DOKUZ EYLUL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

IMPACT OF FISH FARMS ON THE DISTRIBUTION OF ORGANIC MATTERS IN THE AEGEAN SEA: A CASE STUDY

by

Janset KANKUŞ

October, 2011

İZMİR

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"IMPACT OF FISH FARMS ON THE DISTRIBUTION OF ORGANIC MATTERS IN THE AEGEAN SEA: A CASE STUDY"** completed by **JANSET KANKUŞ** under supervision of **PROF. DR. NİHAYET 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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IMPACT OF FISH FARMS ON THE DISTRIBUTION OF ORGANIC MATTERS IN THE AEGEAN SEA: A CASE STUDY

ABSTRACT

In this study, the abundance and almost monthly variations of dissolved (DOC) and particulate (POC) organic carbon in seawater, organic and carbon and nitrogen percentages in the sediment were analysed to observe the potential impacts of aquaculture in Ildırı Bay in the Aegean Sea between December 2008 and February 2011. Beside DOC and POC, inorganic nutrients and physical parameters were also investigated. Phytoplankton and detrital fractions of POC determined from the measured POC and Chlorophyll a (Chl a) values. Statistical analysis has been used to investigate the reason of variables' similarities and differences within the stations and correlations and regressions within the parameters.

Due to the fish farm and land based nutrient inputs, the levels of nutrients were found to be high at the coastal stations, K1 and K2. The particulate organic matter concentrations varied between BDL-353 mikroM for POC, BDL-62.1 mikroM for PON, BDL-7 mikroM for Total Particulate Phosphorus (TPP) in the study area. The C:N:P ratio of Particulate Organic Matter (POM) derived from the regression analysis in the area were 43:9:1. Spatial distribution of particulate matter ratios varied from the Redfield ratio. POC: Chla ratio for the study was observed 154:1.

Despite the eutrophic (only for the upper limits) levels of inorganic nutrients and Chl a, any enrichment of organic matter in the vicinity of the cages has not yet led to notable eutrophication phenomena due to the best site selection (waste matter would be diluted by the sea because of the rapid flushing) and the succesful management of the aquaculture facility.

Keywords: Aquaculture, POC, PhytoC, nutrients, Ildırı Bay

BALIK ÇİFTLİKLERİNİN EGE DENİZİ' NDE ORGANİK MADDE DAĞILIMINA ETKİSİ: ÖRNEK ÇALIŞMA

ÖZ

Bu çalışmada akvakültürün olası potansiyel etkilerinin gözlenebilmesi için Ege Denizi'de bulunan Ildırı Koyu'nda Aralık 2008 ve Şubat 2010 tarihleri arasında deniz suyunda çözünmüş (DOC) ve partikül (POC) organik karbon değerlerinin, sedimentte organik karbon ve azot yüzdelerinin takriben aylık dağılımları ve varyasyonları incelenmiştir. POC ve DOC değerlerinin yanında su kolonunda inorganik besin tuzları ve fiziksel parametlereler de araştırılmıştır. Analiz edilen POC ve Klorofil a (Chl a) değerleri kullanılarak POC'nin fitoplankton ve detritus fraksiyonları saptanmıştır. Değişkenler arasındaki benzerlik ve farkılılıkları ve parametreler arasındaki regresyon ve korelasyonları belirlemek için istatistiksel analizler yapılmıştır.

Balık çiftliği aktivitesi ve karasal nutrient girdisine bağlı olarak karasal istasyonlar olan K1 ve K2'de beklendiği gibi en yüksek besin tuzu değerleri gözlenmiştir. Çalışma alanındaki partikül madde konsantrasyonları POC için BDL-353 mikroM, PON için BDL-62.1 mikroM, Toplam Partikül Fosfat (TPP) için BDL-7 μM aralığında değişim göstermiştir. Regresyon analizleri sonucunda Partikül Organik Madde (POM) içerisindeki C:N:P oranının 43:9:1 olduğu gözlenmiştir. Partikül madde oranlarının alansal dağılımında Redfield oranından sapmalar gözlenmiştir. Çalışma alanının POC:Chl a oranının 154:1 olduğu belirlenmiştir.

Doğru alan seçimi (hızlı bir boşaltım ile atıklar deniz tarafından muhtemelen dilue edilmektedir) ve akvakültür tesisinin başarılı yönetimi sayesinde ötrofik besin tuzu ve Chl a seviyelerine (yalnızca üst limitler için) rağmen kafeslerin çevresindeki organik madde zenginleşmesi belirgin ötrofikasyon fenomenine yol açmamıştır.

Keywords: Akvakültür, POC, PhytoC, besin tuzları, Ildırı Körfezi

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CHAPTER ONE
INTRODUCTION

To fully understand patterns of organic matter cycling in marine environment, it is necessary to examine the carbon forms. Both dissolved and particulate organic matter (DOC and POC) and pigment (Chl a) have a major importance on the marine biogeochemical processes, therefore it has been studying up to now (Ediger, Tuğrul, & Yılmaz, 2005; Hansell & Carlson; 2001; Hung, Lin, & Liu, 2000; Kucuksezgin, Kontaş, Altay, & Uluturhan, 2005; Lyutsarev & Shanin, 1996; Tselepides, Zervakis, Polychronaki, Danovaro, & Chronis, 2000; Williams, 1975). The total organic material (TOM) in water can be described as two major pools: Particulate organic matter (POM) and dissolved organic matter (DOM). According to Degens & Ittekkot (1983) definition, all organics that upon filtration of a water sample are retained on a 0.4 to 1.0 μm filter are termed POM, whereas those passing on into the filtrate are termed DOM. According to Sharp (1973), it is not so appropriate to use the terms 'particulate' and 'dissolved' as strict physical definitions rather than suspended and soluble . He defined the size classes of TOM as particulate and colloidal because of the nature of the filters that have to be used and 0.8 μm pore size membrane filter was used to separate the classes of TOC. Although organic matter plays a major role in marine environments and mainly produced by phytoplankton (Williams, 1975), dissolved inorganic nutrients (phosphate [PO_4^{-3}], nitrite [NO_2^-], nitrate [NO_3^-], ammonium [NH_4^+], silicate [$Si(OH)_4$]) are biologically important elements, which are mainly used by phytoplankton for growth and reproduction. In addition, the bacterial degradation of organic matter in water and sediments leads to the release of inorganic N and P. This will then become available for new phytoplankton production. However, the essentiality of occurrence of these elements for biological productivity means that the atomic ratios among each of them are the actual determinants rather than their concentrations. The atomic ratio in which inorganic forms of carbon, nitrogen and phosphorus in open ocean waters with regard to Redfield, Ketchum & Richards (1963) is 106:16:1 and known collectively as Redfield ratio or Redfield-Richards Ratio. Atomic ratio of silicate in addition to Redfield ratio was determined by Brzezinski. That ratio is 106:15:16:1 (C:Si:N:P)

and known as Redfield-Brzezinski ratio (Brzezinski, 1985). Deviations from these ratios can be observed when get close to shore and these deviations is important to determine the nutrient limitation.

Carbon, nitrogen and phosphorus probably also explains the major part of the work in the dissolved organic content of sea water. DOC and POC are important components in the carbon cycle and serve as a primary food source for aquatic food webs. Supply of dissolved organic matter in sea water is rivers, atmosphere and marine sediments as external sources and products of phytoplankton or zooplankton as internal sources. Williams (1975), explained the temporal and spatial distribution of DOM in his study and he concluded that from a selection of results from all over the world there is a general uniformity of the amounts of dissolved organic carbon, nitrogen and phosphorus between various oceans or their climatic zones but there is a small tendency of decrease with depth of this matters. Hung et al. (2000) also pointed out that DOC concentration is moderately high in the surface layer and generally decreased with depth. DOC, DOP and DON dynamics of DOM is highly associated with planktonic processes. The DON:DOP ratio with a median has been observed as 28:1 in oligotrophic waters of Atlantic Ocean (Vidal, Duarte, & Agusti 1999). However, Souchu et al. (1997), reported the C:N:P ratios in DOM as 1060: 17:1 in a coastal area surface waters which under effect of shellfish farming and river plume. DOC has the special importance in DOM fractions because it is by far the major carbon pool in oceans and has a large influence on the trophic food chain (Pettine et al., 2002). Total organic carbon (TOC) is regarded as the main indicator of the sum content of particle and dissolved organic compounds which evaluate the level of eutrophication. The importance and necessity of determining TOC has been known for years. Since DOC constitutes even 90 per cent of TOC, it is the major component of TOC.

As highlighted by Lyutsarev & Shanin (1996), “Particulate organic matter is of high significance in biogeochemical processes at every stage of organic matter transformation due to its activity, and it is one of the most important parameters in the study of carbon cycle in the sea. At the same time, POM concentration provides a

good characteristic of the productivity of the water pool and its food resources, since POM itself is a food source of many species of marine organisms". POC, particulate organic nitrogen (PON) and particulate phosphorus (PP) are the main parameters which explain the chemical composition of POM. There is a large quantity of researches about POM in all over the world from different type of water bodies: examples are; Eppley, Harrison, Chisholm, & Stewart (1977) in Southern California Bight, Wienke & Cloern (1987) in San Francisco Bay, Lyutsarev & Shanin (1996) in Black Sea, Prahl, Small, & Eversmeyer (1997) in Columbia River estuary, Gundersen, Gardner, Richardson, & Walsh (1998) in Arabian Sea, Polat, Tuğrul, Çoban, Baştürk, & Salihoğlu (1998) in Sea of Marmara, Legendre & Michaud (1999) in the euphotic zone of world oceans, Reigstad et al. (2000) in Norwegian fjords, Gismondi, Giani, Savelli, Boldrin, & Rabitti (2002) in Adriatic Sea, Vezzulli, Poveno, & Fabiano (2002) in NE Atlantic, Hung et al. (2000) in SE China Sea, Tselepides et al. (2000) in Cretan Sea, Ediger et al. (2005) in NE Mediterranean Sea, Bizsel et al. (2000) and Kucuksezgin et al. (2005) in İzmir Bay, Suzumara, Kakubun, & Arata (2004) in Tokyo Bay, Krasakopoulou & Karageorgis (2005) in Sarokinos Gulf, Gardner, Mishanov, & Richardson (2006), worldwide, Bizsel, Süzal, Demiral, Inanan, & Esen (2011) in Gediz River.

In fact, the C:N:P ratios of POM in marine waters may differ from Redfield ratio depend on the hydrography of the different marine regions, nutritional status, growth rates of marine phytoplankton and grazing pressure. The atomic ratios of POC:PON:PP that given in some studies in Turkish waters are 138:14:1 in İzmir Bay (Kucuksezgin et al., 2005), 98:9.5:1 during the period of high production and 78:8.3:1 during the low production period in Sea of Marmara (Polat et al., 1998) and in the range of 109-164:7.5-9.6:1 (Yılmaz et al., 1998) in Southern Black Sea. POC:PON ratio ranges between 6 and 11 in İzmir Bay (Bizsel et al., 2000).

POC has a special position because it has an importance in the cycling of carbon and represents the sea water production by phytoplankton. POC in aquatic environments composed of living and non-living materials.

Highlighted by Parsons (1984), particulate material which has been allowed to settle out of a sea water sample can be examined with a microscope. It is quite apparent that apart from planktonic organisms there are many fragments of detrital material. Microscopic examination of the detrital POC suggests that it may originate from either:

i. Materials of terrestrial origin, transported into the sea either by rivers or via the atmosphere (allochthonous materials).

ii. Substances autochthonous to the marine environment.

Since the bulk of the POC in the sea is derived ultimately from the phytoplankton it would be anticipated that there should be a general relationship between the standing stock of phytoplankton and POC. High concentrations of POC were generally associated with areas of high primary productivity.

Estimation of phyto- and detrital carbon quantity of the total POC is used as an indicator of the POC origin and primer productivity in water body. Chemically measured field samples of POC and Chl a values have being used when determining phytoplankton carbon. (Eppley et al., 1977; Metin, 1995; Reimann, Simonsen, & Stengaard, 1989; Suzumara et al, 2004; Wienke & Cloern, 1987). Suzumara et al., 2004, pointed out that during the low-biomass season; detritus-POC dominated POM, whereas the samples from the high-biomass season were enriched with phyto-POC. A large phytoplankton bloom in spring characterized by very high Chl a/POC ratios in the research of Prahl et al. (1997). In the study of Metin (1995), the ranges of chlorophyll *a* and POC have given for the Izmir Bay which is known as a eutrophic coastal area, a strong correlation between POC and chlorophyll *a* has been found and in comparison with outer İzmir Bay, the bulk of POC is detrital in the polluted inner İzmir bay. Ratio of C: Chl a can vary in a wide range in all over the world in different type of seawaters as proportions of phytoplankton and detritus change (Gardner et al., 2006). According to the review of Putland & Iverson (2007) about the prepublished C:Chl a ratios, the ratios have ranged from about 5 to 300 in oceanic, coastal, and estuarine waters and tend to be highest in oligotrophic waters where chlorophyll levels are low or dominated by small cells.

In samples from nutrient impoverished oceanic surface water the phytoplankton carbon has been observed low and has been relatively smaller fraction of POC and POC has been dominated by organic detritus and phytoplankton in coastal waters. (Eppley et al., 1977). The concentration of POC in coastal waters is generally higher than in oceanic waters. This can be attributed to the higher natural productivity of coastal waters, the addition of allochthonous organic material from the land and occasionally, to the direct effect of particulate organic pollutants (Parsons, 1984).

In aquaculture areas, because of the wastes which can cause enrichment in seawater like fecal pellets and uneaten food, organic matter values are generally high. In fact, mariculture activities can cause environmental impacts as nutrient enrichment, organic matter load and an increase in primary production and in the end may cause eutrophication which creates an undesirable disturbance of the life cycle of organisms resulting in water quality changes. According to the eutrophication discussion of Nixon (1995), the simple and short definition of eutrophication is “an increase in the rate of supply of organic matter to an ecosystem”.

The *cause* of eutrophication may be an increase in the input of inorganic nutrients, a decrease in the turbidity of the water, a change in the hydraulic residence time of the water, a decline in grazing pressure, etc. All of these factors may cause eutrophication, but they are not the phenomenon itself. A variety of other changes may be *associated with* or even *caused* by the increase in the supply of organic carbon to an eco-system. It is also clear that ‘eutrophication’ is a process, a change. It is not a trophic state.

However, it is hard to asses an environment as eutrophic in regard to nutrient levels, Meanwhile, Karydis (1999) published a eutrophication scale developed according to the characteristics of the Greek Seas by use of mean annual values of phosphate, nitrate, ammonium, chlorophyll a and phytoplankton cells.

Aquaculture is an important economic activity in the coastal and rural areas of many countries. Due to the sharp increase in world’s demand for sea foods,

aquaculture became progressively an important sector in worldwide. In 1984 aquaculture accounted for only 8% of fisheries production leaping to ca. 30% in 2002 and in the coming decades aquaculture is predicted to overtake capture fisheries (Staniford, 2002). The growing tendency of the whole world and three specific countries with their large potential and Europe from 1995 to 2005 is shown as volumes in tonnes in Table 1.1 (European Commission, 2008).

Table 1.1 Total aquaculture production of the whole world, whole Europe, Norway, Greece and Turkey from 1995 to 2005. (Volumes in tonnes)

	1995	2000	2005
World	31,195,904	45,660,666	62,959,046
Europe	1,464,743	1,896,703	1,937,347
Norway	277,615	491,329	656,636
Greece	32,644	95,418	106,208
Turkey	**21,607**	**79,031**	**119,177**

The aquaculture sector in Turkey can be characterized by limited species (primarily three species: rainbow trout, sea bass and sea bream) and system diversity (cages), small or medium size farms, a production oriented approach versus export dependent (EU) market (Okumuş & Deniz, 2007). Turkey is currently the second largest producer in Europe of both sea bass and sea bream (after Greece) and of rainbow trout (after Norway). (European Commission, 2008)

All these figures elucidate apparently that aquaculture is an inevitable development, an alternative source and potentially relieving the pressure on the capture fishery sector for aquatic production. Besides its inevitability, fish farming activities are strongly dependent on the healthy aquatic environment, and thus the sustainability is the main challenge. In undeveloped and developing countries aquaculture activities have mostly managerial problems due to mainly deficiency in appropriate technology and administrative policy. As a 'Forward Study of Community Aquaculture' commissioned by the European Commission (EC) states, "As the aquaculture industry has developed and has incorporated technological advances, it has moved from extensive to intensive systems. This intensification of

production methods has been accompanied by an increase in the potential threat to the already precarious ecological equilibrium in our streams, reservoirs and oceans….Recently, this intensification of aquaculture production has led to the industry being regarded as one of the leading polluters of the aquatic environment" (MacAllister Elliot and Partners Ltd, 1999). Therefore, continous monitoring programme is essential in order to be able to improve and refine the contributions from scientific researces on the environmental effects of fish farms.

Considerable research effort has been invested during recent decades to investigate these impacts on environmental parameters (Islam, 2005; Mishra, Rathi, & Thatoi, 2008; Pitta, Apostolaki, Tsaragaki, Tsapakis, & Karakassis, 2006; Porrello et al.; 2005; Yokoyama, 2003). It is apparent that the raising importance of aquaculture requires more monitoring effort to obtain the sustainability of this activity. When it has been focused on Aegean Sea there is an important difference between east and west part in the matter of the number of researches, especially studies on the water quality, lots of study can be found in Greek waters (Belias, Bikas, Dassenakis, & Scoullos, 2003; Karakassis, 2001; Mantzavrakos, Komaros, Lyberatos, & Kaspiris, 2007; Papoutsoglou, Costello, Stamou, & Tziha, 1996; Pavlidis, Angellotti, Papandroulakis, & Divanach, 2003; Pitta, Karakassis, Tsapakis, & Zivanovic 1999; Pitta, Apostolaki, Giannoulaki, & Karakassis, 2005) but unfortunately, in Turkey, there are quite few (Basaran, Aksu, & Egemen, 2006; 2010; Demirak, Balcı, & Tüfekçi, 2006; Gier, Küçüksezgin, & Koçak, 2007, Gier, Uslu, & Bizsel, 2008). However, according to the fishery and aquaculture statistics of FAO (2007), aquaculture production in tonnes in Turkey and Greece is really close. (140,021 and 113,258 tonnes in 2007, respectively). The notable development of the sector was noticed after 1985, Mediterranean countries started developing marine culture, using the gilthead sea bream and the sea bass species (Klaoudatos, 2001).

Disturbance effects of fish farming on the seabed and organic matter accumulation in sediment are well known for the Mediterranean farming industry (Edgar, Macleod, Mawbey, & Shields, 2005; Karakassis, Tsapakis, Hatziyanni,

Papadopoulou, & Plaiti, 2000; Papageorgiou, Kalantzi, & Karakassis, 2010; Pitta et al., 1999; Porrello et al., 2005; Mantzavrakos et al., 2007; Vezzulli**,** Marrale, Moreno & Fabiano, 2003).

The effect of fish farming on water column variables at small spatial scales, i.e. in the immediate vicinity of fish cages of individual farms has been addressed by various authors (Belias et al., 2003; Pitta et al., 1999, 2005). In situ fish farms continuously release substantial particulate and dissolved nutrients to the surrounding environment (Belias et al., 2003; Demirak et al., 2006; Gier et al., 2008; Karakassis, 2001; Mantzavrakos et al, 2007; Pavlidis et al., 2003; Pitta et al., 1999, 2005, 2006) and therefore eutrophication would be expected. These studies reported a moderate increase in concentrations of phosphate and ammonium within the fish cages.

The influences of fish farming on POC or DOC have been previously monitored in Mediterranean (Belias et al., 2003; Gier et al., 2008; Pitta et al., 1999, 2005, 2006). Some of these studies concluded that POC showed no significant differences between fish farming zones and reference sites (Pitta et al., 1999, 2005, 2006). Pitta et al (2006) have monitored fish farm effect on chemical variables of the water coloumn in three different aquaculture zones Mediterranean (Alicante-Spain, Sicily-Italy and Sounion-Greece) and they observed the average POC concentrations as 9.6 $\mu g/l^{-1}$ and 22.8 $\mu g/l^{-1}$ (0.8 μM and 1.9 μM) in Alicante and Sicily, respectively. Gier et al. (2008), have studied the effects of marine fish farming on nutrient composition and plankton communities in another aquaculture area in Aegean Sea, Turkey. POC concentrations has ranged between 1.51-26.55 μM, with a mean value of 9.72 μM and the mean ratios of particles in water column (POC:PON:PP) has been given as 110:13:1.

There are a few researches in the fish farm zone in Ildırı Bay. Basaran et al. (2006) has monitored the impacts of off-shore Cage Fish Farm on Water Quality. Yurga, Koray, Kaymakçı, & Egemen (2005), has studied the microplankton species diversity and physico-chemical parameters in the fish farm area. In fact, all these

effects are depended on the nature of the wastes released, hydro- and ecological characteristics of the site and the efficiency of the management of the farms.

In order to observe the potential impacts of aquaculture, in this study, the abundance and almost monthly variations of different parameters in seawater and sediment were analysed to examine the level of the effect of the fish farm activities on the distribution of organic carbon and their fractions i.e., POC, DOC, Detrital C and Phyto C. For this purpose, concentration of POC, DOC, PON, DOP and phytoplankton biomass (i.e. Chl a) in seawater and OC, ON, TC, TN in sediment were determined in relation to physical and chemical parameters such as; total particulate phosphorus(TPP) and PON as particulate,, total dissolved phosphorus(TDP), dissolved organic phosphorus (DOP), dissolved inorganic nutrients (ammonium, nitrate, nitrite, phosphate and silicate) as dissolved parameters and total phosphorus (TP), TOC, total suspended solids (TSS) and physical parameters (dissolved oxygen, pH, temperature, density and salinity). The role of sediment resuspension on the composition and distribution of organic carbon has been also considered. Phytoplankton and detrital fractions of POC were assumed from the measured POC and Chl a values. Statistical analysis has been used as a tool to investigate the reason of these variables' similarities and differences within the stations and correlations and regression within the parameters.

CHAPTER TWO
MATERIAL AND METHOD

2.1 Study Area

The Ildırı Bay, as one of the inner parts of the Çesme bay is located at the mid west coast of Turkey facing to the eastern coast of island Chios, in Aegean Sea. It is surrounded by Çeşme and Karaburun Peninsulas. The bay is rich in small island formations (Figure 2.1). The prevailing current direction in the area is from northwest to southeast (Çamlı Yem Besicilik Incorporation, EIA Report, 2008).

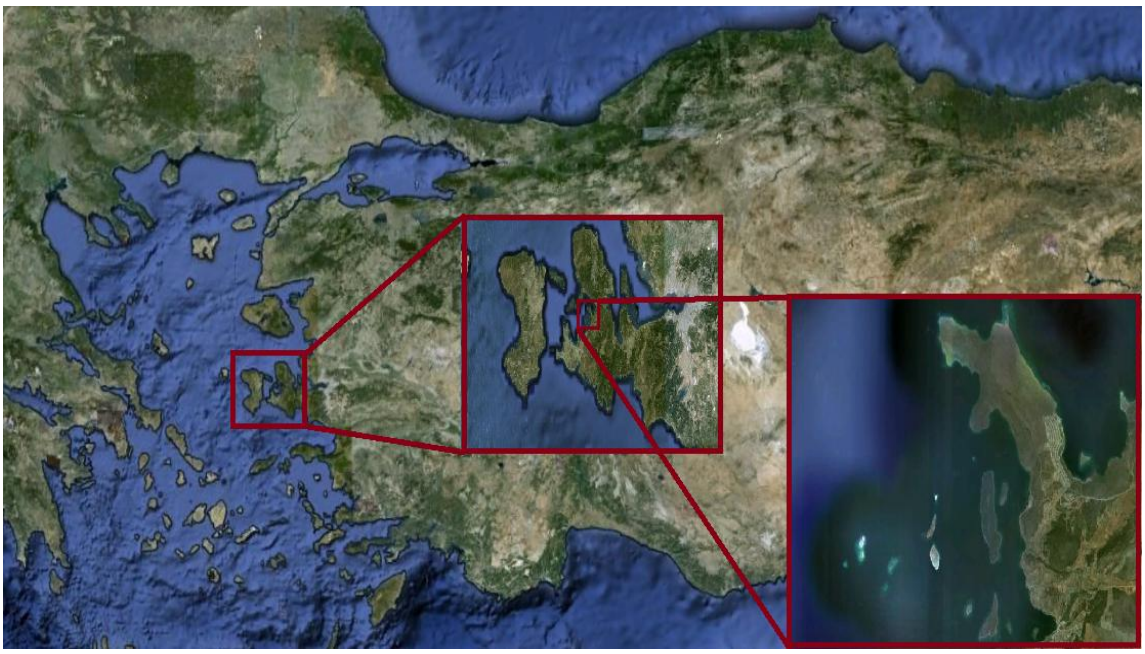


Figure 2.1 Location of the study area (Ground images are from Google Earth, 2011)

The bay is one of the intensive cage culture zones. The annual production capacity of the 20 fish farming establihments is 15,690 ton of seabream and seabass Demirel (2010). There are also bluefin tuna ranching facilities. Another important, perhaps the most prominent, activity in the bay is tourism. Çeşme town and its vicinity, which is an internationally popular tourism area, is located at southern side of Ildırı Bay. Together with the summer houses and resort hotels, the number of touristic visitors are 365.432 per year between 2003-2008. This number reveals that tourism

activity in the area is the another impact source for marine ecosystem (Demirel, 2010).

For determining the contribution of aquaculture activities to the organic matter distribution in the Ildırı Bay, the sampling site includes area where the cages are moored and a reference site at the farthest possible location from the aquaculture facilities. The sampling strategy was designed to resolve large spatial differences.

2.2 Sampling Stations

The collection of seawater and sediment samples were carried out by 'RV / Dokuz Eylül 1' and 'RV / K. Piri Reis'. 12 different sampling survey were conducted over the period December 2008 to February 2011. (Table 2.1).

The data base is rather large with 10 stations where temprature, salinity, densitiy dissolved oxygen, pH, PO_4^{-3}, NO_2^-, NO_3^-, NH_4^+, $Si(OH)_4$, POC, PON, TOC, DOC, TPP, TDP, DOP, TP, TSS and Chl a were determined, and 12 cruises were undertaken.

Table 2.1 Sampling periods in the area with dates.

Sampling No.	Day	Month	Year
1	1-3	December	2008
2	20-22	April	2009
3	23-25	July	2009
4	17-19	February	2010
5	22-23	March	2010
6	19-20	April	2010
7	14-15	June	2010
8	8-9	July	2010
9	6-7	September	2010
10	13-14	October	2010
11	11-12	November	2010
12	10-11	February	2011

In addition to the sampling stations in between the cages and the reference station, there were also two hot sampling points near the shore. Station K1 was near the fish farm discharge source, Station K2 was on the mouth of a little fresh water source. Station 1, 2, 3 and 4 were in between the first cage platform, while Station 5, 6 and 7 were second and the new cage platform. The reference station was on the westernmost part of the study area. At the end of 2009, the first cage platform was moved to a new site at the offshore in accordance with a new regulation entered into force. The locations of stations were showed in Figure 2.2 and the depth characteristics of stations were given in Table 2.2.

Almost each station in the area has its own characteristic features and has different properties. To observe the temporal variations in the parameters as partial classification is used for the area. K1, K2 and Reference stations (Ref) are considered seperately but stations 1,2 and 3 considered as Inner Part (IP) which under effect of K1 and K2 and locate between the land and the island that lied in the north-south direction, stations 5 and 7 assesed as Near Cage (NC) zone which is close to the

cages in the aquaculture area and stations 4 and 6 assesed as Far Cage (FC)zone which is relatively far from the source stations and cages.

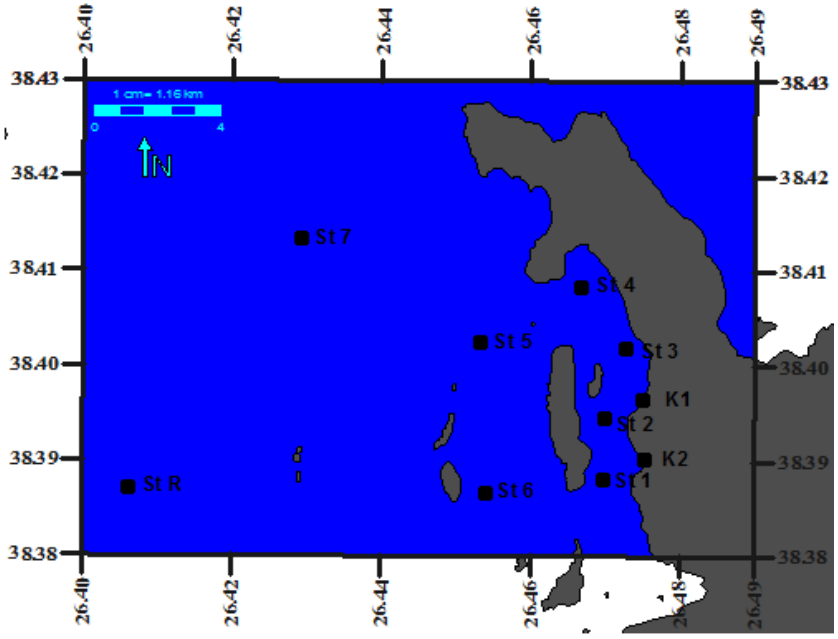


Figure 2.2 Locations of sampling stations.

