Sediment and benthos monitoring.
Mediterranean ١٩٩٩.

Summary

This report presents the results of the EIMP monitoring of contaminants in the sediment (organic matter, nutrients and heavy metals) and the composition of benthic invertebrate fauna (benthos) carried out along the Mediterranean coast of Egypt in ١٩٩٩. The major findings of the ١٩٩٩ monitoring was:

- Alexandria East harbour (Me١٥) was the most polluted site The sediment was markedly polluted by copper, lead and zinc and the organic content of the sediment as well as the concentrations of total phosphorous and total nitrogen were very high. The sediment was polluted by lead to an extent that there is a significant risk of toxic adverse biological effects on flora and fauna according to Canadian sediment quality standards. Copper and zinc were found in concentrations that may pose a slight risk of toxic effects.
- Station NIOF east in Alexandria (Me ١٣) was also quite polluted but to a lesser extent compared to Me ١٥. The sediments were quite polluted by organic matter and heavy metals, especially lead. However, the concentrations of lead only pose a slight risk of adverse biological effects on sensitive organisms according to the Canadian standards.
- The coastal stretch from Maadia to Port Said along the coast off the Nile Delta and Lake Manzala (Me ٢٤-Me ٤١a) was somewhat polluted but not to an extent that may cause alarm.
- The coastal stretch from Nobareia to Alexandria Western Harbour (Me ٧-Me ١٢ and from El Shatby to Abu Quir (Me ١٧a -Me ٢٢) was insignificantly polluted and
- The coastal stretch from Romana to Bardaweel (Me ٤٢-Me ٤٢b) was not polluted
- Generally, impacts on fauna due to pollution could not be demonstrated. A multivariate statistical analysis showed that differences in composition between stations were mainly due to differences in the content of silt clay in the sediment and not to any of the measured water quality parameters or sediment pollutants.
- However, there were indications that the fauna was affected by pollution in Alex Eastern Harbour (Me١٥) and at NIOF east (Me ١٣).

Introduction

The Coastal Water Monitoring Programme (CWMP) aims at establishing a marine monitoring system in the Egyptian coastal waters. The CWMP is part of the EIMP, which is directed by a Steering Committee with representatives from the EEAA and the Danish International Development Assistance (Danida). The EIMP Coastal Water Monitoring Programme comprises ١) Monitoring of water quality parameters (basic-, eutrophication and bacteriological parameters) ٢) Monitoring of contaminants in sediments, shellfish and corals and ٣) Monitoring of benthos and coral reefs.

EIMP has previously reported the results of the monitoring of water quality parameters for ١٩٩٩ (Ref.١). This report presents the results of the monitoring of sediments and benthos along the Mediterranean coast of Egypt in ١٩٩٩.

Benthos is a wide variety of species of mainly polychaete worms, mussels, snails, starfish, sea urchins and crustaceans living in burrows in the sediment or on the sediment surface. The analysis of changes in benthic community structure is widely applied and well suited for the detection and monitoring of impacts from sediment contamination and eutrophication of coastal waters.

The monitoring programme has been designed so that simultaneous measurement of contaminants in the sediment and composition of benthos is obtained from the same sites. In addition the sediment and benthos sampling sites are situated at, or very close to the water-monitoring stations, which are visited bimonthly, so that the water quality data can be included in the interpretation of the results.

The sampling sites for sediment and benthos in the Mediterranean are presented in Figure ١. The sampling took place in October -November١٩٩٩. Three samples for benthos and two samples for chemical analysis were collected at each site. In the laboratory the number of individuals of different species pr m^2 seabed and the number of species was determined for each sampling site. The sediment samples were analysed for grain size distribution, content of organic matter (measured as loss on ignition), total nitrogen (Tot. N), total Phosphorous (Tot. P) and heavy metals (Cu, Cd, Pb and Zn). A multivariate statistical analysis of benthos, sediment-and water quality parameters has been performed in order to elucidate any causal relationships between pollution and adverse impacts on benthos

Figure ١. Sampling stations for sediment and benthos in Mediterrenean ١٩٩٩.

Water Quality

The monitoring of water quality parameters along the Mediterranean coast in ١٩٩٩ showed high levels of nutrients ($NH_{٤}$, $NO_{٢}$, $NO_{٢}$ and $PO_{٤}$) and a high biomass of phytoplankton (measured as chlorophyll-a) in three distinct areas:

- The Alexandria area between El-Mex and Sidi Gaber
- The coastal stretch between Abou quir and Maadia and
- The area from Damieatta El Gededda to Port Said

Very substantial discharge of domestic and industrial wastewater and agricultural run-off take place in these areas

Nutrient levels and phytoplankton biomass were significantly lower west of Alexandria and east of Port Said

Sediment

Composition of sediment

The seabed at most of the monitoring sites consisted of pure sand. However, the sediments had a considerable content of silt/clay at El Maadia (Me ٢٤), in Lake Manzala (Me ٣٩b) at the outlet from lake Manzala (Me ٣٩a, Me ٣٩ and Me ٤٠) and East of Port Said (Me ٤١) (Figure ٢).

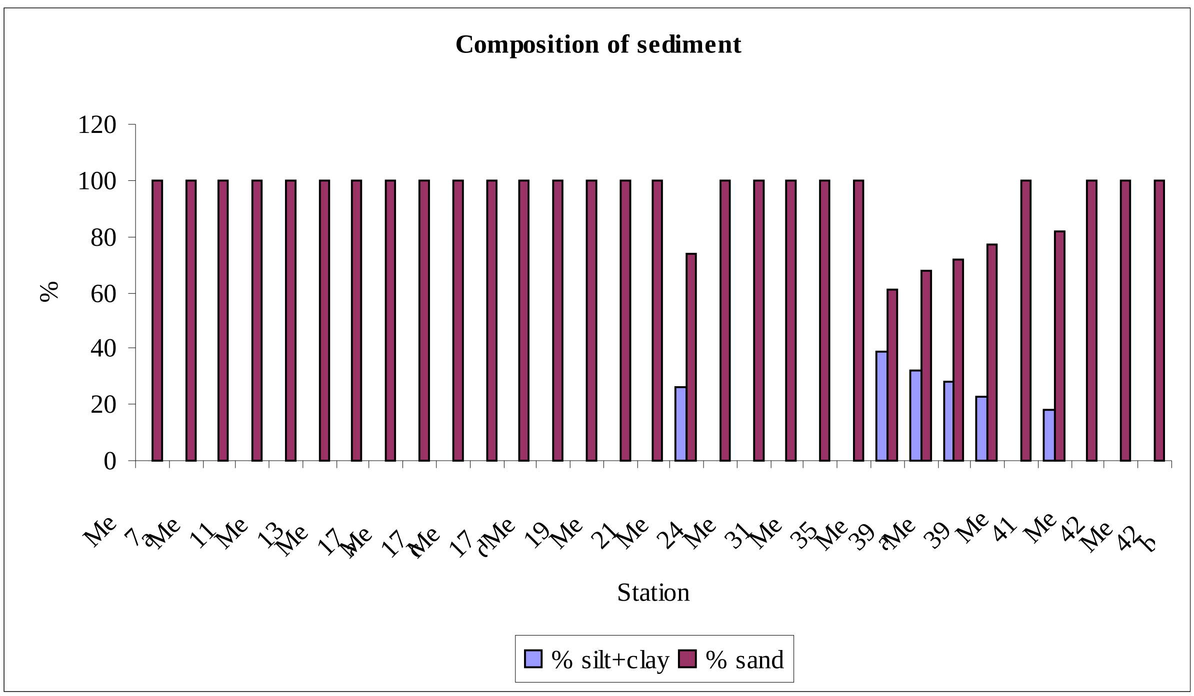

Figure ٢. Composition of the sediment at the monitoring sites

Pollutants in sediments

The measured sediment parameters on individual stations are depicted in Figs ٣-٦. In order to assess the potential for adverse biological effects due to heavy metals in the sediment the results have been compared to recently developed Canadian sediment quality standards which, relates sediment chemistry data to the potential for adverse biological effects (Ref.٢). Based on a considerable number of studies on the correlation between concentration and toxicity a threshold effect level (TEL) as well as a probable effects level (PEL) were established for a wide number of pollutants in sediments. The guideline values TEL and PEL delineate three concentration ranges for a particular chemical:

- Concentrations below the TEL value represent concentrations, which are not expected to cause any adverse biological effects.
- Concentrations equal to and above TEL, but below the PEL represent a range of concentrations within which effects may occasionally occur on sensitive organisms, but there is only a slight risk.
- Concentrations equivalent to and above the PEL value represent a probable-effects range within which adverse biological effects would frequently occur

In Table ١, the range of concentrations of Cu, Zn, Cd and Pb encountered along different stretches of the Mediterranean cost are compared to the Canadian TELs and PELs. In addition the range of concentrations of Tot N and Tot P are indicated. From table ١ and Figs ٣-٦ it appears that:

- The sediments in Alexandria East Harbour (Me ١٥) were markedly polluted by Cu, Pb and Zn and the organic content of the sediment as well as the concentrations of Tot P and Tot N were very high. This area was the most polluted of the sampling sites along the Egyptian Mediterranean coast. The sediment was polluted by Pb to an extent that there is a significant risk of toxic adverse biological effects on flora and fauna. Cu and Zn were found in concentrations that may pose a slight risk of toxic effects
- The sediments at NIOF east (Me ١٣) were also quite polluted especially by lead. However, the concentrations of lead only pose a slight risk of adverse biological effects on sensitive organisms.
- The sediments along the coast of the Nile Delta and Lake Manzala (Me ٢٤-Me٤١a) were polluted by Cu to an extent that there might be slight risks of adverse biological effects on sensitive organisms. The copper polluted sediments were found at Maadia (Me ٢٤), off Rashid (Me ٣١), Damietta (Me ٣٥) and, the coastal areas along Lake Manzala (Me ٣٩a, Me ٣٩b), the outlet from lake Manazala (Me ٣٩, Me ٤٠) and the area off Port Said (Me ٤١,Me ٤١a). Concentrations of Zn that may give a slight risk of toxic effects were also found at Maadia (Me ٢٤).
- The sediments from Nobareia to Alexandria Western Harbour (Me٧-Me١٢), from El Shatby to Abu Quir (Me ١٧a-Me ٢٢) and from Romana to Bardaweel (Me٤٢-Me٤٢b) were insignificantly polluted Toxic concentrations of heavy metals was generally not found in these areas. However, in one sample from Alex Western Harbour concentrations of Cd which may pose a slight risk of adverse biological effects on sensitive organisms was encountered.

The monitoring of water samples revealed a significant pollution (eutrophication) by organic material, nutrients and bacteria in the area from El-Mex outlet (Me١١) to Sidi Gaber (Me١٧b) and from Abu Qir (Me٢١) and eastward to Maadia (Me٢٥). The present monitoring indicate, that with the exception of NIOF East and Alex east harbour the sediments were not polluted along this stretch of the coast. Pollution from the very many sources in this area was thus not found in the sediment along the coast. The sediments were sandy indicating that erosion takes place. Consequently, pollutants are not accumulating in the sediments but are dispersed with the currents elsewhere, may be further offshore. For instance in Abou Quir Bay there are indications from other studies, that finer grained sediments are encountered in the middle of the Bay, so probably much of the pollution from the outlets is accumulated here. In the future revision of the monitoring programme some of the benthos stations will be moved to accretion areas.

The degree of pollution of sediments further east from Maadia to Port Said reflects the degree of eutrophication of the water column. A significant pollution of the water by organic material, nutrients and bacteria is found in this area and the sediments are also polluted. The silt/clay content of the sediment is higher along this stretch of the coast compared to the areas to the west. The elevated silt/clay content indicate an accretion area, which may be why pollutants from the outlets along this stretch of the coast will end in the sediments close to the shore.

Table ١.Range of concentrations of heavy metals (Cd, Cu, Pb and Zn), Tot.N, Tot.P and loss on ignition (LOI) encountered in sediments along various stretches of the Mediterranean coast (ug/g

dry weight). The concentrations of heavy metals are compared to threshold effects levels (TEL) and potential effects levels (PEL) (Ref. ٢). Figures in bold indicate values violating the TEL. There are no TELs and PELs for Tot N, Tot.P and loss on ignition. Figures in parentheses indicate the percentage of total number of samples from the particular stretch of coastline that violate the TEL.

	Nobareia to Alexan-dria West Harbour Me٧- Me ١٢	NIOF east Me ١٣	Alexan-dria East Harbour Me ١٥	El Shatby to Abu Quir Me ١٧a- Me ٢٢	Maadia to Port Said Me ٢٤- Me٤١a	Romana to Barda-weel Me ٤٢ - Me ٤٢b	TEL	PEL
Cd	٠,٠٥٨-٠,١٤٨	٠,٠٩٩-٠,١١٨	٠,٢-٠,٢١	٠,٠٢٤-٠,١٣٧	n.d-٠,٠٨٤	n.d	٠,٦	٤,٢
Cu	٨,٩-١٥,٣	٣٠,٦-٣٢,٧	٧١,٢-٧٤,٩ (١٠٠٪)	٩,١-٢١,٢	٣٠-٥١ (٦٧ %)	٢٢,٣-٢٨,٥	٣٥,٧	١٠٨
Pb	١٢-٣٨ (١٣ %)	٥٠-٧١ (١٠٠٪)	١٦٢-١٧٣ (١٠٠٪)	٤-٢٣	٦-١٨	١٠-١٦	٣٥	١١٢
Zn	١٠,٥-١٩	٨٤,٤-٨٨,١	٢٢٣,٦-٢٢٥,٤ (١٠٠٪)	٩,٥-٤٥,٦	٦٦,٤-١٤١ (٨ %)	١-٣٢,٥	١٢٣	٢٧١
Tot P	٤٦-٢١٠	٨٠٣-٨٠٤	١٠٠١-١٠٣٧	١٧٦-٥١١	٣٨٨-٨٣١	٥٩-٣١٣	-	-
Tot N	٨٤-٣٤٣	٨٦٥-٨٧٩	١٠٨٥-١١٠٢	١٣٢-٦١٢	٦٠-٧٦٢	٧٠-١٥١	-	-
% LOI	٠,٨٩-١,٢٩	٢,١١-٢,٢٦	٢,٨٩-٣,٢٤	٠,٨٢-٢,٤٧	٠,٣٤-٣,٢٥	٠,١٤-٠,٩٢	-	-

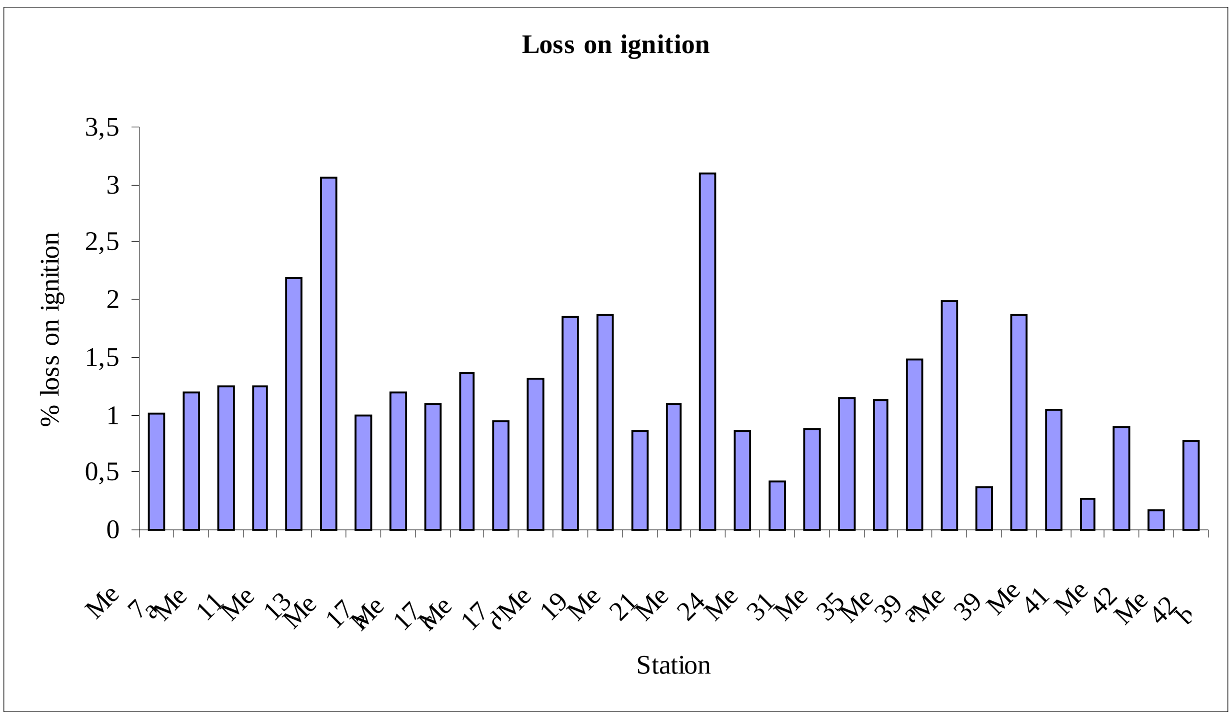

Figure ٣. Content of organic matter in sediments (measured as loss on ignition) in October-November ١٩٩٩.

