DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

AN INVESTIGATION ON THE IMPACTS OF FISH FARMING ON THE MACROZOOBENTHOS

by
Murat ÖZAYDINLI

August, 2011
İZMİR

AN INVESTIGATION ON THE IMPACTS OF FISH FARMING ON THE MACROZOOBENTHOS

A Thesis Submitted to the
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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"AN INVESTIGATION ON THE IMPACTS OF FISH FARMING ON THE MACROZOOBENTHOS"** completed by **MURAT ÖZAYDINLI** under supervision of **ASSIST. PROF. DR. KEMAL CAN BİZSEL** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ABSTRACT

In Turkey, marine fish farming activities, using the floating cages located in the semi-enclosed coastal basins, have been developing rapidly since 1985. The impacts of these activities on benthic environment were revealed by many studies. The main goal of this study is to investigate on some possible relationships between the benthic community structure, physical parameters, dissolved inorganic nutrients and organic carbon and their usability as indicators of the impact of a fish farm located in Ildırı Bay.

Sampling was carried out during four seasonal cruises (April, July, November 2010 and February 2011) on seven stations and one reference station. Sediment samples were collected using Box Corer. The number of individuals (ind./m2) and biomass (g/m2) were determined separately for each taxon. Only Crustacea specimens were identified to lowest possible taxon. Community parameters (diversity and evenness indices) were calculated for each station in each sampling period. Cluster Analysis and Multidimensional Scaling (MDS) analysis was performed

In this study, significant differences were not found for the physico-chemical parameters between the stations. The obvious differences between the stations were not detected in major taxa level; even some fluctuations were observed in abundance and biomass of major taxa. Polychaeta was dominant at all sampling stations in all seasons. Some indicator species in Crustacea taxon allowed the evaluation of pollution factors and the degree of impact. There were not found any pollution indicator Crustacea species in farming area, but found in the area which was assumed to be in recovery process.

Keywords: fish farming, macrozoobenthos, Crustacea, organic carbon, Ildırı Bay

BALIK YETİŞTİRİCİLİĞİNİN MAKROZOOBENTOSA ETKİLERİ ÜZERİNE BİR ARAŞTIRMA

ÖZ

Türkiye’ de, yarı kapalı kıyı havzalarında yüzer kafes kullanılarak yapılan deniz balığı yetiştiriciliği faaliyetleri 1985’ den bu yana hızla gelişmektedir. Bu faaliyetlerinin bentik çevreye etkileri birçok çalışmada ortaya konmuştur. Bu çalışmanın ana amacı, bentik komunite yapısı, fiziksel parametreler, çözünmüş inorganik nütrientler ve organik karbon arasındaki bazı olası ilişkileri ve bunların Ildırı Körfezi’nde bulunan bir balık çiftiliğinin etkisini belirlemede gösterge olarak kullanılabilirliklerinin araştırılmasıdır.

Örneklemeler, bir referans ve yedi istasyonda 4 mevsimsel arazi çalışmasında gerçekleştirilmiştir (Nisan, Temmuz, Kasım 2010 ve Şubat 2011) Sediman örnekleriBox Corer kullanılarak toplanmıştır. Birey sayıları (birey/m2) ve biyokütle (g/m2) her takson için ayrı ayrı tespit edilmiştir. Sadece Crustacea türleri mümkün olan en alt taksona kadar tayin edilmiştir. Komünite parametreleri (çeşitlilik ve düzenlilik indeksleri) her örnekleme dönemindeki her bir istasyon hesaplanmıştır. Küme analizi ve Çok Boyutlu Ölçeklendirme (ÇBÖ) analizi uygulanmıştır.

Bu çalışmada, istasyonlar arasında fiziko-kimyasal parametreler açısından anlamlı bir fark bulunmamıştır. Bolluk ve biyokütlelerinde bazı değişimler gözlenmiş olsa da ana gruplar seviyesinde istasyonlar arasında bariz bir fark tespit edilmemiştir. Tüm mevsimlerdeki tüm istasyonlarda Polychaeta baskındı. Crustacea grubuna dahil olan kirlilik göstergeci bazı türler, kirlilik faktörünü ve etki derecesinideğerlendirmeye imkan sağlamıştır. Yetiştircilik alanında kirlilik göstergeci Crustacea türleri tespit edilmemiş, ancak iyileşme sürecinde olduğu varsayılan alanda tespit edilmiştir.

Anahtar Sözcükler: balık yetiştiriciliği, makrozoobentos, Crustacea, organik karbon, Ildırı Körfezi

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CHAPTER ONE
INTRODUCTION

1.1 General Information

The broad term “aquaculture” refers to the controlled or semi-controlled production of plants and animals in all types of water environments, including ponds, rivers, lakes, and the ocean (National Oceanic and Atmospheric Administration [NOAA], n.d.). Fish farming is a specialized branch of aquaculture involving the cultivation of marine fishes for food and other products in the open sea, an enclosed section of the sea.

Fish farming has rapidly expanded over the last two decades due to new technology, improvements in formulated feeds, greater biological understanding of farmed species, increased water quality within closed farm systems, greater demand for seafood products, site expansion and government interest (Read, 2003).

1.1.1 Cage Aquaculture

The on-growing and production of farmed aquatic organisms in caged enclosures has been a relatively recent aquaculture innovation. Although the origins of the use of cages for holding and transporting fish for short periods can be traced back almost two centuries ago to the Asian region, marine commercial cage culture was pioneered in Norway in the 1970s with the rise and development of salmon farming. The cage aquaculture sector has grown very rapidly during the past 20 years and is presently undergoing rapid changes in response to pressures from globalization and growing demand for aquatic products (Food and Agriculture Organization, 2007).

A boost to this industry came with the success in the controlled reproduction of the European seabass (*Dicentrarchus labrax*) and the gilthead seabream (Sparus *aurata*) which resulted in a massive production and availability of fry. During the last decade, marine finfish cage culture gained a predominant position in the sector.

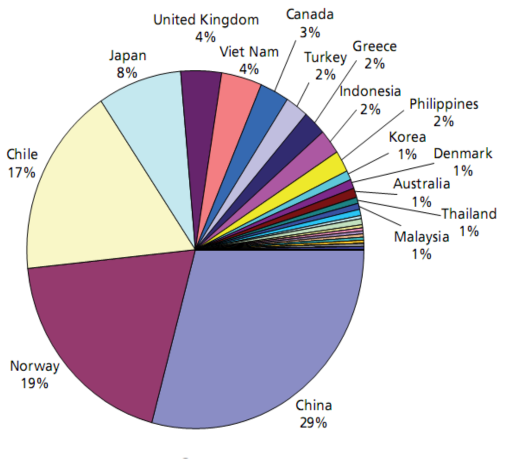
The production trend clearly demonstrates the success and spreading of this technology (FAO, 2007).

1.1.2 State of Cage Aquaculture in the World

Total reported cage aquaculture production from 62 countries and provinces/regions amounted to 2,412,167 tonnes or 3,403,722 tonnes. In 2005, the major cage culture producers are Norway (652,306 tonnes), Chile (588,060 tonnes), China (287,301), Japan (268,921 tonnes), UnitedKingdom (131,481 tonnes), Canada (98,441 tonnes), Greece (76,212 tonnes), Turkey (68,173 tonnes) (FAO, 2007) (Table 1.1)

Table 1.1 Production of the top ten marine and brackish water cage aquaculture countries (FAO, 2007).

Country	Quantity (tonnes)
Norway	652 306
Chile	588 060
China	287 301
Japan	268 921
United Kingdom	131 481
Canada	98 441
Greece	76 212
Turkey	68 173
Republic of Korea	31 895
Denmark (including Faroe Islands)	31 192



1.1.3 State of Cage Aquaculture in Turkey

Cage farming started in 1985 with the production of European seabass and gilthead seabream. The Turkish shoreline, particularly along the Aegean Sea, is similar to the Greek coast with numerous sheltered sites where cage farming can be safely practiced using conventional floating cages and mooring systems. Most marine cage farms are located in the southern Aegean coast. The production from this region was 93.1% of the whole seabass and seabream production. During the period 1995-2009, cage production increased from 7,600 tonnes to 158,729 tonnes with an average annual growth of approximately 25%. In 2009, the production share of cage aquaculture, in terms of quantity, was approximately 52% of the total national production. (Türkiye İstatistik Kurumu [TUİK], 2010; FAO, 2007)

Cage culture for these two species increased dramatically and by 2009 production was 74,916 tons. Sea bass contributes 56.4% to marine and 34.3% to total aquaculture production in 2009, while sea bream contributes 34.3% and 20%, respectively. A small share of Turkish trout production (or 6.4% of the total trout production of 80,886 tons in 2009) was and continues to be reared in marine floating cages along the Black Sea coast. (TUİK, 2010; FAO, 2007) (Table 1.2)

Table 1.2 Aquaculture productions by environment in Turkey in 2000-2009.

Tonnes

Type of fish	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	**79 031**	**67 244**	**61 165**	**79 943**	**94 010**	**118 277**	**128 943**	**139 873**	**152 186**	**158 729**
Inland water										
Trout	42 572	36 827	33 707	39 674	43 432	48 033	56 026	58 433	65 928	75657
Carp	813	687	590	543	683	571	668	600	629	591
Marine water										
Trout	1 961	1 240	846	1 194	1 650	1 249	1 633	2 740	2 721	5229
Sea bream	15 460	12 939	11 681	16 735	20 435	27 634	28 463	33 500	31 670	28362
Sea bass	17 877	15 546	14 339	20 982	26 297	37 290	38 408	41 900	49 270	46554
Mussel	321	5	2	815	1 513	1 500	1 545	1 100	1 772	89
Prawn	27	-	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	2 000	2 200	1 600	196	2247

1.2 Impact of Cage Aquaculture on Marine Ecosystem

Fish farming was once considered an environmentally benign practice, but is now viewed as a potential polluter of the marine environment (Findlay, & Mayer, 1995).

The generation of organic wastes from uneaten feed and fish fecal matter is a major concern in marine and freshwater aquaculture. Fin- and shell-fish aquaculture produces organic wastes, the bulk of which are in the form of faeces and uneaten feed settling out of net-pens or effluent to the sediments. Soluble products of food and excretion are also present. Mortalities in cultured organisms further contribute to organic waste loadings. (EVS Environment Consultants Report, 2000)

Commonly identified environmental impacts of marine farms in many literatures were listed at Table 1.3.

Table 1.3 Commonly identified environmental impacts of marine fish farms (reviesed from Mantıkçı, 2009; Okumuş, 1997)

Medium	Impact
Water Column	Eutrophication
	Modifications in phytoplankton composition and toksic algal blooms
	Settlement of fouling organism
	Depletion of dissolved oxygen and anoxia
Benthos	Organic enrichment
	Increasing in sedimentation
	Decreasing in redox potential
	Decreasing in biomass, abundance and species composition of macrofauna
	Increasing in biomass and abundance of opportunistic species
	Using of antibiotics

Several studies carried out in the Mediterranean have addressed the effects of fish farming on different components and/or features of the ecosystems investigated (Table 1.4).

Deposition of organic material under the cages may cause changes in the composition of basic benthic communities in terms of abundance, dominance and species richness (Pearson & Rosenberg, 1978). Changes in benthic macro faunal community structure have been widely used to detect organic enrichment (Pearson & Rosenberg, 1978). The effects on benthic community structure of organic loading originating from fish farms are most pronounced under and in the immediate vicinity of fish cages but less so at increasing distances from farming operations (Weston, 1990). Particularly in semi-enclosed marine areas with weak currents, the sediment characteristics beneath and around fish farm cages change with the accumulation of uneaten food, metabolic waste and faeces (Maldonado, Carmona, Echeverría, & Riesgo, 2005).

Table 1.4 Studies carried out in the Mediterranean addressing the effects of fish farming on different components and/or features.

Publication	**Year**	**Location**	**Impact on/Process of**
Karakassis, Tsapakis, & Hatziyanni	1998	Ionian Sea and Aegean Sea (Greece)	Sediment chemistry
Karakassis, Hatziyanni, Tsapakis, **&** Plaiti	1999	Ionian Sea (Greece)	Benthic recovery
Katavic & Antolic	1999	Adriatic Sea (Croatia)	Nutrient concentrations & macrobenthic communities
Karakassis, Tsapakis, Hatziyanni, Papadopoulou, & Plaiti	2000	Ionian Sea and Aegean Sea (Greece)	Sediment geochemistry & benthic macrofauna
Mazzola, Mirto, La Rosa, Fabiano & Danovaro	2000	NW Mediterranean Sea-TyrrhenianSea (Italy)	Benthic (Meiofauna)
Karakassis, Tsapakis, Smith, & Rumohr	2002	Ionian Sea (Greece)	Sediment profiling imagery
Mirto, La, Gambi, Danovaro, & Mazzola	2002	NW Mediterranean Sea-TyrrhenianSea (Italy)	Benthic (Meiofauna)
Belias, Bikas, Dassenakis, & Scoullos	2003	Ionian Sea and Aegean Sea (Greece)	Nutrient concentrations & trace metals
Maldonado, Carmona, Echeverría, & Riesgo	2005	Mediterranean Sea (Spain)	Nutrients, Bacterioplankton & benthic macrofauna
Klaoudatos, Klaoudatos, Smith, Bogdanos, & Papageorgiou	2006	Western Aegean Sea (Greece)	Nutrient concentrations & benthic macrofauna
Yucel-Gier, Kuçuksezgin & Koçak	2007	Eastern Aegean Sea (Turkey)	Nutrient concentrations & macrobenthic communities
Neofitou & Klaoudatos	2008	Western Aegean Sea (Greece)	Nutrient concentrations
Yucel-Gier, Uslu, & Bizsel	2008	Eastern Aegean Sea (Turkey)	Nutrient concentrations & plankton communities
Kaymakçı-Başaran, Aksu, & Egemen	2010	Southeastern Aegean Sea (Turkey)	Nutrient concentrations & accumulation of heavy metals
Papageorgiou, Kalantzi, & Karakassis	2010	Ionian Sea (Greece)	Organic enrichment & benthic macrofauna

As with most farming practices, the degree of environmental impact depends on the size of the farm, the cultured species, stock density, type of feed, hydrography and sediment type of the site, and husbandry methods (Şahin, 2004; Kaymakçı-Başaran, Aksu, & Egemen, 2007).

