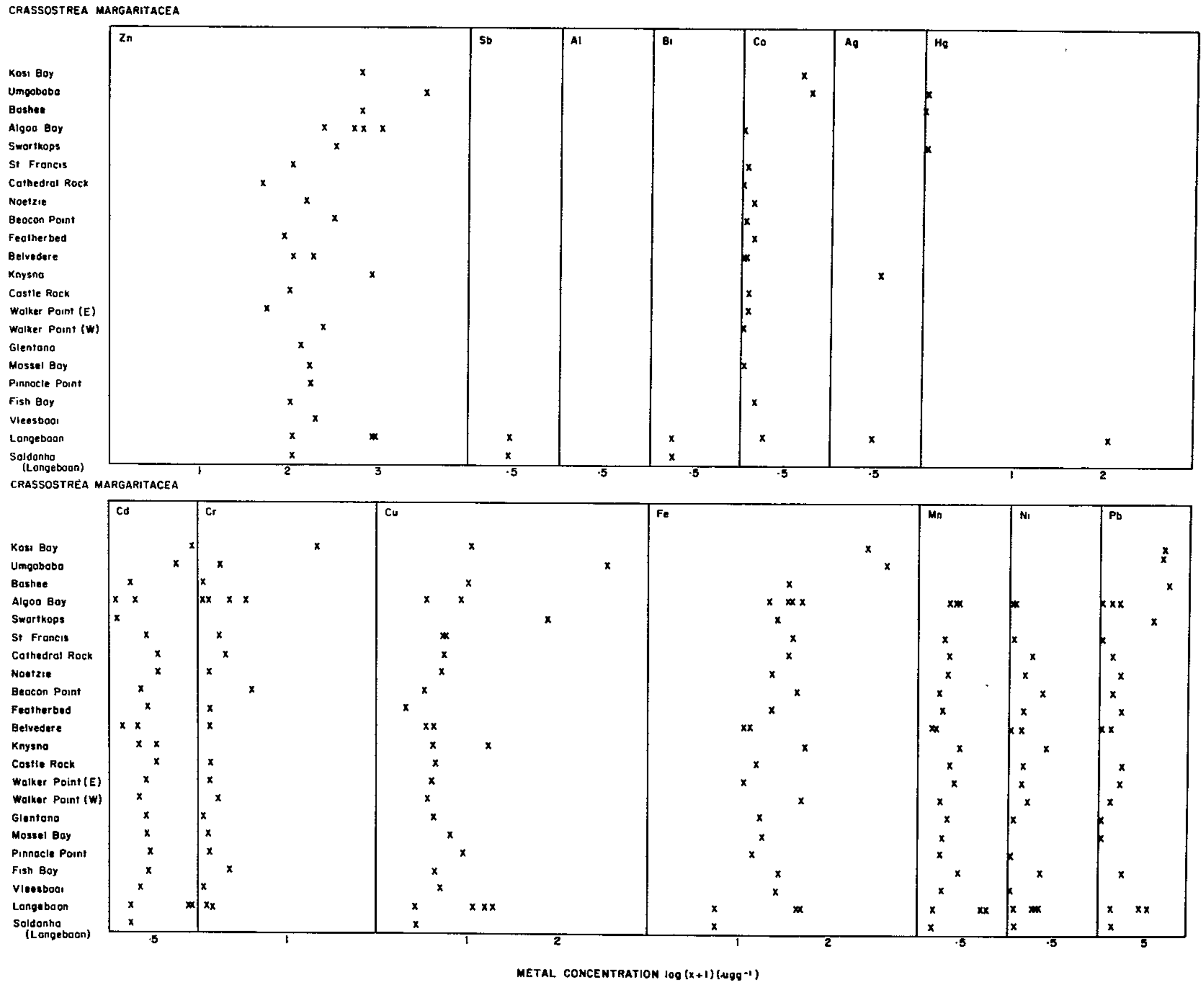


Figure 88 Metal concentrations in Crassostrea margaritacea

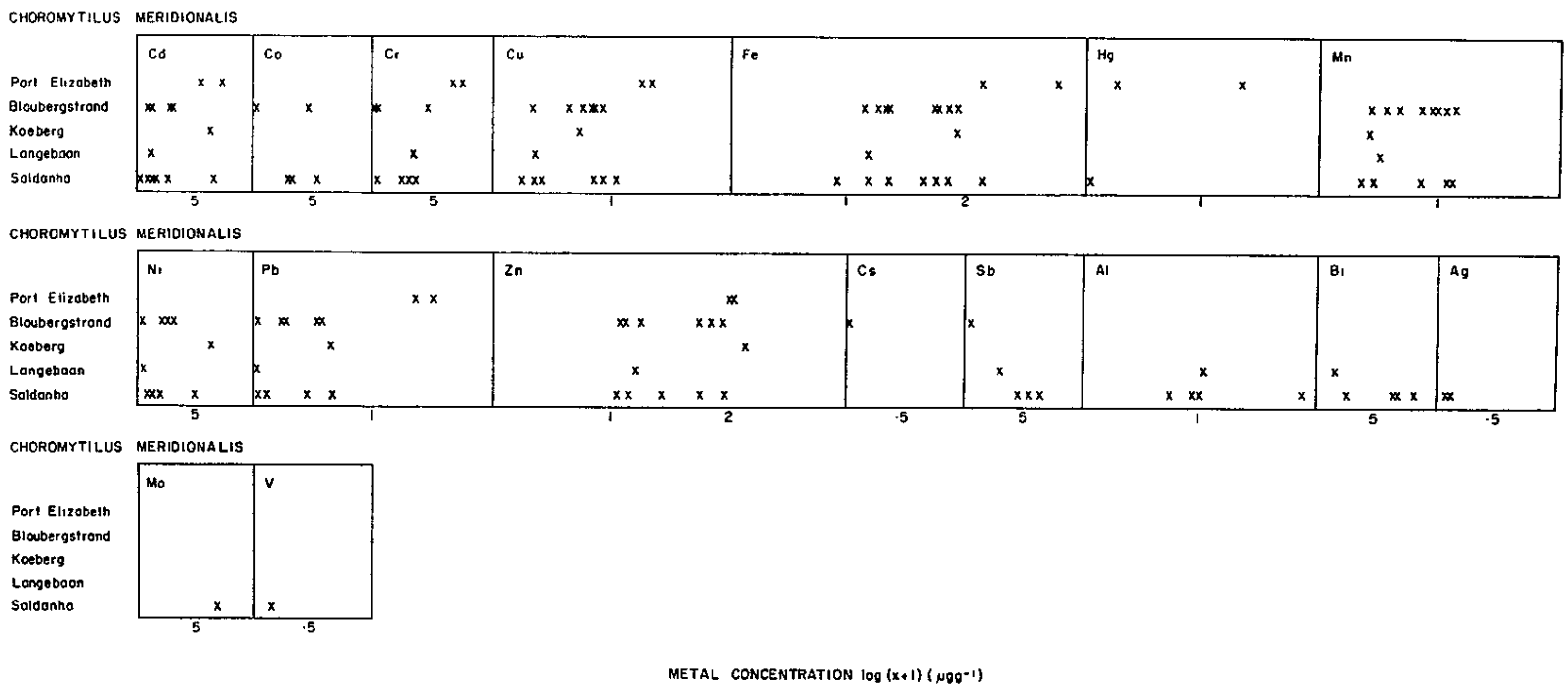


Figure 89 Metal concentrations in <u>Choromytilus meridionalis</u>

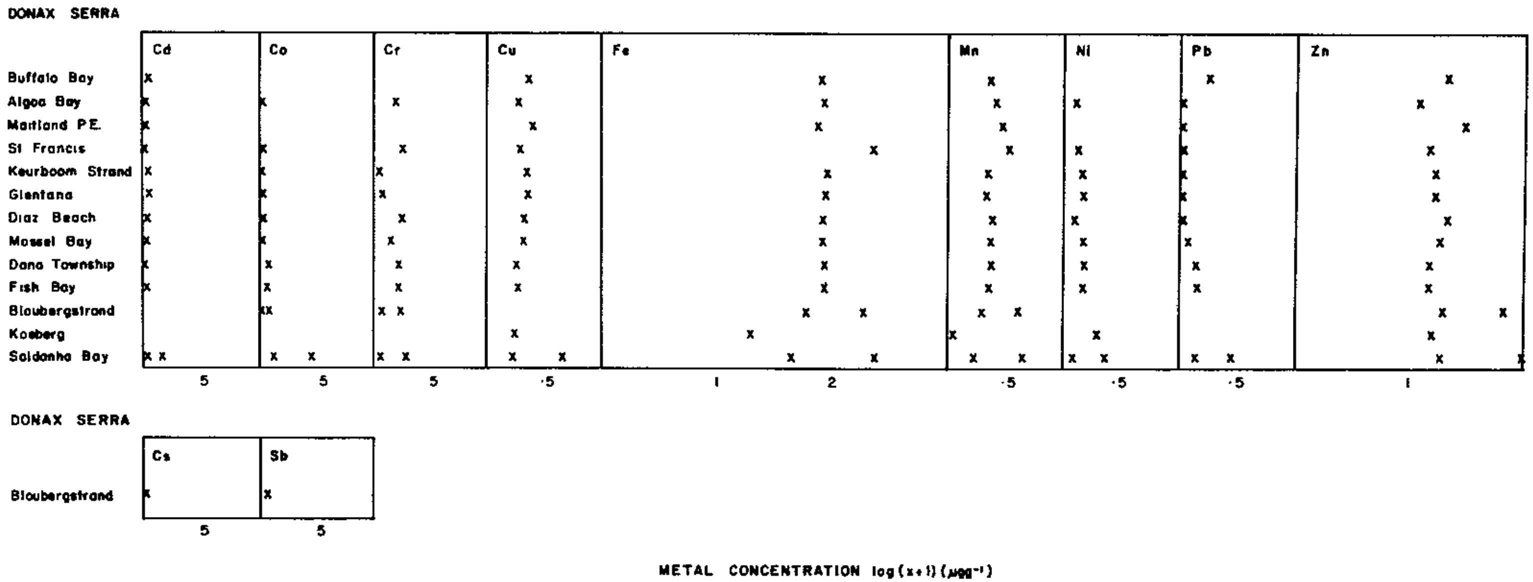


Figure 90 Metal concentrations in <u>Donax serra</u>

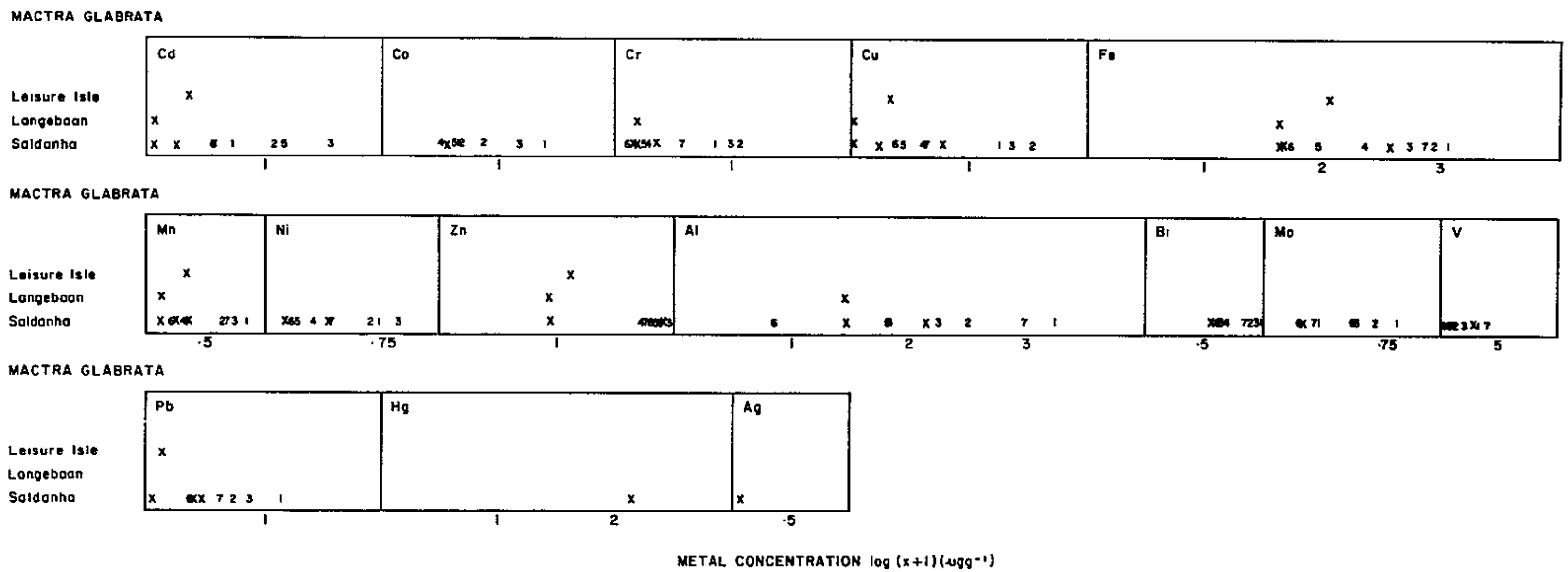


Figure 91 Metal concentrations in <u>Mactra glabrata</u> (1 = heart, 2 = gonad, 3 = gill, 4 = mantle, 5 = adductor muscle, 6 = foot, 7 = remainder)

