DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

THE POLYCHAETA OF THE HOMA LAGOON (IZMIR BAY)

by
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April, 2009
İZMİR

THE POLYCHAETA OF THE HOMA LAGOON (IZMIR BAY)

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Ph.D. THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"THE POLYCHAETA OF THE HOMA LAGOON (IZMIR BAY)"** completed by **ELİF CAN YILMAZ** under supervision of **PROF. DR. BÜLENT CİHANGİR** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy.

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THE POLYCHAETA OF THE HOMA LAGOON
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ABSTRACT

The composition and distribution of the polychaeta fauna on the soft bottom of the Homa Lagoon were presented with the relations between key environmental variables affected on the fauna and faunal distribution patterns between sampling periods January 2006-January 2007. Environmental variables considered included water temperature, salinity, dissolved oxygen, pH, Chl-*a*, nutrients, sediment temperature, organic matter content in sediments and sediment grain size. The community was characterized by *Heteromastus filiformis*, *Glycera tridactyla*. These were accompanied by species *Hediste diversicolor*. *Capitella capitata*. *Spio decoratus*. Some species such as *Polydora ciliata, Nepthys hombergii. Capitella giardi, Sigambra tentaculata, Prionospio multibranchiata, Malacoceros fuliginosus* and *Streblospio shrubsolii* had fewer densities compared to other species in the lagoon. Diversity exhibited a seasonal pattern with highest value was occurred in spring (H'=1.06) and lowest value was in summer (H'=0.66). Secondary production and feeding guilds of the species were indicated from monthly samplings. Salinity, sediment temperature, pH, Chl-*a* and particle size of the sediment highly correlated with biomass and density of the fauna. A weak correlation was occurred between environmental factors and the distribution of polychaetes.

Keywords: Polychaeta, diversity, organic matter, feeding, Homa Lagoon.

HOMA DALYANI POLİKETLERİ
(İZMİR KÖRFEZİ)

ÖZ

Homa Dalyanı'nda dağılım gösteren Poliket fauna kompozisyonu ve dağılımı ile birlikte faunayı etkileyen çevresel faktörler Ocak 2006-Ocak 2007 dönemlerinde gerçekleştirilen örneklemeler sonucunda belirtilmiştir. Çevresel etmenler arasında su sıcaklığı, tuzluluk, çözünmüş oksijen, pH, Chl-*a*, besin tuzları, sediment sıcaklığı, sedimentte organik madde ve sediment tane büyüklüğü yer almaktadır. Kommunitede baskın olarak *Heteromastus filiformis* ve *Glycera tridactyla* türleri, bu türlerden sonra *Hediste diversicolor*, *Capitella capitata*, *Spio decoratus* ve kommunite içerisinde daha az yoğunlukta bulunan türler arasındadırlar. Diğer türlere kıyasla, *Polydora ciliata*, *Nepthys hombergii*, *Capitella giardi*, *Sigambra tentaculata*, *Prionospio multibranchiata*, *Malacoceros fuliginosus* ve *Streblospio shrubsolii* gibi türler lagünde daha düşük yoğunluk göstermişlerdir. Çeşitlilik indeks değerleri, mevsimsel dönemde en yüksek bahar aylarında (H'=1.06) ve en düşük yaz aylarında (H'=0.66) gözlenmiştir. Türlerin ikincil üretimi ve beslenme davranışları aylık örneklemeler doğrultusunda değerlendirilmiştir. Tuzluluk, sediment sıcaklığı, pH, Chl-*a* ve sediment tane büyüklüğü gibi faktörlerin faunanın biyokütle ve yoğunluğuyla önemli ölçüde bağlantılı olduğu, bununla birlikte çevresel faktörlerin Poliket dağılımı üzerinde düşük ölçüde etkili olduğu gözlemlenmiştir.

Anahtar sözcükler: Poliket, ,çeşitlilik, organik madde, beslenme, Homa Dalyanı.

CONTENTS

CHAPTER ONE

INTRODUCTION

Coastal lagoons are generally reported as highly dynamic and unpredictable systems (Barnes, 1980). These shallow coastal environments may be characterized by frequent fluctuations in environmental parameters on a daily and seasonal basis, which cause changes in the structure and distribution pattern of organisms (Koutsoubas et al., 2000). They are typically soft bottom habitats where annelids and especially polychaetes are either the dominant group or an important contributor to the macrobenthic fauna (Arvanitidis, et al., 1999).

The polychaetes are among the evident components of the benthic fauna in the lagoon as a natural source and have an importance of economic value, besides they are served as food for the avifauna and ichtyofauna. Their distribution and diversity is also highly correlated with the ecological conditions and one of the best tools for reflecting the changes in habitat (Bazairi et al., 2003; Carvalho et al., 2005).

Patterns in polychaete diversity and distribution have been studied in coastal lagoon Homa, but little emphasis has been given to the ecology of the polychaeta fauna. This research was a study of the benthic polychaete community assemblages (density, diversity, feeding guilds, species composition and secondary production) in the Homa Lagoon. Comparison was performed between the sampling stations and seasons to see if the difference could be attributed to environmental effects.

Main purpose of this study is; to characterize the composition and distribution of the polychaeta fauna on the soft bottom of the Homa Lagoon and to investigate possible relation between key environmental variables, fauna and faunal distribution patterns.

CHAPTER TWO
COASTAL LAGOONS

2.1 Coastal Lagoons

Coastal lagoons are shallow inland marine waters, usually located parallel to the coast, isolated from the sea by a barrier, and connected to the sea by one or more restricted inlets (Kjerfve & Magill, 1989). Lagoons can be called as fragile, young and highly productive, extremely unpredictable environments (Barnes, 1980; Bazairi, Bayed, Glemarec, Hilly, 2003). The influence of both marine and terrestrial factors can be observed in lagoons because of their position between land and sea (Reizopoulou, Thessalou-Legaki, Nicolaidou, 1996; Carvalho et al., 2005). They are often nutrient rich environments due to their shallowness and confinement from the sea (Reizopoulou et al. 1996; Reizopoulou & Nicolaidou, 2004) or nutrient input by rivers and recycling between sediment-water (Carvalho et al. 2005; Reizopoulou et al. 1996). Nutrient inputs in a lagoon affect these areas negatively and turn to them as naturally stressed environments (Reizopoulou et al., 1996; Koutsoubas et al., 2000; Reizopoulou &Nicolaidou, 2004; Carvalho et al., 2005).

Coastal lagoons are considered important as natural resources because of visiting and migrating birds or nursery habitats, they also provide appropriate fields for fishing and aquaculture (Koutsoubas et al., 2000; Arvanitidis et al., 2005). In Europe, the most significant lagoons are incorporated into nature reserves, while more than half of the larger Mediterranean ones are used for aquaculture (Lardicci, Rossi, Castelli, 1997; McArthur, Koutsoubas, Lampadariou, Dounas, 2000).

These shallow coastal environments may be characterized by frequent fluctuations in environmental parameters on a daily and seasonal basis, which cause changes in the structure and distribution pattern of organisms (Koutsoubas et al., 2000). Salinity is one of the most important physical characteristics of coastal lagoons. The salinity showed variations from fresh water (<3 ppt) to hyposaline/brackish (3–30 ppt), marine (30–35 ppt) or hypersaline (>35 ppt) waters depending on the hydrological balance within the lagoon (Saunders, Mcminn, Roberts, Hodgson, Heijnis, 2007).

Most of the Mediterranean lagoons are shallow and relatively enclosed systems where most features of the living populations are controlled by the degree of isolation (Mistri, Fano, Rossi, Caselli, Rossi, 2000).

The benthos is an important part of the lagoons' fauna (Tenore 1972) and the faunal distributions vary considerably in time and space (Mistri et al., 2000) are also affected by instability of environmental factors. Lagoons are organically enriched areas where high biomass and productivity are achieved (Barnes, 1980; Reizopoulou et al., 1996). On the contrary to this, low benthic diversity, low numbers of species and strong dominance of a few species (Reizopoulou & Nicolaidou, 2004) is typically observed in a coastal lagoon due to rapid and unpredictable fluctuations in environmental parameters (Lardicci et al., 1997; McArthur, 2000).

It is well known that sedimentary organic matter represents a major factor controlling the composition, structure and distribution of macrofaunal communities (Magni et al., 2004). The accumulation of organic matter in sediments is a result of the direct or indirect effects of human activities (De Falco, Magni, Terasvuori, Matteucci, 2004).

2.2 Lagoons in Türkiye

A total of 72 lagooner zones located on the coasts of Türkiye; 14 of them were in Black Sea, 12 of them in Marmara, 29 of them in Aegean and 17 of them located in Mediterranean Sea (Balık, Ilhan, Topkara, 2008).

Homa lagoon is among the group of Aegean lagoons including Karina, Köyceğiz, Cüzmene, Peso, Akköy, Bafa (Sakızburnu), Boğaziçi (Tuzla), and Güllük lagoons; the areas of Karina and Köyceğiz constitute 66% of the Aegean lagoons (Elbek et al., 2003). The physical characteristics of the lagoons show variability; the mean depth is

1.5 m. The mean salinity and pH values are 30.8 and 6.84, the mean temperature values are in winter and summer 8.8, 27.1 ºC, respectively (Elbek et al., 2003).

The lagoons in Türkiye are exposed to several unfavorable marine and terrestrial factors to cause water pollution and eutrophication (Mingazova, Nabeyeva, Türker, Chetinkaya, Bariyeva, 2008).

CHAPTER THREE

POLYCHAETES

3.1 Benthic Polychaeta Community Structure

Lagoons are typically soft bottom habitats where annelids and especially polychaetes are either the dominant group or an important contributor to the macrobenthic fauna (Arvanitidis, Koutsoubas, Dounas, Eleftheriou, 1999).

Polychaeta is a class of the phylum Annelida and they are probably the most abundant and diverse group in marine sediments from the intertidal to the deep-sea (Fauchald, 1977; Fauchald & Jumars, 1979). Polychaetes are an important component of macrobenthic communities; their trophic flexibility and life history traits are considered as an adaptation to conditions of disturbed habitats (Simboura, Nicoladiou, Thessalou-Legaki, 2000; Mistri et al., 2002).

Macrobenthic animals are easy to monitor, because they can be sampled quantitatively and also respond to man-made disturbance (Elias, Rivero, Vallarino, 2003). Polychaetes are one of the most useful marine organisms to detect environmental disturbance (Giangrande, Licciano, Musco, 2005) on community, population and species level (Elias et al., 2003). They are indicator organisms because of readily available, easy to sample, and abundant. They include different trophic levels with sedentary, mobile, and tube-building species (Pocklington & Wells 1992). The presence or absence of some indicator species or even families are currently known as pollution descriptors such as *Capitella capitata* (Fabricius, 1780), some spionids (Tsutsumi, 1990) and the genus *Lumbrineris* Blainville, 1828 (Elias et al., 2003).

It has been demonstrated that environmental factors such as water movement, dissolved oxygen, sediments' grain size and organic matter content played an important role in the distribution of soft-bottom polychaetes (Guerra-Garcia & Garcia-Gomez 2004). Many reports have shown a relation between spatial distribution of polychaeta species and sediment characteristics. In this relationship some polychaeta species have been also known as markers of some environmental conditions. They reflect the impacts of anthropogenic disturbance, because of their highly diverse range of feeding and reproductive strategies (Metcalfe & Glasby, 2008).

3.2 Diversity Measurement

Diversity is currently one of the widely studied topics in ecology. Shallow water systems are particularly interesting, because they are exposed to the severe environmental changes. The abundance, biomass and species richness of benthic organisms are widely utilized parameters in the valuation of coastal environmental quality, especially in monitoring studies within marine soft-bottom environments (Giangrande, 2003).

There are many ways to measure biodiversity (Levin, 1992). Three levels of diversity; α-diversity is the within-habitat or intracommunity diversity, β-diversity or between-habitat diversity is defined as the change in species composition along environmental gradients, γ-diversity is the diversity of an entire landscape and can be considered a composite of alpha and beta (Peet, 1974; Labrune et al., 2008).

Widely used diversity measures are the Shannon index H' and the evenness index J. (Kwiatkowska & Symonides, 1986). The evenness index changes 0 to 1, zero indicates low evenness or high single-species dominance whereas 1 indicates equal abundance of all species or maximum evenness. Species richness or the number of species is currently the most widely used diversity measure (Stirling & Wisley, 2001). But the number of species alone does not describe the structure of the assemblage of species in a given area because the number of individuals per species varies (Gray, 2000).

3.3 Secondary Production

Secondary production is primarily a function of the growth of individuals, recruitment patterns, and mortality observed in nature. Therefore, it is directly related to the life-cycle of a given species. Although secondary production and production/biomass (P/B) ratios are key parameters in population ecology, the ecological significance of such important variables relies on understanding the life-cycle of the species (Sarda, Pinedo, Dueso, 2000). Production is one of the major paths of energy flow through ecosystems, and even modest rates of secondary production could be linked to important organic matter processing and nutrient cycling within ecosystems (Buffagni & Comin, 2000).

Benthic secondary production can be measured directly or can be calculated indirect estimations. Direct methods provide an actual measure of secondary production, and they require long and accurate studies, supported by adequate sampling designs and strategies. When growth and mortality patterns or age composition (cohort analysis) or not determined, the empirically derived quotient of production rate over annual population biomass has been used to estimate the production of animal populations from biomass data (Maurer & Robertson, 1999). Indirect methods differ from direct measurements because they give only an estimation of secondary production, but they have the advantage of being applied a posteriori to existing datasets (Tumbiolo & Downing, 1994).

Secondary production may be a useful tool for resource management, as well as the detection of environmental stress (Buffagni & Comin, 2000; Tagliapietra, Cornello, Pessa, 2007).

3.4 Feeding Guilds of Polychaeta

In coastal areas, benthic assemblages often show great variability at different temporal and spatial scales, which have been related to many processes, such as availability of food (Rossi et al., 2006).

