Rev.Int. Océanogr. Méd.
Tomes LXXXXI-LXXXXII- 1988

EFFECTS OF SEWERAGE ON THE DISTRIBUTION OF BENTHIC FAUNA IN GOLDEN HORN

by

M. UNSAL *

RESUME

Les effets de la pollution sur la distribution de la faune benthique, particulièrement, sur les annélides polychètes, ont été étudiés de Décembre 1985 à Septembre 1986 dans Corne d'Or, qui est un estuaire au milieu d'Istanbul.

Les gradients de pollution ont été basés sur les diminutions de nombre des espèces et les augmentations de nombre des individues par espèce, ainsi que sur les facteurs physico-chimiques.

Trois espèces indicatrices (*Capitella capitata*, *Scololepis fuliginosa*, *Polydora ciliata*) ont été dominantes dans toutes les stations de prélèvement en constituant 89 % en abondance et 86 % en biomasse de toutes les espèces recueillies.

A l'exception d'une seule station à l'entrée de l'estuaire où quelques mollusques, echinodermes et crustacés ont été trouvés, les autres stations sont peuplées presque entièrement par les annélides polychètes.

La similarité faunistique des polychetes dépassait 90 % dans les stations peu profondes, 60 % environ dans celles plus profondes et basse (22 %) entre les stations profondes et peu profondes.

ABSTRACT

Pollution effects on benthic fauna distribution, especially on polychaetous annelids were studied between December 1985 and September 1986 in Golden Horn, estuary in the center of Istanbul.

Pollution gradients were based on decreases in the number of species and increases in the number of individuals per species. Three indicator species (*Capitella capitata*, *Scololepis fuliginosa*, *Polydora ciliata*) were dominant at all sampling stations constituting 89 % in abundance and 86 % in biomass of all species collected. Except a single station situated at the mouth of the estuary, where few molluscs, echeniderms and crustaceans were collected, the other stations were populated almost exclusively by polychaetous annelids.

Faunal similarity of polychaetes was higher than 90 % at shallow stations, about 60 % at deeper ones, and low (22 %) between shallow and deep stations.

---

* Institute of Marine Sciences, Middle East Technical University, P.K. 28 Erdemli-Icel/Turkey

INTRODUCTION

Benthic communities have been widely used in pollution monitoring programs for the reasons (1) most are sessile or move over short distances. (2) they are relatively long lived, easy to collect quantitatively, restricted to a very limited vertical disribution in or just below sediment surface, and they can be identified to species after unlimited preservation (Leppakoski,1975) and (3) they reflect the degree of pollution by showing spatial and temporal variations in distribution (Pearson and Rossenberg, 1978; Rossenberg and Moller 1979; Gray and Mirza 1979; Pearson et al., 1982; Wardwick, 1986) and by accumulating of pollutants in tissues above levels in the surrounding environment (Phillips, 1976; Unsal, 1978, 1983, 1984). Thus, changes in the community structure of benthic animals are indicators of environmental changes in their areas and analyses of the benthos can be used to assess the degree of pollution in an area (Rossenberg, 1976 a).

Although some studies have been performed on the sources of pollution in Golden Horn (Yuce, 1972; Baykut, 1977; Samsunlu, 1977), only one study deals with benthic species (Artuz and Korkmaz, 1975)and gave no data available on the distribution of benthic organisms and their relation to pollution in this estuary. This study documents the seasonal distribution of macrofauna, mainly polychaetous annelids, since they constituted, with the exception of nematodes and oligochaetes, almost 100 % by number and biomass of all organisms found during the sampling period in relation to the degree of pollution in Golden Horn

The main objective of this study is to determine the seasonal variations in numbers of species, individuals and in biomass of Polychaetous Annelids and to evaluate the degree of pollution in this estuary.

STUDY AREA

Golden Horn is an estuary situated in the center of Istanbul City (Fig.1) which is the most industrialized and so most populated (about 6.000.000) center of Turkey. This estuary receives significant amount of untreated sewage and industrial inputs from sewer systems and factories established 41°.01'- 41°.04' N on its either side. It lies between and 28°.56'- 28°.59' E and has a length of approximately 7.5 km, a maximum depth of 42m at the mouth and a sill depth of less than 2 m at the inner part.

