Sediment and benthos monitoring.

Gulf of Suez ١٩٩٩.

Summary

This report presents the results of the EIMP monitoring of contaminants in the sediment and the composition of benthic invertebrate fauna (benthos) carried out in the Gulf of Suez in ١٩٩٩. The major findings were:

- At the majority of the investigated sites in the Gulf of Suez, the sediments were not polluted or only insignificantly polluted by organic matter, nutrients and heavy metals and there were no indications of impacts on benthos due to pollution at most sites.
- However, organic matter and nutrients (eutrophication) significantly influenced the sediments and benthos in the northernmost part of the Gulf of Suez (i.e. Bay of Suez). The source of the organic matter and nutrients is domestic and industrial wastewater from the city of Suez and perhaps also the many ships awaiting passage through the Suez Canal. Elevated levels of copper, zinc and lead were also encountered but the concentrations measured only pose a slight risk, that toxic effect on flora and fauna may occur. The benthos in the Bay of Suez was clearly affected by the high organic load. Generally the high content of plankton and organic material, which is feed for benthos, resulted in elevated density and number of species compared to other areas in the Gulf of Suez. There were however, indications that the benthos close to Suez was suffering from occasional oxygen depletion in the sediment resulting in a decrease of density and number of species. The sediment and benthos was also affected by eutrophication at Ain Sukna.

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 in the Gulf of Suez 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 Gulf of Suez are presented in Figure ١. The sampling took place in October ١٩٩٩. 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 the Gulf of Suez in ١٩٩٩.

Water Quality

The monitoring of water quality parameters in ١٩٩٩ showed that the northernmost part of the Gulf of Suez (Bay of Suez (Su١, Su٢ and Su٣)) was generally heavily influenced by discharge of domestic and industrial wastewater from the city of Suez. The heavy ship traffic in the area probably also contributed significantly to discharge of contaminants. The water quality in other parts of the Gulf of Suez was generally good (Ref.١).

The levels of nutrients (nitrate/nitrite and ammonia) and phytoplankton biomass were significantly higher in the Bay of Suez compared to the other parts of the Gulf of Suez. The same pattern was found for the bacteriological parameters. However, station Su٧ at Ras Gharib also showed very high levels of bacteria.

Dissolved oxygen levels indicated well-oxygenated water at all monitoring sites with a tendency towards a slight decrease in oxygen content with increasing depth. However, the level of dissolved oxygen was never even close to being depleted at any measured stations during ١٩٩٩ (Ref.١).

Sediment

Composition of sediment

The seabed at most of the monitoring stations consisted of pure sand. However, in the Bay of Suez (Su١, Su٣), at station Su ٥ at Ain Sukhna) and at most of the stations along the coast of Sinai (Su١١, Su١٢b, Su١٣ and Su١٣a) the sediments had a considerable content of silt/clay (Figure ٢).

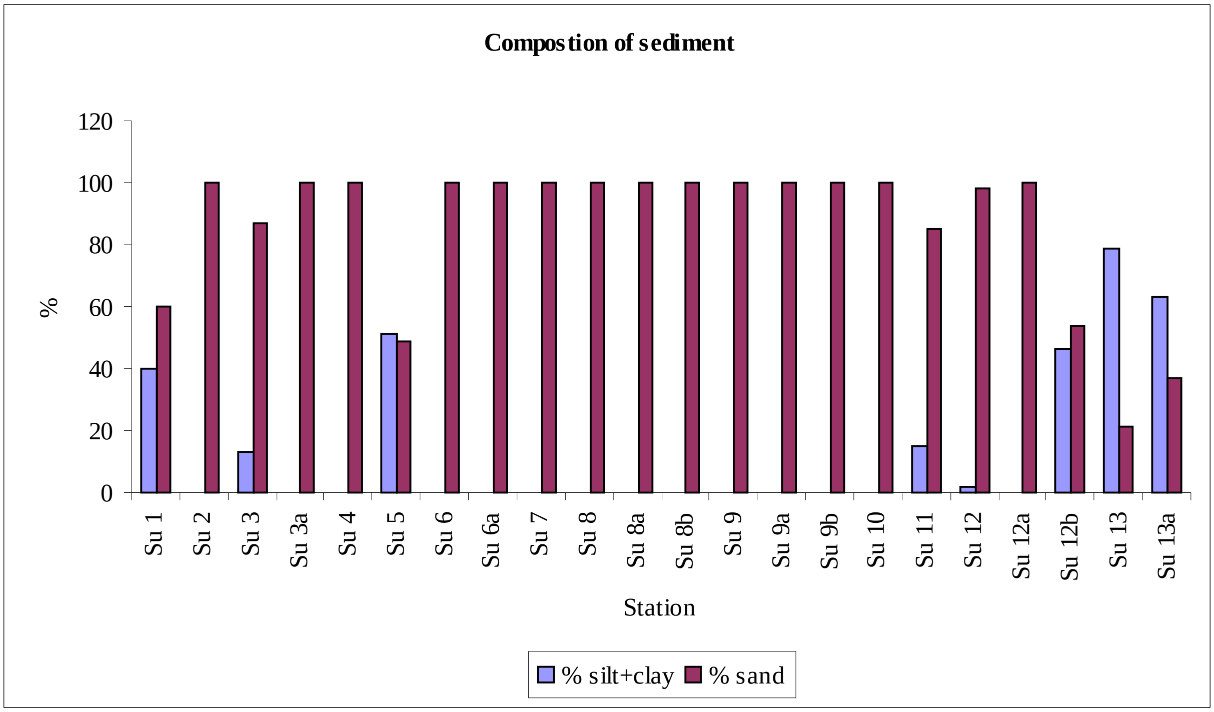

Figure.٢. *Composition of the sediment at the monitoring sites*.

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 two 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 copper, zinc, cadmium and lead encountered along different stretches of the Gulf of Suez cost are compared to the Canadian TELs and PELs. The range of concentrations of Tot N and Tot P and loss on ignition are also indicated. From table ١ and Figs. ٣-٦ it appears that:

- Copper, lead and zinc markedly contaminated the sediments in Suez Bay close to Suez City (Su ١) However, the levels of these metals only pose a slight risk of adverse biological effects on sensitive organisms (above TEL, but below PEL). The levels of total P, total N and organic matter measured as loss on ignition were high. Su١ was the most polluted of the sampling sites in the Gulf of Suez.
- The sediments in Suez Bay further away from Suez City are polluted by lead, but to a much lesser extent compared to Su١. The concentrations of total P and total N were lower compared to Su١ but high levels of organic material (measured as LOI) were encountered.
- Toxic concentrations of cadmium, copper, lead and zinc were not found on any of the remaining sites in the Gulf of Suez. Not even on the stretch from Abu Zenima to El Tur along the East Coast, where elevated concentrations of cadmium were found. (Cf. Fig ٦)
- There was a clear decreasing trend of total N, total P and organic matter when moving along the West Coast southwards from Suez to Ras Shukeir. This trend is similar to the results of the water quality monitoring where a similar decreasing trend of eutrophication parameters was observed.
- The concentration of total P was elevated along the Sinai coast (Su١١-Su١٣)

Table ١. Range of concentrations of Heavy metals (Cd, Cu, Pb, Zn), Tot.N, Tot.P and loss on ignition (LOI) encountered in sediments along various stretches of the Gulf of Suez coast (ug/g dry weight). The concentrations of heavy metals are compared to threshold effects levels (TEL) and potential effect 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.