Polychaetes play an important role in the functioning of benthic communities and this is not only because they often are the numerically dominant macrobenthic taxon, but also because of the diversity of feeding modes they exhibit (Giangrande et al., 2005). Feeding guilds, also called feeding types, refer to a group of animals using a common type of food in a similar way. Fauchald and Jumars (1979) summarized previous studies on the feeding guild of each polychaete family as herbivores, carnivores, omnivores, surface filter-feeding, surface deposit-feeding, and scavengers.

The abundance and various feeding types of polychaetes could supply possibilities to investigate biological processes and physical factors (sediment particle size, organic matter content, etc.) responsible for structuring patterns of biodiversity (Carrasco & Carbajal, 1998; Giangrande et al., 2003). The using of feeding habits as indicators of ecological change was firstly proposed by Fauchald and Jumars (1979) and they suggested that studies on feeding guilds can help ecologists to get a better understanding of the ecological function of each species.

The relationship between the feeding guilds and sediment particle size is very close. Particle size is a good measure of current energy and food variety (Wang 2004). Polychaetes enhance bioturbation, decompose organic matter and recycle of nutrients by their movement and feeding mode in the area (Fauchald & Jumars 1979; Wang, 2004). This is especially true of soft-bottom habitats, where the distribution of species is mainly linked to the sediment particle size (Giangrande et al., 2005). Soft bottom habitats are dominated by deposit feeders because the sediment particle size is appropriate for the feeding characteristics of deposit feeders (Lopez & Levinton, 1987).

CHAPTER FOUR
STUDY AREA

4.1 Gediz Delta

Homa Lagoon is a coastal lagoon located in the Gediz Delta. The Gediz Delta is located on the coast of Izmir Bay, Aegean Sea and it is an extensive wetland consisting of bays, salt marshes, freshwater marshes, large saltpans and four lagoons.

The Gediz River is formed by joining of waters coming from Murat and Saphane mountains in the central western Anatolia. The Gediz River, which frequently changes its bed during overflow periods and forms a delta of approximately 40.000 ha. Agricultural drainage water, industrial and domestic wastewater are transported to the delta by Gediz River (Parlak et al., 2006).

The Lagoons in the delta which are separated from the sea by narrow strips are Kırdeniz (400 ha.), Homa (1824 ha.), Çilazmak (725 ha), from the North to the South. The salt-plan of the State Monopoly Authority of Turkey is located between the Homa fish trap and the eastern shore of Cilazmak lagoon.

The Gediz Delta which is a wetland with abundant food functions as an open air museum with its rich and different habitats. There are large salt swamps in the Delta which are very important for some bird species. In the winter time, Gediz Delta hosts 80.000 wetland birds. Dalmatian pelican (*Pelecanus crispus*), flamingo (*Phoenicopterus roseus*), lesser kestrel (*Falco naumanni*), spur-winged plover (*Vanellus spinosus*), sandwich tern (*Sterna sandvicensis*), black winged stilt (*Himantopus himantopus*), avocet (*Recurvirostra avosetta*) are among the bird species inhabiting in the delta. The delta is one of the two most important breeding areas for Flamingos (http://www.izmirkuscenneti.gov.tr).

The Gediz Delta which accommodates temporary wet meadows, gardens, agricultural areas and small woody areas together with all above mentioned systems is a unique living environment, not only for that region, but also for all Mediterranean regions (http://www.wetlands.org).

The WWF-Turkey office had declared that the site qualified as an IBA (Important Bird Area) for its breeding populations of many bird species (WWF, 2000) including Dalmatian pelican and greater flamingo. The Gediz Delta is, well protected as one of the twelve Turkish Ramsar sites (site No: 945) according to the list, dated 2008, of wetlands of International importance published by Ramsar (http://www.ramsar.org/ sitelist.pdf) and Bern Conventions. (Tapan, 2003).

4.2 The Homa Lagoon

Homa Lagoon is one of the 10 most productive lagoons in the Aegean Sea and it is the third largest, with an 1.800 ha fishing area (İlkyaz et al., 2006). Its management was transferred to the Faculty of Fisheries at Ege University in 1986. Thus, Homa Lagoon has become the only active fish trap in the Izmir Bay since the Ragippasa Lagoon was unfunctional in 2002. Annual fish production varies between 3 to 65 tons. During 1986-1987, 65 tons of production was achieved (Balık et al., 2008). There are five strait (gates), including the fish trap region, where fishing is still carried out actively in the fish trap and the straits and fish traps are opened in December and they are closed again at the beginning of June (Elbek et al., 2003).

Annual fishing production is about 25 tons and commercially valuable fish species such as grey mullets (*Mugil cephalus*, *Liza ramada*, *Liza saliens*, and *Liza aurata*), gilt-head sea bream (*Sparus aurata*), eel (*Anguilla anguilla*), European sea bass (*Dicentrarchus labrax*), and common sole (*Solea solea*) are caught (İlkyaz et al., 2006).

4.3 Previous Studies

Several studies are carried out in Homa Lagoon especially by the scientists from Fisheries Faculty of Ege University.

The Homa lagoon is an important lagoon for fishing activities and because of its efficiency. The studies about fish biology, distribution, diversity etc. are more studied topics than benthos.

The PhD thesis of Onen (1990) was on the distribution of macrobenthic organisms related with the physicochemical parameters in the Homa Lagoon. The distribution of macrobenthic organisms including the species belonging to Crustacea, Mollusca, Polychaeta and Pisces are given in detailed in monthly sampling period of one year. The study about the Polychaeta group has carried out by Tas (2000) in Gediz Delta. Homa lagoon was one of the sampling stations of the study included seasonal sampling periods.

In the same project about Gediz Delta, the study conducted by Balık et al. (2004) has done about Oligochaeta and Aphanoneura (Annelida) fauna of the delta. Türkmen et al. (2005) studied about some morphometric traits of *Penaeus (Melicerstus) kerathurus* (Forskal, 1775) and factors influencing emigration in Sufa (Homa) Lagoon. Serdar et al. (2007) searched the growth and survival rates of *Tapes decussatus* (Linnaeus, 1758) in the Homa Lagoon.

CHAPTER FIVE
MATERIALS AND METHODS

5.1 Sampling Stations

Sampling was carried out from January 2006 to January 2007 with the exception of December because of the bad meteorological conditions in the Homa Lagoon. Samples of fauna were collected seasonally at ten sampling sites which were located on selected transects in the lagoon (Figure 5.1). At each site, five random replicates were taken and more than five replicates (fourteen) were repeated at stations B3, C3, D2 in monthly sampling period (Table 5.1). The area of the lagoon where the study was carried on is 1500 ha with an average depth 0.5-1 m and had a connection to Izmir Bay with a 100m long and 65m mean width. The distance of the stations to the canal is given in Table 5.1.

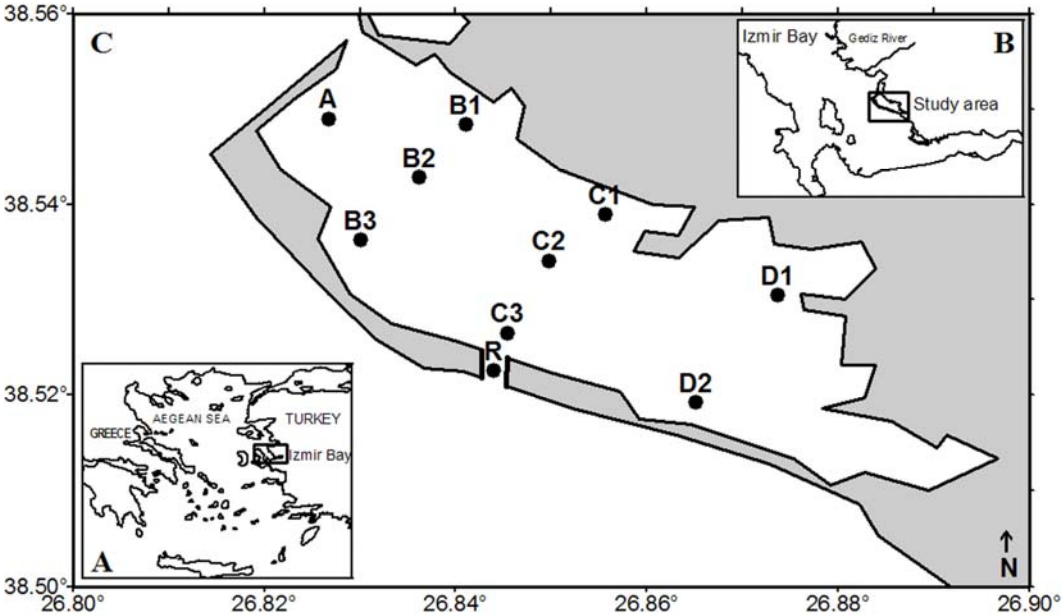

Figure 5.1 (A) Geographical location of the study site, (B) map of Izmir Bay and (C) map of Homa Lagoon indicating sampling stations.

Table 5.1 Information about sampling stations

Stations	Distance (km)	Number of Replicates	Sampling Type
A	3.25	5	seasonal
B1	3.00	5	seasonal
B2	2.30	5	seasonal
B3	1.80	14	monthly
C1	2.30	5	seasonal
C2	1.40	5	seasonal
C3	0.50	14	monthly
D1	3.00	5	seasonal
D2	2.10	14	monthly
R	0.20	5	seasonal

5.2 Sample Treatment and Analyses

Polychaeta species collected from the lagoon by means of a modified van Veen grab. The sampler covered a surface of 400 cm^2 and penetrated to a depth of 15 cm. One additional sample was taken monthly for sediment analyses with a 30 cm long, 8 cm diameter plastic core. The samples were sieved on the 500 µm mesh sieve and faunal samples that were retained on the sieves were fixed in the plastic boxes filled with the 5% formalin solution and than they were kept in 70% ethyl alcohol. All individuals were identified to the species level according to Day (1967), Fauchald (1977) and Hartmann-Schröder (1996). In the laboratory, the specimens were separated from macrobenthic samples after that, they were counted and measured. Selected individuals in different range were dried for 24 h at 60^0C (Méndez, Romero, Flos, 1997).

Water parameters (temperature, salinity and pH) were recorded using a WTW Ph/Cond 340i. Water samples were analyzed for dissolved oxygen by Winkler method, and for chl-*a*, nutrients (nitrites, nitrates, ammonium and phosphates) according to methods in Stricland & Parsons (1972); Grasshoff, Ehrhadt, Kremling (1983). Sediment particle size analyses were carried out according to Hakanson & Jansson (1983) and organic matter analyses according to Hach (1988).

Identified polychaetes were grouped into feeding guilds according to literature (Fauchald & Jumars 1979; Arvanitidis et al., 1999), the species identified were classified according to the following trophic groups: S: surface deposit feeders, B: burrowers, F: filter feeders, Cr: carnivores.

5.3 Data Analyses

Data were analysed using a combination of multivariate and univariate methods. Polychaeta community structure was determined by univariate analyses based on total number of individuals (N), number of species (S) and species richness Margalef's (d), Shannon – Wiener species diversity (H′) and evenness (J) indices. These variables were calculated for each sampling station and sampling period. Cluster analyses (Bray – Curtis similarity index, group average clustering) and non – metric multidimensional scaling (MDS) were used to investigate similarity among stations in each seasonal sampling period using faunal data. Fourth root transformation was applied for data.

Species having the greatest contribution to dissimilarity among the sampling periods were investigated using the similarity percentages procedure SIMPER (Clarke, 1993). An estimation of the variations in the polychaeta community was made by means of distribution of species in geometric size and abundance classes. The percentage of species was plotted against the density (ind.m^{-2}) per species in geometric abundance and against the mean dry body weight biomass (mg.m^{-2}) in size classes (Pearson, Gray, Johannessen, 1983; Warwick, Collins, Gee, George, 1986).

Environmental variables, best correlated with the multivariate pattern of the polycaheta community were identified by means of harmonic Spearman coefficient, ρw (BIO-ENV analyses) (Clarke & Ainsworth 1993). All analyses mentioned above were performed using the PRIMER v 5.0 software package.

The significant differences in univariate indices between sampling stations and periods were tested by using one-way ANOVA. Spearman rank correlation coefficient was used to determine the relationship between environmental parameters and the density, biomass of the fauna by using STATISTICA v7.

The estimated production rates at the three monthly sampled sites were calculated using the method of Tumbiolo & Downing (1994). In the equation annual mean water temperature and depth has been incorporated to estimate production from annual mean biomass of marine benthic invertebrates:

$$\log P = 0.24 + 0.96 \log B - 0.22 \log W_m + 0.03\, T_s - 0.16 \log(Z+1)$$

where;

P: production (g DWm^{-2}yr^{-1})

B: mean biomass of the fauna (g DWm^{-2})

W_m: individual body weight (g DW)

T_s: mean water temperature (ºC)

Z: depth (m)

CHAPTER SIX

RESULTS

6.1 Environmental Properties

Environmental variables were recorded during the sampling period of the Homa Lagoon including water temperature, salinity, dissolved oxygen, pH, Chl-*a*, nutrients, sediment temperature, organic matter content in sediments and sediment grain size.

Monthly variation of water and sediment surface temperatures is given in Figure 6.1. Throughout the sampling period, both water and sediment temperature showed similar variation due to the shallowness. Water temperature ranged with a mean value 3.3-27.1°C and sediment surface temperature ranged 3.4-25.9°C. The maximum values of water and sediment temperature were measured in August and the minimum values were found in January 2006. The temperature measured in January 2007 was higher than the value measured in January 2006.