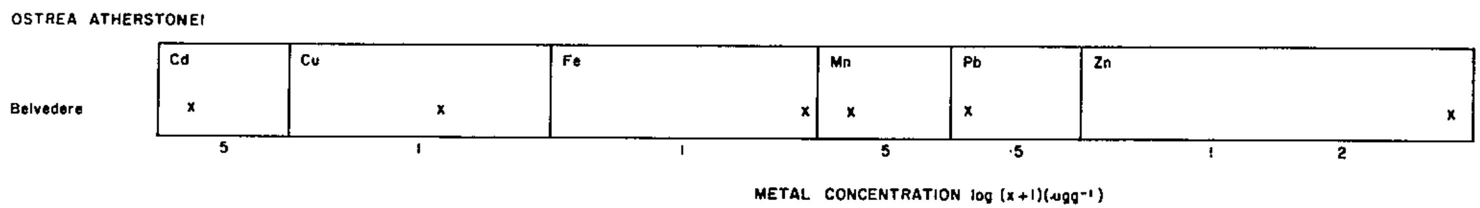


Figure 92 Metal concentrations in <u>Ostrea atherstonei</u>

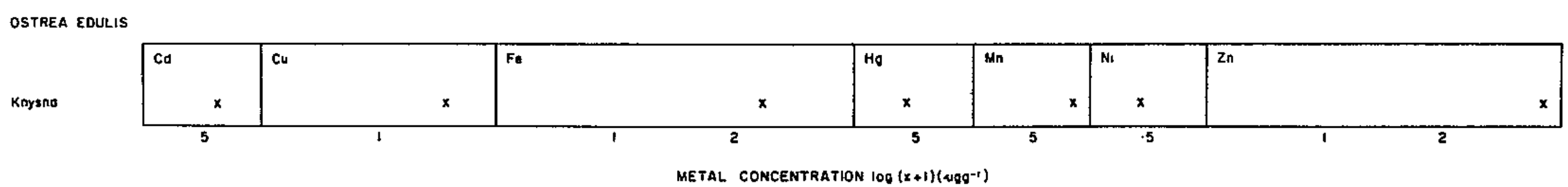


Figure 93 Metal concentrations in <u>Ostrea edulis</u>

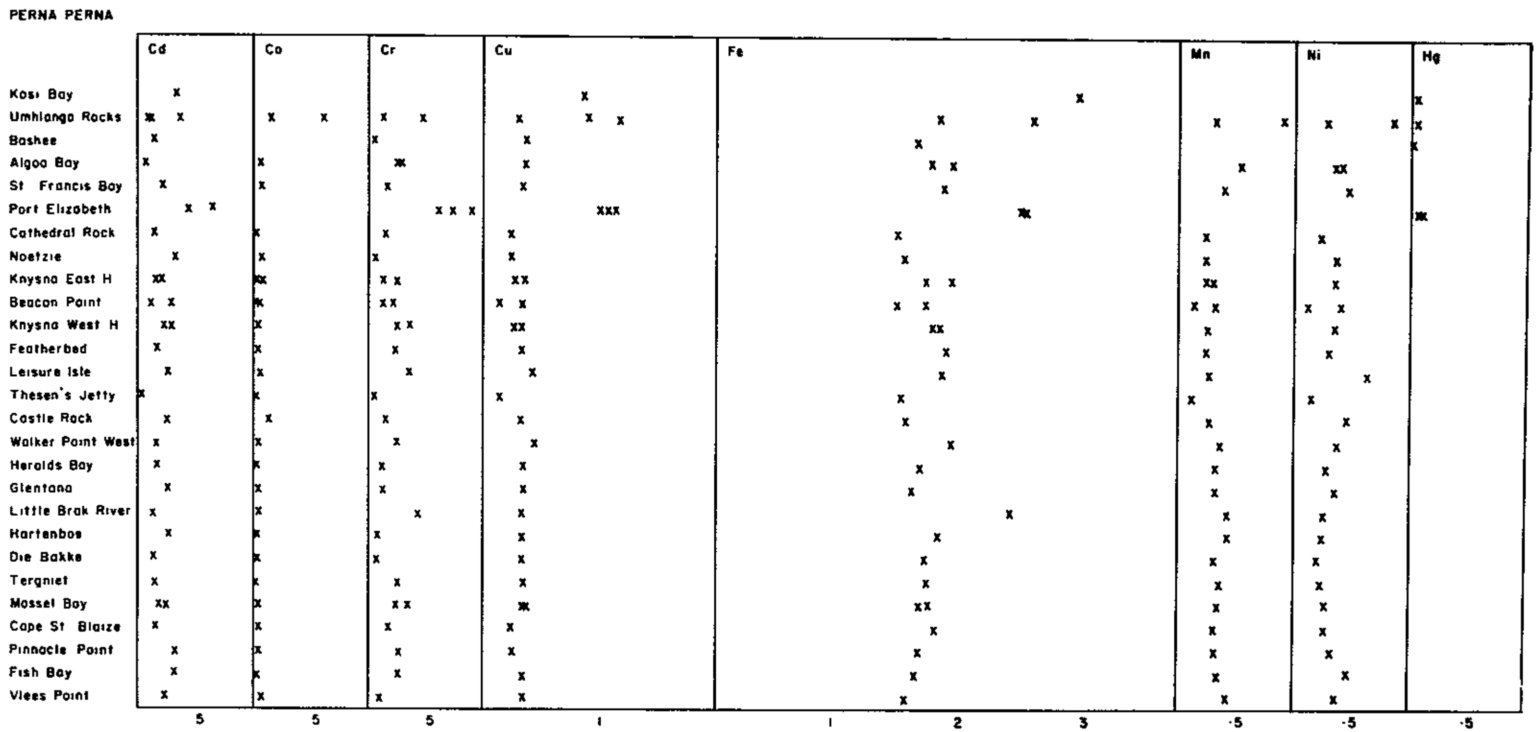
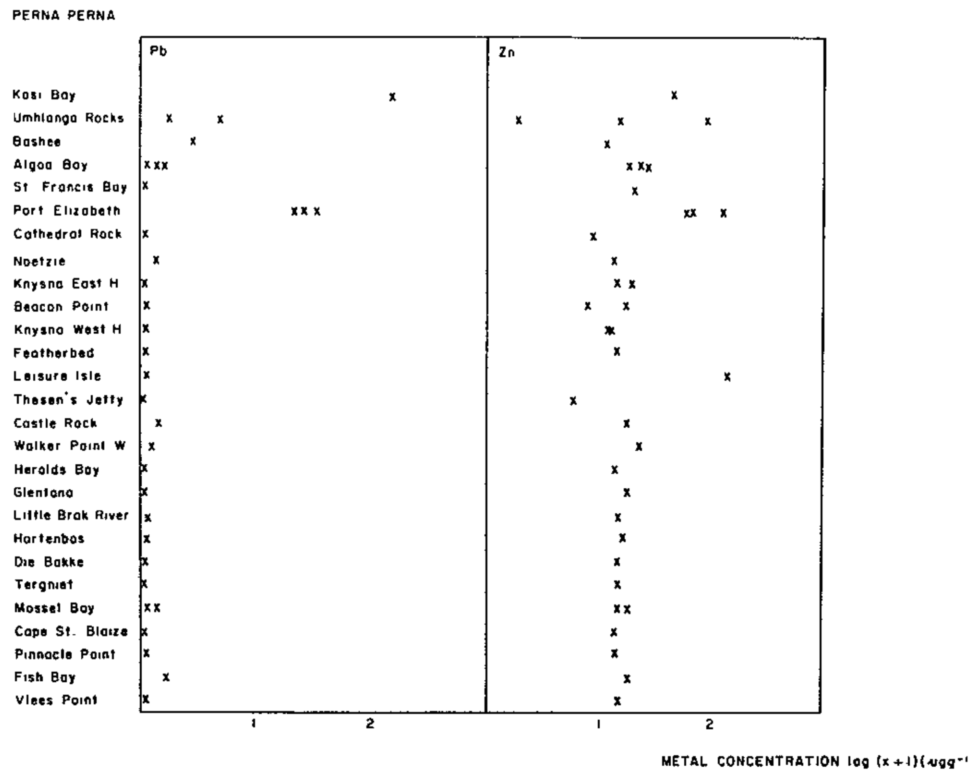