Table 2.2 The depth characteristics of stations

Stations	Depth (m)
St1	14
St2	1
St3	11
St4	20
St5	48
St6	49
St7	67
StR	61
K1	0.5
K2	0.5

2.3 Methods

2.3.1 Determination of Water Coloumn Parameters

2.3.1.1. Physical Parameters

The temperature, salinity and density of the seawater were measured and recorded in situ using the CTD (SBE SEACAT 19 plus and Seabird 911plus) Profiler. The pH were measured by WTW Multi 340i (WTW GmbH & Co. KG, Weilheim). The dissolved oxygen (DO) were determined immediately on the board based on the method first proposed by Winkler (1888) and modified by Strickland & Parsons (1968).

2.3.1.2 Chemical Parameters

Water samples were taken at standard dephts (0, 2, 5, 10, 20) with Nansen sampling bottle at the 0, 2, 5 and 10 m depths and GoFlo sampling bottle at the 20, 30, 40, 50, 60, 70 m depths for analyses of chemically measured parameters (PO_4^{-3}, NO_2^-, NO_3^-, NH_4^+, $Si(OH)_4$, POC, PON, TPP, TOC, TDP, TSS and Chl a). Before sampling, polyethylene bottles were washed with 10% HCl and rinsed 5 or 6 times with distilled water. All samples were sealed in these pre-cleaned bottles and stored in the deep-freezer until analysis.

The sea water samples for TOC analysis were taken into 100 ml plastic bottles which were pre-washed with 10% HCl acid and rinsed with distilled water and the samples were kept frozen until they were processed. The measurements were carried out by a Schimadzu TOC-V CPH/CPN Total Organic Carbon Analyzer by high-temperature combustion method at 680 °C according to APHA 5310 B Total Organic Carbon, High Combustion Method (APHA, 1999).

For POC, PON, TPP and Chl-a analyses, the sampled waters were filtered through zooplankton netting with 200 μm mesh size in order to eliminate possible macro

planktonic contamination, then they were re-filtered through the Whatman GF/F filters (pore size:0.7 μm) pre-exposed to 450 ^{o}C for 2.5 h in the oven for POC, PON, TPP measurements. After filtration, filters for POC/PON analysis were kept frozen until they were processed. Before POC and PON analysis, filters were dried at 50 °C and fumed with concentrated HCl acid to remove inorganic carbon and each filter was placed in a tin capsule and measurements were done by using CHN Carlo ERBA NC2500 Elemental Analyzer (Verardo, Froelich, & Mc Intyre, 1990).

To determine Total Particulate Phosphorus, water samples were filtered through 47 mm GF/F filters (pre-combusted at 450-500 °C for 2.5 h). 4 ml of 0.17 M Na_2SO_4 were added onto filters and they kept frozen into pre-combusted aluminium foils. Filtered water were taken into pre-washed 100 ml plastic bottles and frozen directly for the determinations of nutrients and Total Dissolved Phosphorus (TDP). TPP and TDP were determined spectrophotometrically by using T80 Plus UV/VIS Spectrophotometer (Solorzano & Sharp ,1980).

Sea water samples were filtered through 47 mm GF/F filters for Chl-a samples. Filters were treated with 2 ml 1% $MgCO_3$ and measurements were carried out spectrophotometrically using T80 Plus UV/VIS Spectrophotometer by following the methods of Lorenzen ve Jeffrey (1980) and ESS Method 150.1 (1991).

The determination of NO_2^-+ NO_3^- and PO_4^{-3} were carried out using a 2 Channel Scalar Autoanalyzer according to Strickland & Parsons (1972) while the determination of NO_2^-, NH_4^+ and $Si(OH)_4$ were carried out spectrophotometrically by use of T80 Plus UV/VIS Spectrophotometer according to Grasshoff et al. (1983), Reusch Berg & Abdullah (1977) and Grasshoff et al. (1983), respectively.

The Total Phosphorus (TP) is the sum of the Total Dissolved Phosphorus (TDP) and Total Particulate Phosphorus (TPP) concentrations. The Dissolved Organic Phosphorus (DOP) concentration was calculated by subtracting dissolved PO_4^{-3} from TDP. The Dissolved Organic Carbon (DOC) was also calculated by subtracting POC from TOC.

By assuming that the largest fraction of living material is phytoplankton, and the living organic carbon has been estimated as chlorophyll, the proportion of living (phytoplankton carbon) and non-living (detrital) parts of POC were calculated using the equation according to Parsons (1974) :

POC – Chlorophyll a x f = Detrital POC

When determining phytoplankton or detrital fractions of POC, the ratio derived from a linear regression of POC on Chl a. The slope of the line equals the average f of that organic matter which is associated with the pigment. The intercept with *y*-axis (carbon) is interpreted as the average amount of carbon which is detrital matter. (Banse, 1977).

2.3.2 Determination of Sediment Parameters

The sediment were sampled by 50x50 cm Box Corer and the surface layer of sediment were taken into acid washed glass jars with the care in order to prevent from contamination for organic matter content analysis. Samples were dried at 55 °C until constant weight. For the determination of the percentage organic carbon (%OC), carbonate particles were removed from the filters using acidification in concentrated HCl fumes. The percentage total carbon(%TC), the percentage organic carbon (%OC), the percentage total nitrogen (%TN) and the percentage organic nitrogen (%ON) in the sediment samples were determined by use of a CHN Carlo ERBA NC2500 Elemental Analyzer according to the procedure of Verardo et. al (1990).

2.3.3 Statistical analyses

Correlation and regression analyses were carried out on the collected data to find out the relationships between variables and atomic ratios of particulate and dissolved nutrients. These analyses were done using STATISTICA 8.0. Besides correlation and

regression, Principal Component Analysis (PCA) was applied to the variables which have correlated in each other to explain the similarities and differences of parameters from each other and to find the parameters that have the largest variation. PCA has been preferred as a mathematical tool because large matrices of correlation coefficients are available(Bizsel, N. & Uslu, O., 2000; Lundberg,C., Lönnroth, M., von Numers, M. & Bonsdorf, E., 2005; Wu, M. et al., 2010). PCA analyses were done by PRIMER 5.0. The derived data(DOC,TP and DOP) and some physical parameters haven't been used in PCA.

CHAPTER THREE
RESULTS

The maximum, minimum and mean values, together with standard deviations of the physical and chemical parameters at all sampling stations during the study period have been calculated and summarized in Table 3.1. At two source stations i.e. K1 and K2, organic matter, TPP, TSS and inorganic nutrient values are higher than the other sampling stations meanwhile pH and DO values are lower than the other sampling stations at fish farm source (K1). Also NH_4^+ values in fish farm source are found the highest as expected. In the other sampling stations except source stations, measured vaues of all parameters are found close to each other within each parameter.

Table 3.1 Minimum, maximum, mean and standart deviations of all measured variables in the area during the study period of December 2008-Februray 2011.

		DO (ml/l)	Temp. (^{o}C)	Sal. (psu)	Dens. (g/cm^3)	pH	PO_4^{-3} (µM)	NO_2^- (µM)	NO_3^- (µM)	NH_4^+ (µM)	$Si(OH)_4$ (µM)
	Mean	5.37	20.04	39.22	27.95	8.18	0.04	0.06	0.11	1.42	1.19
	Min	4.24	14.86	38.30	26.66	8.08	BDL	BDL	BDL	BDL	0.18
	Max	8.12	25.19	40.54	29.87	8.31	0.08	0.23	0.70	7.07	3.22
St1	S.D.	0.68	3.47	0.44	0.94	0.06	0.02	0.05	0.13	1.64	0.75
	Mean	5.21	20.10	39.16	27.75	8.18	0.04	0.06	0.20	1.73	1.13
	Min	4.14	14.89	38.20	24.00	8.09	BDL	BDL	BDL	BDL	BDL
	Max	6.74	24.79	39.84	29.14	8.26	0.08	0.26	1.85	17.53	3.35
St 2	S.D.	0.47	3.45	0.44	1.05	0.04	0.02	0.06	0.39	3.68	0.79
	Mean	5.06	19.90	39.12	27.90	8.18	0.04	0.04	0.23	0.10	1.13
	Min	3.94	14.93	38.23	26.85	8.07	BDL	BDL	BDL	BDL	0.04
	Max	5.83	24.64	39.86	29.39	8.27	0.09	0.21	2.03	2.76	2.95
St 3	S.D.	0.40	3.25	0.48	0.87	0.05	0.02	0.04	0.33	0.74	0.71
	Mean	5.13	19.98	39.09	27.86	8.18	0.04	0.05	0.12	1.48	1.05
	Min	3.83	14.86	38.30	26.60	8.06	BDL	BDL	BDL	BDL	0.08
	Max	5.79	24.47	39.63	29.17	8.26	0.18	0.16	0.35	9.56	2.95
St 4	S.D.	0.39	3.27	0.44	0.85	0.05	0.03	0.04	0.10	1.91	0.74
	Mean	5.18	19.11	39.13	28.14	8.18	0.05	0.08	0.25	1.60	1.12
	Min	3.89	14.93	38.30	26.74	8.06	BDL	BDL	BDL	BDL	BDL
	Max	5.71	24.92	39.56	29.10	8.28	0.12	0.37	2.77	21.94	10.50
St5	S.D.	0.38	3.05	0.37	0.79	0.04	0.03	0.09	0.36	3.09	1.21
	Mean	5.24	19.23	39.16	28.12	8.19	0.05	0.09	0.23	1.11	1.07
	Min	3.81	15.06	38.20	26.42	8.09	BDL	BDL	BDL	BDL	BDL
	Max	6.04	25.13	40.45	29.85	8.30	0.61	0.44	1.66	3.48	3.49
St 6	S.D.	0.39	3.12	0.41	0.85	0.04	0.08	0.11	0.30	0.77	0.68
	Mean	5.21	18.86	39.04	28.09	8.19	0.06	0.16	0.35	1.44	1.48
	Min	4.17	14.68	37.42	26.29	8.11	BDL	BDL	BDL	BDL	BDL
	Max	6.09	24.78	39.53	29.20	8.24	0.79	1.00	2.44	5.62	17.19
St 7	S.D.	0.35	2.94	0.43	0.77	0.03	0.09	0.20	0.44	1.02	1.83
	Mean	5.29	18.68	39.09	28.13	8.18	0.05	0.06	0.54	1.23	1.57
	Min	4.56	14.73	37.68	24.19	8.10	BDL	BDL	BDL	BDL	BDL
	Max	7.41	24.35	39.58	29.18	8.28	0.35	0.57	10.55	3.91	7.09
St R	S.D.	0.38	3.03	0.38	0.86	0.04	0.05	0.09	1.30	0.89	1.31
	Mean	5.20	20.94	35.22	24.44	7.70	3.54	2.25	5.08	53.85	14.05
	Min	3.27	16.70	23.27	15.96	7.52	1.05	0.77	1.21	2.63	0.48
	Max	7.02	25.80	38.46	27.17	7.96	5.85	4.79	17.71	290.0	29.58
K 1	S.D.	1.25	2.79	4.14	3.63	0.13	1.52	1.09	4.76	75.96	9.90
	Mean	6.25	21.69	36.02	24.05	8.22	0.08	0.11	2.60	2.61	9.05
	Min	4.49	16.20	11.08	8.18	8.13	BDL	BDL	BDL	BDL	0.71
	Max	9.86	30.20	39.58	28.75	8.29	0.19	0.46	20.10	10.03	55.54
K 2	S.D.	1.48	4.36	8.34	6.74	0.05	0.06	0.14	5.90	3.07	15.24

Table 3.1 Continued.

		TPP (µM)	TDP (µM)	DOP (µM)	TP (µM)	POC (µM)	DOC (µM)	TOC (µM)	PON (µM)	Chla (µg/l)	TSS (mg/l)
	Mean	0.04	0.30	0.28	0.32	14.19	123	137	2.49	0.52	2.25
	Min	BDL	0.04	BDL	0.03	BDL	49	70	BDL	0.10	0.06
	Max	0.11	1.01	0.96	1.02	76.56	271	281	19.64	1.22	12.60
St1	S.D.	0.02	0.22	0.21	0.21	14.46	47	46	3.65	0.30	2.90
	Mean	0.08	0.37	0.34	0.44	17.81	169	187	2.58	0.72	1.65
	Min	BDL	0.04	0.02	0.06	0.06	36	79	BDL	0.11	0.16
	Max	0.84	1.75	1.67	1.77	86.96	1998	2006	16.69	3.26	6.00
St 2	S.D.	0.12	0.31	0.31	0.32	20.38	276	274	4.09	0.62	1.25
	Mean	0.12	0.61	0.58	0.72	20.38	116	134	3.01	0.90	1.77
	Min	0.01	0.05	BDL	0.07	0.20	41	76	BDL	0.11	0.20
	Max	0.89	13.21	13.15	13.27	82.93	250	263	23.85	4.90	8.80
St 3	S.D.	0.21	1.90	1.91	1.90	18.51	45	43	4.75	1.04	1.76
	Mean	0.05	0.30	0.27	0.34	14.75	163	178	2.76	0.88	2.03
	Min	0.01	0.05	BDL	0.06	BDL	32	38	BDL	0.09	0.11
	Max	0.24	1.26	1.24	1.28	67.40	824	832	30.59	3.72	11.30
St 4	S.D.	0.04	0.24	0.24	0.23	16.52	135	135	6.83	0.84	2.73
	Mean	0.03	0.29	0.26	0.31	11.97	151	161	1.63	0.59	1.59
	Min	BDL	0.01	BDL	0.04	0.23	BDL	25	BDL	0.07	BDL
	Max	0.21	1.30	1.18	1.31	39.75	1165	1618	12.56	2.43	11.23
St5	S.D.	0.03	0.21	0.21	0.22	10.74	142	174	2.77	0.50	2.43
	Mean	0.02	0.29	0.25	0.31	10.28	147	164	1.83	0.48	1.17
	Min	BDL	0.03	BDL	0.06	BDL	18	22	BDL	0.07	BDL
	Max	0.06	1.37	1.34	1.38	40.75	583	912	18.30	1.59	7.20
St 6	S.D.	0.01	0.23	0.23	0.24	8.82	97	125	3.54	0.32	1.29
	Mean	0.02	0.29	0.24	0.34	10.68	142	162	1.05	0.49	1.52
	Min	BDL	0.03	BDL	0.06	0.79	57	70	BDL	0.07	0.00
	Max	0.07	0.73	0.72	0.76	70.86	626	1196	16.00	1.33	8.20
St 7	S.D.	0.01	0.16	0.15	0.17	11.25	86	135	2.01	0.34	1.74
	Mean	0.02	0.22	0.18	0.24	14.51	135	146	1.61	0.41	1.73
	Min	BDL	0.01	BDL	0.05	BDL	63	24	BDL	0.08	BDL
	Max	0.07	0.74	0.72	0.75	63.36	776	780	13.09	1.45	9.46
St R	S.D.	0.01	0.13	0.12	0.14	12.15	97	91	2.66	0.31	1.90
	Mean	1.25	4.61	1.32	5.93	160.30	282	442	26.44	5.43	16.05
	Min	0.31	3.15	BDL	3.71	47.87	3	172	0.45	0.03	3.45
	Max	7.03	9.09	3.24	16.12	352.67	1214	1567	62.08	17.29	45.00
K 1	S.D.	1.93	1.79	1.06	3.62	83.92	331	383	20.85	5.61	11.86
	Mean	0.67	0.47	0.53	1.19	52.25	183	175	4.73	0.80	17.79
	Min	0.03	0.01	BDL	0.11	8.03	BDL	40	0.06	0.07	2.80
	Max	4.92	1.47	1.36	6.39	164.59	556	582	21.86	1.51	57.20
K 2	S.D.	1.42	0.41	0.36	1.76	54.13	139	138	6.32	0.43	18.03

3.1 Water Column

3.1.1 Physical Parameters

Seasonal values (minimum, maximum, and mean values with their standart deviation) of temperature, salinity, density, pH and DO in the study area are given in Table 3.2. Salinity and density values ranged from 17.02 psu to 39.30 psu and from 28.26 g/cm^3 to 29.17 g/cm^3, respectively. Salinity values were higher in summer than those in the other seasons. Density values were higher in winter than those in the other seasons.Temperature values vearied seasonally between 15.10 -17.33-°C in spring, 16,95-30.20 °C in summer, 18.48-21.58 °C in autumn and 14.68-19.90 °C in winter.

The study area of the bay has a two-layer temperature structure during summer because of the surface heating. In summer there is a thermocline between 10 and 30 m depth. In winter water column is almost homogenous. There isn't any prominent halocline even in the deepest stations. Depth profiles of temperature and salinity at each sampling station except K1 and K2 (surface sampling stations) for each sampling period are given in Appendix 1.

DO concentrations ranged between 3.27-9.86 ml/l with a mean value of 5.24 ml/l in the whole area. Minimum concentration was observed in K1 in October 2010 while maximum concentration was at K2 in April 2009. DO concentrations were observed higher in winter than those in the other sampling periods. pH values were higher in autumn than those in the other seasons. Minimum value (7.52) of pH found at fish farm source (K1) in April 2010 meanwhile maximum value (8.31) was observed at station 1 in November 2010.

Table 3.2 The seasonal mean, minimum, maximum and standart deviation values of temperature, salinity, density, pH and DO in the study area.

		Spring	Summer	Autumn	Winter
	Min.	17.33	16.95	18.48	14.68
	Max.	15.10	30.20	21.58	19.90
	Mean	21.80	22.38	20.55	15.99
	Std.dev.	1.18	2.73	0.81	1.12
Temperature (°C)	n	153.00	212	99	123
	Min.	17.02	36.24	37.20	23.27
	Max.	39.30	39.96	39.44	40.54
	Mean	38.42	39.36	39.16	38.97
	Std.dev.	1.85	0.39	0.33	1.54
Salinity (psu)	n	153.00	211	99	121
	Min.	28.26	22.10	26.58	15.96
	Max.	29.17	28.82	28.41	29.87
	Mean	28.26	27.37	27.79	28.81
	Std.dev.	2.78	0.88	0.21	1.33
Density (g/cm³)	n	43.00	212	99	120
	Min.	7.52	7.56	7.68	7.62
	Max.	8.26	8.27	8.31	8.30
	Mean	8.17	8.16	8.21	8.18
	Std.dev.	0.09	0.06	0.09	0.08
pH	n	154.00	210	110	109
	Min.	4.42	3.49	3.27	4.83
	Max.	9.86	6.74	5.45	8.12
	Mean	5.52	4.96	5.04	5.56
	Std.dev.	0.51	0.42	0.26	0.47
DO (ml/l)	n	154.00	214	110	122

3.1.2 Dissolved Parameters

3.1.2.1 Inorganic Nutrients

Measured dissolved inorganic nutrients (phosphate [PO_4^{-3}], nitrite [NO_2^-], nitrate [NO_3^-], ammonium [NH_4^+], silicate [$Si(OH)_4$]) during study period at selected stations are given in Table 3.1.

PO_4^{-3} ranged between BDL-0.02 μM in the study area for all sampling periods. PO_4^{-3} varied between 0.01-0.08 μM at St1 , 0.01-0.08 μM at St2, 0.01-0.09 μM at St3, BDL-0.18 μM at St4, BDL-0.12 μM at St5, BDL-0.61 μM at St6, BDL-0.79 μM at St7, BDL-0.35 μM at StR, 1.05-5.85 μM at K1 and 0.02-0.19 μM at K2. The maximum value of PO_4^{-3} was observed at K1 in December 2008.

NO_2^- varied between BDL-4.79 μM in the study area for all sampling periods. The ranges of NO_2^- for all sampling stations are St1: BDL-0.23 μM, St2: BDL-0.26 μM, St3: BDL-0.21 μM, St4: BDL-0.16 μM, St5: BDL-0.37 μM, St6: BDL-0.44 μM, St7: BDL-1.00 μM, StR: BDL-1.00 μM, K1: 0.77-4.79 μM, K2: BDL-0.46 μM. NO_2^- reached its maximum level at K1 in September 2010.

NO_3^- ranged between BDL-20.10 μM in the study area for all sampling periods.. NO_3^- varied between BDL-0.7 μM at St1, BDL-1.85 μM at St2, BDL-2.33 μM at St3, BDL -0.35 μM at St4, BDL -2.77 μM at St5, BDL -1.66 μM at St6, BDL -2.44 μM at St7, BDL -10.55 μM at StR, 1.21-17.71 μM at K1 and BDL -20.10 μM at K2. The maximum value of NO_3^- is observed at K2 in April 2009

NH_4^+ varied between BDL-290 μM in the study area for the whole study period. The ranges of NH_4^+ for all sampling stations are St1: BDL-7.07 μM, St2: BDL-17.53 μM, St3: BDL-2.76 μM, St4: BDL-9.56 μM, St5: BDL-21.94 μM, St6: BDL-3.48 μM, St7: BDL-5.62 μM, StR: BDL-3.91 μM, K1: 2.63-290.00 μM, K2: BDL-10.03 μM. NH_4^+ reached the maximum level at K1 in April 2009.

$Si(OH)_4$ varied between BDL-55.54 μM in the study area for all sampling periods. $Si(OH)_4$ ranged between 0.18-3.22 μM at St1, BDL-3.35 μM at St2, 0.04-2.95 μM at St3, 0.08-2.95 μM at St4, 0.00-10.50 μM at St5, BDL-3.49 μM at St6, BDL-17.19 μM at St7, BDL -7.09 μM at StR, 0.48-29.58 μM at K1 and 0.71-55.54 μM at K2. The maximum value of $Si(OH)_4$ is observed at K2 in April 2009.

The elemental ratios of dissolved inorganic nutrients are summarized in Table 3.3. For the whole area and for all sampling periods the Si:N:P ratio is about 4:2:1.

Table. 3.3 General, seasonal and spatial dissolved inorganic nutrients ratios for the area. Bold Rvalues show that significant relationship(FC:Far Cage zone, NC: Near Cage zone, IP: Inner Part zone).

GENERAL				
		R^2	n	Si: NO_3:PO_4
Nutrients	$Si=3.6PO_4+1.1$ $NO_3=1.3PO_4+0.2$ $Si=0.9NO_3+1.2$	**0.5** **0.3** **0.25**	597 570 566	3.6:1.3:1
SEASONAL				
Season		R^2	n	Si: NO_3:PO_4
Autumn	$Si=2.2PO_4+0.8$ $NO_3=1.1PO_4+0.2$ $Si=1.5NO_3+0.4$	**0.4** **0.5** **0.7**	109 109 109	2.2:1.1:1
Winter	$Si=4.1PO_4+1.8$ $NO_3=0.7PO_4+0.3$ $Si=3.1NO_3+1.2$	**0.65** **0.5** **0.5**	124 123 123	4.1:0.7:1
Spring	$Si=5.0PO_4+1.0$ $NO_3=3.2PO_4-0.02$ $Si=1.5NO_3+1.0$	**0.8** **0.9** **0.8**	152 137 135	5:3.2:1
Summer	$Si=2.9PO_4+1.0$ $NO_3=1.5PO_4+0.3$ $Si=1.7NO_3+0.9$	**0.4** **0.1** **0.15**	211 199 196	2.9:1.5:1
SPATIAL				
Zones		R^2	n	Si: NO_3:PO_4
FC	$Si=3.6PO_4+0.9$ $NO_3=3.9PO_4+0.03$ $Si=1.09NO_3+0.9$	0.01 **0.1** **0.1**	129 130 132	3.6:3.9:1
NC	$Si=7.7PO_4+0.8$ $NO_3=2.1PO_4+0.2$ $Si=0.8NO_3+0.9$	**0.2** **0.1** **0.09**	175 171 162	7.7:2.1:1
IP	$Si=8.5PO_4+0.8$ $NO_3=0.02PO_4+ 0.03$ $Si=1.6NO_3+0.9$	**0.04** **0.1** **0.06**	152 150 142	8.5:0.02:1
K1	$Si=3.9PO_4+2.4$ $NO_3=1.3PO_4-0.01$ $Si=0.9NO_3+9.4$	**0.45** 0.1 0.2	10 11 11	4:1:1
K2	$Si=22.4PO_4+2.1$ $NO_3=72.6PO_4-2.23$ $Si=0.2NO_3+3.4$	**0.5** **0.4** 0.3	11 11 12	22:73:1

3.1.2.2 Organic Matter

Dissolved organic parameters (DOC and DOP) in the study area at each sampling station were summarized in Table 3.1.

DOP ranged between BDL-13.15 μM in the study area for all sampling periods. DOP varied between BDL-0.96 μM at St1, 0.02-1.67 μM at St2, BDL-13.15 μM at St3, BDL -1.24 μM at St4, BDL -1.18 μM at St5, BDL -1.34 μM at St6, BDL -0.72 μM at St7, BDL -0.72 μM at StR, BDL-3.24 μM at K1, BDL -1.36 μM K2. The maximum value of DOP is observed at St 3- 0 m. in June 2010.

DOC varied between BDL-1998 μM in the study area for the whole study period. The ranges of DOC for all sampling stations are St1: 49-271 μM, St2: 36.-1998 μM, St3: 41-251 μM, St4: 32-824 μM, St5: BDL-1165 μM, St6: 18-583 μM, St7: 57-142 μM , StR: 63-135 μM, K1: 2.92-1214 μM, K2: BDL-556 μM. DOC reached its maximum level at St 2- 5 m. in September 2010.

Depth profiles of DOC and DOP at each sampling station except K1 and K2 (surface sampling stations) for each sampling period are given in Appendix 2. Any tendency of decreasing with depth for DOC couldn't observed.

Atomic C:P ratio in dissolved organic matter for the area is 23 and the regression results are given in Table 3.4.

Table 3.4 The linear regression results for DOC against DOP. ($p<0.05$)

	R^2	**n**	**DOC:DOP**
DOC=23.4DOP+127.9	0.01*	473	23.4

*significant

3.1.3 Particulate Matter

As a particulate parameters; POC, PON, TPP, Chl a and TSS values at each sampling station were summarized in Table 3.1.

TSS ranged between BDL-57 mg/l in the whole area during all sampling periods. The ranges of TSS are 0.06-12.60 mg/l at St1, 0.16-6.00 mg/l at St2, 0.20-8.80 mg/l at St3, 0.11-11.30 mg/l at St4, BDL-11.23 mg/l at St5, 0.00-7.20 mg/l at St6, 0.00-8.20 mg/l at St7, BDL-9.46 mg/l at StR, 3.45-45 mg/l at K1, 2.80-5.20 mg/l at K2. The highest value of TSS was observed at K2 in March 2010.

TPP varied between BDL-7.03 μM in the study area for the whole study period. The ranges of TPP for all sampling stations are St1: BDL-0.11 μM, St2: BDL-0.84 μM, St3: 0.01-0.89 μM, St4: 0.01-0.24 μM, St5: BDL-0.21 μM, St6: BDL-0.06 μM, St7: BDL-0.07 μM, StR: BDL-0.07 μM, K1: 0.31-7.03 μM, K2: 0.03-4.92 μM. TPP reached the maximum level at K1 in December 2010.

PON varied between BDL-62.08 μM in the study area for all sampling periods. PON ranged between BDL-19.64 μM at St1, BDL-19.69 μM at St2, BDL-23.85 μM at St3, BDL-30.59 μM at St4, BDL-12.56 μM at St5, BDL-18.30 μM at St6, BDL-16.00 μM at St7, BDL-13.09 μM at StR, 0.45-62.08 μM at K1, 0.06-21.86 μM at K2. The maximum value of PON is observed at K1 in December 2008.

POC varied between BDL-353 μM in the study area for the whole study period. The ranges of POC for all sampling stations are St1: BDL-76 μM, St2: 0.06-90 μM, St3: 0.20-83 μM, St4: BDL-67 μM, St5: 0.23-40 μM, St6: BDL-41 μM, St7: 0.79-71 μM, StR: BDL-63 μM, K1: 48-353 μM and K2: 8.03-164.59 μM. POC reached the maximum level at K1 in April 2010.

The depth profiles of POM (POC, PON and TPP) are represented in Appendix3.

Chl a ranged between 0.03-17 μg/l in the whole area during all sampling periods. The ranges of Chl a are 0.10-1.22 μg/l at St1, 0.11-3.26 μg/l at St2, 0.11-4.90 μg/l at St3, 0.09-3.72 μg/l at St4, 0.07-2.43, μg/l at St5, 0.07-1.59 μg/l at St6, 0.07-1.33 μg/l at St7, 0.08-1.45 μg/l at StR, 0.03-17 μg/l at K1, 0.07-1.51 μg/l at K2. The highest value of Chl a was observed at K1 in February 2010 while the minimum value was observed at K1 December 2008.

Depth profiles of POC, PON and DOP at each sampling station except K1 and K2 (surface sampling stations) for each sampling period are given in Appendix 3. Any tendency of decreasing with depth for POC couldn't observed.

The elemental ratios of particulate organic matters are summarized in Table 3.5. The POC:PON:TPP ratio in the area for all sampling periods is 43:9:1.

Spatial distribution of POM is given in Figure 3.1 and Figure 3.2. For all of the parameters (POC,PON,TPP and TSS) K1 has the widest range. The minimum mean value of POC is found to be at Near Cage zone while the maximum mean value is observed at K1.

Time series of POC and PON, TPP and TSS are given in Figure 3.3 and Figure 3.4 respectively.

Table. 3.5 General, seasonal and spatial particulate organic matter ratios for the area. Bold R values show that significant relationship.