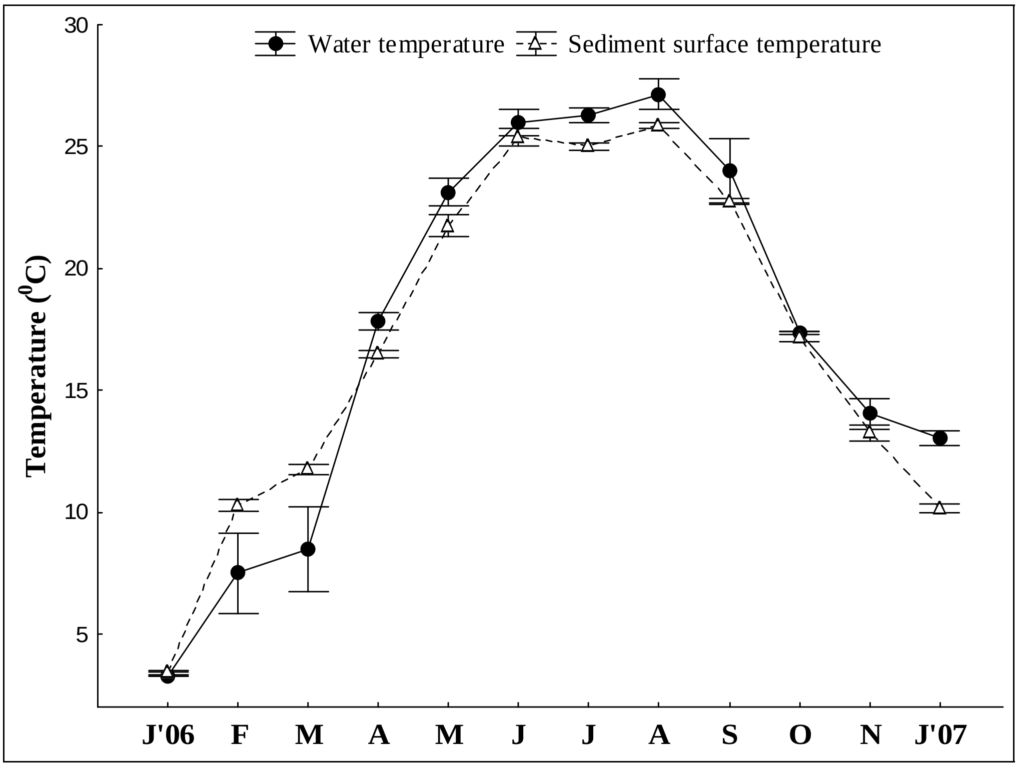

Figure 6.1 Monthly variation in water and sediment surface temperature of the lagoon between January 2006 and January 2007.

Other physicochemical variables in water samples including salinity, dissolved oxygen, Chl-*a*, pH and nutrients are given in Figure 6.2 and Figure 6.3.

In the most of the sampling period, salinity was above 40 psu except February and March and mean salinity values ranged 34.1-56.9 psu. The maximum mean value was measured in August and the minimum mean value was measured in March. A decrease was observed from January 2006 until March. The salinity values increased from April and reached to the highest value in August. The decrease in salinity values continued until the end of sampling period. Precipitation, the input of the water from irrigation canals to the lagoon and evaporation affected on the variation in salinity values (Yazıcı & Büyükışık, 2007). Chl-*a* mean values ranged from 0.4 to 2.7 μg/l, the highest value was observed in January 2007. Mean values of dissolved oxygen was in the range between 4.0-9.1 mg/l. The highest mean value recorded in November and the lowest in July. The reason of the decrease in dissolved oxygen is the decrease in the photosynthetic activity. The wind effect from the sea to the lagoon was a possible reason for the increase in the dissolved oxygen in November (Yazıcı & Büyükışık, 2007). pH values in the lagoon changed between 8.1-8.9. The highest point was observed in January 2006 and the lowest in August. The photosynthetic activities support the increase in pH and the increase in zooplankton cause the decrease in the pH values (Yazıcı & Büyükışık, 2007).

The nitrite+nitrate concentrations showed fluctuations during sampling period. The highest mean concentration was determined in February (3.8 μM) and the lowest mean concentration was determined in May (0.1 μM). An increase in the phosphate concentration was determined particularly after May and the mean values changed between 0.02-0.6 μM. The silicate concentrations in the sampling period showed fluctuations from 0.8 to 7.1 μM. The silicate concentration showed an increase and reached to its maximum value in March. An increase in Chl-*a* was observed with the increase in silicate concentration in March as mentioned in Kutlu & Büyükışık (2007). The maximum mean concentration of ammonium was found in February (8.7 μM) and the minimum in June (0.3 μM). The reason of the increase in ammonium concentration in February was reasoned by the precipitation, after February the decline was observed in spring due to the use of ammonium by phytoplankton species (Kutlu & Büyükışık, 2007).

Monthly variation of the percentages of sediment particle size and organic matter content in the Homa Lagoon are presented in Table 6.1. The sediment was composed by mostly sand and silt particles more than clay. In the most of the sampling period, the composition of sediments were similar, however the sand composition of station R was high among other stations. In January 2006, the percentage of the silt-clay was highest and in November was the lowest. The percentage of sand particles were low and high in January 2006 and November, respectively. The organic matter content of the sediment was not high during whole sampling period and it was between 1.6-3.4%.

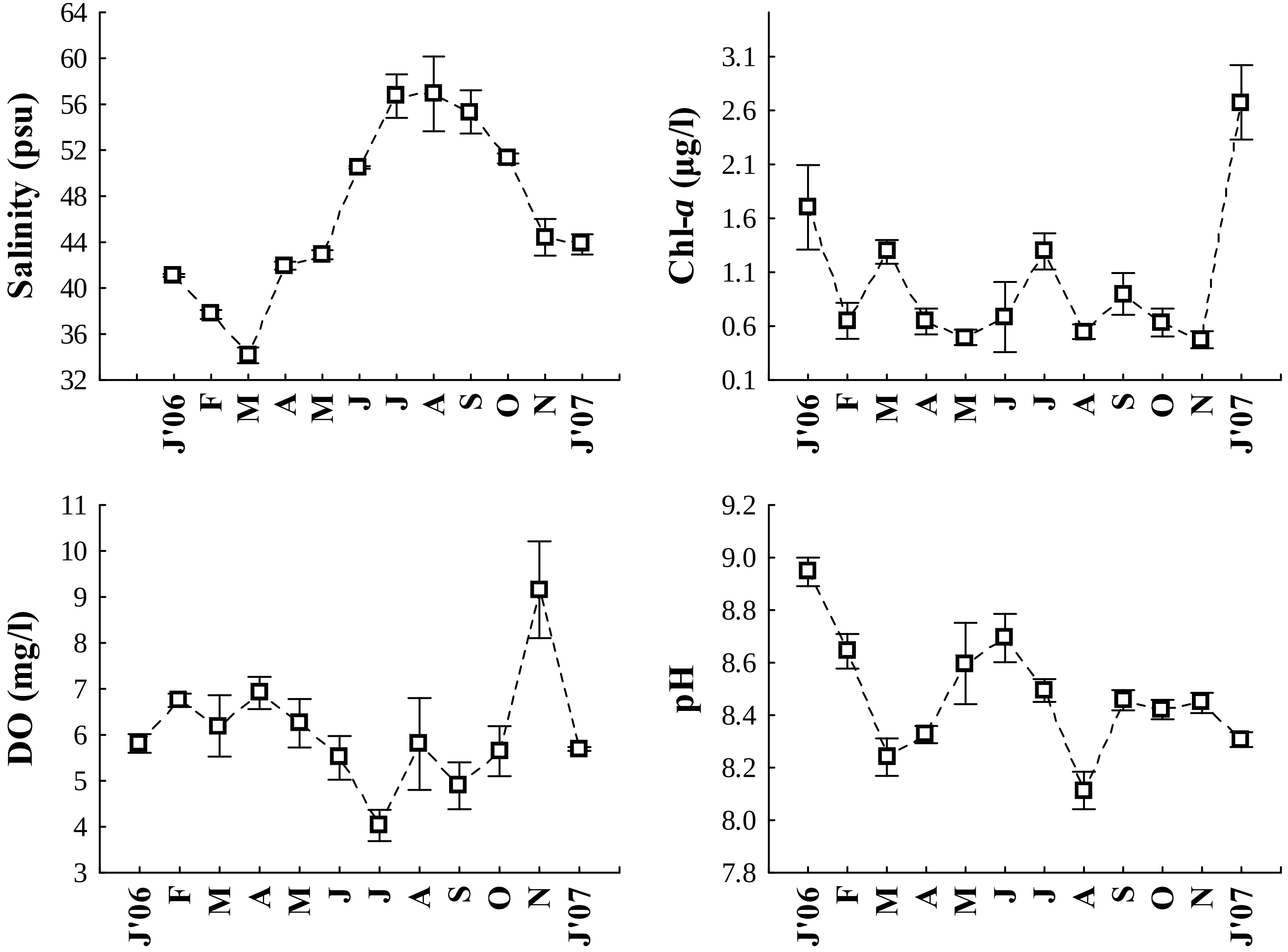

Figure 6.2.Monthly variation in salinity, DO (dissolved oxygen), chl-*a* and pH of the lagoon between January 2006-January 2007.

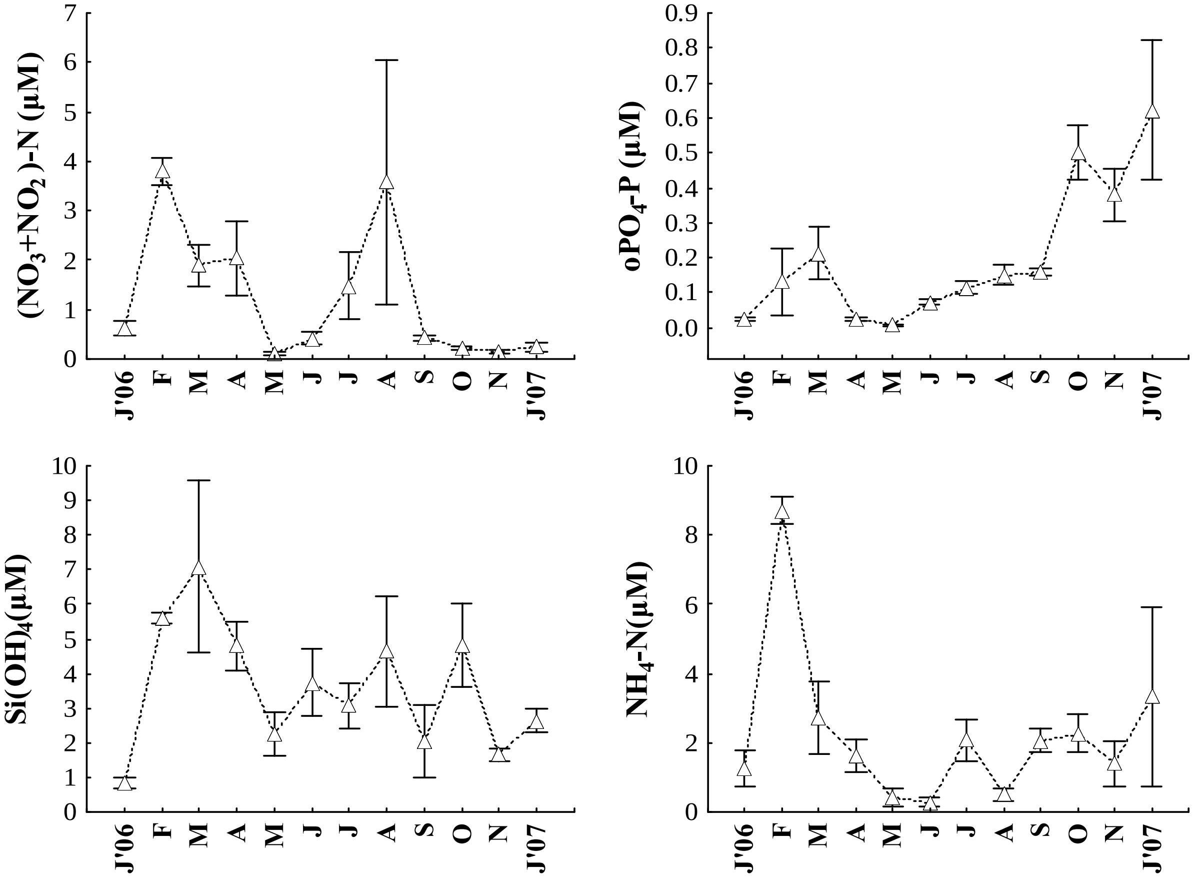

Figure 6.3 Monthly variation in nutrients of the lagoon between January 2006-January 2007

Table 6.1 The mean and standard errors values of the percentage of sediment particle size and organic matter content of the lagoon between January 2006 and January 2007.O.M.: Organic matter

		% Sand	% Silt	% Clay	% O.M.
January 2006	Mean	21.1	74.8	4.1	1.6
	S.e.	4.6	4.8	2.5	0.3
February	Mean	48.8	51.3	0.0	2.4
	S.e.	19.1	19.1	0.0	1.1
March	Mean	52.8	47.3	0.0	1.6
	S.e.	17.3	17.3	0.0	0.7
April	Mean	51.8	41.1	6.9	2.3
	S.e.	5.7	5.5	2.1	0.3
May	Mean	53.0	44.6	2.2	2.1
	S.e.	15.3	14.2	1.8	0.5
June	Mean	54.6	39.8	5.6	2.0
	S.e.	16.0	14.3	3.8	0.8
July	Mean	42.7	55.7	1.5	3.4
	S.e.	8.1	7.5	0.8	0.3
August	Mean	42.0	56.5	2.7	2.8
	S.e.	14.8	13.5	1.9	0.8
September	Mean	42.8	55.0	2.3	2.7
	S.e.	14.1	13.3	1.7	0.8
October	Mean	43.7	54.7	1.7	1.6
	S.e.	13.4	12.4	0.4	0.3
November	Mean	55.4	39.0	3.1	2.4
	S.e.	16.2	14.2	1.8	0.7
January 2007	Mean	30.7	63.0	6.3	2.6
	S.e.	7.4	8.5	1.1	0.8

The distribution of environmental variables is given according to stations sampled in the lagoon in Table 6.2. Some stations were sampled monthly, for this reason the sampling number of the stations (N) are different.