Figure 94 Metal concentrations in Perna perna



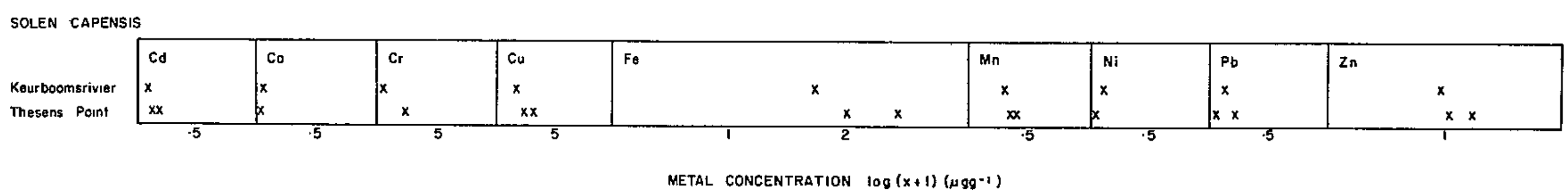


Figure 95 Metal concentrations in <u>Solen capensis</u>

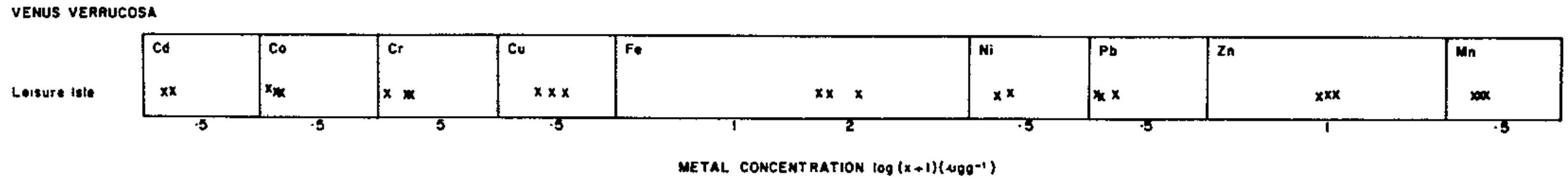


Figure 96 Metal concentrations in Venus verrucosa

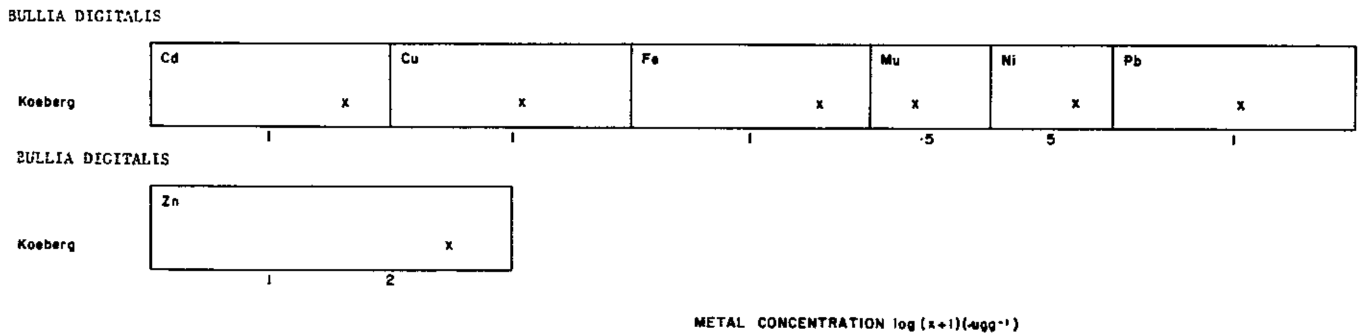


Figure 97 Metal concentrations in Bullia digitalis

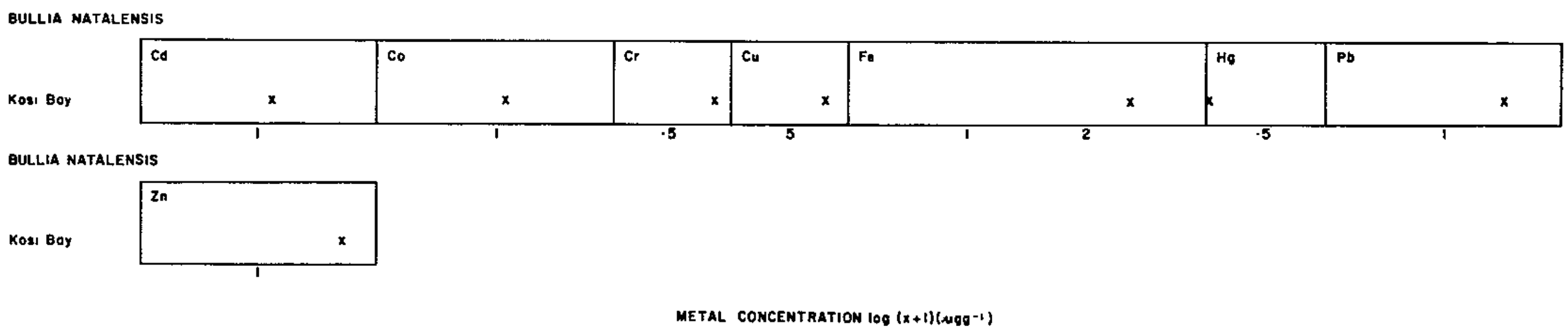


Figure 98 Metal concentrations in Bullia natalensis

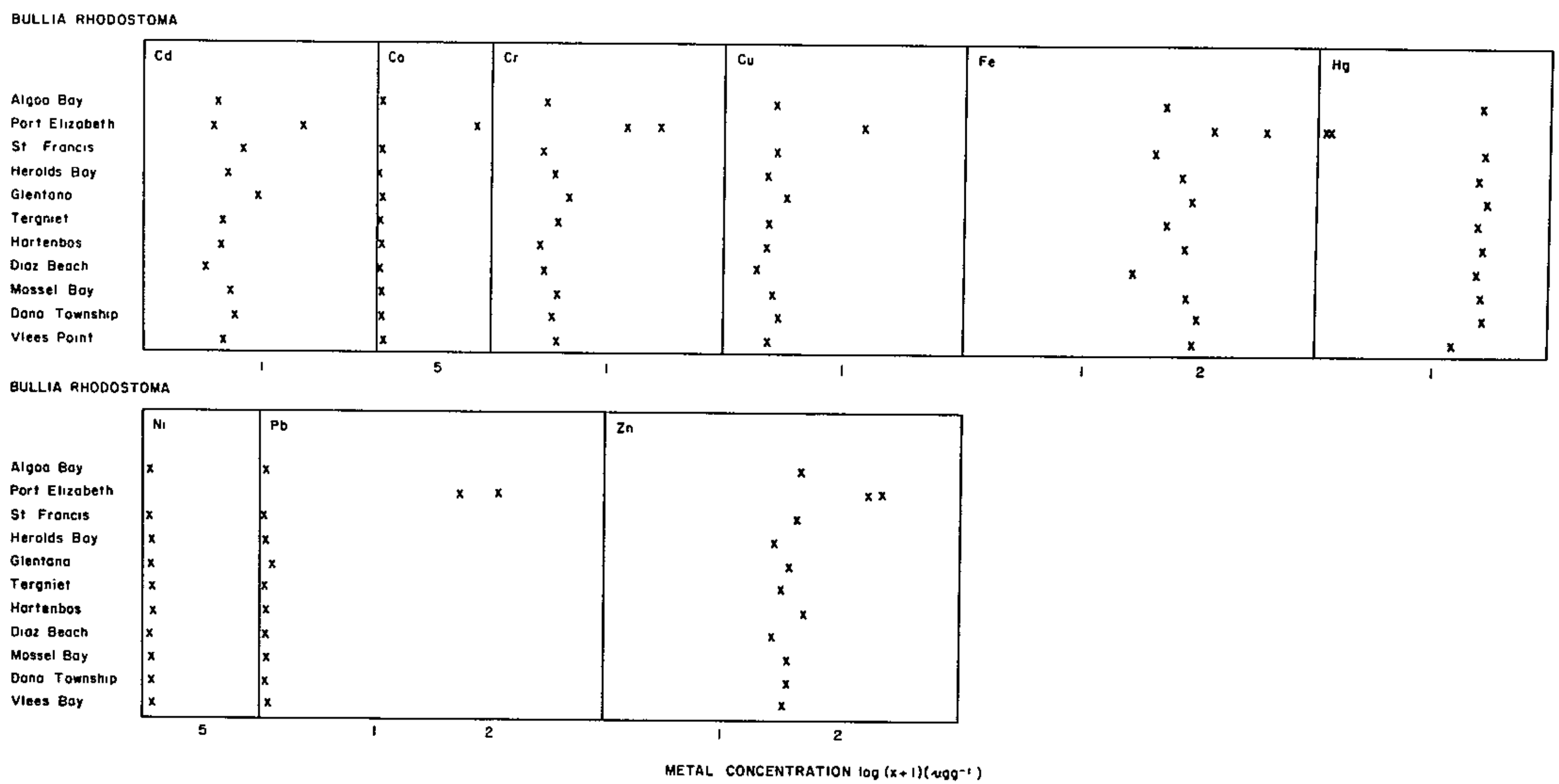


Figure 99 Metal concentrations in Bullia rhodostoma

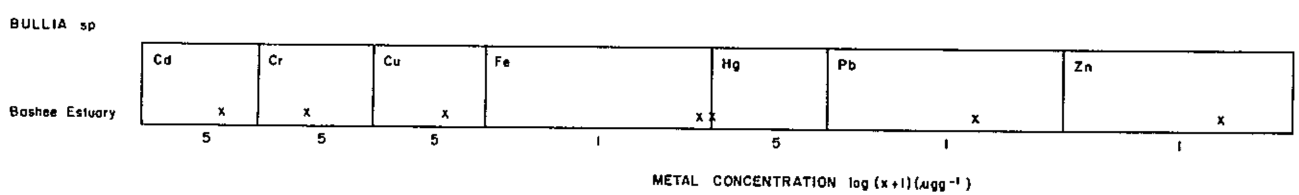


Figure 100 Metal concentrations in Bullia sp

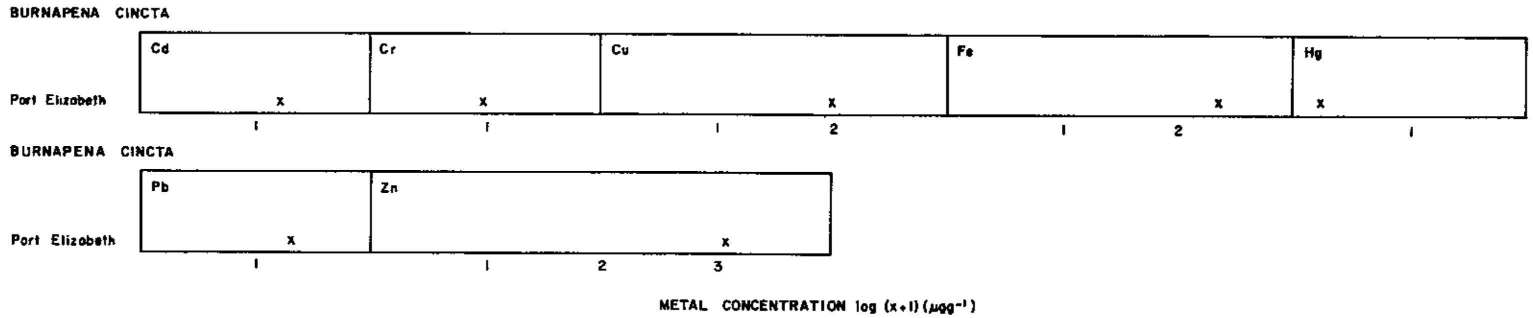


Figure 101 Metal concentrations in <u>Burnupena cincta</u>

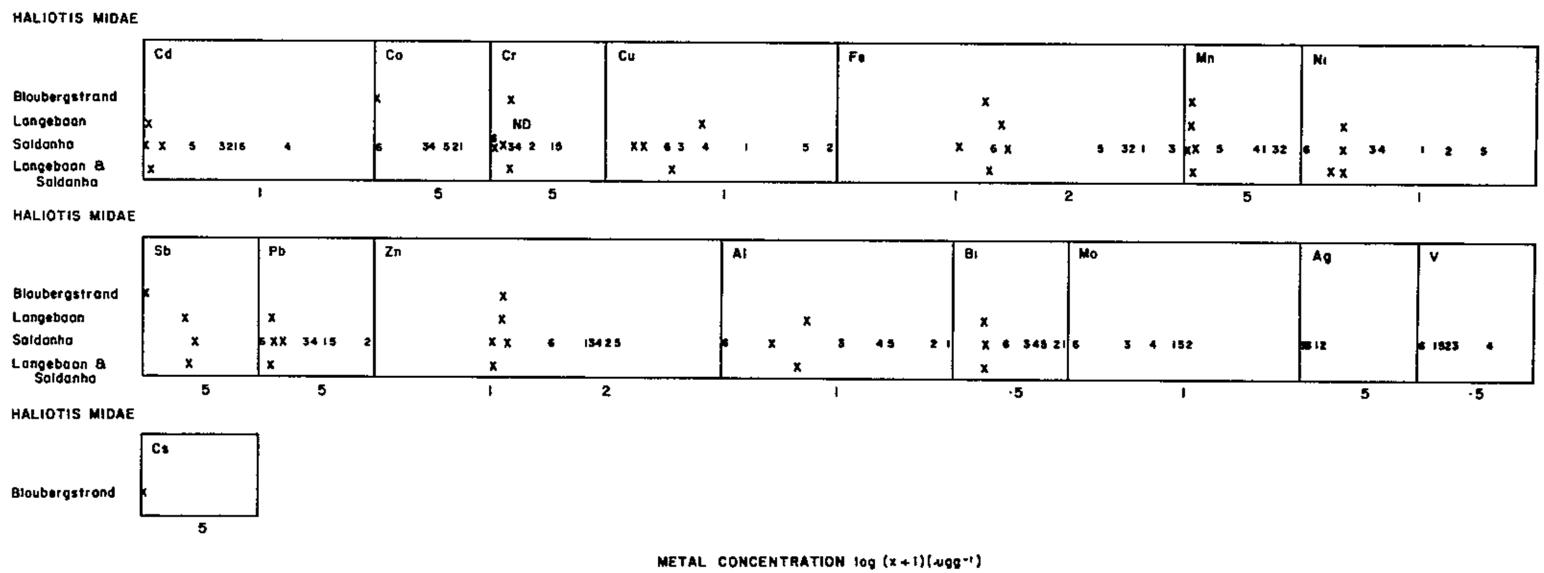


Figure 102 Metal concentrations in <u>Haliotis midae</u> (1 = heart, 2 = gill, 3 = gonad, 4 = kidney, 5 = mantle, 6 = white muscle)