The measurement of changes in the structure of marine communities in combination with appropriate environmental variables is widely used for detection and monitoring of human impact on marine environment (Pearson & Rosenberg, 1978) also which is the main goal of this study. The approach seized upon for the study is to investigate on some possible relationships between the benthic community structure, physical parameters, dissolved inorganic nutrients and organic carbon as well as their usability as indicators of the impact of a fish farm located in Ildırı Bay.

CHAPTER TWO
MATERIAL AND METHOD

The study is conducted as an integral part of the research project carried out between 2008-2011 which was supported by TUBITAK (The Scientific and Technological Research Council of Turkey).

2.1 Study Area

The Bay of Ildırı is located at the middle-Western coasts of Anatolia Peninsula in Turkey. It is surrounded by Çeşme and Karaburun Peninsulas. At the entrance of the bay, there are some islands that separate the bay from Sakız (Chios) Strait (Figure 2.1).

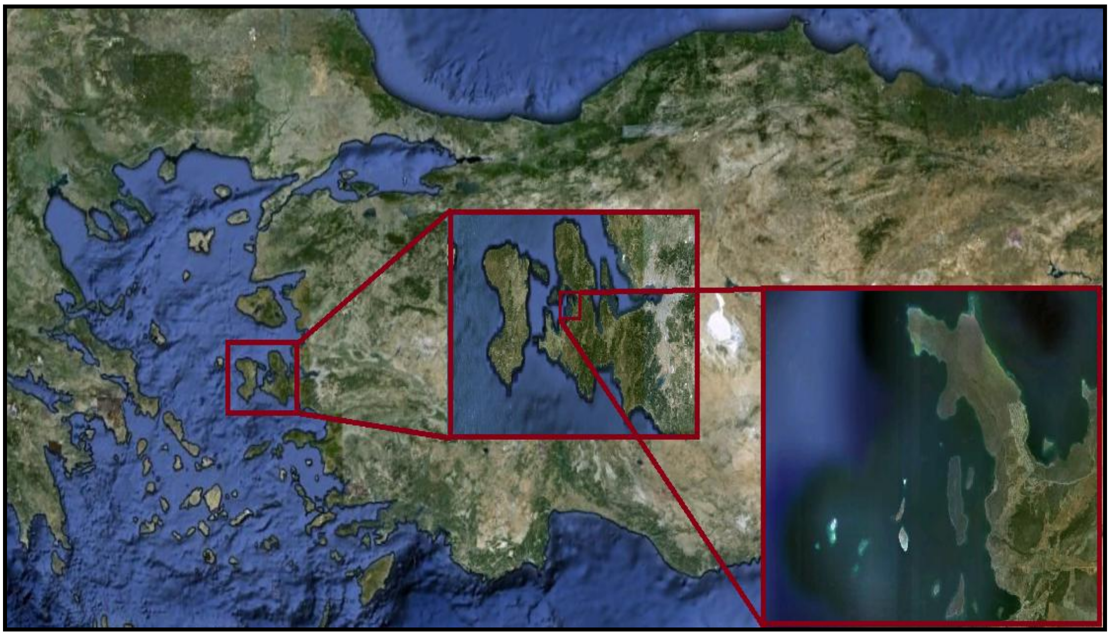


Figure 2.1 Location of the study area (Ground images with different scales are from Google Earth, 2011)

The bay is characterized with high density of aquaculture activity and tourism. The data from The Provincial Agriculture Directorate (TIM) shows that 15,690 tonnes of aquaculture fish (seabream, seabass and bluefin tuna) capacity per year are produced by 20 facilities in Ildırı Bay (Demirel, 2010). Regarding tourism, Çeşme town, which is one of the most popular tourism area in Mediterranean, is located at southern side of Ildırı Bay. Particularly during the period between late spring and early autumn, the tourism activity in the area is highly intensive, and thus, it is the other impact source for marine ecosystem (Demirel, 2010).

2.2 Sampling Stations

Sampling was carried out during four seasonal cruises (April, July, November 2010 and February 2011) aboard the 'R/V Dokuz Eylül 1' and 'R/V K. Piri Reis', at seven stations (St1-St7) and one reference station (StR). St5 and St7 were closely around the fish cages, while St6 was relatively distant. The other four stations, St1, St2, St3 and St4, were at the shallower zone where the fish cages were moored previously until the year that the study began. According to fish farming exist or not, study area were divided into three sub-areas. An area (St 5, 7) was fish farmig area, another (St 6, R) was non farming area and the other (St 1, 2, 3, 4) was in recovery process. The locations of stations were showed in Figure 2.2 and their sea bottom characteristics were described in Table 2.1.

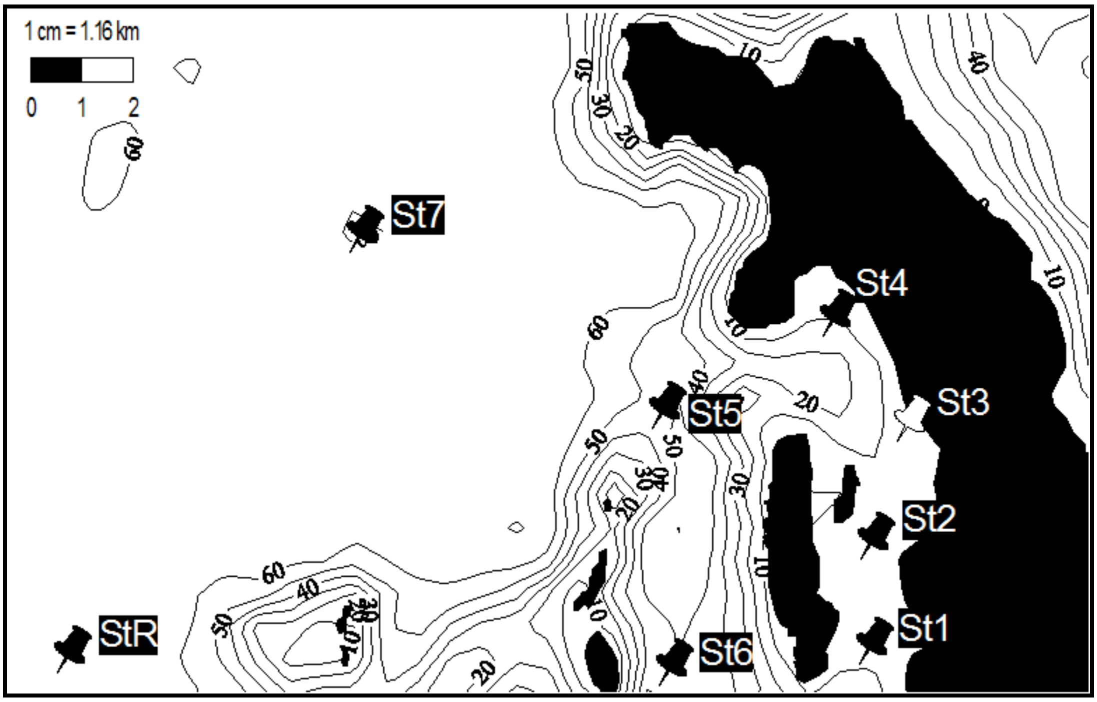


Figure 2.2 Locations of sampling stations.

Table 2.1 Characteristics of sampling stations

Stations	Biotope	Depth
St1	Fine sand, Silt-Clay, Posidonia	15
St2	Fine sand, Silt-Clay, Posidonia	10
St3	Fine sand, Silt-Clay, Posidonia	15
St4	Fine sand, Silt-Clay, Posidonia	20
St5	Coarse and Fine sand, Silt-Clay	50
St6	Coarse and Fine sand, Silt-Clay	50
St7	Fine sand, Silt-Clay	70
StR	Fine sand, Silt-Clay	60

2.3 Physico-chemical Parameters of Seawater and Sediment

The physical properties of the seawater, such as temperature, salinity and density, were measured and recorded in situ by using the CTD profiler (SBE SEACAT Profiler 19 plus). WTW Multi 340i was used for pH measurements. A modified version of the classical Winkler Method (Winkler, 1888) was used for determining the dissolved oxygen (DO) concentrations (Strickland and Parsons, 1972).

For analyses of inorganic macro nutrients in the water samples just above the sea bottom which were collected by GoFlo sampling bottles, different specific methods were used as described in the following.

After collection, the water samples were firstly filtered through GF/F filters (0.7 μm) and then, the filtered water were stored and frozen into 100 ml plastic bottles, all which pre-washed with 10% HCl acid and rinsed with distilled water. Nitrate+Nitrite and Phosphate (NO_3^--N+NO_2^--N and o.PO_4-P) were measured spectrophotometrically by using a 2 Channel Scalar Autoanalyzer, according to procedures given by Strickland & Parsons (1972) and Grasshoff, Ehrhardt, & Kremling (1983), respectively. Ammonium-nitrogen (NH_4^+-N) and Nitrite-nitrogen (NO_2^-N) were also measured individually by using T80 Plus UV/VIS Spectrophotometer according to procedures given by Reusch Berg & Abdullah (1977) and Grasshoff et al. (1983), respectively.

For carbon content analysis, the sediment samples collected by by Box Corer was taken into glass jars from the surface layer with a special for avoiding contamination. The samples were dried at 55 °C until a constant weight was obtained. The percentages of total carbon (TC) were determined by CHN Carlo ERBA NC2500 Elemental Analyzer according to the procedure given by Verardo, Froelich, & Mc Intyre (1990). The percentages of organic carbon (OC) were also determined by the same analyser and procedure, by running a parallel sample treated with 1N HCl acid to remove inorganic carbon.

Grain size analysis of sediment samples were performed using standard sieving and settling procedures (Türk Standartları, 1987). Textural classification of the sediment samples was based on the relative percentages of clay (<0.002mm), silt (0.002 - 0.063mm) and sand (0.063 - 2mm).

2.4 Sampling of Macrobentic Fauna

Sediment samples for analysing macrobentic fauna were collected using Box Corer with a sampling area of 0.25 m^2. Three subsamples from each sample were collected randomly by using a plexiglas sampling cores with 4.5 cm internal diameter. Each subsample was preserved in a plastic vial containing 4% formalin solution until the microscopic analysis in laboratory.

Prior to microscopic analysis, each sample was sieved through a 0.5 mm mesh sieve and was stored in a plastic vial in 4% formaldehyde. The samples were then analyzed under a stereomicroscope (Olympus SZ PT) for sorting them into major taxa (Polychaeta, Mollusca, Crustacea, Echinodermata, Spincula and Nematoda) and obtaining their wet weight rapidly after blotting the excessive liquids on absorbent paper. The number of individuals per unit area for each taxa (ind. m^{-2}) and their biomass per unit area (g m^{-2}) were determined. Only Crustacea specimens were identified to lowest possible taxon level.

2.5 Data analysis

Community parameters based on major taxa and Crustacea species were calculated for each station in each sampling period. Community parameters based on major taxa does not reflect the real species diversity and evenness in the community and they were calculated for relative comparison of the sampling stations and periods in terms of major taxa assemblages. Diversity was calculated by means of the (loge based) Shannon-Wiener index (H') (Shannon & Weaver, 1949) and evenness index (J') was calculated by Pielou (1977).

Shannon-Wiener Diversity Index

$$H' = -\sum_{i=1}^{S} \frac{Ni}{N} \log_e\left(\frac{Ni}{N}\right)$$

S= the number of species in the sample, N= the total number of individuals, and Ni= the number of individuals in the ith species (i= 1 to k).

Pielou Evenness Index

$$J' = \frac{H'}{\log_e S}$$

H'= Shannon-Wiener index, S= the number of species in the sample

Cluster analysis was performed using the Bray-Curtis similarity index (Bray & Curtis, 1957) to obtain the degree of similarity in taxa and species composition between sampling stations. Furthermore, Multidimensional Scaling (MDS) ordination analysis was performed using the Bray-Curtis similarity index to obtain a 2D plot of the spatial and temporal changes in major taxa and species composition of macrofaunal assemblages. Before this, transformation of the data was done, according to Clarke & Warwick (2001), for reducing the influence of dominant and rare taxa and species. Calculations were done using the PRIMER v.5 software package. Statistical analysis (One-way ANOVA, post hoc Tukey HSD, Spearman Rank Order Correlation) were done using STATISTICA 8.0 software package

CHAPTER THREE

RESULTS

3.1 Physico-chemical Parameters

The temperatures prevailing over the sea bottom water expectedly homogenous at all the sampling stations. The only remarkable difference was observed in July 2010, between the stations shallower (St1, St2, St3, and St4) and deeper (St5, St6, St7, and StR) than 50 m. This difference reflected on the range between 14.9 ^{o}C to 24.7 ^{o}C for the stations shallower than 50 m, the range between 14.7 ^{o}C to 20.2 ^{o}C for the deeper stations (Figure 3.1). The highest temperature value was recorded at St1 in July 2010, while the lowest temperature value was recorded at St7 and StR in February 2011.

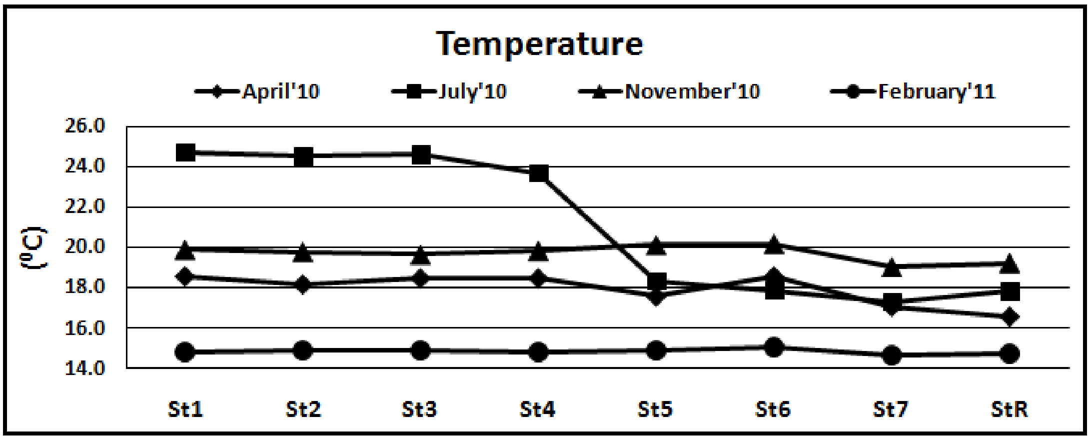


Figure 3.1 Spatio-temporal fluctuations of temperature for all sampling stations and periods

Salinity was usually constant. The only slight fluctuations were observed at the shallower stations during the rainy seasons *i.e.*, in April and November. The highest value was recorded at St2 and St3 in July 2010; while the lowest value was recorded at St4 in April 2010 (Figure 3.2).