Mean temperature value of water and sediment were highest at station **R** **(**19.5±2.2°C, 19.2±2°C) and lowest at station **A** (15.8±4.7°C, 15.1±4.4), respectively. Station **B1** had the highest salinity value (49.4±4.5 psu) but the lowest salinity value was determined in station **R** (37.3±1.7psu). The location of station R is in the canal, which had a connection to sea. Therefore, the salinity value of this station was different from the other stations located inside the lagoon. Dissolved oxygen concentration was similar at all stations and the mean values determined at the sampling stations were more than 5.0 mg/l. The maximum mean value of dissolved oxygen is measured at station **D2** (6.6±0.6 mg/l) and minimum value is measured at station **B1** (5.2±1 mg/l). The highest Chl-*a* concentration was measured at station **C2** (2.1±1 µg/l) and the lowest in station **B2** (0.6±0.2 µg/l). The stations had alike pH values ranged between 8.4-8.7.

Nitrite concentrations did not show any variation among sampled stations. However, nitrate concentrations showed differences from one to another. In the station **B2,** the highest nitrate concentration (2.9±1.8 µM) was measured and station **B1** had the lowest (0.2±0.1 µM) value of all stations. Although the maximum silis concentration was observed at station **C2** (7.1±2.1 µM) and the minimum value (1.6±0.4 µM) was observed at station **A**. Station **D2** and **B1** had the highest (4.1±1.6 µM) and lowest (0.6±0.4 µM) ammonium concentrations. Phosphate concentrations measured at all stations did not show any variation such as nitrite most of the stations (A, B2, B3, C2, C3, D2 and R) had the highest values.

The mean percentage of sand varied from 22.7 to 90.7%. This value changed for silt from 9.3 to 74.4% and from 0.6 to 6.2% for clay. Station **R** contained the highest proportion of sand and where silt percentage was low. On the contrary to station **R** the percentage of silt content was high respect to the sand content at station **D1**. The organic matter contents of the sediment among stations had approximately similar values which the lowest was measured at station R (0.6±0.2%) had and the highest was at station C3 (3.3±0.3%).

Correlation between each pair of abiotic variables within the same category was analyzed and represented by Spearman Rank Correlation coefficient (ρ). Correlations between each pair of variables were evaluated and significant correlations were displayed ($p < 0.05$ and <0.1) (Table 6.3). Results of SRC test indicated that most variables were not highly correlated, since correlation between each two pairs of variables was less than 0.95. Water temperature was positively correlated with sediment surface temperature ($\rho=0.961$) and salinity ($\rho = 0.627$) sediment surface temperature was also positively correlated with salinity (ρ = 0.628). The percentage of silt content of the sediment was negatively correlated with the percentage of sand content of sediment (ρ = -0.931). Organic matter was negatively correlated with sand (ρ = -0.633) and significant positive correlation was observed with silt content of sediment (ρ = 0.629)

Table 6.2 Mean and standard errors of environmental variables of the stations sampled in the Homa lagoon between January 2006-January 2007. (SST:sediment surface temperature; OM:organic matter)

		St A (n=4)	St B1 (n=4)	St B2 (n=4)	St B3 (n=12)	St C1 (n=3)	St C2 (n=4)	St C3 (n=12)	St D1 (n=4)	St D2 (n=12)	St R (n=4)
Temperature	Mean	15.8	16.0	15.6	17.6	16.2	16.1	17.9	16.6	16.9	19.2
(°C)	S.e.	4.7	4.6	4.6	2.1	7.1	4.8	2.5	5.0	2.7	2.4
Salinity	Mean	49.1	49.4	48.6	47.3	47.8	47.8	46.5	48.2	45.5	37.3
(psu)	S.e.	4.4	4.5	4.4	2.7	5.9	3.9	2.4	4.0	1.7	1.7
DO	Mean	5.3	5.2	5.4	5.5	6.0	5.5	6.2	6.1	6.6	5.4
(mg/l)	S.e.	0.6	1.0	0.8	0.5	1.1	0.8	0.2	0.7	0.6	0.4
pH	Mean	8.5	8.6	8.5	8.4	8.7	8.5	8.4	8.6	8.5	8.5
	S.e.	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.1
Chl-a	Mean	0.7	0.9	0.6	0.9	1.1	2.1	0.9	1.3	1.0	0.7
(µg/l)	S.e.	0.3	0.3	0.2	0.2	0.3	1.0	0.1	0.3	0.2	0.1
N0$_2$-N	Mean	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.2	0.2
(µM)	S.e.	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1
NO$_3$-N	Mean	0.5	0.2	2.9	1.8	1.3	1.5	0.6	0.4	0.7	0.7
(µM)	S.e.	0.3	0.1	1.8	0.8	1.0	0.8	0.2	0.2	0.2	0.3
Si (OH)$_4$	Mean	1.6	1.9	2.3	4.2	3.4	7.1	3.5	4.4	3.0	2.3
(µM)	S.e.	0.4	1.0	0.6	0.9	1.8	2.1	0.8	1.8	0.4	0.5
NH$_4$-N	Mean	1.5	0.6	1.1	2.4	1.4	2.0	3.0	3.0	4.1	1.6
(µM)	S.e.	0.8	0.4	0.5	0.8	1.1	0.4	1.6	0.9	1.6	0.5
oPO$_4$-P	Mean	0.2	0.1	0.2	0.2	0.0	0.2	0.2	0.1	0.2	0.2
(µM)	S.e.	0.0	0.1	0.1	0.1	0.0	0.2	0.0	0.0	0.1	0.0
SST	Mean	15.1	15.4	15.4	16.9	14.8	15.8	16.9	15.8	17.1	19.2
(°C)	S.e.	4.4	4.4	4.4	2.1	6.2	4.5	2.1	4.5	2.2	2.0
% Sand	Mean	42.7	30.0	31.7	27.9	38.3	46.7	31.6	22.7	49.2	90.7
	S.e.	6.4	11.5	8.8	3.3	8.8	6.7	4.9	11.6	6.6	3.1
% Silt	Mean	54	63.9	59.4	65.4	55.5	52.1	65.9	74.4	49.2	9.3
	S.e.	8.7	14.2	11.0	4.8	5.6	6.1	4.4	13.7	6.3	3.1
% Clay	Mean	0.6	6.1	5.6	5.8	6.2	1.2	4.7	3.0	1.2	0.0
	S.e.	0.0	3.1	1.9	1.8	3.2	1.2	0.9	3.0	0.7	0.0
%OM	Mean	3.2	2.2	3.2	2.9	2.2	2.8	3.3	3.2	1.6	0.6
	S.e.	0.2	0.6	1.2	0.3	0.3	0.8	0.3	0.1	0.3	0.2

Table 6.3 Spearman rank correlation coefficients for environmental variables, only significant correlations were presented (values vith *P < 0.10 and values in italics P< 0.05). ** means correlations were not significant (P > 0.05 and P > 0.10). (SST:sediment surface temperature; OM:organic matter)

	Temp.	**Salinity**	**DO**	**pH**	**Chl-*a***	**N0$_2$-N**	**NO$_3$-N**	**Si (OH)$_4$**	**NH$_4$-N**	**oPO$_4$-P**	**SST**	**% Sand**	**% Silt**	**% Clay**	**% OM**
Temp.	1.000														
Salinity	*0.627*	1.000													
DO	*-0.393*	*-0.393*	1.000												
pH	**	**	**	1.000											
Chl-a	**	**	**	**	1.000										
N0$_2$-N	**	**	**	**	*0.265*	1.000									
Nitrate NO$_3$-N	**	**	**	**	**		1.000								
Si (OH)$_4$	*0.292*	**	**	-0.212*	-0.222*		*0.321*	1.000							
NH$_4$-N	*-0.268*	**	**	*-0.240*	**	*0.487*	0.205*	**	1.000						
oPO$_4$-P	**	*0.227*	*-0.234*	*-0.244*	**	*0.228*	-0.196*	**	0.205*	1.000					
SST	*0.961*	*0.628*	*-0.432*	**	**	**	**	*0.326*	*-0.261*	0.203*	1.000				
% Sand	**	*-0.294*	**	**	**	**	**	**	**	**	**	1.000			
% Silt	**	*0.272*	**	**	**	**	**	**	**	**	**	*-0.931*	1.000		
% Clay	**	*0.299*	**	**	0.204*	*-0.549*	**	0.198*	*-0.399*	**	**	*-0.334*	**	1.000	
%OM	**	*0.325*	**	**	**	**	**	**	**	**	**	*-0.633*	*0.629*	**	1.000

6.2 Polychaeta Community

A total of 13 polychaeta species belonging to 7 families were found during the study of Homa lagoon (Table 6.4). One of them *Capitella giardi* (Mesnil, 1897), is reported for the first time from the Homa lagoon. The families Spionidae and Capitellidae comprised 61.5 % of polychaeta fauna. Feeding guild categories of the species are presented in Table 6.4. The dominant component of polychaeta fauna, in terms of number of species, is characterized by surface deposit feeders and burrowers (subsurface deposit-feeders. The dominant group (surface and subsurface deposit feeders) composed of 69% of polychaeta fauna. Carnivores and filter-feeders follow them with 23% and 8% respectively.

Table 6.4 List of polychaeta Species found in the Homa Lagoon; FG, Feeding Guilds: S, Surface Deposit-Feeders; B, Burrowers; F, Filter-Feeders; Cr, Carnivores (categorized according to Arvanitidis et al., 1999).

Family	Species	A	B1	B2	B3	C1	C2	C3	D1	D2	R	FG
Capitellidae	***Capitella capitata*** (Fabricius, 1780)	+	+		+			+		+	+	**B**
	Capitella giardi (Mesnil, 1897)	+						+				**B**
	Heteromastus filiformis (Claparède, 1864)	+	+	+	+	+	+	+		+	+	**B**
Glyceridae	***Glycera tridactyla*** Keferstein, 1862			+	+	+	+	+	+	+	+	**Cr**
Nereididae	***Hediste diversicolor*** (O.F. Müller, 1776)		+	+	+			+		+	+	**F**
Pilargidae	***Sigambra tentaculata*** (Treadwell, 1941)									+	+	**Cr**
Syllidae	***Exogone(Exogone) naidina*** *Örsted, 1845*	+		+	+			+	+	+	+	**S**
Nephtyidae	***Nephtys hombergii*** Savigny in Lamarck, 1818							+			+	**Cr**
Spionidae	***Malacoceros fuliginosus*** (Claparède, 1869)			+				+		+	+	**S**
	Prionospio multibranchiata Berkeley, 1927			+						+		**S**
	Polydora ciliata (Johnston, 1838)					+		+				**S**
	Spio decoratus Bobretzky, 1870		+	+	+			+		+		**S**
	Streblospio shrubsolii (Buchanan, 1890)							+		+	+	**S**

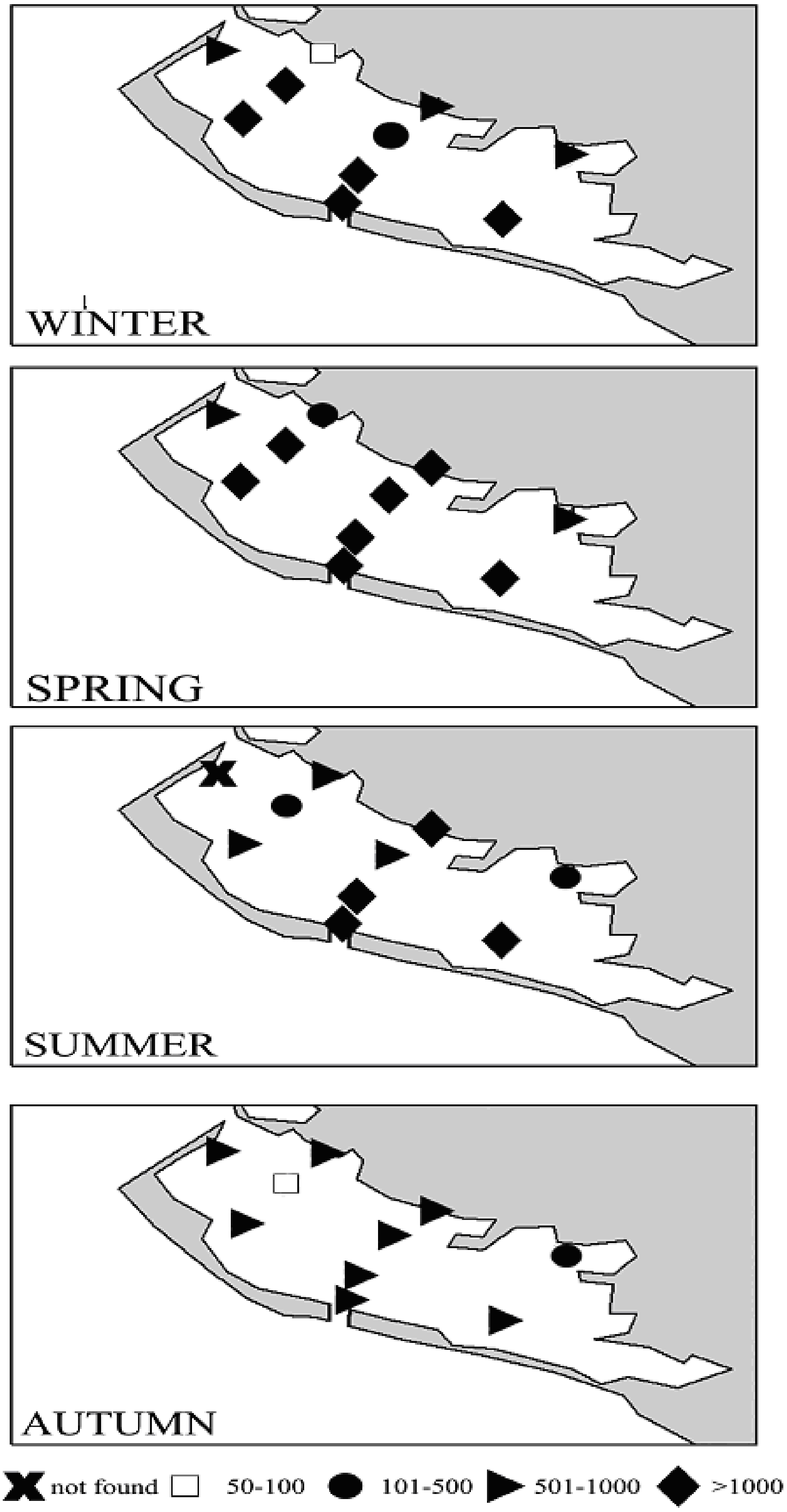

Figure 6.4 Spatial and temporal variation of the total abundance (ind.m^{-2}) of Polycaheta fauna in the Homa lagoon. (Symbols indicating abundance ranges)

The polychaeta abundance pattern observed is given in figure 6.4 according to sampling seasons. In winter sampling period, the most of the abundance of polychaetes was above 1000 ind.m^{-2}. The distribution of polychaetes that abundances ranged between 500-1000 ind.m^{-2} were observed in three stations located in the northern part of the lagoon. The abundance of polychaetes showed similar distribution pattern in spring period as observed in winter. The abundances were more than 1000 ind.m^{-2} at seven sampling stations of ten. The polychaetes' abundance was between 501-1000 ind.m^{-2} at two stations. In summer, no polychaeta species were observed in one station and the abundance was decreased during this sampling period. In autumn, the decrease in abundance was observed.

