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# A preliminary study of an eastern Mediterranean coastal ecosystem: Summer Resorts and Benthic ecosystems

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## Abstract

*The present study investigates whether coastal benthic communities are affected by tourist activities along the coast, which persist for a limited time period. The analysis of benthic macrofauna is based on the ecological parameters (quantitative analyses) as well as on the ecological identity of the species (qualitative analyses). Microbial contamination and some population statistics are correlated with ecological parameters. The disturbance of benthic communities in the vicinity of summer resorts is summarized by a reduction in species number and dominance of opportunistic species characteristic of disturbed and polluted environments. It is found that community diversity and evenness of distribution decrease with the deterioration of water quality, expressed as grade of microbial contamination, which implies that benthic community is also a significant element in assessing the quality of coastal waters. The above parameters were statistically negatively correlated with the number of tourists..*

**Keywords:** Benthos; Biological diversity; Environmental degradation; Evvoikos Gulf; Saronikos Gulf.

## Introduction

### *The Problem*

Today, biodiversity and sustainable development have become major issues worldwide. The effects of industrial and urban effluent on the marine ecosystem, in the vicinity of big towns usually situated in estuarine/marine enclosed areas, have been studied in various parts of the world (ANDERLINI & WEAR, 1992; MORRISON & DELANEY, 1993; MORAND & BRIAN, 1996; ZHANG & MAY, 1996).

Tourism is one of the most significant economic activities carried out in the coastal zone of the European Community. About one third of the international tourism concentrates seasonally in the coastal zone of the Mediterranean. The ‘Blue Plan’ Scenario predicts that the number of tourists will increase from 135 million in 1990 to 235-335 million in 2025 (UNEP/RAC, 1995). According to the same source, it is sufficient to balance out the economic development and the protection of the Mediterranean Environment, and to ensure at the same time a sustainable development. In Greece there are about 16,000 km of coastal zone, that is, approximately one third of the coastal zone of the Mediterranean. Tourism in Greece has led to a tremendous urban development in the last few decades, which in turn has brought an expansion of the urban sites along the coastal area.

Tourists enrich the local populations so abundantly during the summer that, despite the provided infrastructure as well as other facilities, the violation of the use of the coastal zone creates environmental problems that affect the quality of the marine environment.

Consequently, problems caused by tourism are added to the already high pressure on the coastal zone caused by the rapidly increasing urbanization.

In the Mediterranean, tourism has been included among the primary drivers affecting marine biodiversity (EEA, 1999). However, up to date, tourism activities have not been directly associated with marine biodiversity.

*The Study Area*

The increasing urban development of the Athens metropolitan city during the last decades has forced the inhabitants to maintain a second 'summer' house in a nearby coastal area. Thus, several summer resorts have recently appeared in the periphery of Attiki, which have replaced the old small villages. The population of some of these resorts is increasing considerably, reaching that of a small town during the summer months, while they are inhabited by just a few hundred people during the rest of the year.

The effects of environmental degradation due to tourism are continuously observed in several areas. The larger of these resorts are located in the S. Evvoikos Gulf (Marathon, Porto-Rafti, Keratea) and in the Saronikos Gulf (Anavissos, Saronida, Agia Marina). All of the coastal sites selected for this study, have presented an alteration of their natural environment. Studies of the marine ecosystem of the area refer mostly to the water column groups (phyto- and zooplankton) while extensive studies focus mainly on benthic communities of the deeper waters of the Saronikos Gulf (PETRAKIS *et al.*, 1993; ZENETOS *et al.*, 1994; SIMBOURA *et al.*, 1995; ZARKANELLAS & BOGDANOS, 1997; FOUNTOULAKIS & SABELLI, 1999).

Benthic community structure has been documented to be directly reflecting anthropogenic stress such as industrial, urban development and fisheries effluents (EVANS & WAHJU, 1996; SCHINNER *et al.*, 1996; GRALL & GLEMAREC, 1997; HALL & FRID, 1997; PETERSON & HICKERSON, 2000).