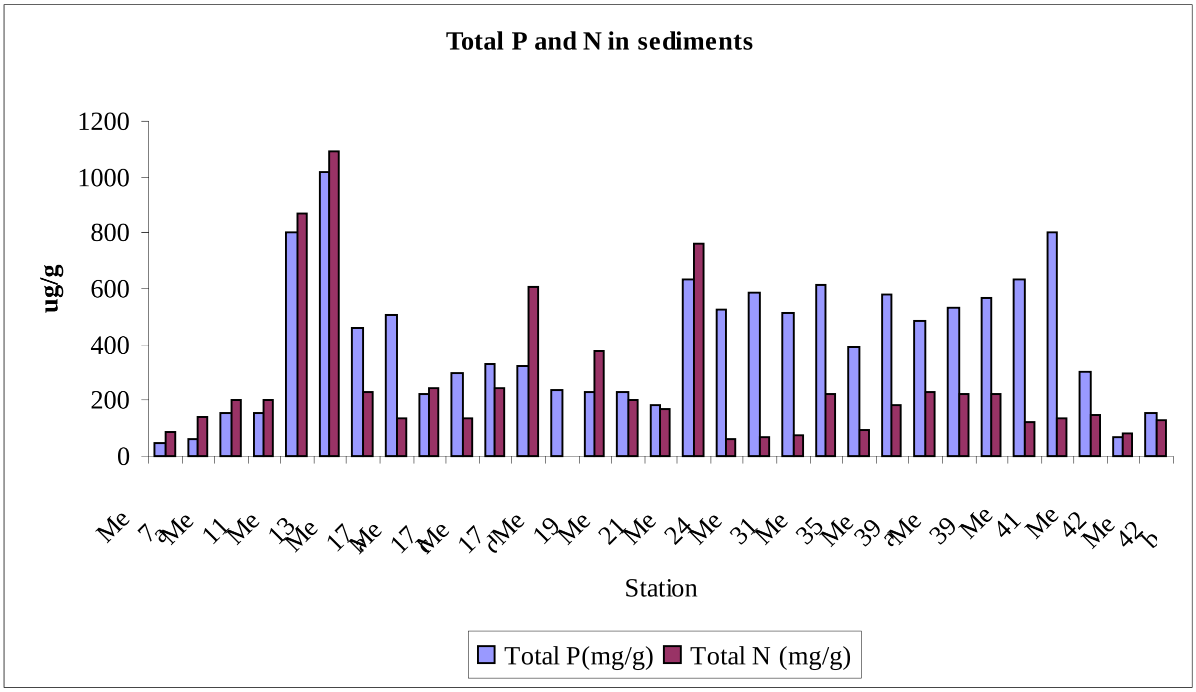

Figure ٤. *Concentration of Total Nitrogen and Total Phosphorous in sediments in October-November* ١٩٩٩.

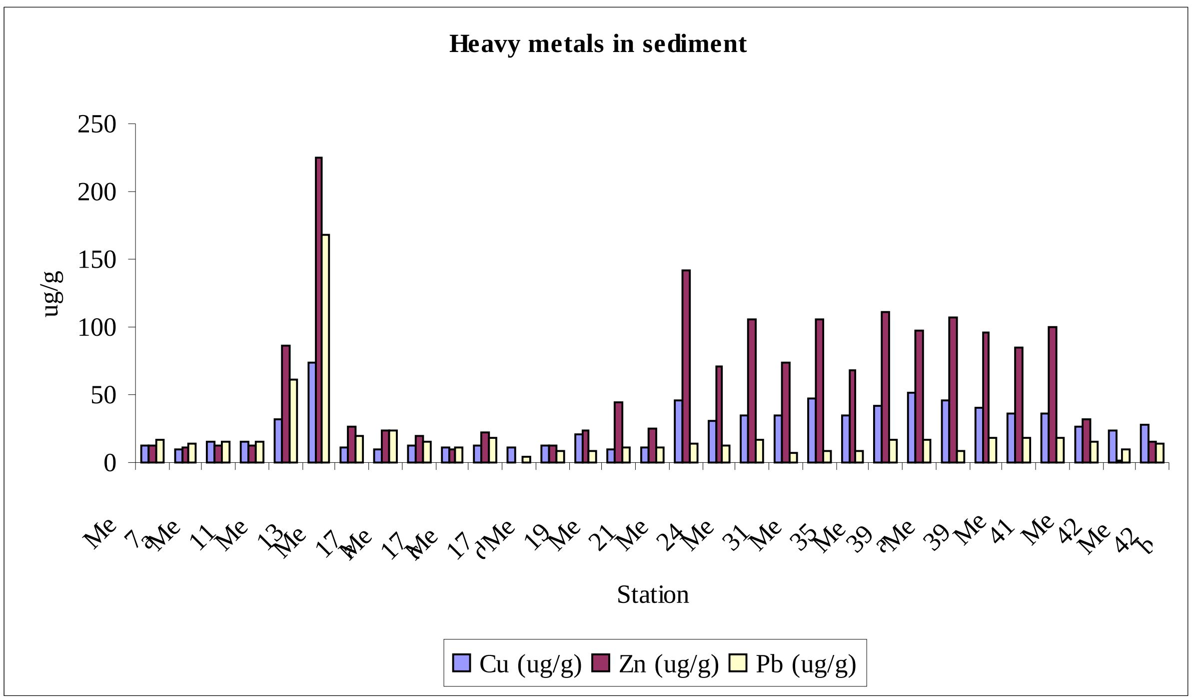

Figure ٥. *Concentration of copper, zinc and lead in sediments in October – November* ١٩٩٩.

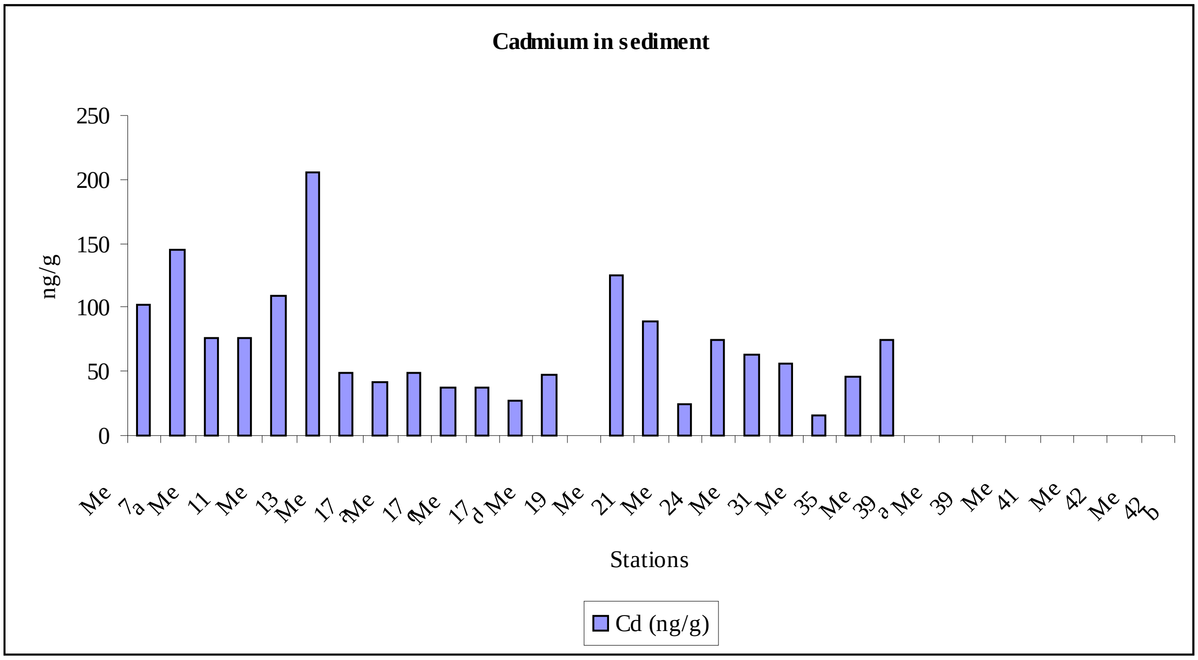

Figure ٦. *Concentration of cadmium in sediments in October-November ١٩٩٩.*

Benthos

The abundance (number of individuals per m²) and the number of species at each station are depicted in Fig.٧ and Fig ٨, respectively. High abundance was generally encountered at the stations from El Burg to Port Said (i.e. mainly the stations at Lake Manzala).This area was also generally characterised by more fine grained sediment. Generally there is a tendency for increasing number of species when moving from west to east along the coast (Fig. ٨)