	Suez Bay Su١	Suez Bay Su٢ and Su٣	West Coast Suez/Ain Sukhna-Ras Shukeir Su٣a-Su٩b	East Coast Ras Sudr Su١٠	East Coast Abu Zenima-El Tur Su١١-Su١٣a	TEL	PEL
Cd	٠,٠٩٣-٠,١	٠,٠٩-٠,١٨٣	n.d-٠,١٦٥	٠,٠٧٥-٠,٠٧٦	n.d-٠,٢٩	٠,٦	٤,٢
Cu	٤١-٤٤ (١٠٠٪)	١١-١٢	٢-٨	٥	٣-٨	٣٥,٧	١٠٨
Pb	٥٢-٦٨ (١٠٠٪)	٢٥-٣٥ (٢٥٪)	٦-٢٣	٦-٨	٧-٢٠	٣٥	١١٢
Zn	١٢٨-١٣٤ (١٠٠٪)	٣٣-٣٦	٧-٣٠	١٢-١٥	٨-٤٣	١٢٣	٢٧١
Tot P	٧٤٤-٨٠٥	٣٤٦-٣٨٠	١٣٦-٣٠٨	٢٧٤-٢٨٣	٢٣٢-٩٣٢	-	-
Tot N	١٩٧٦-١٩٨٦	٦٢٠-٧٢٦	١٥٤-٥٠٦	٢٤٢-٢٥٦	٢١٤-٧١٢	-	-
%LOI	٣,٦٧-٤,٦٤	١,٨٨-٥,١٣	٠,٦٨-٢,٧٧	٠,٨٢-٠,٩٠	٠,٨٢-٢,٥٩	-	-

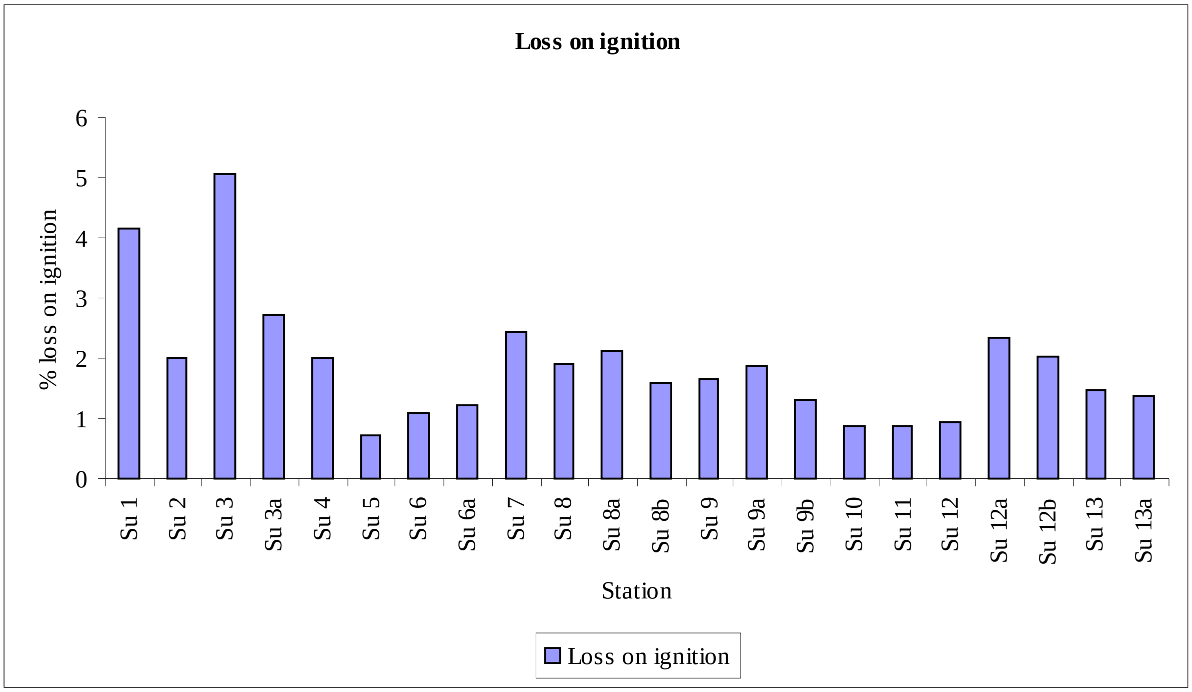

Figure ٣. *Content of organic matter in sediments (measured as loss on ignition) in October ١٩٩٩.*

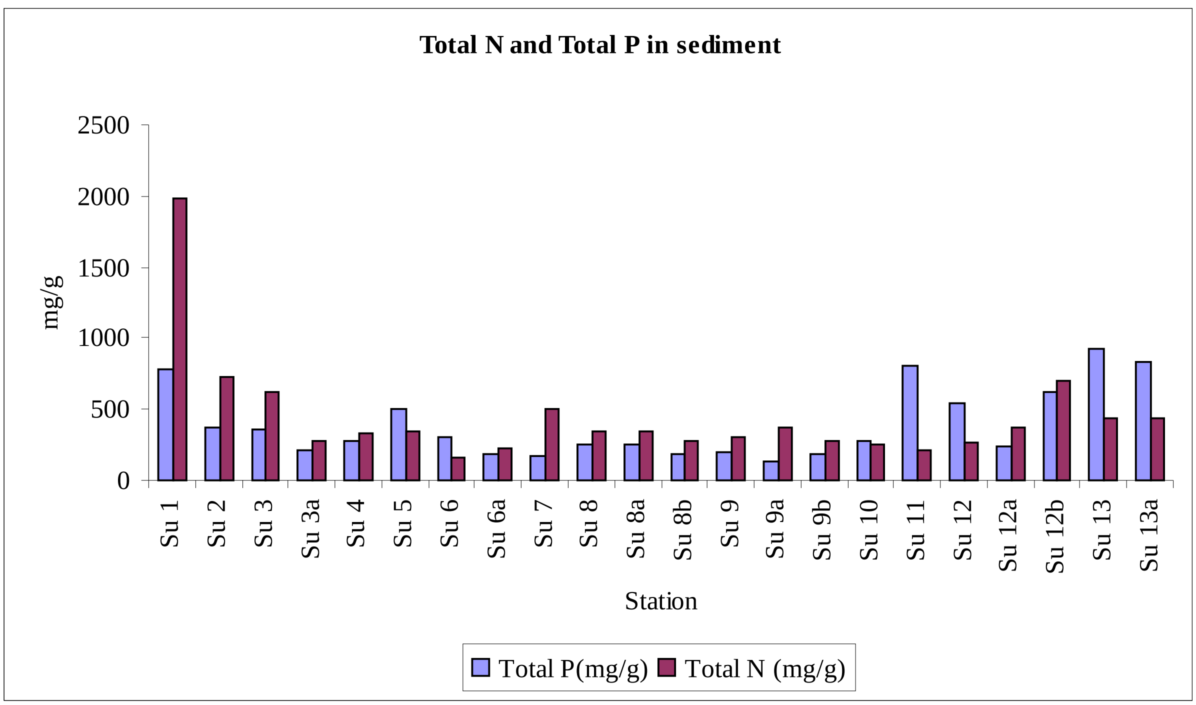

Figure ٤. *Concentrations of Total Nitrogen and Total Phosphorous in sediments in October ١٩٩٩.*