The present work represents a preliminary effort to investigate whether coastal benthic communities are affected by tourist activities (urban effluents mostly), which are more indensive during the summer.

## Methods

Sampling was carried out during the summer of 1996 at 10 stations located in the periphery of Attiki (Fig.1). The study sites are at almost the same distance from the coast in front of the major resorts of Attiki ($E_3$, $E_5$, $E_8$, $E_{16}$, $E_{20}$, $E_{28}$) with reference sites in between them ($E_{10}$, $E_{13}$, $E_{24}$, $E_{30}$).

Two replicate samples were collected from each site with the aid of a Van Veen grab $0.1m^2$. The samples were sieved on board through a 1mm sieve and stored in formalin solution (4%). In the laboratory all specimens were identified to species level, where possible. Part of the sediment was kept for grain size analysis according to FOLK (1974).

Coordinates of stations and waters depth are given in Table 1. Number of inhabitants of the villages and of the nearby resorts during winter (permanent population) and summer (estimated population) as provided by local authorities, is shown in Table 2.

Water samples were analysed in order to determine the concentrations of total

**Table 1**
**Sampling sites and abiotic parameters.**

| Stations | Latitude | Longitude | Depth (m) | Percentage of fines | Percentage of 'contaminated' [a] water samples |
|---|---|---|---|---|---|
| $E_3$ – Agia Marina | 37° 47′ 50 | 23° 50′ 59 | 50 | 33.46 | 58 |
| $E_5$ – Saronis | 37° 44′ 85 | 23° 53′ 25 | 55 | 24.60 | 69 |
| $E_8$ – Anavissos | 37° 42′ 00 | 23° 54′ 85 | 44 | 5.62 | 62 |
| $E_{10}$ – Ref. Site | 37° 38′ 89 | 23° 58′ 99 | 55 | 16.33 | 0 |
| $E_{13}$ – Ref. Site | 37° 43′ 79 | 24° 04′ 99 | 47 | 13.05 | 0 |
| $E_{16}$ – Keratea | 37° 49′ 40 | 24° 03′ 59 | 52 | 24.18 | 54 |
| $E_{20}$ – Porto-Rafti | 37° 53′ 00 | 24° 02′ 43 | 32 | 24.72 | 46 |
| $E_{24}$ – Ref. Site | 37° 57′ 59 | 24° 02′ 79 | 59 | 19.17 | 0 |
| $E_{28}$ – Marathonas | 38° 04′ 99 | 24° 04′ 40 | 34 | 30.47 | 38 |
| $E_{30}$ – Ref. Site | 38° 10′ 15 | 24° 07′ 80 | 43 | 12.51 | 0 |

[a] Percentage of incidents of water samples with high concentrations of total faecal coliforms and faecal streptococci during the summer period of 1996. (Source: Ministry for Environment, Physical Planning and Public Works).