GENERAL				
		R^2	n	POC:PON:TPP
POM	POC=43,4TPP+14,4 PON=8,9TPP+2 POC=3,7PON+7,9	**0,3** **0,3** **0,6**	496 496 496	43:9:1
SEASONAL				
Season		R^2	n	C:N:P
Autumn	POC= 160,6TPP-1 PON=15,0TPP-0,2 POC=8,6PON+4,2	**0,7** **0,5** **0,8**	75 76 88	161:15:1
Winter	POC=34,7TPP+10,6 PON=7,3TPP+0,9 POC=4,8PON+6,1	**0,6** **0,75** **0,9**	105 105 113	35:7:1
Spring	POC=269,4TPP+6,6 PON=50,4TPP+2,6 POC=3,5PON+2,9	**0,8** **0,5** **0,7**	139 139 139	269:50:1
Summer	POC=115,1TPP+12,9 PON=26,7TPP+0,3 POC=2,9PON+13,8	**0,4** **0,5** **0,4**	177 177 182	115:27:1
SPATIAL				
Zones		R^2	n	C:N:P
FC	POC=231TPP+3.9 PON=97.2TPP-1.2 POC=1.8PON+8.2	**0.3** **0.3** **0.5**	126 126 128	231:97:1
NC	POC=79TPP+9.1 PON=45.5TPP+0.4 POC=1.6 PON+9.2	**0.03** **0.09** **0.1**	123 123 139	79:46:1
IP	POC=107.6TPP+11.7 PON=60.9TPP-0.3 POC=3.4PON+9.7	**0.15** **0.3** **0.4**	142 141 149	108:61:1
K1	POC=241TPP-11,9 PON=6.9TPP+14.1 POC=3.2PON+67.9	**0.5** **0.6** **0.6**	10 9 12	241:7:1
K2	POC=23.9TPP+25.6 PON=3.9TPP+2.3 POC=6.6PON+21.1	**0.6** **0.7** **0.6**	10 11 12	24:4:1
Ref	POC=350.6TPP+7.7 PON=111TPP-0.2 POC=1.13PON+11.9	**0.07** **0.1** **0.08**	67 65 72	351:111:1

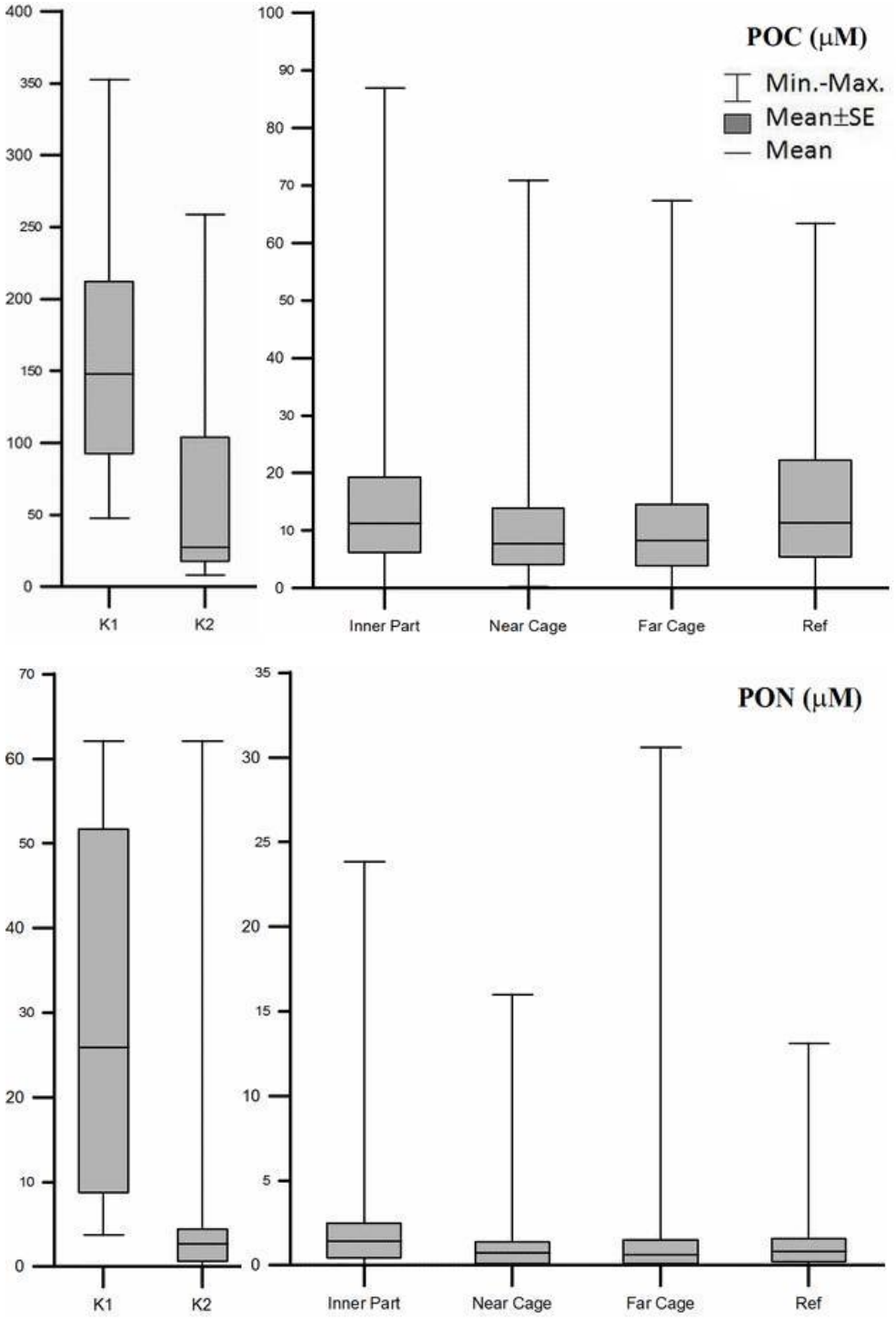


Fig.3.1 Spatial distributions of POC, PON, TPP and TSS in the aquaulture area.

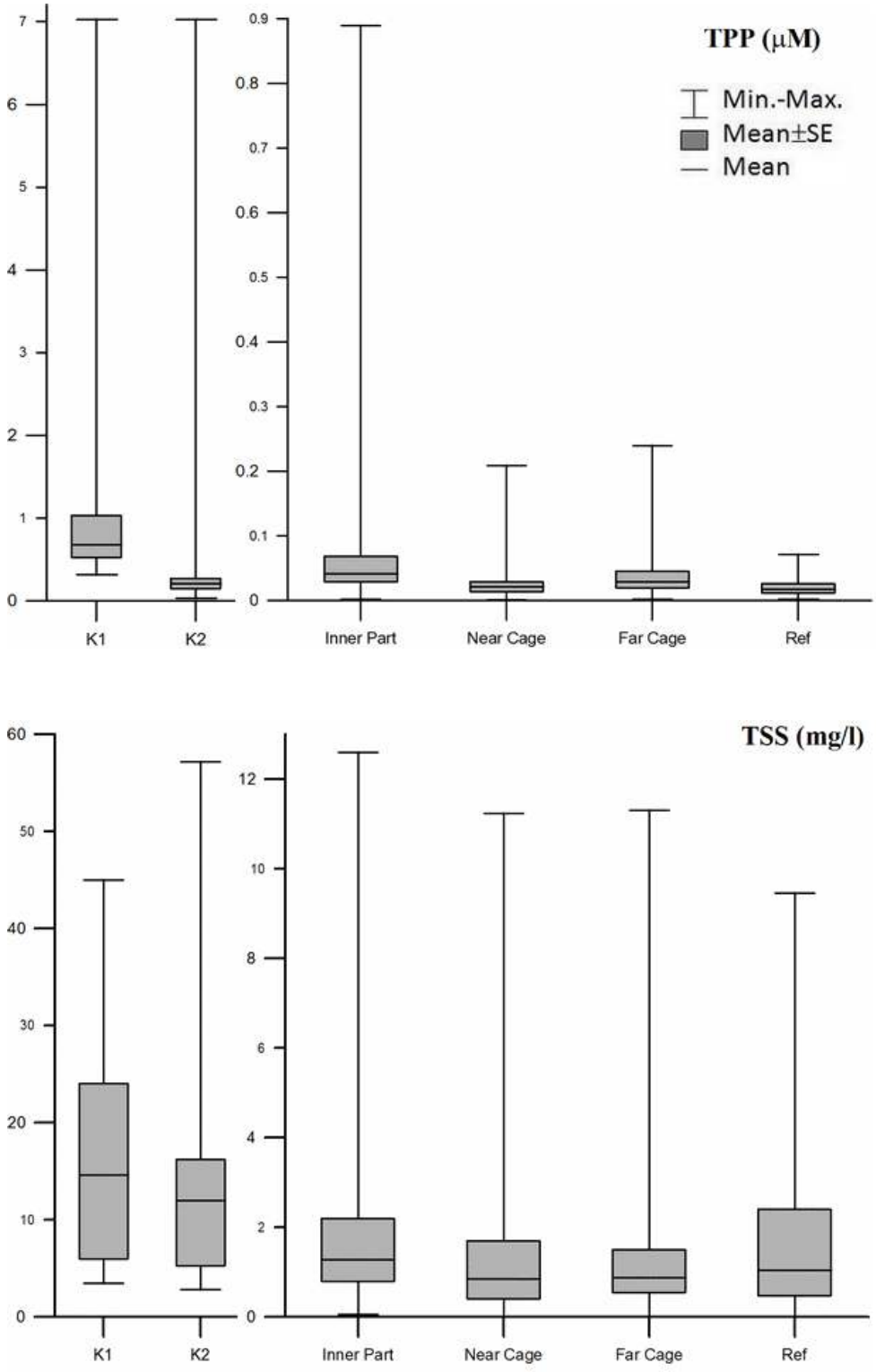


Fig.3.2 Spatial distributions of POC, PON, TPP and TSS in the aquaulture area.

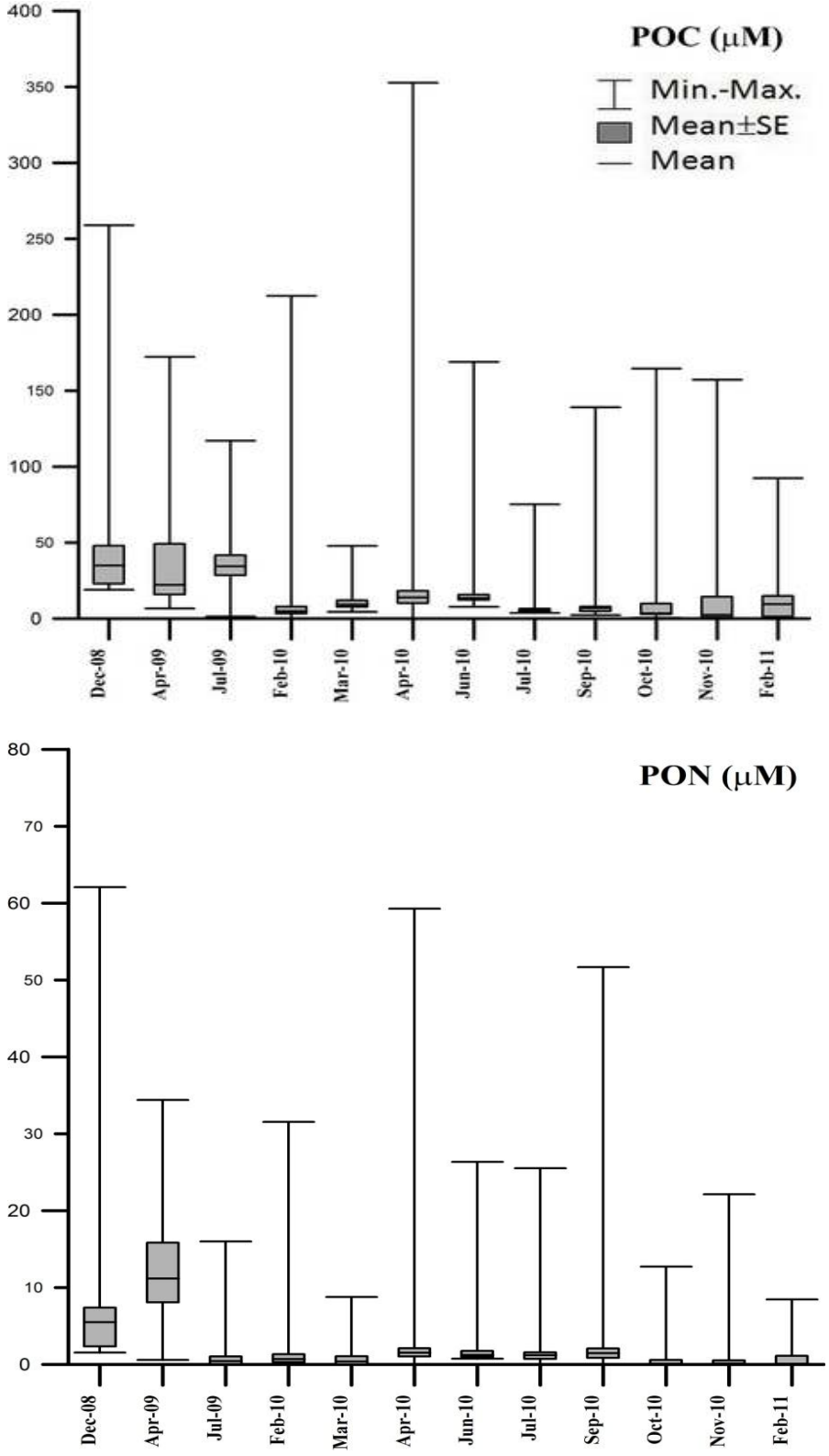


Fig.3.3 Temporal distributions of POC and PON in the aquaulture area.

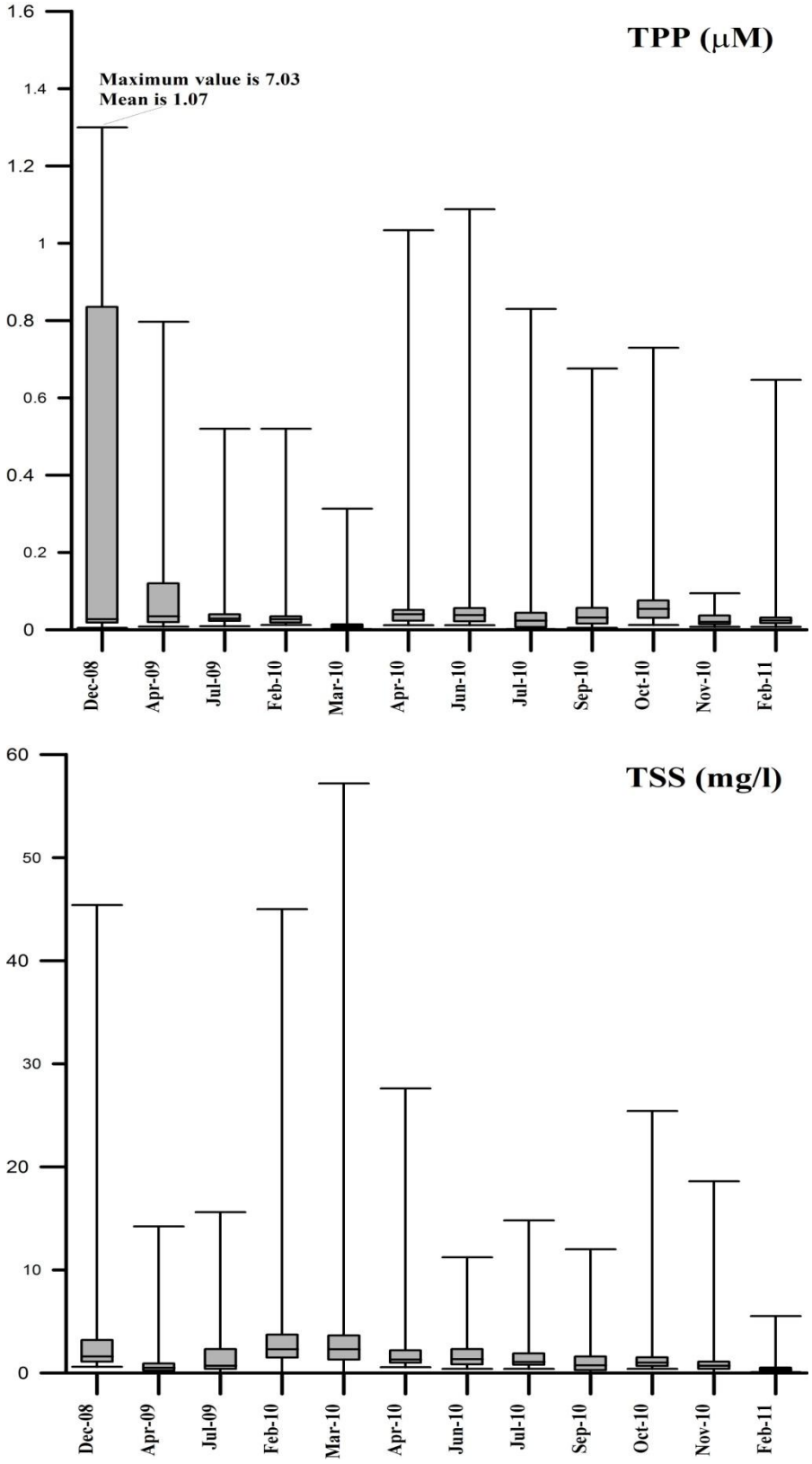


Fig.3.4 Temporal distributions of TPP and TSS in the aquaulture area.

3.1.3.1 Particulate Organic Carbon and Chl a

3.1.3.1.1 Spatio-temporal distributions of C:Chl a ratios. Regressional relationship between POC and Chl a was investigated and the temporal and spatial distributions of C:Chl a ratios were found.

The values of C:Chl a ratio were almost same during autumn and winter; 130:1 in autumn and 126:1 in winter. The minimum ratio in spatial distribution of C:Chl a ratio was found in winter and in this season high POC values' plots have low Chl a values. These plots can cause the decrease of the ratio in winter. There is a wide range in the goodness of fit among seasons. Coefficent of determination (r^2) ranged between 0.2-0.7. The maximum coefficent of determination was observed in autumn. There is a strong relationship between POC and Chl a in autumn than in the other seasons. C:Chl a ratio was found to be 341:1 in spring and as 382:1 in summer. In the case of the conventional C:Chl a ratios' seasonal distribution the ratio increases in winter period and decreases in spring period. Contrary to prospective situation, productivity (as Chl a) is increasing in winter and summer in Ildırı Bay. .In this study the ratios are different because of the high or outlying values of Chl a and POC at K1. In such an area that choosen stations have their own caharacteristics, it is not surprising that all the stations' seston carbon sources are variable and they represent several sources of error(Figure 3.5-3.8).

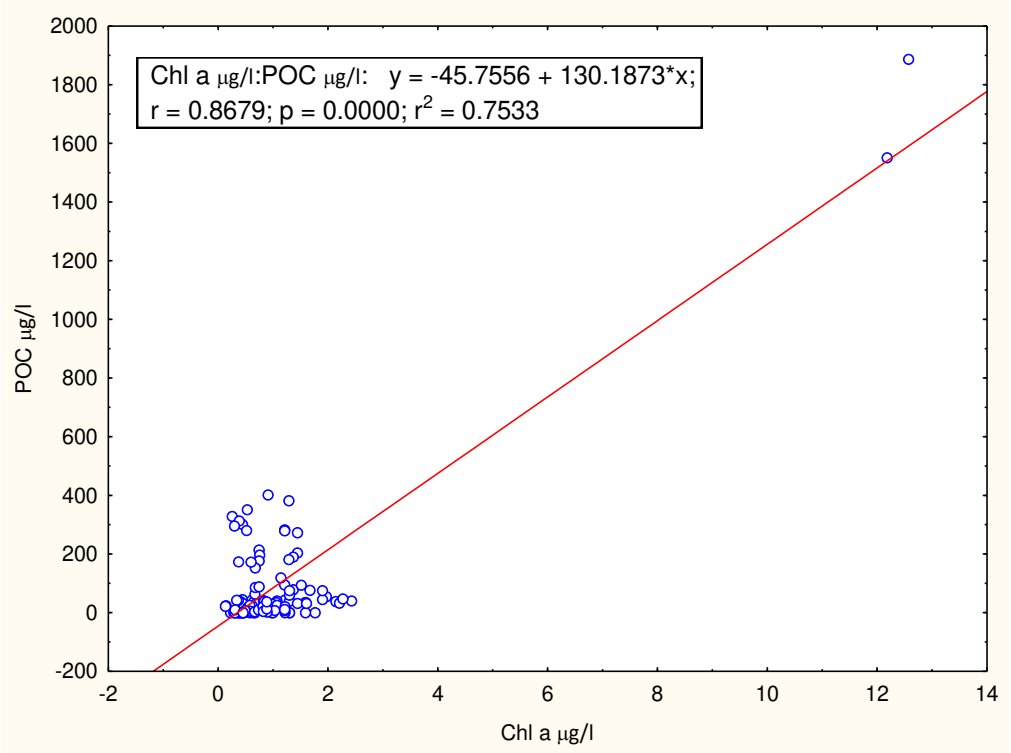


Figure 3.5 Regression graph of POC and Chl a in autumn.

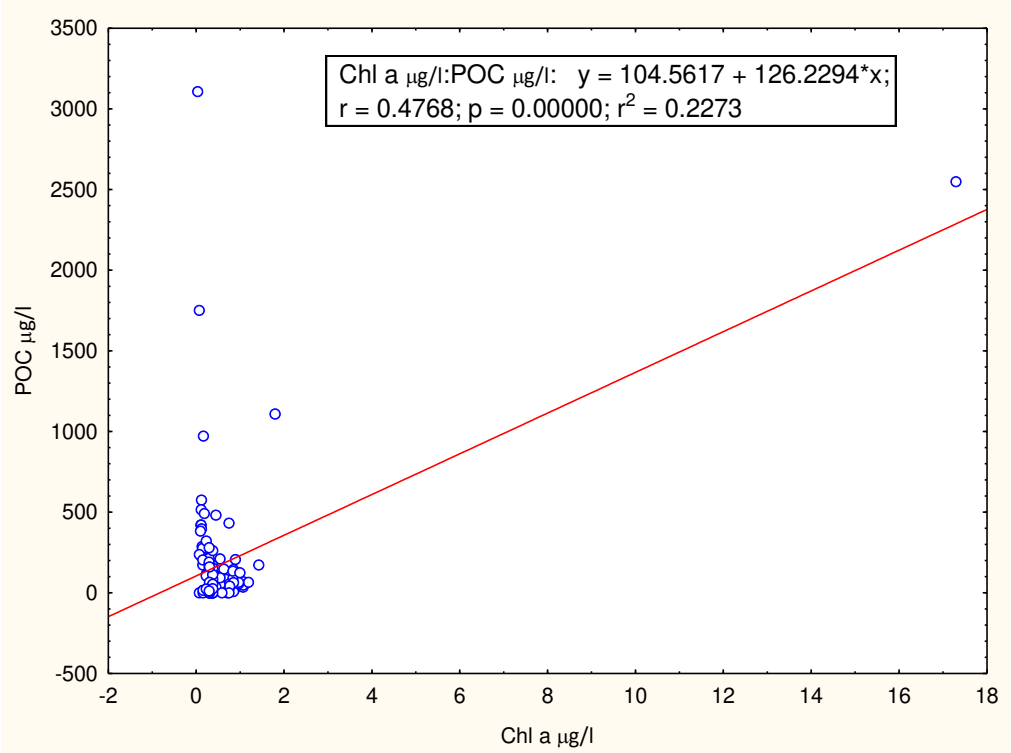


Figure 3.6 Regression graph of POC and Chl a in winter.

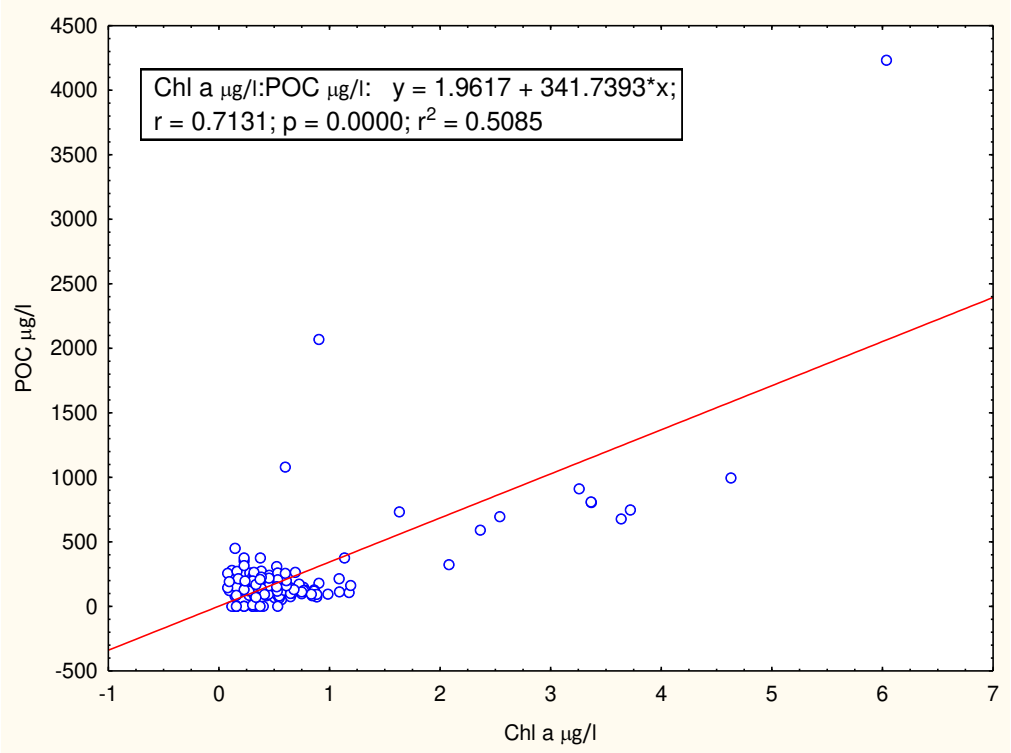


Figure 3.7 Regression graph of POC and Chl a in spring.

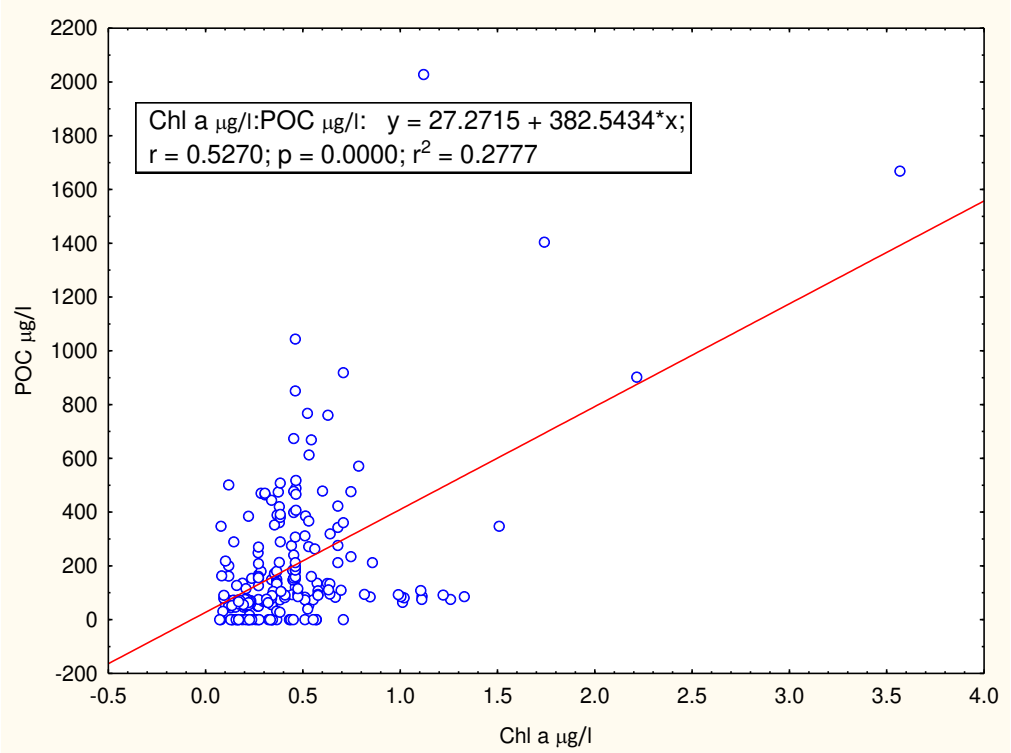


Figure 3.8 Regression graph of POC and Chl a in summer.

The spatial distribution of C:Chl a ratios has a wide range. The ratios varied between 10:1-254:1 in the different parts of the study area. The minimum C: Chl a ratio was found at Far Cage zone as 10. At the Near Cage zone the ratio increase to 21. Large residuals around the regression have been observed at Near Cage zone and the coefficient of determination was really low (0.07). The same trend has been observed also at Inner Part. The coefficient of determination was 0.08 and large residuals around the regression have been observed. The C:Chl a ratio was relatively high (87) and this can be the effect of the high values of POC while Chl a values were relatively low. The coefficient of determination was a bit higher than NC and IP at the Reference zone (0.1) but large residuals around the regression have been also observed. The C:Chl a ratio at Ref found to be at 32. At K1 and K2, POC and Chl a values were quite variable and the outlying values were omitted to eliminate the huge error sources, nevertheless, at K1 r^2 was insignificant. The C:Chl a ratios were found to be at 253:1 and 185:1 at K1 and K2, respectively. There is a wide range in the goodness of fit among the parts of the study area. Coefficent of determination (r^2) ranged between 0.07-0.7. The maximum coefficent of determination was observed at K2 meanwhile the minimum value was observed at the Near Cage zone (Figure 3.9-3.14).