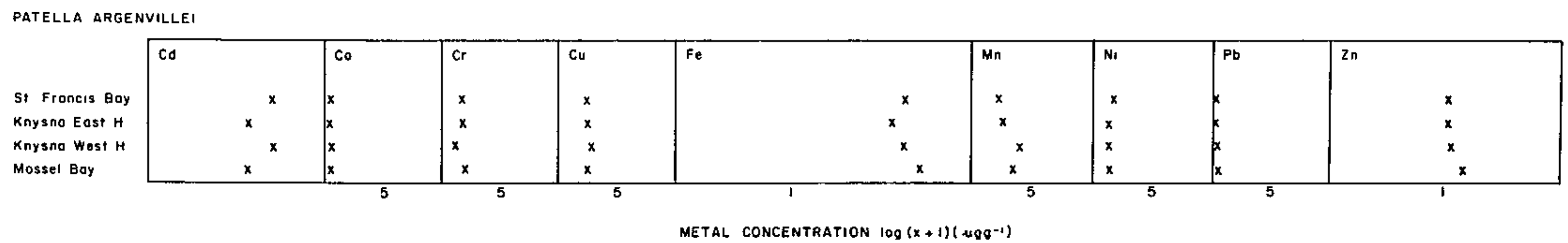


Figure 103 Metal concentrations in <u>Patella argenvillei</u>

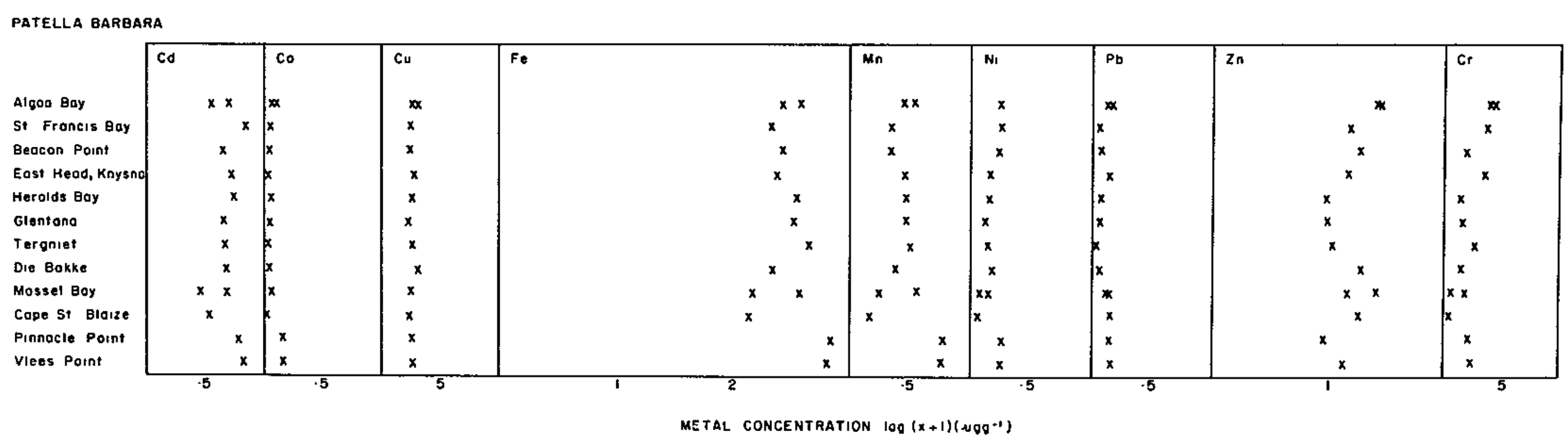


Figure 104 Metal concentrations in <u>Patella barbara</u>

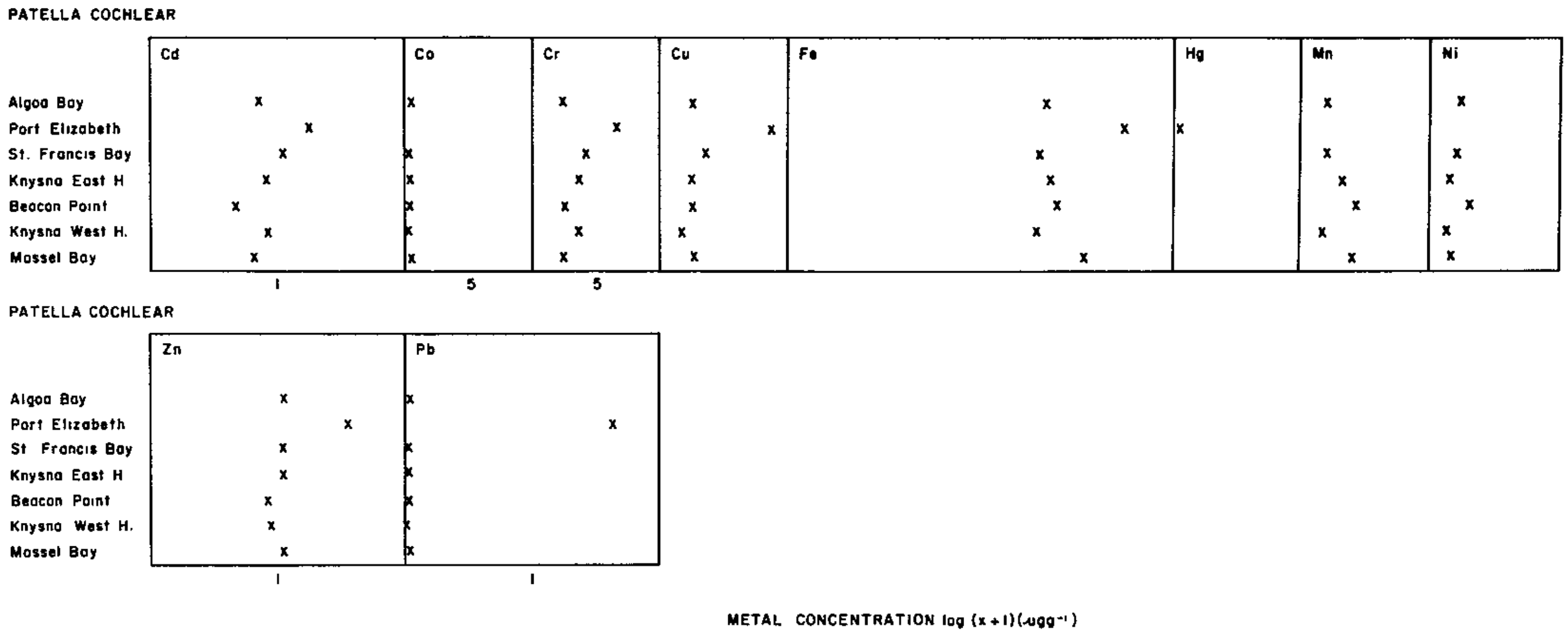


Figure 105 Metal concentrations in <u>Patella cochlear</u>

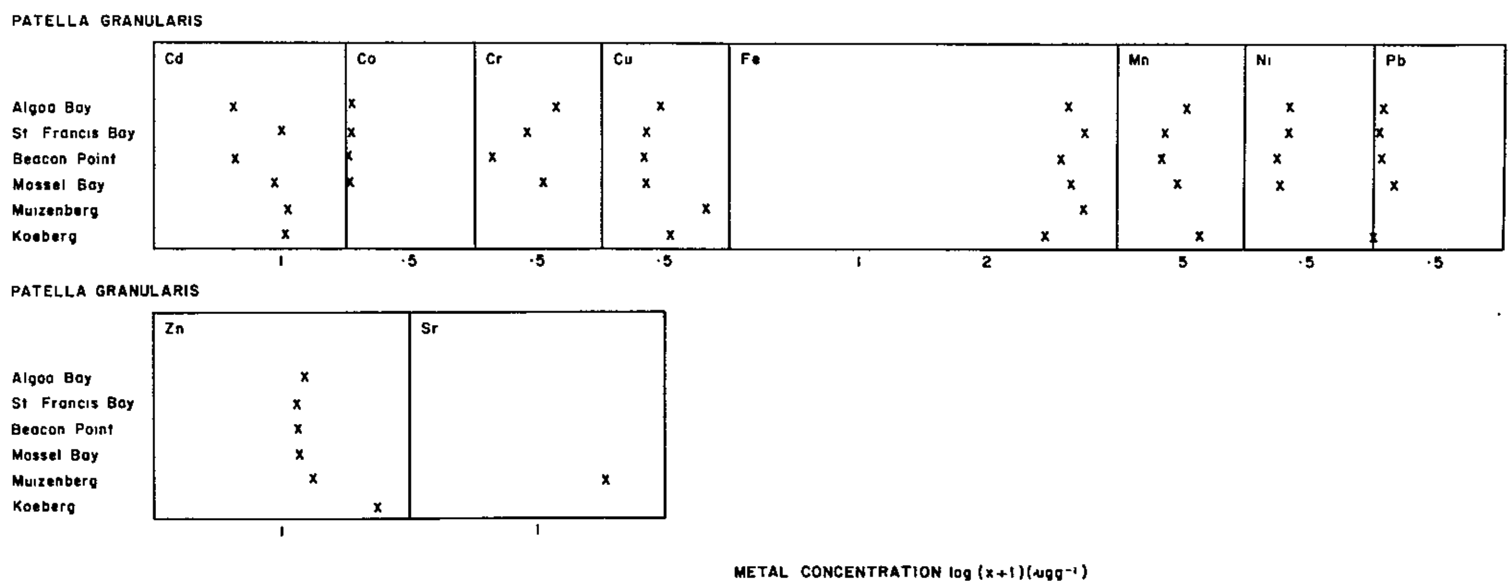


Figure 106 Metal concentrations in <u>Patella granularis</u>

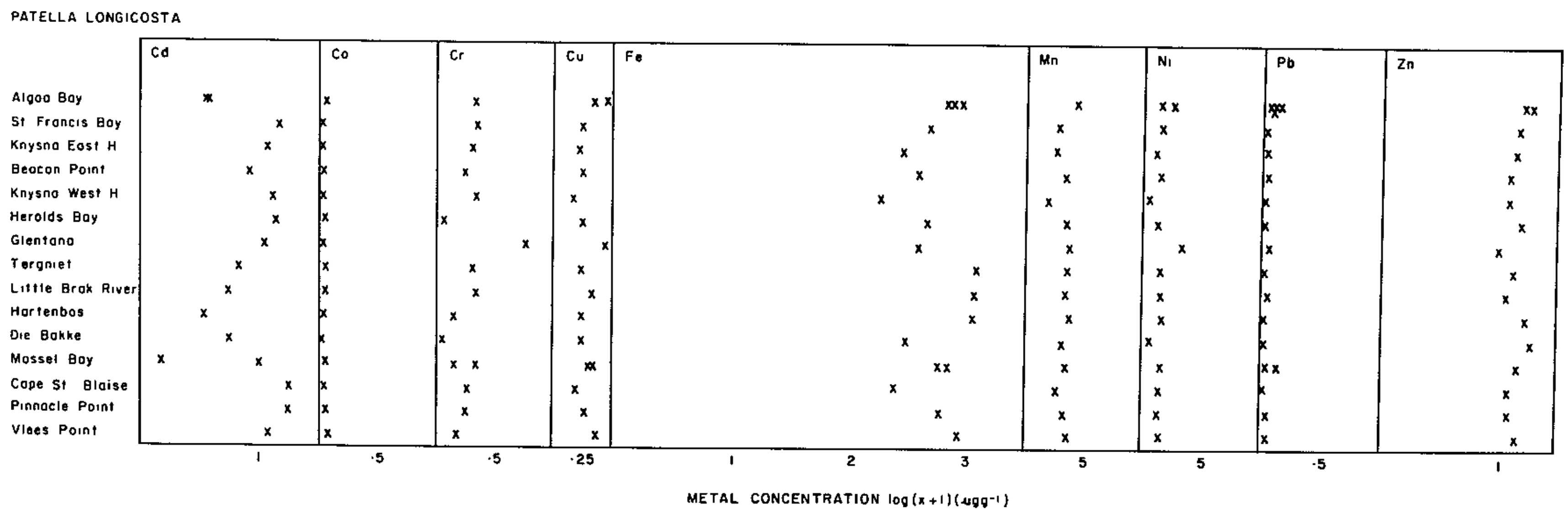


Figure 107 Metal concentrations in Patella longicosta

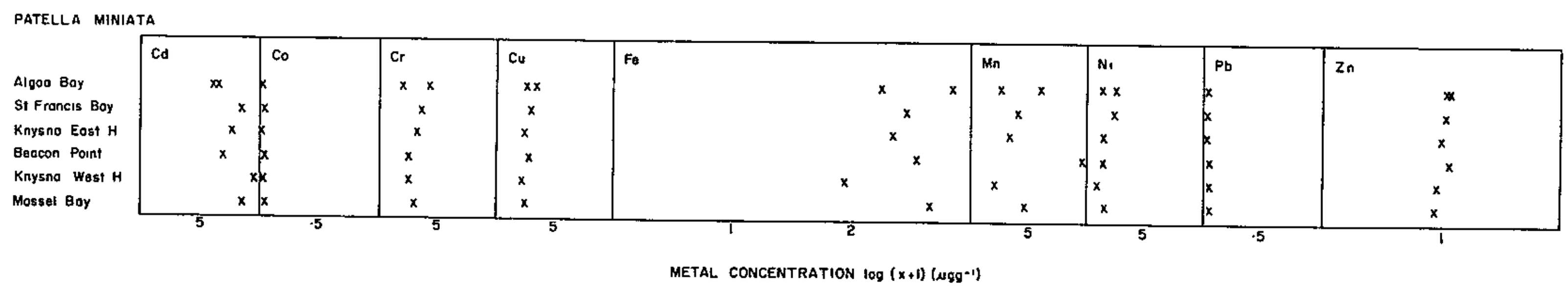


Figure 108 Metal concentrations in Patella miniata

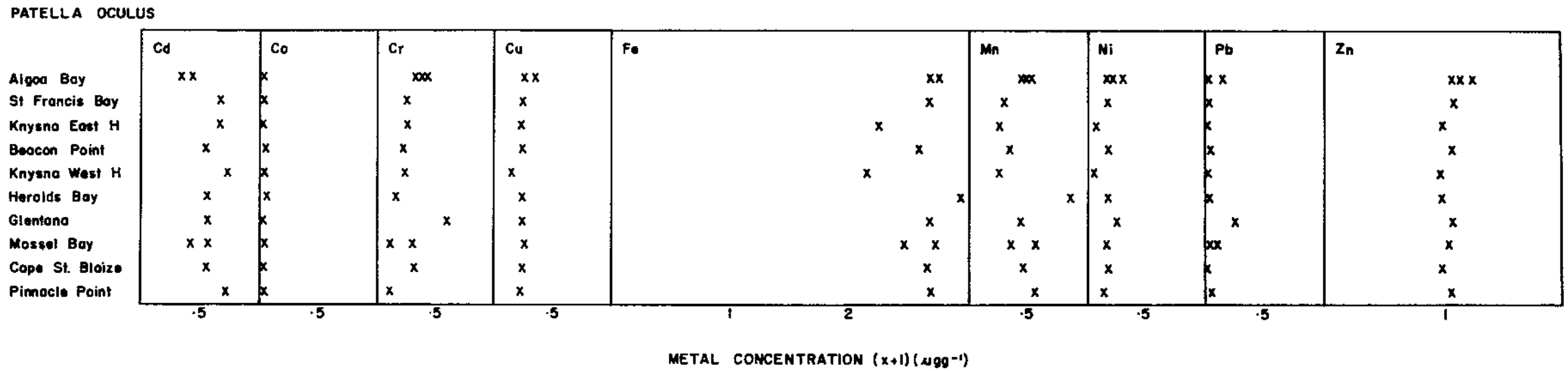


Figure 109 Metal concentrations in Patella oculus

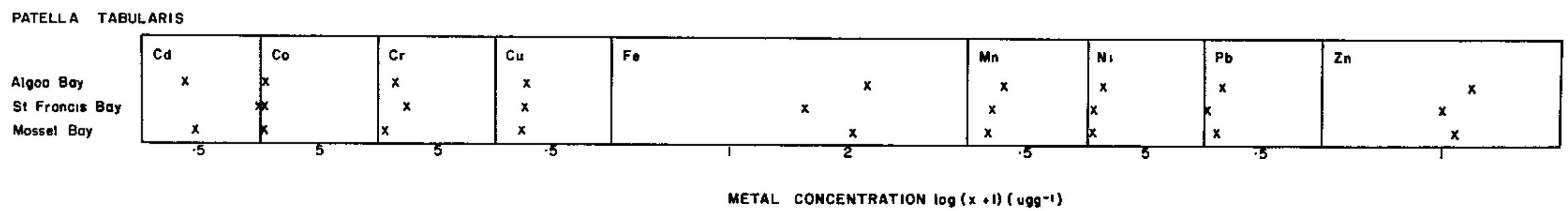


Figure 110 Metal concentrations in Patella tabularis

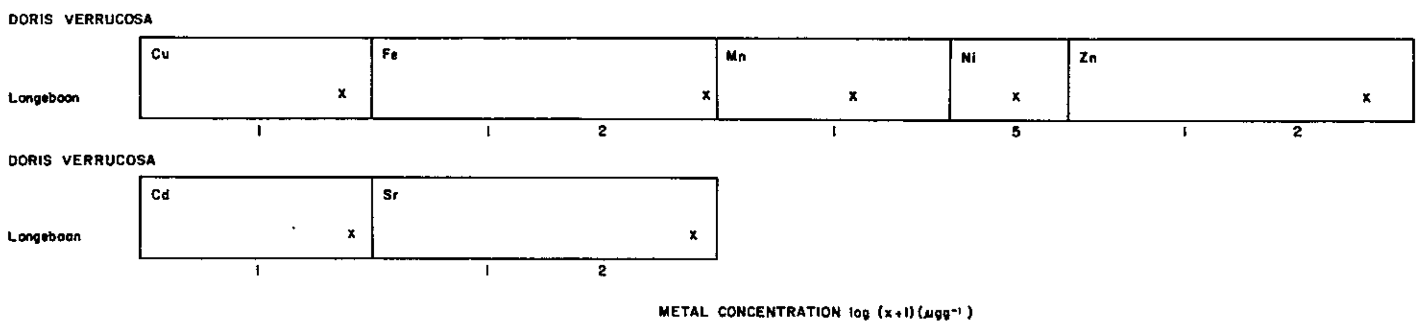


Figure 111 Metal concentrations in Doris verrucosa

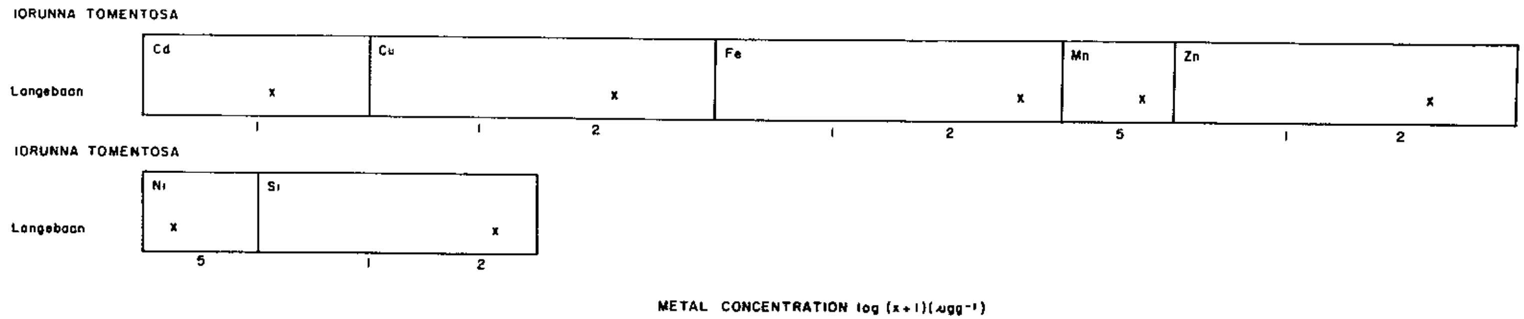


Figure 112 Metal concentrations in <u>Iorunna tomentosa</u>

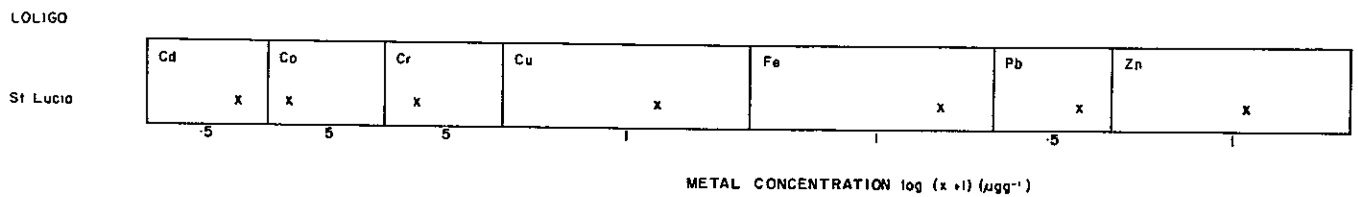


Figure 113 Metal concentrations in <u>Loligo</u> sp.