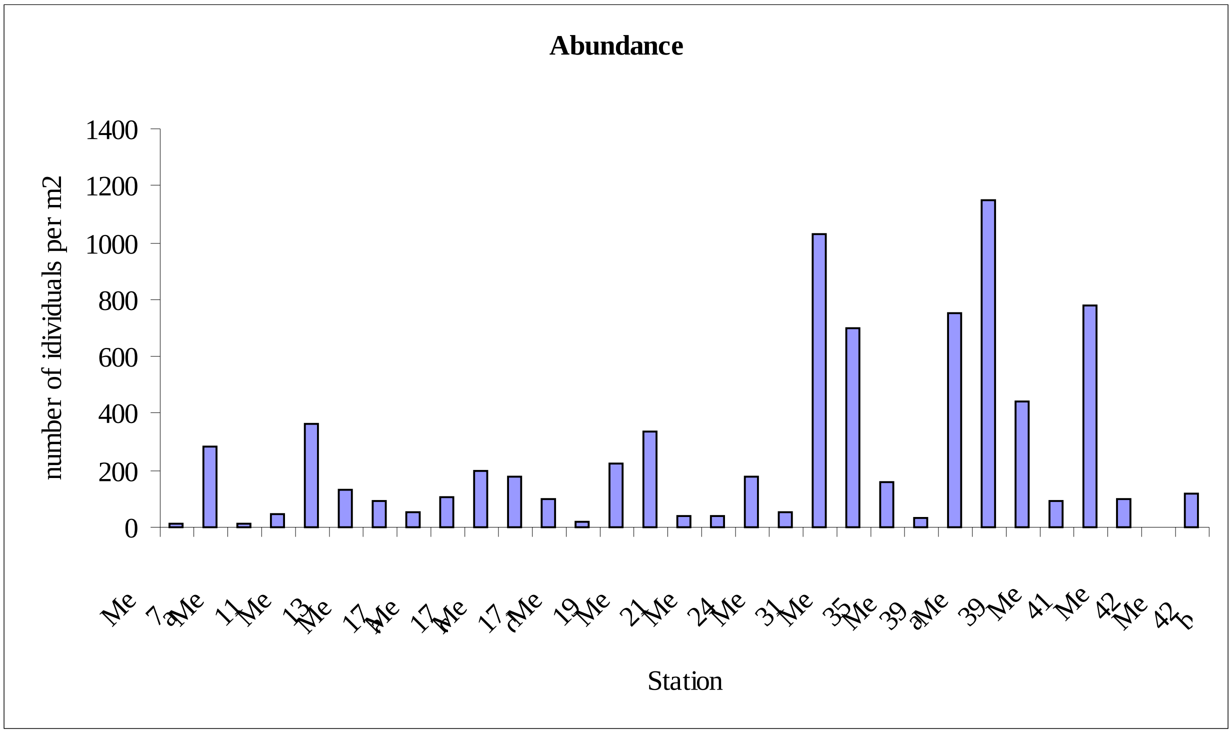

Figure ٧. *Abundance (number of individuals per m² seabed) of benthos on each sampling station in October* ١٩٩٩

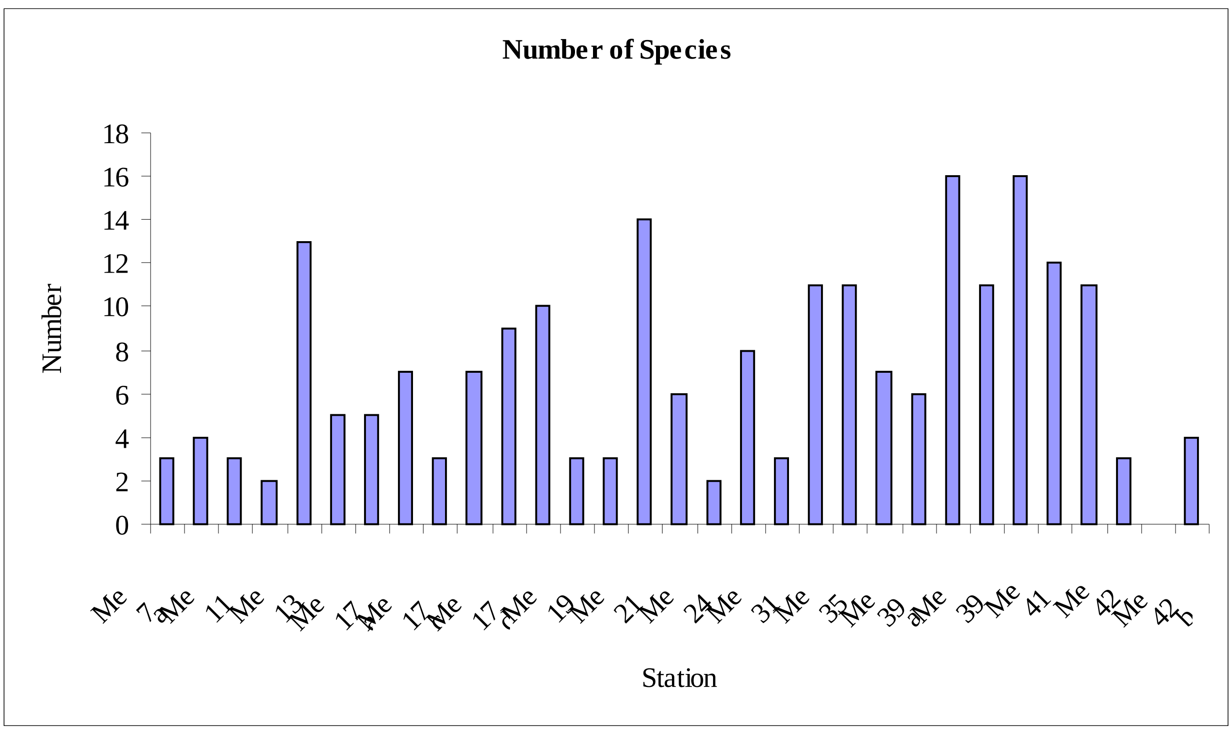

Figure ٨. *Number of species of benthos on each sampling station in October* ١٩٩٩

In Table ٢, mean abundance, mean number of species and mean biomass is compared to the sand, silt and clay content and eutrophication parameters measured in the sediment from different sections along the Mediterranean coast.

There is a clear correlation between the abundance and number of species and the silt/clay content of the sediment. The highest abundance and number of species were encountered in the sediment along the coast from Maadia to Port Said, where the sediment is more silty/clayey compared to all other monitored areas along the Mediterranean Coast.

The factoranalysis of benthos data and the subsequent correlation analysis with water quality data as well as sediment data showed that the fauna on the stations was affected by the content of silt/clay in the sediment. There are no indications that the fauna was affected by pollution. Details of the analysis are presented in Appendix ١. The analysis indicates that the variation in the number and types of benthos from station to staiton can be explained as follows:

- ١٩,٩ % of the variation is due to differences in the composition of sediment (differences in the silt/clay content)
- ٦١,٣ % of the systematic variation cannot be attributed to any of the measured environmental parameters and
- ١٨,٨ % is random variation

The analysis also showed that the fauna on stations Me ٤١a, Me ٣٩b, Me ٣٩a and Me ٣٩ in Lake Manzala area differed significantly from the fauna at all other sites due to a higher content of silt/clay in the sediment.

Although the analysis failed to demonstrate any adverse effect of pollution on the benthos, there are indications that high organic load to the sediment may have affected the fauna at two sites:

- At NIOF east (Me ١٣), the number of species was quite high and the abundance was also higher than at the neighboring stations (Fig ٥ and ٦). The high number of species and abundance may be an effect of the high content of organic matter (Fig٣). A high load of organic matter that does not induce oxygen deficiency normally result in an increase of number of species and abundance, because the organic matter is food for the benthic fauna (Ref.٣).
- In Alex Eastern Harbour (Me ١٥), which was the most polluted site, the fauna was completely dominated by one species of Nematod, which is an opportunistic species often encountered in areas highly polluted by organic material and where there might be oxygen depletion (Ref. ٣). Signs of poor oxygen conditions in the sediments were observed during the sampling (the sediment was completely black, indicating reduced sediment). It would therefore seem reasonable to conclude that the fauna in Alex Eastern Harbour was adversely affected by pollution, probably mainly by organic pollution. However, toxic effects of heavy metals and perhaps other chemicals may also play a part. According to Canadian sediment quality guidelines, the sediment was polluted by Pb to an extent that there is a significant risk of toxic adverse biological effects on flora and fauna and Cu and Zn are found in concentrations that may pose a slight risk of toxic effects (Cf.above).

Table ٢. Mean number of species, mean total abundance, and mean biomass compared to sand, silt and clay content and eutrophication parameters of the sediment in different sections along the Mediterranean coast.