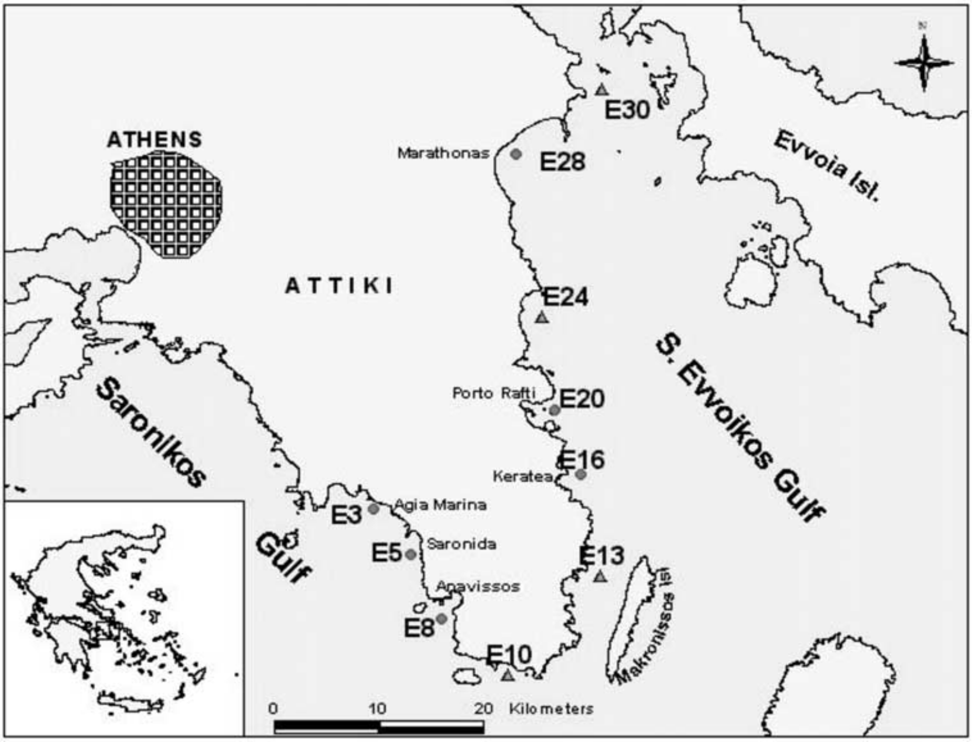


*Fig. 1:* Map showing locations of sampling sites.
(Triangle for reference sites).

coliforms, faecal coliforms and faecal streptococci. These analyses are part of the implementation of the Bathing Waters Directive in Greek waters provided by the Ministry of Environment, Physical Planning and Public Works.

Based on the quantitative and qualitative faunal composition of each station the following ecological parameters were calculated:

a) number of species (S)/ 0.1m$^2$

b) number of specimens N/0.1m$^2$ & N/m$^2$

c) community diversity (H') according to the Shannon-Wiener diversity index (Shannon & Weaver, 1963).

d) Pielou's evenness (J) of distribution of individuals among species (PIELOU, 1969).

In order to investigate faunal similarities, multivariate techniques were applied and the data were transformed by $Y_{ji}=\log(x_{ji}+1)$ (Field *et al.*, 1982). Group average clustering and multidimensional scaling (MDS) were employed with the Bray-Curtis similarity index using the software PRIMER.

Spearman's rank correlation coefficient was employed in order to investigate possible correlation between biotic and abiotic parameters (ZAR, 1984).

## Results

### *The Environment*

Water depth varied between 32m ($E_{20}$) and 59m (E24) (Table 1). The sea bottom at most sites was sandy with less than 33% fines (Table 1). The sand was mainly biogenic (shell debris). Coarser sediment was found at station $E_8$ (5,62% mud) indicating a high energy environment.

### *The Benthic Macrofauna*

A total of 6,454 individuals were collected belonging to 329 species. Species numbers per sampling unit varied between 42 sp/0.1m$^2$ ($E_3$ - Agia Marina) and 97 sp/0.1m$^2$ ($E_{13}$ – Ref. Site). The qualitative examination of the benthic fauna (Table 2) showed that station $E_3$ (Agia Marina) sustaining 42 sp/0.1m$^2$, was not as rich as $E_{28}$ (Marathonas) where the sediment structure was almost identical ($E_{28}$ =87 sp/0.1m$^2$). Polychaetes were the dominant group in terms of species numbers. The species

**Table 2**
**Permanent and temporal population of the resorts and benthic parameters [No of species (S/0.1m$^2$) and abundance (N/m$^2$)].**