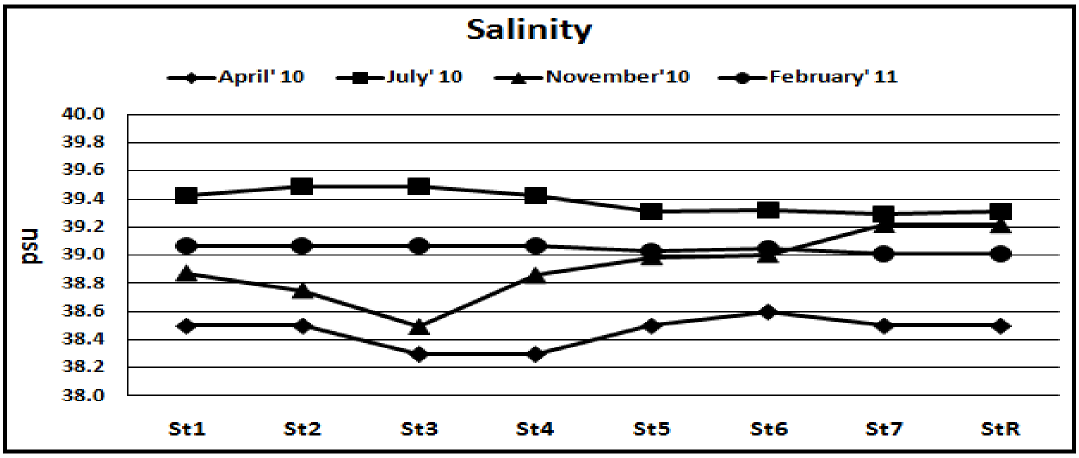


Figure 3.2 Spatio-temporal fluctuations of salinity for all sampling stations and periods.

pH values were also homogenous at all the sampling stations and periods. While the lowest pH value (8.11) was recorded at St7 and St R in July 2010, the highest value (8.31) was recorded at St1 in November 2010 (Figure 3.3).

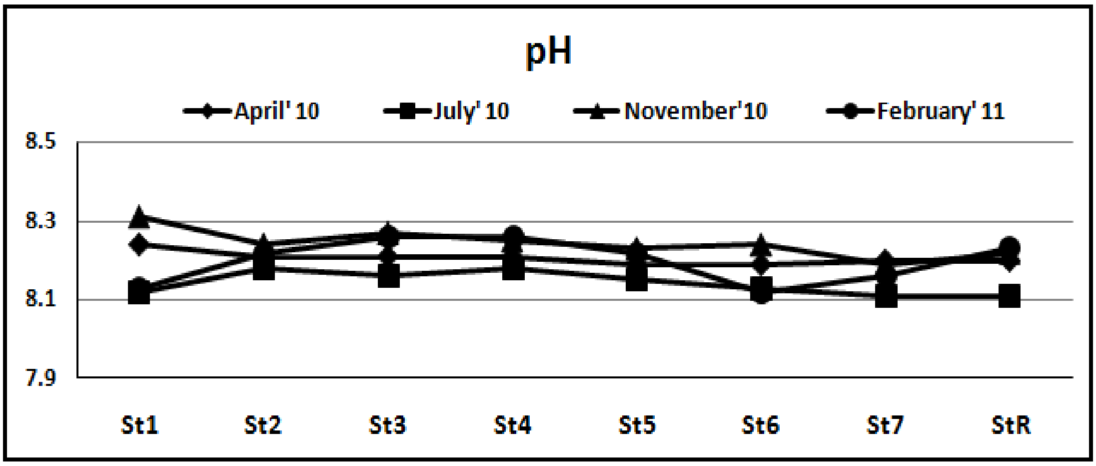


Figure 3.3 Spatio-temporal fluctuations of pH for all sampling stations and periods.

The DO concentrations showed uniform distribution in April 2010 and February 2011, while it showed fluctuations in November 2010 and July 2010. DO concentrations were lower remarkably, at St1, 2, 3, 7 and R in July 2010 and also at St 6, 7 and R in November 2010. DO concentrations ranged from 4.56 to 5.77 mg/l. The highest concentration was recorded at St1 in April 2010, while the lowest concentration was recorded at StR in July 2010 (Figure 3.4)

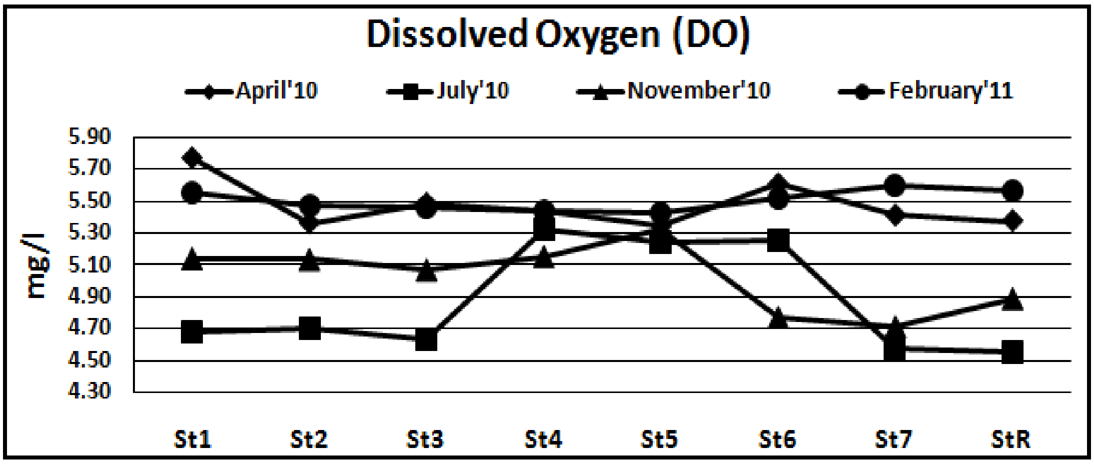


Figure 3.4 Spatio-temporal fluctuations of dissolved oxygen for all sampling stations and periods.

Ammonium-nitrogen (NH_4^+-N) concentrations showed spatial fluctuations. NH_4^+-N concentrations ranged from BDL (Below Detection Limit- 0.001) to 5.90 µM. The highest concentration was measured at St2 in November 2010 (Figure 3.5). Such an outlying single measurement requires precaution, as presented in discussion section.

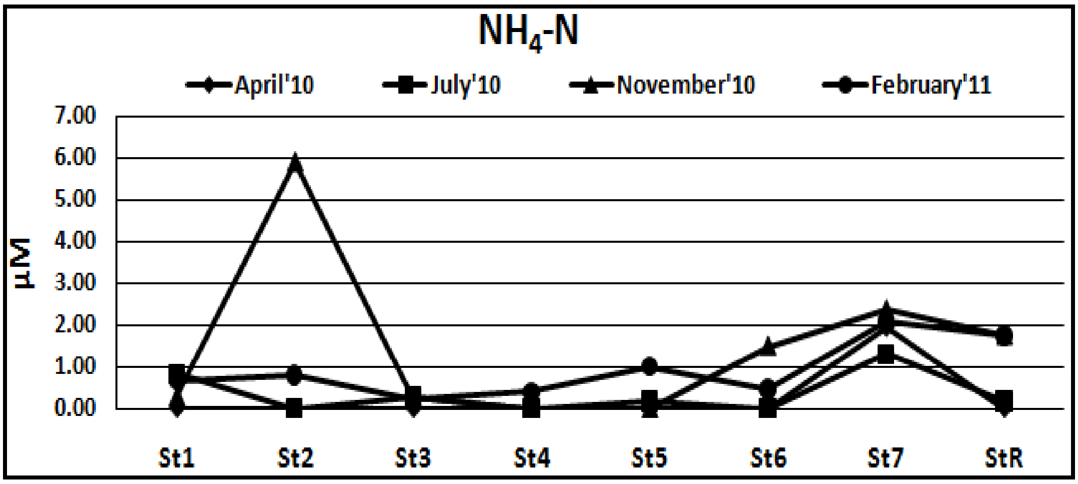


Figure 3.5 Spatio-temporal fluctuations of ammonium-nitrogen for all sampling stations and periods.

Nitrite-nitrogen (NO_2^--N) concentrations showed also spatial fluctuations between the stations around the floating cages and the stations in non-farming areas. NO_2^-N concentrations ranged from BDL (Below Detection Limit- 0.001) to 0.870 µM. The highest concentration was measured at St7 in July 2010 (Figure 3.6).

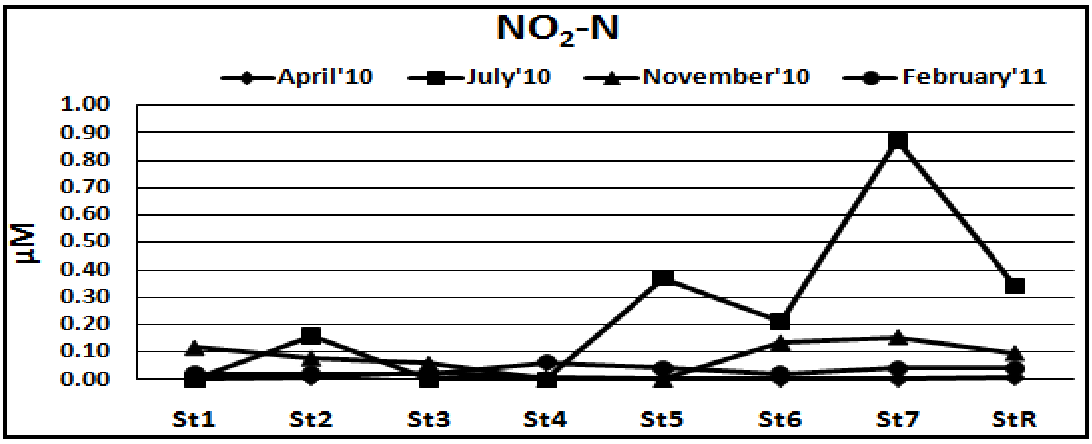


Figure 3.6 Spatio-temporal fluctuations of nitrite-nitrogen for all sampling stations and periods.

Nitrate-nitrogen (NO_3^--N) concentrations showed some remarkable spatial and/or temporal fluctuations between or within some stations. The occurrence of these fluctuations requires attention since some were around the floating cages and some others were in non-farming areas. There are no fluctuations at St1, St2, St4 and St 5. NO_3^--N concentrations ranged from BDL (Below Detection Limit- 0.001) to 1.656 µM. The highest concentration was measured at St6 in February 2011 (Figure 3.7).

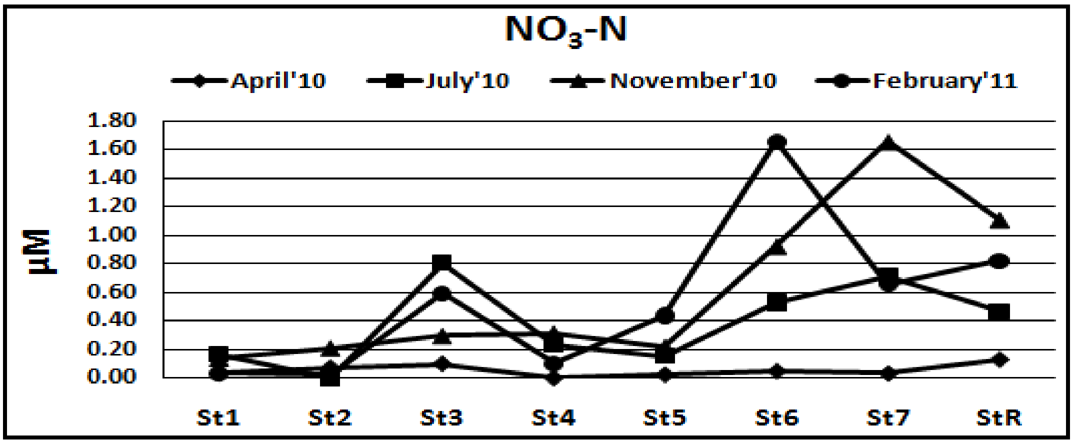


Figure 3.7 Spatio-temporal fluctuations of nitrate-nitrogen for all sampling stations and periods.

At all stations except St7, the o.PO_4^{3-}- P concentrations showed uniform spatio-temporal distribution. St7 had some temporal increases in July 2010 and in November 2010. o.PO_4^{3-}- P concentrations ranged from 0.01 to 0.28 µM. The highest value was measured at St7 in July 2010, while the lowest values were measured at St4 and St6 in July 2010 (Figure 3.8)

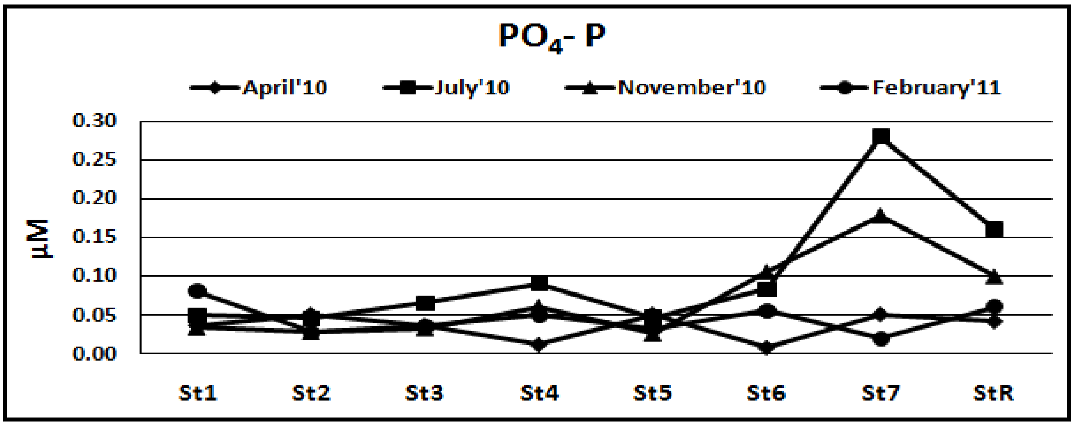


Figure 3.8 Spatio-temporal fluctuations of nitrate-nitrogen for all sampling stations and periods.

