MONTHLY CHANGES IN PRIMARY AND BACTERIAL PRODUCTIVITY IN THE NORTH – EASTERN MEDITERRANEAN SHELF WATERS

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

MONTHLY CHANGES IN PRIMARY AND BACTERIAL PRODUCTIVITY IN THE NORTH – EASTERN MEDITERRANEAN SHELF WATERS

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Within the context of this thesis, it was aimed to compare monthly changes in primary and bacterial production rates of eutrophic shelf waters with those of nutrient impoverished oligotrophic open waters taking into consideration of ambient physicochemical properties of the basin waters. In addition, size fractionated primary production and limiting nutrient experiments were also carried out. To achieve these goals, a total of 25 cruises were realized on board R/V Bilim-2 of IMS-METU to collect biological (primary and bacterial productivity, size-fractionated primary productivity and chlorophyll *a*, phytoplankton marker pigments, bacterial abundance, nutrient enrichment experiments), chemical (nitrite+nitrate, silicate, phosphate, ammonium, dissolved oxygen, pH) and physical (temperature, salinity, density, daily surface PAR, Secchi disc depth) data between September 2008 and October 2011 in the basin. ^{14}C and leucine-^{3}H methods were applied to assess primary and bacterial productivity, respectively.

Depth integrated primary productivity and bacterial productivity varied between 2.05 – 121 and 0.31 – 3.36 $mgCm^{-2}h^{-1}$, respectively in the study area. Annual primary and bacterial productivity were estimated to be 151.2 and 14.6 g $C.m^{-2}$ y^{-1} for the shelf and 65.4 and 12.9 g $C.m^{-2}$ y^{-1} for the offshore, respectively. A highly significant positive correlation was found between bacterial production and chlorophyll *a* and primary production in eutrophic coastal waters.

Phytoplankton at east coast of Mersin Bay had displayed higher carbon to chlorophyll ratio than those in the west. Larger cells (>5μm) have been found to

dominate Primary Production (PP) in the western shelf and picoplankters to dominate PP in the eastern shelf. However, in the east, the top 10 m that was affected greatly from the river runoff was dominated by cells larger than 5 μm. From inshore to offshore a gradual increase in picoplankton contribution to the total primary production was observed (% 41.1 to 54.4 to 70.7). Inversely, a gradual decrease in contribution of larger cells to total primary production was observed towards offshore (%44.1, 27.5, 16.1). While large eukaryotes (diatoms and dinoflagellates) dominated the flora in the eastern shelf, all groups seemed to contribute evenly to the bulk throughout the study period in the western shelf in Mersin Bay. Prokaryotic picoplankton (Prochlorophyta and Cyanophyta) and eukaryotic nanoflagellates (Chrysophyta, Chlorophyta and Prymnesiophyta) together formed the bulk of offshore flora where cyanobacteria and prymnesiophyta (coccolithophorids) shifted with each other in time. P was found to be the limiting nutrient for bacterial growth , while P, N and N+P controlled seasonally the growth of phytoplankton in the basin.

Keywords: Primary Production, Bacterial Production, marker pigments, limiting nutrients, northeastern Mediterranean,

ÖZ

KUZEYDOĞU AKDENİZ KIYI SULARINDA BİRİNCİL VE BAKTERİYEL ÜRETİM MİKTARLARINDA AYLIK DEĞİŞİMLER

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Bu tez çalışması kapsamında, kuzeydoğu Akdeniz'de üretken kıyı suları ve besin tuzlarınca fakir - verimsiz açık sularda birincil ve bakteriyel üretim miktarlarındaki aylık değişimlerin, ortam fizikokimyasal parametreleri dikkate alınarak kıyaslanması amaçlanmıştır. Ayrıca farklı hücre boy gruplarında birincil üretim hızları ve sınırlayıcı besin elementi deneyleri yapılmıştır. Bu hedeflere ulaşmak için Eylül 2008 ve Ekim 2011 tarihleri arasında biyolojik (birincil ve bakteriyel üretim, farklı boy gruplarında birincil üretim ve klorofil *a*, fitoplankton iz pigmentleri, bakteriyel bolluk, sınırlayıcı besin tuzu ekleme deneyi), kimyasal (nitrit+nitrat, silikat, fosfat, amonyum, çözünmüş oksijen, pH) ve fiziksel (sıcaklık, tuzluluk, yoğunluk, günlük yüzey fotosentetik aktif ışınım, Seki disk derinliği) verileri toplamak üzere basende ODTÜ-DBE'ne ait Bilim-2 araştırma gemisi ile 25 adet sefer gerçekleştirilmiştir. Birincil ve bakteriyel üretim miktarlarını belirlemek için sırasıyla karbon-14 ve lösin-^{3}H metodları kullanılmıştır.

Çalışılan bölgede su kolonu birincil ve bakteriyel üretim miktarları sırasıyla 2.05-121 ve 0.31-3.36 $mgCm^{-2}h^{-1}$ aralığında değişim göstermiştir. Yıllık birincil üretim ve bakteriyel üretim miktarları sırasıyla kıyı için 151.2 ve 14.6 g $C.m^{-2}$ y^{-1} ve açık sular için 65.4 ve 12.9 g $C.m^{-2}$ y^{-1} olarak hesaplanmıştır. Verimli kıyı sularında bakteriyel üretim ile birincil üretim ve klorofil arasında yüksek düzeyde pozitif ilişki bulunmuştur.

Mersin Körfezi doğu kıyı fitoplanktonu batı kıyısındakinden birim klorofil başına daha yüksek karbon sentezleme oranına sahiptir. Birincil üretim batı kıyısında 5µm'den büyük hücreler tarafından domine edilirken, doğu kıyıları pikoplankton

tarafından domine edilmektedir. Buna karşın, nehir girdilerinden yoğun olarak etkilenen doğu kıyı sularının ilk on metrelik yüzey kısmında birincil üretim 5µm'den büyük hücreler tarafından domine edilmektedir. Pikoplankton'un toplam birincil üretime yaptığı katkı kıyıdan uzaklaştıkça kademeli olarak artmaktadır (% 41.1'den 54.4'e ve sonrasında 70.7). Buna zıt olarak büyük hücrelerin toplam birincil üretime yaptığı katkı kıyıdan açığa giderek azalma göstermiştir (% 44.1'den, 27.5 ve 16.1'e düşmüştür). Çalışma süresi boyunca Mersin körfezi doğu kıyı sularında fitoplankton kompozisyonunu büyük ökaryotlar (diyatom ve dinoflagellat) domine ederken, batı kıyılarında bütün gruplar eşit derecede katkı yapmıştır. Açık sularda fitoplankton kompozisyonu prokaryotik pikoplankton (Prochlorophyta ve Cyanophyta) ve ökaryotik nanoflagellatlar (Chrysophyta, Chlorophyta ve Prymnesiophyta) tarafından domine edilmektedir. Açık sularda baskınlık zamana bağlı olarak Cyanobacteria ve Prymnesiophyta (kokkolithoforidler) arasında değişmektedir. Basende bakteriyel üretim fosfor tarafından sınırlanırken, fitoplanktonun gelişimi mevsime bağlı olarak fosfor, azot ya da ikisi tarafından kontrol edilmektedir.

Anahtar Kelimeler: Birincil üretim, bakteriyel üretim, iz pigmentler, sınırlayıcı elementler, kuzeydoğu Akdeniz.

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LIST OF ABBREVIATIONS

ALLO: Alloxanthin

B-CAR: β-carotene

BCP: Bacterial Carbon Production

BUT: 19-butanoyloxyfucoxanthin

C/CHLL: unit Carbon produced per unit Chlorophyll

Chl: Chlorophyll

CHL-*a*: Chlorophyll-*a*

CHL-*b*: Chlorophyll-*b*

CPM: Counts Per Minute

DCM: Deep Chlorophyll Maximum

DIAD: Diadinoxanthin

DIPP: Daily Integrated Primary Production

DIV-Chl-a: Divinyl chlorophyll-a

DOC: Dissolved Organic Carbon

DOM: Dissolved Organic Matter

DPM: Disintegrations Per Minute

DRP: Dissolved Reactive Phosphorus

FUC: Fucoxanthin

HBA: Heterotrophic Bacterial Abundance

HEX: 19-hexanoyloxyfucoxanthin

HPLC: High Performance Liquid Chromatography

ICHL: Integrated Chlorophyll

IPP_{inc} : Integrated Primary Production

LSC: Liquid Scintillation Counter

LUT: Lutein

PAR: Photosynthetically Active Radiation

PER: Peridinin

PP: Primary Production

SDD: Secchi Disc Depth

TIN: Total Inorganic Nitrogen

TPP: Total Primary Production

ZEA: Zeaxanthin

1. INTRODUCTION

Energy is transferred from one trophic level to another in the form of chains in the food web. Food chain starts with autotrophs (self-feeding) which are called primary producers or photoautotrophs and chemoautotrophs in seawater (Kirchman, 2008). They produce complex organic compounds from inorganic matter via photosynthesis or chemosynthesis. All marine life relies on this process. Almost all primary production is performed by phytoplankters within the euphotic layer of the world oceans. They support almost all marine communities. Their role is taken by chemoautotrophs below the euphotic zone in the water column, in case or in the presence of anoxic waters (Kirchman, 2008).

Similarly marine microbes, particularly heterotrophic bacteria, shape aquatic areas in the world. Marine bacteria display a vital role in the food web while acting efficiently in cycling of elements, degradation of organic matter and recycling of nutrients, etc. They are present in different environmental conditions in the oceans and freshwater habitats. They can be classified as lithotrophs or organotrophs according to their primary nutritional groups (Kirchman, 2008).

Phytoplankton and bacteria display different trophic strategies including autotrophy, heterotrophy or their combination (mixotrophy). Mixotrophic organisms can use different sources of energy and carbon. Some eukaryotic and prokaryotic cells may have both the light harvesting apparatus and means for uptake of organic compounds. Dinoflagellates can be autotrophic, heterotrophic, parasitic or endosymbionts of marine animals and protozoa (Tomas et. al., 1997). They may act as producers or consumers or both in the same time in the food web (Gaines and Elbrächter, 1987) and they are well known as an opportunistic group.

Microorganisms are able to develop new strategies in accessing nutrients for survival. Different kinds of microorganisms compete for nutrients in their environment. Size is a particularly important factor for accessing the food. It is related with the surface to volume (S/V) ratio of a cell. Small cells have high S/V and they are more advantageous in nutrient poor waters. On the other hand, large cells have large

storage capacity for nutrients in nutrient rich waters (e.g. upwelling, river discharge and coastal areas) (Raven, 1984; Finkel et al. 2005; Falkowski and Raven, 2007).
Physiological rates and ecological function, including metabolic rate (growth, photosynthesis, and respiration), light absorption (Raven, 1984; Finkel, 2001), nutrient diffusion, uptake and requirements (Pasciak and Gavis, 1974; Shuter, 1978; Aksnes and Egge, 1991; Hein et al., 1995), sinking rate, maximum numeric abundance and grazing rates (Frost, 1972; Kiorboe, 1993; Waite et al., 1997) are influenced by the phytoplankton size (Finkel et al., 2010)

During photosynthesis, solar energy is absorbed and converted via pigments from the form of electromagnetic radiation to stored chemical energy by the phytoplankton cells. This chemical energy is stored in the organic compounds. Carbon is assimilated by primary producers in photosynthesis to produce new and complex organic compounds.

Phytoplankton may be present at a certain time and place depending on biological, physical and chemical conditions. Measurement of the rate of photosynthesis gives information about carbon assimilation and production capacity. Radio labeled inorganic compounds have been used for measuring primary production capacity of phytoplankton since 1950. Before radio labeled method, scientists used to calculate the rate of photosynthesis by measuring dissolved oxygen production. But, this method was less sensitive than the radio labeled method, especially in oligotrophic waters (Williams et al., 2002).

Key developments in the measurement of photosynthesis;

1927 - Gaarder and Gran achieved to measure dissolved oxygen concentrations by using Winkler technique for estimating rate of photosynthesis.

1940s - Calvin and co-workers compared uptake of the $^{12}CO_2$ and $^{14}CO_2$ at the mid and late 1940s.

1950-1952 - Einer Steemann Nielsen used radiocarbon (^{14}C) to measure rate of photosynthesis in seawater.

Scientists started to focus on marine microbes in 1940s and, tried to measure microbial activity in nature. Heterotrophic bacterial activity was directly correlated

with dissolved organic material as well as primary production. Heterotrophic bacteria use dissolved organic compounds as carbon and energy sources. They degrade large-complex organic materials in the ocean. Contribution of bacterial biomass to total plankton is very high. They support other trophic levels in the food web. Ciliates and flagellates transfer bacterial biomass to upper trophic levels in microbial loop.

Key developments in the measurement of bacterial carbon production;

1968 – Hobbie and co-workers first used radiolabeled amino acid.

1982 – Fuhram and Azam advised tritium (^{3}H) labeled thymidine (TdR) to be used in DNA synthesis.

1985 – Kirchman and co-workers developed a radiolabeled - leucine method (this amino acid is used in protein synthesis).

1992 – Smith and Azam improved the micro-centrifuge method.

Phytoplankton bear different pigments which are chemical compounds that reflect or absorb certain wavelengths of visible light. Autotrophs use pigments to capture photons from the sun for making their own food by photosynthesis. Each pigment can capture photons within a narrow range of the light spectrum. Basically, photosynthetic pigments are clustered into three main groups; chlorophylls, carotenoids and phycobilins. Chlorophyll *a* is the main pigment in photosynthesis. Others are called accessory pigments which transfer captured photons to chlorophyll *a* (Jeffrey et al. 1997). Chlorophyll molecule makes photosynthesis possible by passing its energized electrons onto molecules which manufacture sugars. All photosynthetic organisms contain chlorophyll *a* (Freeman et al., 2000, URL 1, 2007). And chlorophyll *a* is used as an indicator of algal biomass and productivity in oceanography.

With high performance liquid chromatography (HPLC) method, it is possible to measure chlorophyll *a* as well as any other phytoplankton pigment more precisely and to determine phytoplankton composition more easily and rapidly (Stauber and Jeffrey, 1988; Millie et al., 1993; Jeffrey and Vesk, 1997; Wright et al., 1996; Obayashi et al., 2001; Dos Santos et al., 2003). With this technique, understanding of the global distribution, composition and function of phytoplankton became more feasible. Each

taxon has specific signature or marker pigment. Types of pigments used for the taxonomic purposes are listed elsewhere (Gieskes et al., 1988; Everitt et al., 1990; Jeffrey et al., 1997; Barlow et al., 1999). Among the most widely used marker pigments, peridinin (PER), fucoxanthin (FUC) and zeaxanthin (ZEA) were commonly used to designate dinoflagellates, diatoms and cyanobacteria, respectively (Wright and Jeffrey, 1987; Jeffrey et al., 1997). Previous studies based solely on microscopic observations have established that large size phytoplankters make up the majority of the algal standing stock in the marine environment. With the introduction of new techniques and instrumentation (single cell analysis by flow cytometry and pigment analysis by HPLC), small size phytoplankton (picoplankton, <2 μm) including prochlorophytes (dvCHLa) and cyanobacteria (ZEA) are defined as major contributors to the total photosynthetic biomass in the oceans (Booth, 1988; Li et al., 1993; Partensky et al., 1993), especially in more oligotrophic regions such as subtropical ocean gyres and the Mediterranean (Li et al.,1993; Bell and Kalff, 2001; Uysal, 2006).

Photosynthesis is affected by availability of light, temperature, nutrients, as well as, from many other chemical, physical and biological factors (Jokiel and York, 1984). High light may inhibit photosynthesis. Temperature may effect either negatively or positively the enzymatic processes during photosynthesis based on the type of plankton species (Jokiel and York, 1984; Valiela, 1995). Concentration and composition of inorganic nutrients also affect the growth of microorganisms (Parsons and Takahashi, 1975). Finally, grazing, upwelling, downwelling, diseases (algal parasites, fungi etc.); pollution (petroleum and chlorinated hydrocarbons, heavy metals, radioactive isotopes, and various other agricultural and industrial chemicals) may affect primary productivity in various ways (Waldichuk, 1977; Sparks, 2003).

1.1. The physical oceanography of the Cilician Basin

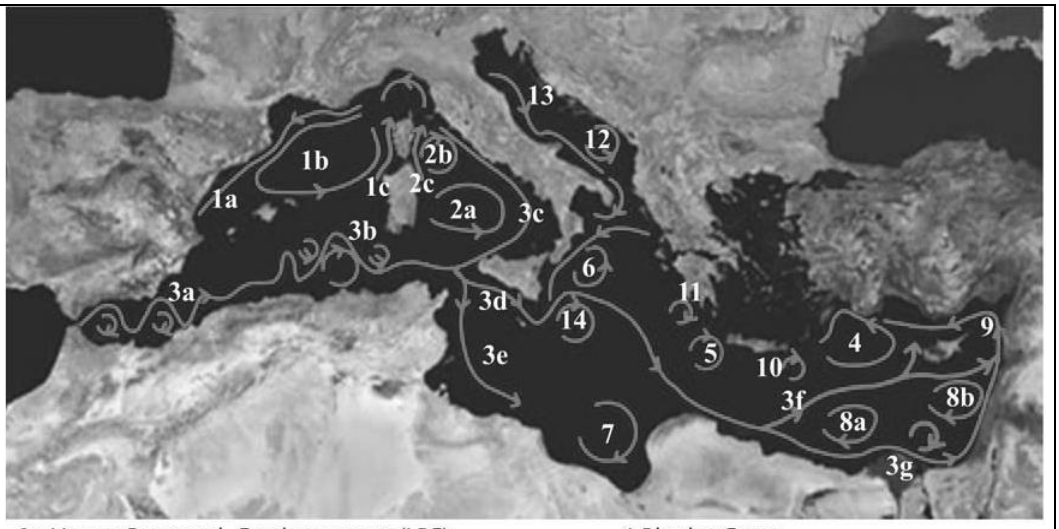
The Mediterranean is almost completely surrounded by land: on the north by Europe, on the east by Asia and on the south by Africa. It is connected with the Atlantic Ocean via the strait of Gibraltar in the west and with the Red Sea via the Suez Canal in the south-east. Mediterranean is divided into two main basins, namely western and eastern basins. The western basin includes the Alboran, the Algerian-Provencial, the Tyrrhenian seas, while the eastern basin includes the Adriatic, the Ionian, the Aegean that is connected throught the Turkish Straits System with the Black Sea and the

Levant Seas. It covers an area of 2.5 million km^2 with a maximum depth of 5267 m in the Calypso Deep of the Ionian Sea. Mean depth of the eastern basin is higher than western basin in the Mediterranean (Barale, 2008). Because of the narrow connection with Atlantic Ocean, very weak tides are observed in the Mediterranean (McElderry, 1963).

In the eastern basin of the Mediterranean water is saltier than in the western part due to higher evaporation rate and limited fresh water input. Also, Mediterranean is more saline and warmer than the adjacent Atlantic Ocean. While denser Mediterranean waters flow towards the Atlantic through the Gibraltar strait at intermediate depths, less dense surface Atlantic waters flow into the Mediterranean (Tomczak and Godfrey, 2003). Özsoy et al. (1989) declared that Atlantic waters become warmer and saltier while traveling towards eastern Mediterranean (Levantine basin).

General circulation and hydrography of the Mediterranean were studied by many scientists (Hecht, 1986); Özsoy et al., 1989; 1991; 1993), Robinson et al., 1991), *POEM* group (1992), Robinson and Golnaraghi, 1994), Malanotte-Rizzoli et al., 1999), Demirov and Pinardi, 2002), Pinardi et al., 2005)). Pinardi et al., (2005) summarized the surface circulation of the Mediterranean based on recent observational data and model simulation (Figure 1.4.).

After Atlantic surface waters flow towards Mediterranean throught the Gibraltar Strait, it is called Atlantic Stream System (ASS) in Alboran Sea. While flowing of ASS towards the eastern Mediterranean, it is called Atlantic – Ionian Stream (AIS) near Strait of Sicily. A branch of the ASS turns south-east forming the Modified Atlantic Water (MAW). As the Atlantic – Ionian Stream travels eastward, Mid-Mediterranean Jet (MMJ) between the cyclonic Rhodes gyre and anticyclonic Mersa-Matruh gyre and Southern Levantine current (SLC) in south of the Mersa – Matruh gyre are formed in the eastern Mediterranean. MMJ and SLC mix again at eastern side of Cyprus, in the area of the Shikmona gyre forming Asia Minor Current (AMC) which travels into Iskenderun Bay and Cilician basin along the Turkish coast towards west (Figure 1.4; Hecht, 1986; Özsoy et al., 1989; Pinardi et al., 2005). While Atlantic surface waters enter Mediterranean with 36.15 ‰ salinity, it reaches 38.6 ‰ in the Levantine Basin (Özsoy et al., 1989; Demirov and Pinardi, 2002; POEM group, 1992). Also, it reaches to 39.5 ‰ in the Cilician Basin surface waters (Uysal et al. 2008).