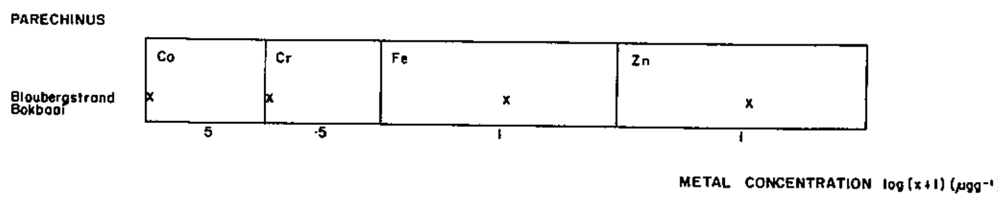


Figure 114 Metal concentrations in <u>Parechinus</u> sp.

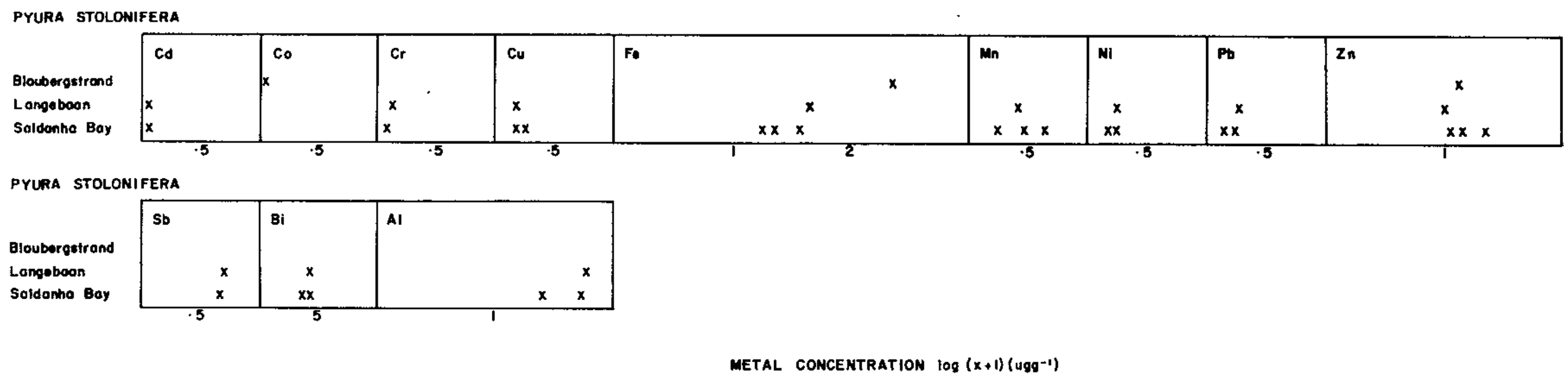


Figure 115 Metal concentrations in <u>Pyura stolonifera</u>

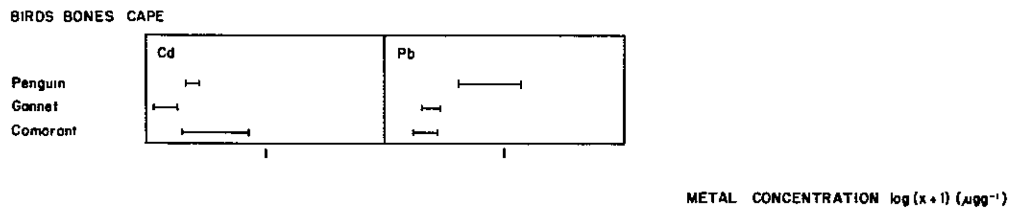


Figure 116 Metal concentrations in bird bones

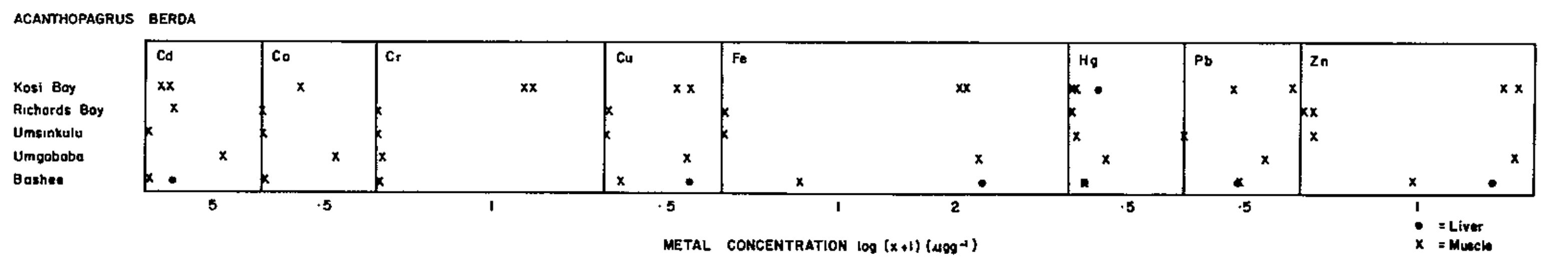


Figure 117 Metal concentrations in <u>Acanthopagrus berda</u>

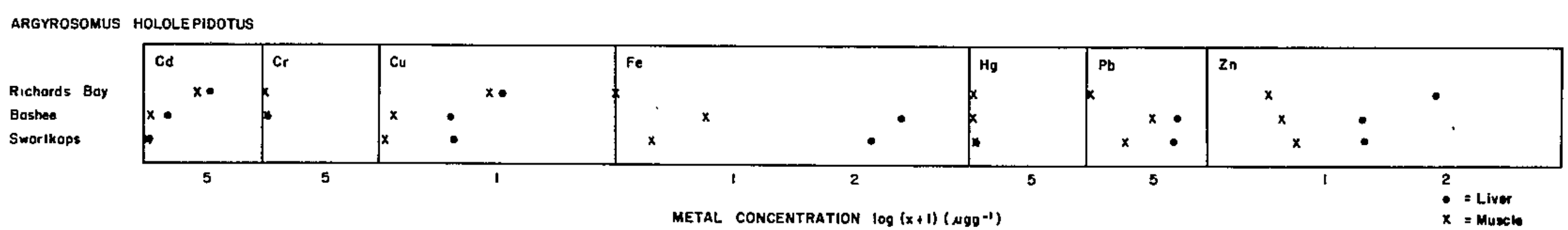


Figure 118 Metal concentrations in <u>Argyrosomus hololepidotus</u>

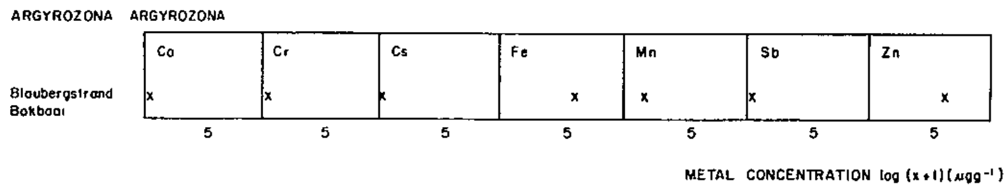


Figure 119 Metal concentrations in <u>Argyrozona argyrozona</u>

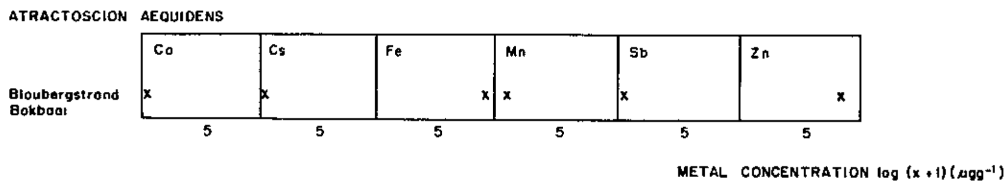


Figure 120 Metal concentrations in <u>Atractoscion aequidens</u>

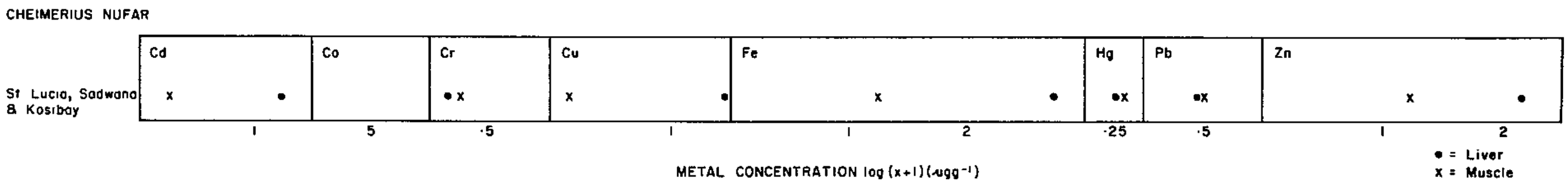


Figure 121 Metal concentrations in <u>Cheimerius nufar</u>

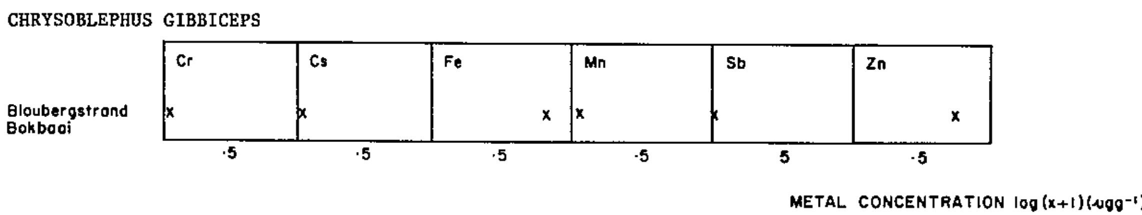


Figure 122 Metal concentrations in <u>Chrysoblephus gibbiceps</u>

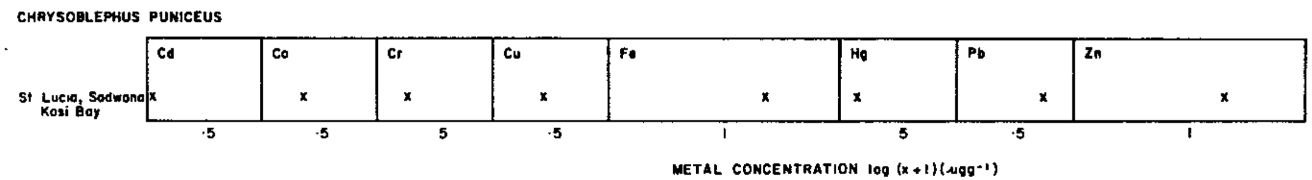


Figure 123 Metal concentrations in Chrysoblephus puniceus

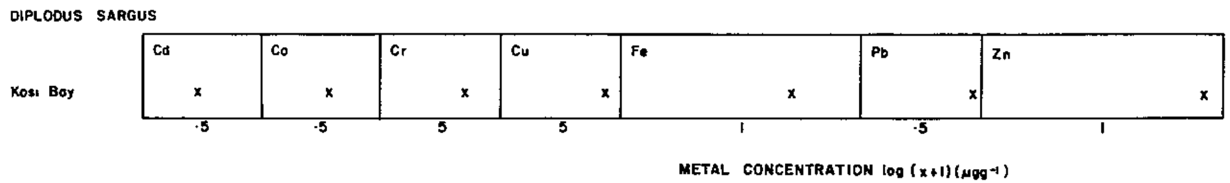


Figure 124 Metal concentrations in Diplodus sargus

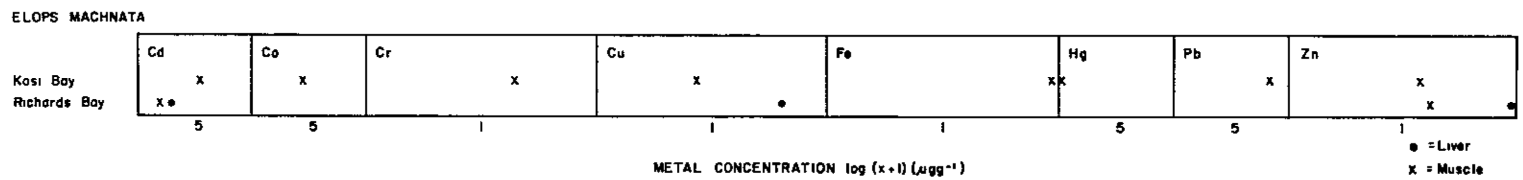


Figure 125 Metal concentrations in Elops machnata

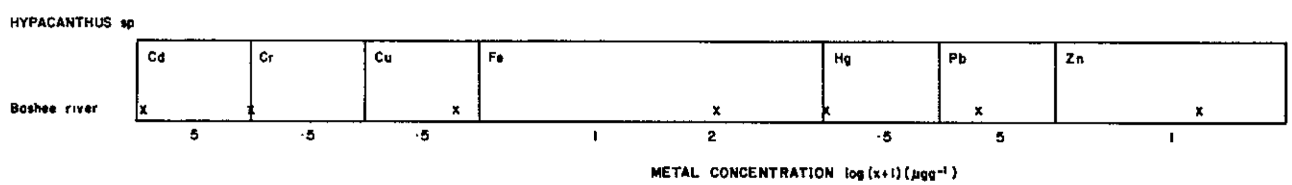


Figure 126 Metal concentrations in Hypacanthus sp.