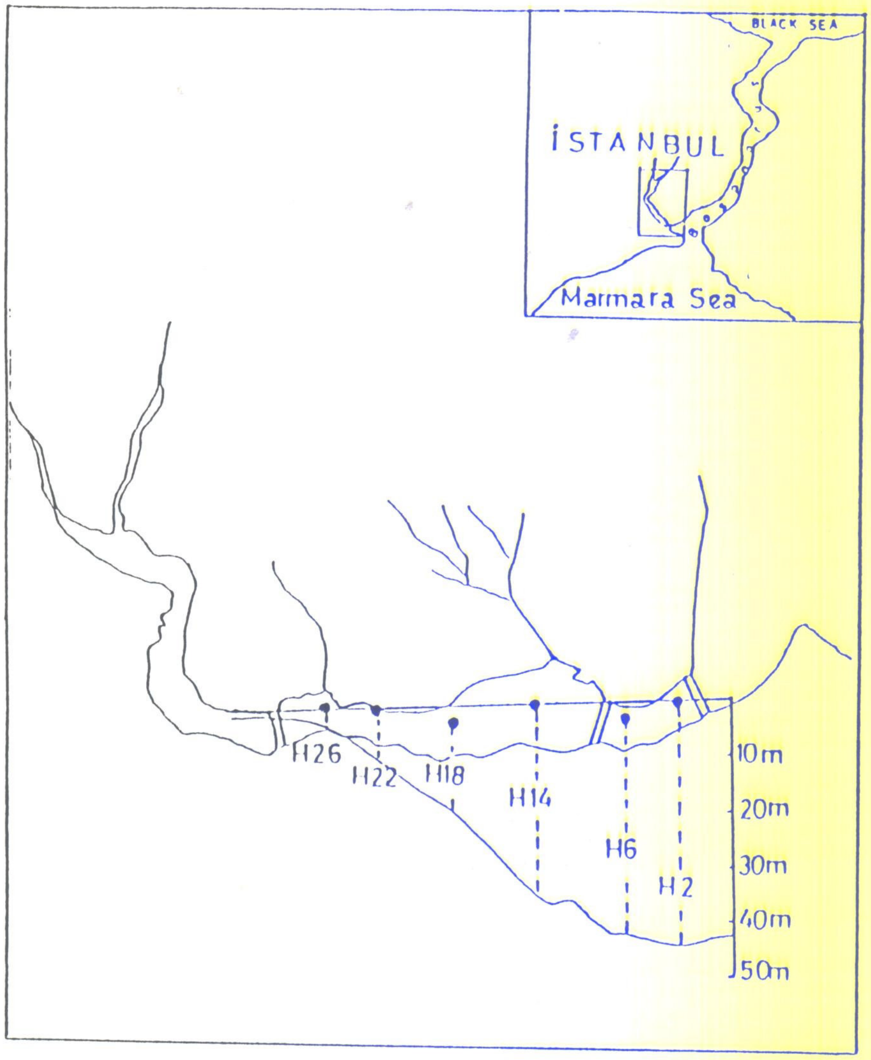

Fig. 1. Sampling stations and bottom topography in Golden Horn.

Hydrographical factors, such as salinity, temperature, dissolved oxygen, currents etc. have recently been studied by the Institute of Marine Sciences of Middle East Technical University (METU, 1986). These studies showed that, the environmental conditions vary in short intervals, monthly or weekly, in the estuary. It receives water inputs from different sources: the bottom layer is occupied up to the middle part by Marmara Sea waters which are of Mediterranean origin and the upper layer by Black Sea waters. In deep sections, the Black Sea waters occupy the upper 20-25m of the water column and extends towards the end of the estuary. The salinity varies between 15-20‰ in the upper layer, while it is between 37-38.5‰ at the lower layer. Thus, these two water masses are separated by an interface (halocline), which varies in its position and sharpness between 15-30m according to the season: at 25-30m in March and 15m in August (METU, 1986).

The dissolved oxygen content of the bottom waters changes also according to their sources: the waters coming from Marmara Sea have relatively low oxygen content while those originating from Black Sea contain much higher dissolved oxygen.

The conditions are different in the innermost part of Golden Horn. Since, the currents do not reach this section to renew the waters and therefore, anoxic conditions prevail in this part of the estuary. However, there is no complete depletion in dissolved oxygen concentrations at the water-sediment interface although the sediments consist mainly of black mud and have a foul smell during the sampling.

The bottom topography shows also variations from the entrance to the end. The depth is about 40 m as far as the middle part, then rises steeply and becomes shallower than 2m towards the inner parts of the estuary (Fig.1).

MATERIALS AND METHODS

Sediment samples were collected on bimonthly basis from December 1985 to September 1986. Three replicate hauls were taken at each of 6 preselected stations (Fig.1) by means of a Van Veen grab having a sample area of 285 cm^2. Thus, a total of 90 samples covering an area of 25.650 cm^2 (>2.5 m^2) have been taken over 5 sampling times.

A medium-size vessel (10m in length), equipped with a manually functioning winch, was used for sample collection. Samples were then transferred immediately to the mother ship (42m in length) and sieved on board through 0.5, 1 and 2 mm mesh-size sieves. Only one additional sample was taken at each station for particule size analyses. The sieved residues were fixed with 2% formalin in sea water buffered with $NaHCO_3$ (pH = 8) and returned to the laboratory for subsequent examination. In the laboratory, the samples were stained with 1% Sudan Black B according to the procedure described by Walker et al., (1974), to facilitate the sorting of organisms under binocular microscope. After sorting, the animals were stored in 70% alcohol and then identified to species, if possible, and counted. Fragments of polychaetes were identified to family. Biomass (wet weight) of the preserved animals were determined by blot drying each species on paper towels for about three minutes before weighing.

The salinity, temperature and dissolved oxygen values were obtained from the water closest (0.5-1m) to the bottom.

Species diversity index, determined with the Shannon-Wiener function (Leppakoski, 1975; Rosenberg and Moller 1979), was calculated as:

$$H' = -\sum_{i=1}^{s} P_i \log_2 P_i$$

and its evenness as:

$$J = H'/H_{max} \quad (H_{max} = \log_2 s$$

where P_i is the proportion of the abundance of species i ($P_i = n_i/N$) = species abaundance/total abundance and s is the number of species.