1a Liguro-Provencal-Catalan current (LPC)
1b Gulf of Lyon Gyre
1c Western Corsica Current
2 Northward Tyrrhenian current and gyres:
2a Northward current and Southern Tyrrhenian Gyres
2b Northern Tyrrhenian Gyre
2c Eastern Corsica Current
3 Gibraltar-Atlantic current system
3a Alboran basin Gyres and meanders
3b Algerian current gyres, eddies and meanders
3c Tyrrhenian bifurcation/current
3d Atlantic-Ionian Stream
3e African MAW (Modified Atlantic Water) Current
3f Mid-Mediterranean Jet
3g Southern Levantine current
4 Rhodes Gyres
5 Western Cretan cyclone
6 Western Ionian cyclonic Gyre
7 Syrte Gyre
8 Anticyclonic system of the South-eastern Levantine basin
8a Mersa-Matruh Gyre system
8b Shikmona Gyre system
9 Asia Minor current
10 Iera-Petra Gyre
11 Pelops Gyre
12 Southern Adriatic cyclonic Gyre
13 Western Adriatic Coastal Current
14 Western Ionian anticyclonic Gyre

Figure 1.1. Schematic of the surface circulation from recent observational data and model simulation. Names of structures and currents are listed (from Pinardi et al., 2005).

Stratification occurs in the water column in the eastern Mediterranean including Levantine surface water (LSW), Atlantic water (AW), Levantine intermediate water (LIW) and Levantine deep water (LDW). LSW can be identified by its warm (16 - 25 ^{o}C) and saline (38.8 - 39.4 ‰) feature. AW is characterized by low salinity (between 38.5 and 39.0 ‰) and temperature of 17 ^{o}C (Özsoy et al., 1993; Robinson and Golnaraghi, 1994). Levantine Intermediate Water is observed with 39.1 salinity and 15.5 ^{o}C temperature, throughout the year below AW (Özsoy et al., 1993; Robinson and Golnaraghi, 1994; Malanotte-Rizzoli et al., 1999). LDW is characterized by low temperature ($\leq$ 13.8 ^{o}C) and low salinity ($\leq$ 38.74 ‰). But this layer can be found in different depths in different seasons and locations (Özsoy et al., 1993; Robinson and

Golnaraghi, 1994; Herut et al., 2000). Özsoy et al. (1991) showed that LSW was found at 0 -100 m, AW at 20 -100 m, LIW at 100 - 400 and LDW below 600 - 700 meters in the Mediterranean.

Among the many gyres present in the Mediterranean. Levantine Basin is affected permanently from the cyclonic Rhodes, anticyclonic Mersa - Matruh and Shikmona gyres and by the Asia Minor Current (Robinson et al., 1991; Özsoy et al., 1993). The eastern Mediterranean is also characterized by many eddies and jets (Robinson et al., 1992). Quasi-stationary warm-core Cyprus eddy situated in the southeast of Cyprus, affects MMJ (Brenner et al., 1991; Tanaka et al., 2007).

Thickness of LSW is 50 meters in summer and it extends down to 100 m during the winter. Surface temperature starts to increase during spring while forming the LSW in the meantime. Surface waters become warmer and more saline in upper mixed layer during the summer (Hecht et al., 1988; Özsoy et al., 1989; Kress and Herut, 2001). LSW above AW remains warmer and saltier than AW (Kress and Herut, 2001). Özsoy et al. (1991; 1993) declared that small scale anticyclonic eddies are observed in the northeastern Mediterranean (Cilician basin).

1.2. The chemical oceanography of the Cilician Basin

The eastern Mediterranean is a good example for low nutrient low chlorophyll (LNLC) ecosystem (Krom et al., 1991; Ediger and Yılmaz, 1996; Yılmaz and Tuğrul, 1998; Kress and Herut, 2001; Eker-Develi 2004; Psarra et al., 2005; Yücel, 2008; Koçak et al., 2010). Krom et al., (2005) reported that the eastern Mediterranean surface waters have extremely low nutrient content. However, a contrasting highly productive coastal ecosystem supported by many rivers does exist at the northeastern corner of the eastern Mediterranean (Uysal et al., 2004, 2008; Yücel, 2008; Koçak et al., 2010). Highly productive shallow shelf waters mainly based in the Mersin and Iskenderun Bays are clearly separated from the highly oligotrophic offshore waters due to limited interaction between them. Distribution of nutrients is mainly controlled by eddies and currents in the eastern Mediterranean. Northern Levantine basin is divided hydrodynamically into three sub areas, cyclonic

Rhodes, anticyclonic Cilician basin and the transitional area between them, all displaying distinct hydrochemical characteristics (Ediger and Yılmaz, 1996).

Because of the river discharge, high nitrite+nitrate and silicate concentrations were observed to coincide with low salinity in surface shelf waters during different seasons (Uysal and Köksalan, 2006; Doğan-Sağlamtimur, 2007). The northeastern shelf waters receive the bulk discharge of nutrient rich freshwater from the Seyhan and Ceyhan rivers (Koçak et al., 2010). On the other hand, previous studies showed that very low nitrogen concentrations were measured in euphotic zone of eastern Mediterranean (out of the continental slope) (Krom et al., 1993; Tuğrul and Yılmaz, 1998; Kress and Herut, 2001; Eker-Develi, 2004; Tuğrul et al., 2010; Koçak et al., 2010).

Silicate is observed generally high in shelf waters. Also, offshore waters held high silicate concentrations (≈1.5 μM) which change according to place and depth (Uysal et al., 2008; Tuğrul et al., 2010). Higher concentrations of silicate were recorded in winter-spring transition period and the lower ones in summer. Because of the remineralization of silicate, silicate concentration in AW is higher than LSW (Kress and Herut, 2001). Surface nitrate concentrations are lower in summer and autumn than spring in the eastern Mediterranean (Yılmaz and Tuğrul, 1998; Uysal et al., 2008; Tuğrul et al., 2010). No seasonality is observed in the phosphate content of the Levantine Basin. Phosphate concentrations in the LSW and AW approach almost to the detection limit (0.02 μM) in surface waters (Yılmaz and Tuğrul, 1998; Kress and Herut, 2001; Uysal et al., 2008; Tuğrul et al., 2010). However, concentrations of nutrients increase in offshore waters, because of the lateral input from Rhodes gyre and vertical mixing in winter and spring seasons in the northeastern Mediterranean (Yılmaz and Tuğrul, 1998). In offshore waters, nutrient concentrations increase with increasing depth in the anticyclonic Cilician gyre, but, vertical distribution of nutrients showed reversed trends in cyclonic Rhodes. The nutricline was formed between 300-500 m depth below the euphotic zone in the eastern Mediterranean. On the other hand, nutricline appeared close to surface at the cyclonic Rhodes gyre (Salihoglu et al., 1990; Yilmaz et al., 1994; Yılmaz and Tuğrul, 1998; Kress and Herut, 2001).

The eastern Mediterranean has higher N/P ratios (28) than the theoretical Redfield ratio which is accepted to be around 16 for most of the oceans (Redfield et al., 1963; Yılmaz and Tuğrul, 1998; Kress and Herut, 2001; Ediger et al., 2005). N/P ratio in the LSW drops to its lowest values during summer. This ratio varies between 5 and 20 in the euphotic zone, but it reaches to maximum at the top of the nutricline. N/P ratios decrease constantly below nutricline with increasing depth (Yılmaz and Tuğrul, 1998). Kress and Herut (2001) tried to explain this as a result of seasonal stratification where transition of nutrients to upper layers is blocked. Many scientists assumed that phosphorus comes from atmosphere (Ganor and Mamane, 1982; Bergametti et al., 1992; Herut et al., 1999b). While concentration of phosphorus is increased due to atmospheric input, N/P ratios decrease in the eastern Mediterranean (Kress and Herut, 2001). On the other hand, measurements of dissolved nutrient concentrations showed opposite trends (higher N/P ratios). In ultra-oligotrophic systems, consumption of nutrients is very fast. Phosphate is utilized faster than nitrate in the surface waters in phosphorus limited system like eastern Mediterranean and concentrations of phosphate and nitrate are measured below detection limits in the surface waters in summer season after stratification (Krom et al., 2005). Biological removal time of particulate aerosols from sea surface is shorter than one week in the northwestern Mediterranean (Buat-Menard et al., 1989). Therefore these processes are supposed to determine the decrease of the N/P from winter to summer (Kress and Herut, 2001).

Biological activity and atmospheric input affect variation of nutrient composition and concentrations in the seawater (Miller et al., 2006). Due to heavy consumption of nutrients by phytoplankton during winter and spring, nutrient composition and concentrations show variability in the water column from season to season (Azov, 1986; Kimor et al., 1987; Krom et al., 1992). Nitrate is consumed rapidly in late winter and early spring while low concentrations of phosphate are present concurrently. Herut et al. (1999a) declared that phosphate can be introduced by atmospheric input into the eastern Mediterranean. But, there is an undetected phosphate signal about atmospheric input in the water column (Kress and Herut, 2001). It could be consumed rapidly by microorganisms (Buat-Menard et al., 1989).

It is widely accepted that phosphorus is the limiting nutrient in primary production for the northeastern Mediterranean (Yılmaz and Tuğrul, 1998; Krom et al., 2005;

Pitta et al., 2005; Thingstad et al., 2005). There are cases where nitrogen limits primary production in the western Mediterranean as well, (Estrada, 1996; Thingstad et al., 2005; Lagaria et al., 2010).

1.3. The biological oceanography of the Cilician Basin

The eastern Mediterranean is one of the least productive seas in the world. Primary productivity and concentrations of chlorophyll-*a* are very low (Krom et al., 1991; Ediger and Yılmaz, 1996; Kress and Herut, 2001; Eker-Develi 2004; Psarra et al., 2005; Yücel, 2008). Annual primary production was estimated between 20.3 and 110 g C m^{-2} y^{-1} in the southern Mediterranean (Dugdale and Wilkerson, 1988; Psarra et al., 2000; Moutin and Raimbault, 2002; Yılmaz, 2006). Chlorophyll concentrations were generally measured below 1 μg l^{-1} in the eastern part of the Mediterranean (Berman et al., 1986; Dowidor, 1984; Azov, 1986; Yacobi et al., 1995; Ediger and Yılmaz, 1996; Herut et al., 2000; Yılmaz, 2006; Yücel, 2008). Rate of primary production and chlorophyll concentration tend to decrease from west to east and north to south in the Mediterranean (Siokou-Frangou et al., 2010). Phytoplankton blooms appear in early winter and spring following the winter convectional mixing (Krom et al., 2003, 2005; Siokou-Frangou, 2010). Primary production is affected from the eddies and currents which control the distribution of nutrients in the eastern Mediterranean (Yılmaz and Tuğrul, 1998). Although, shelf waters receive significant amount of freshwater from the surrounding major rivers and brooks, offshore waters receive very limited input. Also, atmospheric deposition and small scale upwelling events supply a certain amount of nutrients to the oligotrophic offshore waters (Yılmaz and Tuğrul, 1998; Krom et al., 2004; Uysal et al., 2008; Koçak et al., 2010). This atmospheric dry and wet deposition support new production during the spring and autumn periods in the offshore eastern Mediterranean (Markaki et al., 2003; Herut et al., 2005). In addition, primary production and nutrient inputs are supported by regeneration in the euphotic layer in oligotrophic offshore waters (Estrada, 1996).

Actually, the Cilician basin shelf waters as well as the coastal ecosystem have been significantly altered by natural and anthropogenic changes as a result of rapid industrial growth and population explosion in the Çukurova plain region within the

last 2-3 decades. The coastal and the cyclonic areas of the Levantine Basin differ from the open waters in their biology, chemistry and physics since cyclonic areas receive relatively high nutrients from the deep water compared to the open waters and the coastal waters are completely different ecosystems. The rivers Göksu, Tarsus, Seyhan, Ceyhan, Asi and some smaller rivers constitute a large proportion off all available freshwater inputs into the entire oligotrophic eastern Mediterranean, concentrated in relatively small area of the Cilician Basin. In addition to pronounced river inputs during winter and spring, winter convectional mixing and basin wide upwelling events observed in summer also contribute greatly to the nutrient enrichment of the basins shelf waters. For this reason shelf waters are more abundant and contain much higher bacterial, cyanobacterial (*Synechococcus* spp.) and phytoplankton biomass than the oligotrophic offshore waters in the Cilician basin. In this environment, coastal / open sea interactions determine the changes in the coastal ecosystem, including eutrophication processes.

In previous studies, diatoms were reported as the most abundant group in the Cilician Basin shelf waters (Lakkis and Lakkis, 1981; Kideys et al., 1989; Eker et al., 2003; Koray, 1995; Eker and Kıdeys, 2000; Polat et al., 2000; Polat and Işık, 2002; Uysal et al., 2003; Uysal et al., 2008; Yücel, 2008). On the other hand, it is known that Mediterranean is generally dominated by small autotrophs except in front of the eutrophic rivers (Raimbault et al., 1988; Chisholm 1992; Li et al., 1993; Magazzu and Decembrini 1995; Yacobi et al., 1995; Agawin and Agusti, 1997; Ignatides, 1998; Uysal et al., 2004; Uysal, 2006; Psarra et al., 2005; Siokou-Frangou et al., 2010). Microbial carbon biomass is dominated by heterotrophic microorganisms (bacteria, heterotrophic nanoflagellates and ciliates) in upper layer of the euphotic zone (Tanaka and Rassoulzadegan, 2002; Pitta et al., 2005; Tanaka et al., 2007). Tanaka et al. (2007) found that ciliates were more abundant in the top 50 meters, but, they did not find similar patterns for bacteria and heterotrophic nanoflagellates in the euphotic zone. According to flow cytometric measurements, more than 60 % of particles at the surface waters are smaller than 2 μm which dominate chlorophyll concentration in the Mediterranean (Yacobi et al., 1995). Zohary et al., (1998) declared picoplankton as the major contributor to chlorophyll in the eastern Mediterranean. Deep chlorophyll maximum was reported between 50 and 130 m depth in the northeastern

Mediterranean (Ediger and Yılmaz, 1996; Kress and Herut, 2001; Eker-Develi, 2004; Yılmaz, 2006).

To date only few studies dealt with the bacterial production in the northeastern Mediterranean (Zoppini et al., 2008; Amalfitano et al., 2009; Zoppini et al., 2010). Previous studies focused on the western Mediterranean, the Aegean Sea, and the Levantine Basin (Zohary and Robarts, 1992; Robarts et al., 1996; Wambeke et al., 2000, 2002; Turley et al., 2000; Christaki et al., 2003; Tanaka and Rassoulzadegan, 2004). In general, the rate of the bacterial production decreases from west to east exhibiting similar trends with primary production and chlorophyll in the Mediterranean (Siokou-Frangou et al. 2010). In previous studies, the rate of bacterial production varied between 1 and 468 mg C m^{-2} d^{-1} in the western and 7 and 131 mg C m^{-2} d^{-1} in the eastern Mediterranean (Siokou-Frangou et al. 2010 and references there in).

Primary production is known to be limited mainly by phosphorus in the eastern Mediterranean (Krom et al., 1991, 1993; Thingstad and Rassoulzadegan, 1995; Yılmaz and Tuğrul, 1998; Zohary and Robarts, 1998; Ediger et al., 2005; Thingstad et al., 2005; Doğan-Sağlamtimur, 2007). According to some others, primary production is limited by N and P (Pitta et al., 2005; Thingstad et al., 2005; Zohary et al., 2005) and the bacterial production by mainly phosphorus (Siokou-Frangou et al., 2010). But, in western basin of the Mediterranean, primary production was limited by nitrogen and heterotrophic bacteria was not limited in western basin, but, N-limited in the Ionian Basin and N and P co-limited in the Levantine Basin (Tanaka et al., 2010). However, in nature, changes in type of limiting nutrient may occur within short intervals (Sala et al., 2002). For this reason, typical short term experiments may not give the truth always. In order to understand such a dynamic system satisfactorily all other ambient parameters should be simulated efficiently throughout the experiment.

Except general characteristics of the eastern Mediterranean given above, eutrophication remains as the major problem for the northeastern Mediterranean shelf waters. Parallel to increasing eutrophication, quality of the coastal waters tend to decrease in time and long lasting and intensive nuisance phytoplankton blooms

observed in bays turned out to become a threat for both the coastal pelagic and benthic ecosystems. Increased organic matter in turn leads for a gradual decrease in oxygen content of the water column during its degradation by bacteria. To protect our coastal ecosystems from such disasters in the long run, we need to understand the dynamics as well as the fate of microscopic flora in our highly sensitive basins. To achieve this goal we need to conduct more comprehensive studies on the dynamics of microbial communities both in near shore and offshore areas of the basin. Previous studies that have been carried out in the area still remain insufficient in identifying the peculiarities of microbial processes which necessitates fine resolution in time and space. Previous studies either lack the time (time series) or space (near shore and offshore) component or both. Sampling of microbial communities in relatively longer intervals (seasonal) does not fully and adequately represent a community exposing distinct short term (daily-weekly) responses. Phytoplankton forming basis of the primary food chain in oceans have direct link to bacteria in which the ratio among both is directly related to autotrophy or heterotrophy of the water mass in question. This mechanism is mainly controlled by both the efficiency and composition (quality) of the nutrient supply. Availability and quality of nutrients determine greatly the magnitude of primary production and phytoplankton species composition.

1.4. Aim of this study

This dissertation aims to define the functioning of microbial pelagic ecosystem of the Cilician Basin via trying to answer the following raised issues;

1- How does carbon assimilation by phytoplankton differ;

- in time (monthly) and space (with depth as well as in the near shore - offshore extent)
- in different phytoplankton size classes
- under varying nutrient levels

2- How does ^{3}H-leucin incorporation by bacteria differ;

- in time (monthly) and space (with depth as well as in the near shore - offshore extent)

3- Do carbon uptake and ^{3}H incorporation mimic each other or not in time and space?

4- How does phytoplankton respond to changing nutrient levels in time?

5- What is the limiting nutrient for the study area? Does it differ in time and space?

6- How do dominant phytoplankton groups change in time and with depth in the study area? (compare with other findings)

Results to be achieved in this work could guide policy makers for rehabilitation of sensitive coastal areas through serving key parameters on the response of microbial communities to changing ambient parameters.

2. MATERIAL AND METHODS

2.1. Sampling area

In this thesis study, samples were collected from four shelf stations (Figure 2.1) located in the Mersin Bay (northeastern Mediterranean). A total of 25 cruises (Table 2.1) have been realized on board R/V Bilim-2 of the Institute of Marine Sciences of Middle East Technical University to conduct in-situ incubation experiments and collect related parameters. Water samples from the surface and at various depths within the euphotic layer were collected using 5 liters capacity Nansen closing bottles attached to a rosette sampler which, as well, houses the CTD probe. Total depths of the stations were ≈ 30, 50, 200 and 210 meters at T27, BAP1, BAP3, and T48, respectively (Figure 2.1). Shallower shelf stations T27 and BAP1 are affected greately from the local rivers and BAP3 and T48 remain just beyond the shelf edge representing oligotrophic offshore waters.

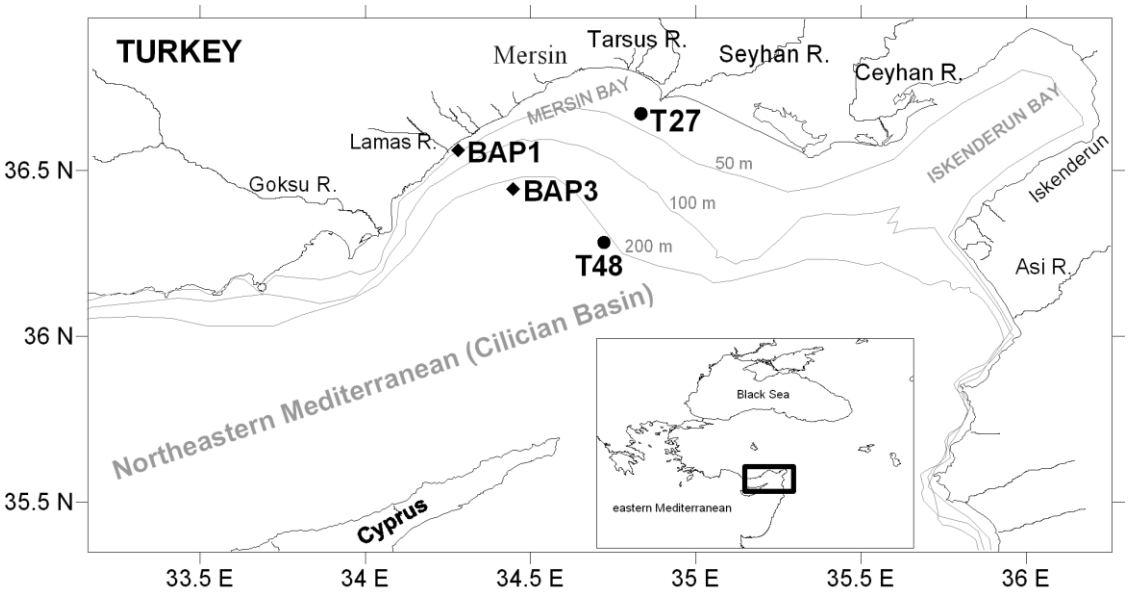


Figure 2.1. Location of the sampling stations.

2.2. Sampling Methods applied in the field

The list of marine physical, chemical and biological parameters that were collected on board ship as well as in the laboratory with associated analytical techniques applied are given below.

Table.2.1. List of parameters collected and techniques applied.