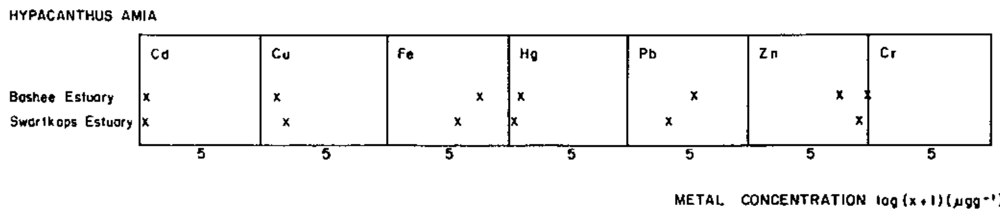


Figure 127 Metal concentrations in Hypacanthus amia

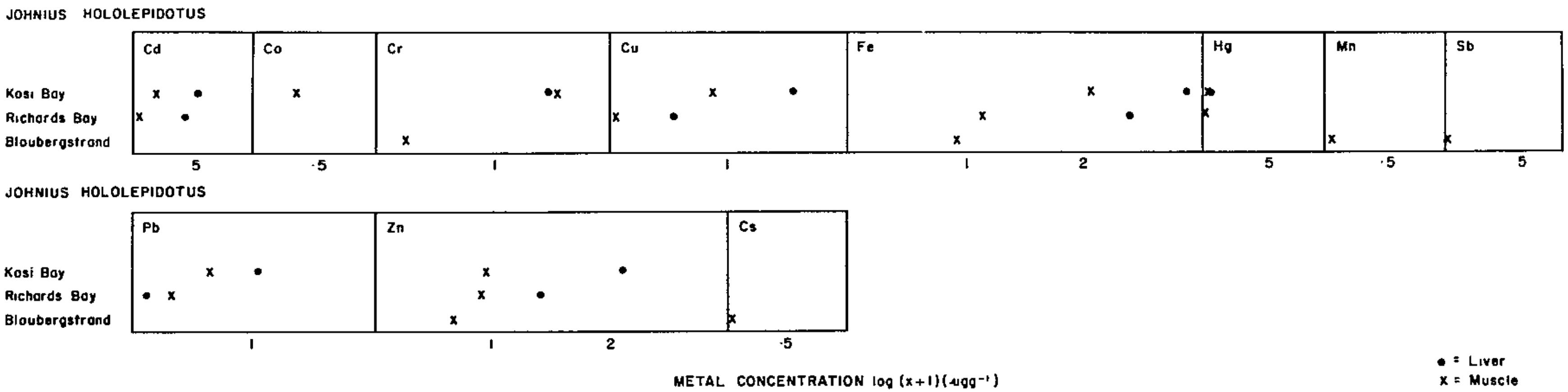


Figure 128 Metal concentrations in Johnius hololepidotus

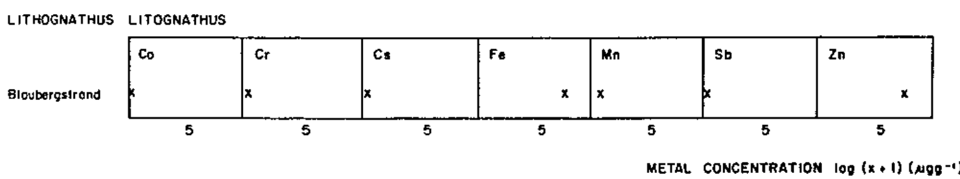


Figure 129 Metal concentrations in Lithognathus lithognathus

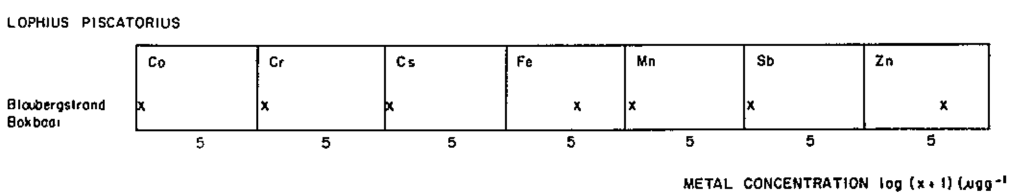


Figure 130 Metal concentrations in Lophius piscatorius

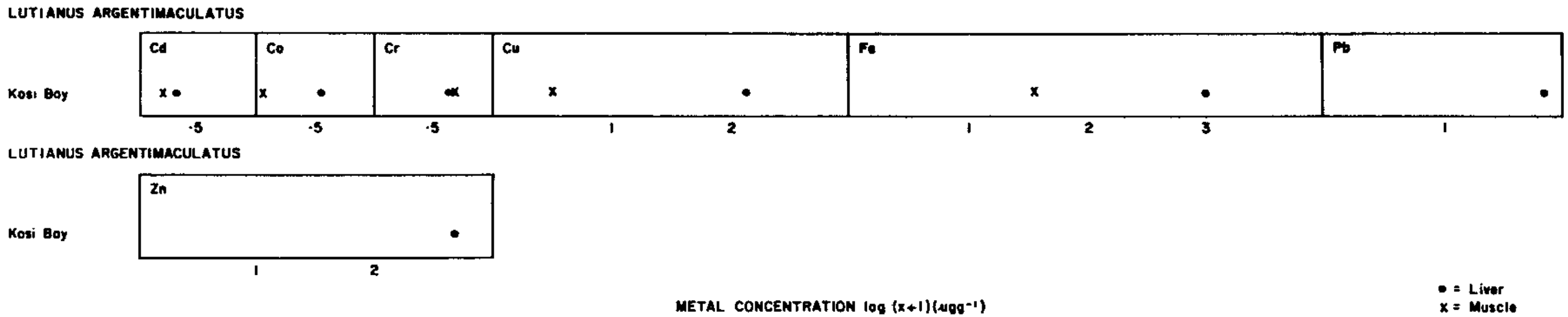


Figure 131 Metal concentrations in Lutianus argentimaculatus

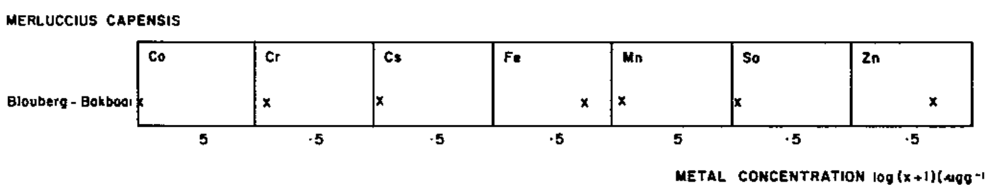


Figure 132 Metal concentrations in Merluccius capensis

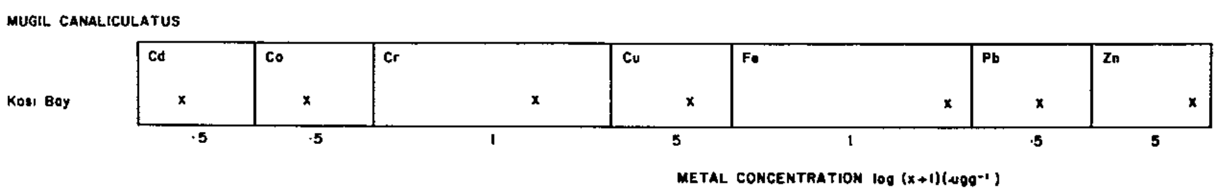


Figure 133 Metal concentrations in Mugil canaliculatus

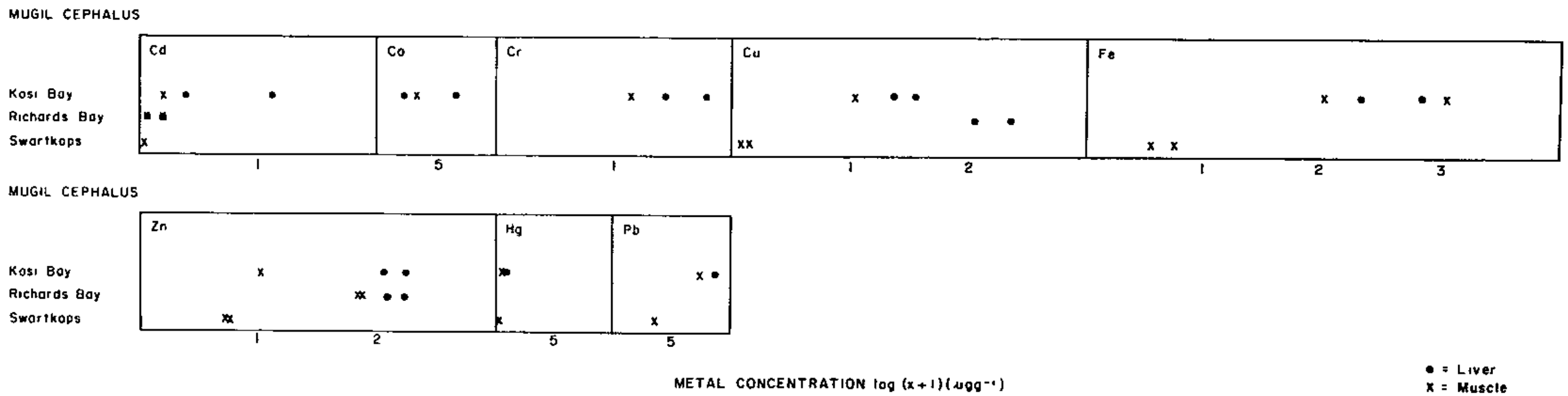


Figure 134 Metal concentrations in <u>Mugil cephalus</u>

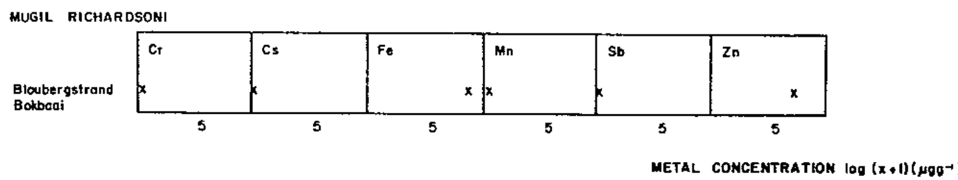


Figure 135 Metal concentrations in <u>Mugil richardsoni</u>

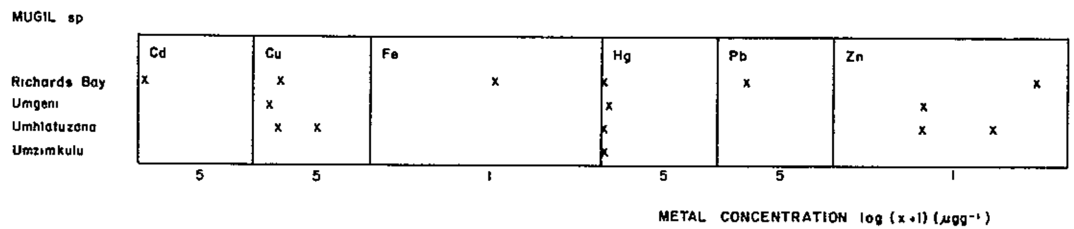


Figure 136 Metal concentrations in <u>Mugil</u> sp.