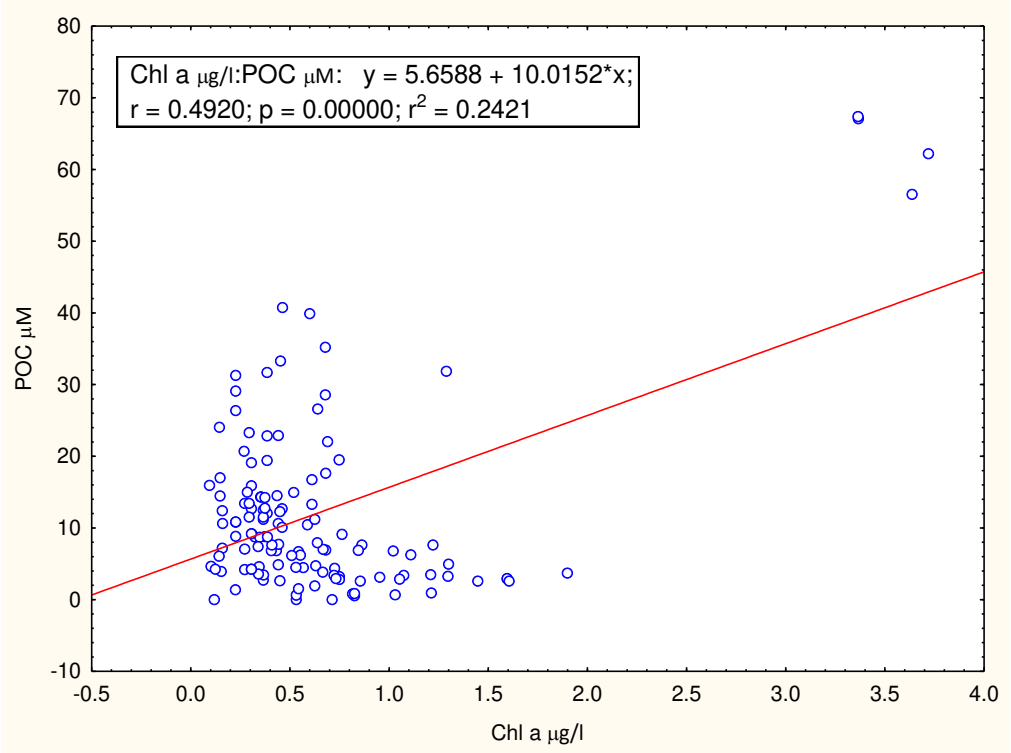


Figure 3.9 Regression graph of POC and Chl at Far Cage zone(FC).

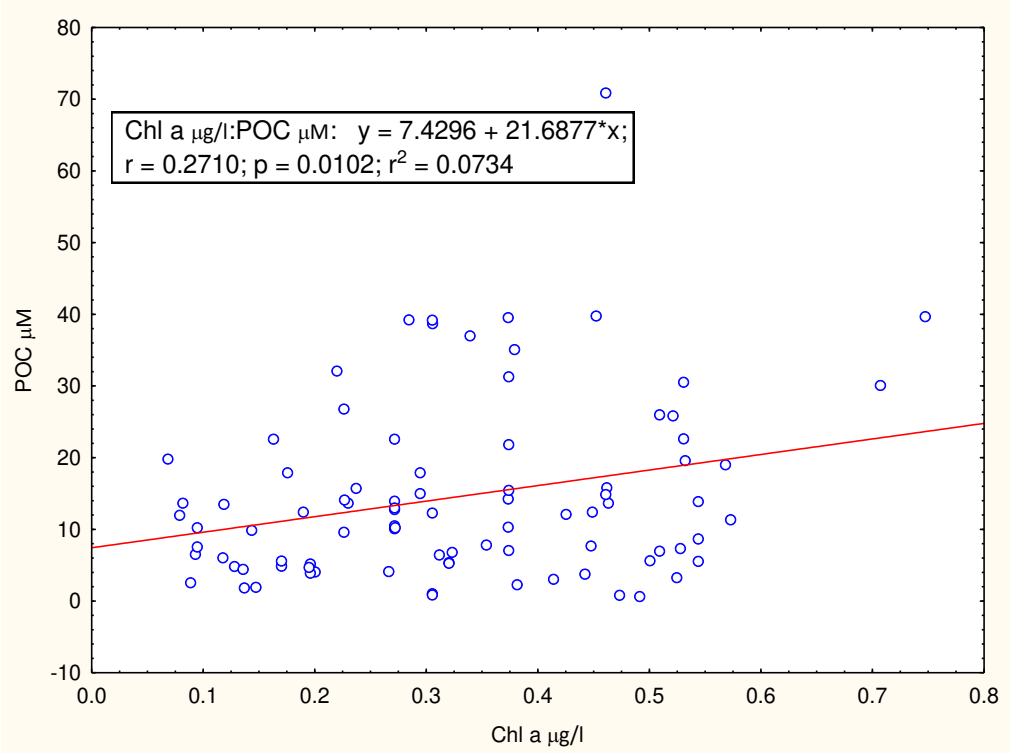


Figure 3.10 Regression graph of POC and Chl at Near Cage zone(NC).

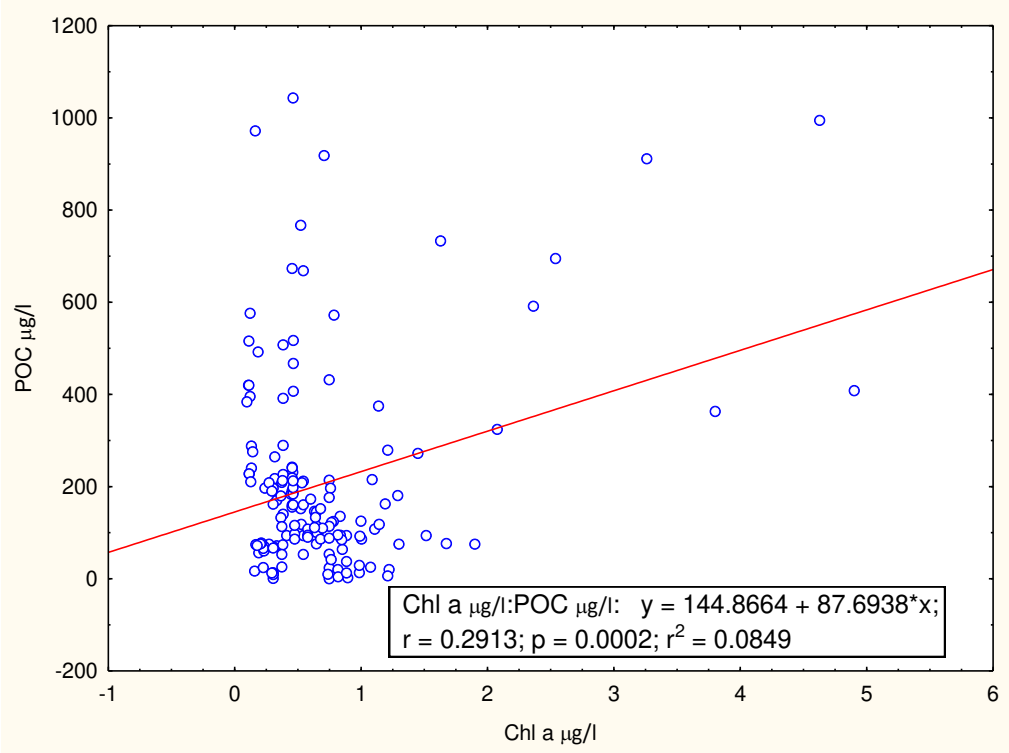


Figure 3.11 Regression graph of POC and Chl at Inner Part(IP).

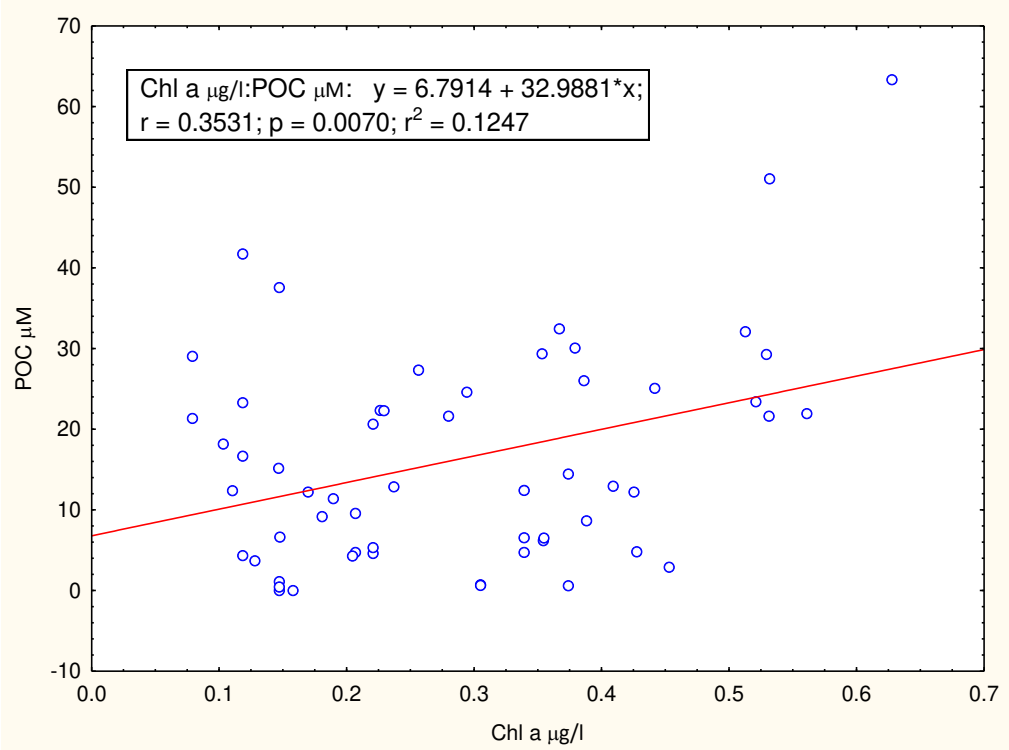


Figure 3.12 Regression graph of POC and Chl at Reference zone(Ref).

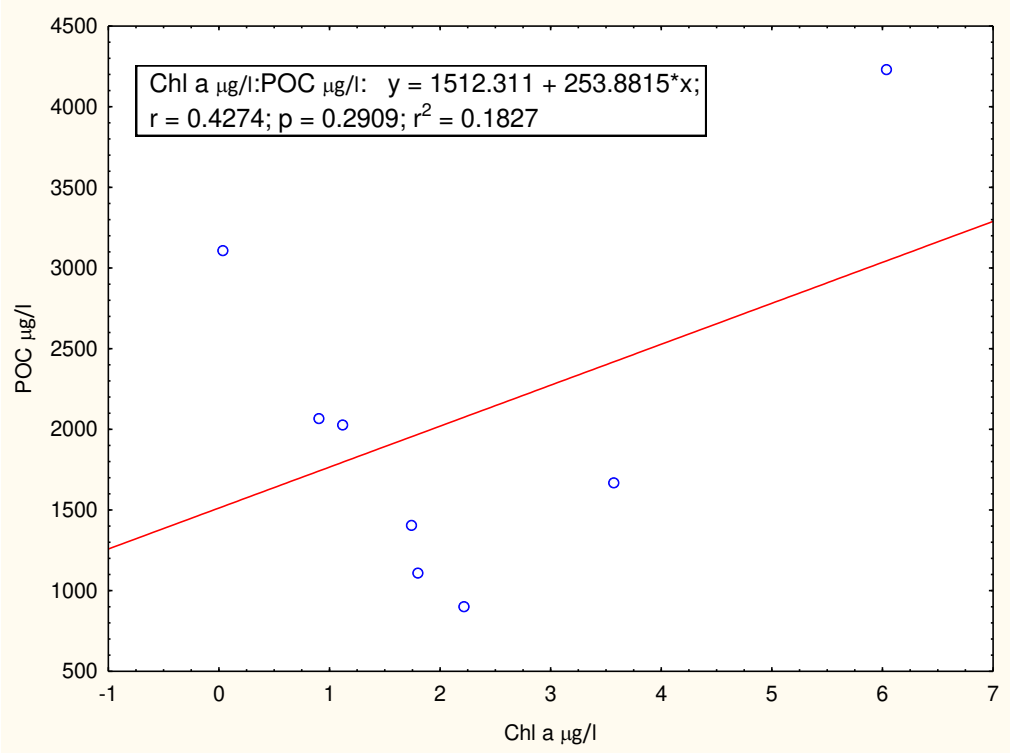


Figure 3.13 Regression graph of POC and Chl at K1.

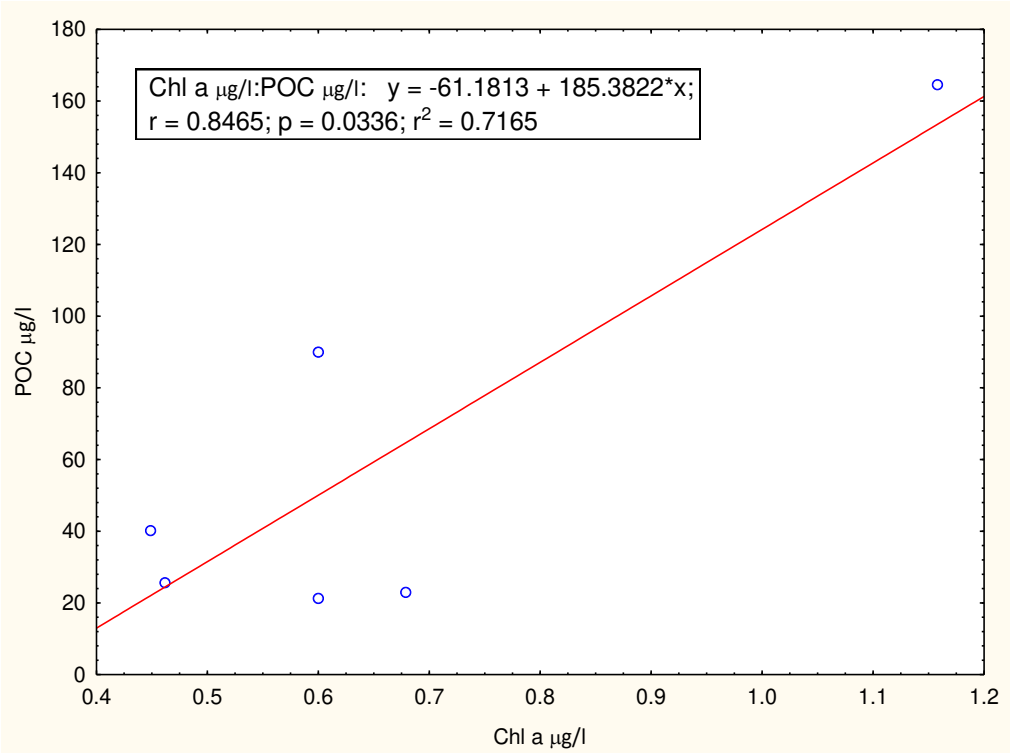


Figure 3.14 Regression graph of POC and Chl at K2.

3.1.3.1.2 Spatio-temporal distributions of fractions of POC. The living (phytoplankton carbon) and non-living (detrital) percentages of POC were calculated using the equation according to Parsons (1974) by assuming that the largest fraction of living material is phytoplankton. The percentages of phytoplankton carbon in total particulate organic carbon are given, the rest of the total organic carbon is assumed as detrital carbon.

The temporal distribution of percentage of phytoplankton carbon (PhytoC) in POC was ranged between 86%-100%. In autumn and in winter, detritalC values found to be at negative values so almost 100% of the total POC consisted of PhytoC. In summer, %86 of the total POC consisted of PhytoC while %99 of the total POC consisted of PhytoC in spring. The mean values of PhytoC for autumn, winter, spring and summer were 99.7µg/l, 185.8µg/l, 228.1µg/l and 168.5µg/l, respectively.

The spatial distribution of percentage of phytoplankton carbon (PhytoC) in POC showed a wide range (27%-100%). At the Far Cage zone 53% of POC consisted of PhytoC while 49% of the total POC consisted of PhytoC at the Near Cage zone. Inner Part had one of the lowest proportion of PhytoC as 28% and the percentage was 58% at Reference zone. The minimum percentage of PhytoC in total POC was observed at K1 meanwhile the maximum percentage was observed at K2(27% and 100%, respectively). At K2, detritalC values found to be at negative values so almost 100% of POC consisted of PhytoC. The mean values of PhytoC for FC, NC, IP, Ref, K1 and K2 were 6.5µg/l, 7.1.µg/l, 61.4µg/l, 9.4µg/l, 552.7µg/l, 60.7µg/l, respectively. The PhytoC value was really high at K1 because both POC and Chl a values reached the highest values at this station.

The relative importance of phytoplankton as a component of suspended particulate organic matter is highly variable in space and time, ranging from about 27% to 100% during th study period.

3.1.4 Other Chemical Parameters

In the dataset of the present study there are chemical parameters that includes both dissolved and particulate matter. These parameters are TOC (the sum of POC and DOC), TDP (the sum of PO_4^{-3} and DOP) and TP (the sum of TDP and TPP).

TOC ranged between 22-2006 μM in the study area for all sampling periods. TOC varied between 70-281 μM at St1 , 79-2006 μM at St2, 76-263 μM at St3, 38-832 μM at St4, 25-1618 μM at St5, 22-912 μM at St6, 70-1196 μM at St7, 24-780 μM at StR, 172-1567 μM at K1 and 40-582 μM at K2. The maximum value of TOC is observed in St2 at 5 m in September 2010 while the minimum value is observed in St6 at the bottom layer in July 2010.

TDP varied between 0.01-13.21 μM in the study area for the whole study period. The ranges of TDP for all sampling stations are St1: 0.04-1.01 μM, St2: 0.04-1.75 μM, St3: 0.05-13.21 μM, St4: 0.05-1.26 μM, St5: 0.01-1.30 μM, St6: 0.03-1.37 μM, St7: 0.03-0.73 μM, StR: 0.01-0.74 μM, K1: 3.15-9.09 μM, K2: 0.01-1.47 μM. TDP reached the maximum level at St3-0 m in April 2010 while the minimum value was observed in St5 at 20 m in July 2009.

TP varied between 0.03-16.12 μM in the study area for all sampling periods. TP ranged between 0.03-1.02 μM at St1, 0.06-1.77 μM at St2, 0.07-13.27 μM at St3, 0.06-1.28 μM at St4, 0.04-1.31 μM at St5, 0.06-1.38 μM at St6, 0.06-0.76 μM at St7, 0.05 -0.75 μM at StR, 3.71-16.12 μM at K1 and 0.11-6.39 μM at K2. The maximum value of TP is observed at K1 in December 2008 while the minimum value is observed at St1-bottom in April 2009.

The partition of dissolved and particulate parts of TOC for each sampling station during sampling periods are presented in Figure 3.15-3.19. The scales of TOC concentrations are different in each graph.

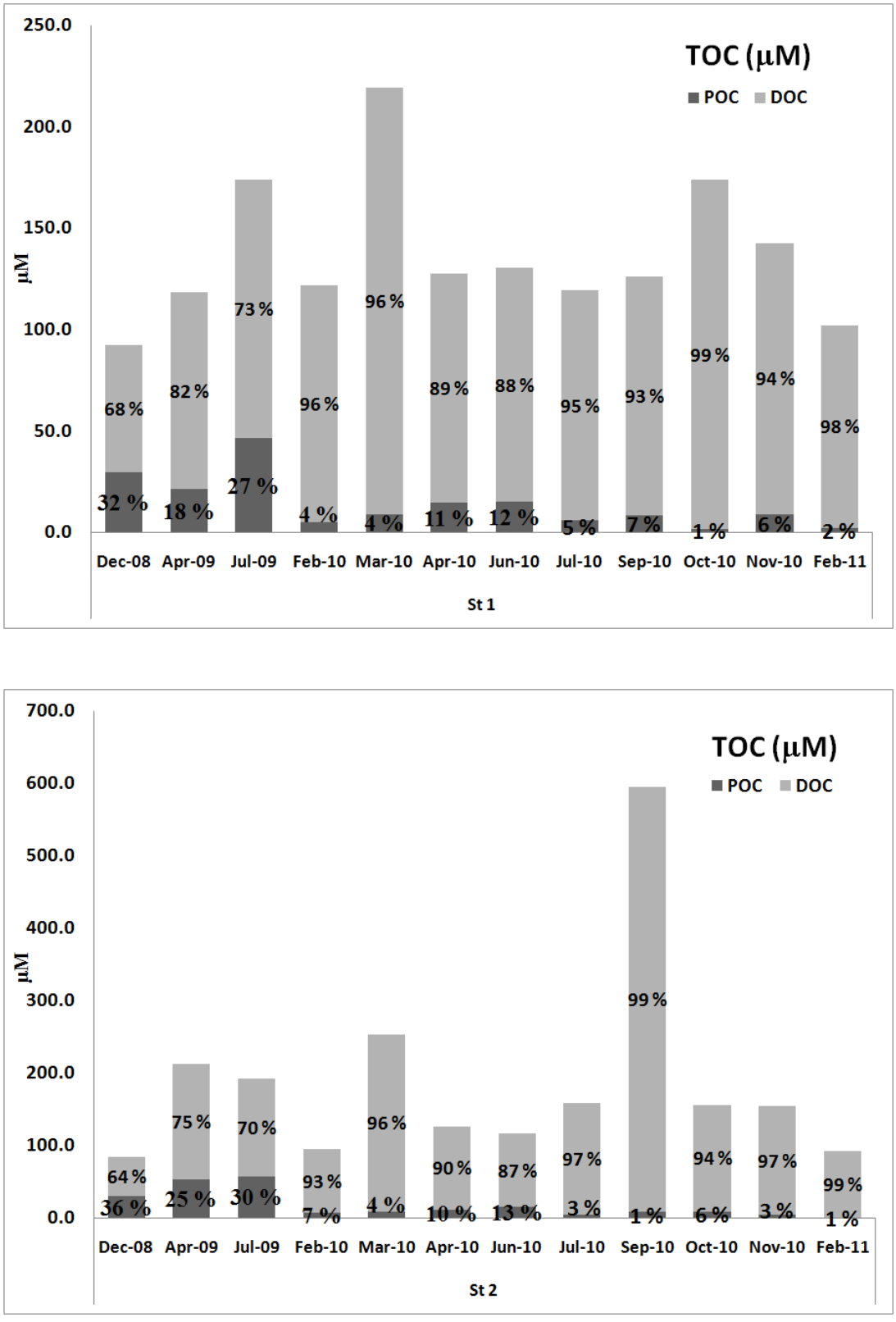
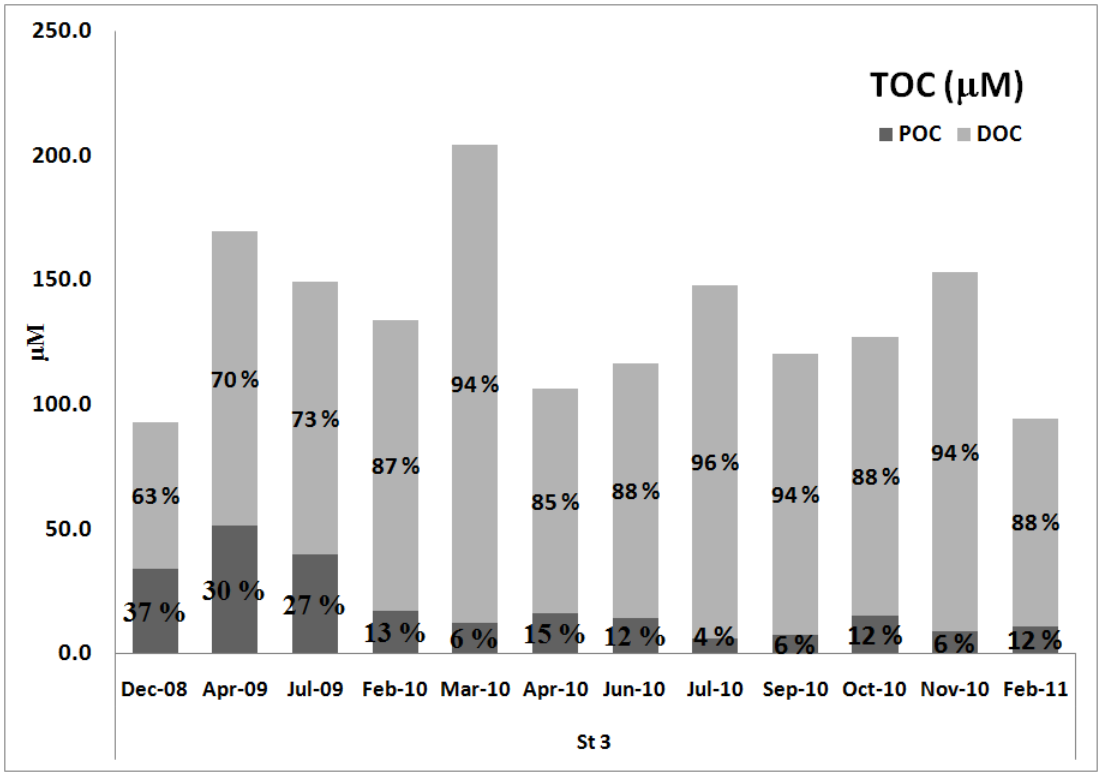


Figure 3.15 POC and DOC persentages in TOC at St1 and St2 for each sampling time.



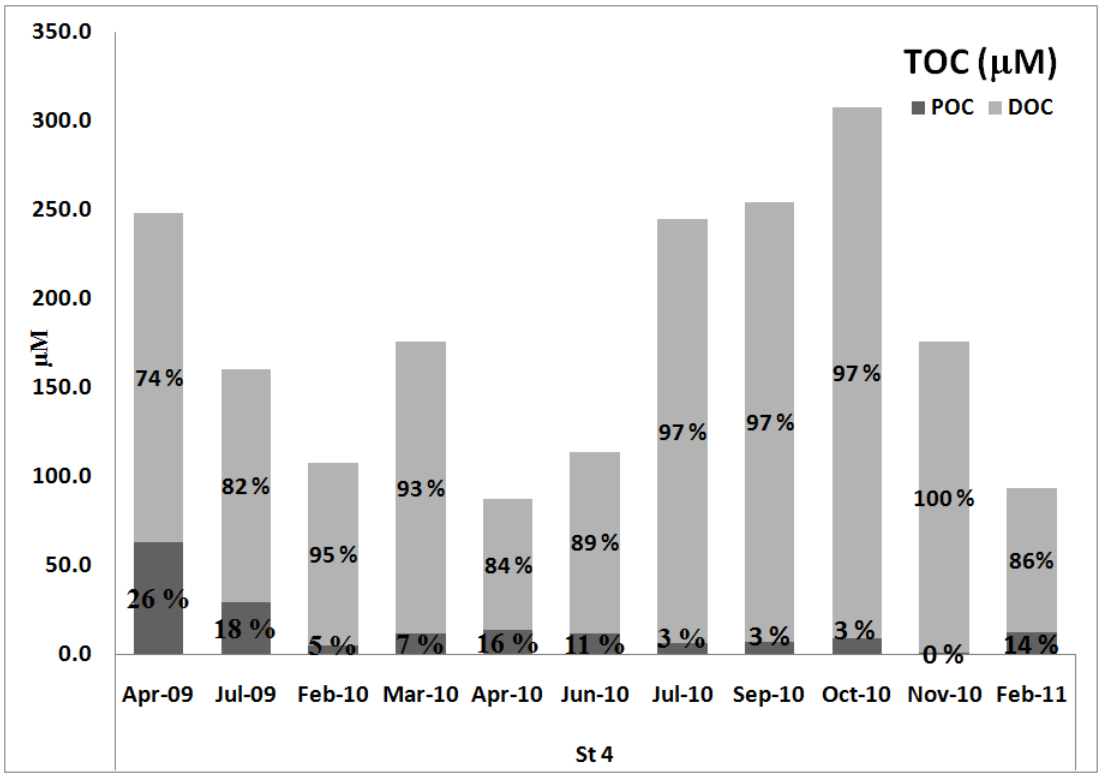


Figure 3.16 POC and DOC persentages in TOC at St3 and St4 for each sampling time.