6.2.1 Community Pattern of Seasonal Sampling

Figure 6.5 shows similarity dendograms and MDS ordination plots of the stations sampled seasonally for polychaeta fauna in the Homa Lagoon. In the winter sampling period, three groups were formed at similarity level 50%. Stations B3, B2, D2, C3 and R were in the first group. C1, A were in the second and D1, B1 were in the third group. The highest similarity was observed between D2 and C3 with a 70% similarity level. The joining of station C2 was appearing to have a transitional position between the two groups.

The stations were clustered at higher similarity level than the stations clustering in winter period. In spring, two main groups are observed excluding station B1, with a similarity level above 50%. The first group had two subgroups; D2,C2, A and C3,B3,R. The highest similarity value was obtained between stations D1 and B2 in the second group and the station C1 joined this group with a high similarity value.

In the summer, station A was not taken into consideration, because no polychaeta species was recorded. Two groups are observed including stations B2-B1 (above 70%) and station C3, B3, D2, R, C1 (above 50%). The joining of station D1 and secondly C2 to these groups showed very low similarity levels. The highest similarity is occurred at stations R-C1 (91.5%) and the similarity level of stations

C3-B3 was above 70%, station D2 joined to this group with a similarity level 63%. Abundance of four species including *H. filiformis*, *G. tridactyla, H. diversicolor* and *S. tentaculata* were effective on the high similarity values among stations which were placed in the dendogram of summer sampling period.

Results obtained from autumn sampling period, are similar to those of summer. The main groups in the dendogram illustrated for autumn period had a very low similarity (below 30%), on the contrary to this similarity level, the subgroups of this cluster had high similarity levels which were the lowest one above 50%. The highest similarity level was observed at stations D2-A (81.7%), because of the abundance of of *H. filiformis* and *G. tridactyla* at these stations.

Table 6.5Contribution (%) of species responsible for most of the dissimilarities among group of stations, based on fourth-root transformed abundances according to the simper analysis

	Winter	**Spring**	**Summer**	**Autumn**
Glycera tridactyla	29.13	24.34	13.85	35.02
Heteromastus filiformis	27.99	39.89	54.48	37.29
Spio decoratus	8.65	_	9.39	9.19
Capitella capitata	5.29	7.76	_	_
Sigambra tentaculata	2.98	_	_	_
Hediste diversicolor	1.17	8.98	3.02	5.56
Malacoceros fuliginosus	_	3.50	_	_
Totals:	**75.21**	**84.47**	**80.74**	**87.06**

In Table 6.5, contribution of species responsible for most of the dissimilarities among group of stations is displayed. Seven species were responsible mostly for the dissimilarities among stations. These species were: *G. tridactyla, H. filiformis*, *S. decoratus*, *C. capitata*, *S. tentaculata, H. diversicolor*, *M. fuliginosus.* In the winter period, the contribution of *G.tridactyla* was the highest than other species. In other sampling period the species *H. filiformis* was responsible for most of the dissimilarity. The total amount of contribution of species had highest value in autumn and lowest in winter. Besides, the total number of the species responsible for dissimilarity was maximum in winter. *G. tridactyla*, *H. filiformis*, *H. diversicolor* were common species contributed to dissimilarity of all sampling period.

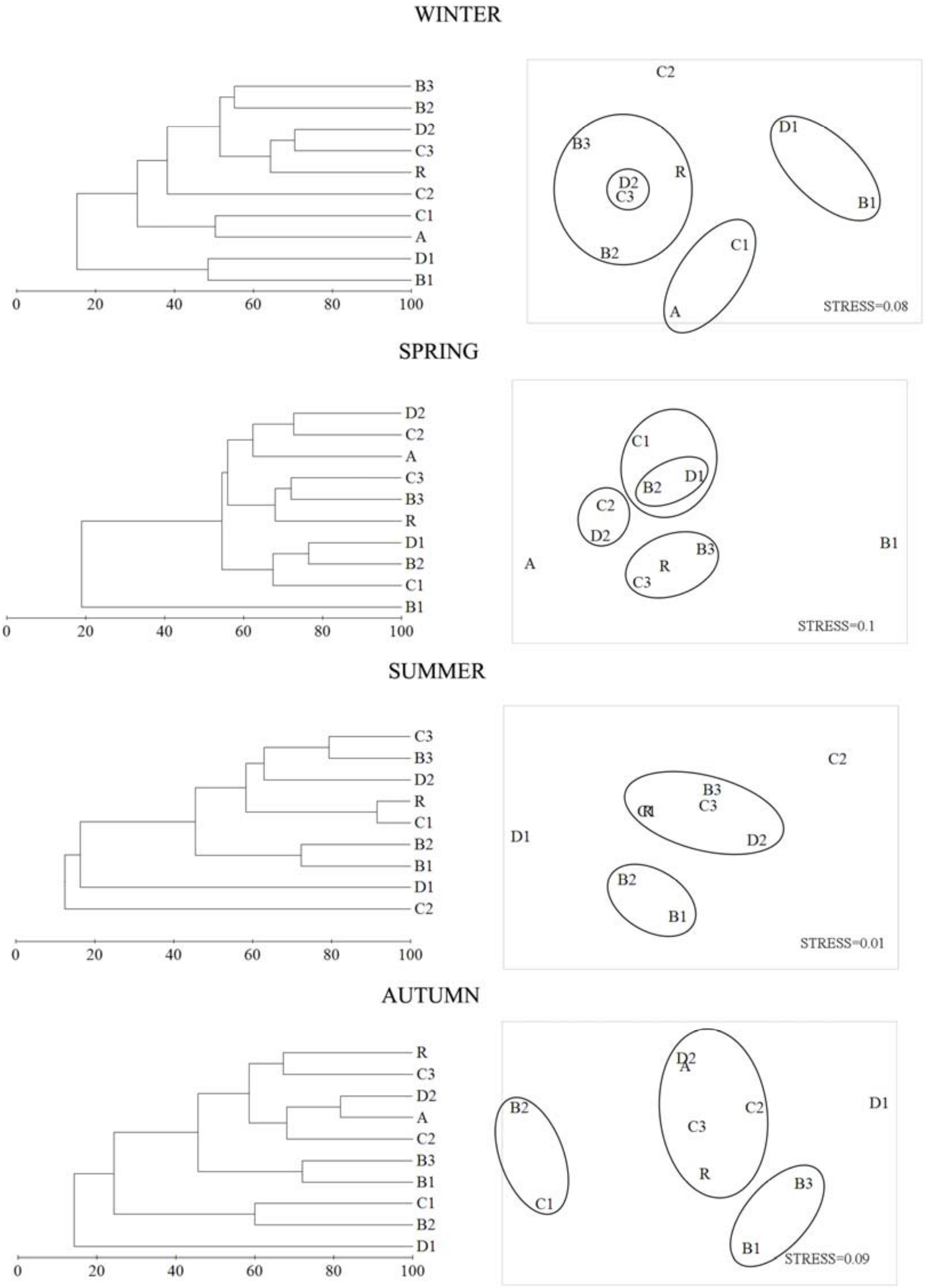

Figure 6.5 Similarity dendograms and multidimensional scaling (MDS) ordination plots of stations by sampling period.

6.2.2 Distribution of Geometric Abundance and Size Classes

Geometric abundance and size classes for each sampling period and the univariate results of the polychaeta community are presented in Figure 6.6 and Table 6.6. The number of the species showed a small increase from winter to spring period (11 to 12 species). The lowest species number was observed in summer with 8 species and in autumn sampling period, 10 species were observed. The lowest and highest values of species richness were 0.61 in summer and 0.91 in spring sampling period, respectively. Species diversity (H') and evenness (J') varied 0.66-1.06 and 0.72-0.88, respectively. Species diversity was highest in spring and lowest in summer. The lowest and highest values of evenness were observed in summer and autumn, respectively. The number of geometric size classes increased from winter to spring (7 to 9), decreased from spring to summer (9 to 8) and summer to autumn (8 to 5). The number of geometric abundance classes increased from winter to spring (5 to 7) and decreased from summer to autumn (7 to 6). The geometric abundance classes of spring and summer were the same.

Geometric abundance and size classes in the sampling stations are presented in Figure 6.7. Species richness varied 0.31 to 1.39 and evenness varied 0.72 to 0.98. The diversity values ranged 1.38 to 0.4 at stations B3 and D1 (Table 6.6). The number of geometric abundance classes of Station C1 had more classes (7 classes) than other stations and fewer in the station D1 (2 classes). The number of geometric size classes showed different values from the geometric abundance classes. Station B2 and C2 had more geometric abundance classes (8 classes) than other stations and fewer geometric abundance classes in the station A (4 classes).

The significant differences were tested using one-way ANOVA between univariate results, sampling stations and sampling period (Table 6.9). The significant differences of species number were occurred between species number and evenness values within stations.

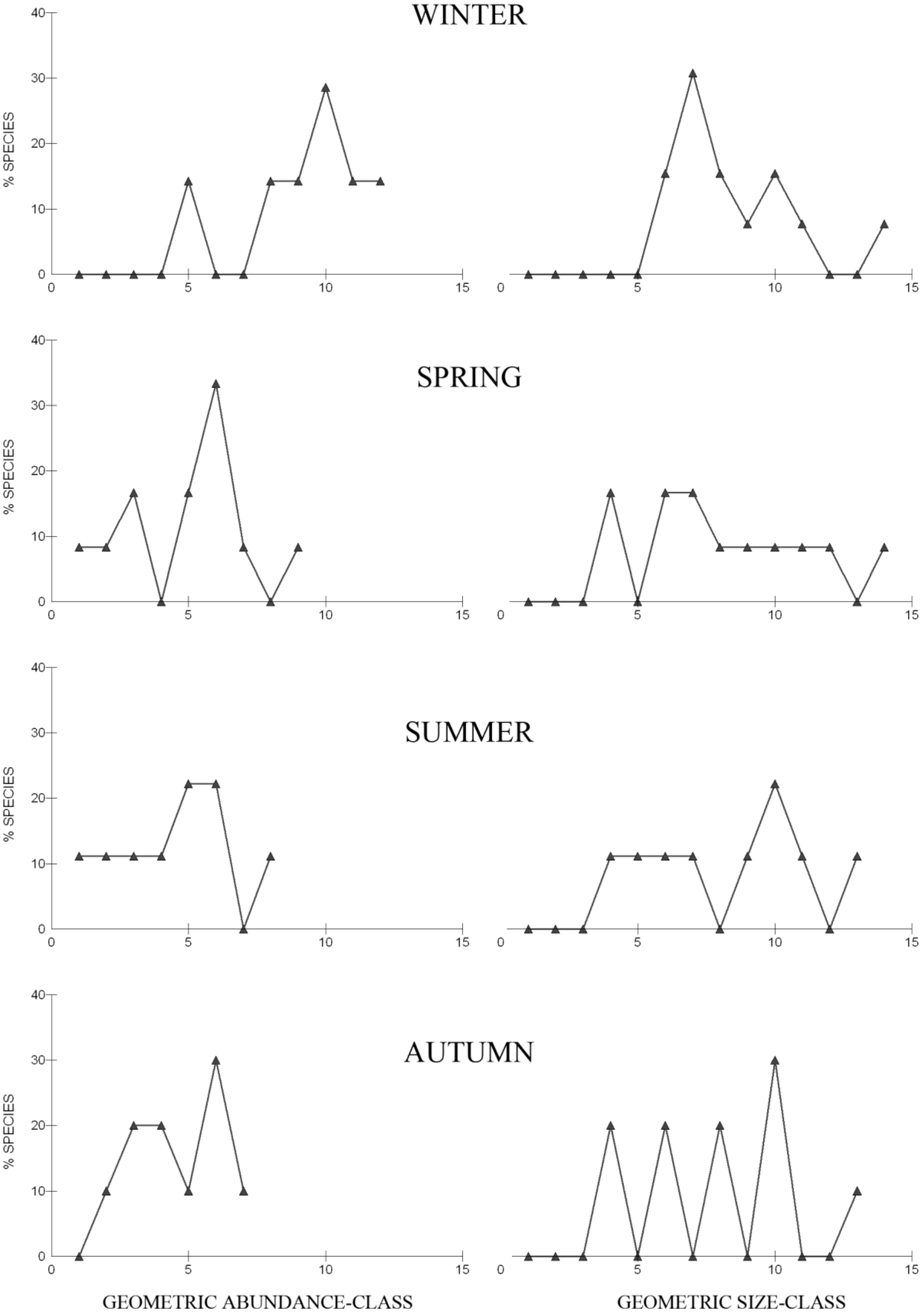

Figure 6.6 Geometric abundance (ind m^{-2}) and size classes (mg m^{-2}) of the species by sampling period.