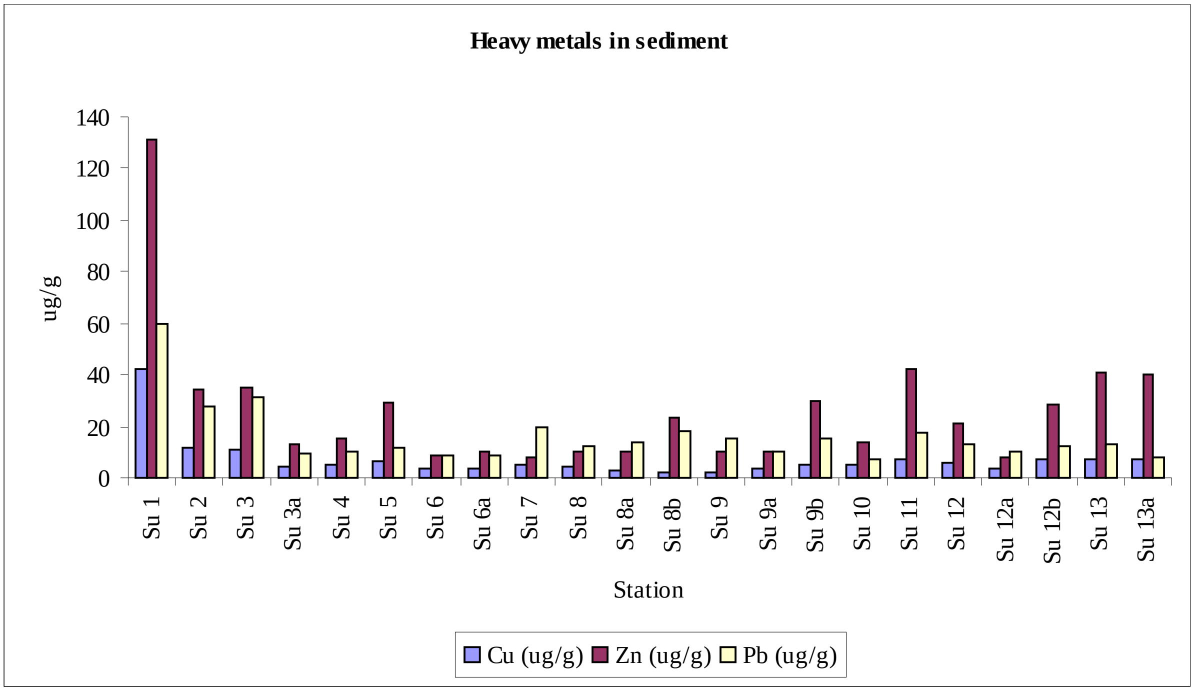

Figure ٥. Concentration of copper, zinc and lead in sediments in October ١٩٩٩.

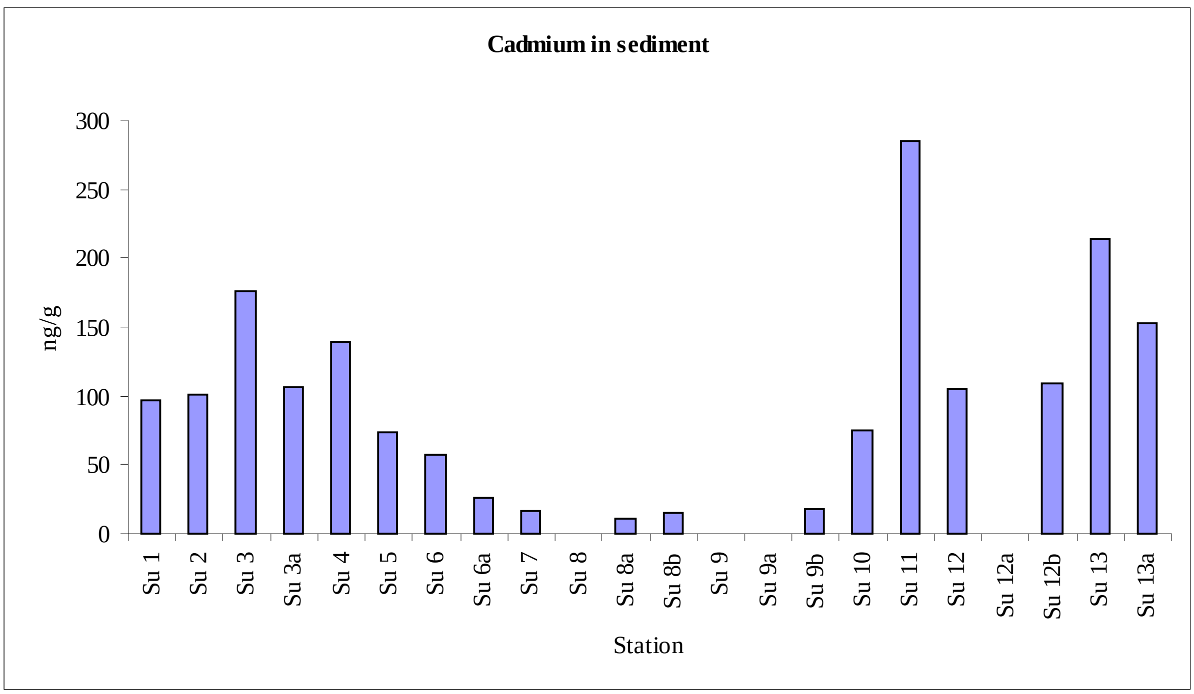

Figure ٦. Concentration of cadmium in sediments in October ١٩٩٩.

Benthos

The abundance (number of individuals per m² seabed) and the number of species at each station are depicted on Fig.٧and Fig.٨, respectively. The highest abundance was generally encountered in the northernmost part of the Gulf of Suez (Su١, Su٢, Su٣ and Su ٣a) and at Ain Sukhna (Su٥). Relatively high numbers of species number were also found here and at Ras Budran (Su١٢), Abu Rudeis (Su ١٢b) and in the El Tur area (Su ١٣ and Su ١٣a).

The differences in composition of benthos are due to differences in environmental parameters, including pollution.

The benthos is affected by a wide number of environmental parameters, which can be grouped in three: Physical parameters, biological parameters and pollution. The composition of benthos on a site is determined by a complex interaction of all these parameters. Pollution can affect benthos in a number of ways:

- Toxic substances may kill some animals and weakening others, which in the end will result in a change of the benthos community. In severe cases all animals may be killed.
- Increased loads of organic material can affect the fauna.

Based on a substantial amount of data Pearson & Rosenberg (Ref. ٣) found a general succession pattern of benthic infauna in response to increased eutrophication and resulting increasing load of organic material to the sediment:

- Initially increasing load of organic matter will result in an increase of the number of species, the biomass and the density (abundance) of organisms because the amount of food for the organisms increases.
- When the load reaches a certain level, the number of species, the biomass and the density decline. The reason being that the oxidised layer of the sediment becomes thinner because the organic matter consumes oxygen.
- At very heavy loads, oxygen depletion in the seabed may periodically take place. Only very few species can tolerate such conditions so the number of species decrease further as a result. Longer periods of oxygen depletion lead to the extinction of the fauna. When oxygen conditions improve the area is rapidly recolonised by a very few so-called opportunistic species, which may occur in high densities.