	Nobareia to Alexandria West Harbour Me٧-Me ١٢	NIOF East Me ١٣	Alexandria East HarbourMe ١٥	El Shatby to Abu Quir Me ١٧a-Me ٢٢	Maadia to Port Said Me ٢٤-Me٤١a	Romana to Bardaweel Me ٤٢ -Me ٤٢b
Mean No of Species	٣	١٣	٥	٦,٦	٩,٥	٢,٣
Mean Abundance (indiv/m^2)	٨٨,٥	٣٦٢	١٣٢	١٣٣	٤٥٠	٧٢
Mean Biomass (g/m^2)	٤٧,٩	٤١,٢	٠,٠٥	٤٩,٩	٩١,٦	٤٦,٧
Mean %Sand	١٠٠	١٠٠	١٠٠	١٠٠	٨٦,١٥	١٠٠
Mean %Silt/clay	٠	٠	٠	٠	١٣,٨٥	٠
Mean LOI (%)	١,١	٢,٢	٣,١	١,٣	١,٢	٠,٦
Mean conc TP (ug/g dw)	١١٧,٤	٨٠٣	١٠١٩	٣٠٠,٠	٥٧١,٠	١٧٥,٠
Mean conc. TN (ug/g dw)	١٩٣,١	٨٧٢	١٠٩٣	٢٥٣,٨	١٩٨,٥	١١٧,٤

Conclusion

The sediments at the monitoring stations along the Mediterranean Coast can be ranked with respect to degree of pollution as follows:

- Alexandria East harbour (ME١٥) was the most polluted site
- NIOF east (Me ١٣) was also quite polluted but to a lesser extent compared to Me ١٥
- The coastal stretch from Maadia to port Said along the coast off the Nile Delta and Lake Manzala (Me ٢٤-Me ٤١a) was somewhat polluted but not to an extent that may cause alarm in any way.
- The coastal stretch from Nobareia to Alexandria Western Harbour (Me ٧-Me ١٢ and from El Shatby to Abu Quir (Me ١٧a -Me ٢٢) was insignificantly polluted and
- The coastal stretch from Romana to Bardaweel (Me ٤٢-Me ٤٢b) was not polluted

The sediment on the monitoring site in Alexandria East Harbour (Me ١٥) was the most polluted of the sampling sites along the Egyptian Mediterranean Coast. The sediment was markedly polluted by copper, lead and zinc and the organic content of the sediment as well as the concentrations of total phosphorous and total nitrogen were very high. The sediment was polluted by lead to an extent that there is a significant risk of toxic adverse biological effects on flora and fauna according to Canadian sediment quality standards. Copper and zinc were found in concentrations that may pose a slight risk of toxic effects. The benthic fauna in Alex Eastern Harbour was indeed adversely affected by pollution probably mainly by the organic pollution. The organic load seems to be so high, that poor oxygen conditions in the sediment occur periodically. However, toxic effects of heavy metals and perhaps other chemicals may also play a part.

The sediments at NIOF east (Me ١٣) were also quite polluted by organic matter and heavy metals, especially by lead. However, the concentrations of lead only pose a slight risk of adverse biological effects on sensitive organisms according to the Canadian standards. Abundance and number of benthic species were quite high at NIOF east (Me ١٣). This is probably a result of a stimulating effect of high organic content in the sediment, which constitute a food source for the benthos. Based on the composition of the fauna the sediment does not seem to be subject to equally poor oxygen conditions as in the East Harbour. This may be due to better renewal of water at NIOF east compared to the enclosed basin of East harbour. However, the organic load at NIOF East seems to be sufficiently high for oxygen depletion to take place in the future.

The sediments along the coast of the Nile Delta and Lake Manzala from Maadia to Port Said were polluted by Cu to an extent that there may be slight risks of adverse biological effects on sensitive organisms. The copper polluted sediments were found at Maadia (Me ٢٤), off Rashid (Me ٣١), Damietta (Me ٣٥) and, the coastal areas along Lake Manzala (Me ٣٩a, Me ٣٩b) the outlet from lake Manazala (Me ٣٩, Me ٤٠) and the area off Port Said (Me ٤١,Me ٤١a). Concentrations of Zn that may give a slight risk of toxic effects were also found at Maadia (Me ٢٤). However, there were not indications of the benthos being affected by pollution along this stretch of the coast. The highest abundance and number of species were actually encountered in the sediment along the coast from Maadia to Port Said. This probably due to the fact that the sediment here is more silty/clayey compared to all other monitored areas along the Mediterranean Coast.

The sediments from Nobareia to Alexandria Western Harbour and from El Shatby to Abu Quir were insignificantly polluted. Toxic concentrations of heavy metals were generally not found in these areas and there were no signs of the fauna being affected by pollution.

The EIMP monitoring of water quality parameters revealed significant pollution (eutrophication) by organic material, nutrients and bacteria at very many sites along the coast from Nobareia to Alexandria Western Harbour and from El Shatby to Abu Quir. Pollution from the many sources in these areas was not found in the sediment at the EIMP monitoring stations. The sediments are sandy indicating that erosion takes place. Consequently, pollutants are not accumulating in the sediments but are dispersed with the currents elsewhere. In the future revision of the monitoring programme it should be considered to move some of the sediment/benthos stations to accumulation areas.

The sediments from Romana to Bardaweel are not polluted and there were no signs of the fauna being affected by pollution.

References

١) EIMP (١٩٩٩). Annual Report of Environmental Data from Coastal waters of the Mediterranean Sea in ١٩٩٩.

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٣) Pearson T.H & R. Rosenberg (١٩٧٨). Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol. Ann. Rev. ١٦, ٢٢٩-٣١١

APPENDIX ١

Factor analysis (PCA) analysis of benthos data from ١٩٩٩.

١. INTRODUCTION

The benthos data from ١٩٩٩ were analysed by Factoranalysis and subsequent correlation analysis in order to assess the communtity structure and the influence of environmental parameters on the composition of benthos (including impacts of pollution) .

٢. METHODS

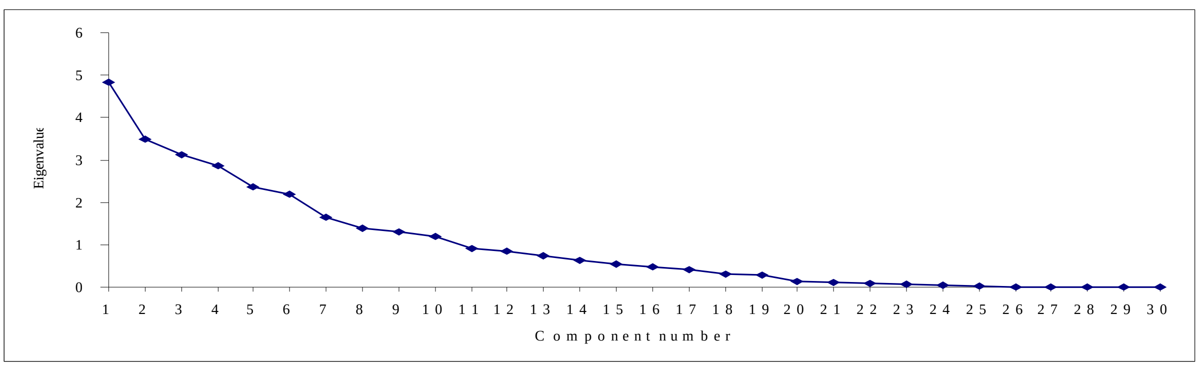
The data were analysed by Factor analysis using Pricipal Component Analysis (PCA) for initial factoring procedure (Ref ١). Input data was the abundance of each species per $m^{٢}$. The factor loadings were rotated using the varimax orthogonal rotation. The rotated factor scores were used for the interpretation of the analyses. The data were ln (x +١) transformed in order to stabilise the variances.

Correlation analyses of the factor scores and the following parameters were carried out:

- Sediment parameters (% silt+clay, % sand, mean size Phi, loss on ignition)
- Concentrations of Total P and Total N in sediments
- Concentration of heavy metals in sediment (Cu , Zn, Cd , Pb)
- Salinity of water. Annual mean for each station in ١٩٩٩
- Dissolved oxygen in water. Annual minimum ١٩٩٩
- Concentration of Chlorophyll. Annual mean for each station in ١٩٩٩
- Concentration of nutrients ($NH_{٤}$-N, $NO_{٢}$-N, $NO_{٣}$-N, TotN (uM) and $PO_{٤}$-P (uM). Annual mean for each station in ١٩٩٩

The Pearson correlation coefficient (r) was computed.

٣. RESULTS



٣,١.Factors

Ten factors accounting for ٨١,٢ % of the total variation in the data have been extracted (Cf. Fig ١). This means that the systematic variation in the data can be described as the sum of seven factors, which may be related to environmental parameters. The remaining ١٨,٨ % of the variation can be regarded as random. The percentage, which each factor is accounting for, is indicated in Table ٣.

Figure ١. Scree plot of the eigenvalues. Any factor with an eigen value of less than ١ cannot be taken seriously as a factor

٣,٢. Interpretation of the factors

The factors have been identified from the factor loadings for the different species (Table ١) and the results of the correlation analyses of the factor scores and the depth, the loss on ignition and the content of silt/clay in the sediment (Table ٢).

The interpretations of the factors are indicated in Table ٣.

The analysis indicate that the variation in the benthos can be explained as follows (Table ٣):

- ١٩,٩ % of the variation is due to differences in the composition of sediment (differences in the silt/clay content) (Factor ٣ and ٤)
- ٦١,٣ % of the systematic variation cannot be attributed to any of the measured environmental parameters (Factors ١،٢،٥،٦،٧،٨،٩،١٠)and
- ١٨,٨ % is random variation

Table ١. Factor loadings. Factor loadings are correlation coefficients between the original variable and the factors. Factor loadings numerically larger than ٠,٥ and therefore important for the interpretations of the factors are shown.