| Stations | No of inhabitants in winter | No of inhabitants in summer | No of species/0.1m$^2$ (S) | No of individuals/m$^2$ (N/m$^2$) |
|---|---|---|---|---|
| $E_3$ – Agia Marina | 17500 [b] | 40000 [b] | 42 | 1625 |
| $E_5$ – Saronis | 1570 [b] | 25000 [b] | 86 | 3980 |
| $E_8$ - Anavissos | 4100 [b] | 50000 [b] | 91 | 4365 |
| $E_{10}$ – Ref. site | 0 | 0 | 68 | 2165 |
| $E_{13}$ – Ref. site | 0 | 0 | 97 | 3590 |
| $E_{16}$ – Keratea | 9700 [b] | >20000 [b] | 83 | 4255 |
| $E_{20}$ – Porto-Rafti | 3300 [b] | >30000 [b] | 67 | 3265 |
| $E_{24}$ – Ref. site | 0 | 0 | 65 | 2000 |
| $E_{28}$ – Marathonas | 13000 [b] | >30000 [b] | 87 | 4540 |
| $E_{30}$ – Ref. site | 0 | 0 | 77 | 2485 |

[b] Source: Local Municipalities. 1996 data.

composition of the different animal groups varied moderately among stations with polychaetes always dominating [45,9% ($E_3$) - 61,2% ($E_{28}$)] while molluscs (12,6% -29,5%) and crustaceans being followed (5,3-15,7%).

The highest values of density (>4,000indiv/m$^2$) were recorded in stations of Saronida ($E_5$), Anavissos ($E_8$), Keratea ($E_{16}$) and Marathonas ($E_{28}$).

The quantitative contribution of the various benthic groups to the composition of the macrobenthic fauna shows the animal groups responsible for the high abundance observed at the sampling sites (Fig.2). Polychaetes were the dominant group throughout the study area with a contribution of 63,5% ($E_{24}$) to 81,2% ($E_{28}$). It is clear from Fig.2 that the increase of polychaete individuals takes place mainly at the expense of the molluscs and of the crustaceans. It is also clear that at the aforementioned sites with highest abundances, polychaetes dominated making up more than 75% of the total number of individuals.

Minimum value of Shannon-Widner index was calculated for the station $E_3$ (4.95) and maximum values for the reference stations E13 (6.19) and $E_{30}$ (6.21) (Fig.3). Values of the evenness index (J) ranged from 0.80 at station $E_8$ (Anavissos), to 0.91 at the reference station $E_{30}$ (Fig.3). The highest values of evenness index were always found at the reference stations.

Species considered as indicators of disturbance and their idensities are noted in Table 3. *Levinsenia gracilis* was found in $E_3$ (200 ind./m$^2$) and E16 (170ind./m$^2$), characteristic of silty and sandy sediments and pollution tolerant (CHANG *et al.*, 1992). *Monticellina dorsobranchialis*, also characteristic of disturbed areas was found in all sampling sites, with highest values in $E_5$ (260 ind./m$^2$), $E_{16}$ (310 ind./m$^2$), $E_{20}$ (240 ind./m$^2$) and $E_{28}$ (340 ind./m$^2$). The polychaete *Paralacydonia paradoxa*, indicator of organic pollution (Bellan *et al.*, 1985) was found in most stations. The largest numbers of the above species were found at stations $E_3$ (185 ind./m$^2$), $E_5$ (385 ind./m$^2$), $E_{16}$ (180 ind./m$^2$), $E_{20}$ (190 ind./m$^2$) and $E_{28}$ (135 ind./m$^2$). The opportunistic species *Chone filicaudata* (Bellan *et al.*, 1985) was found at most of the sampling sites. Highest densities of the above were noticed in