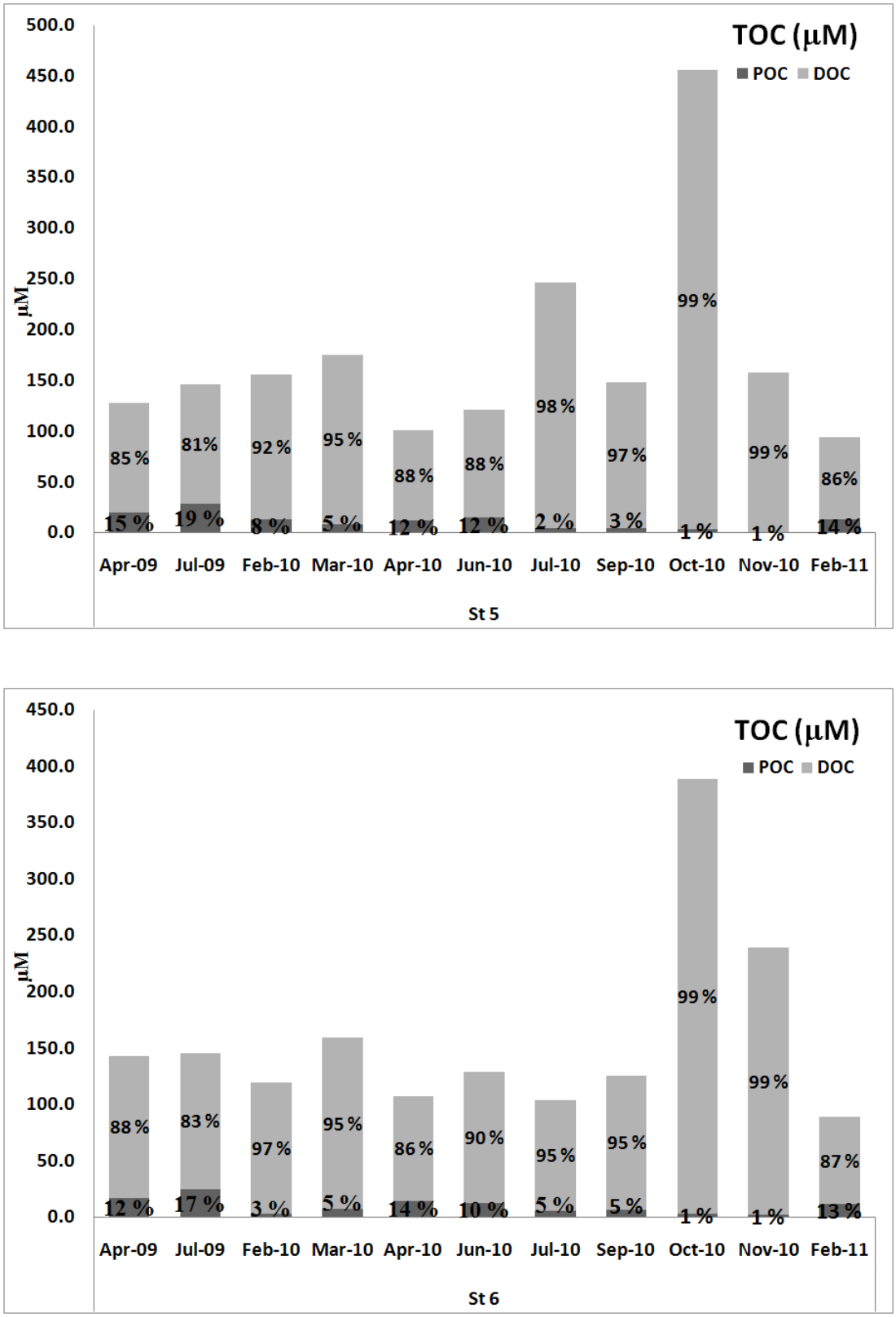
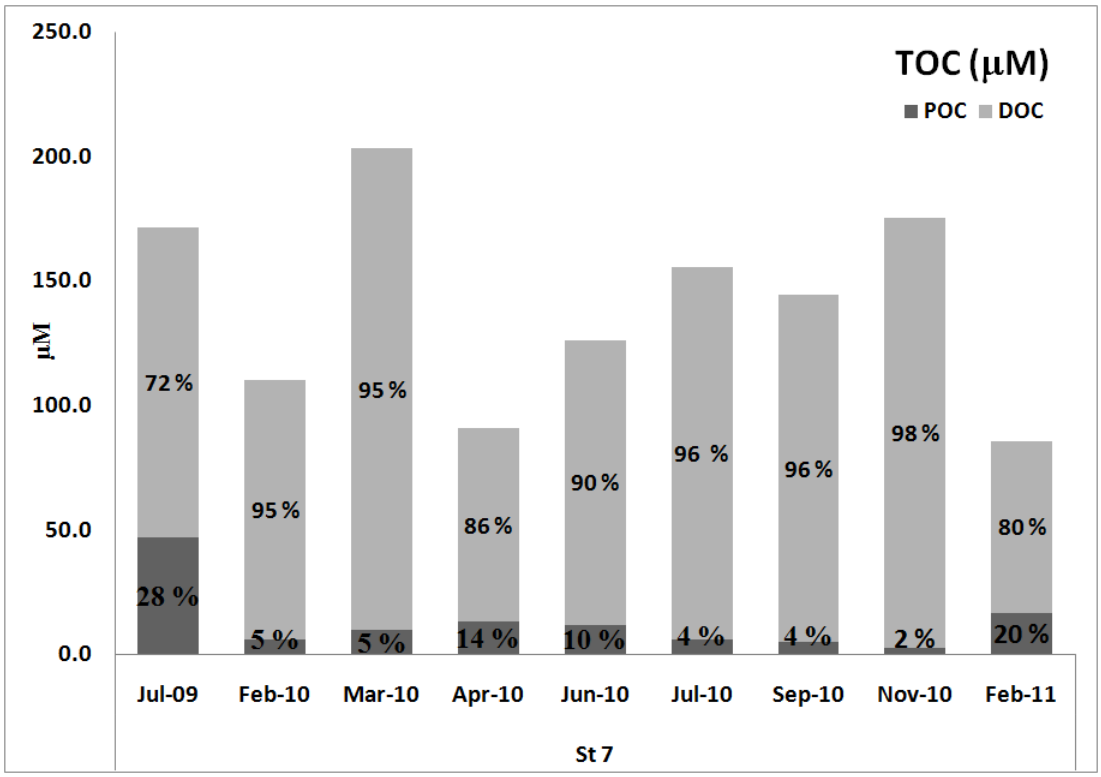


Figure 3.17 POC and DOC persentages in TOC at St5 and St6 for each sampling time.



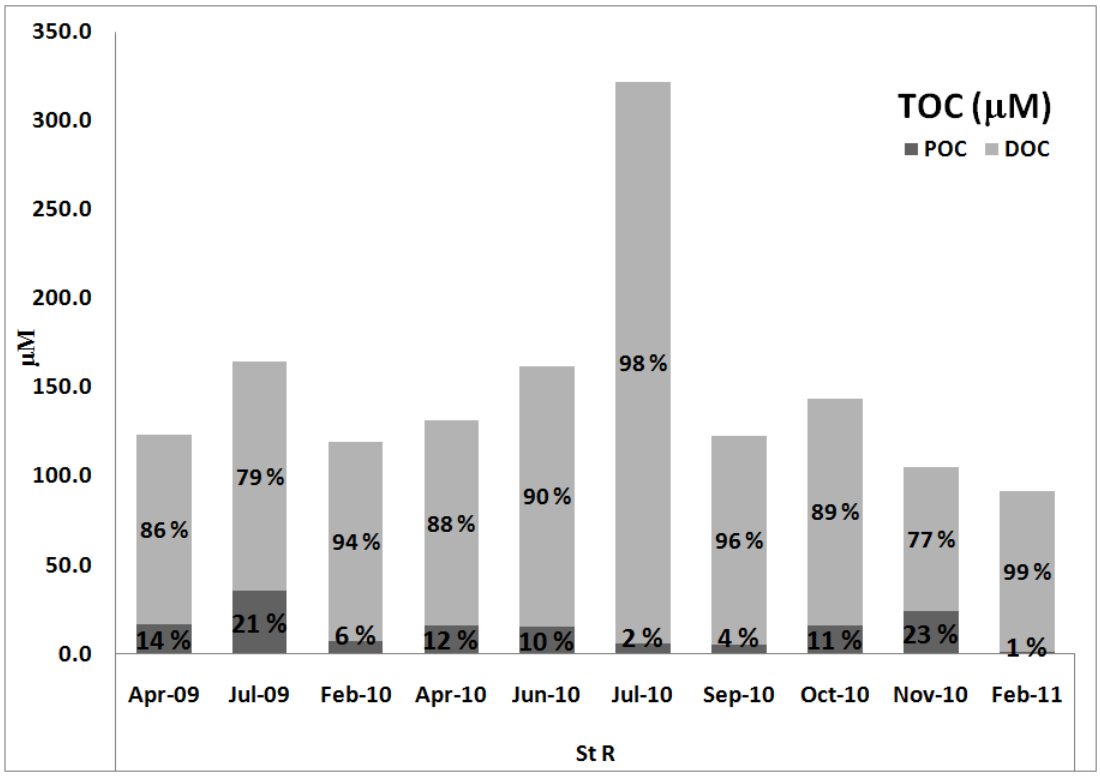
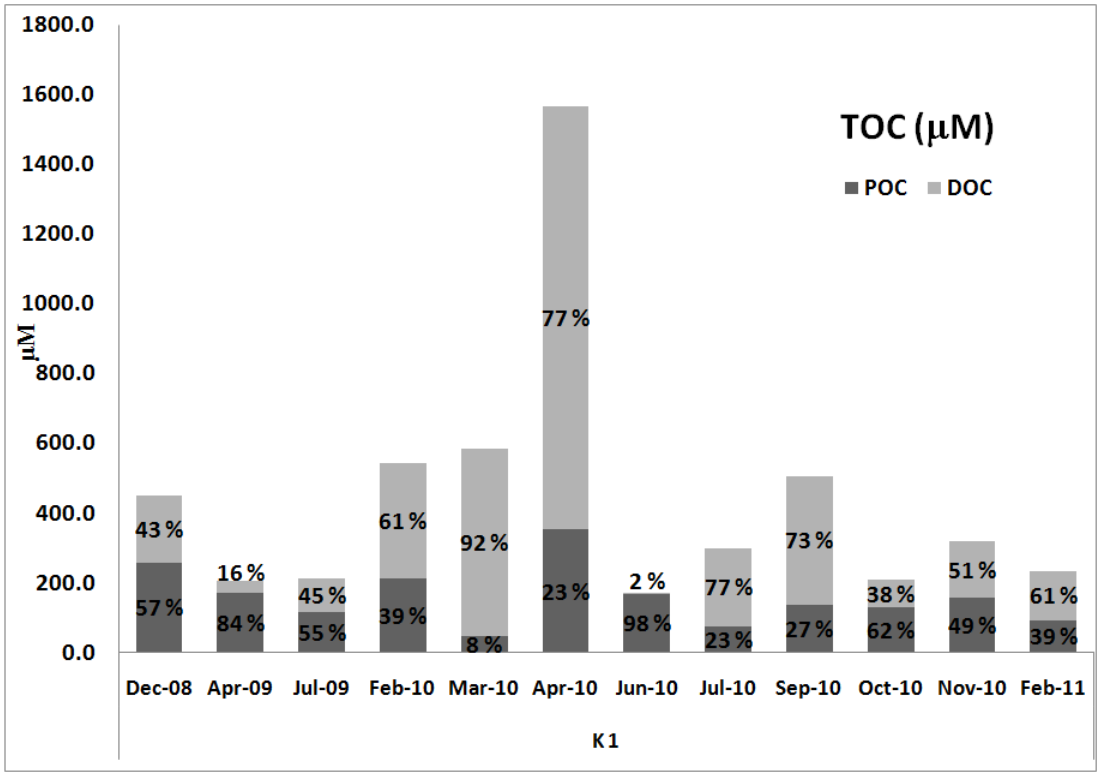


Figure 3.18 POC and DOC persentages in TOC at St7 and StR for each sampling time.



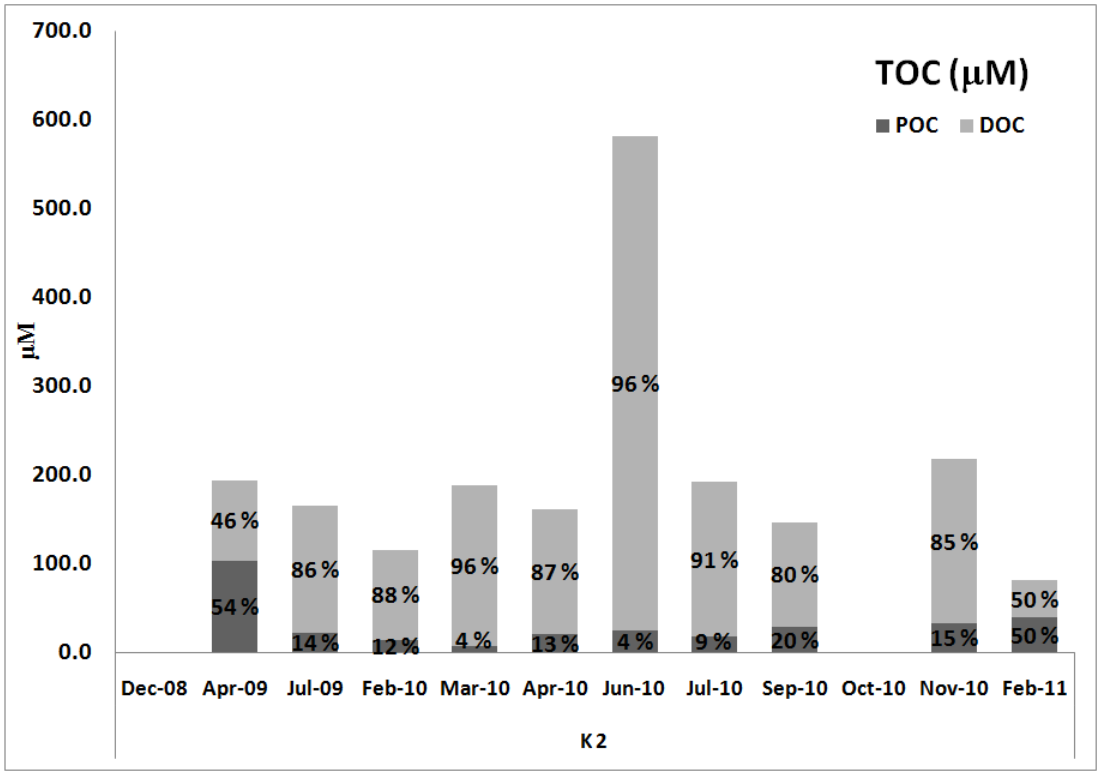


Figure 3.19 POC and DOC persentages in TOC at K1 and K2 for each sampling time.

3.2 Sediment

The percentages of organic carbon and organic nitrogen in the sediment samples of each sampling period at the stations of the study area is given in Figure 3.20-3.25. Each figure shows the contour map of the study area at all the stations that sampled for each sampling period.

OC% ranged between 0.06 and 9.20 in the whole area during all sampling periods. The maximum value is observed at St3 in December 2008 while the minimum value was obreved at K2 in February 2011. TC% varied between 0.55 and 14.78 the whole area during all sampling periods. TC% reached the maximum value at St4 in April 2010 while the minimum value was obreved at K2 in February 2011. ON% ranged between BDL and 0.94 in the whole area during all sampling periods. ON% reached the maximum level at St6 in April 2009 while the minimum value (0.005%) was observed at St6 in July 2009. %TN varied between BDL and 0.96 in the whole area during all sampling periods. The maximum value is observed at St6 in April 2009 while the minimum value (0.01%) was observed at St6 in July 2009.

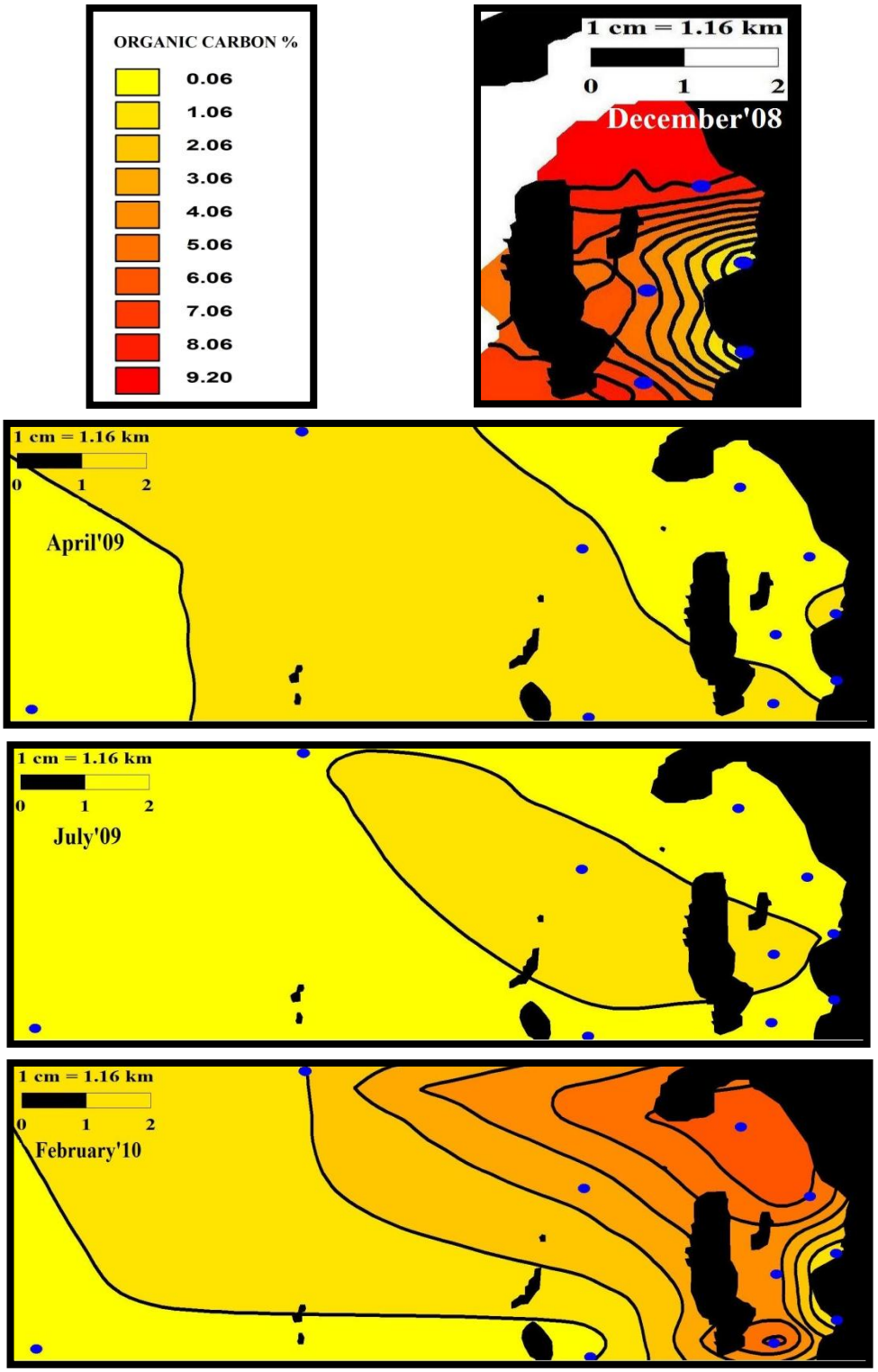


Figure 3.20 OC% distribution in the study area in December 2008, April 2009, July 2009 and February 2010. (Blue points represents the place of the sampling stations for each sampling period).

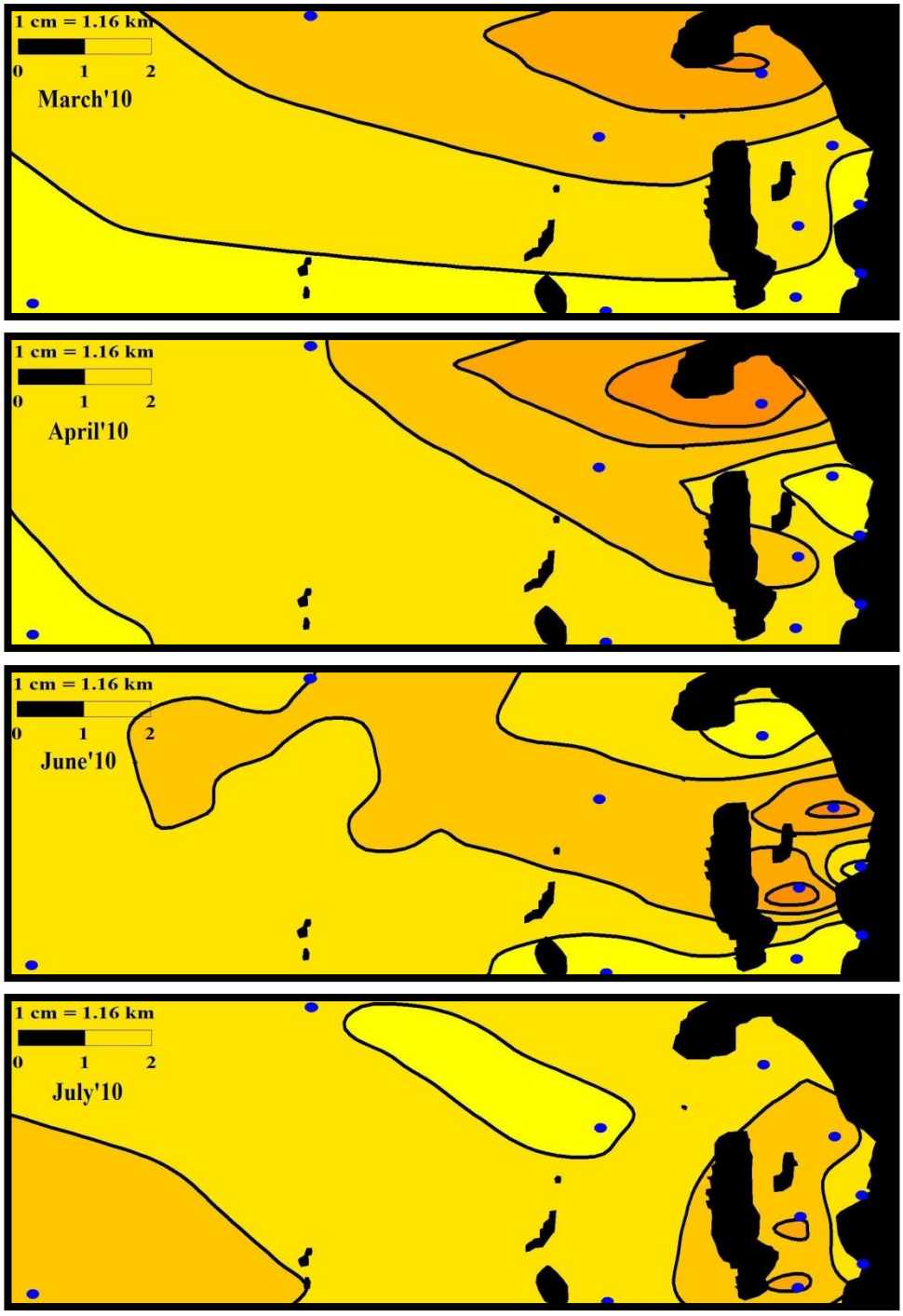


Figure 3.21 OC% distribution in the study area in March 2010, April 2010, June 2010 and July 2010. (Blue points represents the place of the sampling stations for each sampling period).

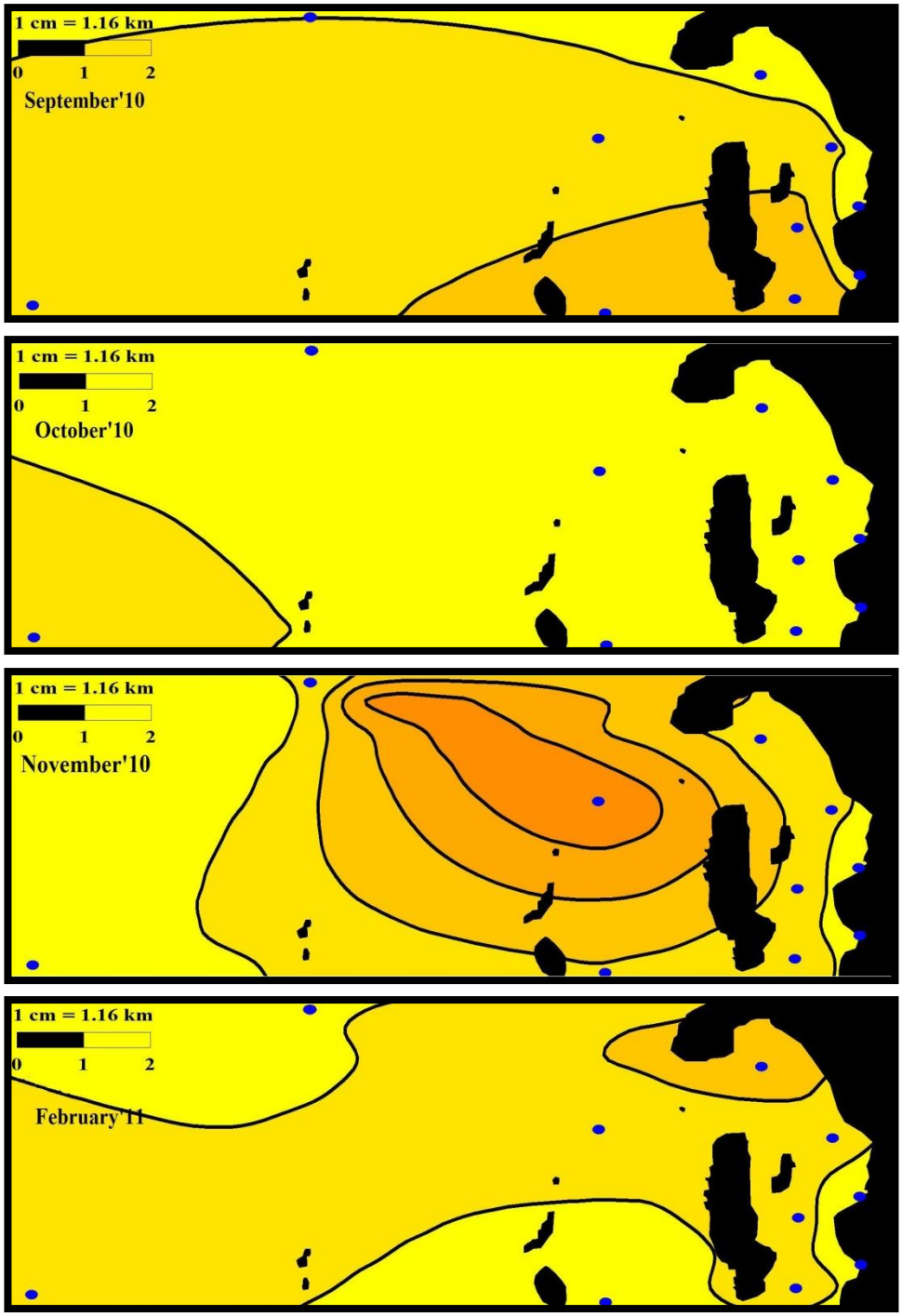


Figure 3.22 OC% distribution in the study area in September 2010, October 2010, November 2010 and February 2011. (Blue points represents the place of the sampling stations for each sampling period).

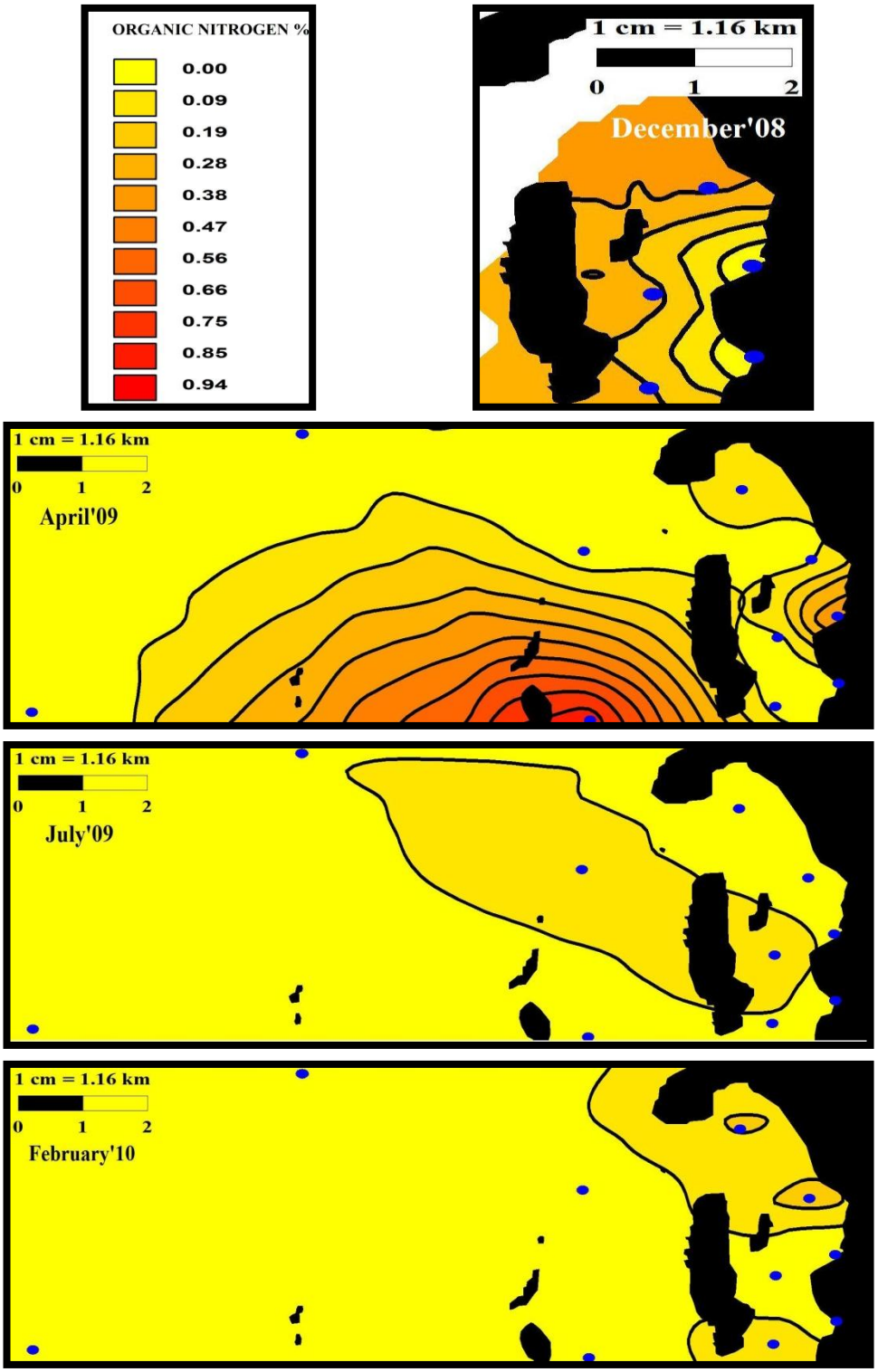


Figure 3.23 ON% distribution in the study area in December 2008, April 2009, July 2009 and February 2010. (Blue points represents the place of the sampling stations for each sampling period).