Sanders' (1968) rarefaction technique was also applied as an alternative to species diversity index.

Faunal similarity index (affinity index) at all pairs of stations was calculated according to the method described by Sanders (1960) to assess the differences in community structure and the degree of differences among sampling stations.

Particule size of sediments was analysed by the pipette method described by Folk (1974).

RESULTS

Population changes at each station

The total number of species found during the sampling period, and the mean species number (S), abundance (A) and biomass (B) of animals found over 5 sampling time, at each of 6 preselected station are shown in Table 1.

There are fluctuations in the population at each station Thus, the total number of species was highest at the entrance station (St.H2) but it started to decrease towards the inner part and reached its lowest level at the last station (St.H26). Station H14, located in the middle of the studied area, was most affected with lowest abundance and biomass (Tab.2). Although the number of species at St.H2 was 10 times that of at St.H26, the mean number of individuals per species was 4 times and the biomass was also quite high at this last station. These high values of abundance in St.H26 resulted from extreme rise of the abundance of *Capitella capitata* (64,000 ind/m²) in May.

Fig.2 shows the species-area curve which is a function of increasing number of species to increasing number of samples examined. As can be seen from this figure, 90% of species at St.H2 and about 100% at other three stations were found after 0.25m² had been sampled. Thus, with the exception of St.H2, the repeated sampling did not contribute to the increased number of species at other stations. This is because the community is composed of a very limited number of particularly pollution resistant species. Therefore, the curves obtained for stations H6, H14 and H26 have a more or less steep slope for first samples and followed by an rectangular transition into a line parallel to the x-axis for further samples which is characteristic for heavily polluted communities.

Three most abundant species at each station are listed in Table 3, together with the mean number of species per m² and their dominancy in percent of the total number of individuals over the sampling period.

As can be seen from Table 2, *Capitalla capitata* and *Scolelepis fuliginosa* occurred at all sampling stations and they constituted at stations H14-H26 more than 99% in number of all the fauna obtained during the sampling period. The number of *C.capitata* was very low at St.H2 but increased towards the inner part of the estuary. However *Polydora ciliata* was most abundant at stations H2 and H6, but it

Table 1. Population changes over five sampling time at six sampling stations

Station	Depth (m)	Total number of species found during sampling period	Mean number of species found in each sampling time (S)	Mean abundance per sampling time (A)	Mean wet weight biomass per sampling time B(g/m²)	Mean number of individuals per species (A/S)	Mean weight per individuals (B/A)(mg)
M2	43	20	8.2	21692	73.1	2645	3.4
M6	41	5	3.4	4952	21.0	1456	4.5
M14	35	3	1.2	3101	9.0	2584	0.3
M18	20	3	1.9	12752	26.1	7084	2.0
M22	10	3	1.4	3803	46.7	2716	12.3
M26	4	2	1.2	12855	100.4	10713	7.8

Table 2. Dominant species at each sampling station: mean number per m² and dominancy in percent

	Stations											
	M2		M6		M14		M18		M22		M26	
Species	N	%	N	%	N	%	N	%	N	%	N	%
C.capitata	20	0.09	1078	21.7	3056	98.6	11782	92.4	3371	88.6	11791	91.7
S.fuliginosa	3324	5.3	1652	33.3	41	1.3	956	7.5	414	10.9	1064	8.3
P.ciliata	11873	54.7	2188	44.1	4	0.1	0	0	19	0.5	0	0
E.gemmifera	2949	13.6	0	0	0	0	14	0.1	0	0	0	0
Percent of total		83.77		99.1		100		100		100		100

decreased, towards the inner part. Another dominant polychaete species was *Exagon gemmifera* at St.H2. It appeared also in small numbers at St.H18 but was totally absent at other stations. So, with the exception of stations H2 and H6, the other stations were populated by the same dominant species, that is *C.capitata* and *S.fuliginosa*. The dominancy of *C.capitata* and *S.fuliginosa* increased from St.H2 to St.H26 while that of *P.ciliata* decreased. After St.H6 an inverse relationship was observed between *C.capitata* and *S.fuliginosa*: the percentage of one species decreased when that of the other increased (Fig.3).

Diversity

The diversity of the benthic communities calculated by Shannon-Wiener function and its evenness are shown in Fig.4. The diversity H' was highest (2.02) at St.H2, relatively high (1.58) at St.H6, but lowest (0.11) at St.H14. After this station it was also moderately high in the inner part of the estuary. Evenness J showed about the same trend as diversity at all stations. The results of Sanders' rarefaction technique applied to three station (Fig.5) were in agreement with those obtained by diversity index: high diversity resulted from high number of species at St.H2 and low diversity from low number of species at St.14.

Faunal affinity

The percentage similarity of the polychaete fauna was studied by comparing all pairs of stations according to the method described by Sanders (1960) and the stations were classified by means of a dendogram (Fig.6) established by clustering technique called "pair-group method with arithmetic averages" (Davis, 1973). Two separate group of stations were distinguished: stations H14, H18, H22 and H26 showed a similarity of more than 90% (group A) and stations H2 and H6 a similarity of 60% (group B). The high similarity found among A group stations was due to the permanent occurence of *C.capitata* and *S.fuliginosa* at those stations.