Percentages of TC and OC in sediment usually showed stable spatial and temporal distributions at all of sampling stations and periods, except in April 2010. Excluding April values the TC and OC ranges were between1.25 –5.17% and 0.19 - 3.18%, respectively. The highest TC value measured was at St4 in unstable period, *i.e.*, April 2010, while the lowest value measured was at St7 in November 2010. The highest OC value was again measured at St4 in April 2010, while the lowest values measured was also at St3 in April 2010, however same lowest value were also obtained at St6 in February 2011 (Figure 3.9).

According to the grain size analysis, silt+clay texture were dominant among the sea bottom of all stations. However, the granulometric composition of the sediments displayed considerable seasonal variations for St5 and St6 within coarser sediment fractions in July 2010. The highest percentage of silt+clay (95.1%) measured was at St1 in April 2010. The highest percentage of fine sand (65.1%) and coarse sand (49.8%) measured were at St6 and St5 in July 2010, respectively (Figure 3.10).

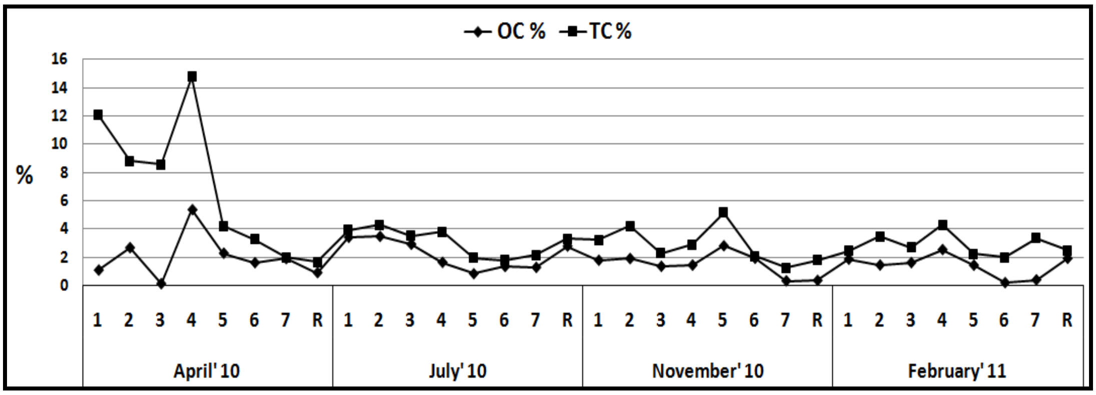


Figure 3.9 Spatio-temporal fluctuations of TC% and OC% for all sampling stations and periods.

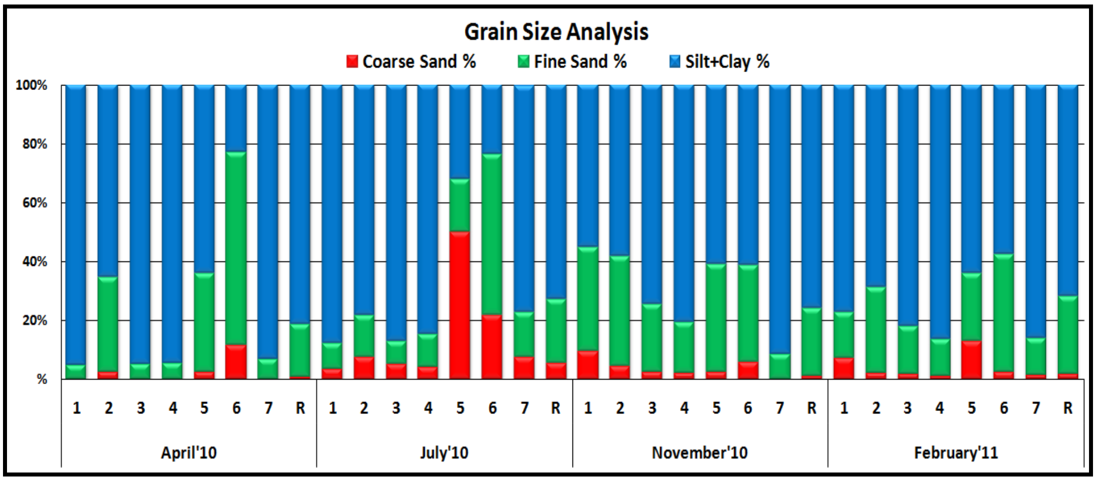


Figure 3.10 Spatio-temporal variation of grain size for all sampling stations and periods.

3.1.1 Statistical analysis of physico-chemical parameters

The results of one-way ANOVA of some physico-chemical parameters between stations during sampling period were given in Table 3.1. Stations were not significantly different for all parameters. Significant differences between sampling periods for temperature, salinity, pH, dissolved oxygen, NO_2-N and total carbon were observed as expected, due to fact that some of these parameters related with each other and shows seasonal fluctuations.

Table 3.1 Values of one-way ANOVA for all sampling periods

	Stations			Seasons		
Variable	**d.f**	***F***	***p level***	**d.f**	***F***	***p level***
Temperature	7	0.4835	ns	3	17.47	*
Salinity	7	0.0807	ns	3	60.2937	*
pH	7	0.7517	ns	3	10.2192	*
Dissolved Oxygen	7	0.3208	ns	3	17.2715	*
NH_4-N	7	1.5222	ns	3	2.1255	ns
NO_2-N	7	1.6565	ns	3	2.9886	*
NO_3-N	7	2.3035	ns	3	2.7496	ns
o.PO_4- P	7	1.5558	ns	3	2.8717	ns
Organic Carbon	7	0.9443	ns	3	0.5659	ns
Total Carbon	7	1.2394	ns	3	0.0091	*

*** p<0.05**
ns: non -significant

3.2 Macrofauna

A total of six faunal taxa (Polychaeta, Crustacea, Mollusca, Echinodermata, Spincula and Nematoda) were found. While the maximum macrofaunal abundance (17,703 ind./m^2) was recorded at St2 in July 2010, the minimum (1,292 ind./m^2) was at St3 in February 2011.The maximum biomass was recorded (63.11 g/m^2) at St5 in November 2010. The minimum biomass (2.26 g/ m^2) was recorded at StR in November 2010 (Figure 3.11).

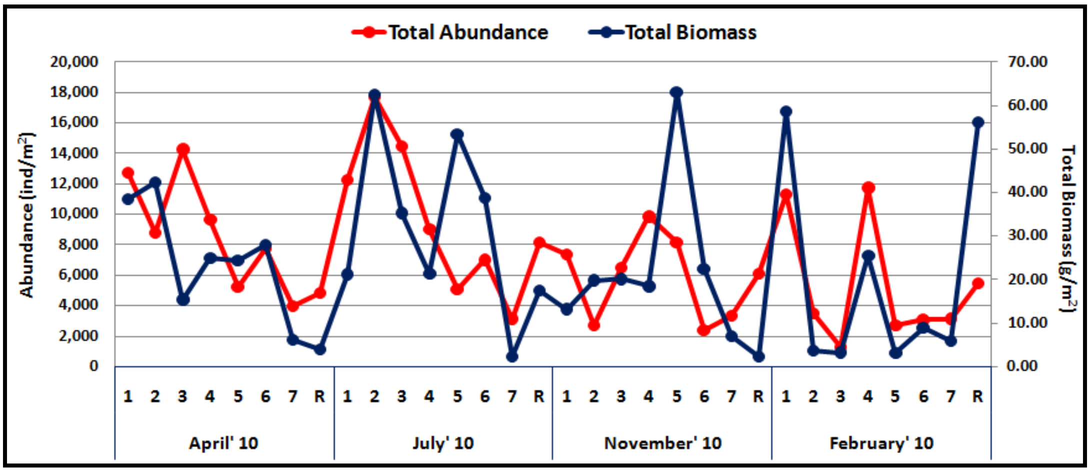


Figure 3.11 Spatio-temporal changes in total abundance and total biomass in the study area

The values of Shannon-Wiener diversity (H') and Pielou evenness (J') indices for all major taxa at all stations for all seasons were presented in Table 3.2. The highest diversity and evenness value (H'=1.14. J'=0.82) was observed at St R in February 2011. The lowest diversity and evenness value (0.00) was observed at St7 in November 2010. The zero diversity value of St7 can be explained with invasion of habitat by only one taxon (Polychaeta) in the community.

Table 3.2 Diversity and evenness indices for all stations in all sampling periods.

	Stations	**Number of Taxa**	**Shannon-Wiener Diversity**	**Pielou Evenness**
	St	**S**	**H'(loge)**	**J'**
April' 10	1	6	0.91	0.51
	2	4	0.68	0.49
	3	5	0.50	0.31
	4	3	0.34	0.31
	5	3	0.64	0.58
	6	3	0.33	0.30
	7	5	1.08	0.67
	R	5	1.06	0.66
July' 10	1	5	0.64	0.40
	2	6	0.96	0.53
	3	5	0.93	0.58
	4	6	0.78	0.44
	5	5	0.55	0.34
	6	6	0.50	0.28
	7	3	0.49	0.44
	R	3	0.54	0.49
November' 10	1	5	0.96	0.59
	2	4	1.05	0.76
	3	2	0.38	0.55
	4	3	0.64	0.58
	5	4	0.64	0.46
	6	5	0.47	0.29
	7	1	0.00	0.00
	R	3	0.69	0.63
February' 10	1	5	0.60	0.37
	2	6	0.86	0.48
	3	5	0.71	0.44
	4	5	1.03	0.64
	5	3	0.69	0.63
	6	5	0.45	0.28
	7	3	0.63	0.57
	R	4	1.14	0.82

According to Spearman Rank Order Correlation Analysis, a negative correlation was found between the percentage of Polychaeta abundance and Shannon-Wiener diversity indices ($r=-0.8827$. $p<0.05$). Besides, the percentage of Polychaeta abundance negatively correlated with Pielou evenness indices ($r=-0.7857$. $p<0.05$). It can be said that high dominancy of Polychaeta abundance decrease the value of diversity and evenness indices.

3.2.1 Abundance and Biomass Distributions of Major Taxa

Spatial and temporal fluctuations in abundance and biomass of Polychaeta were presented in Figure 3.11. While the highest abundance was found at St3 in April 2010; the lowest was found at St3 in February 2011. The highest biomass value was determined at St5 in November 2010. St7 had the lowest mean abundance value amongst the stations (Figure 3.12).

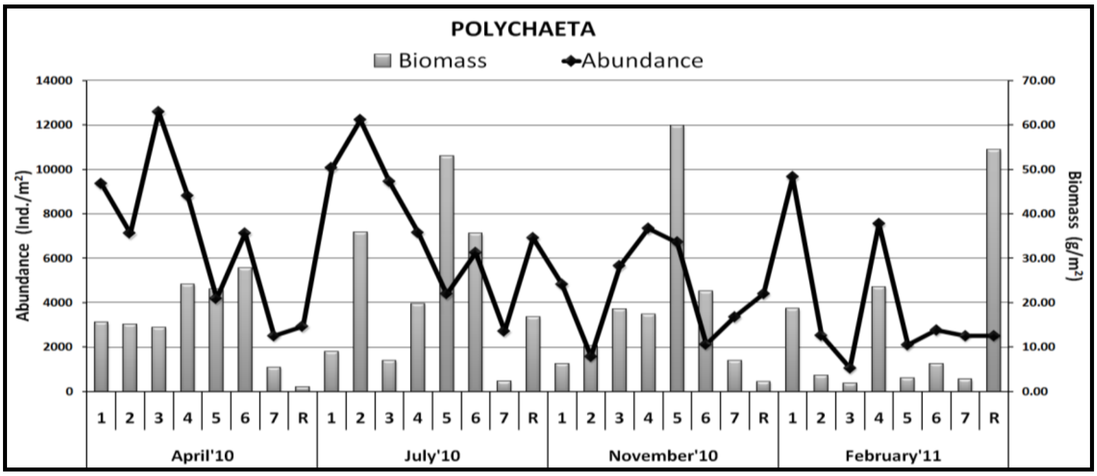


Figure 3.12 Spatio-temporal fluctuations in abundance and biomass of Polychaeta.

Abundance and biomass of Crustacea showed spatial and temporal variations in the study. The highest abundance (1573 ind./m^2) was found at St4 in February 2011. However, this high abundance value does not reflect the highest biomass value in consequence of the species with smaller body size that found in this station. On the other hand, due to biomass contribution of species larger body size, *Ethusa mascarone* (Herbst. 1785); the highest biomass value was found at St1 in November

2010. Additionally, it is remarkable that any Crustacea species were not found at St7 in July and November 2010 (Figure 3.13).

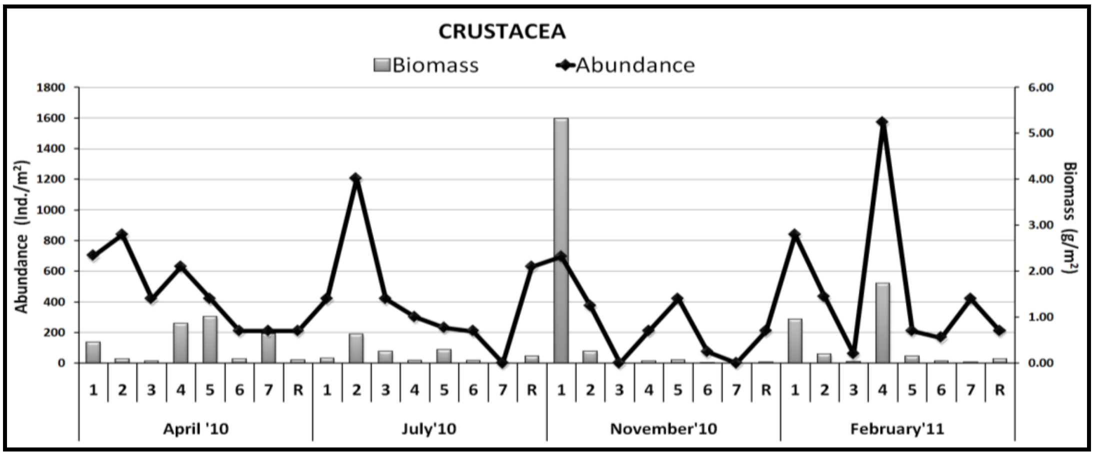


Figure 3.13 Spatio-temporal fluctuations in abundance and biomass of Crustacea.