The benthos data from the Gulf of Suez can be interpreted in the context of the Pearson & Rosenberg succession of benthos in relation to increasing eutrophication and organic load (and content of silt/clay in the sediment).

In Table ٢, mean abundance, mean number of species and mean biomass is compared to eutrophication parameters measured in the sediment from different sections of the Gulf of Suez.

The abundance of species and the number of species increased significantly when moving northwards from Ras Shukier to Suez Bay along the West Coast of the Gulf of Suez. A parallel increase of organic matter (LOI), silt/clay content of the sediment and total concentration of N and P in the sediment is also evident. The abundance and number of species, however, decreased again at the northernmost station Su١, close to the city of Suez (Fig ٧).

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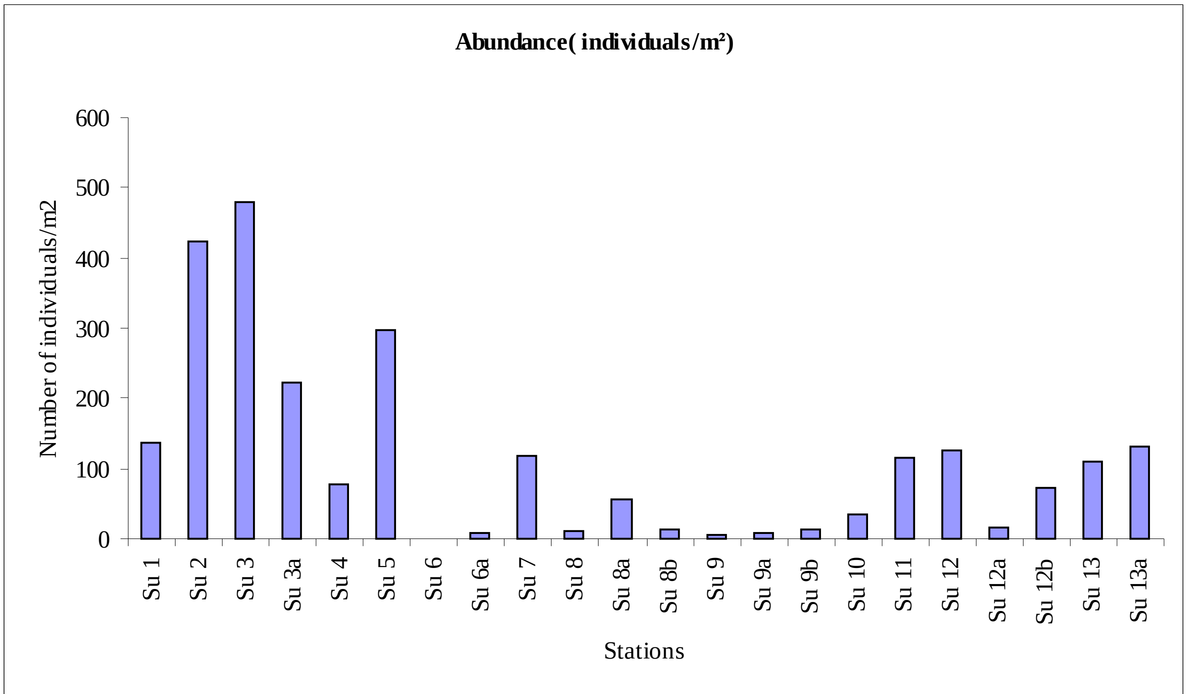


Figure ˆ. *Abundance (number of individuals per m² seabed) of benthos on each sampling station in October˚ ₫₫₫.*

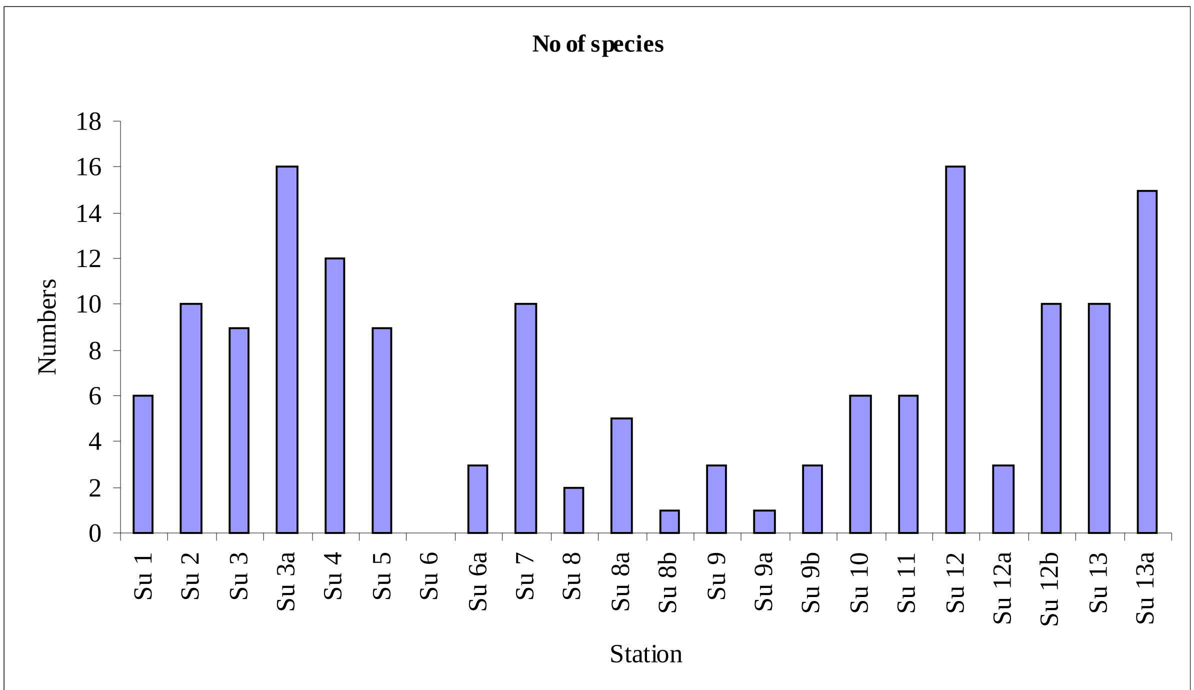


Figure ٨. *Number of species of benthos on each sampling station in October ١٩٩٩.*

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

	West Coast Suez Bay Su١	West Coast Suez Bay Su٢ and Su٣	West Coast Suez/Ain Sukhna Su٣a-Su٥	West Coast Waddy El Dom -Ras Shukier Su٦-Su ٩b	East Coast Ras Sudr Su ١٠	East Coast Abu Zenima -El Tur Su ١١-Su ١٣a
Mean No of Species	٦	٩,٥	١٢,٣	٣	٦	١٠
Mean Abundance (indiv/m^2)	١٣٧	٤٥١	١٩٩	٢٦,٢	٣٥	٩٥,٣
Mean abundance Capitellidae (indiv/m^2)	٦٧	٣١٦	٧٨	٠,٣	٠	٠
Mean Biomass (g/m^2)	١,٢	٨,٢	٢٣,٢	٢,٤	٠,٥	٧١,٦
Mean %Sand	٦٠,٣	٩٣,٢	٨٣,١	١٠٠	١٠٠	٦٥,٦
Mean %Silt/clay	٣٩,٧	٦,٨	١٦,٩	٠	٠	٣٤,٤
Mean LOI (%)	٤,٢	٣,٥	١,٨	١,٧	٠,٨٦	١,٥
Mean conc TP (ug/g dw)	٧٧٤,٥	٣٥٩,٥	٣٣٢,٣	٢٠٨	٢٧٨,٥	٦٦٢,٦
Mean conc. TN (ug/g dw)	١٩٨١	٦٧٤	٣١٥,٣	٣١٠,٧	٢٤٩	٤٠٣,٥

In addition to the increase of abundance and number of species there was a parallel increase in the occurrence of a species of Capitellid polychate worm. Capitellids are opportunistic species, which are characteristic for sediments highly polluted by organic matter, often in areas with poor oxygen conditions in the sediment. The density of the Capitellid species was highest at Su٢ and Su٣ and a little lower at Su١. It was the dominating species at these sites and at one site at Ain Sukhna. During sampling it was observed that the sediments at Su١, Su٢ and Su٣ were black on the surface indicating reduced conditions caused by oxygen deficiency. The sediments further south in the Gulf of Suez was all well oxygenated.