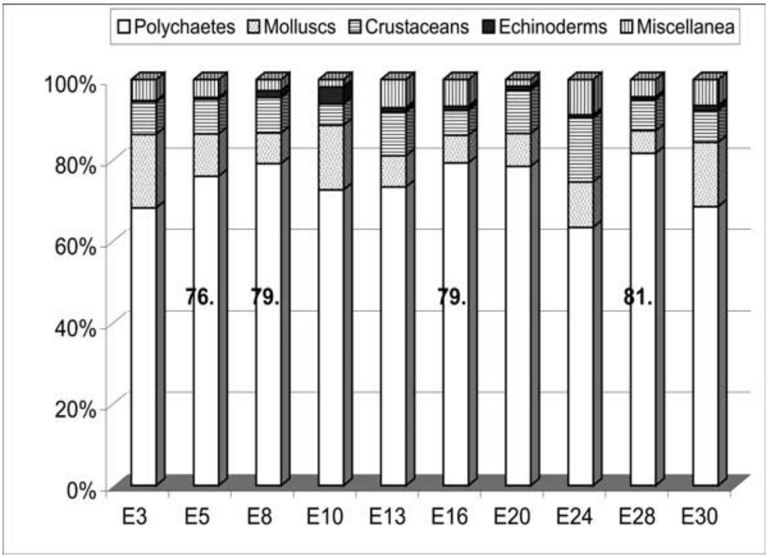


***Fig. 2:*** Percentage composition of the major benthic groups in terms of abundance.

**Table 3**
**Percentage of dominant species (abundance>4%) at each station.**

| Species | E3 | E5 | E8 | E10 | E13 | E16 | E20 | E24 | E28 | E30 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Aponuphis brementi* | + | + | + | + | + | + | 5.36 | + | 3.86 | + |
| *Apseudes latreilli* | + | + | + | | | + | 7.04 | 11.25 | | |
| *Aricidea fauveli* | 5.54 | 4.27 | + | 4.39 | + | + | + | + | + | + |
| *Chaetozone* spp. | + | + | + | + | + | + | + | 4.50 | + | 5.03 |
| *Chone filicaudata* | | + | 19.01 | 8.55 | + | + | | + | + | |
| *Euchone rosea* | + | + | 9.51 | + | + | 4.11 | + | + | + | + |
| *Exogone verugera* | | + | + | + | + | 5.99 | | + | + | + |
| *Levinsenia gracilis* | 12.31 | 7.16 | + | | + | 4.01 | + | + | 5.41 | + |
| *Lubrineris latreilli* | + | + | + | + | + | + | + | + | 7.84 | 4.63 |
| *Magelona* sp. | | 4.02 | + | + | + | + | 4.44 | + | + | + |
| *Monticellina dorsobranchialis* | 6.15 | 6.53 | 4.35 | + | + | 7.29 | 7.35 | 4.25 | 7.51 | + |
| *Myrtea spinifera* | 6.15 | + | + | | | + | + | | | |
| Nematoda | | + | + | + | + | 4.11 | + | | + | + |
| *Nematonereis unicornis* | | + | + | + | + | + | 5.82 | + | 6.29 | + |
| *Nephtys hystricis* | 7.08 | + | + | + | | + | + | + | + | + |
| *Notomastus latericeus* | + | + | + | + | + | + | 4.06 | + | + | + |
| *Onchnesoma steenstrupii* | + | + | | + | + | + | + | 5.25 | + | + |
| *Paralacydonia paradoxa* | 11.38 | 9.67 | + | 6.70 | + | 4.23 | 5.82 | + | + | + |
| *Prionospio banyulensis* | + | 8.42 | + | + | 11.42 | 9.05 | + | 6.00 | + | + |
| *Pseudoleiocapitella fauveli* | | + | + | + | | | 9.80 | + | + | |