Mollusca individuals were mostly found at St1. St2 and St3 in all sampling periods, but rarely or never found at St4. St5. St6. St7 and StR in the study. The highest abundances were found at St1. St2 and St3 in April, July and November 2010, respectively. The highest biomasses were found at St2 and St3 in April and July 2010, respectively (Figure 3.14).

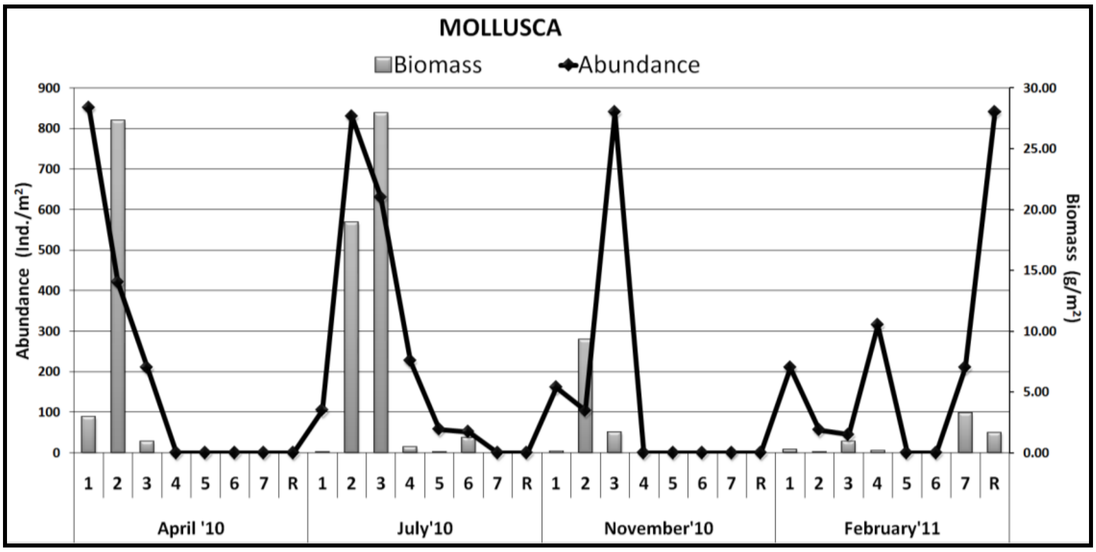


Figure 3.14 Spatio-temporal fluctuations in abundance and biomass of Mollusca.

St1 was the only station that Echinodermata individuals were found in all sampling periods. On the other hand, Echinodermata individuals were rarely found at other stations. But, it is remarkable that this taxon were never found at St7 in all sampling periods (Figure 3.15).

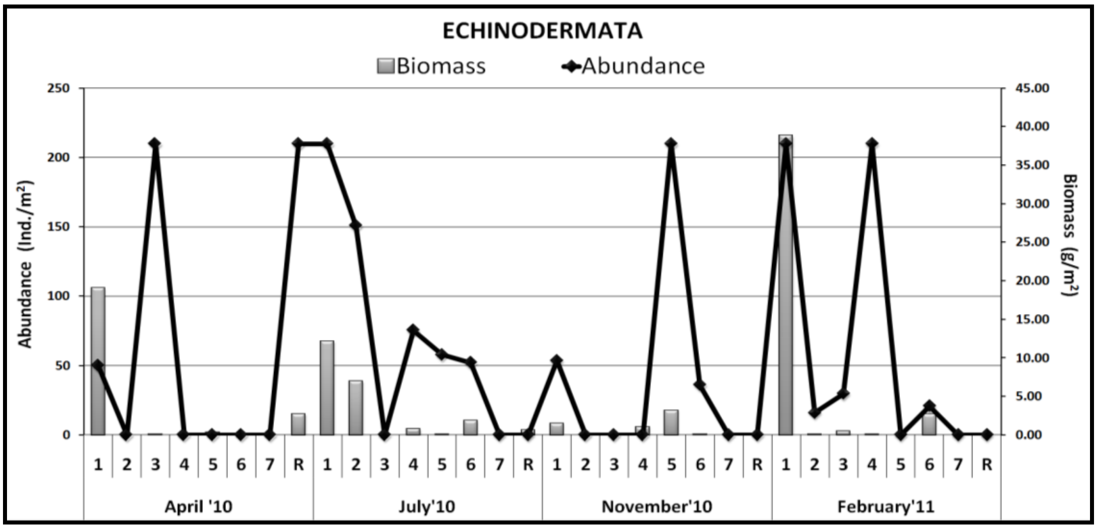


Figure 3.15 Spatio-temporal fluctuations in abundance and biomass of Echinodermata.

Spincula was the rarest taxon in all sampling periods. But, a relatively increase in abundance and biomass was observed in July 2010. Also, the highest abundance and biomass value were found at St4 in this sampling period (Figure 3.16).

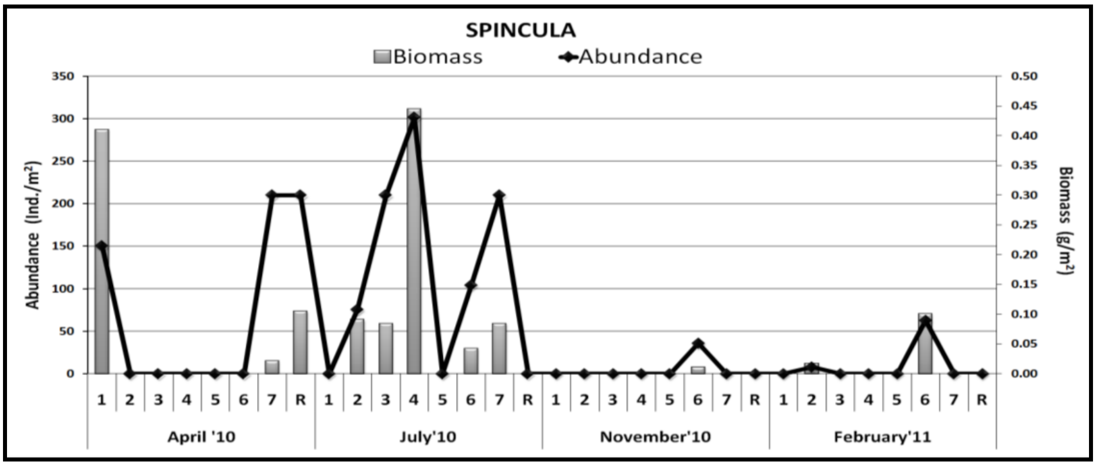


Figure 3.16 Spatio-temporal fluctuations in abundance and biomass of Spincula.

Although Nematoda was the second most abundant taxon in all sampling periods, its contribution to the total biomass was lower as a result of its small body size. The highest abundance and biomass values were found at St3 in July 2010. Additionally, it is remarkable that abundance and biomass of this taxon was mostly lower at St7 in comparison with other stations (Figure 3.17).

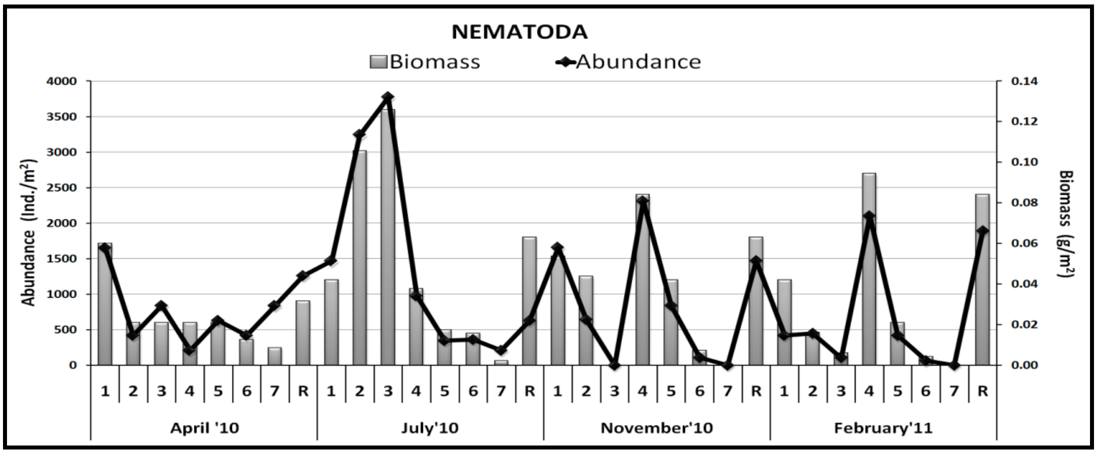


Figure 3.17 Spatio-temporal fluctuations in abundance and biomass of Nematoda.

3.2.2 Comparison of Distributional Properties Within and Among Sampling Stations

The percentages of abundance and biomass of the major taxa for each sampling stations were presented in Figure 3.17. Although Polychaeta was the most abundant taxon at all sampling stations, Mollusca and Echinodermata was prominent in biomass especially at St1. St2 and St3 in some sampling periods.

St1 was different from the other stations with its higher biomass value of Echinodermata. The presence of Decapoda species, *Ethusa mascarone* (Herbst. 1785) which is a species with larger body size, was also reflected on percentage of biomass in November 2010 (Figure 3.18a). St1 reached its maximum diversity value as a decrease in abundance of Polychaeta. This state also resulted with increase in evenness at this station (Table 3.2).

St5 and St6 show almost similar community pattern with higher abundance of Polychatea (more than 80%) and lower abundance of other taxa. St6 was different from other stations only with its low evenness and low diversity values in all sampling periods (Figure 3.18e.f).

A monotonic dominance of Polychaeta in terms of abundance at St7 in July and November 2010 was remarkable (Figure3.18g). Moreover, the community consisted of only single taxon *i.e.,* Polychaeta, in this station in November 2010. Consequently, the diversity and evenness values were calculated as zero (Table 3.2).

A decrease in diversity value, as a consequence of a decrease in number of taxa, was observed at StR in July 2010 and November 2010. The community consisted of three taxa, Polychaeta, Crustacea and Nematoda, in these sampling periods. It was also remarkable that Mollusca were only found in February 2011, at StR and at St7 (Figure 3.18h).

Cluster Analysis of the major taxa abundaces for each stations and seasons at the study site, using group-average clustering of Bray-Curtis similarities, was presented in Figure 3.19 and Figure 3.20, respectively. As seen in these dendograms, sampling stations did not show obvious difference between the seasons in terms of major taxa and the lowest similarity at each station was more than 60% (Figure 3.19). Dendogram for seasons indicated that stations did not show obvious difference seasonally and the lowest similarity was higher than 60% *i.e.,* in November 2010 (Figure 3.20).

A dendogram for hierarchical clustering of the major taxa abundaces including all stations at the study site was presented in Figure 3.21. As seen in this dendogram, sampling stations did not show obvious difference and the similarity between the all stations was more than 60%. Also, Multi Dimensional Scaling (MDS) analysis showed a similar pattern with cluster analysis (Figure 3.22). Even there was a high similarity among the stations, Cluster and MDS analysis showed that St7 was distant from other stations in July and November 2010, whereas St3 was only in November 2010.

Figure 3.18 Percentage of abundance and biomass of major taxa at all stations and in all sampling periods.

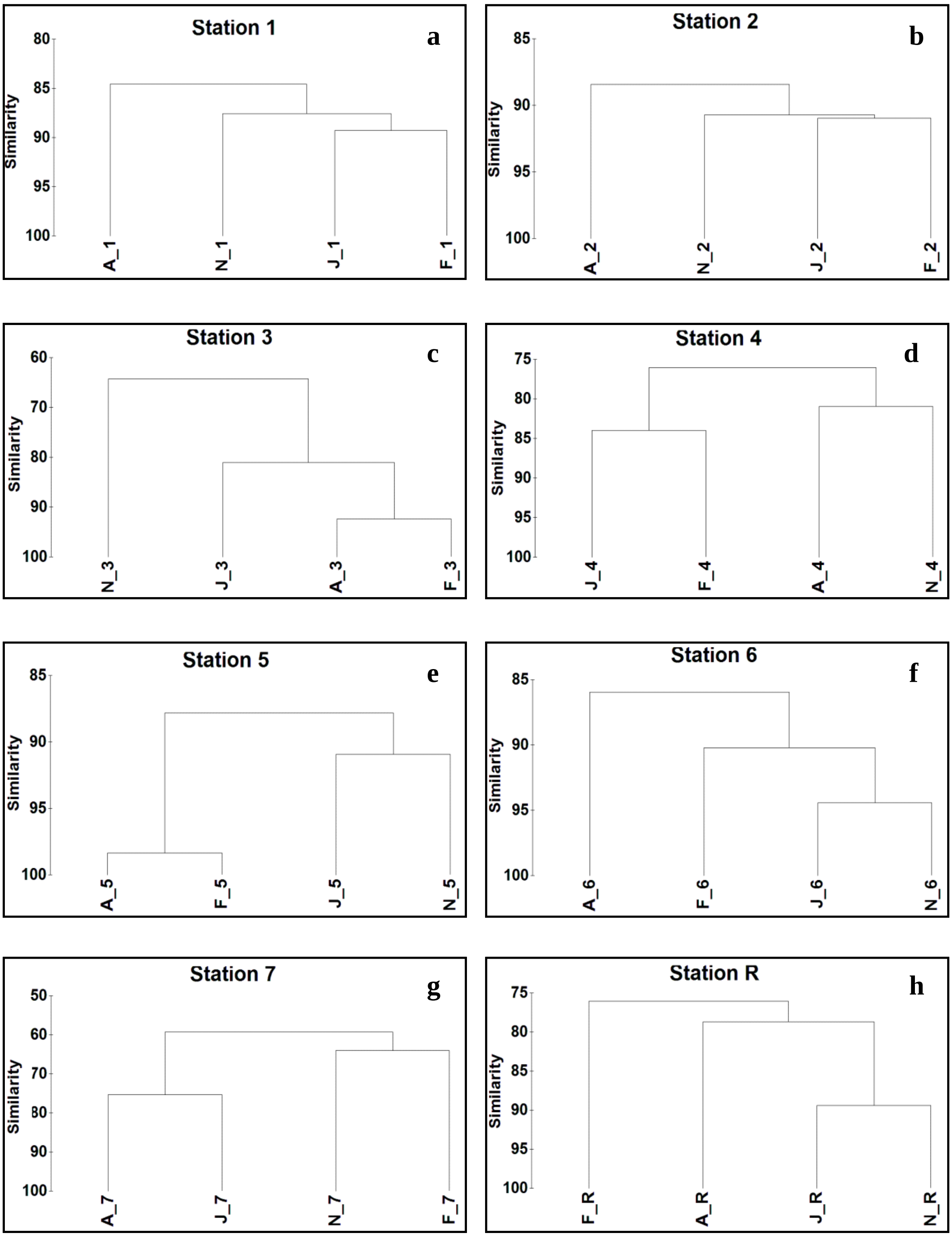


Figure 3.19 Dendogram for hierarchical clustering of the major taxa for each stations at the study site (A: April 2010. J: July 2010. N: November 2010. F: February 2011)