Factor	Species	Factorloading
١	*Orchestia sp.*	٠,٩٥٦٠
	Mactra corralina	٠,٨٦٠٠
	Magelona sp.	٠,٨٣٦٠
	Onuphis eremita	٠,٦٠١٠
	Macoma cumana	٠,٥٢٠٠
٢	*Chone filicaudata*	٠,٩٦٠٧
	Paraonidae	٠,٩٥٨٠
٣	*Apsuedes latreillei*	٠,٩٧١٠
	Tellina tenuis	٠,٨٩٩٠
٤	*Tanis cavolini*	٠,٩٥٢٠
	Mediomastus cirripedes	٠,٨٢٨٠
	Macoma cumana	٠,٦١٥٠
٥	*Donax venustus*	٠,٩٢٨٠
	Donax trunculus	٠,٨٤٤٠
٦	*Scolelepis carunculata*	٠,٨٦٩٠
	Sagitta enflata	٠,٨١٧٠
٧	*Andara diluvi*	٠,٩٧٥٠
٨	*Owenia fusiformis*	٠,٩٢٩٠
	Glycera convoluta	٠,٥٥٤٠
٩	*Stenthoe gallensis*	٠,٦٩١٠
	Elasmopaus pectinicus	٠,٦٢٤٠
١٠	*Nassarius gibbosulus*	٠,٩٠٧٠

Table ٢. Correlation between the factors and measured environmental parameters r = Pearson correlation coefficient.

		١	٢	٣	٤	٥
% silt+clay in sediment	r	-٠،٠١٤	-٠،٠٣٩	,٣٧٦(*)	,٦٣٨(**)	-٠،١٥٥
	p	٠،٩٤٢	٠،٨٣٣	٠،٠٣٧	٠	٠،٤٠٦
% sand in sediment	r	٠،٠١٤	٠،٠٣٩	-,٣٧٦(*)	-,٦٣٨(**)	٠،١٥٥
	p	٠،٩٤٢	٠،٨٣٣	٠،٠٣٧	٠	٠،٤٠٦
Mean size Phi. sediment	r	٠،١٢٤	-٠،٠٥٦	٠،٠٩٧	,٥٦٧(**)	٠،٠٣٨
	p	٠،٥٠٧	٠،٧٦٥	٠،٦٠٣	٠،٠٠١	٠،٨٤
Loss on ignition of sediment	r	-٠،٠٠٣	-٠،١٥١	-٠،١٠١	-٠،٠٥	-٠،١٧٣
	p	٠،٩٨٩	٠،٤١٦	٠،٥٩	٠،٧٨٨	٠،٣٥١
Total P(mg/g) in sediment	r	٠،١١١	-٠،١٠٢	٠،٢٤١	٠،٢٧٦	-٠،٠٨٨
	p	٠،٥٥٣	٠،٥٨٦	٠،١٩٢	٠،١٣٣	٠،٦٣٨
Total N (mg/g) in sediment	r	-٠،٠٣٧	-٠،٠٣٣	-٠،٠٧٤	-٠،٠٤٩	-٠،٢٠٩
	p	٠،٨٤٣	٠،٨٥٩	٠،٦٩٢	٠،٧٩٣	٠،٢٦
Cu (ug/g) in sediment	r	٠،١٨٣	-٠،١٤٩	٠،١٨	,٣٨٢(*)	٠،٠٤٥
	p	٠،٣٢٤	٠،٤٢٣	٠،٣٣٢	٠،٠٣٤	٠،٨١١
Zn (ug/g) in sediment	r	٠،١٢	-٠،٠٠٥	٠،١٢٥	٠،٣٣١	-٠،٠٥٥
	p	٠،٥٢١	٠،٩٨	٠،٥٠٤	٠،٠٦٩	٠،٧٦٩
Cd (ng/g) in sediment	r	-٠،١٨٦	٠،٢٧٥	-٠،٣٥	-٠،٣١٧	-٠،٠٩١
	p	٠،٣١٧	٠،١٣٤	٠،٠٥٤	٠،٠٨٢	٠،٦٢٨
Pb (ug/g) in sediment	r	-٠،١٥٣	-٠،٠١	-٠،١٠٩	-٠،٠٨٦	-٠،١٥٨
	p	٠،٤١١	٠،٩٥٦	٠،٥٥٨	٠،٦٤٥	٠،٣٩٧
Salinity of water	r	٠،٠٣١	-٠،٠٠٢	-٠،١٢١	-,٤٦٦(**)	٠،٠٨٧
mean ١٩٩٩	p	٠،٨٦٨	٠،٩٩	٠،٥١٧	٠،٠٠٨	٠،٦٤٣
Dissolved oxygen in water	r	٠،١٩٧	-٠،٢٦١	-٠،١٦٢	٠،٠٢٦	٠،١٦٩
min ١٩٩٩ (mg/l)	p	٠،٢٨٩	٠،١٥٧	٠،٣٨٣	٠،٨٩١	٠،٣٦٢
Chlorophyll-a (ug/l) in water	r	٠،١٤٤	-٠،١٣٤	٠،٢١	٠،٣١٥	-٠،١٠٢
mean ١٩٩٩	p	٠،٤٤	٠،٤٧٣	٠،٢٥٦	٠،٠٨٤	٠،٥٨٥
NH$_{٤}$-N in water	r	٠،٠٩٥	٠،٢٥١	-٠،١٥	-٠،١٣٢	٠،٠٦٥
Mean ١٩٩٩ (uM)	p	٠،٦١٢	٠،١٧٣	٠،٤٢١	٠،٤٧٧	٠،٧٢٨
NO$_{٣}$-N in water	r	٠،٠٣٧	٠،١٩٥	-٠،١١٨	-٠،٠٨٦	-٠،١٩٦
Mean ١٩٩٩ (uM)	p	٠،٨٤٥	٠،٢٩٢	٠،٥٢٩	٠،٦٤٥	٠،٢٩
N٠$_{٢}$-N in water	r	-٠،١١٩	٠،٣١٧	٠،٠٩١	٠،٢٧١	-٠،١٦١
Mean ١٩٩٩ (uM)	p	٠،٥٢٥	٠،٠٨٢	٠،٦٢٧	٠،١٤	٠،٣٨٦
Tot. N in water	r	-٠،٠٤٧	٠،٠١٩	٠،٢٠٧	٠،٣٣٩	٠،٠٧١
Mean ١٩٩٩ (uM)	p	٠،٨٠٢	٠،٩١٩	٠،٢٦٤	٠،٠٦٢	٠،٧٠٥
PO$_{٤}$-P in water	r	-٠،١٥	٠،٠٦٧	٠،٠٢٣	٠،٢٠٩	-٠،٢٠٧
Mean ١٩٩٩ (uM)	p	٠،٤٢١	٠،٧٢	٠،٩٠٤	٠،٢٥٩	٠،٢٦٤

**Correlation is significant at the .٠١ level

*Correlation is significant at the .٠٥ level

Table ٢ (continued). Correlation between the factors and measured environmental parameters r = Pearson correlation coefficient.