Station H2 had very low similarity (2-12 %) and St.H6 a moderate similarity (23-33 %) with other stations. The similarity between two group of stations (group A and B) was 22 % (Fig.6).

Changes During the Sampling Period

Variations in the species, abundance and biomass (S A B) during the sampling period are illustrated in Fig.7. It can

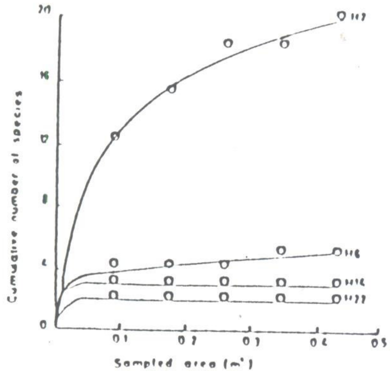

Figure 2

Cumulative number of species and sampling area at four stations based on all samples collected over five sampling time.

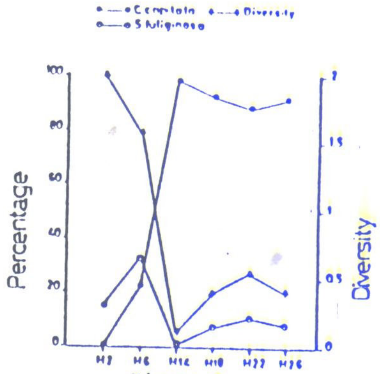

Figure 3

Dominancy in percent and corresponding diversity of *Capitella capitata* and *Scololepis fuliginosa*.

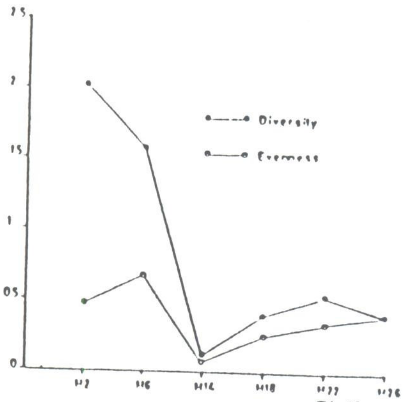

Figure 4

Diversity index and its evenness at six sampling stations.

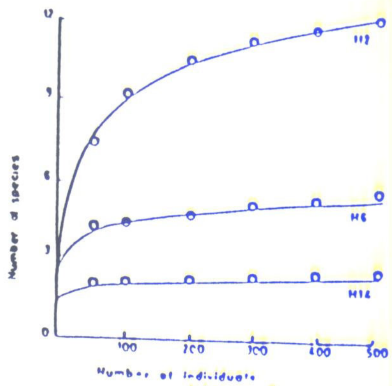

Figure 5

Rarefaction curves obtained for three sampling stations.

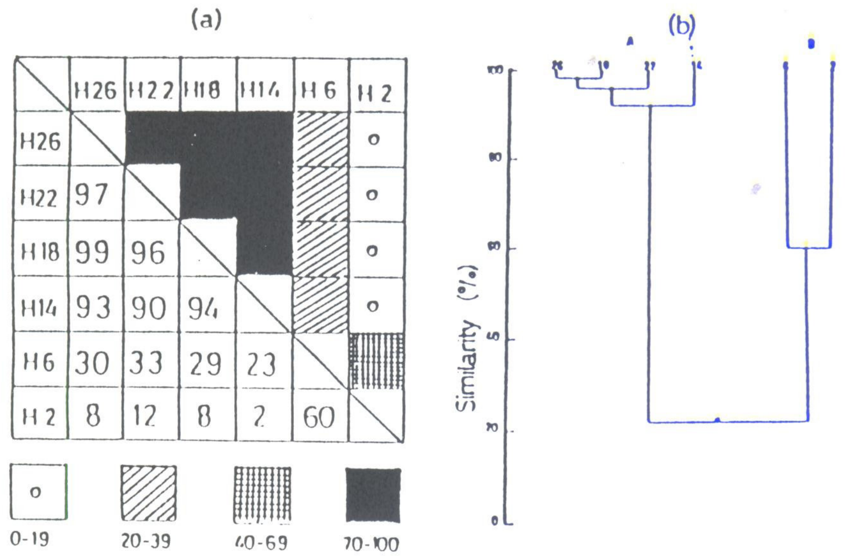

Fig. 6. Percentage similarity of Polychaete fauna illustrated as Trellis Diagram (a) and Dendogram (b) between pairs of stations in Golden Horn.

be seen from this Figure that, with the exception of September, the biomass showed the same pattern as abundance througout the sampling period. They started to increase in March and reached their higest values in May, but then declined suddenly in July. A sharp rise in abundance was also observed in September while the biomass remained low at this time. These changes were reflected in the variations of biomass/abundance (B/A) and abundance/species (A/S) ratios which showed also peaks in May (Fig.8). The only exception was observed in December, where B/A was high, because of relatively high biomass and low abundance in this month.

All these fluctuations were in accordance with those observed in the populations of dominant species that are *C.capitata*, *S.fuliginosa* and *P.ciliata* over the sampling period (Fig.9).