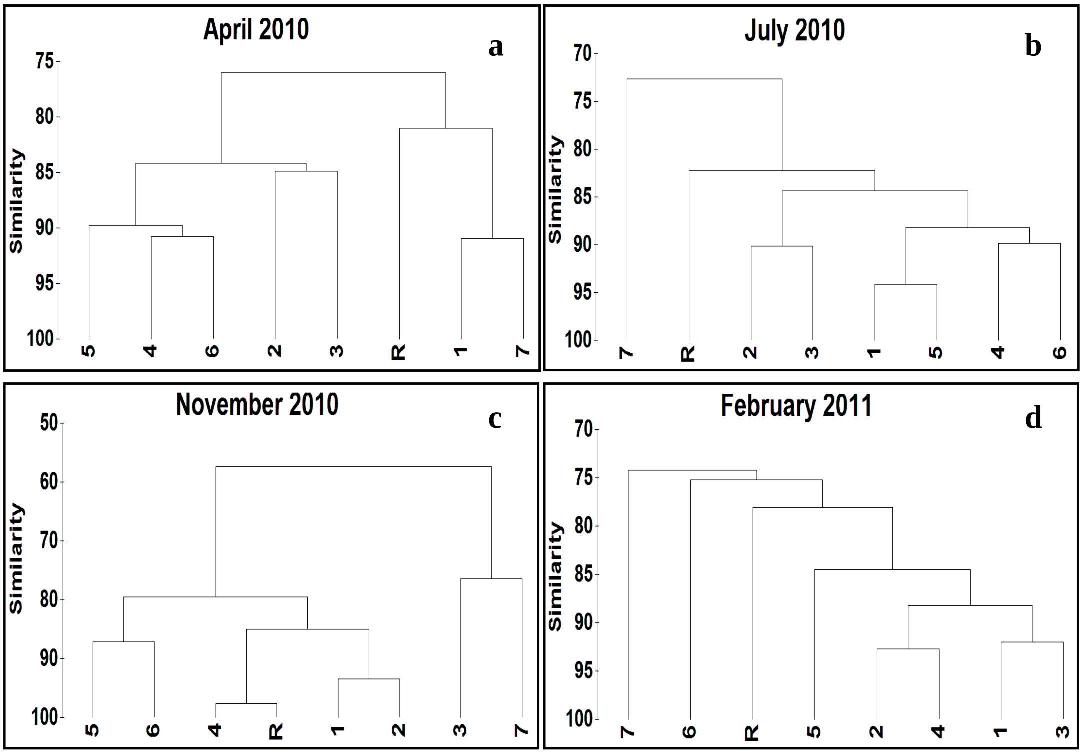


Figure 3.20 Dendogram for hierarchical clustering of the major taxa for sampling periods

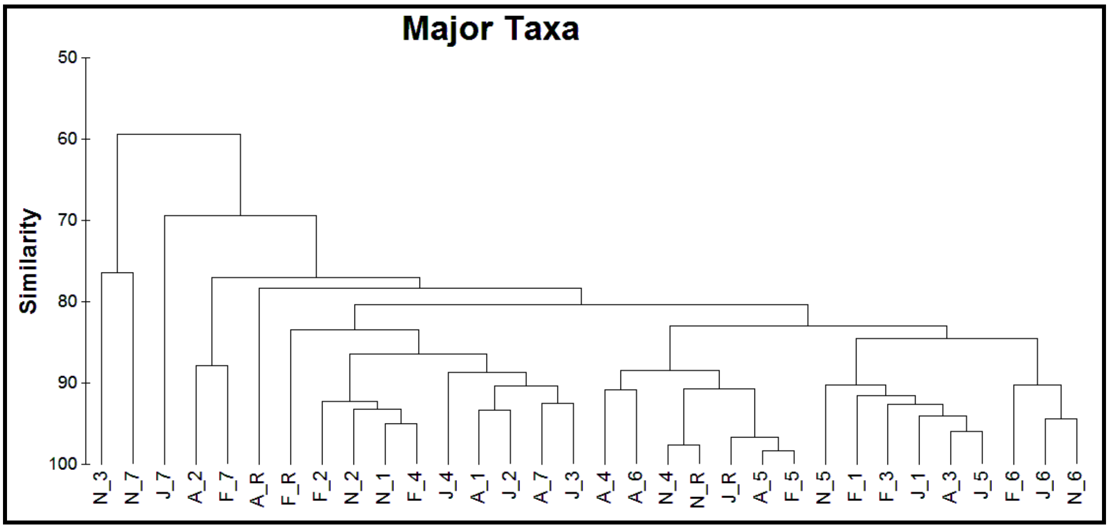


Figure 3.21 Dendogram for hierarchical clustering of the major taxa for all stations at the study site (A: April 2010. J: July 2010. N: November 2010. F: February 2011)

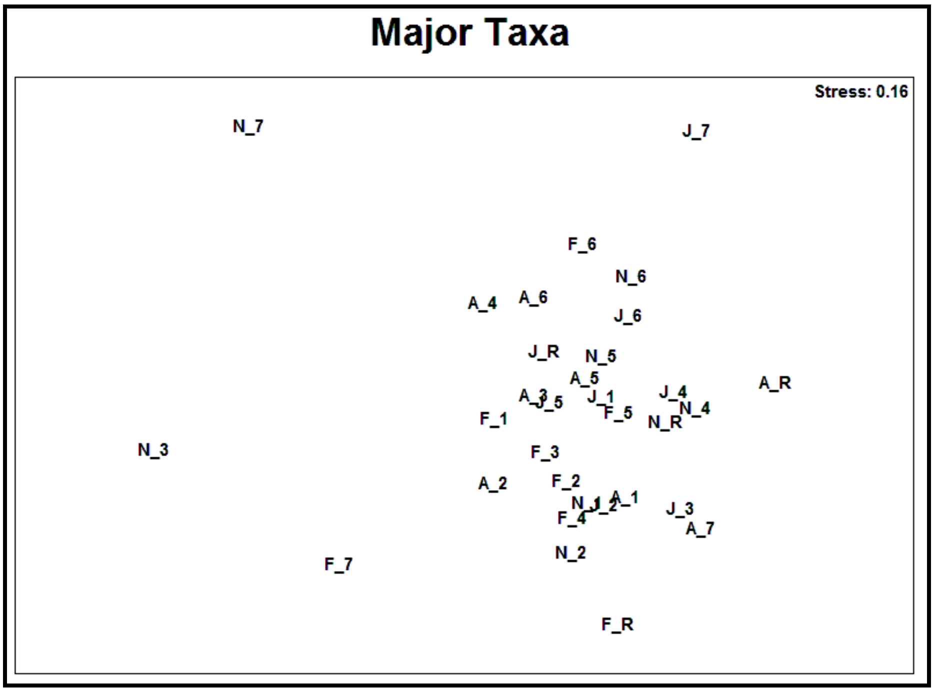


Figure 3.22 Multi Dimensinal Scaling (MDS) for major taxa at the study site

The results of Spearman Rank Order Correlation Analysis were presented in Table 3.3. Significant correlations were found between the abundance of major taxa and phsyco-chemical parameters. Polychaeta, Crustacea and Mollusca were significantly negatively correlated with depth ($p<0.05$). Crustacea was significantly correlated with OC ($r=0.5035$, $p<0.05$). Also negative significant correlation was found between NO_2-N and DO ($r=-0.3836$, $p<0.05$). %Silt+Clay was significantly correlated only with Polychaeta ($r=0.3667$, $p<0.05$)

Table 3.3 Results of Spearman Rank Order Correlation Analysis, significant correlations (p<0.05) highlighted in bold

	Polychaeta	Crustacea	Mollusca	Echinodermata	Spincula	Nematoda	OC	Depth	Temperature	DO	NH4-N	NO2-N	NO3-N	o.PO4-P
Crustacea	**0.5792**													
Mollusca	0.3318	**0.4160**												
Echinodermata	**0.3985**	0.3275	0.1899											
Spincula	-0.0087	-0.1555	0.1384	0.1531										
Nematoda	**0.4553**	**0.4879**	0.3493	0.2634	0.1620									
OC	0.3004	**0.5035**	0.2191	0.0753	-0.0548	**0.3962**								
Depth	**-0.4184**	**-0.5054**	**-0.4884**	-0.3003	0.0861	-0.2685	-0.3443							
Temperature	**0.4503**	0.0509	0.0555	0.1323	0.1175	0.3304	0.2796	-0.3315						
DO	-0.0770	0.1639	0.1761	0.1095	-0.1138	-0.1221	-0.2917	-0.0344	**-0.6157**					
NH4-N	**-0.5703**	-0.2910	0.0397	-0.3285	-0.0547	-0.2431	-0.1483	0.2897	-0.2591	-0.1052				
NO2-N	-0.2714	-0.1758	-0.0529	-0.0401	-0.0774	-0.3059	-0.2125	0.1942	-0.1346	**-0.3856**	**0.4055**			
NO3-N	**-0.4267**	**-0.4832**	-0.1855	-0.2076	0.0606	-0.3144	**-0.3651**	**0.5089**	-0.2212	-0.1150	**0.4581**	**0.3582**		
o.PO4-P	0.0638	-0.2538	-0.1056	-0.0190	0.3221	0.0625	-0.0256	0.3292	0.1014	**-0.4923**	0.1911	0.3156	**0.4590**	
% Silt+Clay	**0.3667**	0.1905	0.3214	0.0790	0.1735	0.2217	0.1248	-0.0284	0.0292	0.0658	0.0460	-0.2864	-0.1261	0.0670

3.2.3 Crustacea Species

In the study area, Crustacea has been represented with 2 classes, 5 orders, 25 families and 40 species. Even though Ostracoda is classified as the member of meiofauna, its specimens were also included to the analysis, as they retained on the sieves. Systematic and spatio-temporal distributions of the Crustacea species at study site were presented in Appendix 1 and Appendix 2, respectively.

Amphipods were the dominant taxon in terms of species richness (15 species), followed by both tanaids (8 species) and decapods (8 species). Cumaceans and isopods were represented by 4 and 3 species, respectively. Although tanaids were the most abundant taxon with 6,180 ind./m^2 in total, decapods were the dominant taxon in terms of biomass (5.73 g/m^2, 42% of total). Nevertheless, amphipods have overall dominancy since they are secondary taxon both in terms of abundance and biomass.

The most abundant tanaid species was *Leptochelia savignyi* (Kroyer, 1842) with 4,236 ind./m^2 in total. *L. savignyi* was found in every sampling periods at St1 and St2, but rarely at St3 and St4. This species was never found at stations that closed to the floating cages in off-shore.

Three species, *Harpinia dellavallei* Chevreux, 1910, *Perioculodes longimanus angustipes* Ledoyer, 1983 and Agathotanaidae (sp.) were only found in StR. Besides, *Achaeus cranchii* Leach. 1817 was the species that found at St7 only in single sampling period.

Results of Shannon-Wiener diversity and Pielou evenness indices were presented in Table 3.4. St2 was richest stations in terms of Crustacea species for all sampling periods except April 2010. Hence, the highest diversity values were obtained in this station *i.e.*,H’=1.83 and H’=1.67 in July and November 2010, respectively. As a consequence of higher abundance of *Leptochelia savignyi* (Kroyer, 1842), the highest abundance values were found at St2 and St4 in July 2010 and February 2011, respectively.

Table 3.4 Community parameters of Crustacea species

	Stations	Number of Species	Total Individual	Pielou Evenness	Shannon-Wiener Diversity
	St	S	N(ind./m^2)	J'	H'(loge)
April' 10	1	5	700	0.89	1.43
	2	3	839	0.95	1.04
	3	1	419	0.00	0.00
	4	3	629	1.00	1.10
	5	2	419	1.00	0.69
	6	1	210	0.00	0.00
	7	1	210	0.00	0.00
	R	1	210	0.00	0.00
July' 10	1	2	419	1.00	0.69
	2	9	1205	0.83	1.83
	3	2	419	1.00	0.69
	4	3	301	0.95	1.04
	5	4	231	1.00	1.39
	6	3	208	0.95	1.04
	R	3	629	1.00	1.10
November' 10	1	4	693	0.68	0.94
	2	7	372	0.86	1.67
	4	1	210	0.00	0.00
	5	2	419	1.00	0.69
	6	2	72	1.00	0.69
	R	1	210	0.00	0.00
February' 11	1	3	839	0.95	1.04
	2	10	432	0.62	1.43
	3	3	60	0.95	1.04
	4	5	1779	0.70	1.12
	5	1	210	0.00	0.00
	6	5	165	0.93	1.49
	7	1	140	0.00	0.00
	R	1	210	0.00	0.00

A dendogram for hierarchical clustering of the Crustacea abundances at the study site, using group-average clustering of Bray-Curtis similarities was presented in Figure 3.23. As seen obviously in this dendogram, the outer stations (St5, St6, St7 and StR) differentiated from the inner stations (St1, St2, St3 and St4), in terms of abundance of Crustacea species. The similarity between these two groups was lower than 20%. *Leptochelia savignyi* (Kroyer, 1842), Ostracoda (sp.) 1 and *Eudorella truncatula* (Bate, 1856) was mainly responsible for dissimilarity between the inner and the outer stations. StR differentiated from the other stations in all sampling periods except in July 2010 (J_R) due to presence of *Leptochelia savignyi* (Kroyer, 1842) (Figure 3.23).