Copper, lead and zinc significantly contaminated the sediment at Su١. At Su٢ and Su٣ the sediment was polluted by lead. However, when comparing the sediment results with sediment quality standards it is obvious that these metals only pose a slight risk of adverse biological effects on sensitive organisms (Cf. above), so the benthos was hardly affected by these heavy metals.

It therefore seems that the benthos was affected by organic pollution in Suez Bay and at Ain Sukhna. Generally it seems that the organic load to the sediment had a stimulating effect on the fauna, with elevated abundance and number of species. There were indications of the fauna being occasionally affected by poor oxygen conditions in the sediments in Suez Bay. The decrease in abundance and number of species on the northernmost station (Su١) may be an effect of this. If the organic load increases further there may be a risk of adverse impacts and decreasing abundance and number of species in a larger area due to oxygen depletion.

The benthos in the major part of the Gulf of Suez south of Suez Bay between Suez Bay and Ain Sukhna and south of and Ain Sukhna did not seem to be adversely affected by pollution.

This interpretation of the data is confirmed by the multivariate statistical analysis (Factoranalysis). 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 station can be explained as follows:

- ٢١,٤٪ of the variation in the composition of benthos on the different stations may be related to effects of eutrophication (nutrients, phytoplankton biomass)

- ٢٢,٤ % of the variation may be a result of differences in the composition of sediment (which to a certain extent also may be influenced by eutrophication)
- ٨,٨٪ of the variation may be related to transparency
- ٢٨,٥ % of the systematic variation cannot be attributed to any of the measured environmental parameters and
- ١٨,٩ % is random variation

The analysis also indicated that:

- The fauna on the stations in Suez Bay (Su١,Su٢ and Su٣) and station Su٥ at Ain Sukhna was affected by eutrophication
- The fauna on the stations at Ras Budhran (Su١٢) and El Tur (Su ١٣ and Su١٣a) was influenced by fine grained sediment
- The fauna on the other stations in the Gulf of Suez was not affected by eutrophication or influenced by fine grained sediment.

Conclusion

The sediment and benthos monitoring in ١٩٩٩ generally showed the same trends as those observed for the water quality parameters. There were no or only slight indications of pollution of sediments or impacts on benthos due to pollution in the major part of the Gulf of Suez. However, there were clear indications that organic matter and nutrients (eutrophication) heavily influenced the sediments and benthos in the northernmost part of the Gulf of Suez. The organic matter and nutrients are discharged from domestic and industrial wastewater from the city of Suez and perhaps also from the many ships awaiting passage through the Suez Canal. The sediment and benthos was also affected by eutrophication at Ain Sukna.

The monitoring of contaminants in the sediment showed that:

- The sediment at Su١ close to the city of Suez was heavily affected by eutrophication with high levels of total phosphorous, total N and organic matter in the sediment. Markedly elevated concentrations of copper, lead and zinc were also found in the sediments. However, the levels of these metals only pose a slight risk that adverse biological effects may occur. The benthos was clearly affected by high organic load and perhaps occasional oxygen depletion.
- The sediments at Su٢ and Su٣ in Suez Bay further away from Suez City were also polluted, but to a much lesser extent compared to Su١. High concentrations of organic matter, Tot N and Tot P were encountered, the high eutrophication level clearly affecting the benthos. The high organic load had a stimulating effect on the fauna with elevated abundance and number of species. Significantly elevated levels of lead was also found. However, the concentration level only poses a slight risk that toxic effects may occur.
- Toxic concentrations of Cd, Cu, Pb and Zn were not found on any of the remaining sites in the Gulf of Suez. Not even on the stretch from Abu Zenima to El Tur along the East Coast, where elevated concentrations of Cd were found.
- Somewhat elevated levels of organic matter were encountered on the stations from Suez Bay to Ain Sukhna (SU٣a-SU٥) but not to an extent that may cause alarm in any way.
- There were no signs of contamination of the sediments on the stations at the coastal stretches from Wadi El Dom to Ras Shukeir (Su٦-Su٩b) along the West Coast
- The stations from Abu Zenima to El Tur (Su١٠-Su١٣a) along the Sinai coast had elevated concentrations of Tot P

The Benthos monitoring clearly showed that:

- The fauna on the stations in Suez Bay (Su١, Su٢ and Su٣) and station Su٥ at Ain Sukhna was affected by eutrophication.
- The fauna on the stations at Ras Budhran (Su١٢) and El Tur (Su ١٣ and Su١٣a) was influenced by fine grained sediment
- The fauna on the other stations in the Gulf of Suez was not affected by eutrophication or influenced by fine grained sediment.

References

١) EIMP (١٩٩٩). Annual Report of Environmental Data from Coastal Areas of the Gulf of Suez, Red Sea proper and Gulf of Aqaba in ١٩٩٩.

٢) CCME. Canadian Council of Ministers of the Environment (١٩٩٩). Canadian sediment quality guidelines for the protection of aquatic life. Summary Tables. In: Canadian environmental quality guidelines, ١٩٩٩, Canadian Council of Ministers of the Environment, Winnipeg.

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 community structure and the influence of environmental parameters on the composition of benthos (including impacts of pollution).

٢. METHODS

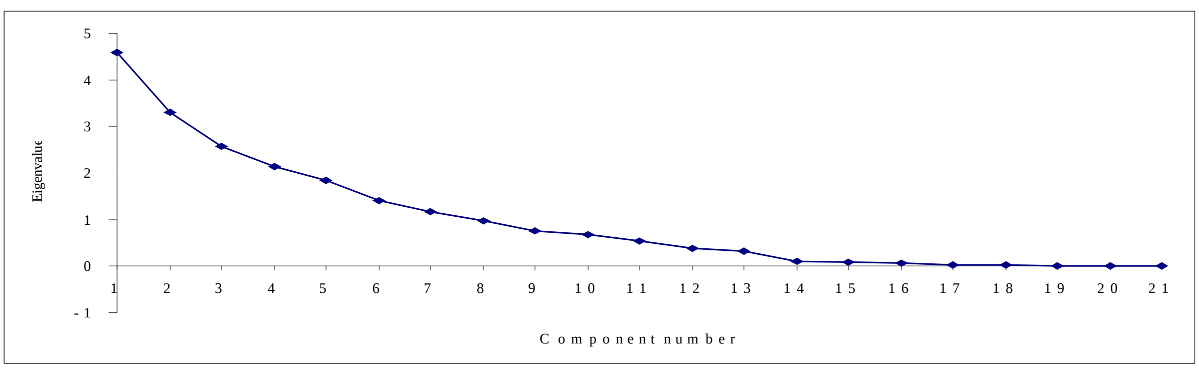
The data were analysed by Factor analysis using Principal Component Analysis (PCA) for initial factoring procedure (Ref.١). Input data was the abundance of each species per m^2. The factor loadings were rotated using the varimax orthogonal rotation. The rotated factor scores were used for the interpretation 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 mean and annual minimum ١٩٩٩
- Concentration of Chlorophyll-a, total suspended matter and transparency (m) in water. 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