DISCUSSION

The changes in number of species, abundance and biomass (S A B) occurring along transects originated at the effluent discharge points were described by Leppakoski (1975), Pearson and Rosenberg (1978) and Pearson et al.,(1982). These authors observed that after the discharge point, the abundance showed a high peak due to few pollution-tolerant opportunistic species (Peak of opportunists-PO), and the biomass a small peak, but the species encountered were few. The peaks of abundance and biomass were then declined to a minimum level which is described as "ecotone point" by Pearson and Rosenberg (1978) or as "primary minimum" by Leppakoski, (1975) since the benthic community at this point was poor in species abundance and biomass. After this minimum, a secondary maximum was observed in species and biomass values, while abundance remained constant.

In the present study, the abundance was found to be high and species number low at two inner stations (St.H26 and H18). The biomass was also high at St.H26 but decreased towards the middle stations (Fig.10).

The abundance at St.H22 was lower than that found at stations H26 and H18 which were situated at its either side (Fig.1). During the last sampling in September 1986, there was no benthic organisms at stations H26 and H22, because the location of these stations was dredged by Municipality of Istanbul for cleaning purposes. Disturbance of benthic organisms by dredging was reported by Rosenberg (1977 a). The high biomass and abundance observed at St.H26 was due to the very high increase of *C.capitata* (58.856 ind./m^2) in May. So,

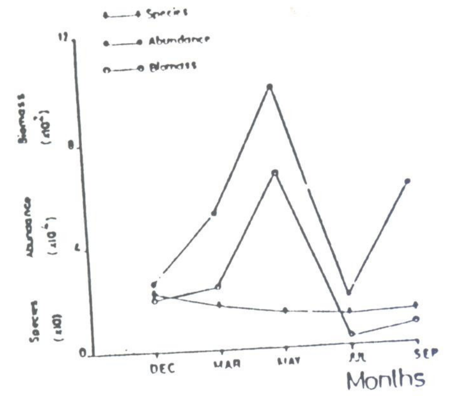

Figure 7

Variation in total number of species (•), in total abundance (•) and total biomass (o), (S A B) during study period.

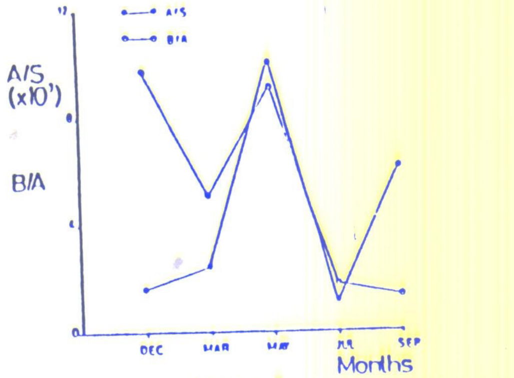

Figure 8

Variation in the ratios of biomass to abundance (B/A) (o) and abundance to species (A/S), (•) over sampling period.

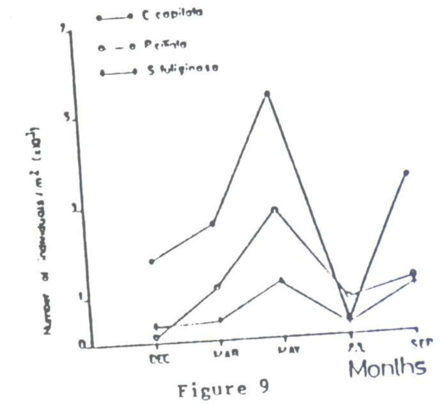

Figure 9

Fluctuations in abundance of *Capitella capitata*, *Polydora ciliata* and *Scolelepis fuliginosa* in different sampling times.

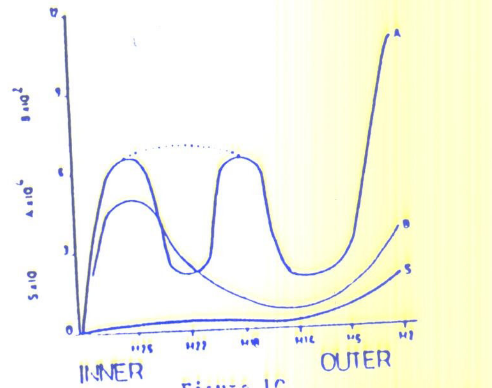

Figure 10

Changes in species (S), abundance (A) and biomass (B), (S A B) curves in relation to pollution from inner to outer part of Golden Horn. (Dotted line is the expected abundance for St.HII).

the abundance value at St.H22 should be at the same level as that found for stations H26 and H18. Assuming that the pollution has mostly originated from the innermost part of the estuary due to considerable inputs. An initial peak or primary maximum for abundance and biomass could cover the statons H26, H22 and H18 which were situated close to pollution sources.

The S A B values were all low at stations H14 and H6. These stations constituted presumably the ecoton point or primary minimum. The S A B values were then increased at the mouth station (H2) which is considered to be less polluted than the other sampling stations. Thus typical S A B curves described by Leppakoski (1975), Pearson and Rosenberg (1978) and by Pearson et al.(1982) along a decreasing gradient of organic pollution were also observed in the present study (Fig.10).