As it can be seen in dendogram for outer stations, StR (J_R. N_R and F_R) and St7 (A_7) showed no similarity with other stations as a consequence of species that only found in this stations (Figure 3.24).

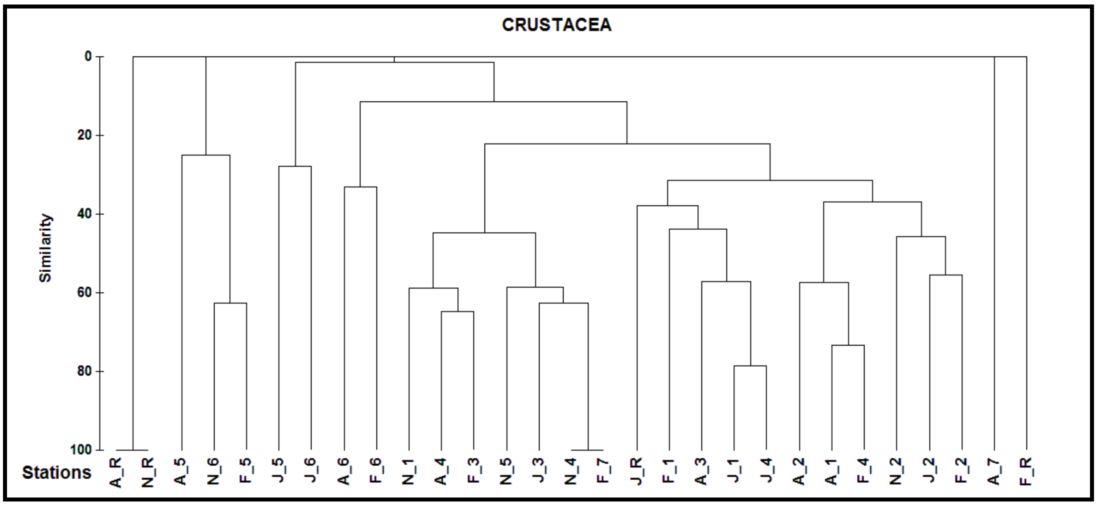


Figure 3.23 Dendogram for hierarchical clustering of the Crustacea assemblages at the study site (A: April 2010. J: July 2010. N: November 2010. F: February 2011)

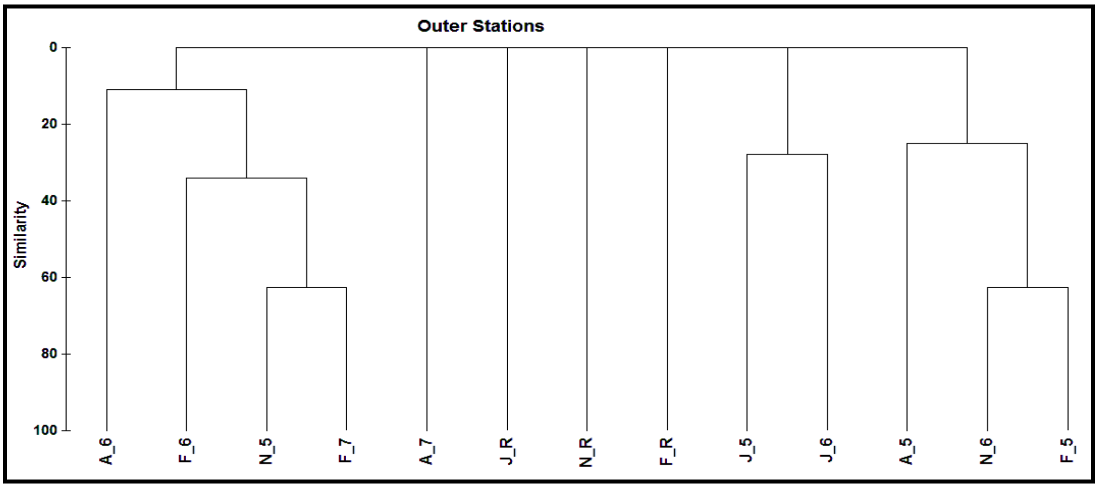


Figure 3.24 Dendogram for hierarchical clustering of the Crustacea assemblages at outer stations (A: April 2010. J: July 2010. N: November 2010. F: February 2011).

Multi Dimensional Scaling (MDS) shows the similar results with Cluster analysis. The results of MDS were presented in Figure3.23.

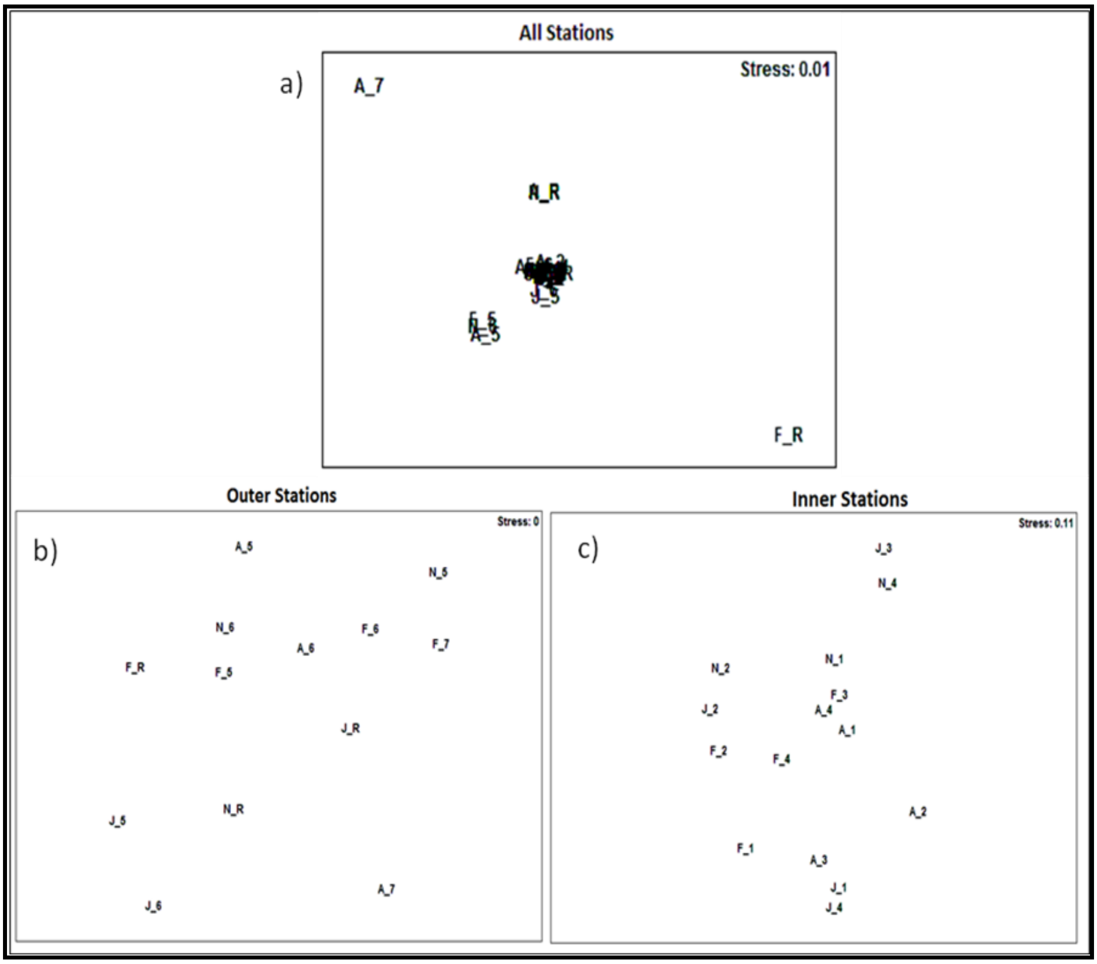


Figure 3.25 Multi Dimensional Scaling (MDS) of a) all sampling stations b) outer stations c) inner stations.

CHAPTER FOUR
DISCUSSION AND CONCLUSION

4.1 Physico-chemical Parameters

The temperatures prevailing over the sea bottom water expectedly homogenous at all the sampling stations. The difference in temperature range between the shallower and deeper stations *i.e.*, in July 2010 shows that the members of the macrofauna were subjected to different temperature regime.

Salinity and pH was constant amongst the stations and significant difference was not found. Salinity and pH ranged in the typical levels for Mediterranean Sea.

The lowest dissolved oxygen (DO) values were recorded in July 2010 in our study. There was no significant difference between stations. DO concentrations were remarkably lower, at St1, 2, 3, 7 and R in July 2010 and also at St 6, 7 and R in November 2010.

In comparison with the criteria recommended by Abo & Yokoyama (2007) for sustainable aquaculture; the lowest DO values measured in stations fixed in farming area were above the ‘‘critical’’ farm value (3.7mg/l), but below the ‘‘healthy’’ fish farm value (5.6mg/l). The highest DO values, measured in stations in the area which is assumed to be in recovery process, were not above the healthy fish farm value; but were very close to it.

Vaquer-Sunyer & Duarte (2008), reviewing relevant literature to oxygen thresholds, reported that thresholds of hypoxia range broadly from 0.28 mg/l to 4 mg/l, most reports refer to a value of 2 mg/l or lower. According to Vaquer-Sunyer & Duarte (2008), this threshold may be inadequate to describe the onset of hypoxia impacts for many benthic organisms; and they proposed a precautionary limit (4.6 mg/l) to avoid catastrophic mortality events and effectively conserve marine biota. Hypoxia thresholds also vary greatly across taxonomic groups, and the most vulnerable taxonomic group was Crustacea which presented significantly higher oxygen thresholds for sublethal responses than polychaetes and echinoderms (Vaquer-Sunyer & Duarte, 2008). In our study, DO concentrations were not below the precautionary limit proposed by Vaquer-Sunyer & Duarte (2008). On the other hand, absence of Crustaceans at St7 in July and November 2010 may be explained with lower DO concentrations in these periods.

Although some fluctuations were observed in nutrient concentrations in the study area; significant difference were not found neither between stations nor between periods, except NO2-N values in April 2010 and July 2010. The relatively higher NO_2^{-}N, values at deeper stations in July 2010 can be explained with low conversion rate between NO2-N and NO3-N, as a result of lower dissolved oxygen values. Moreover, according to Spearman Rank Order Correlation Analysis, DO was negatively correlated with NO_2^{-}N ($r=-0.5253$, $p<0.05$). Relatively higher NH_4^+-N values at St7 in all seasons may be derived from the excretions of mass population of farmed fishes in the cages On the other hand, a remarkably higher NH_4^+-N value at St2 in November 2010 can be explained due to fact that this station was close to the discharge unit of hatchery section of the fish farm facility.

Pitta et al.(1999), investigating three fish farms in the eastern Mediterranean, reported that except for a significant decrease in nitrate values at cage station compared to its control station in one of the fish farms, nitrite and nitrate concentrations at cage and its respective control stations were not significantly different. Yucel-Gier et al. (2007), investigating nutrients and benthic community at a fish farm site at the Eastern Aegean Sea, found that the concentrations of ammonium at the cage stations were higher than those of the control stations during spring, summer and fall. Also, significant difference was found for NO_3-N between the sampling stations (Yucel-Gier et al., 2007). Kaymakçı-Başaran et al. (2010), investigating eight fish farm in Salih Island at Southeastern Aegean Sea, reported that no significant differences were detected between seasons and between the cage stations and the control station for nutrient (nitrite, nitrate, ammonium, phosphate and silicate) concentrations. Nutrient concentrations in similar regions were given in Table 4.1.1 for comparison with our results.

Table 4.1 Range of nutrient values (µM) in fish farming areas in different parts of Mediterranean Sea

	NO_3-N	**NH_4-N**	**NO_2-N**	**o.PO_4-P**
Cephalonia[1]	0.30-1.0	0.03-1.8	0.09-0.21	0.05-0.06
Ithaki[1]	0.20-1.0	0.80-3.6	0.04-0.22	0.06-0.23
Sounion[1]	0.30-0.6	0.10-0.3	0.02-0.80	0.05-0.06
Engeceli Bay[2]	0.10-2.2	0.11-3.9	0.01-0.20	0.02-0.73
Salih Island[3]	nd-2.28	nd-3.18	nd-1.29	nd-0.61
Ildırı Bay	BDL-2.68*	BDL-2.36*	BDL-0.87	BDL-0.28

[1]Pitta et al. (1999)
[2]Yücel-Gier et al. (2007)
[3]Kaymakçı-Başaran et al. (2010)

nd: none detected
BDL: Below Detection Limit
*Values in outer stations (close to cages)

Organic enrichment of the seabed is the most widely encountered effect of culturing fish in cages (Karakassis et al.2000, Karakassis et al. 2002). Increasing organic load in sediments might have a strong effect on the structure of benthic communities (Karakassis et al. 2000, Klaoudatos et al. 2006, Yucel-Gier et al. 2007). Karakassis et al. (1998) reported that organic matter contribution to the upper most sediment layer ranged from 20 to 40% under the cages and around 10% at the control site. Maldonado et al. (2005) reported exceptionally low values (<1%) at one of the farms both under the cages and at the respective control site. Kaymakçı-Başaran et al. (2010) reported organic matter values ranged from 3.23% to 9.37% at the sampling site. In our study the percentage of total carbon ranged from 1.25 to 14.78 % and percentage of organic carbon ranged from 0.1 to 5.3%. Stations and sampling periods were not significantly different for organic carbon values. Maldonado et al. (2005) affirms that the rates of organic matter accumulation on the sea bed under the cages are known to vary from farm to farm, and are influenced by mostly local hydrological and geomorphologic features, in addition to their dependence on fish production and fodder quality. Organic carbon concentration itself does not adequately describe the ecological impact of fish farming relative to a control site (Karakassis et al., 1998; Mazzola et al., 2000; Maldonado et al., 2005)

Cluster analysis for grain size analysis showed that stations can be divided into three groups. To determine the difference on the major taxa assemblages according to grain size, cluster analysis were done in terms of mean abundances of this three groups. Cluster analysis showed that major taxa assemblages were similar more than 95%. As a consequence, major taxa assemblages did not show any difference according to sediment grain size. Additionally, only Polychaeta had significant correlation (r=0.3637, p<0.05) with the percentage of silt+clay.