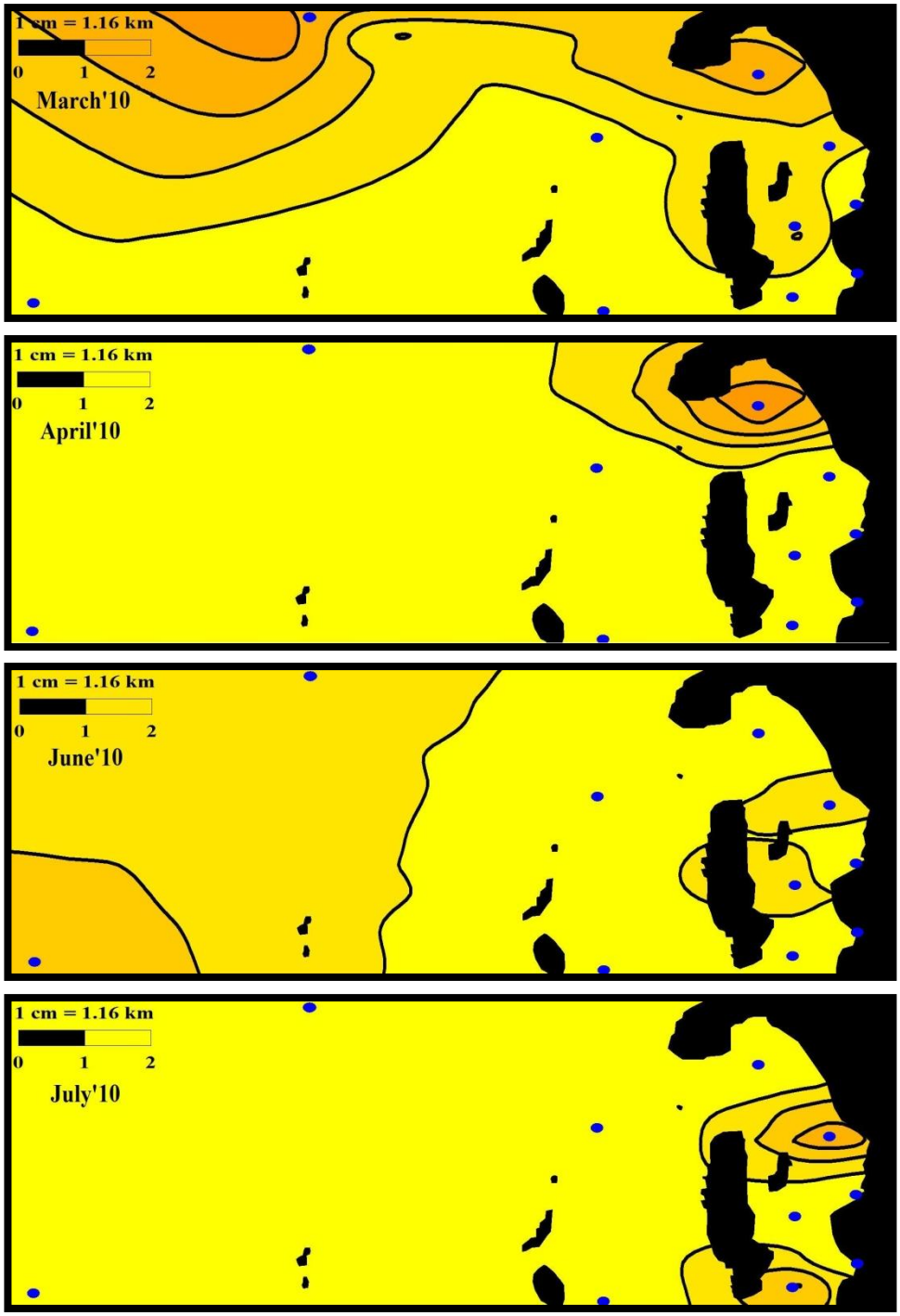


Figure 3.24 ON% distribution in the study area in March 2010, April 2010, June 2010 and July 2010. (Blue points represents the place of the sampling stations for each sampling period).

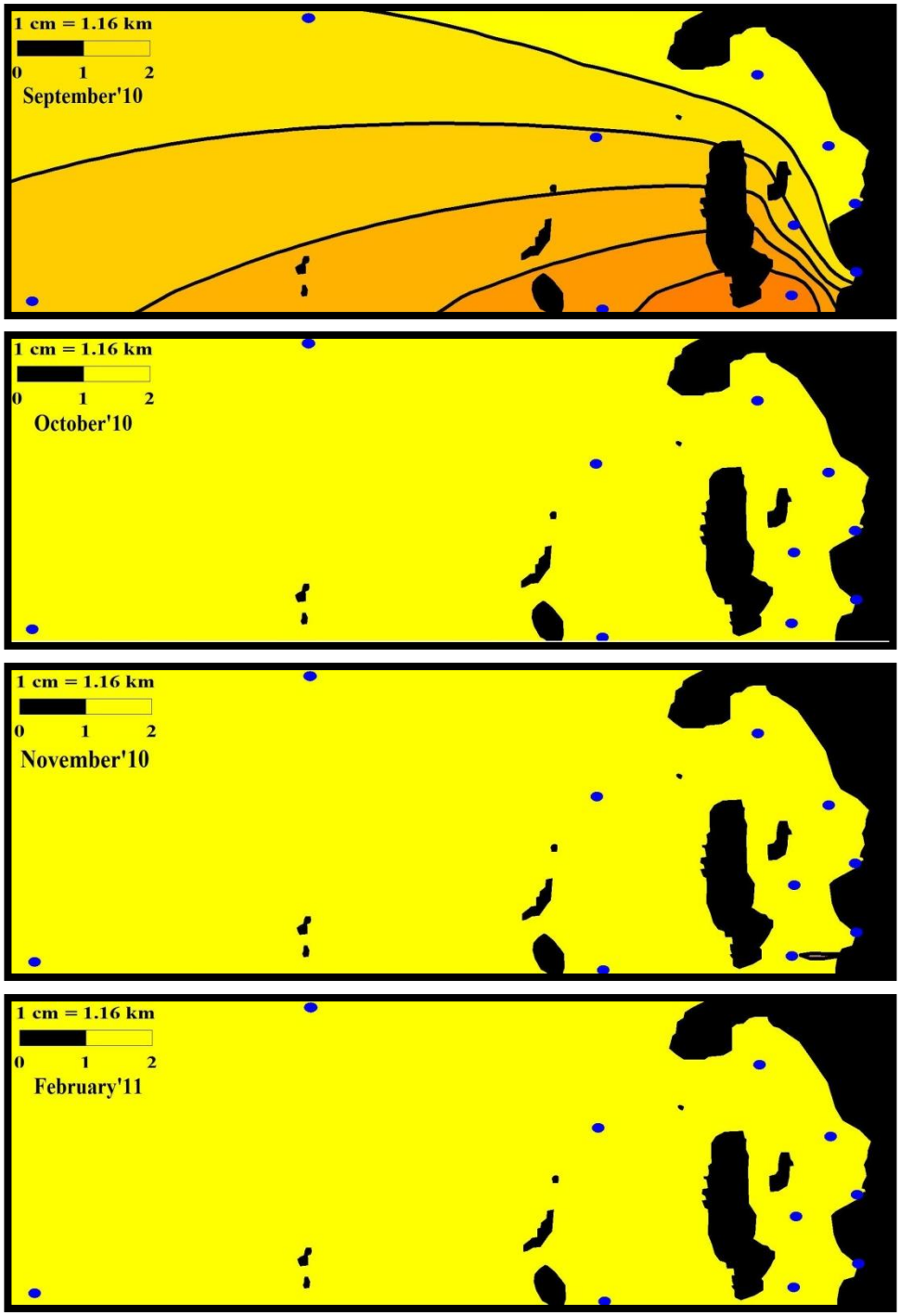


Figure 3.25 ON% distribution in the study area in September 2010, October 2010, November 2010 and February 2011. (Blue points represents the place of the sampling stations for each sampling period).

3.3 Correlation and Principle Component Analysis(PCA)

3.3.1 Correlation Matrix

The results of the Correlation Analysis at all stations and for all sampling periods were presented in Table 3.6. The correlation matrix shows remarkable levels of correlation with both positive and negative values among different variable pairs.

Significant correlations were found between the physical parameters and the other parameters. While temperature positively significantly correlated with other parameters, DO, salinity, density and pH negatively significantly correlated with other parameters. High negative correlation coefficients were observed between salinity and $Si(OH)_4$ and TP (-0.87 and -0.93, respectively).

Significant correlations were found between the inorganic nutrients and the other parameters. There was not significant correlation between DOC and Total Inorganic Nitrogen (TIN), $Si(OH)_4$ and PO_4^{-3} .The highest correlation coefficients were observed between $Si(OH)_4$ and TP and PO_4^{-3} and TPP (0.84 and 0.81, respectively).

Significant correlations were found between the organic matter and the other parameters. High correlation coefficients were observed between POC and PON, POC and DOC (both 0.70).

Table 3.6 Results of the Correlation Analysis of the parameters at all stations and for all sampling periods (n=351, p<0.05). Significant correlation are highlighted in bold.

	TIN	**$Si(OH)_4$**	**PO_4^{-3}**	**TPP**	**TDP**	**DOP**	**TP**	**POC**	**DOC**	**TOC**	**PON**	**Chl a**	**TSS**	**DO**	**Temp.**	**Sal.**	**Density**	**pH**
TIN	1																	
$Si(OH)_4$	**0.45**	1																
PO_4^{-3}	**0.55**	**0.43**	1															
TPP	**0.56**	**0.55**	**0.81**	1														
TDP	**0.32**	**0.24**	**0.57**	**0.49**	1													
DOP	0.06	0.07	**0.11**	**0.12**	**0.88**	1												
TP	**0.13**	**0.84**	**0.13**	**0.22**	**0.18**	**0.17**	1											
POC	**0.52**	**0.46**	**0.65**	**0.67**	**0.40**	**0.11**	**0.30**	1										
DOC	-0.04	0.00	0.02	0.01	-0.03	-0.05	0.02	-0.10	1									
TOC	0.08	0.06	**0.17**	**0.16**	0.07	-0.02	0.04	**0.12**	**0.97**	1								
PON	**0.46**	**0.55**	**0.57**	**0.60**	**0.30**	0.04	**0.41**	**0.70**	0.02	**0.16**	1							
Chl a	**0.14**	0.07	**0.35**	**0.49**	**0.16**	-0.01	0.03	**0.41**	0.10	**0.19**	**0.40**	1						
TSS	**0.32**	**0.32**	**0.39**	**0.51**	**0.25**	0.08	**0.16**	**0.42**	-0.03	0.06	**0.22**	**0.33**	1					
DO	**0.18**	**0.50**	-0.07	0.02	-0.07	-0.02	**0.49**	-0.01	-0.04	-0.07	**0.17**	**-0.20**	0.07	1				
Temp.	0.02	-0.06	0.10	**0.14**	**0.14**	**0.11**	0.02	0.10	**0.23**	**0.25**	-0.08	-0.06	0.09	**-0.42**	1			
Sal.	**-0.31**	**-0.87**	**-0.23**	**-0.29**	**-0.11**	-0.02	**-0.93**	**-0.34**	0.00	-0.03	**-0.47**	-0.05	**-0.19**	**-0.55**	0.08	1		
Density	**-0.24**	**-0.60**	**-0.25**	**-0.32**	**-0.18**	-0.10	**-0.71**	**-0.32**	**-0.16**	**-0.20**	**-0.29**	0.01	**-0.21**	**-0.11**	**-0.66**	**0.68**	1	
pH	**-0.50**	**-0.30**	**-0.63**	**-0.53**	**-0.37**	-0.08	-0.07	**-0.59**	0.00	**-0.13**	**-0.60**	**-0.27**	**-0.26**	0.07	-0.02	**0.13**	**0.11**	1

3.3.2.Principle Component Analysis (PCA)

When all sampling stations and all sampling periods were assessed, eigen vectors belonging to variables at three principal components axis were found. First principal component (PC1) explains 43%, second principal component (PC2) explains 13.8% and third principal component (PC3) explains 8.7% of the variance. The first three principal component axis explains 65.5% of the total variance. 43% of the variance is related to POC, PON and PO_4^{-3}, 13.8% of the variance is related to DO and temperature and 8.7% of the variance is related to Chl a (Table 3.7)

Table. 3.7 The eigen vectors of the variables for first three principle components.

Variable	PC1	PC2	PC3
TIN	0.253	0.058	0.043
Si	0.318	0.277	0.188
PO_4^{-3}	**0.397**	0.099	0.018
TPP	0.291	0.149	0.366
TDP	0.319	0.097	0.215
POC	**0.400**	0.052	0.006
TOC	0.227	0.270	0.230
PON	**0.379**	0.067	0.020
Chl a	0.237	0.258	**0.640**
TSS	0.268	0.007	0.249
DO	0.081	**0.662**	0.061
Temp.	0.025	**0.542**	**0.503**

The plot of the parameters according to first two principal components is presented in Figure 3.26. A notable grouping is observed at the middle of the PC2 axis and at the positive side of the PC1 axis. This grouping involves all the prameters except TOC, POC and temperature that are observed at beside of the grouping through the negative part of the PC1 axis. Temperature is positioning on the middle of the PC2 axis but a bit far away from the group through the negative part of the PC1 axis. The striking differences of TOC and POC from the group are seen. Meanwhile TOC is at the most negative parts of the PC2 and PC1 axis, POC is at the positive side of the PC2 axis and on the zero point of PC1 axis.The derived parameter DOC is reprsented by TOC and POC, it should occur somewhere between

POC and TOC away from the grouping. The other derived parameters(TP and DOP) are represented by TDP, TPP and PO_4^{-3}.

The plot of the stations according to first two principal components is presented in Figure 3.27. A notable grouping is observed at the intersection of the zero points of PC2 axis and PC1 axis. K1 samplings are seen away from the grouping. First two samplings of K1 and K2 (December 2008 and April 2009) are appeared as a different group at the negative side of PC2 axis and at the right part of PC1 axis. Three different little groupings (1:K2 march 2010 and K2 July 2010, 2:St1 December 2008 and StR March 2010, 3:St3 April 2009, June 2010 and St4 April 2009, September 2010) are being occured just beside the big grouping.

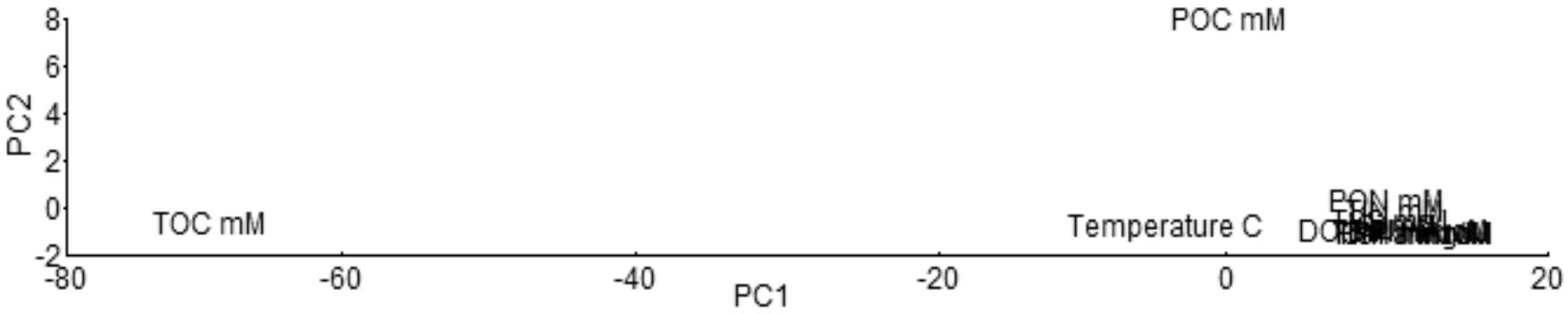


Figure 3.26 Plot of parameters in respect to first two principle components.

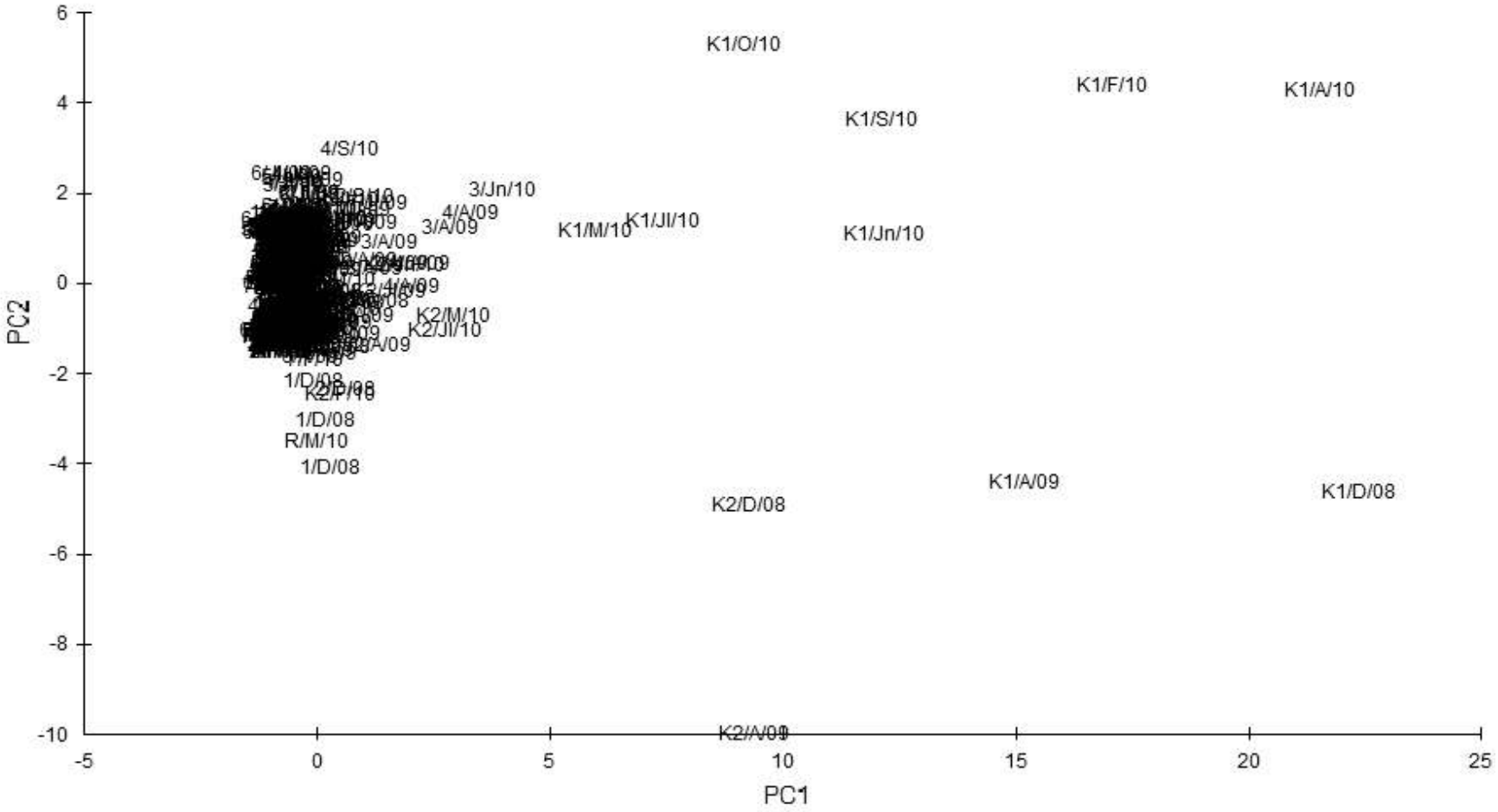


Figure 3.27 Positioning of stations in respect to first two principle components.

CHAPTER FOUR
DISCUSSION AND CONCLUSIONS

The measured chemical parameters in the aquaculture area are found to be highest at the station K1 which behaves as a hotpoint source for the whole area. Despite the striking values at this point , it seems that fish farm waste does not effect the water quality at the surrounding water. It had been assumed that waste matter would be diluted by the sea water because of the rapid flushing. The other hot point for the bay is the station K2 where the samples taken from 0.2 m below the surface near the mouth of small wadi at shallow water (about 0.4 m depth).The importance of K2 lies in its high total phosphorus and total suspended solid and low salinity values. This point is under the effect of the small wadi which carries the agricultural waste from the surrounding land with it.

The extreme values (NH_4^+: 290 μM, POC: 353 μM, DOC: 1214 μM TOC: 1567 μM) which was observed at K1 can be a result of any possibilities. The offspring production continues for 10-11 months in a year in the hatchery but just for once there is a cleaning and drying break. In these kind of close systems there are biological filters which converts the toxic NH_4^+ to NO_2^- and NO_3^- with its microorganism content. When the bacteria content of the filters increase the cleaning is inevitable. Furthermore, during the living feed (Artemia and Rotifer) production activity in the hatchery the feed generally is condensed. After this condensation the rest of the living animals is discharged. Consequently, the reasons of the extreme values at K1 are i) backwash of the close system, ii) living feed harvesting and iii) probable accidents (dropping of anything that contains organic material to the canal).

$Si:PO_4^{-3}$ and NO_3^-: PO_4^{-3} ratio in the area (3.6 and 1.3) is lower than the Redfield-Brzezinski ratio(Si:N:P, 15:16:1). Same trend is observed for the seasonal ratios of $Si:NO_3^-:PO_4^{-3}$ as 2:1:1 in autumn, 4:2:1 in winter, 5:3:1 in spring and 3:2:1 in summer. When spatial distribution of $Si:PO_4^{-3}$ and NO_3^-: PO_4^-3 ratios are considered except K2, low ratios are observed in Inner Part, Far Cage and Near Cage zones, Reference point and K1. This low ratios indicate nitrate limitation in the area.

Regarding NO_3^-: PO_4^{-3} ratio, Ildırı Bay shows same features with İzmir Bay (N/P ranged between 0.3 and 6 in İzmir Bay, Bizsel&Uslu, 2000 and Si/N ranged between 0.34 and 18 in the inner İzmir Bay, Ozkan et al.,2008) which is highly eutrophic area in Aegean Sea and it differs from the general characteristics of the Aegean Sea and the eastern basin of the Mediterrenean Sea. The range of N/P ratio in the NE Mediterrenean Sea was observed as 5-29 which are relatively higher than Ildırı Bay (Ediger et al., 2005). In K2 where under effect of fresh water plume, the ratio is 22:73:1 and this value indicates P-limitation.

The elemental composition of POM in marine waters depend on the hydrography, nutritional status, growth rates of phytoplankton and grazing pressure (Yılmaz et al., 1998). The POC:PON, PON:TPP and POC:TPP ratios in the area varied seasonally. High values of POC:TPP is observed in summer, spring and autumn (115, 269 and 161, respectively) and they are above the Redfield ratio (106). In winter the POC:TPP ratio is 35 which is really low. The low C:P (35) and N:P (7) ratios of particulate matter in winter indicate that P enriched POM in the aquaculture area. POC:PON ratios in the different seasons take place within a limited range (3-8). High POC:PON and POC:TPP ratios have been monitored at the Far Cage zone and Reference station (FC:2 and 351, Ref: 351 and 1), the ratios are quite above the Redfield ratio and these values indicate that there is a selective accumulation of carbonaceous compounds in bulk POM at these zones of the aquaculture area.This situation can be a result of the current that carries the POC input from the cages and source stations through these stations which are located relatively far from the coast. High POC:PON ratios in these parts of the aquaculture area indicates low production at K1 station and in the Inner Part zone which is really close to K1 and under the effect of high values of K1 because of the island that disables the chance of dilution in that zone, POC:TPP values are higher than the Redfield ratio meanwhile PON:TPP ratios are lower.

Comparison of organic matter values and ratios of Ildırı Bay with three aquaculture areas in the world and with Izmir Bay which is an area that under the effect of intense anthropogenic input and with Thau Lagoon which is under effect of

a river plume and shellfish farming in France and semi-enclosed seas in Turkey is given in Table 4.1. Organic matter concentrations (DOC, POC and PON) in Ildırı Bay have similar values except the highest values seen in source stations. In comparison with the study of Pitta et al. (2006) POC and PON values seem higher but the ratios of POC:PON:PP are lower that those have been found in the present study. The present particulate organic matter ratios as a polluted estuary are even lower than the semi-enclosed seas in Turkey (Marmara Sea, Polat et al., 1998; Sothern Black Sea, Yılmaz et al., 1998; North Eastern Mediterrenean Sea, Ediger et al., 2005) and it means that the aquaculture activity did't cause a eutrohic and critic situation in the present study area. The DOC:DOP ratio in the present study is also lower than Thau Lagoon (Souchu et al., 1998) which can be explained by the high DOP concentrations of fresh water (Rhone river) input in addition to aquaculture (shell fish farming) activity. DOC concentrations in Ildırı Bay found lower than Gulf of Gaeta (La Rosa et al., 2002) and Thau Lagoon (Souchu et al., 1998) which are under effect of aquaculture but higher than Astakos Gulf and İzmir Bay. The lower DOC concentrations than Gulf of Gaeta and Thau Laagon are not surprising because in Gulf of Gaeta in addition to fish farm activity there are mussel farms and in Thau Lagoon there is fresh water input in addition to shell fish farming. The maximum C:Chla ratios in Ildırı Bay are lower than the maximum ratios of İzmir Bay (Kucuksezgin et al., 2005; Metin, 1995) and NE Mediterranean Sea (Ediger et al., 2005) but higher than Marmara Sea (Polat et al., 1998).

Table 4.1. Comparison of organic matter values and ratios of Ildırı Bay with other aquaculture areas in the world, polluted estuaries and semi-enclosed seas in Turkey

		POC (μM)	PON (μM)	POC:PON:PP	DOC:DOP	C:Chl a	DOC (μM)	TOC (μM)
FISH FARM AREAS	**Ildırı Bay** Persent results	0-353 (mean:18.1)	0-62 (mean:2.8)	43:9:1 3.7:1(C:N)	23	126-382:1 (154:1)	3-1998 (mean:151)	22-2006 (mean:168)
	Alicante-Sicily-Sounion Pitta et al., 2006	0.8-1.9 (mean)	0.7-2.4 (mean)					
	Engeceli Bay Gier et al., 2008	1.5-26	0.03-4.2	110:13:1				
	Gulluk Bay Basaran et al., 2009	16.7-97						
	Gulf of Gaeta La Rosa et al.,2002						66-3608 (mean:898)	
	Astakos Gulf Belias et al., 2003						81-94	
ESTUARIES	**Thau Lagoon** Souchu et al., 1997	6-74 (mean:27)	>2-12		1060		130-~520	
	İzmir Bay							
	Bizsel et al., 2000	274(max)	45(max)	6-11(C:N)				
	Gungor et al.,2004	2.8-32	0.3-3.7				38-128	40-142
	Metin G.,1995					13-1173		
	Kucuksezgin et al., 2005	3.2-197 (mean:35)	0.3-30	138:14:1 6-15(C:N)				
SEMI-ENCLOSED SEAS	**Marmara Sea**(upper layer) Polat et al., 1998			78-98: 6-9:1 7.4-8.3(C:N)	38.4 (max)	38.4 (max)		
	Southern Black Sea (euphotic zone)	3.8-29	0.6-3.1	112-254: 11-32:1 7-10(C:N)				
	NE Mediterrenean Sea (euphotic zone) Ediger et al., 2005	1.4-4.6	0.2-0.5	93-222 :8-21:1 7-12.5(C:N)		51- ~1000		
	Aegean Sea (surface waters) (0-100m)							55-87(South) 52-128(North)

The chemical approach that phytoplankton carbon can be estimated by the regression of POC on Chl a assuming that the slope of the regression line equals the C:Chl a ratio and the intercept equals the detrital carbon in POC (Legendre et al, 1999).

In this study the coefficient of determination derived from the linear regression analyses of POC and Chl a generally found to be low both spatially and temporally. The highest r^2 values were 0.7 in autumn for the temporal regressions and again 0.7 at K2 for the spatial regressions. High coefficients of determination of the linear regressions indicated two variables has a strong relationship elucidate that the bulk of the seston consisted principally of organic material composed of living phytoplankton.

Parson's equation to find the living and detrital fractions of POC is a rough method. There are some different techniques to improve the equations but still chemical approach overestimates the F value. F value can be really different from the natural one because of the error sources. Microscopical investigation of phytoplankton carbon and zooplankton carbon (if there is any after the prefiltration-200μm) and also nonliving carbon particles ought to be performed and with the conversion factor, the C content of this particles have to be find to eliminate the errors of the chemical approach. There is another situation that in any case, even if the microscopical approach were used, the F value can be biased because of the biased POC values for the reasons of the range of operational definitions in the literature with pore sizes from 0.2 μm up to 1.0 μm, seawater patchiness, contamination, higher pressure in pumps, artificial particle formation during processing (Turnewitsch, 2007), the potential of DOC absorbtion of the glass fiber filters, the little zooplankton that pass through the prefiltration and the different sources of POC that we couldn't identify. Sources of POC in estuaries are diverse and can include phototrophs (epibenthic microalgae, vascular plants, macroalgea, phytoplankton), sewage derived POC, zooplankton, fecal pellets, pseudofaeces of benthic in fauna, aggregates of inorganic-organic materials and bacteria (Wienke et

al, 1987). In an aquaculture area the feed pellets are an additional factor to these sources.