	Parameters	Units	Technique
Physical	Temperature	℃	CTD
	Salinity	psu (‰)	
	Density	sigma-theta (σ_t)	
	PAR (in water)	µEinsteins/m^2/s	
	PAR (in surface - daily)	µEinsteins/m^2/s	PAR meter
	Secchi Disc Depth	meter (m)	Secchi Disc
Chemical	Nitrite + Nitrate	µM	Auto Analyzer
	Phosphate	µM	
	Silicate	µM	
	Ammonia	µM	
	Oxygen	µM	Winkler Titration
	pH		pH Meter
Biological	Total Chlorophyll-a	µg/l	Spectrofluorometer
	Pigments	µg/l	HPLC
	Primary Production	mg C m^{-3} h^{-1}	^{14}C method
	Bacterial Production	mg C m^{-3} h^{-1}	^{3}H-Leucine method
	Bacterial Abundance	cell ml^{-1}	Epifluorescence microscope

Table.2.2. List of sampling procedure and work calendar.

Cruises		Stations				Parameters							
		T27	**T48**	**BAP1**	**BAP3**	Size fractionated Primary Production (0.2-2-5 µm)	Bacterial Production	Phytoplankton Pigments	Size fractionated Chlorophyll (0.2-2-5 µm)	Bacterial Abundance	Limiting Nutrient Experiments	Physical Parameters (CTD, PAR, SDD)	Chemical Parameters (Diss. Nutrients and Oxygen)
1	September–2008	✸	✸			✸		✸				✸	✸
2	February–2009	✸	✸			✸		✸				✸	✸
3	April–2009	✸	✸			✸		✸				✸	✸
4	August–2009	✸	✸			✸		✸				✸	✸
5	October–2009	✸	✸			✸		✸				✸	✸
6	February–2010	✸	✸			✸		✸				✸	✸
7	April–2010	✸	✸			✸		✸				✸	✸
8	May–2010			✸	✸	✸		✸	✸	✸		✸	✸
9	June–2010			✸	✸	✸		✸	✸	✸		✸	✸
10	July–2010	✸	✸	✸	✸	✸		✸	✸	✸		✸	✸
11	August–2010			✸	✸	✸		✸	✸	✸		✸	✸
12	September–2010			✸	✸	✸		✸	✸	✸		✸	✸
13	October–2010			✸	✸	✸		✸	✸	✸		✸	✸
14	November–2010	✸	✸	✸	✸	✸		✸	✸	✸		✸	✸
15	December–2010			✸	✸	✸		✸	✸	✸		✸	✸
16	January–2011			✸	✸	✸	✸	✸	✸	✸	✸	✸	✸
17	February–2011	✸	✸	✸	✸	✸	✸	✸	✸	✸	✸	✸	✸
18	March–2011			✸	✸	✸	✸	✸	✸	✸	✸	✸	✸
19	April–2011			✸	✸	✸	✸	✸	✸	✸	✸	✸	✸
20	May–2011			✸	✸	✸	✸	✸	✸	✸	✸	✸	✸
21	June–2011	✸	✸	✸	✸	✸	✸	✸	✸	✸	✸	✸	✸
22	July–2011			✸	✸	✸	✸	✸	✸	✸	✸	✸	✸
23	August–2011			✸	✸	✸	✸	✸	✸	✸	✸	✸	✸
24	September–2011			✸	✸	✸	✸	✸	✸	✸	✸	✸	✸
25	October–2011	✸	✸	✸	✸	✸	✸	✸	✸	✸	✸	✸	✸

2.2.1. Physical parameters

Among the physical parameters temperature, salinity, density, oxygen saturation, PAR (Photosynthetically Active Radiation) and fluorescence were obtained *in situ* using a Seabird model (SBE 19 plus) CTD sensor mounted on a Rosette sampler. Density (sigma-theta σ_t) is calculated from the temperature and salinity data by the software being installed. The signals are then formatted and transferred from CTD to a PC.

Daily surface PAR measurements were obtained using a QSR-2100 Scalar PAR Reference Sensor (Biospherical Instrument Inc.) with digital signal output. This device measures irradiance within 400-700 nm range using a 2pi steradian hemispherical Teflon collector. The signals were then formatted and transferred from collector to a PC at every minute interval. PAR was measured since December 2010, daily.

Water transparency (Secchi Disc Depth (SDD)) was measured with Secchi Disc around noon between 10:00 am and 14:00 pm hours.

2.2.2. Chemical parameters

Samples for nutrients (nitrate+nitrite, reactive silicate, phosphate and ammonium) and dissolved oxygen were taken parallel to biological samples from the surface and below surface at standard depths.

2.2.2.1. Nutrient analyses

Standard colorimetric methods (Strickland and Parsons, 1972) for nitrate+nitrite, reactive silicate, phosphate and ammonium were used for measuring the nutrient concentrations. Sample seawater drawn from the Nansen bottles were then stored into 100 ml high density polyethylene bottles (HDPE) which were pre-cleaned with 10 % HCl. Nitrate+nitrite, phosphate, silicate and ammonium samples were kept frozen (-20 ^{o}C) until analysis. Nutrient concentrations are measured using a SEAL model multi-channel auto-analyzer according to the procedure given in Standard Colorimetric Methods (Strickland and Parsons, 1972). Detection limits for nitrite+nitrate, phosphate,

silicate and ammonium were 0.05 μM, 0.02 μM and 0.3 μM, 0.05 μM, respectively.

2.2.2.2. Dissolved Oxygen

Prior to nutrient sampling seawater is collected into 100 ml Pyrex bottles using tygon plastic tubes to avoid formation of air bubbles. Immediately after manganese (II) chloride and alkaline potassium iodide solutions were added to the sample. Bottles were then screwed tight and shaken strongly for storage in dark for half hour. The dissolved oxygen content of samples was measured via Winkler titration method over a Metrohm 725 Oxygen Auto-Titrator Analyzer (APHA, 2005; Carpenter, 1965).

2.2.3. Biological parameters

2.2.3.1. Size Fractionated Primary Productivity

Samples for primary productivity rate measurements were taken from surface and at lower depths within the euphotic layer taking into account the incident PAR levels (at depths where 75, 50, 25, 10, 1 and 0.1 % of surface PAR levels were achieved). Experiments were consistently tried to be held around noon between 10:00 am and 14:00 pm hours. Overall, the rate measurements followed the well known in-situ ^{14}C method of Steeman-Nielsen (1952). In-situ incubations allow samples to be exposed to the natural temperatures and light levels. A 1.55 μCi ^{14}C-NaHCO3 solution was added to each bottle. Samples were incubated in 75 ml transparent polycarbonate bottles (six light bottles and one dark bottle for each depth) at collection depths for 3 hours. After incubation, the contents of each pair of light bottles were filtered over nucleopore polycarbonate filters (0.2, 2.0 and 5.0 μm pore sizes and 25 mm diameter) at a low vacuum pressure (< than 0.5 atm.) for each depth. The contents of the dark bottles were filtered through 0.2 μm pore size filters as blank. Different filter sizes were applied to designate different phytoplankton size classes namely the picoplankton (0.2-2.0 μm), nanoplankton (2.0 - 5.0 μm), and those larger than 5 μm. The filters were then placed into scintillation vials and acidified with 1 ml 0.5 N HCl. After about minimum 8 hours, scintillation cocktail was added to vials for further reading on **L**iquid **S**cintillation **C**ounter (**LSC**, Perkin Elmer – TriCarb 2810TR in IMS-METU) as three replicates.

CPM (Counts per Minute) values were converted to productivity rates per hour (µg $C.l^{-1}.h^{-1}$) using the following equation;

Primary Production (µg $C.l^{-1}.h^{-1}$) = (Rs-Rb)*W*1.05)/(R*N)

Where:

Rs = CPMs in filtered sample

Rb = CPMs in blank bottle

R = CPMs in stock solution

W = $1.90.10^{-4}$ $mgC.m^{-3}$ (DIC concentration in samples)

1.05 = correction for the lower uptake of ^{14}C compared to ^{12}C

N = hours

Depth integrated production rates (mg C m^{-2} h^{-1}) are calculated by the trapezoidal method. The production rate at the shallowest layer is assigned as a constant level and the rate at the deepest layer is assigned as 0 productions. The total production is measured by taking weighted average of individual production at respective depth intervals. The production calculated at each depth is summed up to get a total production value for the whole water column.

Daily primary production rates were calculated by using daily surface photosynthetic active radiation (PAR). In-situ incubation were realized between 10 am – 14 pm for three hours. PAR was measured and stored for each minute. Three hours integrated primary production (IPP) rates were converted to daily IPP by using the following equation;

DIPP (mg C m^{-2} d^{-1}) = IPP_{inc}* (PAR_Area_{allday} / PAR_Area_{inc})

Where:

DIPP: Daily Integrated Primary Production (mg C m^{-2} d^{-1})

IPP_{inc}: Integrated Primary Production (mg C m^{-2} $3h^{-1}$)

PAR_Area_{allday}: The Area of Photosynthetic Active Radiation for all day

PAR_Area_{inc}: The Area of Photosynthetic Active Radiation for the incubation period

2.2.3.2. Bacterial Carbon Production

Bacterial carbon production (BCP) is based on the incorporation of ^{3}H-leucine by bacteria. For extraction the micro-centrifugation method (Smith and Azam, 1992) was applied. Samples were collected parallel to those for primary productivity measurements including two extra depths (150 and 200 meters) in the offshore station. Sea water samples of 1.7 ml volume are transferred to 2 ml centrifuge vials (three replicates and one blank) from selected depths. For blank samples, 90 µl 100 % (final concentration 5 %) trichloroacetic acid (TCA) were added to kill bacteria in the vials. 10 µl of [4,5-^{3}H]-leucine whose activity is 40-60 Ci mmol^{-1} was added and then final concentration reached to 10nM . Samples were incubated *in situ* for three hours at the station. After incubation, 90 µl 100 % TCA was added to kill all bacteria. Tubes were then centrifuged for 10 minutes at 14000 g, and then the supernatant was removed by pipette. After discarding the supernatant, 2 ml of 5 % cold TCA was added, mixed with vortex and centrifuged again. The supernatant was again discarded and 1.7 ml 80 % ethanol was added, mixed and centrifuged. After centrifuging, supernatant was sucked, and 1 ml scintillation cocktail was added to vial. Samples were counted for three times at LSC. CPM values were converted to DPM (disintegrations per minute) considering quenching and efficiency.

The rate of incorporation of leucine was calculated using the following equation;

$$\mathbf{Leu_{inc}\ (nmol\ l^{-1}.h^{-1}) = DPM_{inc} * SA^{-1} * 4{,}5.10^{-4} * t^{-1} * V^{-1}}$$

Where:

$DPM_{incorporated}$ = $DPM_{sample} - DPM_{blank}$

SA = Specific activity of added leucine (Ci mmole^{-1})

$4{,}5.10^{-4}$ =nCi DPM^{-1}

t = incubation time (h)

V = Sample volume (l)

The rate of incorporation of leucine in BCP was converted to carbon by using leucine conversion factor of 3.1 kg C produced per mole of leucine incorporated (Kirchman, 1993).

2.2.3.3. Limiting Nutrient Experiment

For limiting nutrient experiment, water samples collected (from ≈2m) by Niskin bottles were transferred (by using 200 µm pore size mesh for avoiding predation on phytoplankton) to 40 L transparent polyethylene bottles from BAP-1 and BAP-3 stations. Subsamples were transferred to 5 L transparent polyethylene bottles for each set. Nutrient or nutrient combinations were added to each bottle except the control (Table 2.3). Samples were incubated 72 hours in the tank under artificial light exposure (6 bulbs with 30 Watt each) light condition. Sub-samples were taken from the bottles daily for nutrient analysis from the beginning to the end of the experiment (max 72 hours). Phytoplankton pigment concentrations were only measured at the beginning and termination of the experiment. Primary (^{14}C) and bacterial (^{3}H) production rate measurements were carried out after 48 hours. Sub-sampling was done for enumeration of heterotrophic bacteria and *Synechococcus spp.* at T0 and T72.

Table 2.3. Set of nutrients and their concentrations designed for the limiting nutrient experiment.

Bottle ID	1	2	3	4	5	6	7
Nutrient type	N	P	Si	N+P	N+P+Si+Fe+EDTA	P+F	Control
Amount added (ml) (Final concentrations in bottles (µM))	3.2	0.2	3	3.2 + 0.2	3.2+0.2+3+0.1+1.66	0.2 + 0.1	---

2.2.3.4. HPLC analyses

1 to 2.5 liters of seawater samples were taken from the Nansen bottles at selected stations. Samples were filtered over 25 mm GF/F filters at a vacuum of less than 0.5 atm and filtrates were then preserved in liquid nitrogen (-196 ^{o}C) until analysis in the laboratory. Extraction was carried out with 3 ml 90 % HPLC grade acetone under sonication (60 Hz for 1 minute). The samples kept overnight (about 12 hours) in the dark at 4^{o}C (in the refrigerator) for extraction. Samples were then centrifuged at 3500 rpm for 10 min to remove cellular debris. The method chosen in this study (Barlow et al., 1993 c.f. Yılmaz, 2006) is a modification of the reverse-phase method described in Mantoura and Llewelyn (1983, c.f. Yılmaz, 2006). Pigment analysis was done with an Agilent 1100 HPLC system using a C8 column equipped with vacuum degasser, binary pump, a UV absorbance detector and a fluorescence detector.

500 µl of the extract was filtered through 0.2µm pore size Millipore filters and mixed with 500 µl 1M ammonium acetate ion pairing solution for the measurement. Buffered extracts were injected (100 µl) into a Thermo Hypersil MOS-2 C8 column (150 x 4.6mm, 3µm particle size, 120Å pore size and 6.5% carbon loading) using an Agilent HPLC system (Quaternary pump, manual injector) having 100 µl loop. By using a binary mobile phase system, pigments were separated with linear gradient.

Mobile phases used in the gradient elution consisted of a primary eluant (A) composed of methanol and 1M ammonium acetate (80:20 v/v), and a secondary eluant (B) consisted of 100 % methanol. Pigments were then separated at a flow rate of 1 ml min^{-1} by a linear gradient programmed as follows (minutes; % solvent A; % solvent B): (0;75;25), (1;50;50), (20;30;70), (25;0;100), (32;0;100). Then, the column was reconditioned to original conditions for the following 7 minutes. Ammonium acetate was used as an ion pairing reagent, and it is recommended that it should be present in both the sample and mobile phase to improve pigment separation and suppressed dissociation of isolated compounds. Pigments were detected by absorbance at 440 nm using an Agilent variable wavelength detector (Mantoura and Llewellyn, 1983, c.f. Yılmaz, 2006).

Collection and integration of data was performed via a PC-based Chemstation Chromatography Package. The HPLC system was calibrated for each pigment with commercial standards, such as chlorophyll a, b provided by Sigma Co; chlorophyll c2,

chlorophyllc3, peridinin, 19-butanoyloxyfucoxanthin, fucoxanthin, 19-hexanoyloxyfucoxanthin, diadinoxanthin, alloxanthin, lutein, zeaxanthin, divinyl chlorophyll-a and β-carotene provided by VKI, Denmark. The detection limit for chl-a and marker pigments was about 0.005 - 0.007 µg/l. Calculation of pigment concentrations was based on the 'external standard' equation of Jeffrey et al., 1997.

Cp = (Ap x Vext x 10) / (B x Vflt x Vinj x 1000 x Rf) where;

Cp(μgL^{-1}); concentration of a particular pigment

Ap (mAU*s); peak area of the eluting pigment

Rf (ng mAU^{-1}); the slope of the calibration curve (ng $column^{-1}$)

Vfilt (l); the volume of filtered seawater

Vext (ml); the solvent used for the extraction,

Vinj (µl); the solvent injected onto the chromatographic system and

B; the buffer dilution factor.

2.2.3.5. Classification

In this study, 13 different pigments namely chlorophyll c_3 and c_2, peridinin (PER), buthanoloxyfucuxanthin (BUT), fucuxanthin (FUC), 19'hexonoloyxyfucoxanthin (HEX), diadinixanthin (DIAD), alloxanthin (ALLO), zeaxanthin (ZEA), chlorophyll-b (CHL-B), divinyl chlorophyll-a (DIV-A), lutein (LUT) and ß-carotene (B-CAR) were measured in addition to Chlorophyll-a using the chromatographic method. Seven of them are used to designate certain phytoplankton groups (Jeffrey et al., 1997) which are namely; fucoxanthin for diatoms (Barlow et al., 1993), 19'hexonoloyxyfucoxanthin for prymnesiophyceae (coccolithophorids e.g. *Emiliania huxleyi*) (Bjornland and Liaaen-Jansen, 1989; Wright and Jeffrey, 1987), peridinin for dinoflagellates, chlorophyll-b for chlorophytes, zeaxanthin for Cyanophyta, buthanoloxyfucuxanthin for Chrysophyta (Bjornland and Liaaen-Jansen, 1989) and lastly divinyl chlorophyll-a for Prochlorophyceae. The remaining are accessory pigments which are present in all phytoplankton groups (Jeffrey et al., 1997). Also,

we have tried to cluster pigments under major phytoplankton groups where ZEA+dvCHL*a* used to designate prokaryotic picoplankton i.e. cyanobacteria and prochlorophytes, FUC+PER to large eukaryotes i.e. diatoms and dinoflagellates and lastly BUT+HEX+CHL*b* to designate eukaryotic nanoflagellates composed of chrysophytes, prymnesiophytes and chlorophytes (Bidigare et al., 1990; Gibb et al., 2000).

2.2.3.6. Size-fractionated Chlorophyll *a*

Seawater samples (0.5 to 2.5 liters) were collected from stations at selected depths for fluorometric assessment of their Chl-*a* contents. Samples of seawater were then filtered over Whatman nucleopore polycarbonate filters for size fractionation (0.2, 2.0 and 5.0 µm pore sizes and 47 mm diameter) at a low vacuum (< than 0.5 atm.). The filtrates were then kept deep frozen in liquid nitrogen until analysis. The filters were then extracted with 5 ml 90% acetone solution by using ultrasonicator (60 Hz for 1 minute). Then, the volume of the extract increased up to exactly 10 ml. The samples were kept in the dark overnight (about 12 hours) at + 4 °C (in the refrigerator). Samples were then centrifuged at 3500 rpm for 10 minutes to remove cellular debris. Fluorometric analysis was done by using a Hitachi F–3000 type fluorescence spectrophotometer. Before measurement, fluorometer was set to zero with 90% acetone (blank reading), than fluorescence intensity of 2 ml extract was measured before and after acidification at 420 nm excitation and 669 nm emission wavelength. Chlorophyll a and phaeopigment concentration was calculated by the following formula given by Strickland and Parsons (1972).

$$\textbf{Chl-}a\ \textbf{(µg/L)} = \frac{F_m \times (F_o - F_a) \times V_{ext} \times K_s}{(F_m - 1) \times V_{flt}}$$

$$\textbf{Phaeo (µg/L)} = \frac{F_m \times [(F_m - F_a) - F_o] \times V_{ext} \times K_s}{(F_m - 1) \times V_{flt}}$$

Where;

F_m, acidification coefficient (F_o/F_a) for pure chl-a (usually 2,2)

F_o, reading before acidification

F_a, reading after acidification

K_s, door factor from calibration calculations (1/slope)

V_{ext}, extraction volume (ml)

V_{flt}, filtration volume (ml)

Chlorophyll-a standard obtained from Sigma was used to quantify the sample fluorescence intensities. The concentration of the standard stock solution was determined by using spectrophotometer. A minimum of five dilutions were prepared from this standard. Then, emission and excitation wavelengths are adjusted using the same standard. Before and after acidification with 2 drops of 1 N HCl fluorometer readings were recorded. The detection limit of instrument was about 0.01 µg l^{-1}. The precision was better than 7% (Relative Standard Deviation), (Yılmaz, 2006).