The cumulative number of species was plotted against the sampling area (Fig.2) assuming that the larger the area of samples will yield a larger number of species found.According to Stirn (1981) the curves, like that obtained for St.H2, is a typical "Arrhenius" curve for communities in clean or only slightly polluted environments and those obtained for the other stations (H6-H26) are exclusively significant for heavily polluted communities. Of the species found after five sampling time, 90 % at St.H2 and about 100 % at other stations were obtained from three samples. Thus, it is suggested that three samples should be representative for the stations H6-H26, but some additional samples should be required for St.H2.

Dominant species and their dominancy during study period at all sampling stations are listed in Table 3. It can be seen from this Table that, *C. capitata* was the first and *S. fuliginosa* was the second species in abundance at stations H14-H26 throughout the sampling period. However, at statations H2 and H6, *C.capitata* was replaced by *P.ciliata*. The other dominant species, *S.fuliginosa* was always the second in dominancy. Also, *E.gemmifera* was quite abundant at St.H2. With the exception of *E.gemmifera*, the other species were known to be characteristic for heavily polluted areas (Cognetti, 1972; Ergen, 1976; Pearson and Rosenberg, 1978; Rosenberg and Moller, 1979; Gray, 1981). Certain polluted areas were also characterised by the existance of *C.capitata*-S.fuliginosa or *C.capitata-P.ciliata* communities (Bagge,1969; Rosenberg,1972; Leppakoski,1975). The abundance of *C.capitata* increased from the mouth to the inner part of the estuary, while that of *P.cilaita* decreased. The letter disappeared at St.H14 but reappeared in small numbers at St.H14. However, *S.fuliginosa* showed fluctuations in its total abundance. Gray (1981) pointed out that, *C.capitata* is a classical r-selected species: it can reproduce both by planktonic larvae, has a short life-cycle and reaches maturity from the egg in about 3 weeks. It can, therefore, continuously repopulate sediments subjected to pollution from organic matter. According to the same author, under normal conditions, without pollution stress, r-selected species are gradually outcompeted and replaced by *K*-selected species. Thus, it is very likely that, the number of *K*-selected species decreases from the mouth to inner parts of Golden Horn, while that of r-selected species such as *C.capitata* increases. The density of *S.fuliginosa* was highest at stations H2 and H6. It is probably due to the fact that this species shows also *K*-selected character as well as it is a r-selected species. Although *P.ciliata* was known to be an opportunistic species (Gray,1981) and so a pollution indicator (Bagge, 1969; Cognetti, 1972; Leppakoski, 1975). Its occurrance was restricted at stations H2 and H6 which were situated below interface, where hydrological conditions remain constant and the pollution is less pronounced. Although *C.capitata*, *S.fuliginosa* and *P.ciliata* are known to be r-selected species, the difference in dominancy between *P.ciliata* and other two species at stations H2 and H6 and between *C.capitata* and *S.fuliginosa* at stations H14-H26 suggest the existance of a competition among these species

Diversity index used to characterize benthic communities in Golden Horn has been estimated by Shannon-Wiener function as was applied by several authors (Rosenberg,1973, 1977b, 1977b; Leppakoski, 1975; Pearson and Rosenberg, 1978) to assess the degree of pollution. The same authors have also used Sanders' (1968) rarefaction technique as an alternative method, since Sanders found good agreement between his technique and Shannon-Wiener function. From the results obtained by Shannon-Wiener expression, it was pointed out that the diversity was low if only one or few species are dominant, which is an expected phenomenon for polluted areas (Rosenberg, 1973.) Thus, as the number of species increases, so does the diversity index. But the diversity index will also increase as the propotion of individuals per species becomes more constant (Gray, 1981).

In the present study, the highest diversity (H') value (2.02) was recorded at St.H2 where the number of species was also highest compared with other sampling stations. According to Rosenberg (1973) a high diversity is positively correlated with richness of species.

Diversity decreased towards the inner parts and reached minimum value at St.H14 and then slightly increased at stations H18, H22 and H26 (Fig.3). According to Leppakoski (1975) the benthic diversity decreases with an increasing degree of pollution.

The diversity has strongly been dependent on the dominancy (percentage) of *C.capitata*. In other words, there was a significant negative correlation (r-0.99) between diversity and dominancy of *C. capitata* (Fig. 3). Rosenberg (1973) indicated that the decrease in diversity has been caused by one or two species occurring in huge numbers and the proportion of the two most common species at a station has been negatively correlated with the value of diversity. Pearson and Rosenberg (1978) found also a correlation between diversity, its evenness and abundance of opportunistic species.

As previously mentioned, *C.capitata* was an opportunistic species and a good indicator of areas subjected to organic pollution. This species was found to be dominant at St.H14 and resulted in the lowest diversity at this station, but it occurred in small number at St.H2 where diversity was highest (Fig.3). It was thus suggested that the St.H14 was most affected and St.H2 least. The other stations were also very polluted but not as severly as St.H14. The lowest diversity caused by unfavorable conditions at St.H14 are not only due to the organic waste input, but also due to unstable hydrological conditions, because this station was occupied at certain times of year e.g. in March, by Black Sea waters having low salinity and low temperature but at most of time by Marmara Sea waters with high salinity and high temperature. Rosenberg (1976 a) found that variations in an environment, e.g. through seasonal climate, are reflected by fluctuations in the ecosystem. This means low diversity ecosystems are associated with unstable environmental factors. These changes in hydrological conditions are brought about the alterations in the occurrence and dominancy of benthic organisms living in that area. The possible explanation of the dominancy of *C.capitata* at this station (St.H14) is that this species adapted to continuous disturbance by continuous reproduction (Gray, 1981).