Seven factors accounting for ٨١,١ % of the total variation in the data were 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 ١٨,٩ % 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):

- ٢١,٤٪ of the variation in the composition of benthos on the different stations may be related to effects of eutrophication (Factor ٢ and Factor ٧).
- ٢٢,٤ % of the variation may be a result of differences in the composition of sediment (which to a certain extent also may be influenced by eutrophication) (Factor ٣ and Factor ٤)
- ٨,٨٪ of the variation may be related to transparency (Factor ٥)
- ٢٨,٥ % of the systematic variation cannot be attributed to any of the measured environmental parameters (Factor ١ and Factor ٦) and
- ١٨,٩ % 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	*Caullariella alatus*	٠,٩٤٣٠
	Notomastus sp	٠,٨٧٤٠
	Tapes sulcarius	٠,٨٢٢٠
	Brachiostoma lanceolatum	٠,٧٩٣٠
	Prionospio cirrifera	٠,٦٨٠٠
	Chone filicauda	٠,٦٤٤٠
٢	*Capitellidae sp.*	٠,٨٩٥٠
	Onuphis eremita	٠,٧٨٨٠
	Apseudes latreillei	٠,٧١٠٠
٣	*Scoloplos arimiger*	٠,٩٧٧٠
	Chaetozone cf. Setosa	٠,٩١٧٠
٤	*Ocypode sp.*	٠,٩٦٦٠
	Tellinella staurella	٠,٦٨٧٠
٥	*Lumbrinereis latreilli*	٠,٨٤٤٠
	Prionospio cirrifera	٠,٦٤٠٠
٦	*Stenothoe gallensis*	٠,٩٨٤٠
٧	*Bowerbanbkis imbricata*	٠,٩٦٢٠

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

		Factor ١	Factor ٢	Factor ٣	Factor ٤	Factor ٥	Factor ٦	Factor ٧
% silt+clay in sediment	r	-٠،١٥٩	٠،١٥	,٦٠٩(**)	,٥٠٨(*)	٠،٠٠٩	-٠،٠٣٩	٠،١٣٧
	p	٠،٤٨١	٠،٥٠٦	٠،٠٠٣	٠،٠١٦	٠،٩٦٩	٠،٨٦٣	٠،٥٤٤
% sand in sediment	r	٠،١٥٩	-٠،١٥	-,٦٠٩(**)	-,٥٠٨(*)	-٠،٠٠٩	٠،٠٣٩	-٠،١٣٧
	p	٠،٤٨١	٠،٥٠٦	٠،٠٠٣	٠،٠١٦	٠،٩٦٩	٠،٨٦٣	٠،٥٤٤
Mean size Phi. sediment	r	-٠،١٨١	٠،١١٩	,٤٩١(*)	,٤٦٠(*)	-٠،٠٠٣	٠،٠٦	٠،٢٣٧
	p	٠،٤٢	٠،٥٩٩	٠،٠٢	٠،٠٣١	٠،٩٩١	٠،٧٨٩	٠،٢٨٨
Loss on ignition of sediment	r	٠،١٥٢	,٤٨٣(*)	-٠،١٩	٠،٠٣٦	-٠،٠٦	-٠،٠١	,٥١٣(*)
	p	٠،٤٩٨	٠،٠٢٣	٠،٣٩٦	٠،٨٧٣	٠،٧٩٢	٠،٩٦٥	٠،٠١٥
Total P(mg/g) in sediment	r	-٠،١٢٤	٠،١٦٤	,٥٥٤(**)	,٤٩٦(*)	-٠،١٠٢	-٠،٠٠٩	٠،٢٦٦
	p	٠،٥٨٣	٠،٤٦٧	٠،٠٠٨	٠،٠١٩	٠،٦٥١	٠،٩٦٩	٠،٢٣٢
Total N (mg/g) in sediment	r	-٠،٠٨٦	٠،٣١٣	-٠،٠٣١	٠،٢	-٠،٢٠٦	-٠،٠٠٧	,٨٢٦(**)
	p	٠،٧٠٤	٠،١٥٦	٠،٨٩١	٠،٣٧٢	٠،٣٥٨	٠،٩٧٤	٠
Cu (ug/g) in sediment	r	-٠،٠٢٥	٠،٣٢٢	-٠،٠٠٧	٠،١٤٤	-٠،٢٢٨	-٠،٠٩٥	,٨٥٠(**)
	p	٠،٩١١	٠،١٤٤	٠،٩٧٤	٠،٥٢٣	٠،٣٠٨	٠،٦٧٥	٠
Zn (ug/g) in sediment	r	-٠،٠٥٩	٠،٣٢٤	٠،١٤٩	٠،٢٤٦	-٠،٢١٣	-٠،١٠٦	,٧٨٣(**)
	p	٠،٧٩٣	٠،١٤١	٠،٥٠٧	٠،٢٦٩	٠،٣٤١	٠،٦٣٩	٠
Cd (ng/g) in sediment	r	٠،٠٩٩	٠،٣٠٧	٠،٣٩٨	٠،٢٦٨	٠،١٦١	-٠،١٤٤	٠،١٠٩
	p	٠،٦٦٢	٠،١٦٥	٠،٠٦٦	٠،٢٢٧	٠،٤٧٥	٠،٥٢٣	٠،٦٢٩
Pb (ug/g) in sediment	r	-٠،٠٨٥	,٤٩٨(*)	-٠،٠٩٦	-٠،٠٢٢	-٠،٢٦٧	-٠،٠٦٤	,٧٥٩(**)
	p	٠،٧٠٦	٠،٠١٨	٠،٦٧٢	٠،٩٢٢	٠،٢٢٩	٠،٧٧٧	٠
Salinity of water	r	٠،٣٠٢	٠،٣٨٥	-,٤٥٧(*)	-٠،٢٧٩	٠،١٨٥	-٠،٠٦٤	٠،١٧٨
mean ١٩٩٩	p	٠،١٧٢	٠،٠٧٧	٠،٠٣٣	٠،٢٠٨	٠،٤١	٠،٧٧٦	٠،٤٢٨
Dissolved oxygen in water	r	٠،١٣٤	-٠،١١٤	-٠،٢٥	-٠،١٣١	-٠،١٤٧	٠،١٨١	-٠،٣٩٥
mean ١٩٩٩ (mg/l)	p	٠،٥٥١	٠،٦١٤	٠،٢٦٢	٠،٥٦	٠،٥١٣	٠،٤٢	٠،٠٦٩
Dissolved oxygen in water	r	-٠،٠٣٤	-٠،٤١٩	٠،٠٨١	-٠،٠١٨	٠،١٠٢	٠،١٦١	-,٥٧٠(**)
min ١٩٩٩ (mg/l)	p	٠،٨٧٩	٠،٠٥٢	٠،٧١٩	٠،٩٣٦	٠،٦٥١	٠،٤٧٥	٠،٠٠٦
Chlorophyll-a (ug/l) in water	r	-٠،٠٤٣	,٨٦٤(**)	-٠،١٤٦	-٠،٠٤٣	-٠،٠٢٥	-٠،١٦٥	٠،١٣٧
mean ١٩٩٩	p	٠،٨٤٩	٠	٠،٥١٧	٠،٨٤٩	٠،٩١١	٠،٤٦٣	٠،٥٤٣
Total suspended matter in water	r	-٠،٠٠١	,٨٣٦(**)	-٠،٠٥	٠،٠٥٤	-٠،٠٤	-٠،١٩٢	٠،٤١٥
mean ١٩٩ (mg/l)	p	٠،٩٩٨	٠	٠،٨٢٦	٠،٨١٣	٠،٨٥٩	٠،٣٩١	٠،٠٥٥
Transparency of water	r	٠،٤٠٧	-,٦٤٤(**)	٠،١٦٥	٠،٠٥٩	,٤٩٢(*)	٠،٠١٢	-٠،١٤٨
Mean ١٩٩٩ (m)	p	٠،٠٦	٠،٠٠١	٠،٤٦٣	٠،٧٩٦	٠،٠٢	٠،٩٥٩	٠،٥١١
$NH_{٤}$-N in water	r	-٠،٠٤٦	,٧٤٨(**)	-٠،٠٣٢	٠،٠٤٥	-٠،٠١٨	-٠،١٢٦	٠،٢٩٧
Mean ١٩٩٩ (uM)	p	٠،٨٣٨	٠	٠،٨٨٧	٠،٨٤٢	٠،٩٣٨	٠،٥٧٨	٠،١٧٩
$NO_{٢}$-N in water	r	-٠،٠٤٧	,٨٤٣(**)	-٠،١٢٣	-٠،٠٠٩	-٠،٠٤١	-٠،١١	٠،٢٤٦
Mean ١٩٩٩ (uM)	p	٠،٨٣٦	٠	٠،٥٨٦	٠،٩٦٩	٠،٨٥٦	٠،٦٢٧	٠،٢٧
N٠$_{٣}$-N in water	r	-٠،٠٣٧	,٨٦١(**)	-٠،١٢٩	-٠،٠١١	-٠،٠٣١	-٠،١١١	٠،٢٠٩
Mean ١٩٩٩ (uM)	p	٠،٨٧٢	٠	٠،٥٦٧	٠،٩٦	٠،٨٩	٠،٦٢٣	٠،٣٤٩
Tot. N in water	r	٠،١٣٤	,٦٨٥(**)	-٠،١٩٢	-٠،٠٦٣	٠،١٠٩	-٠،٠٩٥	,٤٢٥(*)
Mean ١٩٩٩ (uM)	p	٠،٥٥١	٠	٠،٣٩٣	٠،٧٨١	٠،٦٢٨	٠،٦٧٣	٠،٠٤٩
$PO_{٤}$-P in water	r	٠،١٣٤	-٠،٢٠٧	-٠،٠٣٢	-٠،٠٨٣	٠،٢١١	-٠،١٤٩	-٠،١١٤
Mean ١٩٩٩ (uM)	p	٠،٥٧٣	٠،٣٨	٠،٨٩٥	٠،٧٢٨	٠،٣٧٢	٠،٥٣	٠،٦٣٢