2.2.3.7. Heterotrophic bacteria and *Synechoccoccus* counts

For the enumeration of heterotrophic bacteria and cyanobacterium *Synechoccoccus*, 50 ml seawater samples were transferred to precleaned borosilicate dark bottles. 1.25 ml of 25% glutaraldehyde (to achieve a final concentration of 0.625%) was added to each sample to fix bacteria. Samples were then stored at room temperature in the dark. Depending on the amount required, 10 to 15 ml aliquots from each sample were filtered onto 25 mm diameter, black, polycarbonate, nuclepore membrane filters with a 0.2 µm pore-diameter (LI & WOOD, 1988; UYSAL 2000, 2001). During filtration 200 µl of acridine orange (3,6-bis dimethylamino acridine) was added to filtration funnel to stain DNA and RNA contents of the cells (Hobbie, *et al.*, 1977; Uysal, *et al.*, 2004). The filters were then mounted on glass slides using non-fluorescent immersion oil and counted using a Nikon epifluorescence microscope (EFD3) at 1000X with a filter combination of B-2A (blue excitation - DM 505, EX 450–490, BA 520) and G-1A (green excitation - DM 575, EX 546/10, BA 580)

(Uysal, 2001). Since the main light harvesting pigment of *Synechococcus* is phycoerythrin, it fluoresces orange to red when excited with green light. A minimum of 20 microscope fields were chosen at random and counted on each slide for their cell contents. Both the heterotrophic bacteria and *Synechococcus spp.* were counted on the same slides. Cell counts were transformed to cell numbers per milliliter using the formula;

$$\mathbf{N = MF \times Avg. V^{-1}}$$

Where;

MF: Multiplication factor

Avg. : Average cell number counted on all microscope fields for each slide

V: Total volume filtered (ml)

2.2.4. Statistical analysis

In order to find out any probable relationship between physical, chemical and biological parameters, Spearman rank-order correlation analysis is performed. The formula for the Spearman rank-order correlation coefficient is as follows;

$$r_s = \frac{\left[\sum (x-\bar{x})(y-\bar{y})\right]}{\sqrt{\sum (x-\bar{x}) \sum (y-\bar{y})}}$$

Where;

$\bar{x}$: mean rank of the sample from variable 1,

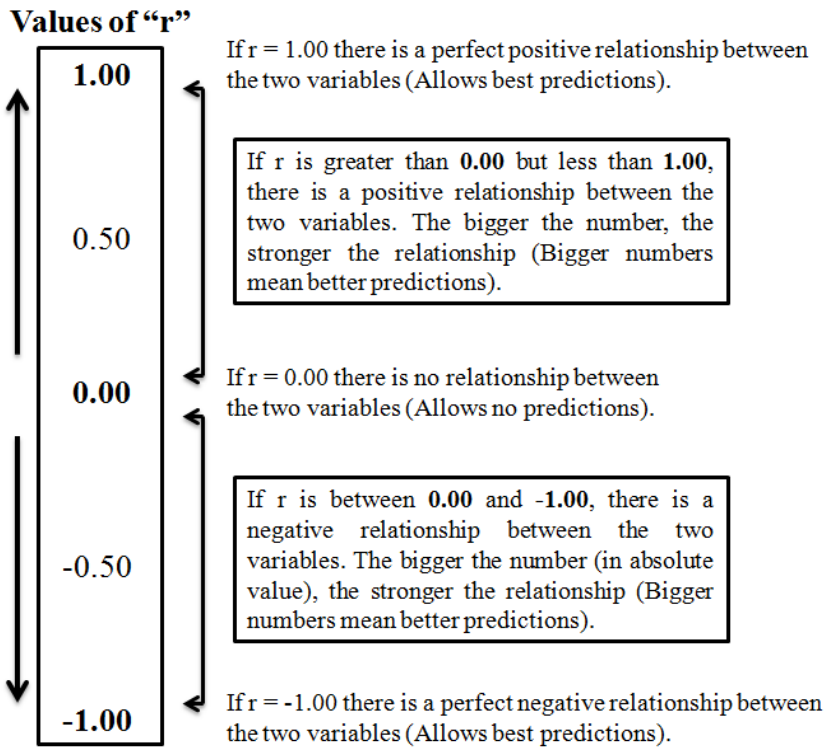
$\bar{y}$: mean rank of the sample from variable 2,

Degrees of freedom = n-2, where n = sample size.

If $r_s \geq r_s$ critical: significant result and if $r_s \leq r_s$ critical: non-significant result.

This analysis tells us whether the relationship is positive or negative and how important the relationships between variables are.

The evaluation of the value of r_s is given in the scheme below.



(From URL 2, 2008).

Correlation coefficients and p values were obtained on SPSS 15.0 for Windows.

3. RESULTS

3.1. Physical Parameters

Changes in physical parameters (temperature, salinity, density, Secchi disc depth, PAR) will be discussed separately for the east and west coast of the Mersin Bay area in this section.

3.1.1. Seasonal variations of Secchi disc depth, temperature, salinity and density in the eastern part of the Mersin Bay.

Two stations namely T27 and T48 were visited seasonally during the period between September 2008 - October 2011.

3.1.1.1. Variation in Secchi Disc Depth (SDD)

The SDD was measured around noon (10 am – 12 pm) at both stations. Only in two cases, SDD could not be measured due to high waves. SDD varied between 3 and 10.5 m (mean: 6 m) at the shallow and between 18 and 29 m (mean 23 m) at the offshore station during the study period. Highest value was observed in November 2010 at the shallow and during June-October 2011 in the deep station. Shallow coastal waters were found to be most turbid in August 2009 and the SDD was measured as to 3 m, due to increased production in the coastal waters fed by riverine input.

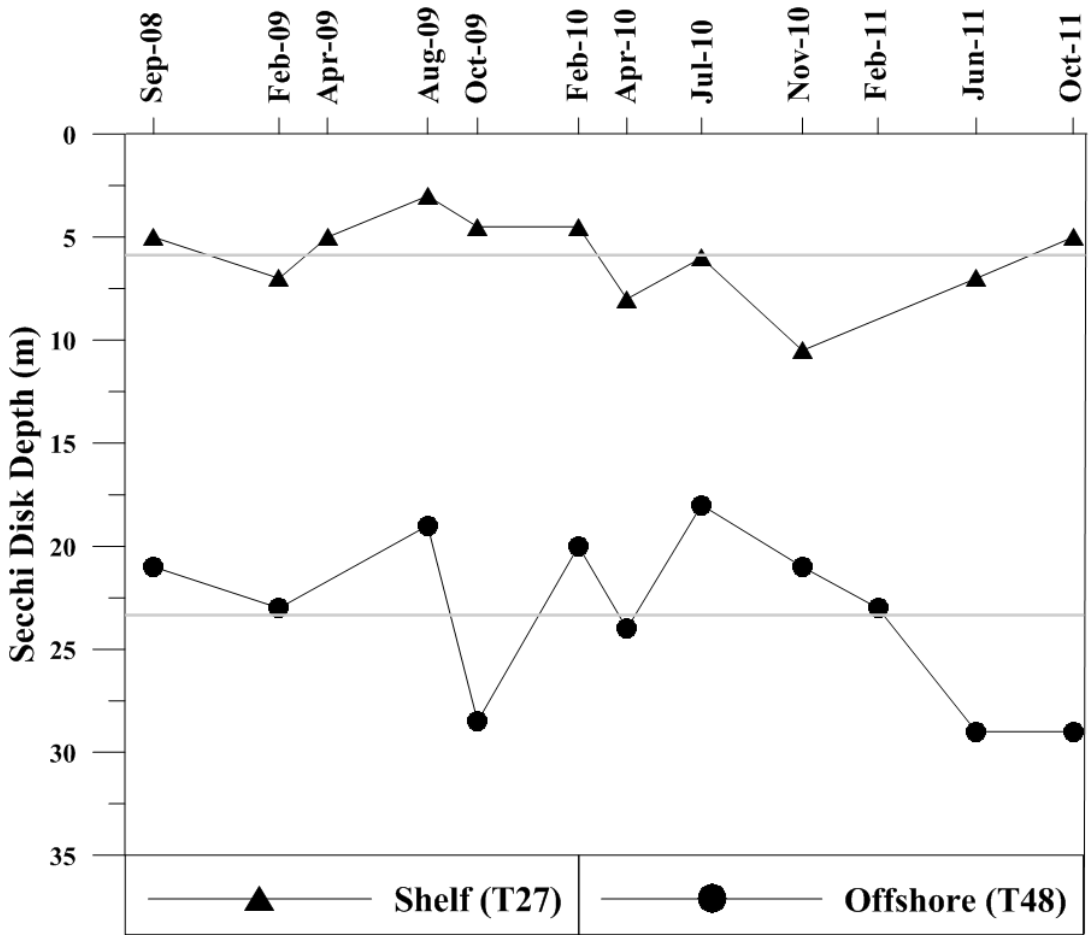


Figure 3.1. Changes in SDD at both coastal & offshore stations in the eastern Mersin Bay.

3.1.1.2. Seasonal variations in temperature, salinity and density in the eastern part of the Mersin Bay.

Seasonal temperature, salinity and density profiles are shown in Figures 3.2 and 3.3 for the shallow and deep station, respectively. Water column temperature varied between 15 and 30.1 ºC throughout the sampling period in the study area (Figures 3.2 and 3.3). Changes in temperature with depth at the shallow station were minor compared to the deep station, except the period of pronounced freshwater discharges from the nearby Seyhan River. Coastal water temperature dropped to its lowest level in February and was warmest during August-September. Similar fluctuations were observed in surface temperature and salinity in both stations. Lower salinity and

temperature were measured in February 2010 than February 2009 and February 2011 in the shallow station. Surface water temperature started to increase in April in shelf waters. Surface temperature reached to a maximum of 30.13 ºC in August 2009. Salinity rather than temperature had displayed pronounced gradients especially during winter-spring period in the shallow station. Conversely, changes in temperature with depth were most pronounced during summer at the deep station (Figure 3.3). Surface salinity decreased as low as to 38.76 in offshore waters in February 2010. Seasonal thermocline & halocline were observed at around 50 m in offshore waters. Salinity varied in the range 36.53 - 39.68 in the nearshore and in the range 38.39 – 39.99 in the offshore station throughout the study period, respectively (Figures 3.2, 3.3). Marked decreases in surface salinity were observed near river outlets during the rainy seasons (Figure 3.2). Salinity at near surface waters marked peak levels in late summer early autumn when the surface waters became hottest (Figures 3.2, 3.3). Shelf waters became thoroughly mixed during winter and early spring. Invasion of surface waters with nearby Seyhan River is clearly seen in Figure 3.2.

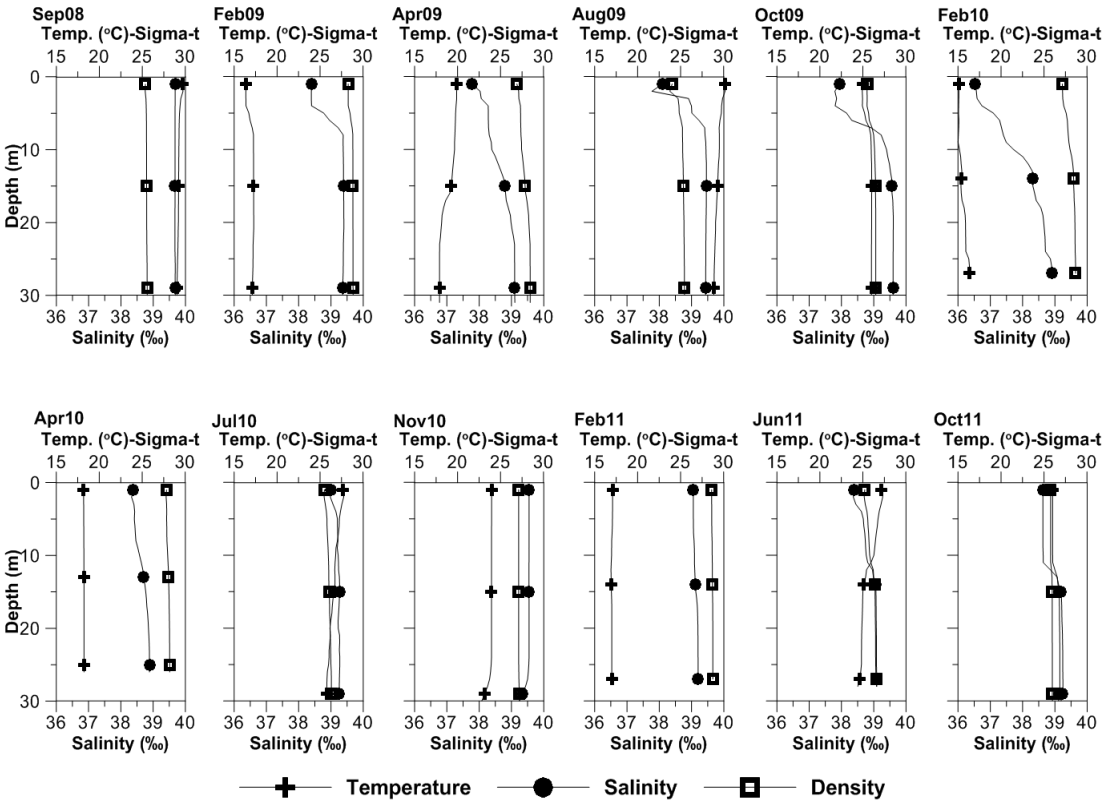


Figure 3.2. Temperature, salinity and density profiles for the shallow station T27 in the east side of the Mersin Bay.

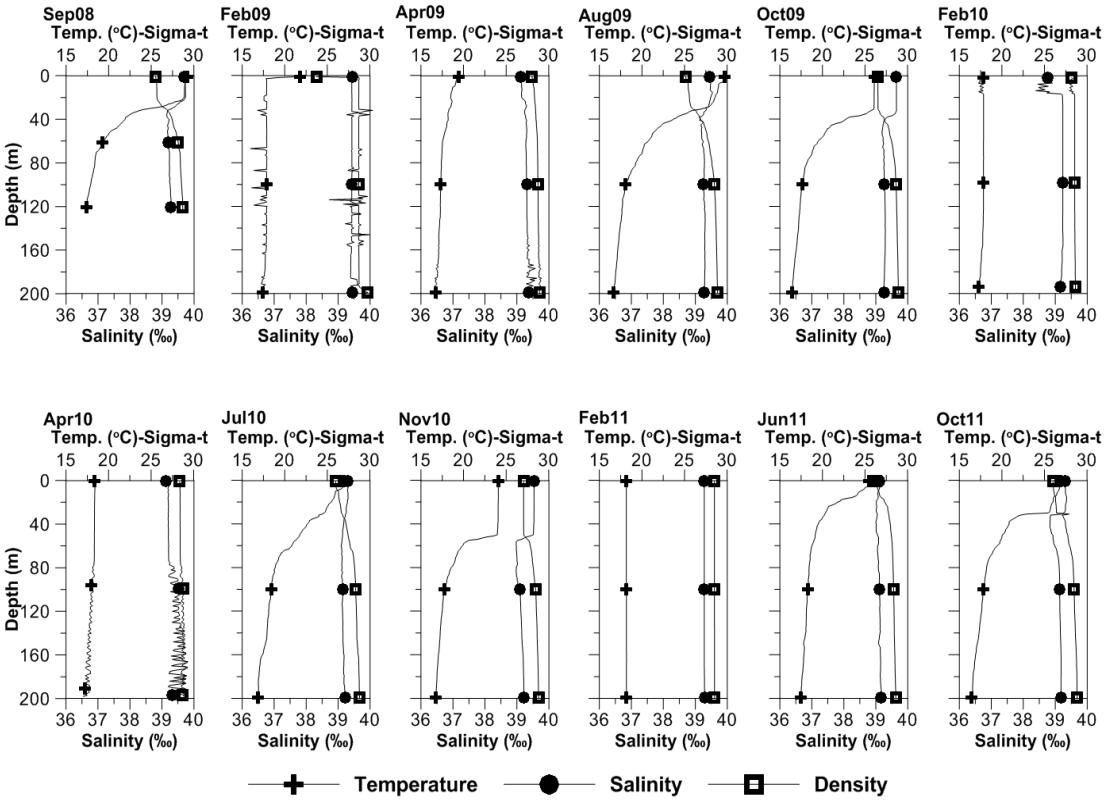


Figure 3.3. Temperature, salinity and density profiles for the deep station T48 in the east site of the Mersin Bay.

3.1.2. Monthly variations in Secchi disc depth, temperature, salinity and density in the western part of the Mersin Bay.

Western stations BAP1 and BAP3 were visited monthly from May 2010 to October 2011. Monthly variations of physical parameters are presented in this section.

3.1.2.1. Variation in Secchi Disc Depth (SDD)

Secchi disc depth (SDD) measurements were performed during midday between 11 am and 13 pm at both stations. SDD could not be measured during February 2011 due to high waves. The mean SDD was 10.5 and 26 m in the shallow coastal and offshore deep station, respectively. SDD varied between 3 and 20 m at the shelf and 15 and 34 m at the offshore station throughout the sampling period. To a highest value was reached during September 2010 in the shallow shelf station and during July 2011 in the deep station. Water transparency was lowest during March 2011 at both stations. Lamas River carries considerable amount of particulate matter and

nutrients to the coast in the west (Doğan-Sağlamtimur, 2007) which in turn block the available light and limit transparency.

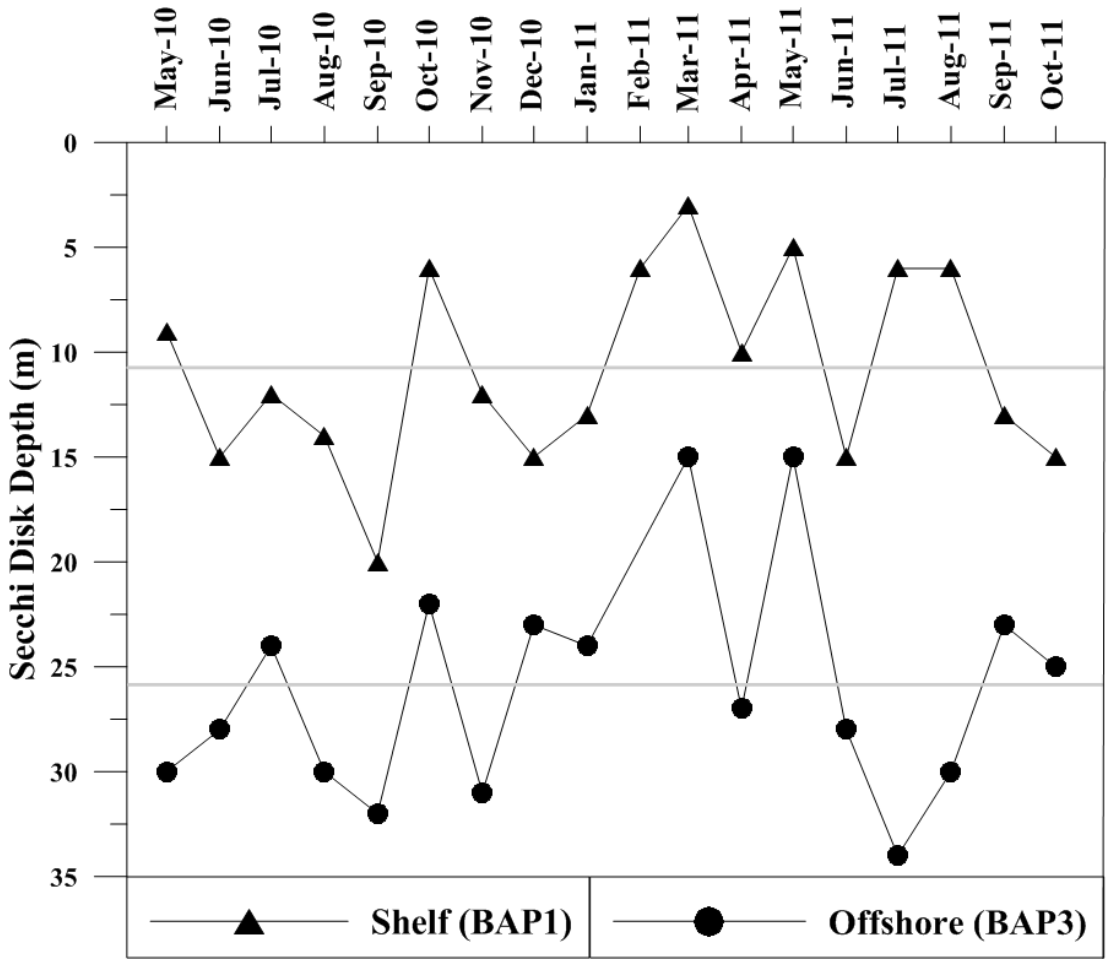


Figure 3.4. Changes in SDD at both coastal and offhore stations in the western Mersin Bay.

3.1.2.2. Monthly variations in temperature, salinity and density in western Mersin Bay.

Temperature, salinity and density profiles for the period 2010-2011 are given in Figures 3.5 and 3.6. Over the year, water column temperature varied in the range 16.63 – 30.23 ^{o}C in the shallow BAP1 and in the range 16.10 and 30.32 ^{o}C in the offshore BAP3 station. Similar fluctuations were observed in surface temperature at both stations. On the other hand, surface salinity was found highly variable in shelf

stations. Temperature did not change significantly with depth in coastal waters except during summer 2011. In July 2011, sharp changes in temperature and salinity were observed at around 36 m in the shallow station and colder water occupied the near bottom waters (Figure 3.5). Surface water was coldest during February 2011 at the top 7 meters, and during March 2011 at near surface waters below 7 m in the shallow station whereas to a maximum was reached during September 2010 at this station. Surface water was coldest in February 2011 and warmest in August 2010 in the offshore BAP3 station. Temperature and salinity profiles displayed vertically uniform features from the surface to the bottom due to winter convectional mixing during winter. With the onset of spring, a gradual warming of the surface waters was observed. With increasing irradiance, the surface waters started to warm up and the temperature gradient became much thicker during late spring & summer period. Surface temperature reached its maximum level of 30.32 ºC in August 2010. In September, a well defined surface mixed layer was observed at the top 45 meters (Figure 3.6). Underneath takes place the thermocline to a depth of approximately 60 m. Surface mixed layer became thicker with further cooling and convectional mixing throughout autumn and early winter yielding a much thinner and a deeper thermocline below it. Water column became thoroughly mixed during the period January to March.