In all sampling periods relatively high TOC and DOC concentrations have been observed. In spite of the particulate input of carbon to the environment in fish farm zones high concentrations of POC didn't occur in the surrounding area for the present study. High concentrations of DOC can be explained by the rapid transformation of POC into DOC. POC is the available form of organic carbon for most of the organisms but DOC can be utilized by marine bacteria. When POC introduced in the ocean environment it represents more direct pathway of organic carbon than DOC, as POC transported to the higher trophic levels DOC introduces the environment by lysis, exudation and senescense of the cells, sloppy feeding by zooplankton, the excretion of waste products by aquatic animals, or the breakdown or dissolution of organic particles from terrestrial plants and soils (Van den Meersche et al., 2004). This dissolved form of organic carbon firstly utilized by bacteria and returned to higher trophic levels (microbial loop). So, high concentrations of DOC may be a reason of rapid turnover of labile DOM supported relatively high rates of bacterial production (Rich et al., 1997).

The POC percentage of the TOC is closer to 1% in oceanic waters but increases in nearshore and shallow waters due to detritus as well as living phytoplankton (Sharp, 1973). According to Sorokin, 1983 10% of TOC was assumed to be in the form of POC in the Black Sea. In our results deviations from this percentage have been observed. At K1 in all sampling periods except March 2010 all the POC percentages are quite high because of the continuous discarge of the hatchery. At K2 high POC percentages was observed in April 2009 (54%), November 2010(15%) and Februray 2011(50%), these concentrations can be a result of the precipitation in that periods. In September the percentage of POC in TOC is also high (between 18% and 37%). At St1, St2, St3 and St4 the POC percentages in TOC and concentrations of POC were obviously high in the first three sampling periods. These stations were located close to the first locations of the cages then the cages were moved to off-shore between July 2009-October 2009, at the same time these stations were close to the

first locations of the cages (the cages moved to off-shore between July 2009-October 2009), close to the shore and under the effect of K1 and K2 and there is an island in front of them through the off-shore that prevent the dilution of the aquaculture load so at these stations in the first three sampling period the effect of aquaculture can be seen obviously in terms of POC percentage in TOC. In the other sampling periods at St1, St2, St3 and St4 the percentage of POC in TOC ranged between 1% and 16%. In April 2010 there is an increase of the percentage of POC at St1, St2, St3 and St4 because of the high values of POC at K1. After the transportation of the cages i.e.after July 2009, any increase of the POC concentrations and POC percentages in TOC couldn't observed during the high aquaculture activity between May 2010 and October 2010.The feeding rate was high in these months than the other months of the year around the cages(St5 and St7).

As expected, POC positively significantly correlated with TSS, Chl a, PON, TOC (0.42, 0.41, 0.70 and 0.12, respectively). This situation suggests that in-situ production, allochtonous source and probably resuspension control the POC loading. The increasing loading of POC will result in an increase of the concentrations of PON and TOC. Correlations between POC and TSS, Chl a, PON,TOC have been reported before (Gier et al., 2008, Hung et al., 2000, Painchaud, J. & Therriault,J., 1989). The negatively strong correlation (-0.87) between salinity and silicate can be explained by the fresh water input in the area.

In respect to results of Principle Component Analysis that used to find the parameters which are close to or far from each other and to determine the parameters that cause the largest variation and the differences between stations in the study area, the first three component explains 65.5 % of the total variance. Bizsel&Uslu (2000), Lundberg et al. (2005) and Wu et al. (2010) used PCA in their studies in coastal eutrophication areas (Izmir Bay, Gulf of Finland and Daya Bay, respectively). The first three principle components could explain 59% of the total variance in the study of Bizsel&Uslu. The first two principle components could explain 65.6% of the total variance in the study of Wu et al. (2010), and approximately 80% of the total variance in the study of Lundberg et al. (2005). Due to these three study ,the reason

of obtaining such a high percentage at the first three component with PCA in the present study is the quite strong relationships between the variables. The parameters that have the most variation in the aquaculture area in the whole study period are POC, TOC and the derived parameter, DOC. As for temperature have a partial variation in comparison with POC, TOC and DOC. The parameters that in the group which seem in the plot of the PCA results don't have a considerable variation pattern as the parameters which far from the aggregation. All samplings of K1 and K2 in December 2008 and April 2009 has different characteristics from the other stations in allsampling periods because of the high concentrations of the parameters (POC, PON, PO_4^{-3}) which 43% of the variance related. The samplings which are plotted at the zero points of PC1 and PC2 axis have less variation and more stability. The samplings which are plotted between the big groping and K1 plots have similar characteristics to the less variated samplings and the outlying plots of K1 and K2 but not as critical as K1.

Organic matter accumulation in sediment is a well known phenomena for the fish farming industry (Karakassis et al, 2000; Papageorgiou et al,2010; Pitta et al., 1999; Porrello et al., 2005). In the present study percentage of organic carbon in sediment and percentage of organic nitrogen ranged between 0.06-9.20 and 0.00-0.94, respectively in the whole area for all sampling period. These values is found to be same with research of Basaran et al., 2010, the percentage of organic carbon ranged between 3.2% and 9.4% in that aquaculture area but lower than the research of Karakassis et al., 2000, the percentage of organic carbon ranged between 10% and %40 in the fish farming zone. Mcghie et al., (2000), found a distinct decrease of percentage of organic carbon in the sediments after 12 months from the remove of the cages in that area. In the present study area an apparent decrease of the percentage of organic carbon in the sediment could not observed after July 2009 which is the time that the transportation to off-shore began.But after October 2010 the OC% in the first location of the cages (at St1, St2, St3 and St4) were not higher than 1.9% while the high values of OC% (reached at 9.2) were being observed before.

However, it is hard to asses an environment as eutrophic in regard to nutrient levels our results involves eutrohic maximum levels of PO_4^{-3} , NO_3^-, NH_4^+ and Chl a and oligotrophic minimum levels of these parameters according to the eutrophication scale developed by Karydis (1999) (Table 4.2). The results involves the sampling stations of the area except K1 and K2. According to PO_4^{-3} and NO_3 scales present results are in the oligotrophic range, according to NH_4^+ in the high mesotrohic range and according to Chla in the low mesotrophic range.

Table 4.2. The eutrophication scale developed according to the characteristics of the Greek Seas(Karydis, 1999).

EUTROPHICATION SCALE					PRESENT RESULTS	
Parameter	Oligotrophic	Low mesotrophic	High mesotrophic	Eutrophic	**Range**	**Mean**
PO_4^{-3}(μM)	<0.07	0.07-0.14	0.14-0.68	>0.68	0.00-0.79	0.05
NO_3^-(μM)	<0.62	0.62-0.65	0.65-1.19	>1.19	0.00-10.55	0.28
NH_4^+(μM)	<0.55	0.55-1.05	1.05-2.20	>2.20	0.00-21.94	1.37
Chl a (μg/l)	<0.10	0.1-0.6	0.60-2.21	>2.21	0.07-4.90	0.58

Despite the eutrophic (only for the upper limits) levels of inorganic nutrients and Chl a any enrichment of organic matter in the vicinity of the cages has not yet led to noticeable eutrophication phenomena due to the best site selection (waste matter would be diluted by the sea because of the rapid flushing), succesful management of the aquaculture facility and probably the relatively oligotrophic character of the Aegean Sea.

The rapid development of fish farming in the Mediterranean region has caused significant problems. Coastal aquaculture brings significant benefits to both national economies and people living in coastal areas, but the success in this sector is sometimes tarnished by environmental and to some extent, by social and marketing problems.

The integrated management, the optimization of the operational conditions and the systematic monitoring with respect to the carrying capacity of the system are required in order to minimize the undesirable consequences. In addition, an overall approach using methods such as environmental risk assessment, economic evaluation, vulnerability assessments, resource accounting and cost benefit analysis could lead to sustainable coastal aquaculture development.

The co-existence of increased fish production from coastal aquaculture and good quality of the neighboring marine environment is a difficult task, but its success is vital for the Mediterranean. A collaboration between scientists, citizens, institutions, local authorities and NGOs is a prerequisite. Marine scientists have to participate in the relevant research, monitoring and management projects because success will be impossible without scientific guidance.

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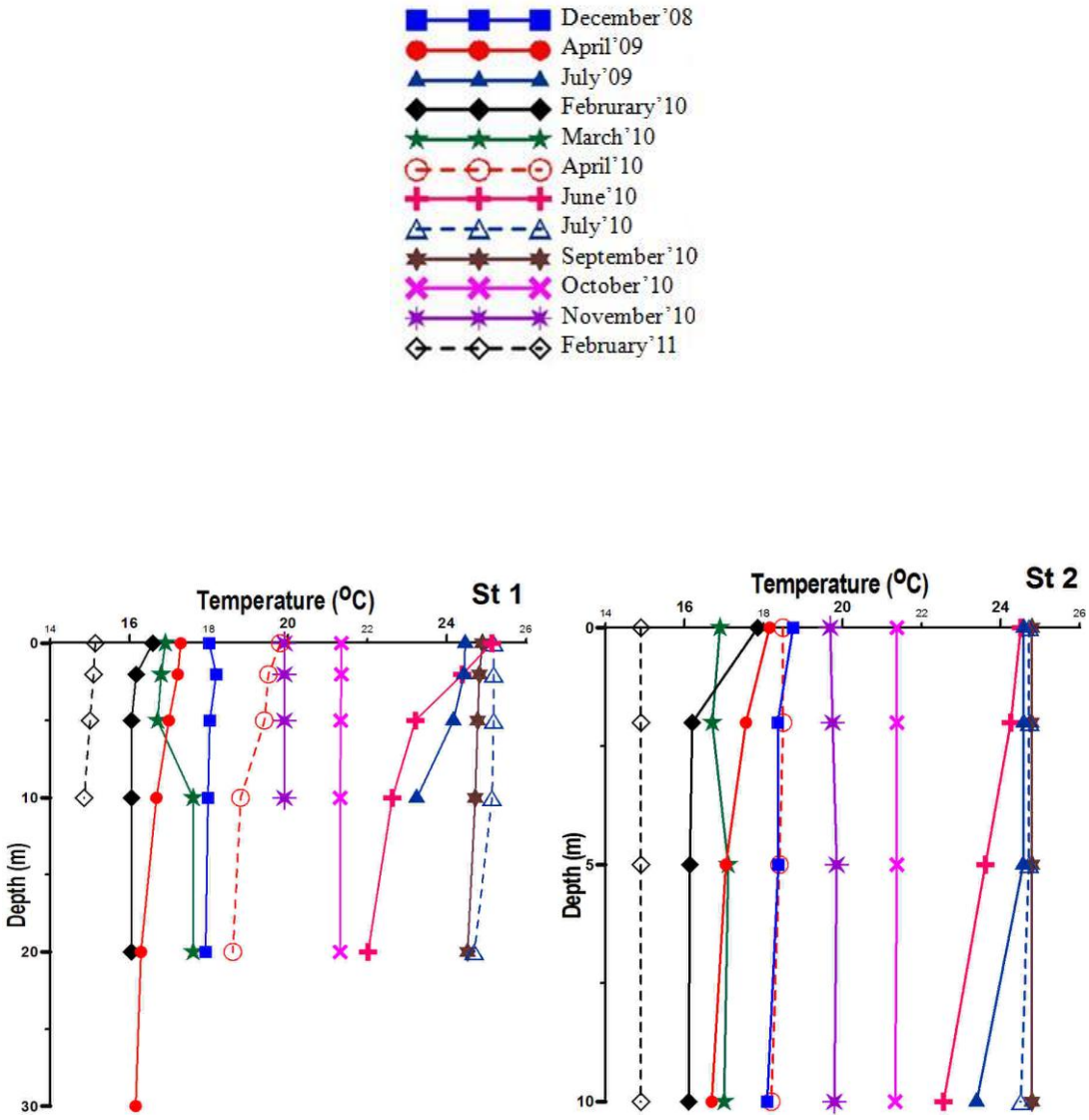
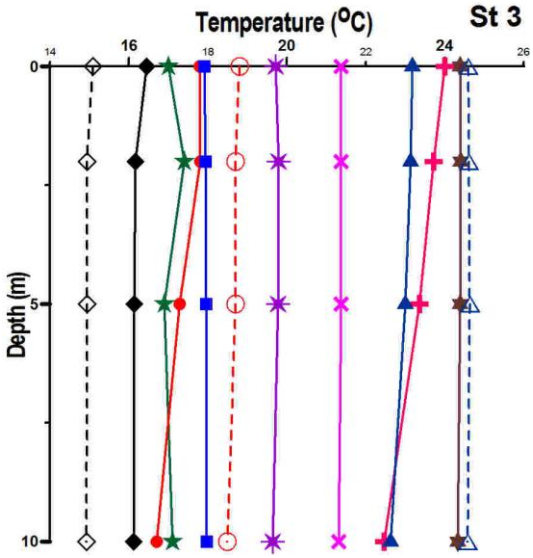
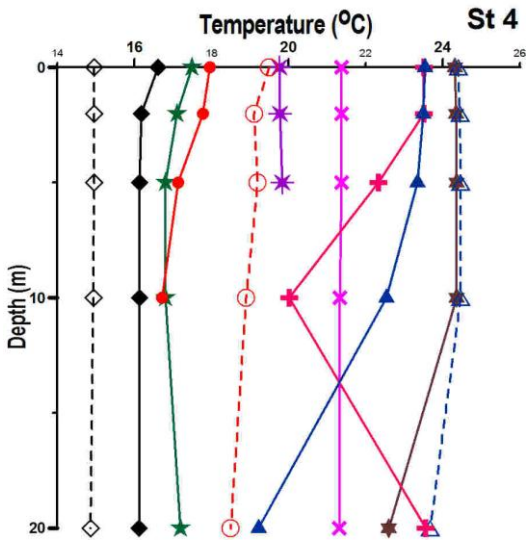
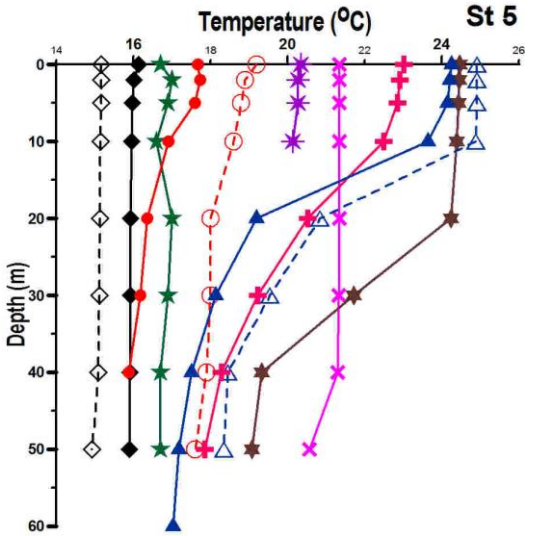
APPENDICES

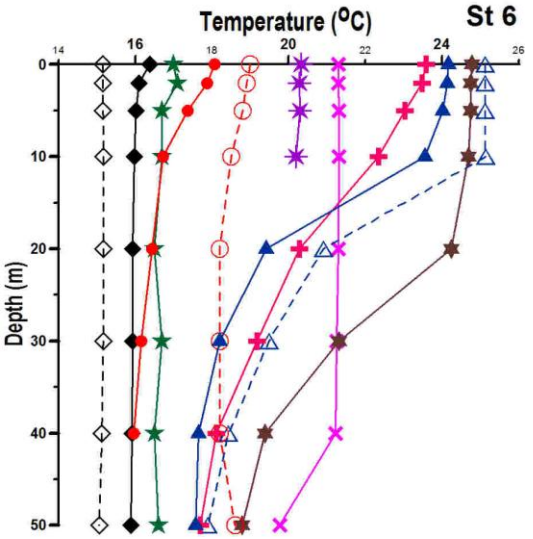
Appendix 1. Depth Profiles of Temperature and Salinity.

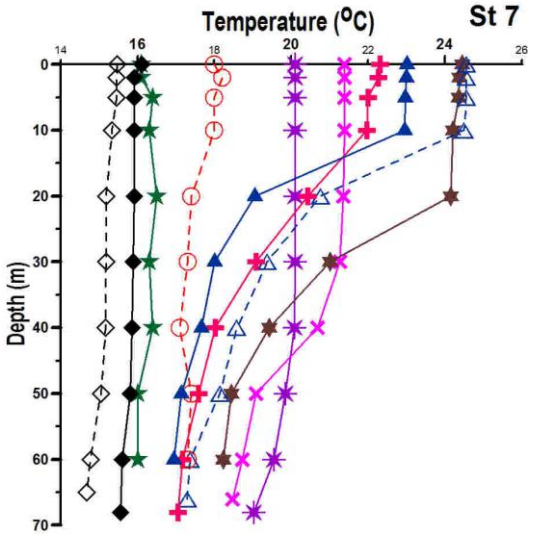


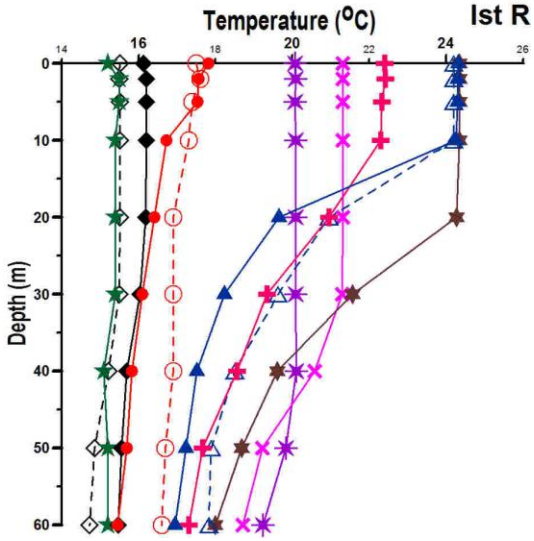

Temperature (°C)
St 3
Depth (m)

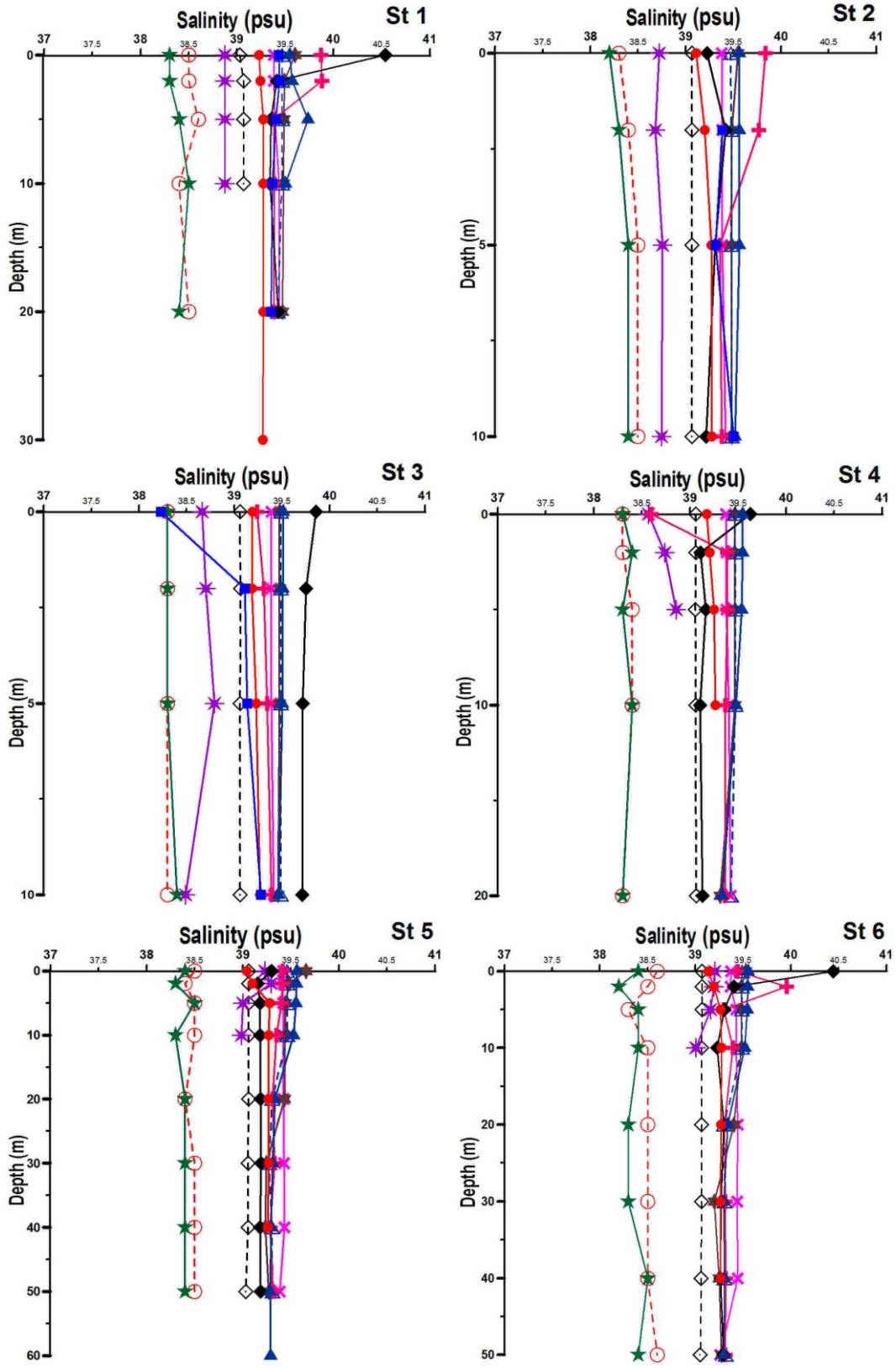

Temperature (°C)
St 4
Depth (m)

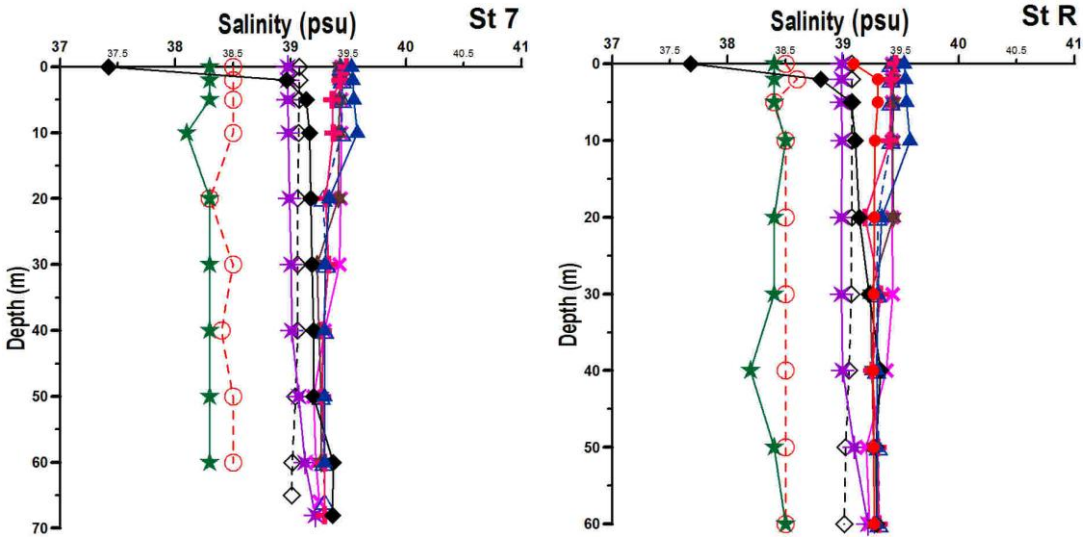

Temperature (°C)
St 5
Depth (m)


Temperature (°C)
St 6
Depth (m)

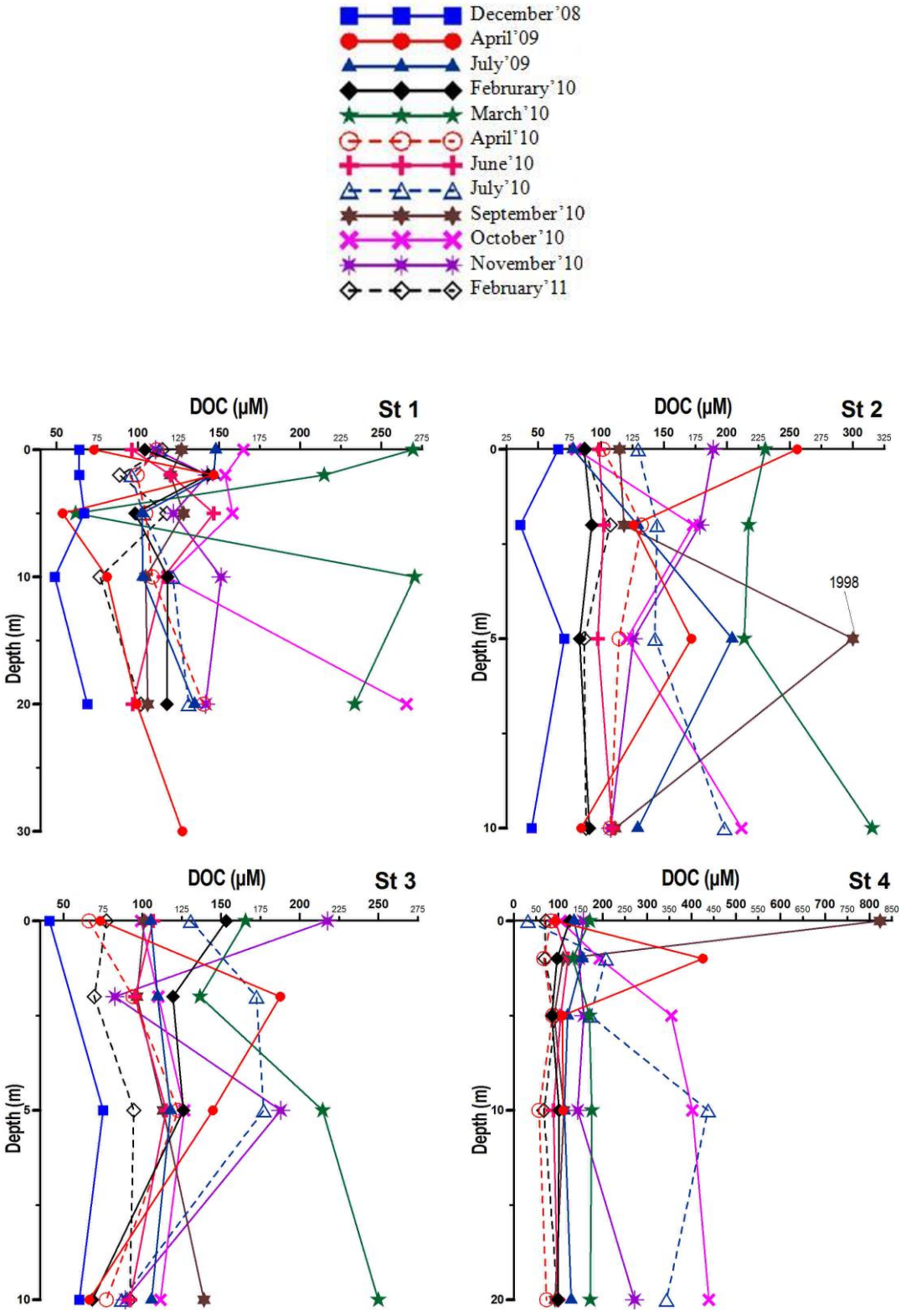

Temperature (°C)
St 7
Depth (m)

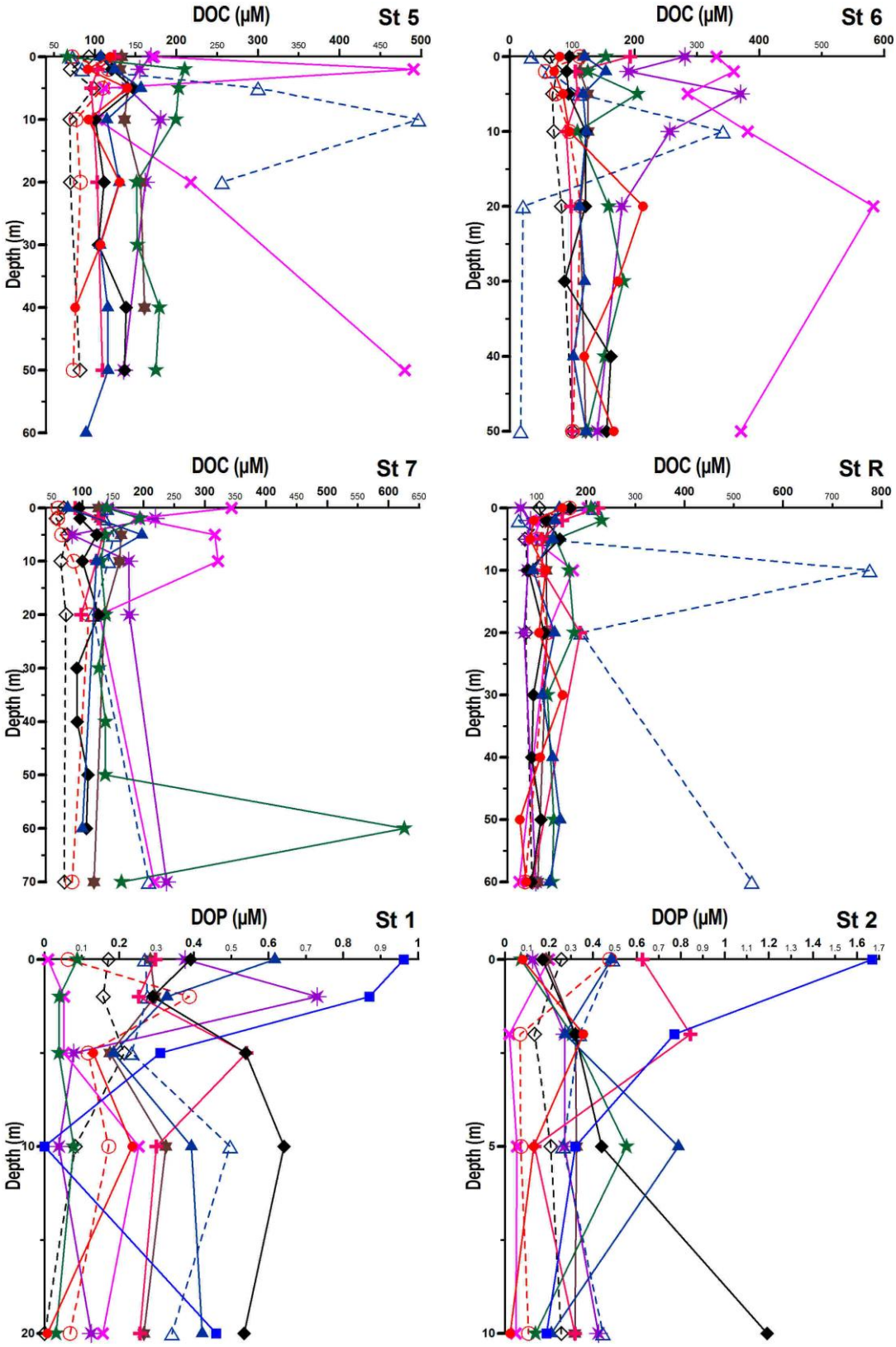

Temperature (°C)
Ist R
Depth (m)