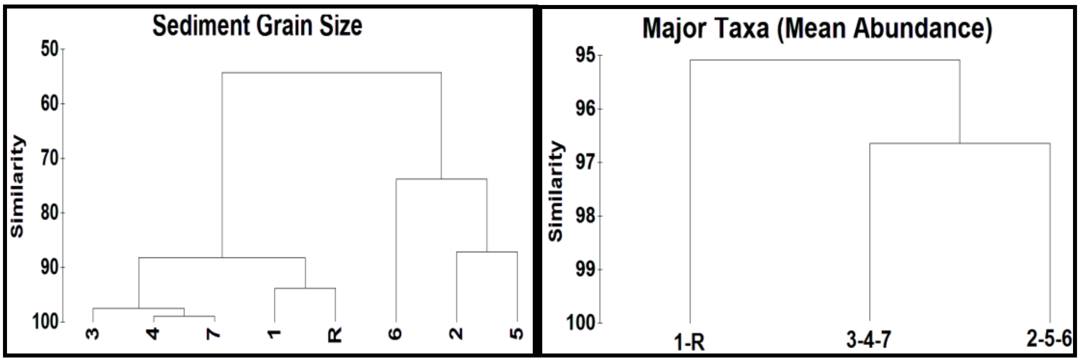


Figure 4.1 Dendogram for hierarchical clustering of sediment grain size and major taxa

4.2 Macrofauna

A negative correlation was found between the percentage of Polychaeta abundance and Shannon-Wiener diversity indices (r=-0.8827, p<0.05). Besides, the percentage of Polychaeta abundance negatively correlated with Pielou evenness indices (r=-0.7857, p<0.05). Also, Yucel-Gier (2007) reported that highest diversity and evenness values that calculated based on major taxa, were found at control station in which Polychaeta abundance was low in all periods (H'=1.35; J'=0.84). Due to the mathematical formula of indices, high abundance of single taxon decreases the diversity and evenness value. In our study, high dominancy of Polychaeta abundance decreased the value of diversity and evenness indices. As Fauchald & Jumars (1979) pointed out, Polychaetes are among the most frequent and abundant marine metazoans in benthic environments and they often comprise over one third the number of macrobenthic species and may be even more dominant in numbers of specimens. Their trophic flexibility and life-history traits are considered a pre-adaptation to the condition of disturbed habitats (Tomassetti & Porrello, 2005)

Lower abundance values or absence of Mollusca at stations deeper than 50 m. may be explained with that Mollusca was negatively correlated with depth ($r=-0.4884$, $p<0.05$)

Increasing in Nematoda abundance at St2 and St3 in July 2010 may be explained with increasing in organic carbon and nutrients which could be derived from the discharge of hatchery unit.

Dendogram for each stations and seasons indicated that stations did not show obvious difference seasonally and the lowest similarity was higher than 60%. Feeding activities in floating cages is higher in April and July, due to process in fish farming. So, it was remarkable that there were not obvious difference in April and July 2010 in when the feeding activities were higher.

According to Cluster and MDS analysis, St7 was distant from other stations in July and November 2010, whereas St3 was only in November 2010. It seems that these differences were related with the absence of Nematoda and/or Crustacea taxa during these sampling periods. As abovementioned, lower DO concentration might cause this difference. Also it is remarkable that St3 was close to the discharge unit of hatchery section of the fish farm facility.

The sampling stations were divided into two groups according to depth as a result of negative correlations; Group I (St 1, 2, 3, 4) and Group II (St 5, 6, 7, R). One-way ANOVA was performed in terms of mean abundance of major taxa in these stations. Polychaeta, Crustacea, Spincula and Nematoda were significantly different between this two groups and also this two groups were significantly different from each other (post hoc Tukey HSD, $p<0.05$)

Moreover, stations were divided into three groups according to fish farming exist or not. Group I (St 5, 7) was fish farmig area, Group II (St 6, R) was non farming area and Group III (St 1, 2, 3, 4) was in recovery process. One-way ANOVA was performed with including all seasons. Polychaeta and Crustacea was significantly different between this three groups ($p<0.05$). Also Group I and Group III were significantly different each other (post hoc Tukey HSD, $p<0.05$). Additionally, One-way ANOVA was performed for each sampling periods. Significant difference was found only in July 2010. Polychaeta was significantly different in this sampling period ($p<0.05$). Group I and Group III were significantly different (post hoc Tukey HSD, $p<0.05$).

In the study area, Crustacea has been represented with 2 classes, 5 orders, 25 families and 40 species. Amphipods were the dominant taxon in terms of species richness (15 species), followed by both tanaids (8 species) and decapods (8 species).

As Aslan-Cihangir & Panucci- Papadopoulou (2011) reported that, among peracarids, amphipods confirm their important leading role in defining the structure of assemblages; they dominate in species richness along environmental gradients and may play a key-role in coastal benthos due to their wide ecological and functional properties (Scipione et al., 2005; Bellan-Santini et al., 1998). Şahin (2004) reported that Ampelisca genus, especially *Ampelisca sarsi* (Chevreux, 1888), is resistant to pollution. In our study, members of the Ampelisca genus were found at stations which were assumed to be in recovery process, but they were not found in farming area.

Aslan-Cihangir & Panucci- Papadopoulou (2011) also reported that depth is an important factor in peracarid distribution patterns (Robertson, Hall, & Eleftheriou, 1989; Corbera, & Cardell, 1995; Lourido, Moreira, & Troncoso, 2008) and they found negative correlation ($r=-0.4424$, $p<0.05$) between peracarid abundance and depth. As well in our study, Crustacea abundance was negatively correlated with depth ($r=-0.5054$, $p<0.05$)

As Chintiroglu et al. (2004) pointed out; crustaceans are excellent objects for biomonitoring studies. The ratio of the abundance (or dominance) of certain peracarid genera might represent a reliable indicator of pollution (Chintiroglu et al., 2004).

According to Chintiroglu et al. (2004), species of the genera Corophium, Erichthonius and Leptochelia often dominate under polluted conditions and they are commonly referred to the characteristic of organic rich environments. In contrast, species of the genera Tanais and Elasmopus usually occur in clear waters (Chintiroglu et al., 2004).

In our study, the most abundant species was *Leptochelia savignyi* (Kroyer. 1842) which was found in every sampling periods at St1 and St2. but rarely at St3 and St4. This species was never found at stations that closed to the floating cages in off-shore. Besides, *Tanais dulongii* (Audouin, 1826) was found at St6 in November 2010 and at St5 in February 2011. It is notable that *Leptochelia savignyi* (Kroyer. 1842), referred to characteristic of the organically rich environments, were found very abundant at the station (St1, St2, St3 and St4) which assumed to be in recovery process. With considering the relatively high organic carbon values, it may be affirmed that this stations are in the early stage of recovery process. Karakassis et al., (1999) pointed out that monitoring of the recovery succession needs to be based on several variables and adequate time scales; besides there is no universal criterion for deciding whether a site has recovered or not. On the other hand, the presence of *Tanais dulongii* (Audouin, 1826) at St5, closed to the floating cages, can be indicator of that the impact of fish farming is limited. Also this indication may be an adequate baseline for further studies monitoring this area.

In this study, significant differences were not found for the physico-chemical parameters between the stations. Organic carbon content and dissolved oxygen, in prior importance for benthic communities, were not significantly different between sampling stations; although some seasonal differences were found for DO. The obvious differences between the stations were not detected in major taxa level; even some fluctuations were observed in abundance and biomass of major taxa. Polychaeta was dominant at all sampling stations in all seasons. It is well pronounced that opportunistic species in heavily polluted areas were generally Polychaeta, due to fact their trophic flexibility and life-history traits are considered a pre-adaptation to the condition of disturbed habitats (Tomassetti & Porrello, 2005) On the other hand, some indicator species in Crustacea taxon allowed the evaluation of pollution factors and the degree of impact. There were not found any pollution indicator Crustacea species in farming area, but found in recovery area

In conclusion, within the scope of the data obtained in this study, the impact of fish farming on macrozoobenthos cannot be mentioned in major taxa and Crustacea species level. But further studies should be done for monitoring the farming area against the impact risk, and for monitoring the recovery process in the area.

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APPENDICES

Appendix 1. Systematics of Crustacea species identified in the study

Class	Order	Family	Species
Malacostraca	Amphipoda	Ampeliscidae	*Ampelisca sp.*
			Ampelisca jaffaensis (Bellan-Santini & Kaim-Malka, 1977)
			Ampelisca sarsi (Chevreux, 1888)
			Ampelisca truncata Bellan-Santini & Kaim-Malka, 1977
			Ampelisca typica (Bate, 1856)
		Phoxocephalidae	*Harpinia dellavallei* Chevreux, 1910
		Leucothoidae	*Leucothoe sp.*
			Leucothoe oboa Karaman, 1971
			Leucothoe venetiarum Giordani- Soika, 1950
		Corophiidae	*Leptocheirus longimanus* Ledoyer, 1973
		Maeridae	*Maera sp.*
		Aoridae	*Microprotopus cf. maculatus* Norman, 1867
		Oedicerotidae	*Perioculodes aequimanus* (Korssman, 1880)
			Perioculodes longimanus angustipes Ledoyer, 1983
			Synchelidium longidigitatum Ruffo, 1947
	Tanaidacea	Agathotanaidae	Agathotanaidae (sp.) 1
		Apseudidae	*Apseudes latreillii* (Milne-Edwards, 1828)
		Leptocheliidae	*Heterotanais oerstedii* (Kroyer, 1842)
			Leptochelia savignyi (Kroyer, 1842)
		Leptognathiidae	*Leptognathia brevimana* (Bird & Holdich,1984)
			Leptognathia gracilis (Kroyer, 1842)
		Tanaidae	*Tanais dulongii* (Audouin, 1826)
		Paratanaoidea	*Pseudoparatanais batei* (G.O. Sars, 1882)
	Cumacea	Nannastacidae	*Campylaspis sp.*
			Cumacea (sp.)
		Leuconidae	*Eudorella truncatula* (Bate, 1856)
		Bodotriidae	*Iphinoe sp.*
	Isopoda	Gnathiidae	*Gnathia sp.*
			Gnathia vorax (Lucas, 1849)
			Gnathia oxyuraea (Lilljeborg, 1855)
	Decapoda	Inachidae	*Achaeus cranchii* Leach, 1817
		Paguridae	*Anapagurus sp.*
		Callianassidae	*Callianassa subterranea* (Montagu, 1808)
		Ethusidae	*Ethusa mascarone* (Herbst, 1785)
		Galatheidae	*Galathea intermedia* Liljeborg, 1851
			Paguridae (sp)
		Diogenidae	*Paguristes syrtensis* De Saint Laurent, 1971
		Processidae	*Processa cf. canaliculata* Leach, 1815
Ostracoda			Ostracoda (sp.) 1
			Ostracoda (sp.) 2

Appendix 2. Spatial and temporal distribution of Crustacea species at study site

	April-10								July-10							November-10						February-10							
Species	1	2	3	4	5	6	7	R	1	2	3	4	5	6	R	1	2	4	5	6	R	1	2	3	4	5	6	7	R
Ampelisca sp.						210											41										41		
Ampelisca jaffaensis (Bellan-Santini & Kaim-Malka, 1977)				210																									
Ampelisca sarsi (Chevreux, 1888)	50									75												210	24		105				
Ampelisca truncata Bellan-Santini & Kaim-Malka, 1977																							16				21		
Ampelisca typica (Bate, 1856)																							8						
Harpinia dellavallei Chevreux, 1910															210														
Leucothoe sp.											210																		
Leucothoe oboa Karaman, 1971																								15					
Leucothoe venetiarum Giordani- Soika, 1950												75																	
Leptocheirus longimanus Ledoyer, 1973																							8		210				
Maera sp.										75																			
Microprotopus cf. maculatus Norman, 1867										75																			
Perioculodes aequimanus (Korssman, 1880)																53													
Perioculodes longimanus angustipes Ledoyer, 1983															210														
Synchelidium longidigitatum Ruffo, 1947																						210	8						
Agathotanaidae (sp.)																													210
Apseudes latreillii (Milne-Edwards, 1828)					210															36									
Heterotanais oerstedii (Kroyer, 1842)	50	210																											
Leptochelia savignyi (Kroyer, 1842)	200	210	419	210					210	527		151			210	107	145					419	264	15	1150				
Leptognathia brevimana (Bird & Holdich,1984)										75			58	104															
Leptognathia gracilis (Kroyer, 1842)														52															
Tanais dulongii (Audouin, 1826)																				36						210			
Pseudoparatanais batei (G.O. Sars, 1882)	150	419																							105		21		
Campylaspis sp.													58																
Cumacea (sp.)										75													16						
Eudorella truncatula (Bate, 1856)								210													210								
Iphinoe sp.										75							83						8						
Gnathia sp.																			210										
Gnathia vorax (Lucas, 1849)					210																								
Gnathia oxyuraea (Lilljeborg, 1855)														52															
Achaeus cranchii Leach, 1817							210																						
Anapagurus sp.																											21		
Callianassa subterranea (Montagu, 1808)													58																
Ethusa mascarone (Herbst, 1785)																53													
Galathea intermedia Liljeborg, 1851																	21												
Paguridae (sp)																							24						
Paguristes syrtensis De Saint Laurent, 1971										75			58				21												
Processa cf. canaliculata Leach, 1815																	21												
Ostracoda (sp.) 1	250			210						151	210					480	41	210	210				56	30	210		62	140	
Ostracoda (sp.) 2									210			75																	