The curves obtained by Sanders'(1968) rarefaction technique for stations H2,H6 and H14 (Fig.5) were in good agrement with the results obtained by Shannon-Wiener function. The curve obtained for station H2 represent an area less affected by pollution and that obtained for St.H14 was characteristic for most affected areas.

The degree of similarity of the benthic fauna at six stations in Golden Horn was assessed by faunal similarity index and the results have been clustered by means of a dendogram (Fig.6). From this dendogram, two group of stations can be distiguished: group A contains shallow stations (H14-26) located above interface and group B contains the deeper stations (H2 and H6) below interface. The faunal composition among A-group stations showed very high (90%) percentage similarity, probably because of the small number of species with few dominant as was also indicated by Pearson and Rosenberg (1978). Indeed, these stations above the interface (halocline) were populated by few and almost same species e.g. *C.capitata* and *S.fuliginosa*, whereas those below interface contained more and different species. Rosenberg and Moller (1979) studying the salinity stratified benthic macrofaunal communities along the west coast of Sweden distinguished two group of stations below and above halocline. They also observed a group of stations above the halocline and dominated by pollution tolerant species.

Relatively weak similarity (22%) was found between group A and group B. The highest similarity (99%) was found between St.H18 and H26 where *C.capitata* and *S.fuliginosa* were dominant and constituted 99% and 100% in number of all fauna at St.H18 and H26 respectively. The lowest similarity (2%) was observed between most and least affected stations (H14 and H2) by unfavorable conditions.

Although the number of species was found to be high in December, when compared with other sampling times, the value of abundance was quite low (Fig.8). This led to decrease the A/S and to increase B/A ratios at this sampling period (Fig.9). The diversity was also low because of the dominancy of *C.capitata* which constituted about 70% of all species collected during this time.

An increase in abundance and biomass, and a decrease in the number of species was observed in March (Fig.8). But this increase in biomass has not been as significant as in abundance because, although a rise of more than 100% was found in abundance, it has been only 20% in biomass. Therefore, the B/A ratio was low at this time. The low ratio resulted also from the increment of the density of *E.gemmifera* since, the abundance of this species increased in March and constituted about 17.5% in number of all fauna obtained in this month.The increase in number of this species had a significant contribution to total abundance but much less to total biomass, because, this species is made up of small individuals. The diversity increased slightly since more than one species were dominant at this time

In May, both, total biomass and abundance reached a peak (Fig.8) which resulted especially from the increase in abundance of *C.capitata*, *S.fuliginosa* and *P.ciliata* (Fig.10). These species grouped as "progressive species of 1st order" by Leppakoski, (1975) occurred in great numbers in polluted areas, as was previously discussed, and expand their distribution and density when degree of pollution increases until inhibitory effects set in. Plankton studies carried out by Uysal (1986) in Golden Horn showed that the Polychaete larvae showed a significant peak in March and a relatively important peak in May. These results suggest that, although the reproduction of Polychaetes can be obseeved all over the year, it occurs mainly in March and May. The increase in abundance of above species should lead to the suggestion that the input of organic matter increased probably in this period. There was about no changes in the number of species from March to May. The diversity was decreased to about December level, because there was more than one dominant species.

A sudden decrease in abundance, biomass and even in number of species was observed in July (Fig.7) This decrease reflected also on A/S and B/S ratios. The most abundant species was *P.ciliata* and followed by *Nereis caudata*. Also *C.capitata* and *S.fuliginosa* occurred as the third and forth species in dominancy. But the abundance of these species does not differ much from each other. So, there was no species exceeding 50% in abundance and therefore the diversity reached to the highest level in this month.

Same faunal composition as May has been found in September. An important rise in total abundance which was due to *C.capitata* and slight increase both in biomass and species number (Fig.8) was observed. This resulted in the low B/A ratio and the high A/S ratio in this month (Fig.9). On the other hand, the diversity decreased slightly because of the dominancy of *C.capitata*.

Finally, the distribution of polychaetous annelids showed variations in space and time in relation to different environmental factors in Golden Horn. The studies are still continuing in order to assess the recovery of benthic fauna since, the estuary is trying to be cleaned up by Municipality of the City of Istanbul.

Acknowledgements. I wish to thank the assistace given by Research Assistants, K.C. Bizsel, A.E. Kideys and Z. Uysal both at sea and during laboratory work.
This work was financed by Istanbul water and sevage Administration.

REFERENCES

Artuz, I. and Korkmaz, K., 1975- Halicte su kirlenmesinin bugunku durumu. Paper presented at Golden Horn Symposium 10-11 December 1975. Ist. Techn. Univ. No:1 14 pp. Istanbul.