		٦	٧	٨	٩	١٠
% silt+clay in sediment	r	٠،٠٠٠٩	-٠،١٩	-٠،١٤٧	-٠،١	-٠،١١٣
	p	٠،٩٦٣	٠،٣٠٧	٠،٤٢٩	٠،٥٩٣	٠،٥٤٤
% sand in sediment	r	-٠،٠٠٠٩	٠،١٩	٠،١٤٧	٠،١	٠،١١٣
	p	٠،٩٦٣	٠،٣٠٧	٠،٤٢٩	٠،٥٩٣	٠،٥٤٤
Mean size Phi. sediment	r	٠،٠٣٣	٠،٠٨٧	٠،٠٦٦	٠،٢١٦	٠،٠٣١
	p	٠،٨٥٩	٠،٦٤١	٠،٧٢٤	٠،٢٤٣	٠،٨٦٨
Loss on ignition of sediment	r	-٠،٠٧٦	-٠،٠٧٥	-٠،٢٩٦	-٠،٢٣٢	-٠،٠٤٨
	p	٠،٦٨٤	٠،٦٨٧	٠،١٠٦	٠،٢٠٨	٠،٧٩٧
Total P(mg/g) in sediment	r	٠،١٤	٠،١٣١	٠،١٤٢	٠،٢٤٢	٠،٠٨٣
	p	٠،٤٥٣	٠،٤٨٣	٠،٤٤٥	٠،١٨٩	٠،٦٥٧
Total N (mg/g) in sediment	r	-٠،٠٤٥	-٠،٠٩٧	-٠،٢٤٦	-٠،٠٣	-٠،١٥٤
	p	٠،٨٠٨	٠،٦٠٣	٠،١٨١	٠،٨٧١	٠،٤٠٩
Cu (ug/g) in sediment	r	٠،١١٣	٠،٠٦١	٠،٠٨٩	٠،٠١٥	-٠،٠٤١
	p	٠،٥٤٤	٠،٧٤٥	٠،٦٣٤	٠،٩٣٨	٠،٨٢٨
Zn (ug/g) in sediment	r	٠،١٢٤	٠،٠٥	٠،١٣٢	٠،١٥٣	-٠،٠٠١
	p	٠،٥٠٦	٠،٧٨٩	٠،٤٨	٠،٤١٢	٠،٩٩٨
Cd (ng/g) in sediment	r	٠،٠٧٣	-٠،١٥١	٠،٠٨١	٠،١٢٢	-٠،١٢٥
	p	٠،٦٩٦	٠،٤١٦	٠،٦٦٤	٠،٥١٤	٠،٥٠٣
Pb (ug/g) in sediment	r	٠	-٠،٠٠٠٩	-٠،٠٧٩	٠،١٢	-٠،١٢٢
	p	١	٠،٩٦٣	٠،٦٧٤	٠،٥٢٢	٠،٥١٣
Salinity of water	r	-٠،٠٤٢	٠،٠٣٣	-٠،٣١٤	٠،٠٣٢	٠،١٦
mean ١٩٩٩	p	٠،٨٢٣	٠،٨٦١	٠،٠٨٥	٠،٨٦٥	٠،٣٨٩
Dissolved oxygen in water	r	-٠،٠٦١	-٠،١٢٣	٠،٠٩٧	-٠،١٢٧	٠،١١٢
min ١٩٩٩ (mg/l)	p	٠،٧٤٣	٠،٥٠٩	٠،٦٠٣	٠،٤٩٦	٠،٥٤٨
Chlorophyll-a (ug/l) in water	r	-٠،١٨٤	٠،١٦٧	-٠،٢٣٣	٠،١٧٤	-٠،١٤٨
mean ١٩٩٩	p	٠،٣٢٢	٠،٣٧١	٠،٢٠٧	٠،٣٤٩	٠،٤٢٧
Total suspended matter in water	r	٠،٣٠٨	٠،٠٩٣	٠،٠٣١	-٠،٠٠٥	-٠،٠٢
mean ١٩٩ (mg/l)	p	٠،٠٩٢	٠،٦١٨	٠،٨٦٧	٠،٧٩	٠،٩١٧
NH٤-N in water	r	-٠،٠٧٨	٠،٠٢٥	٠،١١١	٠،١٣٨	-٠،١٠٤
Mean ١٩٩٩ (uM)	p	٠،٦٧٥	٠،٨٩٦	٠،٥٥٣	٠،٤٥٨	٠،٥٧٨
NO٢-N in water	r	-٠،٠٣٧	-٠،٠٠٠٩	-٠،٠٠٠٨	٠،٠٩٩	-٠،١٦٤
Mean ١٩٩٩ (uM)	p	٠،٨٤٣	٠،٩٦٢	٠،٩٦٧	٠،٥٩٧	٠،٣٧٩
N٠٣-N in water	r	-٠،١١٦	-٠،٠٥١	-٠،١٩	-٠،٠٩	-٠،٢٥٢
Mean ١٩٩٩ (uM)	p	٠،٥٣٦	٠،٧٨٥	٠،٣٠٧	٠،٦٢٩	٠،١٧٢
TotN in water	r	٠،٠٧٧	٠،٣٠٩	٠،١٨٨	٠،٢٧٦	-٠،٠٩٦
Mean ١٩٩٩ (uM)	p	٠،٦٨	٠،٠٩	٠،٣١١	٠،١٣٣	٠،٦٠٧
PO٤-P in water	r	-٠،٠٤	٠،٠٣٩	-٠،٠٢٩	٠،١٠٧	-٠،٢٨٩
Mean ١٩٩٩ (uM)	p	٠،٨٣٢	٠،٨٣٧	٠،٨٧٧	٠،٥٦٧	٠،١١٤

**Correlation is significant at the .٠١ level

*Correlation is significant at the .٠٥ level

Table ٣. Interpretation of factors based on factorloadings (Table ١) and correlations between factor-scores and measured enviromental parameters (Table ٢).

Factor	Percent of total variance	Significant correlations	Interpretation
١	١٦,١٪	• Positively correlated with the abundance of *Orchestia sp., Mactra corralina, Magelona sp., Onuphis eremita, Macoma cumana*	Factor ١ represents variation in these species, a variation which cannot be attributed to measured environmental parameters
٢	١١,٦ %	• Positively correlated with the abundance of *Chone filicaudata,Paraonidae*	Factor ٢ represents variation in these species, a variation which cannot be attributed to measured environmental parameters
٣	١٠,٤ %	• Positively correlated with the abundance of *Apsuedes latreillei,Tellina tenuis* • Positively correlated with the silt/clay content of the sediment • Negatively correlated with the content of sand in the sediment	Factor ٣ can be interpreted as a gradient of increasing content of silt/clay in the sediment.
٤	٩,٥ %	• Positively correlated with the abundance of *Tanis cavolini,, Mediomastus cirripedes, Macoma cumana* • Positively correlated with the content of silt/clay in the sediment • Positively correlated with Cu in sediment • Negatively correlated with the content of sand • Negatively correlated with salinity	Factor ٤ can be interpreted as a gradient of increasing content of silt/clay in the sediment and a decreasing salinity of water. The correlation with Cu is probably due to co-variation between Cu and silt/clay, heavy metals being primarily attached to the fine-grained material in the sediment.
٥	٧,٩ %	• Positively correlated with the abundance of *Donax venustus,Donax trunculus*	Factor ٥ represents variation in these species, a variation which cannot be attributed to measured environmental parameters
٦	٧,٣ %	• Positively correlated with the abundance of *Scolelepis carunculata,Sagitta enflata*	Factor ٦ represents variation in these species, a variation which cannot be attributed to measured environmental parameters
٧	٥,٥٪	• Positively correlated with the abundance of *Andara diluvi*	Factor ٧ represents variation in this species, a variation which cannot be attributed to measured environmental parameters
٨	٤,٦ %	• Positively correlated with the abundance of *Owenia fusiformis* and *Glycera convoluta*	Factor ٨ represents variation in these species, a variation which cannot be attributed to measured environmental parameters
٩	٤,٣ %	• Positively correlated with the abundance of *Stenthoe gallensis* and *Elasmopaus pectinicus*	Factor ٩ represents variation in these species, a variation which cannot be attributed to measured environmental parameters
١٠	٣,٩ %	• Positively correlated with the abundance of *Nassarius gibbosulus*	Factor ١٠ represents variation in this species, a variation which cannot be attributed to measured environmental parameters

٣,٣. Factor scores

The factor scores for each station each year in is presented in table ٤.

The factor scores for factor ٢ and ٣ are plotted in fig ٢. The relative location of the factor scores along the axes indicates the degree of similarity in composition of the benthic fauna between stations and years.

The plot indicates that the benthos on stations ٣٩, ٣٩a, ٣٩b, Me٤٠, Me ٤١ Me ٤١a differ from the benthos on the other stations, due to higher content of silt/clay in the sediment

Table ٤. Factor scores.