+= presence

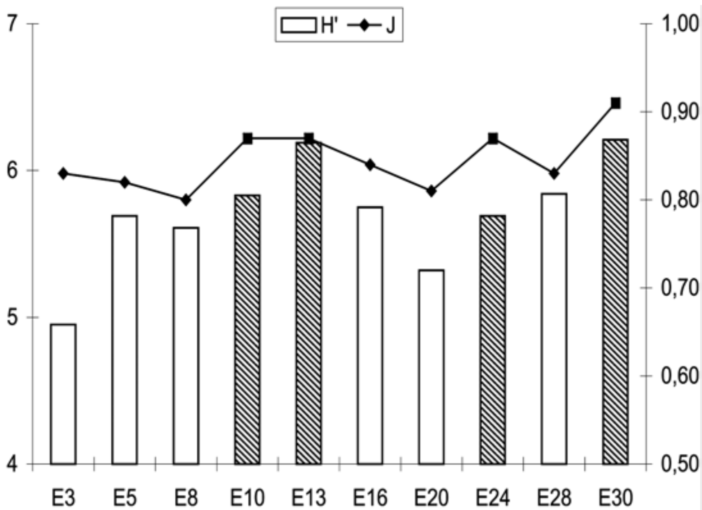


***Fig. 3:*** Community Diversity (H′) and Evenness (J) of distribution at the study sites. (Reference sites shaded).

$E_8$ (830 ind./$m^2$). The bivalve *Myrtea spinifera*, an indicator of disturbance was dominant in station $E_3$ (Agia Marina). The latter site was also characterized by high densities of the gastropod *Philine catena* and the polychaete *Sternaspis scutata*, species characteristic of coastal terrigenous mud (VTC) (PICARD, 1965).

*Multivariate Analysis*

MDS analysis, based on the fauna composition of the study sites (Fig.4), clearly separated station E3, from the remaining ones. This station had the lowest number of species. The rest of the stations, which are close to tourist areas, form a separate group in the MDS.

The superimposition of the number of summer inhabitants on the faunistic plot (Fig.5) indicates that the increase of population during the tourist season may be one of the main factors responsible for the grouping of the sites. A sub-group, consisting of the disturbed stations, located near the summer resorts is also observed, while the reference stations are widely separated from the rest of the sites. Station E3 where the lowest values of ecological indices occurred is well separated from the remaining stations (Fig.3). It is worth noting that station E3, which is potentially the most disturbed station, is situated near Agia Marina the resort with the highest number of inhabitants even during the winter (Table 2). Moreover, superimposing abiotic parameters on the faunistic plot suggests that sediment type (percentage of fines) is also one of the potential controlling factors (not shown).

*Non Parametric Statistics*

Correlation between ecological indices (S, N/$m^2$, H′, J) and managerial/environmental factors (number of inhabitants during summer, percentage of 'contaminated' water samples) showed that community diversity-H′ and evenness-J were correlated with the tourist activities indicators during the summer.

The increase in the number of inhabitants during summer was associated with a decrease of the diversity index ($p=0.02$) and with the evenness of the benthic communities ($p=0.008$). Similarly, the percentage of 'contaminated' water samples was negatively correlated with the diversity index ($p=0.05$) and the evenness of the benthic communities ($p=0.01$). It should also be noted that the increasing of number of inhabitants during summer was positively correlated with the

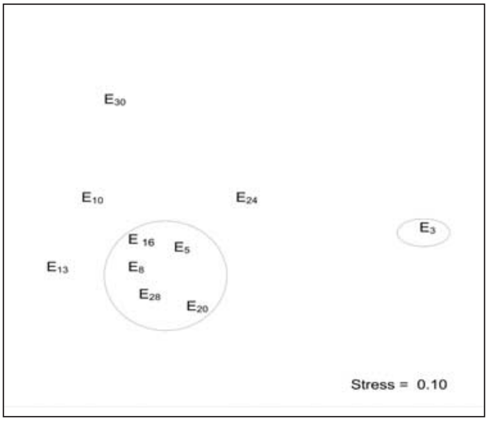


***Fig. 4:*** Multidimensional scaling plot based on the fauna distribution.

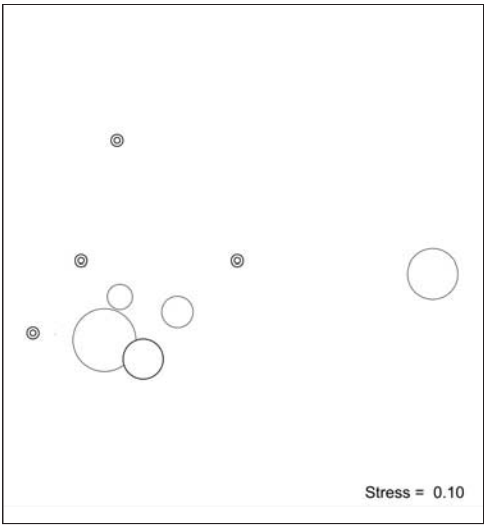


***Fig. 5:*** Multidimensional scaling plot based on the fauna distribution with superimposing number of inhabitants during summer.