**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	٢١,٨ %	• Positively correlated with the abundance of *Caullariella alatus,Notomastus sp., Tapes sulcarius, Brachiostoma lanceolatum, Prionospio cirrifera, Chone fillicauda.*	Factor ١ represents variation in these species, a variation which cannot be attributed to measured environmental parameters
٢	١٥,٨ %	• Positively correlated with the abundance of *Capitellidae sp. Onuphis eremita* and *Apseudes latrieilliei* • Positively correlated with organic matter in sediment (loss on ignition) • Positively correlated with Pb in sediment • Positively correlated with concentrations of chlorophyll-a, suspended matter and nutrients in water • Negatively correlated with the transparency of the water	Factor ٢ can be interpreted as a gradient of increasing eutrophication, which is affecting the fauna. The most eutrophicated sites also have the highest concentrations of lead in the sediments.
٣	١٢,٢ %	• Positively correlated with the abundance of *Scoloplos armiger* and *Chatetozone cf. Setosa* • Positively correlated with the silt/clay content of the sediment • Positively correlated with the concentration of total P in the sediment • Negatively correlated with the content of sand in the sediment • Negatively correlated with the salinity	Factor ٣ can be interpreted as a gradient of increasing content of silt/clay in the sediment and decreasing salinity.
٤	١٠,٢ %	• Positively correlated with the abundance of *Ocypoda sp* and *Tellina staurella* • Positively correlated with the content of silt/clay in the sediment, the loss on ignition and the total P • Negatively correlated with the content of sand	Factor ٤ can be interpreted as a gradient of increasing content of silt/clay and organic matter in the sediment, possibly also influenced by eutrophication.
٥	٨,٨ %	• Positively correlated with the abundance of *Lumbrinereis latreilli* and *Prionospio cirrifera* • Positively correlated with transparency of water	Factor ٥ can be interpreted as a variation of these species with highest abundance in clear water.
٦	٦,٧ %	• Positively correlated with the abundance of *Stenothoe gallensis*	Factor ٦ represents variation in this species, a variation which cannot be attributed to measured environmental parameters
٧	٥,٦ %	• Positively correlated with the abundance of *Bowerbanbkia imbricata.* • Positively correlated with loss on ignition of sediment • Positively correlated with total N, Cu, Zn and Pb in sediment • Negatively correlated with the minimum concentration of dissolved oxygen on the water	Factor ٧ may be interpreted as a gradient of increasing eutrophication, which is affecting the fauna. The most eutrophicated sites also have the highest concentrations of copper, zinc and lead in the sediments.

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 Su١, Su٢, Su٣ and Su٥ differ from the benthos on the other stations, due to higher level of eutrophication (higher content of organic matter in sediment and higher concentrations of chlorophyll-a, suspended matter and nutrients in water
- The benthos on Su١٣a, Su١٢ and Su١٣ differ from the benthos on the other stations due to finer grained sediments

Table ٤. Factor scores.