Station	Factor ١	Factor ٢	Factor ٣	Factor ٤	Factor ٥	Factor ٦	Factor ٧	Factor ٨	Factor ٩	Factor ١٠
Me ٧a	-٠،٢٨	-٠،١١	-٠،٧١	-٠،٧٦	-٠،٦٥	-٠،٠٣	-٠،٢٨	-٠،٥٣	١،٤١	-٠،٦٢
Me ٧	-٠،٢٥	-٠،٥٠	-٠،٣٩	-٠،٣٣	-٠،٠٩	-٠،٠٤	٠،٠٠	٠،٠٤	-٠،٠١	-٠،٩٠
Me ١١	٠،٠٢	-٠،٢١	-٠،٤٧	-٠،٦١	-٠،٥٣	-٠،١٧	-٠،٦٨	-٠،٩٨	-٠،٣٠	-٠،٥٠
Me١١a	-٠،١٩	-٠،١٢	-٠،٢٤	-٠،٢٩	٠،٠٧	-٠،١٨	-٠،١٠	-٠،٢٢	-٠،١٢	-٠،٢٦
Me ١٥	-٠،٦١	٠،٠٦	-٠،٦٧	-٠،٤٢	-٠،٦١	٠،٢٣	-٠،١٢	-٠،٣٩	٠،٦١	-٠،٤٥
Me ١٣	-٠،٢٢	-٠،٠٧	-٠،٢٦	-٠،٢٢	-٠،٢٦	-٠،٠٤	-٠،٠٦	-٠،١٨	-٠،٠٢	-٠،١٩
Me ١٧a	٠،٠٤	-٠،٠٤	-٠،٢٢	-٠،٢٣	-٠،٥٠	٠،٠٥	٠،٢٢	-٠،٤٠	-٠،٠٦	-٠،١٣
Me ١٧b	-٠،٠٤	-٠،١١	-٠،٢٩	-٠،٤٠	-٠،٦٣	٠،٠٧	-٠،٢٩	-٠،٨٦	-٠،١٧	-٠،٤٦
Me ١٧c	-٠،٠٤	٠،٠٢	-٠،٣٩	-٠،٥٣	-٠،٣٨	-٠،٢١	-٠،١٤	-٠،٢٦	-٠،٢٩	-٠،٢٢
Me١٧cc	-٠،٢١	-٠،٣٣	-٠،١٢	٠،٠١	-٠،٢٣	-٠،١١	-٠،٢٩	-٠،٦٤	٠،٠٧	٣،٦١
Me ١٧d	-٠،٠٨	-٠،٥٤	٠،٥٢	٠،١٥	٠،٦٢	-٠،٤١	-٠،٣٦	٠،٠٣	-٠،٢٦	-٠،٢٣
Me ١٩	-٠،٢٢	٠،٠٢	-٠،٣٩	-٠،٦٥	-٠،٧١	-٠،١٤	-٠،١٨	-٠،٤٩	-٠،٤٢	١،٣١
Me ١٨	-٠،١١	-٠،١٩	٠،٨٩	-٠،٣١	-٠،١٨	-٠،١٩	-٠،٠١	٠،٠٠	-٠،٩٥	-٠،١٤
Me ٢٠	-٠،١٠	-٠،٥٤	-٠،٤٢	-٠،٢٩	-٠،٣٨	-٠،٠٧	٠،٢٣	-٠،٦٤	٠،١٠	-٠،٣٢
Me ٢١	٠،٤٠	٥،٢١	-٠،١١	-٠،٣٥	٠،٦٤	-٠،٢٧	-٠،٠١	-٠،٠٥	٠،٢٤	-٠،١٦
Me ٢٢	-٠،٦٣	-٠،٠٨	-٠،٥١	-٠،٥٧	-٠،٥٥	٠،٢٠	٠،٠٦	١،٣٨	٠،١٣	-٠،٨٣
Me ٢٤	٠،٠١	-٠،٥٠	-٠،٣٥	-٠،٢٨	-٠،٣٥	-٠،١٥	-٠،٥٨	-١،١٣	-٠،٠٧	-٠،٣٦
Me ٢٩	-٠،٤٨	-٠،٢٦	-٠،١٢	-٠،٢٢	-٠،١٣	٠،٢٠	-٠،٤٥	٣،٥٧	٠،٠١	-٠،٧٨
Me ٣١	-٠،٦٣	٠،١٩	-٠،٢٠	-٠،٦٣	-٠،٥٧	٠،٠٠	٠،١٠	٢،٨٣	-٠،٥٢	١،٨٩
Me ٣٢	٠،٣٢	-٠،٣٨	-٠،٣٣	-٠،٤٣	٢،٢٥	٤،٦٨	٠،٠٢	-٠،١٢	٠،٢٧	٠،٠٨
Me ٣٧	-٠،٧٠	-٠،٣٢	-٠،٠٧	٠،١٣	٢،٩٧	-١،٤٢	-٠،٠٣	-٠،٤٤	-٠،١٠	١،٩٥
Me ٣٥	٥،١٥	-٠،٥٦	-٠،٤٨	٠،٠٧	٠،١٠	-٠،٦٢	-٠،٠٩	٠،٦٨	٠،٦٨	٠،٢٧
Me٣٩a	-٠،١٠	-٠،٢٥	-٠،٤٦	١،٢١	-٠،٢٣	-٠،٥٧	-٠،٣٥	-٠،٥٧	-٠،٠٧	-٠،٣٦
Me٣٩b	٠،٦٥	٠،١٥	٣،٥٥	٠،١٦	-٠،٥٦	٠،٥٩	-٠،٢٥	-٠،٢٨	-٣،٢١	-٠،٢٧
Me ٣٩	-٠،٢٧	٠،٥٩	-٠،٤٦	٣،٩٨	-٠،٦٧	١،١٦	-٠،٣٩	-٠،٤٤	٠،١٩	٠،٠٤
Me ٤٠	-٠،٢٩	-٠،٣٦	-٠،٣٣	٢،٨٥	٠،١٣	-٠،٨٠	-٠،٣٦	٠،٩٦	-٠،٠٣	-٠،٣٤
Me٤١	-٠،٠٧	-٠،١٨	٠،٢٧	٠،٣٥	-٠،١٧	-٠،١٤	٥،٢٥	-٠،١٤	٠،٢٢	-٠،١٤
Me٤١a	-٠،٤٢	-٠،٢١	٣،٥٤	-٠،١٠	-٠،٠٩	-٠،٢١	-٠،٥٣	٠،٠٠	٣،٧٨	-٠،٠٣
Me٤٢	-٠،١٥	٠،٠٧	-٠،٢٦	-٠،٣٥	-٠،٨٦	٠،٢٥	-٠،٠١	-٠،٢٣	-٠،٠١	٠،٨٠
Me٤٢a	-٠،١٤	-٠،٠١	-٠،٤٤	-٠،٧٧	-٠،٦١	-٠،١٦	-٠،١٧	-٠،٥٠	-٠،٥٥	-٠،٦٤
Me٤٢b	-٠،٣٥	-٠،٤٤	-٠،٠٨	-٠،١٦	٣،١٥	-١،٥٠	-٠،١٤	٠،٠١	-٠،٥٨	-١،٦٤

٣,٤ Conclusion

From the analysis it can be concluded, that the fauna on the stations is affected by the content of silt/clay in the sediment. There are no indications that the fauna is affected by pollution.

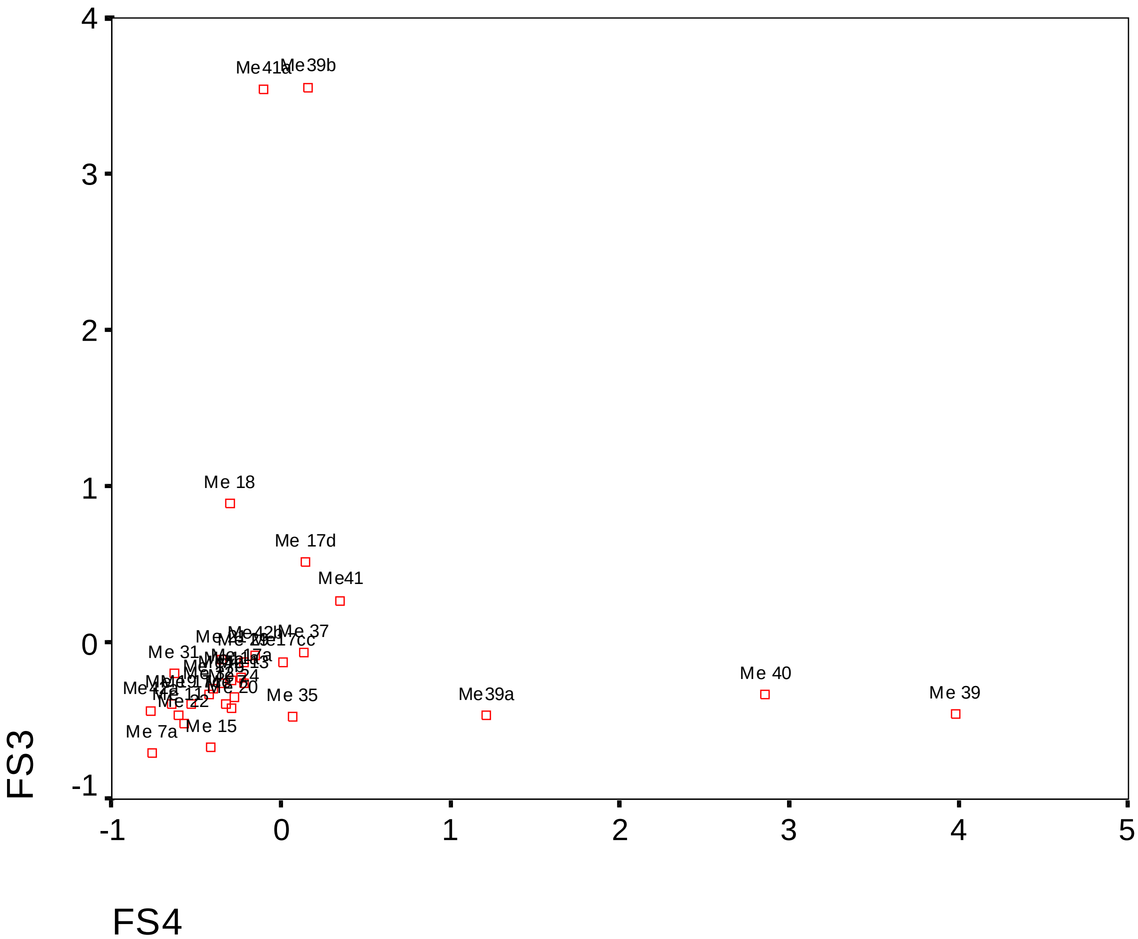


Figure ٢ . Factor plots ١٩٩٩ data Factor analysis based on abundance of different species of benthos. The factor scores for each station are plotted on factor axes ٣and ٤. Stations with a high score on Factor ٣ or on Factor ٤ are characterised by higher content of silt/clay in the sediments than stations with lower scores (Table ٣).