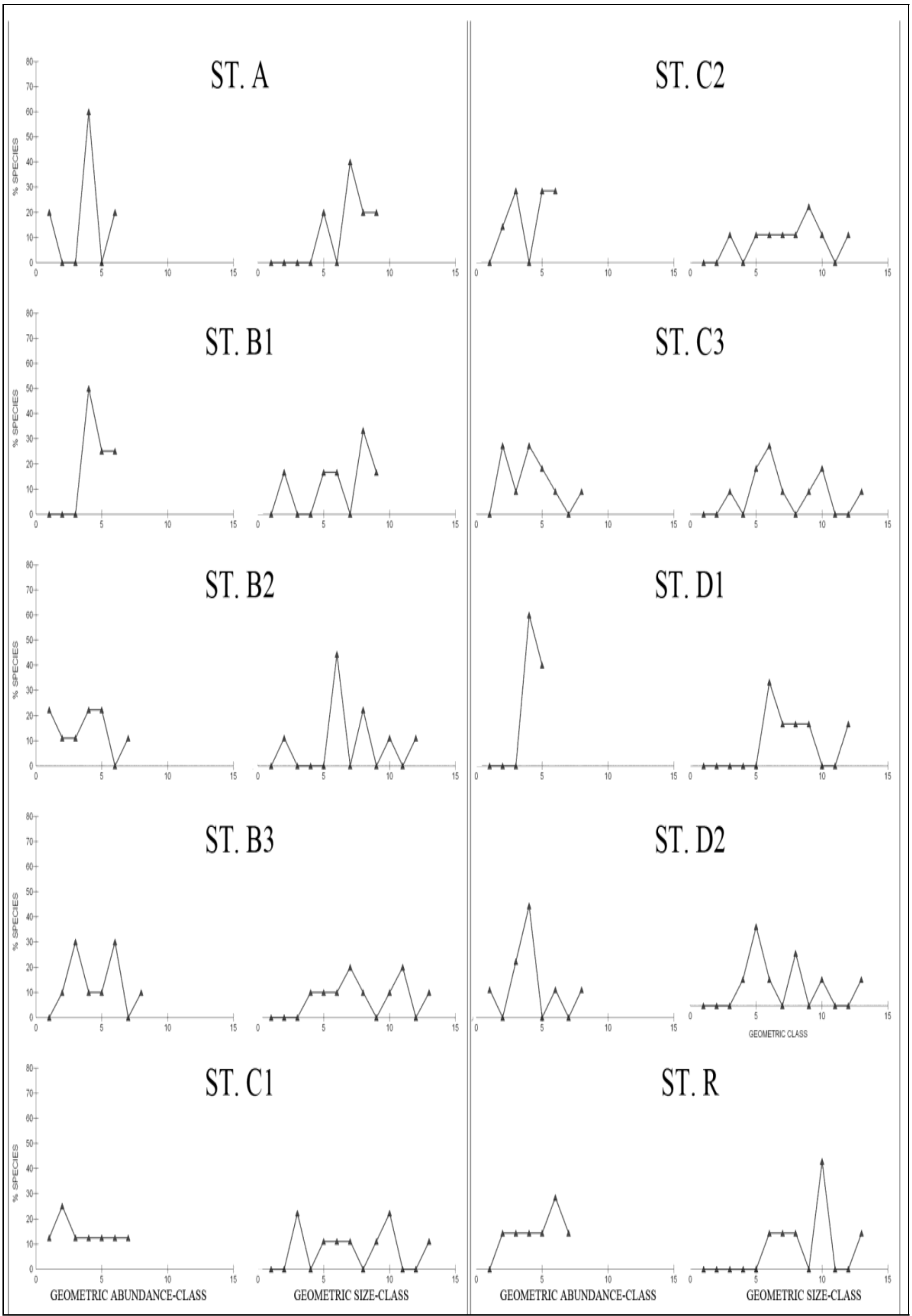

Figure 6.7 Geometric abundance (ind m^{-2}) and size classes (mg m^{-2}) of the species by sampling stations.

Table 6.6 Univariate community structure descriptors of the Polychaeta fauna by sampling periods and sampling stations (S:number of species, d :species richness, H': species diversity, J': evenness).

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	S	***d***	***J'***	***H'***
Winter	11	0.79	0.80	1.03
Spring	12	0.91	0.74	1.06
Summer	8	0.61	0.72	0.66
Autumn	10	0.69	0.88	0.94
A	4	0.38	0.73	0.48
B1	4	0.31	0.90	0.45
B2	7	0.80	0.75	0.86
B3	6	1.27	0.76	1.38
C1	3	0.59	0.73	0.85
C2	2	0.56	0.89	0.94
C3	11	1.39	0.73	1.36
D1	2	0.22	0.98	0.44
D2	10	1.02	0.72	1.16
R	9	0.91	0.85	1.29

Table 6.7 Results of one-way analysis of variance for all sampling periods and stations.
(ns: nonsignificant)

	Season			**Station**		
	df	F	*p*	df	F	*p*
S	3	1.48	ns	9	2.65	<0.05
d	3	0.26	ns	9	5.88	ns
J'	3	1.46	ns	9	0.73	<0.05
H'	3	0.47	ns	9	1.59	ns

6.2.3 Effects of Environmental Factors on Polychaeta Community

6.2.3.1. Biomass, Density and Species Number

The environmental data were compared to density and biomass of the polychaeta fauna with SRC coefficients. The ρ values obtained by the performance of SRC in each sampling period between the density, biomass, species number and environmental variables are given in Table 6.9. In winter, pH and sediment surface temperature negatively correlated with biomass and density, with the correlation coefficient $\rho = -0.733$, $\rho = -0.735$; $p < 0.05$, respectively. In spring period, salinity, pH and the distance were correlated with the biomass, density and species number.

Salinity (ρ =-0.702, ρ =- 0.782, ρ =-0.859) and distance (ρ = -0.769, ρ =-0.782, ρ =0.827) had negative correlation with the density, biomass and species number and pH was positively correlated (ρ =0.669) with biomass of the fauna. Between distance and sand content of the sediment were found a correlation in summer period. Distance had negative correlation as in spring period (ρ = -0.648, ρ =-0.697, ρ =-0.700) and sand was positively correlated with biomass and density (ρ = 0.705, ρ =0.686). In autumn, the correlation was obtained between the environmental factors including salinity, Chl-*a* and sediment surface temperature with biomass. When Chl-*a* and sediment temperature showed a positive correlation (ρ = 0.928, ρ =0.826), the salinity showed negative (ρ =-0.826).

Table 6.8.Significant Spearman's (ρ) coefficient values, showing correlations between density, dry weight biomass, number of species and the corresponding environmental factors over all sampling periods and stations (DO: dissolved oxygen, OM: organic matter, Sed. Temp**.:** Sediment surface temperature $p < 0.05$).

WINTER			
	pH	**Sed. Temp.**	
Biomass	-0,733		
Density		-0,730	
Sp. No			

SPRING			
	pH	**Salinity**	**Distance**
Biomass	-0,702	0,669	-0,769
Density	-0,782		-0,782
Sp. No	-0,859		-0,827

SUMMER			
	Sand	**Distance**	
Biomass	0,705	-0,648	
Density	0,686	0,697	
Sp. No		-0,700	

AUTUMN			
	Salinity	**Sed. Temp.**	**Chl-*a***
Biomass	-0,826	0,928	0,826
Density			
Sp. No			

6.2.3.2. Multivariate Pattern

The highest values of the harmonic Spearman rank coefficient (ρw) deriving from the performance of the BIOENV analysis in each sampling period are given in Table 6.11. The result of BIOENV analysis showed weak correlations between environmental variables and the community.

In winter, pH (ρw =0.279) correlated with the community structure, the combinations of Chl-*a*, silt and organic matter and pH, sediment surface temperature showed the next highest values of ρw. The group of variables correlated with the polychates in spring, showed a rather weak correlations compared to other sampling periods. The water temperature and ammonium, the second group with the combination of salinity, sediment temperature with ammonium and just ammonium had almost similar correlations. In summer, Chl-*a* showed a value of 0.284, with joining of pH the correlation value was 0.282 and of water temperature the value was 0.268. Organic matter content and particle size of the sediment best correlated with fauna in autumn.

Table 6.9 Summary of the combinations of the environmental variables showed the the harmonic spearman rank coefficient (ρw) with fauna in the sampling periods.

Environmental variables	**ρw**
WINTER	
pH	0.279
Chl-*a*, silt, organic matter	0.227
pH, sediment surface temperature	0.201
SPRING	
Water temperature, ammonium	0.013
Salinity, ammonium, sediment surface temperature	0.012
Ammonium	0.009
SUMMER	
Chl-*a*	0.284
pH, Chl-*a*	0.282
Water temperature, Chl-*a*	0.268
AUTUMN	
Organic matter	0.261
Sand, silt	0.251
Silt	0.250

6.2.4. Community Pattern of Monthly Sampling

Monthly sampling stations were chosen according to the abundance of the polychaeta species. In all stations a similar trend was observed in the total number of individuals of the polychaeta species. In April, the abundance of the group was the highest at B3 and C3, however the highest number of individuals at D2 in September. The polychaeta abundance was the lowest in August at stations B3, D2 and in September at C3 (Fig. 6.8).

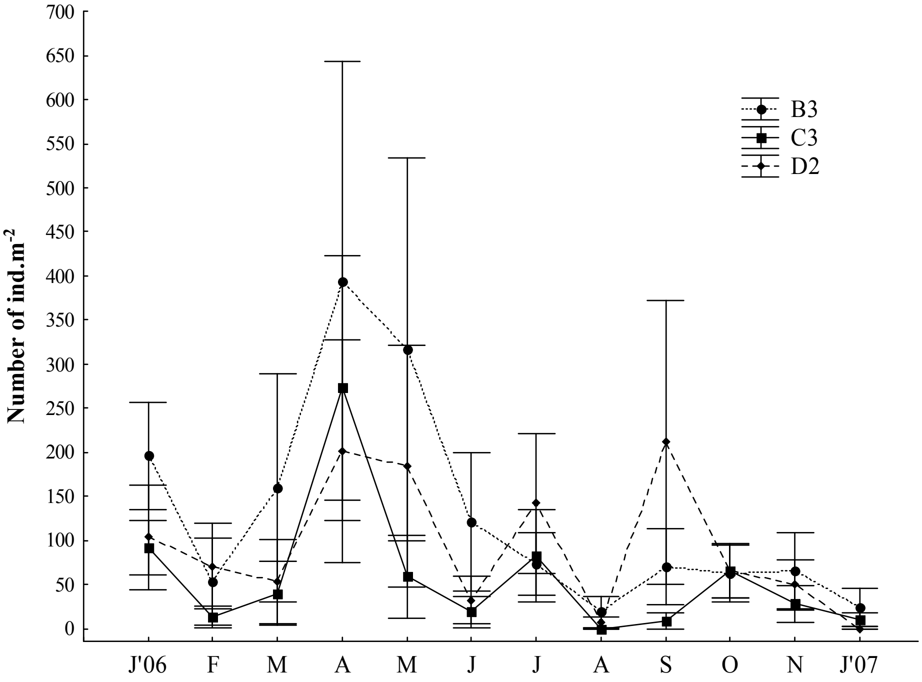

Figure 6.8 .Monthly variation in the total number of individuals of the polychaetes in stations B3, C3 and D2 during the sampling period (symbols; mean. bar lines; standard error).

The variations in density and biomass throughout the sampling period from January 2006 to January 2007 are given in figures 6.9 and 6.10. The community was characterized by *H. filiformis*, *G. tridactyla* and accompanied these species mainly *H. diversicolor*, *C. capitata*, *S. decoratus* . Some species such as *S. shrubsolii*, *P. ciliata, N. hombergii, C. giardi, S. tentaculata, P. multibranchiata, M. fuliginosus* had been presented with lower number of individuals than other species in the lagoon. *C. giardi* and *P. multibranchiata* were recorded only one time throughout the sampling period.

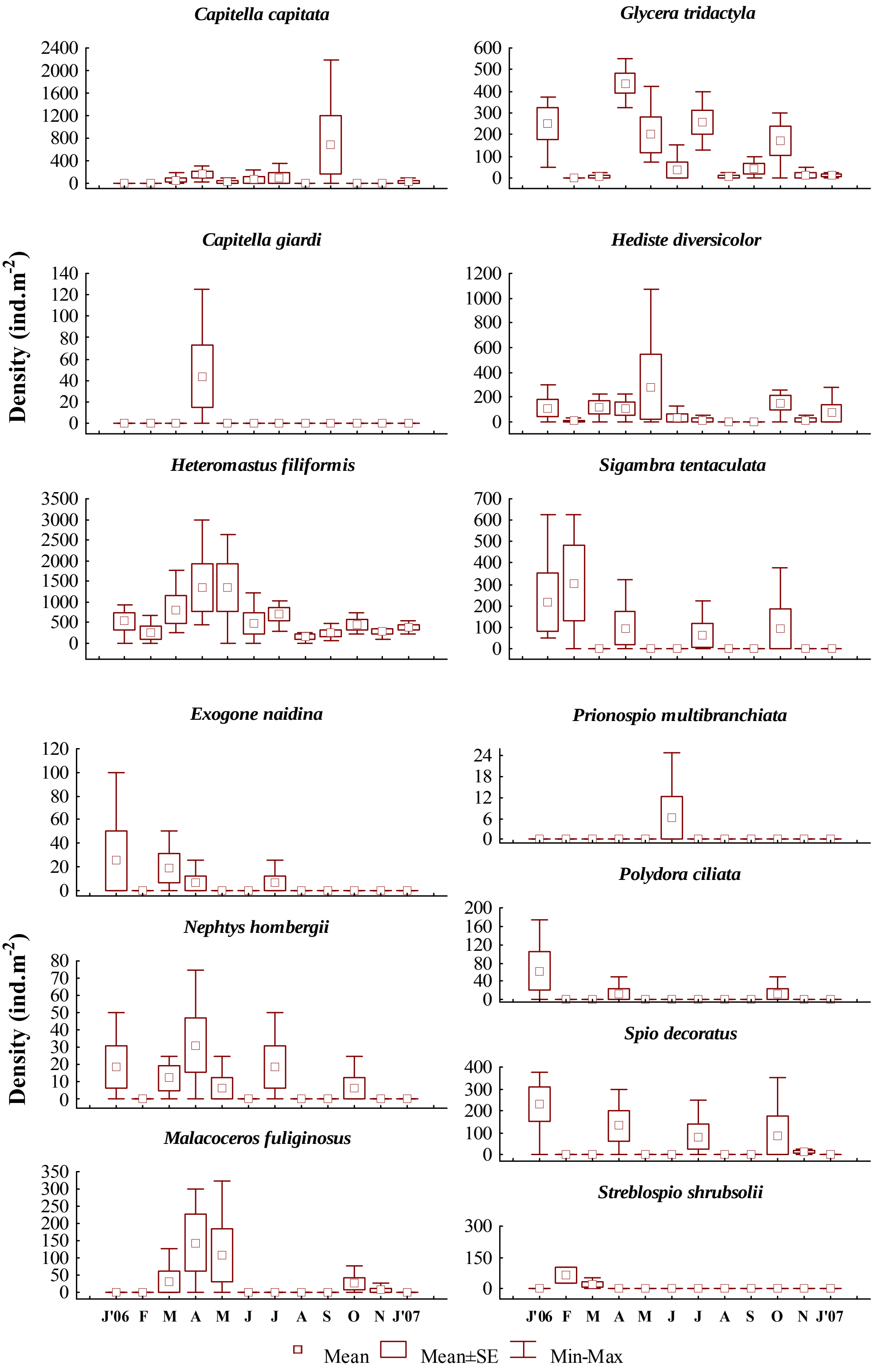

Figure 6.9 The variations in density of polychaeta species throughout the sampling period from January 2006 to January 2007.