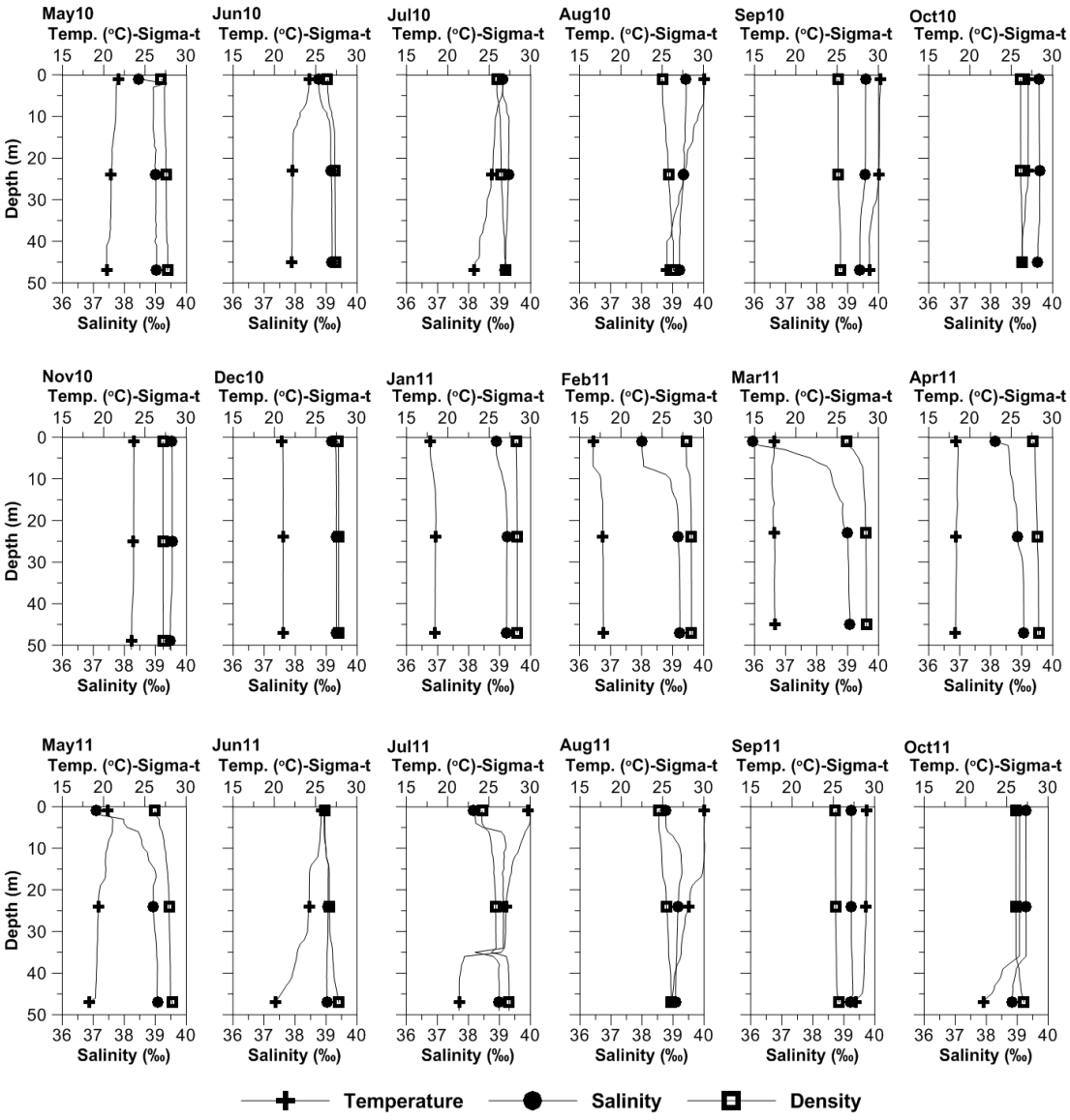


Figure 3.5. Temperature, salinity and density profiles for the shallow station BAP1 in the west site of the Mersin Bay.

Coastal shelf waters were highly affected from the freshwater discharge by Lamas river throughout the rainy season (winter and spring) (Figure 3.5-3.6). Salinity varied in the range 35.9 and 39.6 in the shallow BAP1 and 37.4 and 39.6 in the deeper part of BAP3 station (Figure 3.5 - 3.6). Surface salinity decreased significantly during the rainy season (Figure 3.5); minimal levels were recorded in March 2011. Salinity reached peak levels during September 2010 in offshore waters (Figure 3.5-3.6). Because of extensive evaporation throughout late spring and summer, surface salinity

in offshore waters tend to increase with increasing temperature until October (Figure 3.6). Formation of a weak halocline was observed during both consecutive years.

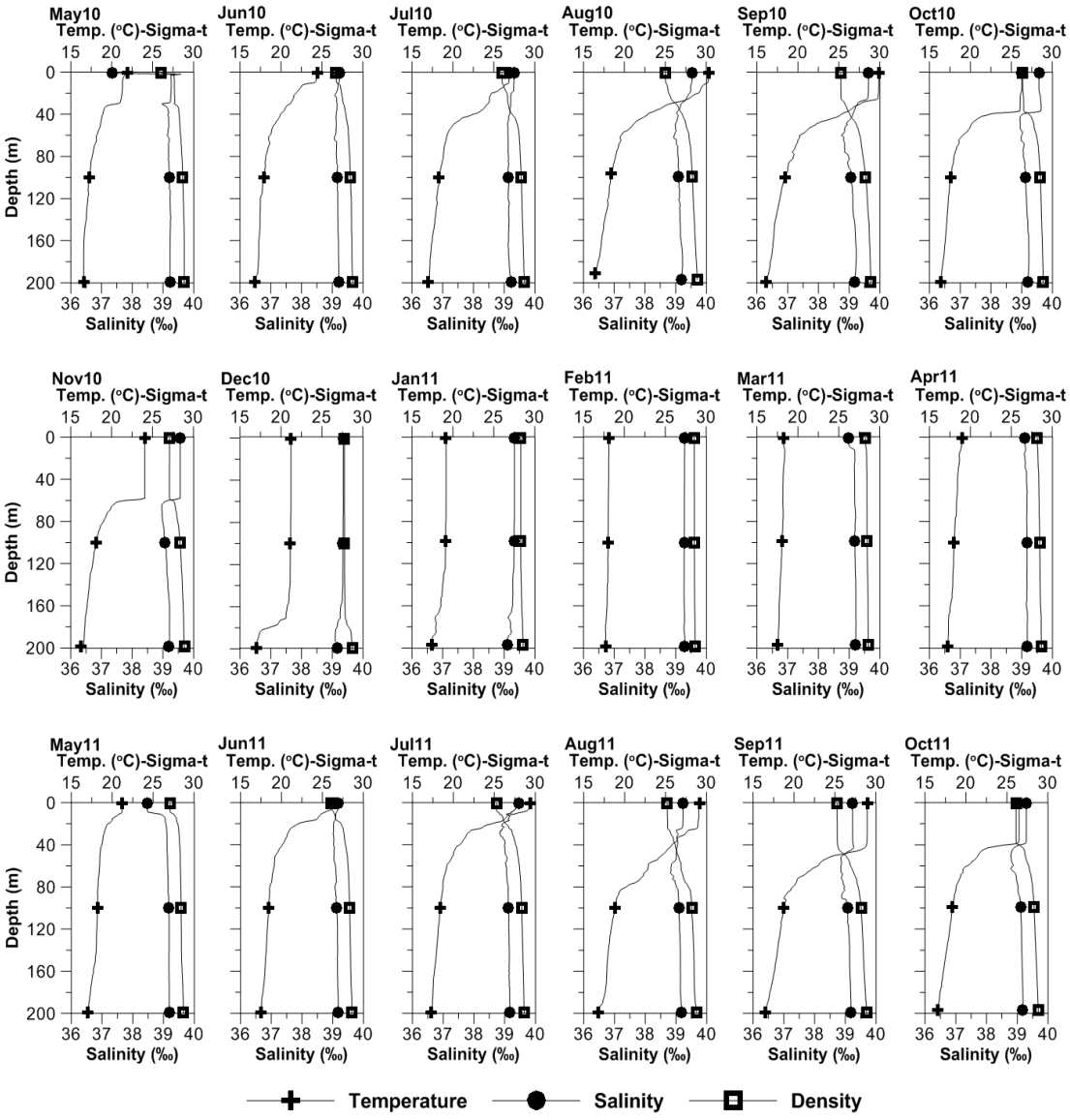


Figure 3.6. Temperature, salinity and density profiles for the deep station BAP3 in the west site of the Mersin Bay.

3.1.3. Short and long term changes in Photosynthetically Active Radiation (PAR) in west coast of Mersin Bay.

PAR has been measured since December 2010 in IMS-METU. Daily and monthly mean levels will be presented in this section. Daily surface PAR levels varied from a low level of 500 µEinsteins/m^2/s during December 2011 to a high level 2710 µEinsteins/m^2/s in June 2011 throughout the study period. Significant impacts of clouds were also observed time to time during daily and long term observations (Figures 3.7 - 3.8). Such cases are also true for the *in situ* incubation periods mostly undertaken during the winter.

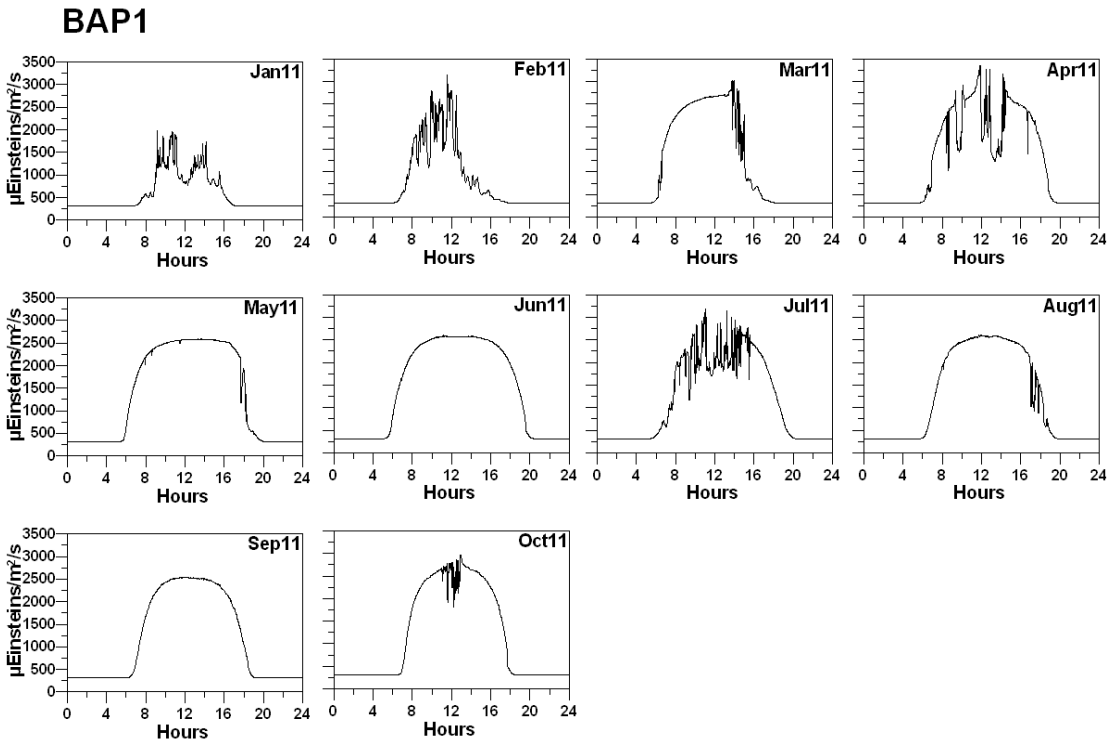


Figure 3.7. Changes in PAR levels during *in situ* incubations performed at station BAP1.

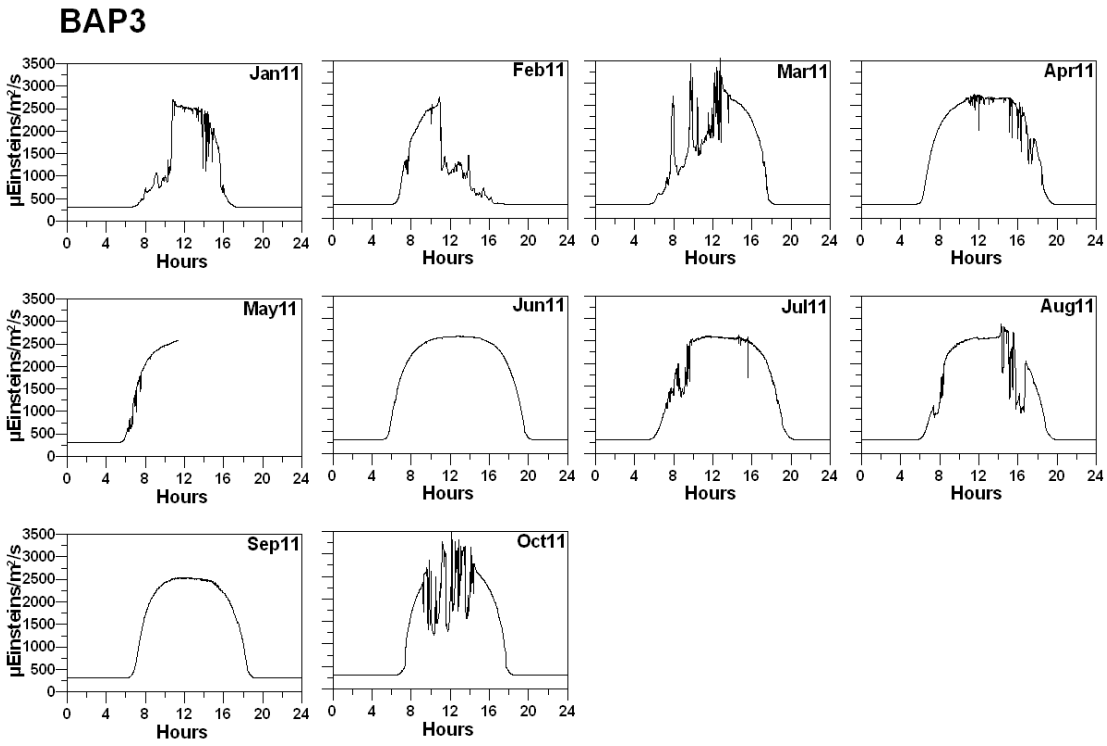


Figure 3.8. Changes in PAR levels during *in situ* incubations performed at station BAP3.

Monthly mean PAR values are given in Figure 3.9. It is clearly evident from the plots that light is more available during summer (almost 2.1 times higher) than winter in the region. Low levels were mostly retained during late autumn and early winter. Highest mean level was reached in June 2011 and conversely a minimum was observed during December 2011. Seasonal mean PAR values were almost the same in spring and autumn in the study area.

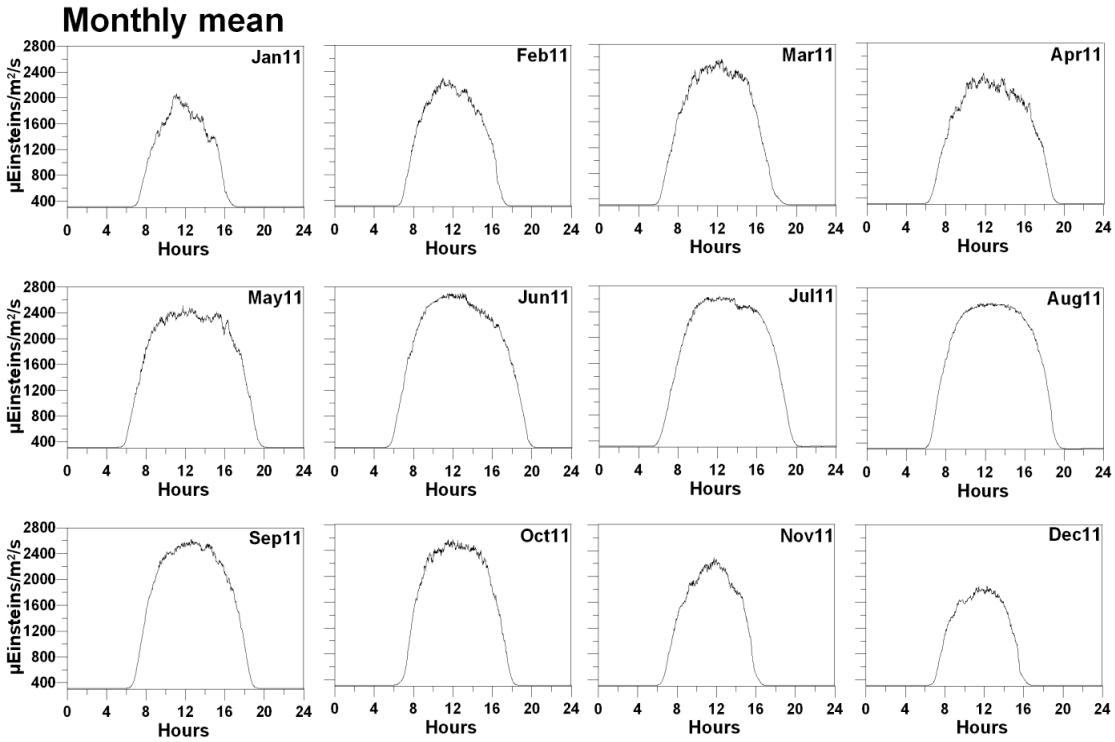


Figure 3.9. Distribution of monthly mean PAR values in 2011 in western Mersin Bay.

3.2. Chemical Parameters

Changes in chemical parameters (nitrite+nitrate, silicate, phosphate and dissolved oxygen) at surface and in the water column is presented in this section for the eastern and western coast of Mersin Bay.

3.2.1. Seasonal changes in nitrite-nitrate, silicate and phosphate concentrations in the east coast of Mersin Bay.

Nitrite+nitrate concentration varied in the range 0.06 – 10.22 µM with an average concentration of 0.96 µM at the coastal station (T27). To maximum concentrations were reached near Seyhan River at surface during February 2010 (Figure 3.10). Minimum concentrations were observed in July 2010 and June 2011. Mean surface nitrite+nitrate concentrations were calculated as 1.77 and 0.15 µM for the shelf and offshore, respectively. Shelf waters hold 12 times higher nitrite+nitrate concentrations than offshore waters. Coastal areas fed by direct river inputs had relatively much higher nutrient concentrations. Nitrite+nitrate content of the water

column decreased with increasing depth in the shelf waters (Figure 3.10.). In the shelf, higher concentrations were measured at top 5 meters in February 2009. Then, it decreased quickly with depth. Very low values were observed in summer and early autumn in coastal waters. Concentrations started to increase in rainy seasons (late autumn, winter and spring).

Similar to nitrate+nitrite, silicate concentrations varied in a broader range (0.43 - 11.14 μM) in shelf waters (Figure 3.10). The mean concentration at station T27 for the study period was 2.20 μM. Maximum concentration was again measured in February 2010 at this station (Figure 3.10). The average silicate concentration was 3.43 μM at the surface of the shelf station. Higher concentrations of silicate were measured in August, October 2009 and February 2010. Coastal areas seemed to hold relatively higher concentrations compared to offshore waters. Trends in silicate almost mimicked that of nitrite+nitrate in shelf waters (Figure 3.10). Higher concentrations were observed at top ten meters. Small increases in silicate concentration were measured near bottom.

Phosphate concentration varied at a much narrower range between 0.02 - 0.13 μM with a mean level of 0.05 μM in the area (Figure 3.10). Concentrations remained generally below 0.06 μM. Higher phosphate concentrations were measured in shallow coastal waters, ranging between 0.02 - 0.13 μM. The offshore values varied slightly between 0.02 - 0.07 μM.

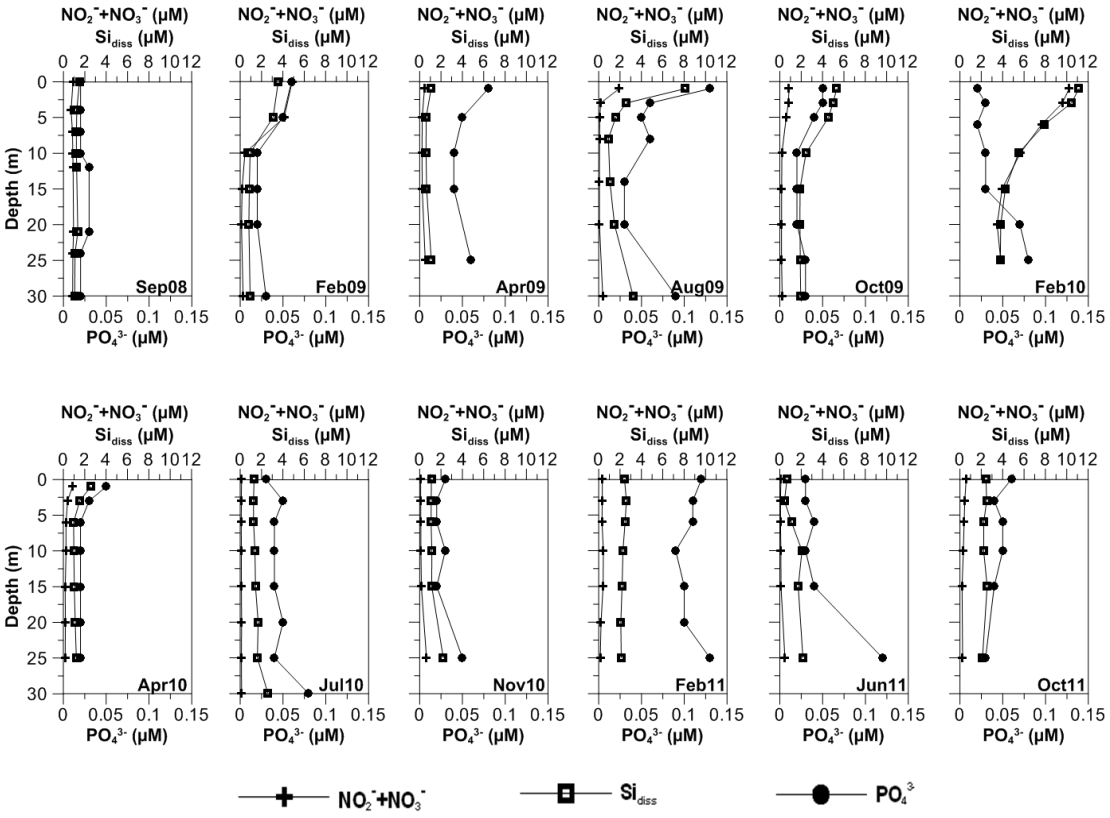


Figure 3.10. Nutrient profiles at station T27.