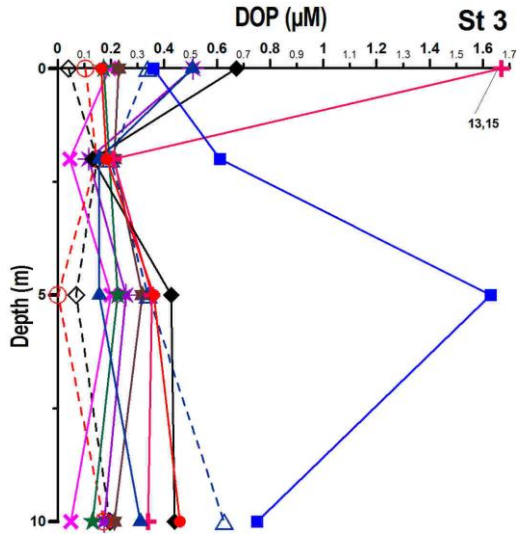

St 1
Salinity (psu)
Depth (m)
St 2
Salinity (psu)
Depth (m)
St 3
Salinity (psu)
Depth (m)
St 4
Salinity (psu)
Depth (m)
St 5
Salinity (psu)
Depth (m)
St 6
Salinity (psu)
Depth (m)

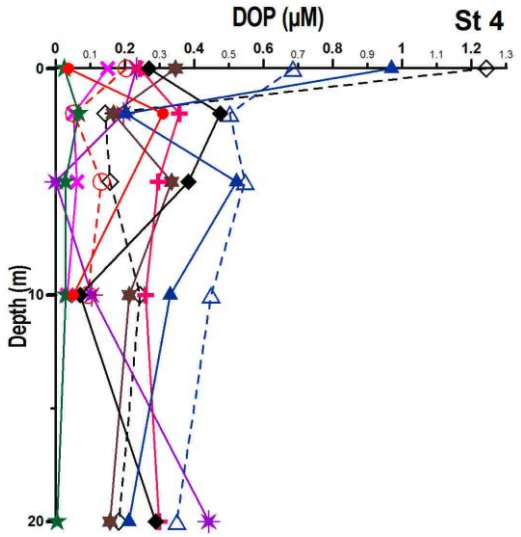

Salinity (psu)
St 7
Depth (m)
Salinity (psu)
St R
Depth (m)

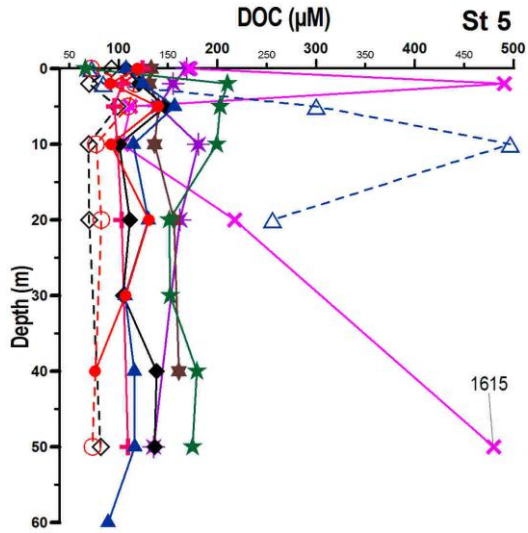
Appendix 2. Depth Profiles of DOM (DOC and DOP). (The concentation scale and depth scale are different for each station).

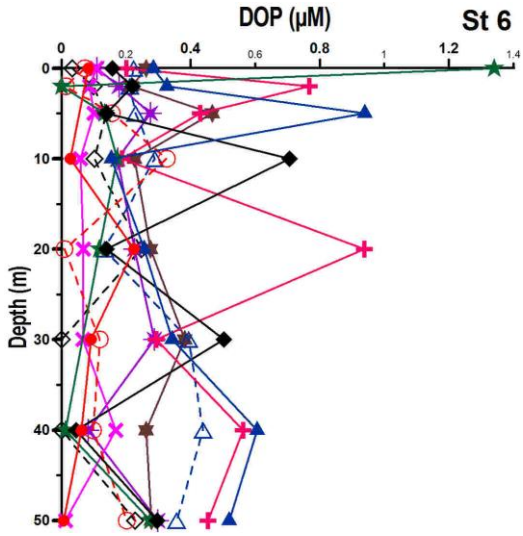


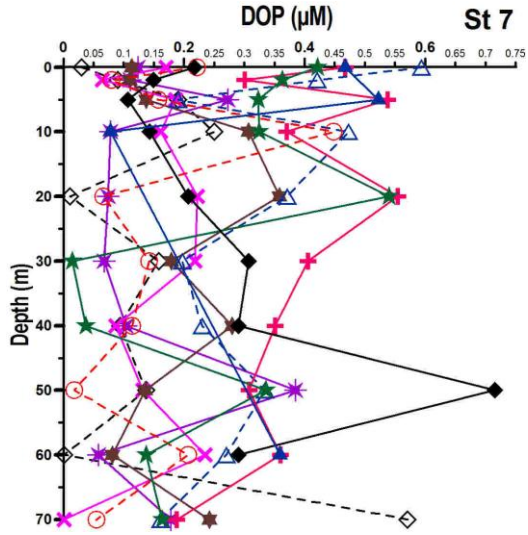

DOC (μM)
St 5
Depth (m)
DOC (μM)
St 6
Depth (m)
DOC (μM)
St 7
Depth (m)
DOC (μM)
St R
Depth (m)
DOP (μM)
St 1
Depth (m)
DOP (μM)
St 2
Depth (m)

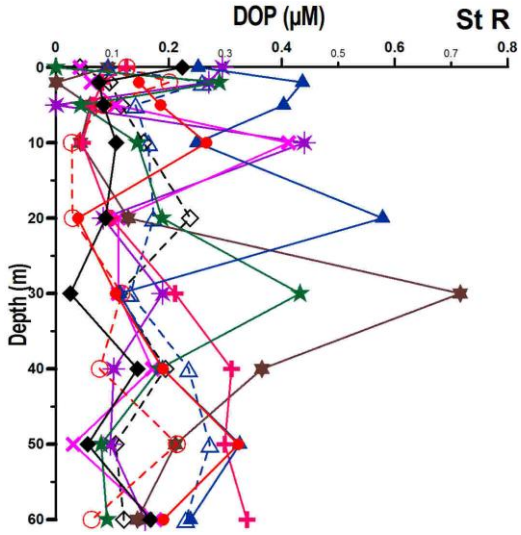

DOP (μM)
St 3
Depth (m)
13,15


DOP (μM)
St 4
Depth (m)

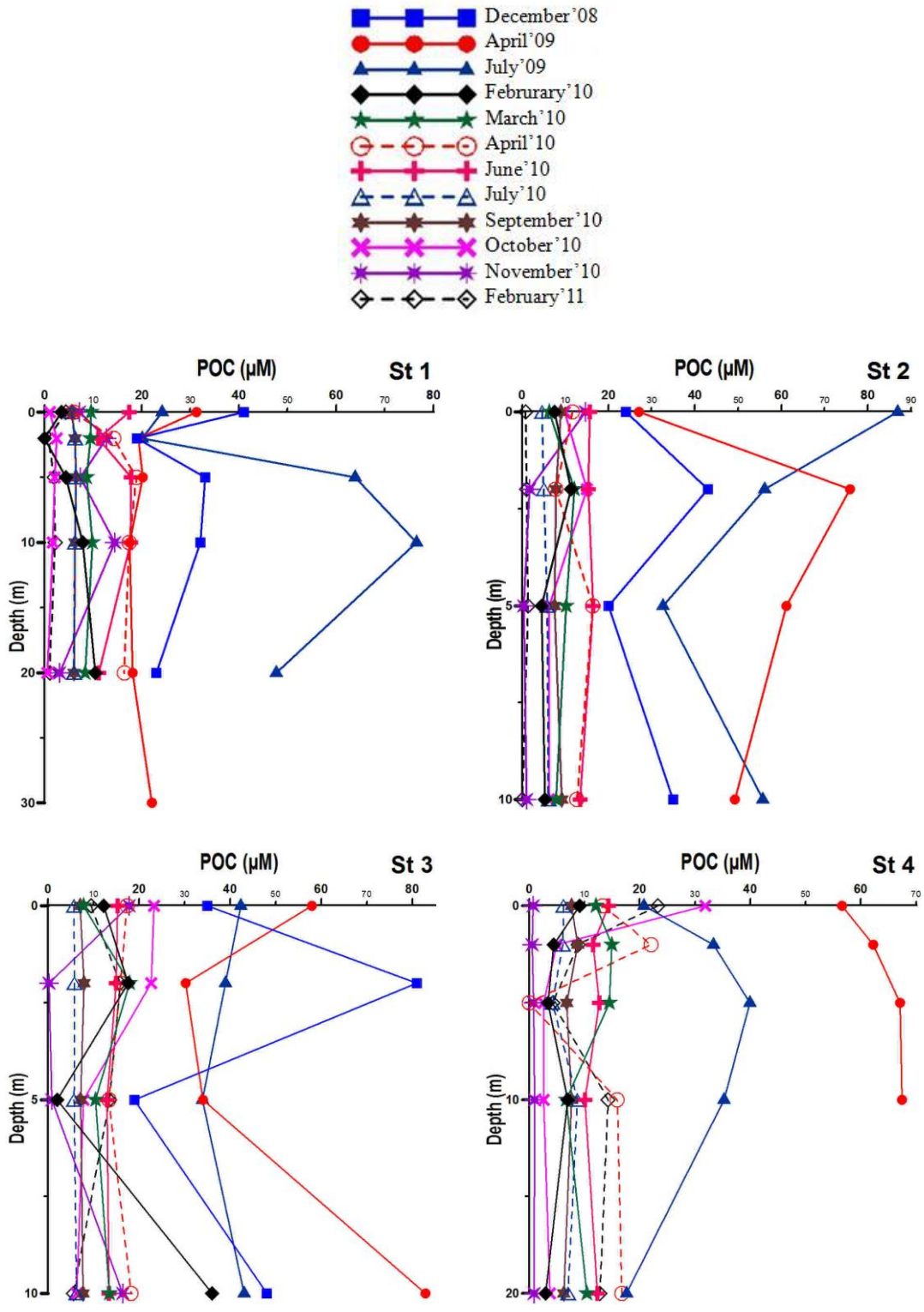

DOC (μM)
St 5
Depth (m)
1615

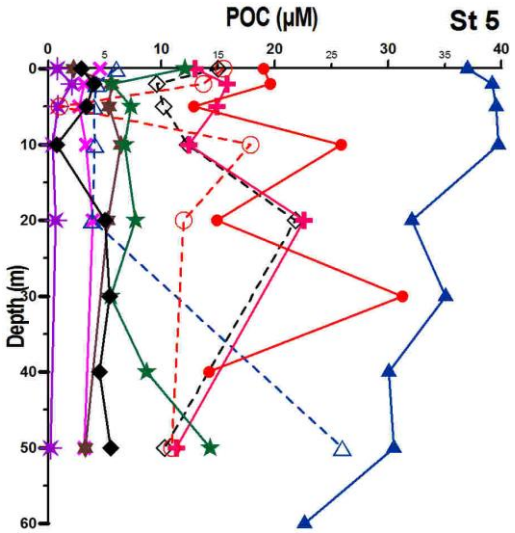

DOP (μM)
St 6
Depth (m)

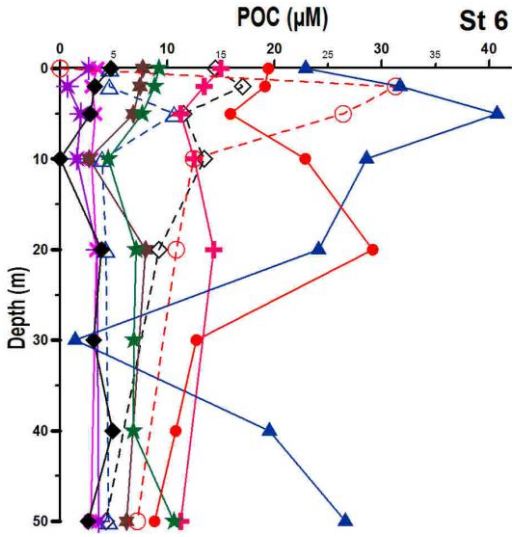

DOP (μM)
St 7
Depth (m)

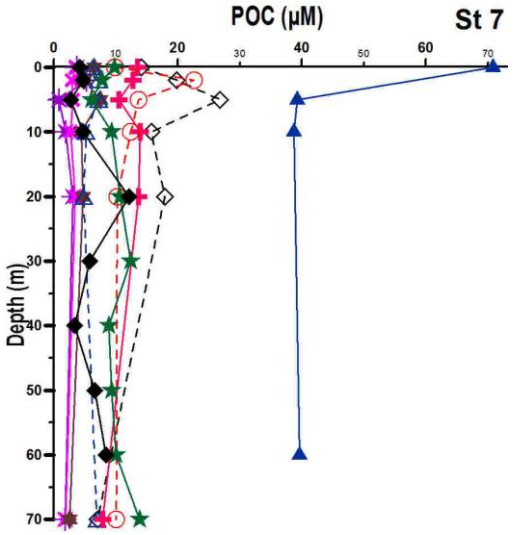

DOP (μM)
St R
Depth (m)

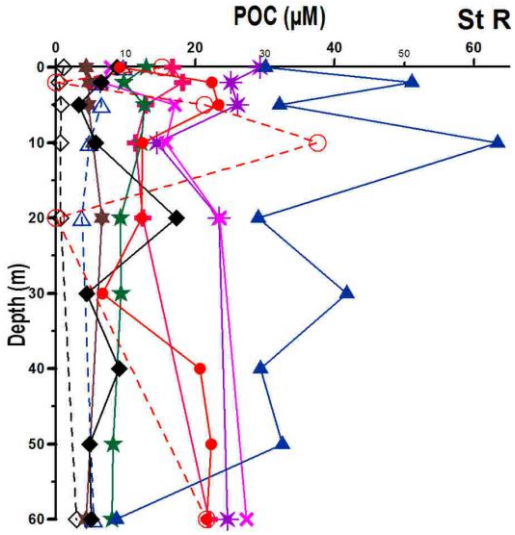
Appendix 3. Depth Profiles of POM (POC, PON and DOP). (The concentation scale and depth scale are different for each station).

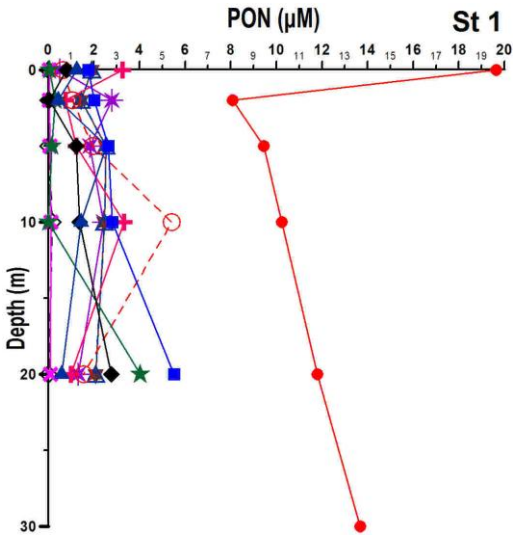


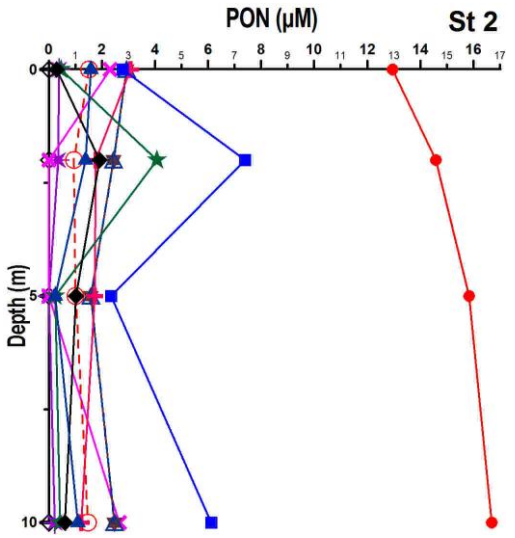

POC (μM)
St 5
Depth (m)

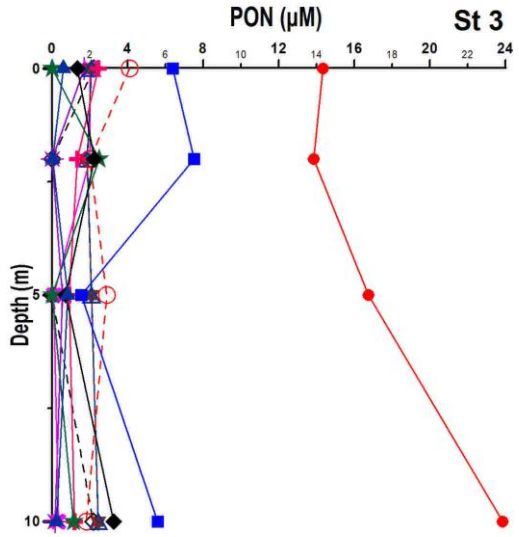

POC (μM)
St 6
Depth (m)

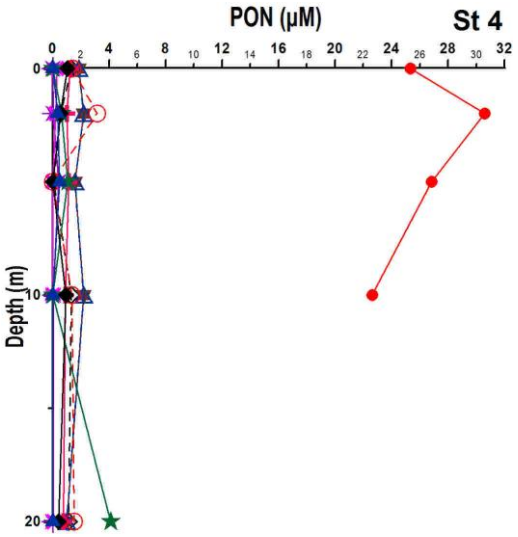

POC (μM)
St 7
Depth (m)

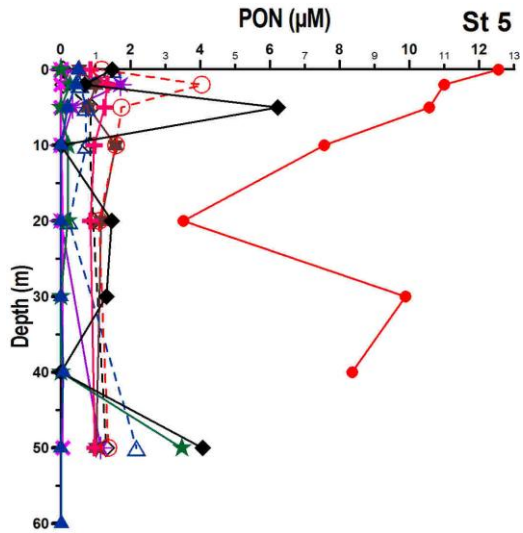

POC (μM)
St R
Depth (m)

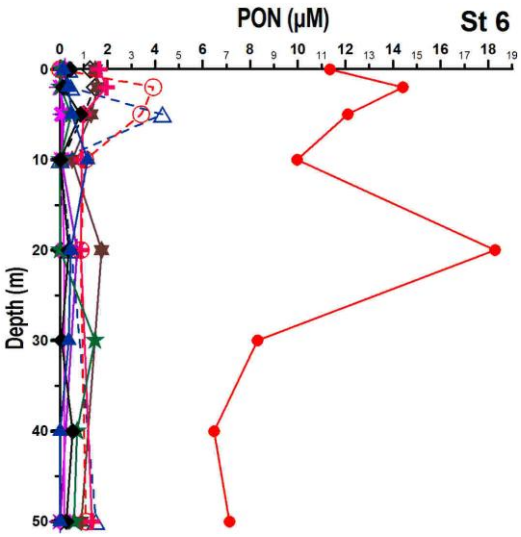

PON (μM)
St 1
Depth (m)

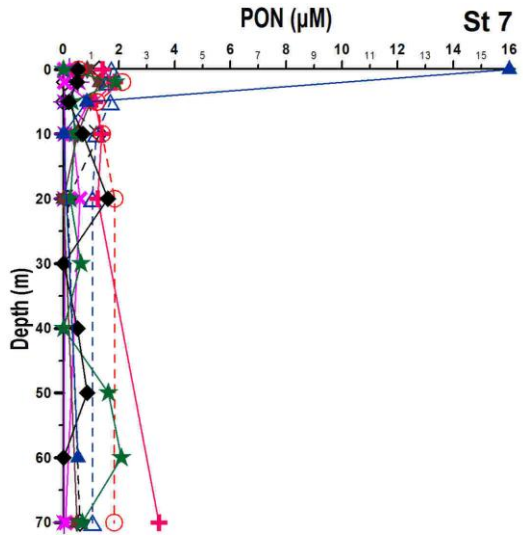

PON (μM)
St 2
Depth (m)

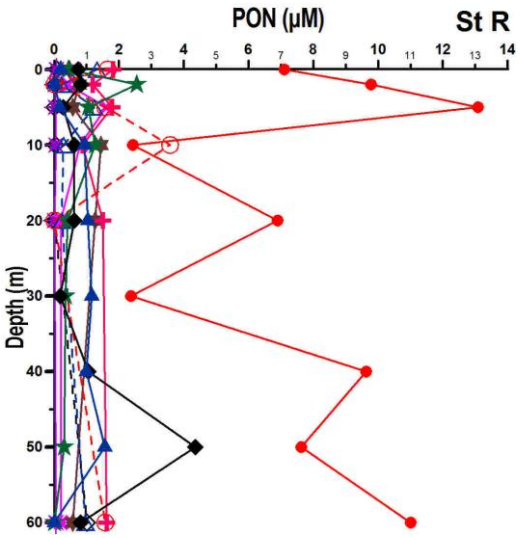

PON (μM)
St 3
Depth (m)

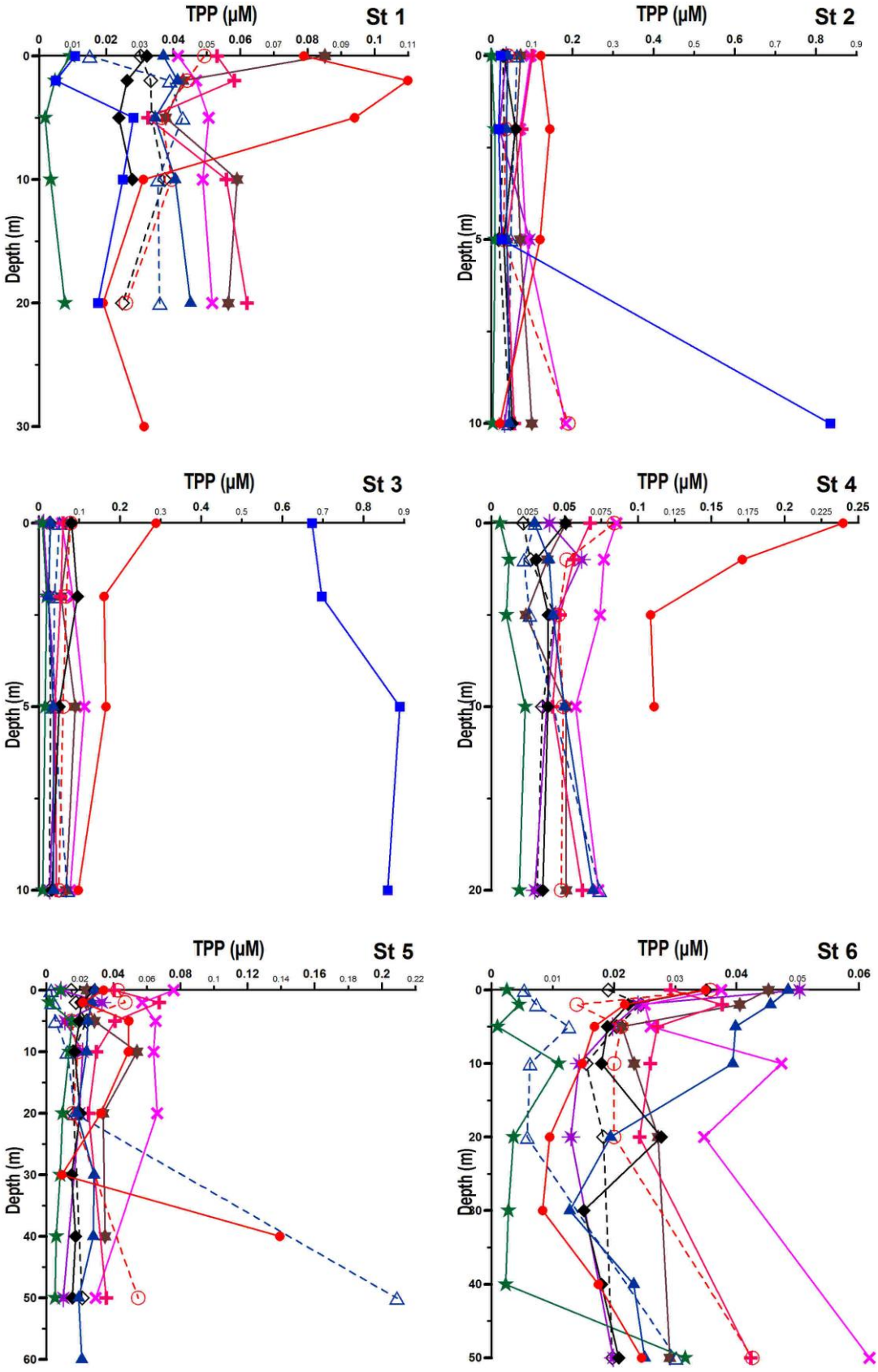

PON (μM)
St 4
Depth (m)

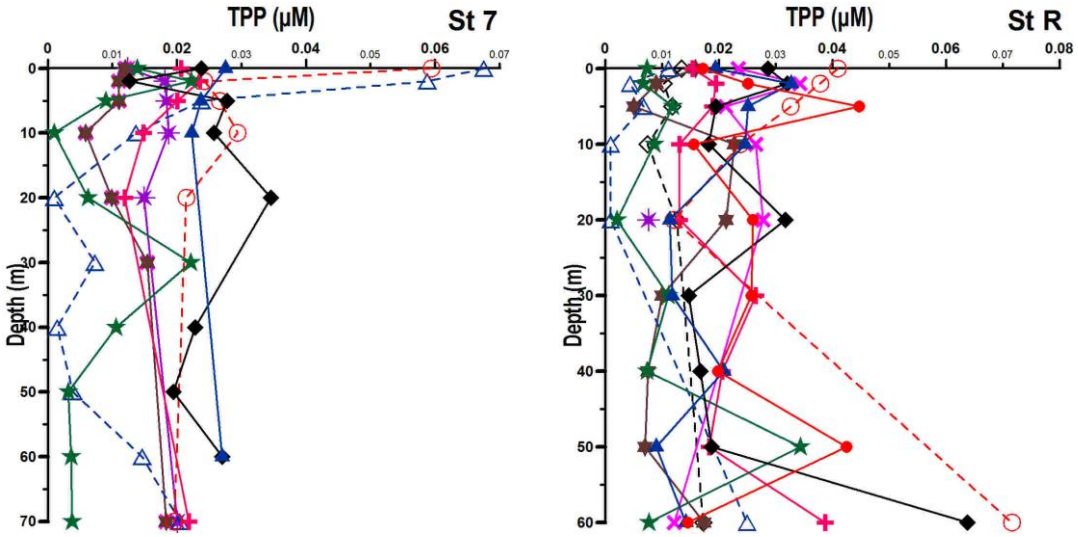

PON (μM)
St 5
Depth (m)


PON (μM)
St 6
Depth (m)


PON (μM)
St 7
Depth (m)


PON (μM)
St R
Depth (m)


TPP (μM)
St 1
Depth (m)
TPP (μM)
St 2
Depth (m)
TPP (μM)
St 3
Depth (m)
TPP (μM)
St 4
Depth (m)
TPP (μM)
St 5
Depth (m)
TPP (μM)
St 6
Depth (m)


TPP (μM)
St 7
Depth (m)
TPP (μM)
St R
Depth (m)