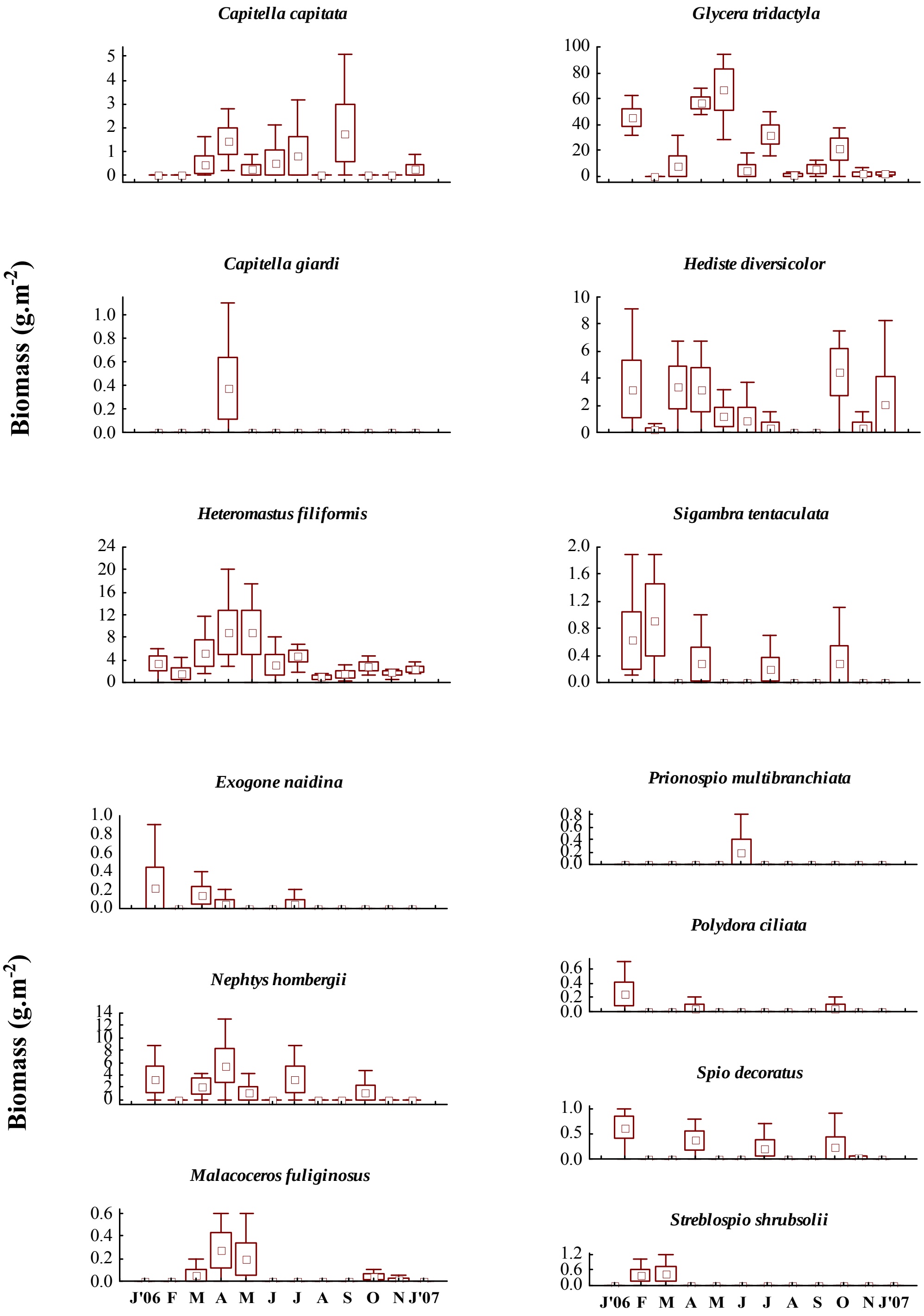

Figure 6.10 The variations in biomass of polychaeta species throughout the sampling period..

The mean biomass value concerning *G .tridactyla* was highest among other species and its maximum biomass value was observed in May. *G .tridactyla* was presented in April and May, with high density and biomass, respectively. In April, the individual of the species was small but in high quantity. This situation reflected on the biomass value measured in May. The highest mean biomass of *H. filiformis* was observed in April like its density value. The individuals probably included into the population in early spring and increased the both density and biomass values.

6.2.5. Secondary Production of the Species

Secondary production of three sampling stations is presented by species and stations and annual secondary production in Table 6.13.

Table 6.10 Mean annual biomass (B, g Dw m^{-2}) and secondary production (P, g Dw m^{-2} yr^{-1}) of the polychaeta community at the three sampling stations by species.

	Station B3			**Station C3**			**Station D2**		
	P	***B***	***P/B***	***P***	***B***	***P/B***	***P***	***B***	***P/B***
C.capitata	2.15	2.07	1.04	2.02	0.94	2.15	1.63	8.07	0.20
H.filiformis	2.03	7.14	0.28	1.91	3.10	0.62	1.70	4.05	0.42
G.tridactyla	1.93	20.00	0.10	1.70	26.67	0.06	1.51	28.24	0.05
H.diversicolor	2.01	8.78	0.23	1.92	2.77	0.69	1.74	2.64	0.66
S.tentaculata	2.36	0.23	10.14	2.20	0.16	14.16	1.86	0.75	2.48
E.naidina	2.30	0.45	5.10				1.97	0.23	8.76
N.hombergii	2.01	8.78	0.23	1.88	4.39	0.43			
M.fuliginosus				2.12	0.34	6.21	1.96	0.25	7.87
P.ciliata	2.33	0.32	7.40	2.11	0.39	5.48			
S.decoratus	2.26	0.67	3.36	2.10	0.42	5.00	1.93	0.35	5.51
S.shrubsolii	2.23	0.90	2.48	2.10	0.44	4.76	1.95	0.28	6.97

In station B3, the annual production value of *S .tentaculata* (2.36 g DW m^{-2} yr^{-1}) was the highest value and the production of *G. tridactyla* (1.93 g DW m^{-2} yr^{-1}) had lowest value. The same species *S. tentaculata* (2.20 g DW m^{-2} yr^{-1}) had highest production value and *G. tridactyla* (1.70 g DW m^{-2} yr^{-1}) had the lowest annual production observed in station C3. The annual production of *E. naidina* (1.97 g DW m^{-2} yr^{-1}) and *G. tridactyla* (1.51 g DW m^{-2} yr^{-1}) had highest and lowest production values displayed in station D2, respectively.

6.2.6. Feeding Guilds of the Species

The polychaeta species of the lagoon were categorized in four feeding guilds; surface deposit feeders, burrowers, filter feeders and carnivores. The dominant component of polychaeta fauna in terms of number of species is characterized by surface deposit feeders and burrowers (subsurface deposit-feeders). The dominant group (surface and subsurface deposit feeders) composed of 61% of polychaeta fauna. Carnivores and filter-feeders follow with 23 and 8% respectively. Burrowers were abundant feeding guild at all stations in most of the sampling period the sampling period besides they were the single feeding guild observed in August at station B3 and in February. June, September at station C3 burrowers were the only feeding guild. Carnivores followed burrowers as a second frequently seen feeding guild in all stations. Although surface deposit feeders were not seen as frequently as burrowers and carnivores, they showed dominancy in terms of their higher abundance.

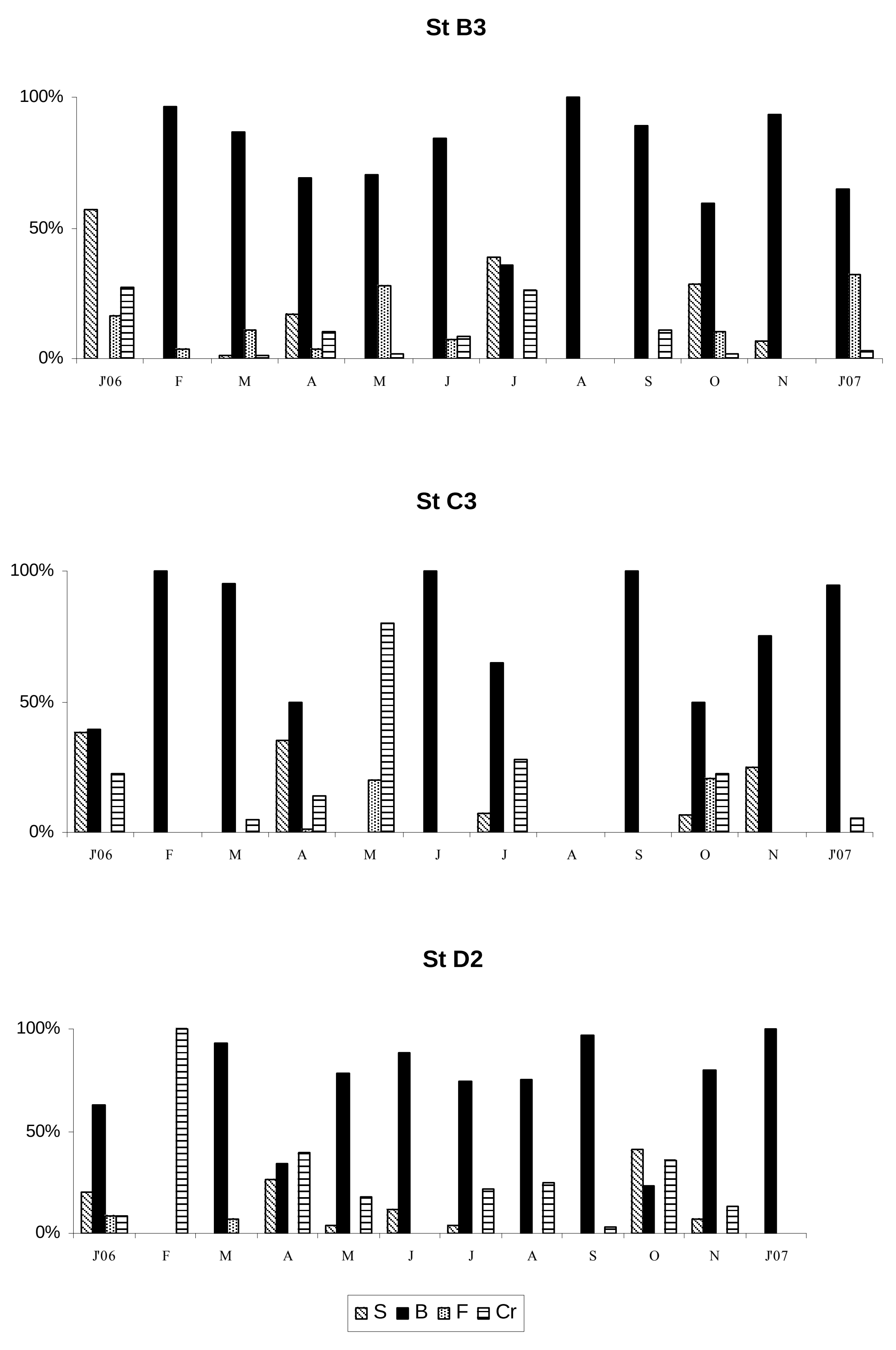

Figure 6.11 Feeding guild composition of polychaetes in the sampling period (S: surface deposit feeders. B: burrowers. F: filter feeders. Cr: carnivores

CHAPTER SEVEN
DISCUSSION

7.1 Faunal Composition Pattern

In Mediterranean coastal lagoons, the benthic community is represented mainly by the groups including opportunistic species with high tolerance to organically enriched sediment and another group of typically euryhaline brackish-water species which are characteristic of lagoon zones (Lardicci et al. 2001). The species of Homa lagoon has been taken a part of both categorizations (Nicolaidou et al. 1988; Cardell et al. 1999; Ergen et al. 2002; Mistri et al 2002; Kevrekidis 2005).

The species list of the polychaetes observed in this study showed differences when compared to other studies had performed in the Homa Lagoon and in the Gediz Delta. It can be said that the polychaeta fauna appeared to be impoverished and some species became as a dominant species. In the present study; 13 polychaeta species were recorded, the species *Capitella giardi* was the first time recorded in the lagoon and the dominant species of the lagoon was *Heteromastus filiformis*. In the study of Onen (1990), 28 polychaeta species were recorded such as *Nereis* sp., *Archiannelida* (sp.), *Capitella capitata*, *Glycera tridactyla* and *Notomastus* sp. and the most dominant species was *Nereis* sp. The distribution of polychaeta fauna in Gediz Delta was introduced by Tas (2000) and the Homa Lagoon was among the sampling stations in the study. There were 19 polychaeta species recorded in the thesis study of Tas (2000) and Ergen et al. (2002); *Glycera tridactyla*, *Spio decoratus*, *Prinospio multibranchiata*, *Streblospio shrubsolii*, *Capitella capitata* and *H. filiformis* were the species observed in all sampling period, *Spio decoratus* was the dominant species of the lagoon and in the outer part of the lagoon, *H. filiformis* was dominant. The distribution of soft bottom polychaetes in Izmir Bay was presented between years 1997 and 2002 by Ergen et al. (2006). The group of stations which some of them were close to the Homa Lagoon was represented by a total of 190 species and the species showed dominancy were different from the lagoon.