Bagge, P., 1969- Effects of pollution on estuarine ecosystems. II. The succession ot the bottom fauna coomunities in polluted estuarine habitats in the Baltic-Skageral region. Merentutkimuslait. Julk./Havsforskningsinst. Skr. 228, 119-130.

Baykut, F., 1977- Cevre kirlenmesi ve Halic. Paper presented at National Symposium on the problem of the Golden Horn, 11-13 February 1976. Bogazici Univ. No:139, 9pp Istanbul.

Cognetti, G., 1972- Distribution of Polychaeta in polluted waters. Rev. Int. Oceanogr. Med. 25, 23-34.

Davis, J.C., 1973- Statistic and data analysis in Geology, 550 pp. New York : John Wiley & Sons Inc.

Ergen, Z., 1976- Investigation on the taxonomy and ecology of polychaeta from Izmir Bay and its adjacent areas. Sci. Rep.of Faculty of Science, Ege Univ. No: 209, 73 pp. (in Turkish with an English summary).

Folk, R.L., 1974- Petrology of sedimentary rocks, 182 pp. Austin, Texas: Hamphill Publishing Company.

Gray, J.S., 1981-The ecology of marine sediments, 185 pp. London: Cambridge Univ. Press.

Gray, J.S. and Mirza, F.B., 1979- A possible method for the detection of pollution-induced disturbance on marine benthic communities. Mar. Pollut. Bull. 10, 142-146.

Leppakoski, E., 1975- Assessment of degree of pollution on the basis of macrozoobenthos in marine and brackish-water environments. Acta Acad. abo.,Ser.B., 35, 1-90.

M.E.T.U., 1986- Golden Horn. Oceanographic Investigations, 92 pp. First Annual Rep. Inst of Mar. Sci. Erdemli-Icel TURKEY.

Pearson, T.H. and Rosenberg, R.,1978- Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol. Ann. Rev. 16, 229-311.

Pearson, T.H., Duncan, G. and Nuttal, J., 1982- The loch eil project: population fluctuations in the macrobenthos. J.exp. mar. Biol. Ecol. 56, 305-321.

Phillips, D.J.H., 1976- The Common mussel *Mytilus edulis* as an indicator of pollution by zinc, cadmium, lead and copper. II: Relationship of metals in the mussel to those discharged by industry. Mar. Biol. 38, 71-81.

Rosenberg, R., 1973- Succession in benthic macrofauna in a Swedish fjord subsequent to the closure of a sulphite pulp mill. Oikos, 24, 244-258.

Rosenberg, R.,1976a- The relation of treatment and ecological effects in brackish water regions. Pure & Appl. Chem, 45, 199-203.

Rosenberg, R., 1976b- Benthic faunal dynamics during succession following pollution abatement in a Swedish estuary. Oikos, 27, 414-427.

Rosenberg, R., 1977a- The effect of dredging operations on estuarine benthic macrofauna. Mar. Pollut. Bull. 8, 102-104.

Rosenberg, R.,1977b- Benthic macrofaunal dynamics, production and dispersion in an oxygen-deficient estuary of west Sweden. J. exp. mar. Biol. Ecol. 26, 107-133.

Rosenberg, R. and Moller, P., 1979- Salinity stratified benthic macrofaunal communities and long - term monitoring along the west coast of Sweden. J.exp. mar. Biol. Ecol. 37, 175-203.

Samsunlu, A., 1977- Istanbul kanalizasyon projesinin Halic yonunden uygulama imkanlari. Paper presented at National Symposium on the problems of the Golden Horn, 11-13 February 1976, Bogazici Univ. No:139, 14 pp. Istanbul.

Sanders, H.L., 1960- Benthic studies in Buzzards Bay. 3. the structure of the soft-bottom community. Limnol. Oceanogr. 5, 138-153.

Sanders, H.L., 1968- Marine benthic diversity: a comparative study. Am. Nat. 102, 243-282.

Stirn, J., 1981- Manual of methods in aquatic environment research. Part 8. Ecological assessment of pollution effects. FAO Fish. Tech. Pap. (209), 70 pp.

Uysal, Z., 1987- Fate and distribution of plankton around the Bosporus. M.Sc. Thesis. IMS-METU, 151 pp.

Ünsal, M., 1978- Etude des voies de transfert et des phenomenes d'accumulation du vanadium chez les mollusques: *Mytilus edulis* (L.) Rev. Int. Oceanogr. Med. 51-52 71-81.

Ünsal, M., 1983- Transfer pathways and accumulation of vanadium in the crab. *Carcinus maenas*. Mar. Biol. 72, 279-283.

Ünsal, M., 1984- Accumulation and loss of tin by mussel. Oceanol. Acta 7, 493-498.

Walker, D.A., Linton, A.E. and Schafer, C.T., 1974- Sudan Black B: A superior stain to Rose Bengal for distinguishing living from non-living foraminifera. J. Foram. Res. 4, 205-215.

Wardwick, R.M., 1986- A new method for detecting pollution effects on marine macrobenthic communities. Mar. Biol. 92, 557-562.

Yüce, R., 1972- Halicin hidrografik ve polluyon (kirlenme) durumlarinin etudu. Ist. Univ. Fen Fak. Hidrobiol. Arast. Enst. Yayinlari. 21 pp. Istanbul.