Station	Factor ١	Factor ٢	Factor ٣	Factor ٤	Factor ٥	Factor ٦	Factor ٧
Su ١	-٠،٠٥	٠،٤٩	-٠،٢٣	٠،٣٣	-١،٢١	-٠،٢٤	٤،٠٤
Su ٢	-٠،٢٢	٢،١٣	-٠،٢١	-٠،٢٥	٠،٥٧	-٠،١٤	-٠،٢٣
Su ٣	٠،٠٥	٣،١٥	-٠،٤٦	٠،٠٦	-٠،١٨	-٠،٤٦	-٠،٣١
Su ٣a	٤،٢٢	-٠،٣٠	-٠،٣٤	٠،٠٥	٠،٧٧	-٠،٢٧	٠،٠٤
Su ٤	-٠،٧٧	-٠،٩٠	-٠،١٤	-٠،٨٠	٣،٧٢	٠،٠١	١،٣٤
Su ٥	-٠،٥٦	١،٢٥	-٠،١٦	-٠،٦٠	٠،٩٩	-٠،٠٥	-١،٠١
Su ٦	-٠،٣٩	-٠،٤٧	-٠،٤٣	-٠،٣٩	-٠،٦٣	-٠،٥٠	-٠،٢٩
Su ٦a	٠،٠٥	-٠،٥٣	-٠،٤١	-٠،٣١	-٠،٨٢	-٠،٤٩	-٠،٢٤
Su ٧	-٠،٥١	-٠،٤٩	-٠،٥٤	-٠،٢٨	-٠،١١	-٠،٦٤	-٠،١٣
Su ٨	-٠،٣٨	-٠،٨٧	-٠،٣٢	-٠،٢٣	-٠،٠٩	-٠،٣٦	-٠،٨١
Su ٨a	-٠،١٥	-٠،٠٦	-٠،٣٥	-٠،٤٣	-٠،١٧	٣،٨٤	-٠،١٠
Su ٨b	-٠،٣٣	-٠،٢٣	-٠،٠٩	-٠،٤١	٠،٠٥	-٠،١٩	-٠،١٠
Su ٩	-٠،٣٦	-٠،٣٥	-٠،٢٥	-٠،٤٠	-٠،٢٧	-٠،٣٤	-٠،١٩
Su ٩a	-٠،٣٤	-٠،٢٨	-٠،١٦	-٠،٤١	-٠،٠٩	-٠،٢٦	-٠،١٤
Su ٩b	٠،١٤	-٠،٢٢	-٠،٢٠	-٠،٣٢	-٠،٣٣	-٠،٣٢	-٠،١٠
Su ١٠	٠،٤٤	-٠،٨٢	-٠،٣٨	-٠،٠٨	-٠،٤٥	-٠،٤٦	-٠،٧٧
Su ١١	-٠،٢٦	-٠،٢٤	-٠،٤٤	-٠،١٠	-٠،٧٤	-٠،٥٧	-٠،٢٦
Su ١٢	٠،٧٠	٠،٤٣	١،١٩	-٠،٠٣	-٠،٤٠	١،٢٢	-٠،١٤
Su ١٢a	-٠،٤٦	-٠،٨٧	-٠،٣٢	-٠،٤٨	-٠،٨٧	-٠،٣١	-٠،٠٤
Su ١٢b	-٠،٢٩	-٠،٥٦	-٠،٤٣	١،٨٤	-٠،٣١	١،٤٠	-٠،١٦
Su ١٣	-٠،٠٩	-٠،١٤	٤،١٥	-٠،٥٩	-٠،٢٥	-٠،٢٩	-٠،٠١
Su ١٣a	-٠،٤٥	-٠،١٢	٠،٥١	٣،٨٣	٠،٨١	-٠،٦٠	-٠،٣٦

٣,٤ Conclusion

From the analysis it can be concluded that:

- the fauna on the stations in Suez Bay (Su١,Su٢ and Su٣) and station Su٥ at Ain Sukhna are affected by eutrophication
- the fauna on the stations at Ras Budhran (Su١٢) and El Tur (Su ١٣ and Su١٣a) are influenced by fine grained sediment
- the fauna on the other stations in the Gulf of Suez are not affected by eutrophication or influenced by fine grained sediment.

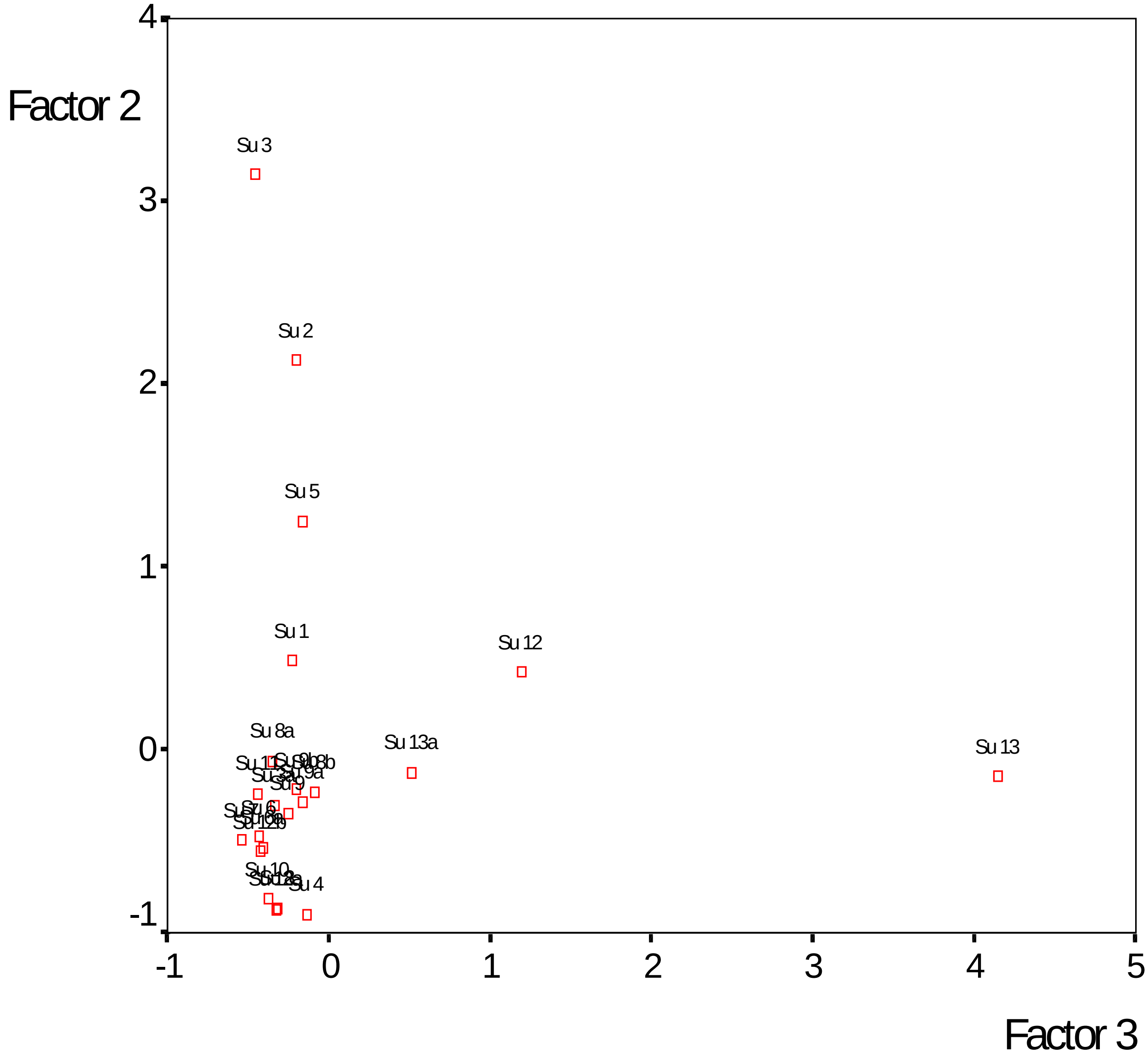


Figure ٢ . Factor plots ١٩٩٩ data Factor analysis based on abundance of different species of benthos. The factor scores for each station are plotted on factor axes ٢ and ٣. Stations with a high score on factor ٢ are characterised by higher levels of eutrophication and stations with a high score on factor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

٣,٥. References

١) Morrison D.F (١٩٦٧). Multivariate statistical Methods. Mc Graw-Hill. International Book Company.