In the offshore station T48, nitrite+nitrate concentrations varied in a much narrower range (0.05 – 2.06 µM) with an average concentration of 0.34 µM compared to the shallow coastal station (0.96 µM). In contrast to shallow areas, higher concentrations were retained at near bottom waters whereas the deep maximum concentration was seen in October 2009 (Figure 3.11). Surface minimum was observed in June 2011. Nitrite+nitrate concentrations tend to increase below 100 m (euphotic zone) in nutrient poor offshore waters (Figure 3.11). Annual mean of the surface nitrite+nitrate was 0.15 µM in offshore waters during the study period. Minimum water column mean concentration was seen in February 2009 (0.11 µM), but, surface nitrite+nitrate increased from 0.11 in February 2009 to 0.99 µM in October 2011. Concentrations were very low at top 80 meters and mean of the top 80 meters dropped to 0.16 µM.

Offshore silicate concentrations increased from 0.25 µM to 2.64 µM near bottom (Figure 3.11) Maximum concentrations were measured in April 09 (Figure 3.11). In

parallel to other nutrients, silicate concentrations tend to increase with increasing depth. Silicate profiles mimicked those of nitrate+nitrite in offshore waters (Figure 3.11). The lowest values were seen in October 2011 (0.35 μM). The mean concentration of Si in the top 75 meters was 0.95 μM. Surface concentrations displayed a decreasing trend after July 2010. The near bottom Si concentrations varied between 0.85 – 2.64 μM during the study period (Figure 3.11).

Phosphate concentration varied in a low range of 0.02 - 0.07 μM with an average value of 0.03 μM at station T48 (Figure 3.11). Water column concentrations varied slightly between 0.02 and 0.03 μM. Surface mean value was 0.03 μM. Offshore surface phosphate concentration remained almost constant from August 2009 till June 2011. No detectable increase with depth was observed in the water column where Si&nitrate displayed apparent increasing trend.

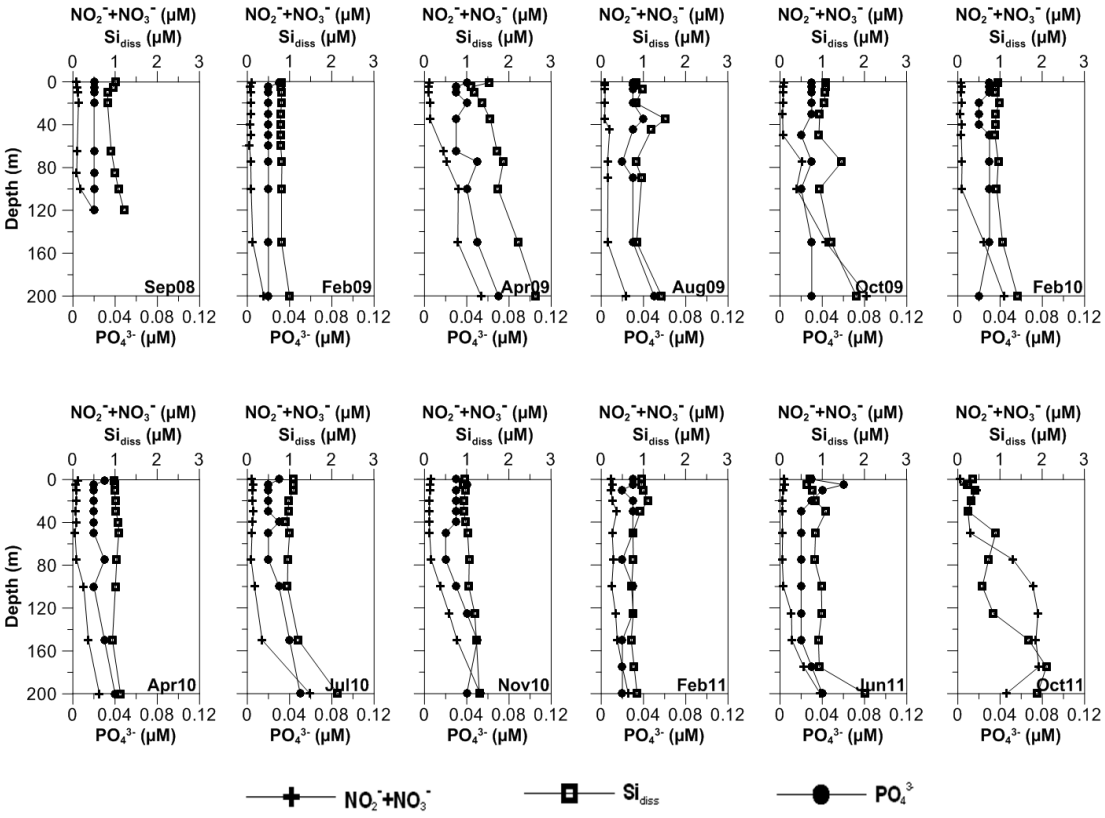


Figure 3.11. Nutrient profiles at station T48.

N/P (TIN/DRP) molar ratios exceeded 16for the period September 2008, February 2009-2010, October 2009-2010 and April 2010 in the shallow shelf station (Figure 3.12.) whereas to a maximum ratio of 519 was retained during February 2010. Low N/P ratios were observed in the remaining period. N/Si (TIN/Si) ratios were generally below 1.1 in the shallow coastal station. In offshore waters, N/P and N/Si ratios were observed below 16 and 1.1, respectively. N/P and N/Si values increased with depth in the offshore station. N/Si ratios approached to 1.1 in deeper layers in the offshore station (Figure 3.12.). The highest N/P ratio was estimated 75 near bottom in offshore waters in October 2009.

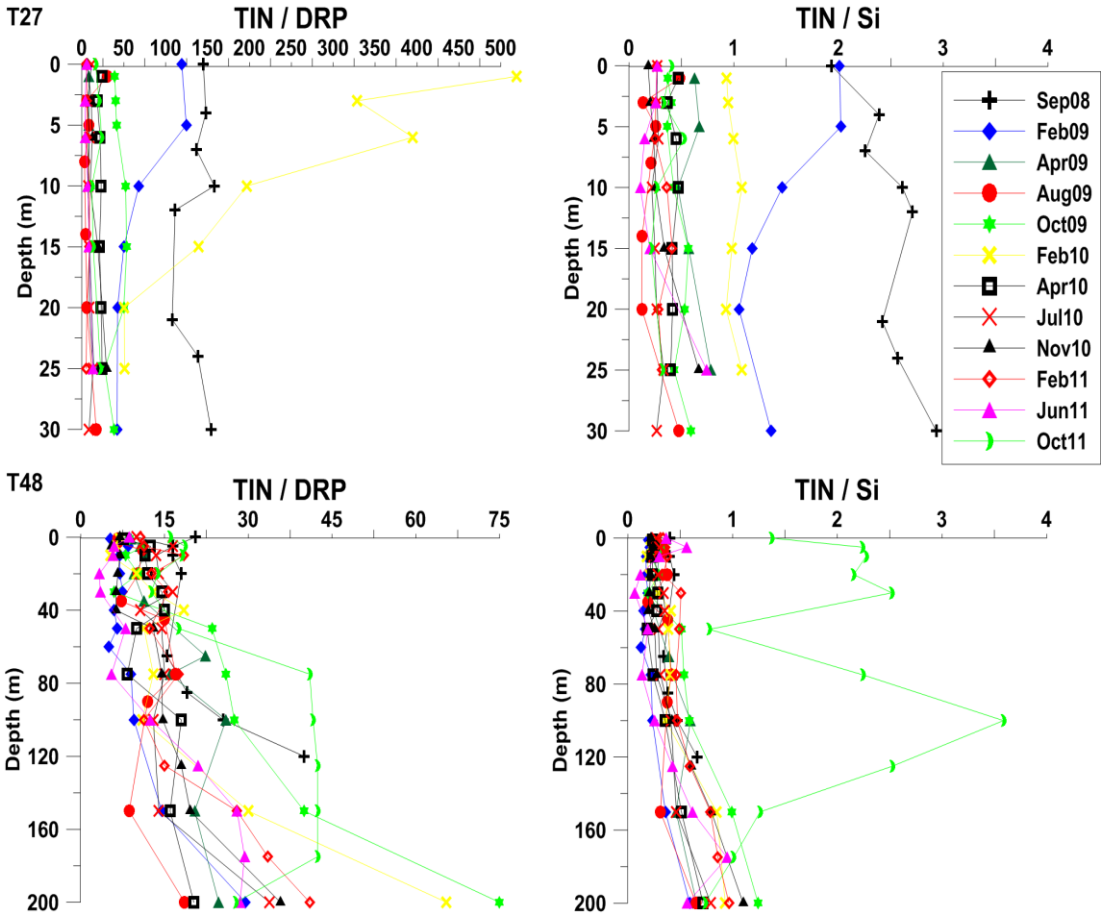


Figure 3.12. Changes in TIN/DRP and TIN/Si ratios with depth at stations T27 and T48.

DO concentration varied seasonally between 180 and 270 µM at the shelf and 178 and 246 µM at the offshore station during the sampling period (Figure 3.13). Highest values were measured in February 2010 at the shallow shelf station and in November 2011 at the offshore station (Figure 3.13). The lowest DO concentration was recorded in the east coast of the Mersin Bay during August 2009. It is clearly seen from the results that higher phytoplankton biomass production in winter and spring result in increases of DO in the colder shelf and offshore waters. Oxygen concentrations decreased with increasing temperature in the surface layer. In offshore waters, a subsurface peak of DO was observed at around 40-80 m depth range during summer and autumn (Figure 3.13).

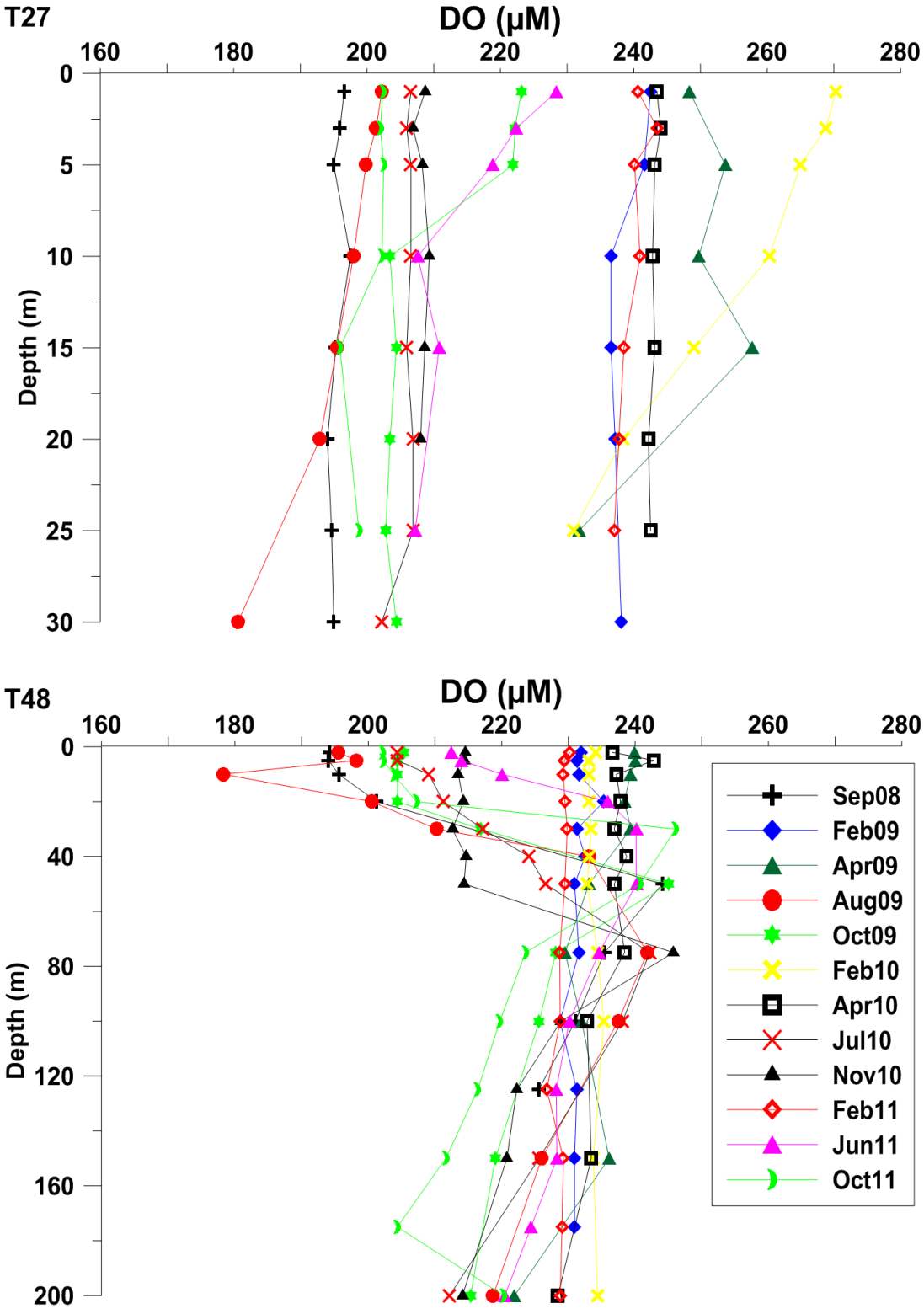


Figure 3.13. Dissolved oxygen profiles obtained at stations T27 and T48.

3.2.2. Monthly changes in nitrite-nitrate, silicate and phosphate concentrations in west coast of Mersin Bay.

BAP1 and BAP3 stations have been visited monthly from May 2010 to October 2011 in east side of the Mersin Bay. Nitrite+nitrate concentrations varied in the range 0.05 – 11.56 μM with an average concentration of 0.50 μM for coastal waters. Surface maximum was observed near Lamas River during March 2011 (Figure 3.14). In general, nitrite+nitrate concentrations remained below 0.3 μM in the shelf area which has close contact with the nearby Lamas River. Concentrations tend to increase from November to March with a rapid decline afterwards (Figure 3.14). Minimum concentrations were measured during summer and early autumn towards the end of the sampling period. High concentrations were measured during late winter and early spring. Except winter, low nitrite+nitrate concentrations were observed for the rest of the year. Comparison of consecutive periods such as the period May – October 2010 with May – October 2011 indicate much higher levels during the former. Both the highest and lowest values were measured in February 2011. In general, areas under the influence of river discharges held much higher concentrations compared to offshore waters. Nitrite+nitrate concentrations decreased with depth in the shelf (Figure 3.14.). Mean nitrite+nitrate concentration was 1.19 μM at surface and 0.28 μM near bottom. Surface mean concentration was about 5 times higher than the near bottom mean concentration. High concentration was also measured in July 2011. Monthly fluctuations were observed in the water column mean values of the shelf during summer and autumn.

Silicate concentrations varied from a low level of 0.22 to a high level of 4.27 μM in the shallow shelf station (Figure 3.14) with an average concentration of 1.26 μM. Highest concentration was recorded during February 2011 at surface (Figure 3.14). Minimum concentrations were measured during May and June 2011. Silicate concentrations increased in January and February 2011 then started to decrease in the following months at top 10 meters in the shelf. Higher concentrations were observed below 20 meters during August 2010. Second peak was observed at 20 meters in July 2011. Fluctuations in silicate were more pronounced during 2011 than 2010. In addition, high concentrations were also observed in July and August 2011 (Figure

3.14). Mean annual concentration was calculated as 1.31 for surface and 1.43 for near bottom.

Phosphate concentrations ranged between 0.02 - 0.08 μM in the shelf (Figure 3.14). The average of shelf station for the study period was 0.04 μM with a major peak in July 2011 (Figure 3.14.). In general concentrations stayed below 0.06 μM. Low values were measured in May 2010 and April 2011. In January 2011, phosphate displayed similar trends with nitrite+nitrate and silicate during which surface high followed by an abrupt decline in the shelf (Figure 3.14). Initial highs observed during summer and autumn ended up with low concentrations towards the termination of these periods. Average concentration for the spring was found lower compared to rest of the seasons. Phosphate mean concentration was also found high in September 2011 in the water column (Figure 3.14).

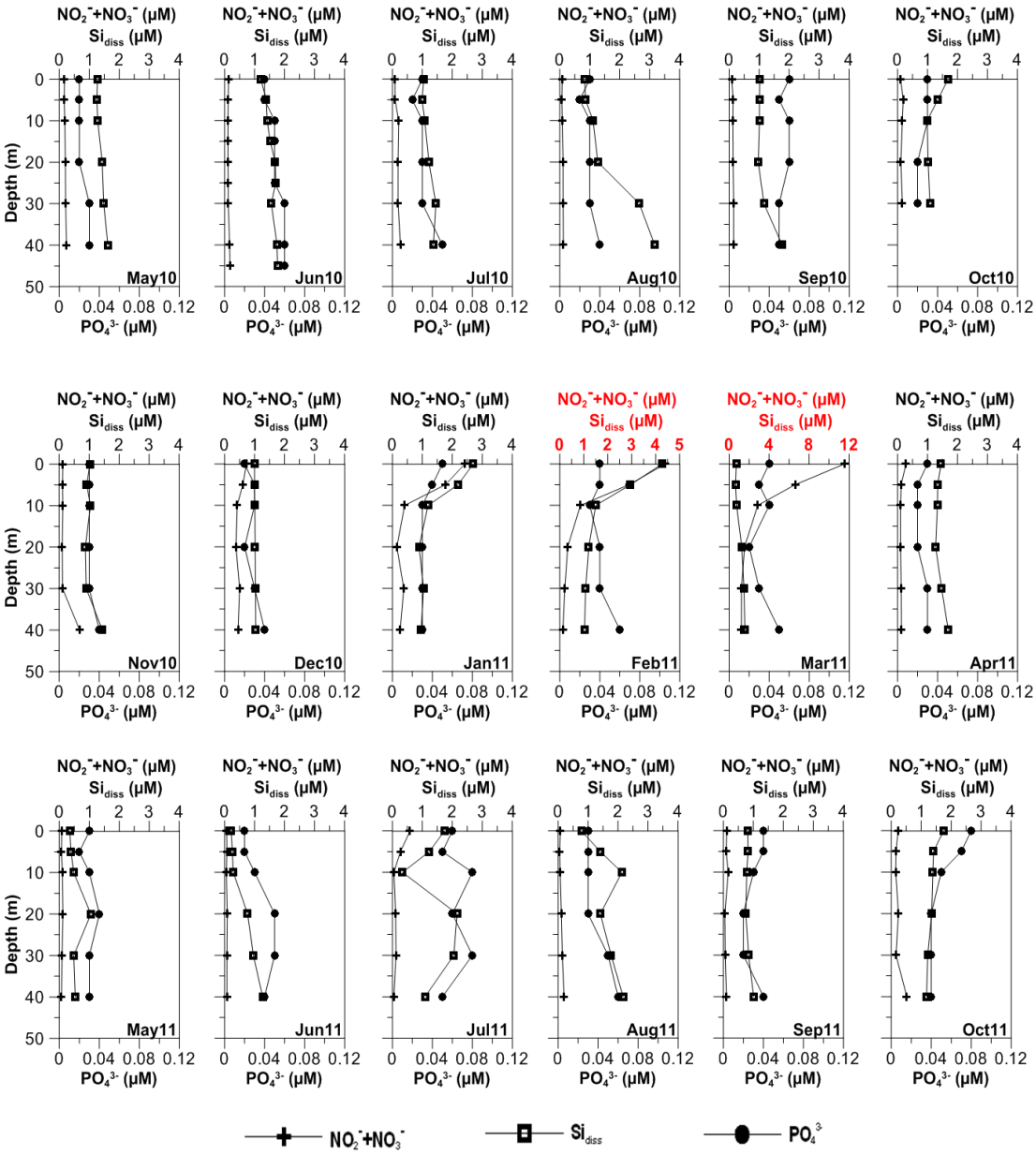


Figure 3.14. Nutrient profiles at station BAP1.

Nitrite+nitrate concentration varied in the range of 0.05 – 3.06 μM with an average concentration of 0.38 μM in the offshore station BAP3. Maximum concentration was observed near bottom during September 2010 (Figure 3.15). In general, nitrite+nitrate concentrations remained at low levels below 0.2 μM at the top 100 meters followed by an apparent increase below it. Much higher concentrations were observed during March 2011 in the water column. Higher concentrations were measured near bottom during late summer and autumn (Figure 3.15). A homogenous profile was recorded during December 2010. Average concentration was higher during the first year (May 2010 – October 2010) than the second year (May 2011 – October 2011) (Figure 3.15). Additional subpeaks were observed in the water column during October 2010 and March 2011 in offshore waters. Fluctuations were observed in surface waters during the study period (Figure 3.15).