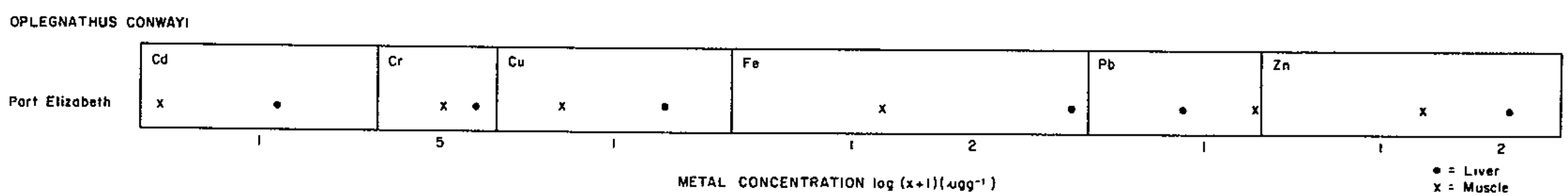


Figure 137 Metal concentrations in <u>Oplegnathus conwayi</u>

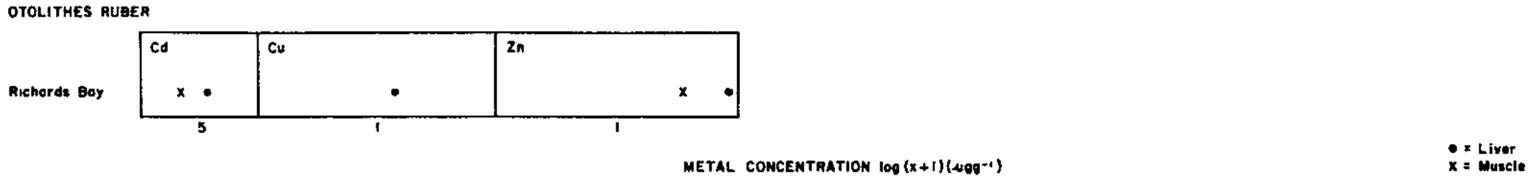


Figure 138 Metal concentrations in <u>Otolithes</u> <u>ruber</u>

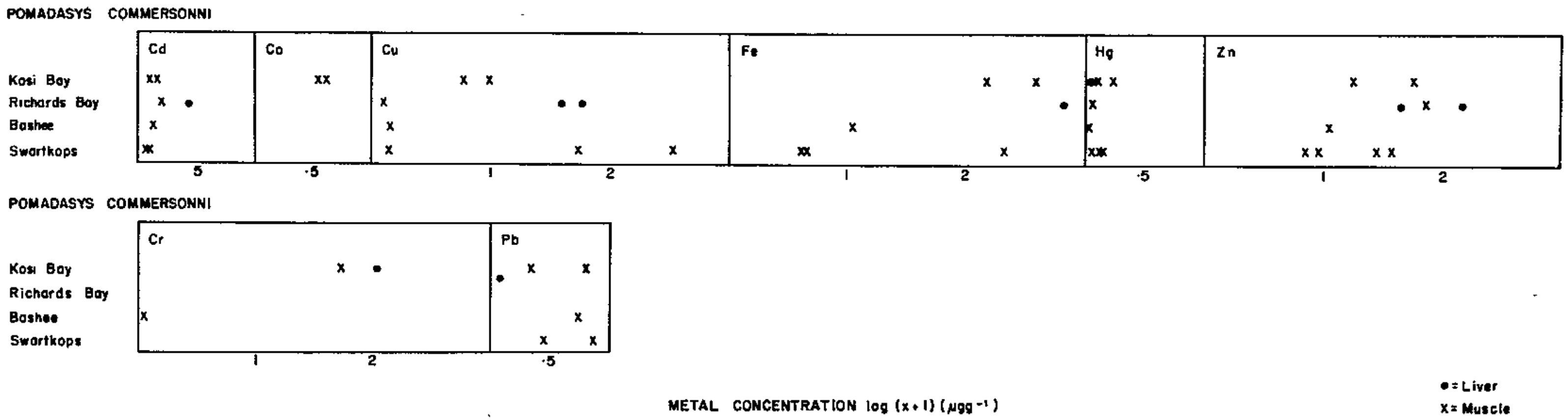


Figure 139 Metal concentrations in <u>Pomadasys</u> <u>commersonni</u>

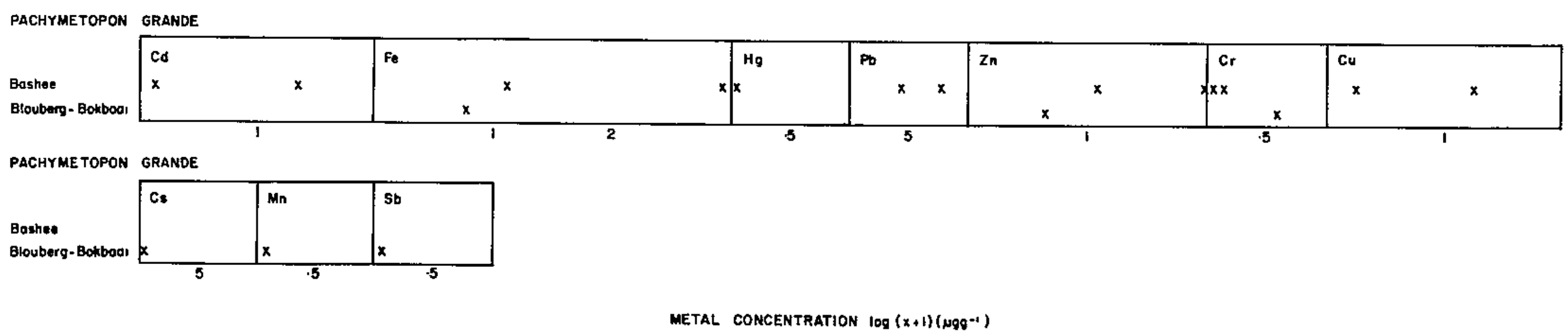
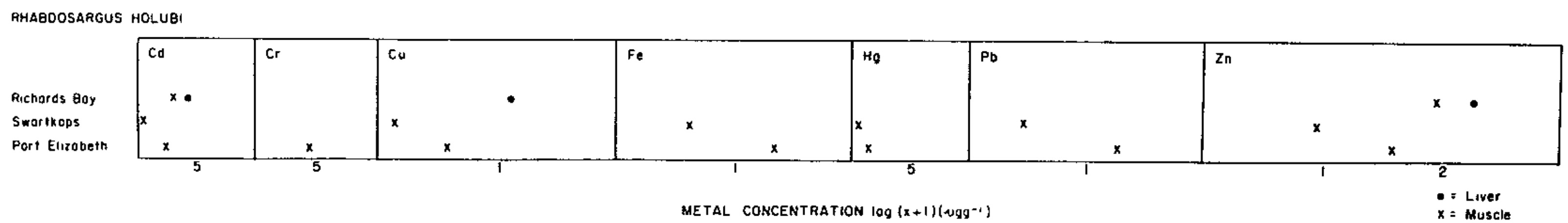


Figure 140 Metal concentrations in <u>Pachymetopon</u> <u>grande</u>



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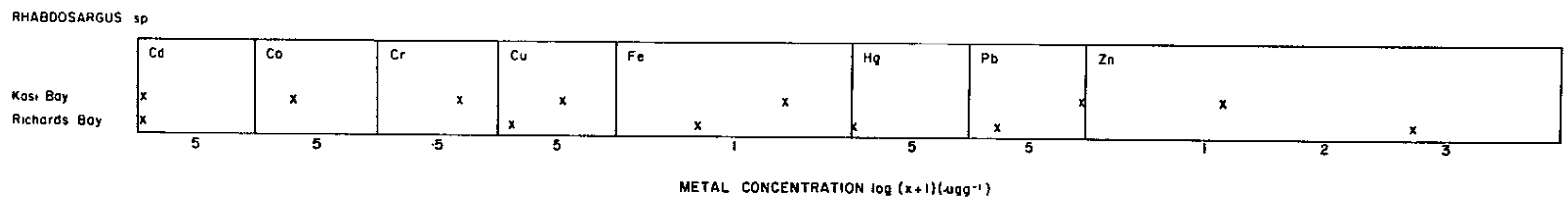
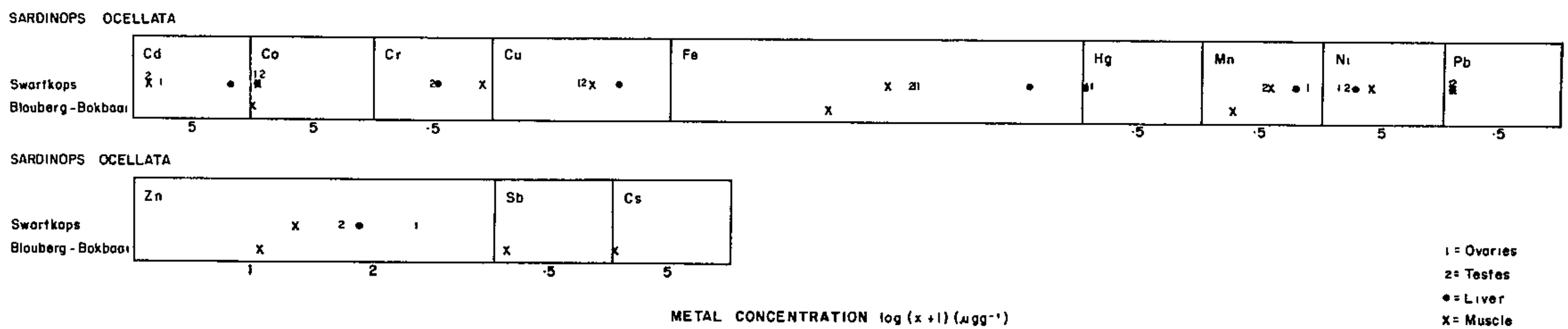


Figure 142 Metal concentrations in Rhabdosargus sp.



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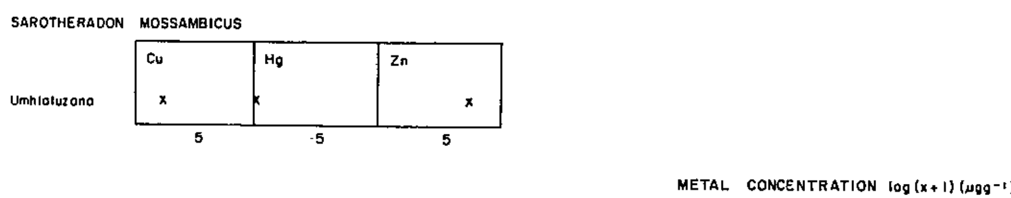
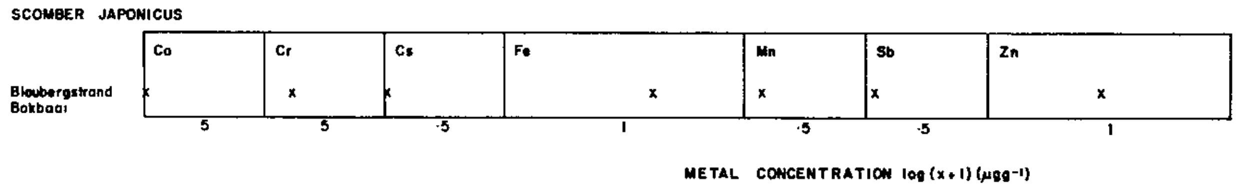


Figure 144 Metal concentrations in Sarotheradon mossambicus



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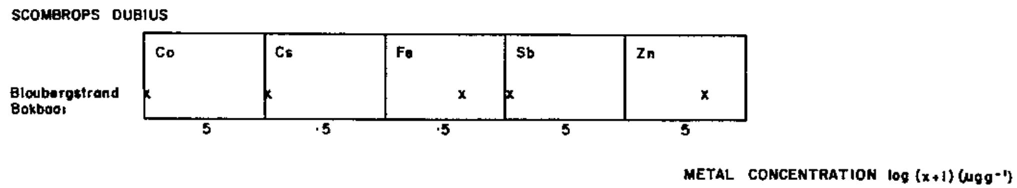


Figure 146 Metal concentrations in <u>Scombrops dubius</u>

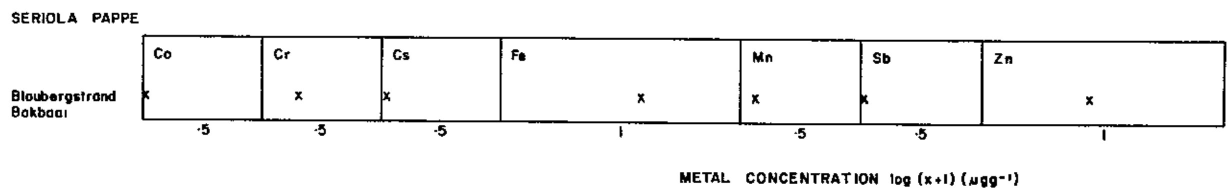


Figure 147 Metal concentrations in <u>Seriola pappe</u>

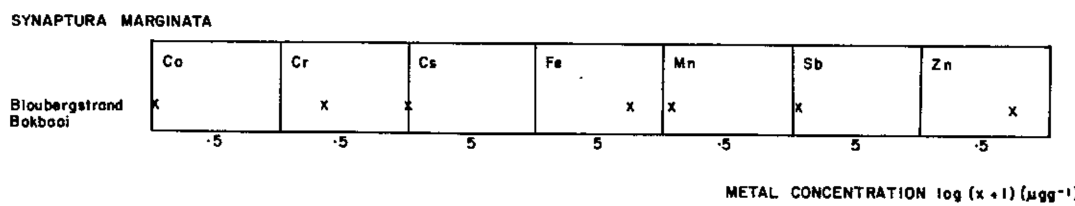


Figure 148 Metal concentrations in <u>Synaptura marginata</u>

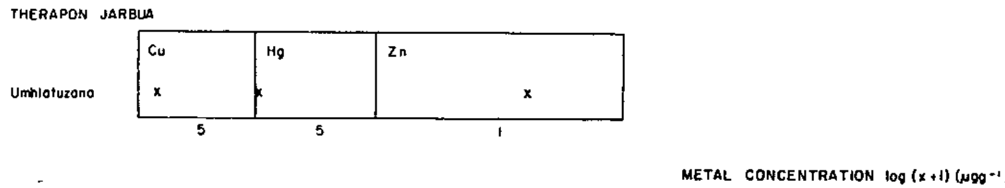


Figure 149 Metal concentrations in Therapon jarbua

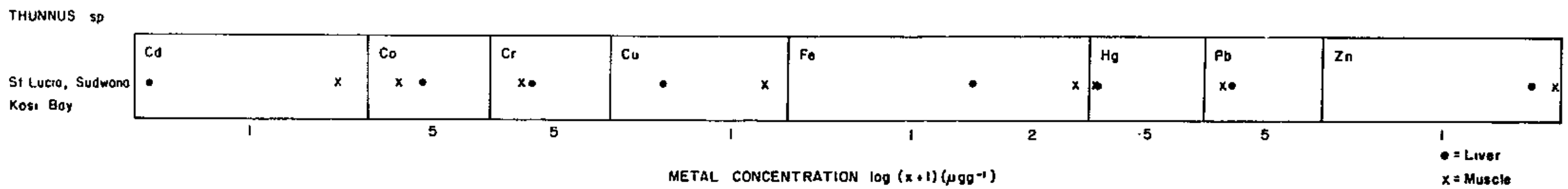


Figure 150 Metal concentrations in Thunnus sp.