◎ Reference sites

percentage of polluted water samples ($p=0.01$).

A decrease of species variety with water depth, a basic pattern in Mediterranean habitats, was also observed in the study area, though not statistically significant ($p=0.44$). The same pattern with depth was also valid for the community diversity (but also not statistically significant).

**Discussion**

Tourist development of the coastal zone of E-SE Attiki is associated with the disturbance of the coastal environment. Disturbance in this area is caused primarily by the organic pollution (wastes of coastal villages, ports etc).

Studies in the S. Evvoikos (PETRAKIS *et al.*, 1993; SIMBOURA *et al.*, 1998) have shown a noticeable variety of macrozoobenthic species. Benthic communities of the Saronikos Bay follow a zonation pattern along organic pollution gradient (SIMBOURA *et al.*, 1995). In the Evvoikos, changes were found in faunistic composition of benthic populations such us the increase of polychaetes and also the abnormal dominance of 'opportunistic species'.

The variety of benthic fauna in most stations reflects the type of the sediment. Station $E_{13}$ with coarse heterogeneous sediments was the 'richest' in species number (97 species/0.1m$^2$). Other studies of benthic communities in the Saronikos and S. Evvoikos Gulf with relative depths and sediments also reported similar values of number of species (ZENETOS *et al.*, 1994; NCMR, 1997). Generally, the number of species reported is comparable with other Greek gulfs. The only exception is station $E_3$ (Agia Marina) characterized by silty sand and depth 50m, with 42 species/0.1m$^2$, a value comparable with moderately polluted areas of the Saronikos (SIMBOURA *et al.*, 1995).

The diversity index showed relatively high values between $4.95<H'<6.21$ and does not seem to clearly indicate any environmental degradation in the area. The highest values were found in $E_{13}$ (6.19), E30 (6.21) and the lowest were found in $E_3$ (4.95) and $E_{20}$ (5.32). Evenness presented small fluctuations $0.80<J<0.91$ with lowest values in $E_8$ (0.80) and $E_{20}$ (0.81) suggesting possible disturbance in those stations.

Polychaetes are the least sensitive benthic organisms in disturbed conditions (PEARSON & ROSENBERG, 1978; WARWICK & CLARKE, 1994). The highest numbers of polychaetes were found in stations $E_5$ (Saronida) (76%), $E_8$ (Anavissos) (79%), $E_{16}$ (Keratea) (79%), $E_{20}$ (Porto Rafti) (78%) and $E_{28}$ (Marathonas) (82%). The communities of those stations were dominated by large numbers of opportunistic species, characteristic of organically enriched or disturbed areas, such as the polychaetes *Levinsenia gracilis, Monticellina dorsobranchialis, Paralacydonia paradoxa*, and *Chone filicaudata* (CHANG *et al.*, 1992; BELLAN *et al.*,1985).

Correlation of benthic community evenness index with number of inhabitants during summer months showed that evenness decreases with the increase of population of the coastal areas.

A negative correlation of benthic community evenness index with the percentage of samples of polluted waters was also observed. This fact indicates that community evenness decreases with the deterioration of water quality, expressed by the microbial contamination. Consequently, the results of this study suggest that benthic communities could potentially serve as a key element in assessing the environmental status.

The multivariate analysis also demonstrated a direct correlation with the number of inhabitants during the summer. Stations nearby over-populated coasts during the summer months were grouped together, except E3 that it is not classified with the rest, because of the different composition of the benthic fauna and the lowest values of ecological indices (Table 2).

Coastal areas with deterioration of water quality, expressed as grade of microbial contamination, were characterized by low ecological indices. The seasonal growth of human pressure is an important factor for the degradation of the water quality and also for the decrease of biodiversity in the coastal area.

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