Silicate concentrations varied from a low level of 0.14 to a high level of 2.69 μM with an average concentration of 1.02 μM in the offshore station (Figure 3.15). To a highest concentration was met at near bottom depths during September 2010 (Figure 3.15). Minimum concentrations were measured during October 2011. Similar to nitrate-nitrite, average silicate concentration was higher during the first year (Figure 3.15). Low concentrations observed in offshore surface waters during May 11 followed by higher ones at depths. Mean surface concentration decreased continuously from May 2010 to October 2011. Average concentrations were higher in summer compared to the rest of the sampling period. In spring, concentrations increased below 80 meters, implying intense uptake by phytoplankton above it (Figure 3.15).

Phosphate concentration ranged between 0.02 - 0.07 μM in the offshore (Figure 3.15) with highs observed during July & September 2011. The average concentration for the study period was 0.03 μM. Water column averages clearly indicated a winter maxima with much higher contents near bottom. Except January and August 2011 phosphate concentrations oscillated near detection limits (Figure 3.15.). Mean water column concentrations was 0.042 in January 2011.

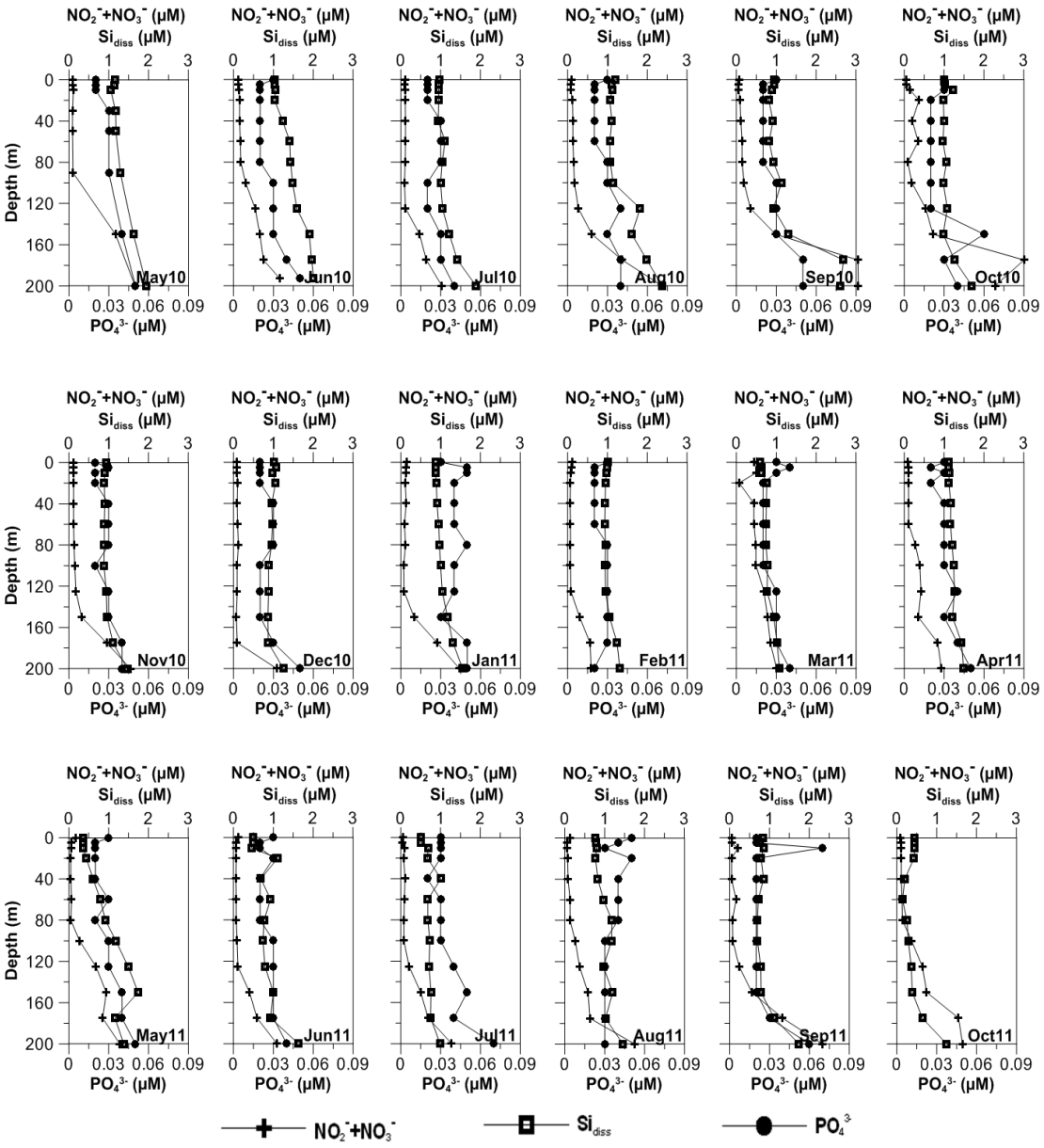


Figure 3.15. Nutrient profiles at station BAP3.

N/P (TIN/DRP) ratios were generally higher than 16 from November to April in the shelf station (Figure 3.16.). In March 2011, it reached to a peak value of 298 at surface. On the other hand, lower N/P ratios were observed from May to October. Average N/P ratio was calculated as 15.3 (except March) for the shelf. A sudden drop in the ratio was observed following March 2011 in shelf waters. N/Si (TIN/Si) ratios were generally below 1.1 at the shelf station. The highest value (16.6) was recorded in March 2011. In offshore waters, N/P ratios were found below 16 in the top 80 meters, and then increased with depth (Figure 3.16.). The highest value (106)

was calculated in October 2010 (175m). N/Si ratios were generally observed below 0.5 in offshore waters. N/Si values increased with depth in the offshore station. N/Si ratios approached to 1.1 at lower depths at the offshore station (Figure 3.16.).

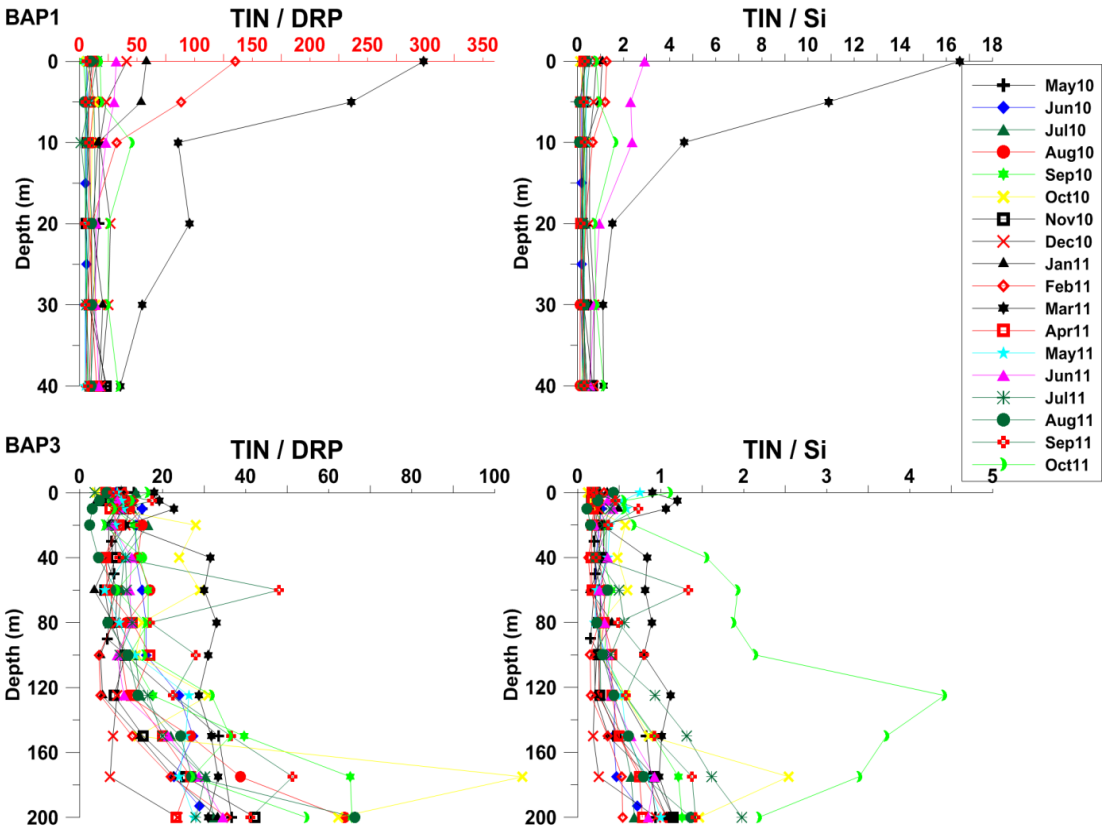


Figure 3.16. Changes in TIN/DRP and TIN/Si ratios with depth at stations BAP1 and BAP3.

The mean dissolved oxygen (DO) was 219 and 224 µM in shelf and offshore water column respectively. DO varied between 185 and 350 µM at the shelf and 194 and 253 µM at the offshore station during the sampling time (Figure 3.17). Highest DO contents were measured in March 2011 at both stations (Figure 3.17). Coversely, the lowest DO concentration was observed in September. Very low DO concentrations were measured in August 2011 in offshore deep waters (150-200 m). Concentrations peaked in March 2011 in the shelf at top ten meters. Apart from this, changes in DO content of the shallow station with depth were negligible for most of the sampling period. DO content of offshore surface waters started to decrease from March to September, and then started to increase again till next March. In summer and

autumn, offshore surface waters had low DO concentrations (mean was 223 and 218 μM, respectively), but, reached a maximum in midway (between 40 – 80 m), then decreased towards the bottom again (Figure 3.17). Due to winter convectional mixing DO was distributed homogenously in the water column down tom 150 meters during December 2010 and January 2011.

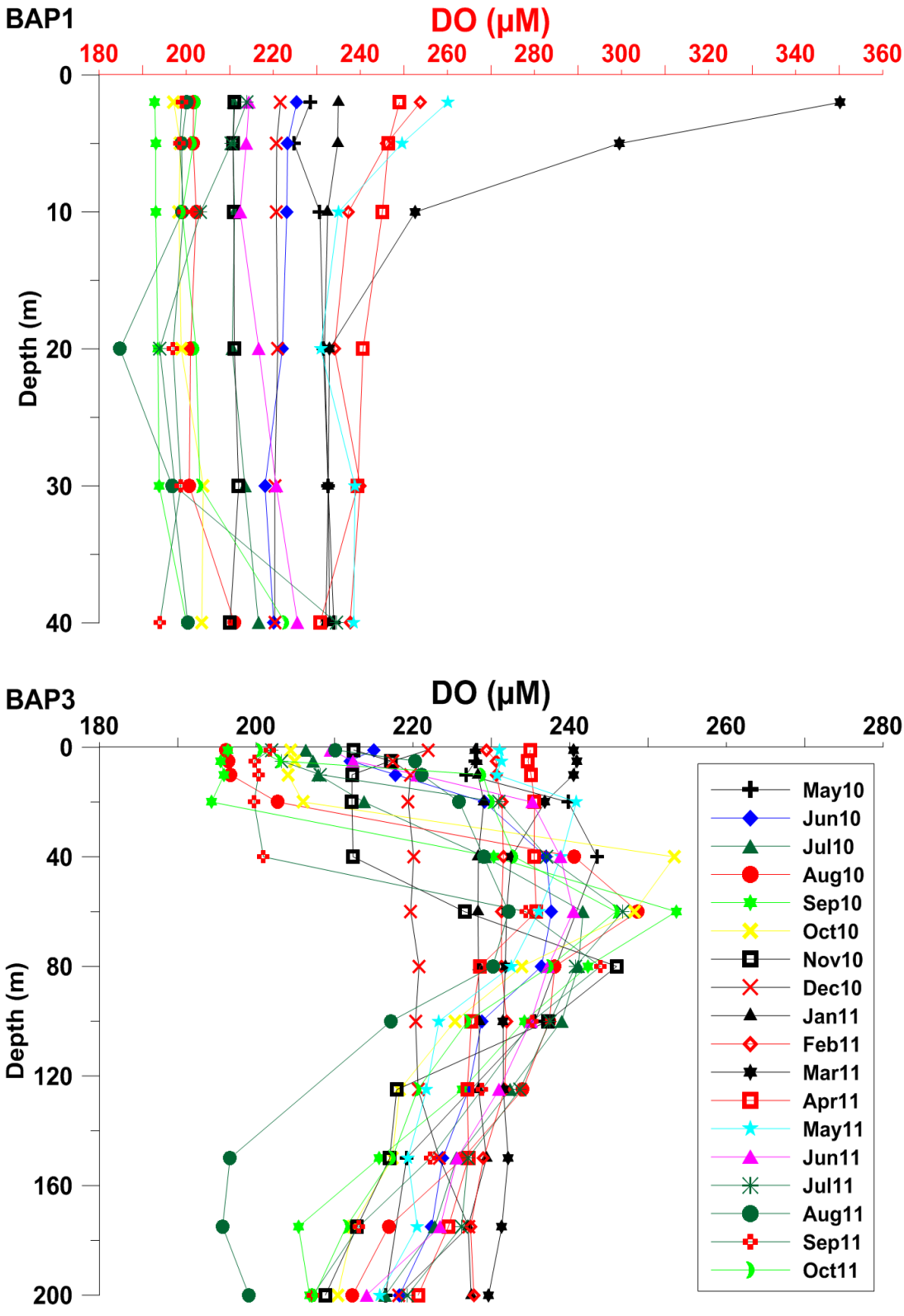


Figure 3.17. Monthly dissolved oxygen profiles at stations BAP1 and BAP3.

3.3. Biological Parameters

Biological parameters will be presented separately for the eastern and western coast of Mersin Bay. Some biological parameters, namely, bacterial carbon production and bacterial abundance (heterotrophic bacteria) are missing for the eastern coast.

3.3.1. Seasonal changes in biological parameters (size-based chlorophyll *a*, size-fractionated primary productivity, phytoplankton pigment composition) in the east coast of Mersin Bay.

Size fractionated chlorophyll *a*, and primary productivity as well as phytoplankton pigment results are presented in this section. Measurement of size fractionated chlorophyll *a* was started in July 2010 in the eastern part of the Mersin Bay.

3.3.1.1. Size-Based Chlorophyll *a*

Total chlorophyll *a* concentrations fluctuated between 0.06 – 1.07 and 0.02 – 0.25 mg m^{-3} with water column mean levels of 0.40 and 0.08 mg m^{-3} in the shelf and offshore, respectively. The highest concentration was measured in February 2011 in shelf waters. Homogenous chlorophyll profiles were observed during February 2009 and February – April 2010 in the shallow station. Top ten meters had higher chlorophyll contents. In some cases, two peaks, one at surface and the other at the bottom were also observed during April – August 2009 and November 2010.

Mean surface concentration of shelf waters (0.52 mg m^{-3}) was 7.5 times higher than offshore waters (0.068 mg m^{-3}). According to surface concentrations, shelf and offshore waters showed opposite trends. Chlorophyll concentration suddenly decreased in October 2009 in shelf waters. While picoplankton derived chlorophyll dominated total chlorophyll in July and November 2010, contribution of larger plankton to total chlorophyll was excess during February and June 2011 in shelf waters. Although the highest concentration was observed in February 2011, contribution of pico and nanoplankton to total chlorophyll were measured very low near bottom, 0.003 and 0.002 mg m^{-3}, respectively. Share by pico and larger plankton of total chlorophyll was almost equal for the water column during October 2011 in the shelf. Dominance of the groups changed with depth in shelf and offshore waters.

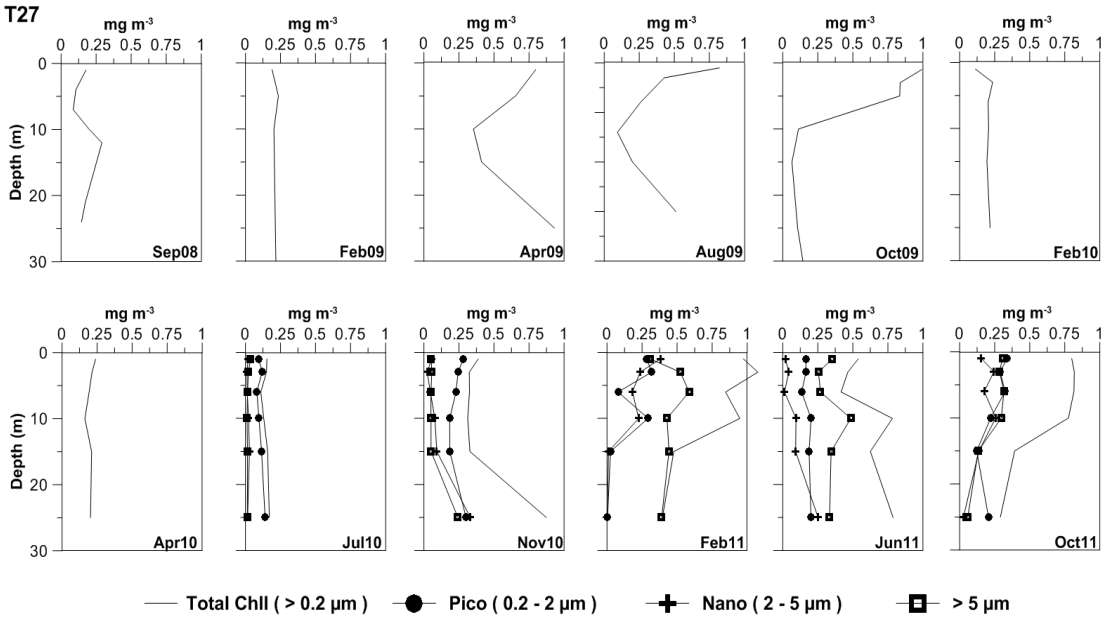


Figure 3.18. Size fractionated and total chlorophyll profiles at shelf station T27.

Chlorophyll levels peaked in different depths in offshore waters. It reached to maximum concentrations in October 11. Total chlorophyll increased with increasing depth in June 2011. Because of the vertical mixing, chlorophyll was homogenously distributed in the offshore water column in winter (February 2009, 2010, 2011). Total chlorophyll was dominated by picoplankton where contributions from nanoplankton and larger phytoplankton were minor at the offshore station. Concentrations of all groups increased at 75 meters in October 2011 (Figure 3.19). Contribution of larger cells to total chlorophyll increased in February 2011 in offshore waters. Same concentrations (0.18 mg m^{-3}) were measured in the same depth (5m) in February 2009 and 2010.

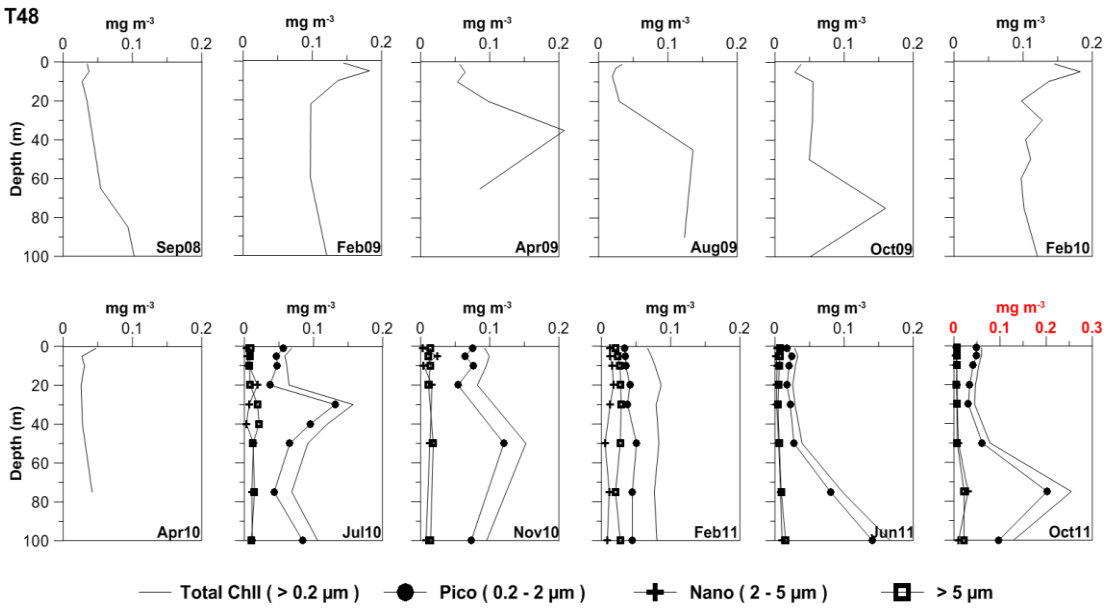


Figure 3.19. Size fractionated and total chlorophyll profiles at offshore station T48.

Depth integrated chlorophyll (ICHL) concentrations fluctuated between 3.7 – 17.04 and 2.37 – 11.73 with water column mean levels of 9.63 and 8.45 mg m^{-2} at the shelf and offshore stations, respectively (Figure 3.20). This difference may rise to almost 5 times in the shelf (0.385 mg m^{-2}) and offshore (0.08 mg m^{-2}) mean values are converted to values per m^{-2}. According to ICHL, while larger cell dominated chlorophyll composition in shelf waters, picoplankton was found to be the major contributor in offshore waters in east side of the Mersin Bay (Figure 3.20).