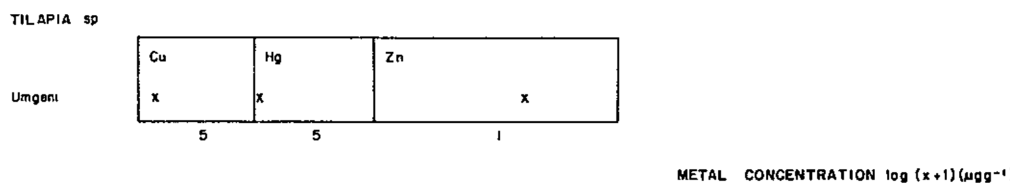


Figure 151 Metal concentrations in Tilapia sp.

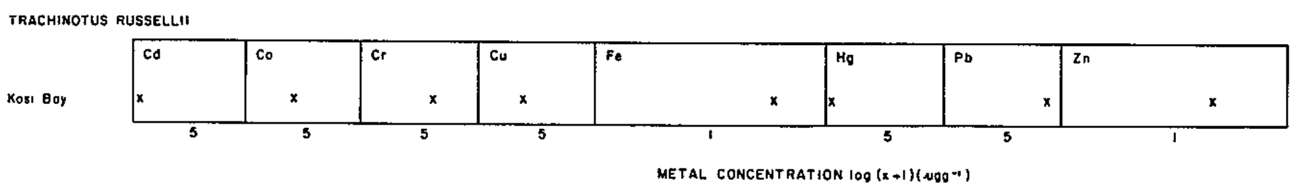


Figure 152 Metal concentrations in Trachinotus russellii

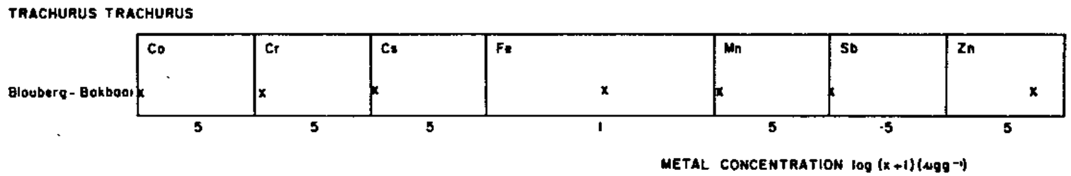


Figure 153 Metal concentrations in Trachurus trachurus

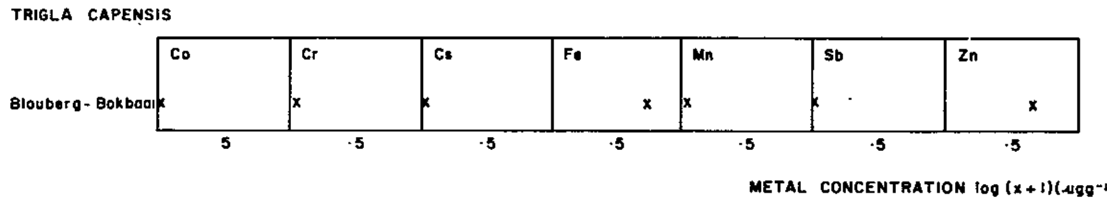


Figure 154 Metal concentrations in Trigla capensis

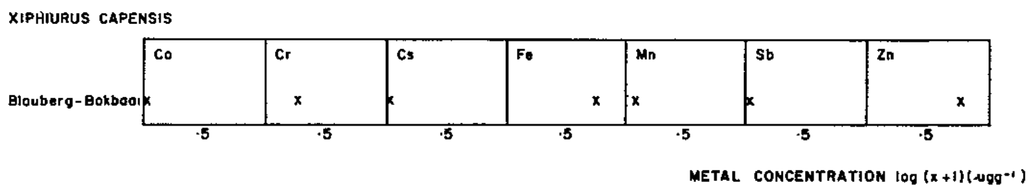


Figure 155 Metal concentrations in Xiphiurus capensis

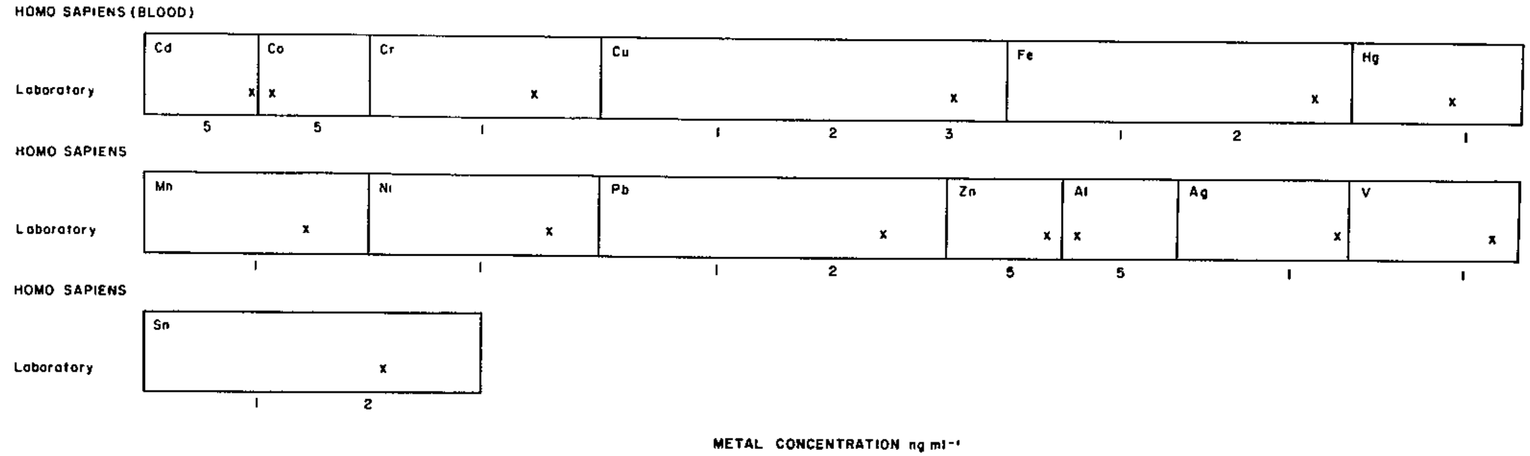


Figure 156 Metal concentrations in <u>Homo sapiens</u> (blood)

Figure 157 Metal concentrations in <u>Homo sapiens</u> (hair)

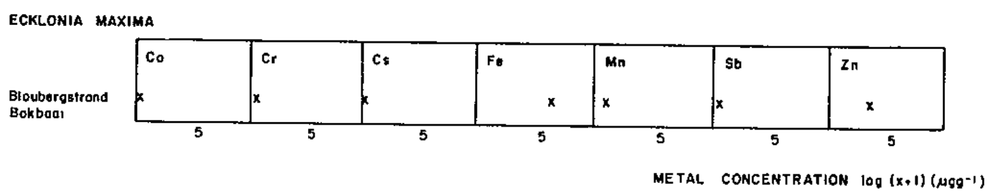


Figure 158 Metal concentrations in <u>Ecklonia maxima</u>

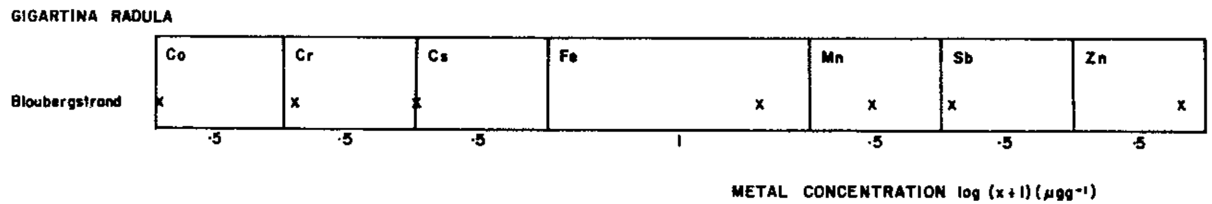


Figure 159 Metal concentrations in <u>Gigartina radula</u>

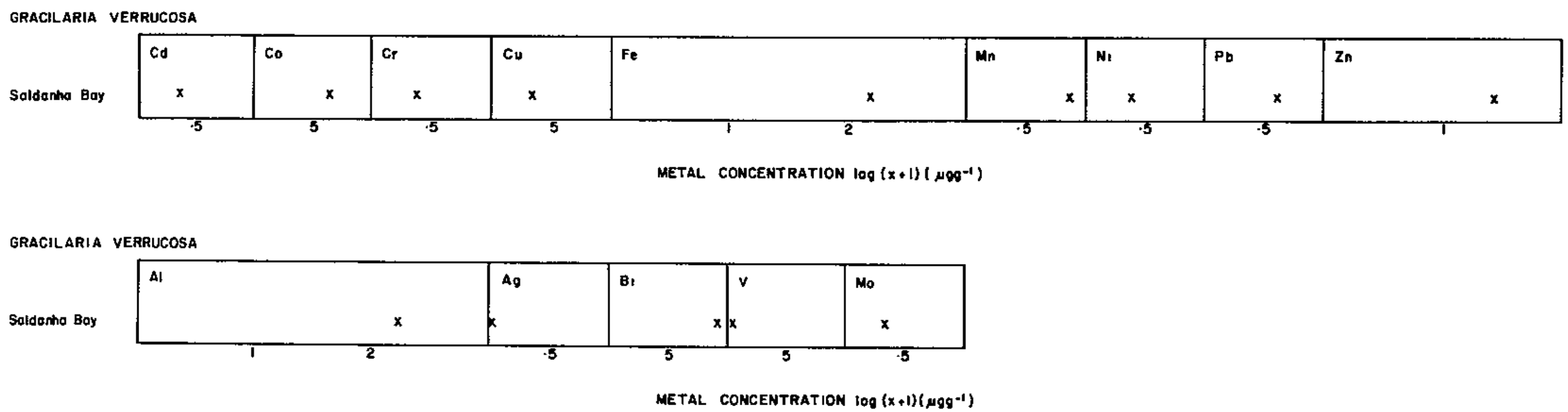


Figure 160 Metal concentrations in <u>Gracilaria verrucosa</u>

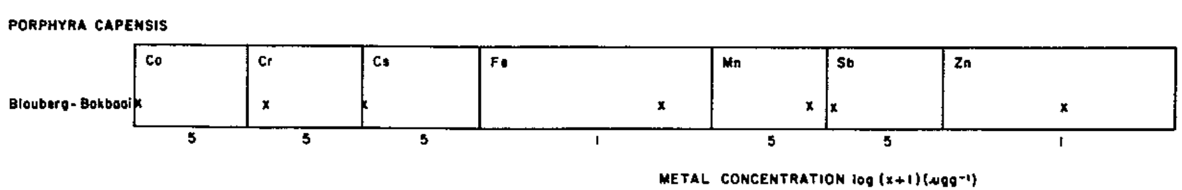


Figure 161 Metal concentrations in <u>Porphyra capensis</u>

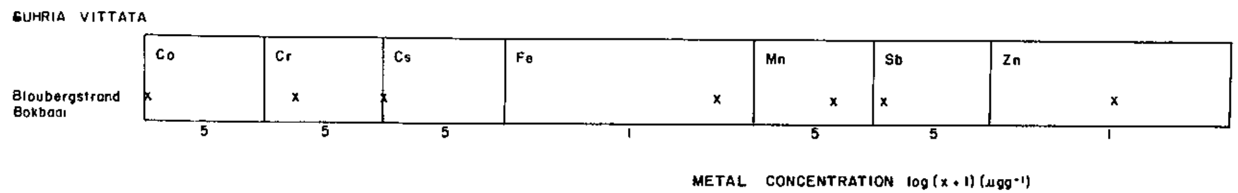
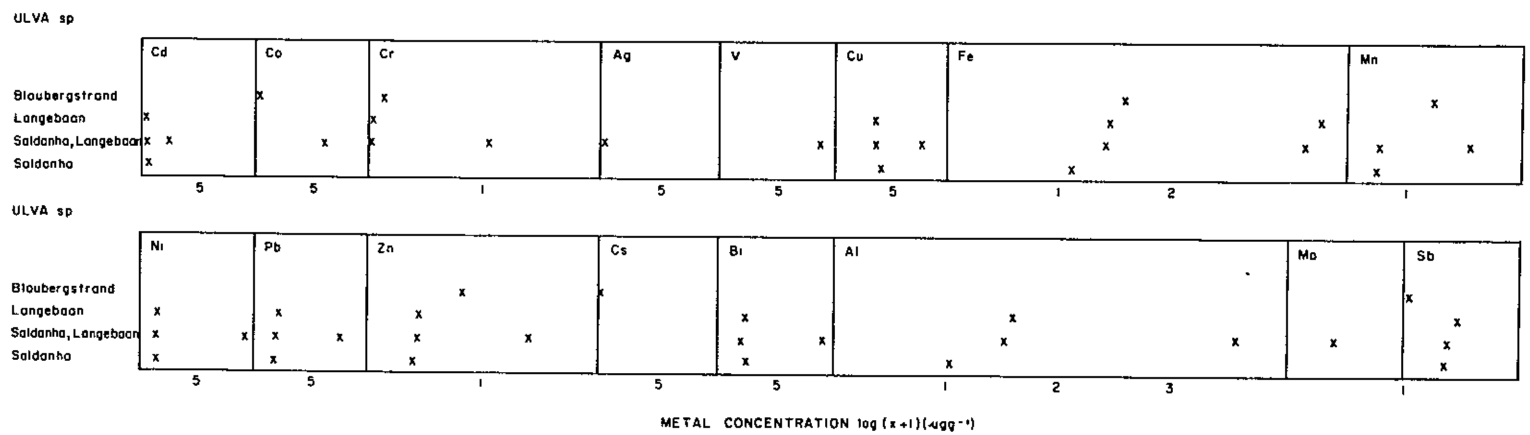


Figure 162 Metal concentrations in Suhria vittata



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