The fauna of the lagoon was characterized generally by a higher dominance and abundance of opportunistic species which can be called small sized r selected forms (Mistri et al., 2001). The soft bottom of polychaeta fauna of Izmir Bay was categorized into four major species assemblages due to the multivariate analysis (Ergen et al., 2006). The fauna characteristics of the lagoon comprises the species from the group developed in the polluted inner bay with high population densities of opportunistic species such as *Capitella capitata*, *Heteromastus filiformis*, *Malacoceros fuliginosus* (Mistri et al., 2001; Ergen et al., 2006).and the second group including *Glycera tridactyla*, *Nepthys hombergi*i, *Spio decoratus* inhabiting in sandy sediments which can tolerate small amounts of mud and organic matter (Ergen et al., 2006).

7.2 Diversity

The species composition of the polychaeta community in the Homa lagoon seems quite similar to the situation previously found in other Mediterranean lagoonal ecosystems (Mistri et al., 2001, 2002) that is a limited number of species, a strong dominance in abundance by a few of these species and a relatively low diversity.

Diversity in the Homa Lagoon compared to that of other studies in Mediterranean lagoons (Martin et al., 1993; Arvanitidis et al., 1999; Ergen et al., 2002; Mistri et al., 2002) in Table 7.1.

Table 7.1 The comparison of diversity values of Homa lagoon with other lagoons.

Location	Lagoon	H’	Reference
Spain	Ebro	0.2 - 3.3	Martin et al., 1993
Greece	Gialova	0.8 - 1.9	Arvanitidis et al., 1999
Italy	Valli di Comacchio	0.3 - 2	Mistri et al., 2002
Turkiye	Homa	2 - 3	Ergen et al., 2002
	Kırdeniz	0 - 1.5	Ergen et al., 2002
	Cilazmak	0.4 - 2	Ergen et al., 2002
	Homa	0.7 - 1.1	This study

The highest diversity was observed in spring (1.1) and the lowest diversity was in summer (0.7). Spring is the time period when an increase was occurred in species number, density and diversity with the appropriate environmental factors affect on the fauna (Gravina et al., 1989). Spring period was also favourable for the fauna in Homa lagoon. In the previous studies in Kırdeniz, Homa and Çilazmak lagoons, the diversity showed differences among lagoons (Ergen et al., 2002). The diversity value of the fauna inhabiting Kırdeniz Lagoon ranged 0 (summer) - 1.5 (spring), the values ranged 2 (spring) – 3 (winter) in the Homa Lagoon and in Çilazmak Lagoon, the values were between 0.4 (autumn) – 2 (summer). Diversity values of this study were similar with Kırdeniz Lagoon situated close to the Gediz River. In the study of Ergen et al. (2002), it is mentioned that the species occurred in the stations including Kırdeniz, Homa lagoons and one more station closer to the Gediz River had relatively low number of species.

In other Mediterranean lagoons, e.g. in the Gialova Lagoon, summer and autumn were the sampling periods when the highest and lowest diversity are observed, respectively. As a result of the annual sampling period, the fauna in Valli di Comacchio showed both highest and lowest diversity values in summer. Low diversity is a result of the variable environmental conditions in the lagoons which are originated by their shallowness and restricted communication with the marine environment due to seasonal variations (Reizopoulou. & Nicolaidou, 2004).

Natural stress levels increase with increase in confinement which results in a decrease in the variety of species and an increase in the density of individuals of a few species (Reizopoulou. & Nicolaidou. 2004). In the Gialova lagoon, diversity values of the stations which were close to the opening to sea were higher than the other stations (Arvanitidis et al., 1999). In the Homa lagoon the stations which were closely located to the canal opening to Izmir bay had higher diversity values, besides the negative correlation was occurred between the distance and the number of species, density and biomass of the polychaeta fauna in spring and summer.

7.3 Environmental Factors affecting on Density, Biomass and Distribution of the Species

In all sampling period, the environmental factors showed high correlations with the density and biomass of the fauna, however they had a weak correlation with the distribution the species.

In winter, pH and sediment surface temperature showed a negative correlation with the biomass and the density of the fauna with a high correlation coefficient. The distribution was governed by pH and secondly by the combination of Chl-a, silt and organic matter content of the sediment. pH showed negative correlation with both density, biomass and salinity showed positive correlation with biomass of the fauna. The combination of water temperature and ammonium had a very weak correlation coefficient on the distribution in spring. The biomass and density of fauna in summer was affected by sand particle size of the sediment with positive correlation, another environmental variable Chl-a governed the distribution of the polychaeta species. In autumn period, salinity was negatively correlated with biomass, besides sediment surface temperature and Chl-a were positively correlated. Organic matter and sand-silt content of the sediment were effective on the distribution.

Distribution of soft bottom polychaetes has been related to sediment characteristics, depth, temperature and salinity (Moreira et al., 2006). Sediment particle size, inflow of fresh water and the contribution of nutrients are also very important in controlling diversity (Gravina, Ardizzone, Scaletta & Chimenz, 1989).The decrease occurred in temperature values generally causes a reduction in activity and reproduction of the fauna (Gravina et al., 1989; Kevrekidis, 2005).

Salinity has been considered as a major factor controlling the species distribution; some authors have indicated that the salinity variability is not the main factor on the contrary to this approach (Lardicci et al., 1997; Bazairi et al., 2003). In the Homa Lagoon, salinity negatively correlated with the density and biomass of the fauna, however it had a weak correlation with the distribution, consequently salinity seemed to play a minor role in the distribution the species.

Nutrient concentrations are related to some environmental factors such as temperature (Arvanitidis et al., 1999). In the Gialaova Lagoon, phosphate concentration was the only nutrient which is correlated with the distribution of the fauna and the phosphates are mentioned as a better indicator of anoxic conditions (Arvanitidis et al., 1999). In the Homa Lagoon, ammonium and water temperature had a weak correlation with the distribution. Both ammonia and dissolved oxygen are effective on the distribution when nitrogen originating form the decomposition of organic matter in sediments transformed to ammonia under reducing oxygen levels (Mistri et al., 2002).

Summer was characterized by the typical dystrophic crisis due to higher temperature, salinity and lower oxygen concentration (Gravina et al., 1989), Chl-a concentration with the oxygen limitations can cause for the fauna in utilizing the food sources (Arvanitis et al., 1999). In summer, distribution of the fauna in the lagoon was affected by Chl-a values with pH and water temperature. The decreasing temperature and water mixing made the sediment more oxygenated and supply a suitable habitat for the benthic organisms (Gravina et al., 1989) in autumn. Organic matter was found to be correlated with the distribution of the fauna in the lagoon. Chl-a and sediment temperature were positively correlated with the biomass. Both organic matter and associated microorganisms supply food for deposit feeders (Tsutsumi et al., 1990).

7.4 Secondary Production of the Fauna

Production is the result of metabolic processes and ecologists have known for many years that the temperature affects on the biological activities (Tumbiolo & Downing, 1994). Tumbiolo & Downing (1994) developed a model on marine populations that includes the effect of environmental variables such as temperature and depth which were supposed to have strong influence on marine benthos production. They highlighted the strong effect of temperature on production in marine environments.

Although it is rather difficult to make detailed comparison among different studies and locations because of differences in sampling procedures, taxa considered, mesh size and the calculation method adopted, the production estimates in this study are compared to the other production values which are given by other authors. In natural populations and communities, the P/B ratio has been shown to decrease with the age of an organism (Mistri et al., 2001). The life cycle of the species *G. tridactyla* and *N. hombergii* are more than a year period and the annual production value of these species were lower than the annual production of other species.

Table 7.2 Secondary production of polychaetes obtained from other studies.

	Biomass	**Production**	**P/B**	**Reference**
S.decoratus	0.0005	0.016	8.00	Mistri et al., (2001)
	0.3-0.7	1.93-2.26	3.36-5.51	This study
S.shrubsolii	0.008-0.047	0.059-0.341	7.20-7.38	Mistri et al., (2001)
	0.201-0.286	0.449-0.611	2.14-2.23	Kevrekidis (2005)
	0.28-0.9	1.95-2.23	2.48-6.97	This study
C.capitata	0.034-0.145	0.246-0.994	6.86-7.24	Mistri et al., (2001)
	0.94-8.07	1.63-2.15	0.2-1.04	This study
H.diversicolor	0.1-0.6	0.3-2.8	3.4-4.3	Dolbeth et al., (2003)
	4.6-9.6	5.1-34.4	1.1-3.6	Gillet& Torresani., (2003)
	2.64-8.78	1.74-2.01	0.23-0.69	This study
P.ciliata	0.0077-0.042	0.057-0.822	7.12-7.40	Mistri et al., (2001)
	3.3	1.4		Sprung, (1994)
	0.32-0.39	2.11-2.33	5.48-7.4	This study
H.filiformis	0.0005	0.0004	8.00	Mistri et al., (2001)
	7.1	3.3		Sprung, (1994)
	3.10-7.14	1.7-2.03	0.28-0.42	This study
N.hombergii	0.047-0.078	0.138-0.220	2.82-2.94	Mistri et al., (2001)
	276.9	116.2		Sprung, (1994)
	4.39-8.78	1.88-2.01	0.23-0.43	This study
G.tridactyla	1095.6	353.1		Sprung, (1994)
	20-28.24	1.51-1.93	0.05-0.1	This study

In the Homa lagoon, the numerically dominant smaller species despite their high abundance contributed poorly to the community production compared to the bigger ones. On the other hand, since P/B declines with body size, such species exhibit higher renewal rates and are more resilient to environmental variations (Tumbiolo & Downing, 1994; Mistri et al., 2001). Sandy and muddy bottoms are less productive, as mentioned in the study of Dolbeth et al, (2003). They compared the areas covering with macrophytes and unvegetated areas. The habitats covered with mocrophytes supply species advantages of the protection from predators and food resources. Therefore, the production in these habitats is higher than muddy habitats.

7.5 Feeding Guilds

The presence or absence of some specific species in sediments provides an indication of the conditions of benthic environments (Carraso & Carbajal, 1998). In muddy sediments such as lagoons', marked seasonal fluctuations in density of the fauna which are dominated by deposit feeders have been observed (Lardicci & Rossi, 2002). Densities generally show peaks during spring and early summer. In late summer and autumn, these populations often decline. This case is related to the availability of food in the sediments (Lardicci & Rossi, 2002). In particular, the depletion of food in summer has been indicated as an important factor in limiting the growth of populations (Lardicci & Rossi, 2002).

In the present study, deposit-feeders were dominant; generally they were positively correlated with muddy sediments and organic matter content. An increase in species belonging to the families Spionidae and Capitellidae such as *Capitella capitata*, *Heteromastus filiformis*, *Polydora ciliata* is probably related to the increase in the organic matter content in sediments (Sprung, 1993). The sediment characteristic of the Homa Lagoon was rather uniform. The level of organic matter in sediments is related to the sediment grain size (Magni et al., 2004). The organic matter content of three monthly sampled stations were ranged 1.6 to 3.3 % with the highest value was observed in station C3 and the lowest in station D2.

Due to percentage of organic matter content, the burrowers were dense at stations B3 and C3 when compared to D2.

The feeding habits showed variations among the polychaeta species; Some capitellids build tubes at or near the surface of the sediment like *Capitella capitata*, some others build horizontal or vertical tubes or burrows up to 15 cm below the surface like *Heteromastus filiformis*. *Hediste diversicolor* had various feeding characteristics due to the environmental conditions and food type or carnivores species like *Nepthys hombergii* and *Glycera tridactyla* can feed on small sized polychaetes. (Fauchald & Jumars, 1979).

CHAPTER EIGHT
CONCLUSION

In this study, the composition and distribution of the polychaeta fauna on the soft bottom of the Homa Lagoon were presented with the relations between key environmental variables affected on the fauna and faunal distribution patterns between sampling periods January 2006-January 2007.

Taxonomic works have been recently published on the polychaeta fauna of the lagoon, but the soft bottom polychaeta fauna of this lagoon is poorly known in ecological studies. This study provided an opportunity to be able to make a comparison with the previous studies in the same area and revealed new features in some ecological properties of the fauna (feeding guilds, secondary production) and the environmental factors affecting fauna diversity and distribution.

A different viewpoint is tried to be presented to the polychaeta fauna of the Homa Lagoon as a result of this dissertation. When the results are compared to the previous studies, the impoverishment was observed in the fauna of the lagoon. Variations were determined in the diversity and distribution of the species. The characteristic species still have been occurred in the lagoon, but the dominant species of the lagoon were different. The highest and lowest diversity values were obtained in spring and summer, respectively due to seasonal variations in environmental factors. The increase in confinement was also effective on the density and biomass of the fauna. Salinity and pH had stronger influence in the seasonal period among environmental factors and they play a role in the variation of density and biomass. The distribution of polychaetes were governed by some environmental factors, although had a weak relationship.

The secondary production and feeding guilds of the polychaetes investigated firstly in the lagoon. The surface and subsurface deposit feeders were abundant in the lagoon due to uniform sediment type and organic matter related to particle size.

Coastal lagoons are unpredictable environments and the influence of both marine and terrestrial factors can be observed in lagoons because of their position between land and sea. As related to the characteristics of the lagoons, the fauna can also show variations in the time periods. Long-term studies can be recommended to distinguish meaningful changes in the overall structure of the lagoon and interactions in benthic assemblages to manage and preserve as a sustainable habitat for all living resources in the Homa lagoon.

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