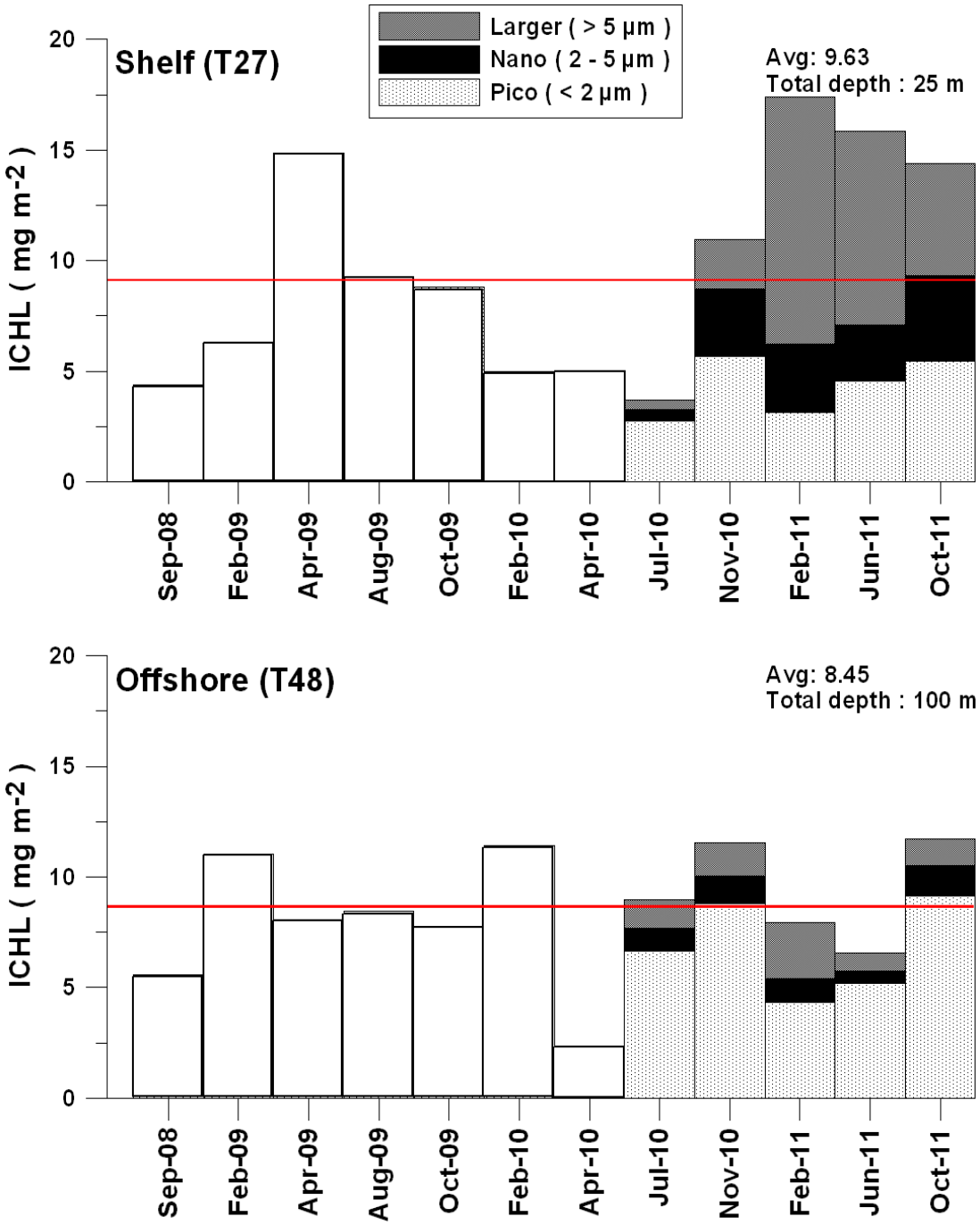


Figure 3.20. Depth integrated chlorophyll *a* (ICHL) rates at stations T27 (note that the total sampling depth = 25m) and T48 (total sampling depth = 100m).

3.3.1.2. Size-Based Primary Productivity

Rates of primary production fluctuated between 0.005 – 13.23 and 0.007 – 0.952 with water columns mean levels of 1.773 and 0.246 $mgC.m^{-3}$ h^{-1} in the shelf and offshore, respectively. High surface value was measured in August 2009 in the shallow shelf station where PP decreased with depth in most cases. The top 10

meters were more efficient and productive than the lower depths. Despite the high rates recorded mainly in August & October 2009 and February 2011, values remained below 3 $mgC.m^{-3}\ h^{-1}$ for the rest of the sampling period. PP was high in February 2010 and 2011 compared to February 2009 in shelf waters. Also, in October 2009, PP was measured 20 times higher than October 2011 in station 27. PP had displayed two peaks in June 2011, one at the surface and the other just below at ten meters. Contribution of size groups to total primary production (TPP) varied greatly in time. Groups shifted with each other in the water column. Picoplankton in February 2009, larger plankton in February 2010 and larger and nanoplankton in February 2011 dominated total primary production in the shelf. Picoplankton was the major contributor to PP in July and November 2010 in coastal waters. Nanoplankton, being least active overall, was the dominant group at surface in front of the Seyhan River only during August 2009. While larger cells dominated total PP at surface, it shifted with picoplankton below surface during October 2009 (Figure 3.21).

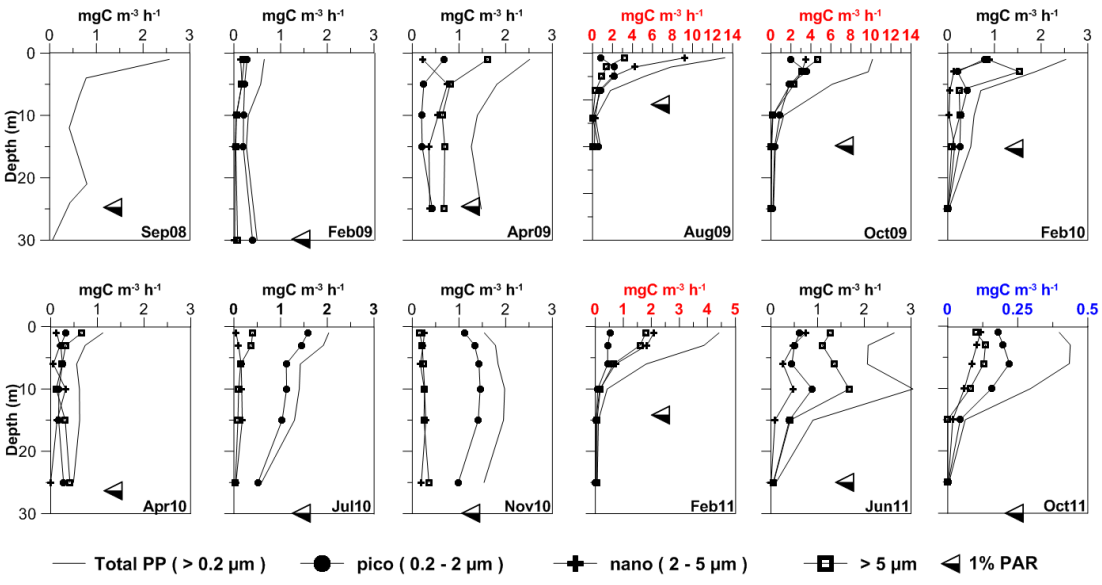


Figure 3.21 Size fractionated and total primary production profiles at shelf station T27.

Low PP values were measured in offshore (Sta T48). Throughout the study period, maximal rate was reached at the deepest depth during August 2009. Almost equal rates were also measured in July 2010 at top ten meters. PP decreased with depth except August and October 2009. Two peaks were observed in PP profiles for

February and October 2009. Surface waters were always found to be more productive than deeper parts of the water column during the winter (February). PP was measured higher in October 2009 than October 2011. Picoplankton was found to be the major contributor to PP in offshore waters where contributions from nano and larger plankton were equally shared.

In general, nanoplankton shifted with larger cells in offshore station. Also, contribution of larger cells to total PP was higher than nanoplankton in surface waters during the sampling period. Contribution of larger cells was negligible (0.0001-nothing) for the top 20 meters during October 2011 (Figure 3.22).

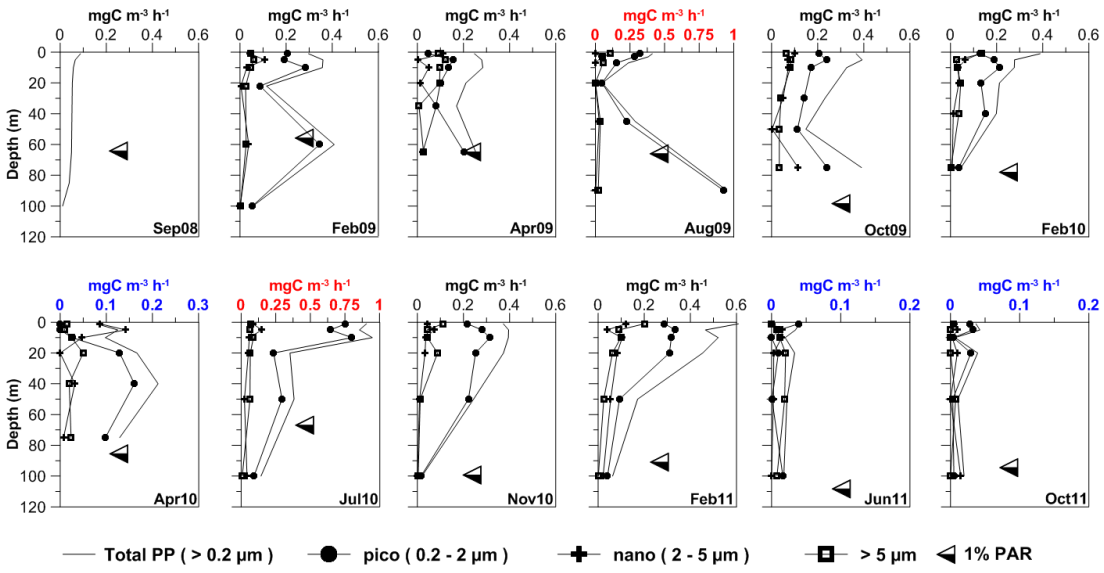


Figure 3.22 Size fractionated and total primary production profiles at offshore station T48.

Integrated primary production (IPP) rate was as low as 2.05 mgC.m^{-2} h^{-1} in the offshore and increased to 72.2 mgC.m^{-2} h^{-1} in the nearshore waters enriched by river discharges in the eastern part of the Mersin Bay (Figure 3.23). The mean IPP was 33.58 and 19.29 mgC.m^{-2} h^{-1} in shelf and offshore, respectively. In the nutrient-depleted Cilician Basin offshore waters, PP was dominated by picoplankton (0.2-2.0 µm). Larger cells (>5 µm) dominated phytoplankton composition in nutrient rich shelf waters according to season, especially during the winter. Picoplankton dominated shelf waters during summer and fall (Figure 3.23). Nanoplankton was

found major contributor in April 2009 in shelf waters. Very low values were calculated for October 2011 in both stations.

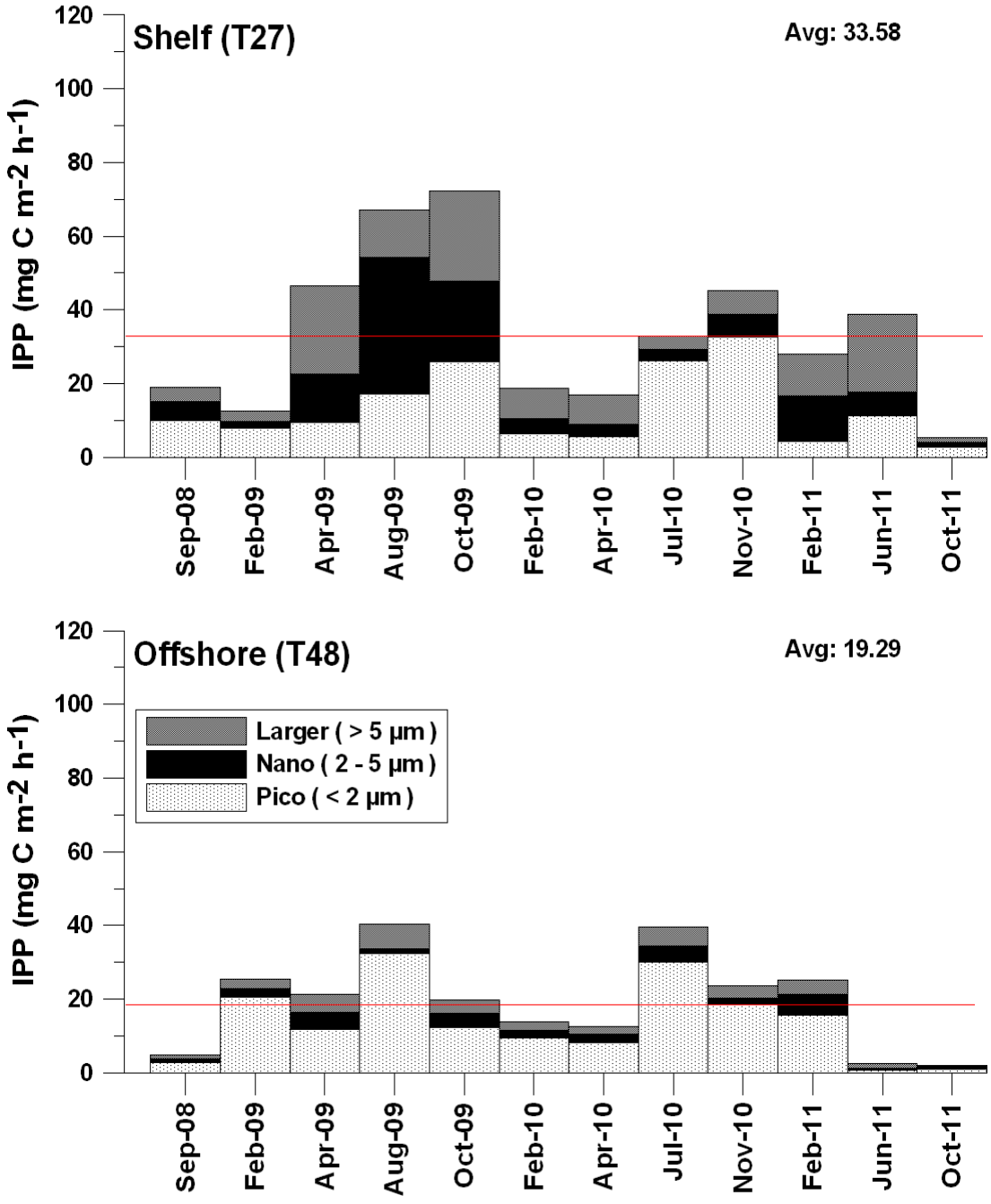


Figure 3.23. Depth integrated primary production rates at stations T27 (note that the total sampling depth = 25m) and T48 (total sampling depth = 100m).

3.3.1.3. Carbon to Chlorophyll Ratio

Carbon to chlorophyll (C/CHLL) ratio increased during summer and autumn in the shelf (except October 2011). Picoplanktonic C/CHLL was found higher in July and

November 2010, but, nanoplanktonic C/CHLL increased in February 2011 in the shelf. These ratios were found high during August 2009, April & July 2010 in offshore waters. Mean values were calculated as 4.12 and 2.49 for the shelf and offshore, respectively. While picoplankton was found more active in the shelf, nanoplankton was most active in the offshore.

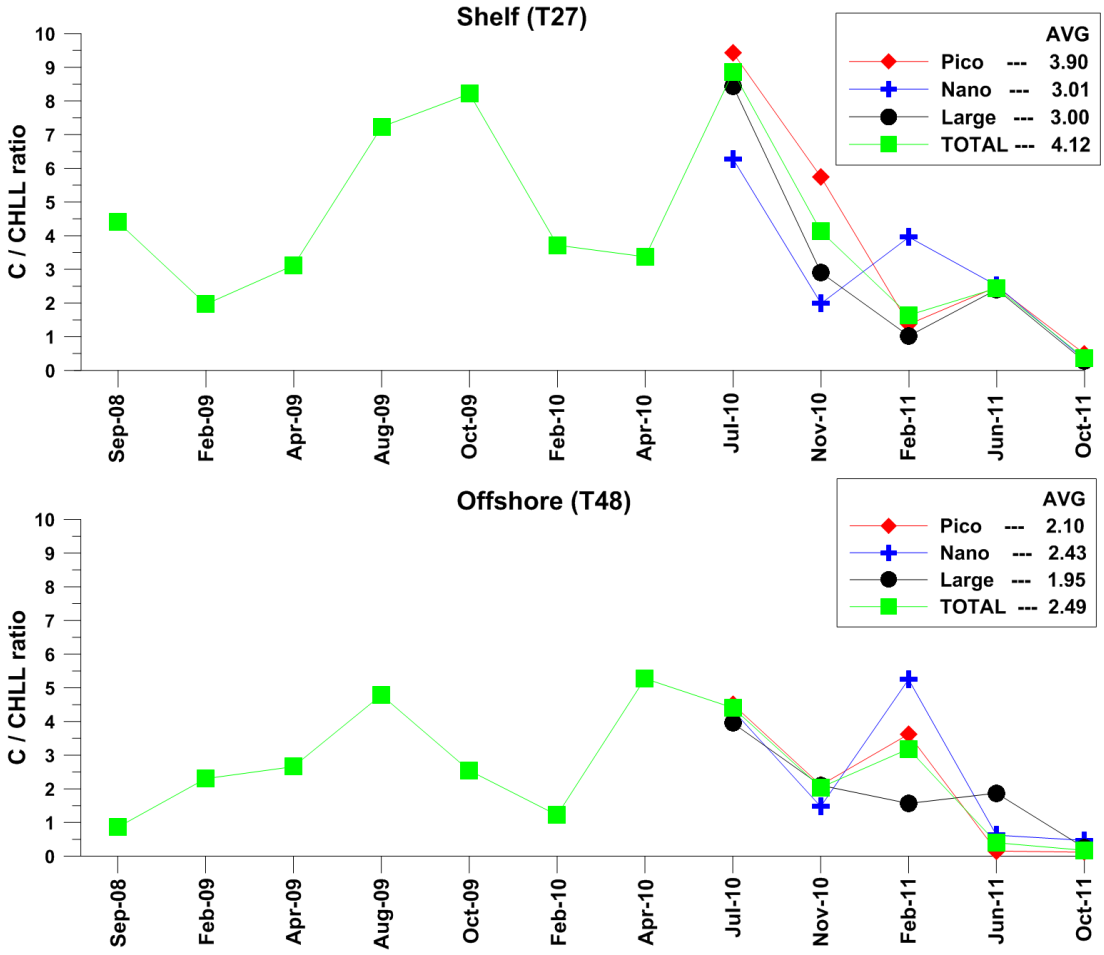


Figure 3.24. Changes in carbon to chlorophyll ratios in time at stations T27 and T48.

3.3.1.4. Phytoplankton Pigment Composition

Based on pigment composition, surface shelf flora was primarily dominated by diatoms with marked contributions extending from April 2009 to October 2011 (except July and November 2010). Its contribution to total chlorophyll exceeded 60% in February 2009 and June 2011. Diatoms were followed by cyanobacteria with peak concentrations in August 2009 and July 2010. Significant contribution of prymnesiophytes was also observed in the shelf. Large eukaryotes dominated by

diatoms were replaced by prokaryotic picoplankton and eukaryotic nanoflagellates in time in shelf waters. However this picture was reversed in the offshore where the pico and nanoplanktonic forms (cyanobacteria, prochlorophytes and prymnesiophytes especially the coccolithophorid *Emiliana huxleyi*) dominated the bulk in an alternating manner. Prokaryotic picoplankton (cyanobacteria and prochlorophytes) made significant contributions during the summer whereas prymnesiophytes were observed more abundant during winter and fall in the oligotrophic offshore surface waters. Contribution of prochlorophytes (DIV-A) to prokaryotic picoplankton was negligible during the period April 2009 to April 2010 and in June and October 2011 in shelf. Eukaryotic nanoflagellates dominated the flora in February 2009, August 2009, February 2010 and February 2011 in the offshore. Although all groups were present in varying quantities in the shelf, large eukaryotes were almost missing from the offshore. Similarly, eukaryotic nanoflagellates and large eukaryotes were not observed at top 40 meters in July 2010 in the offshore. Shelf flora was dominated by eukaryotic nanoflagellates in February 2009 and by large eukaryotes from April 2009 to October 2011 and June 2011 except August 2009, July and November 2010. On the other hand, concentrations of prokaryotic picoplankton reached maximal levels in the water column during summer months in the shelf. Prokaryotic picoplankton and eukaryotic nanoflagellates were equally present in shelf waters during November 2010. Contribution of large eukaryotes was most significant during February 2010 and June 2011. In general, group concentrations remained below 0.1 $\mu g\ l^{-1}$ in offshore waters where the bulk was dominated by prokaryotic picoplankton and prymnesiophytes of which was mainly composed eukaryotic nanoflagellates.

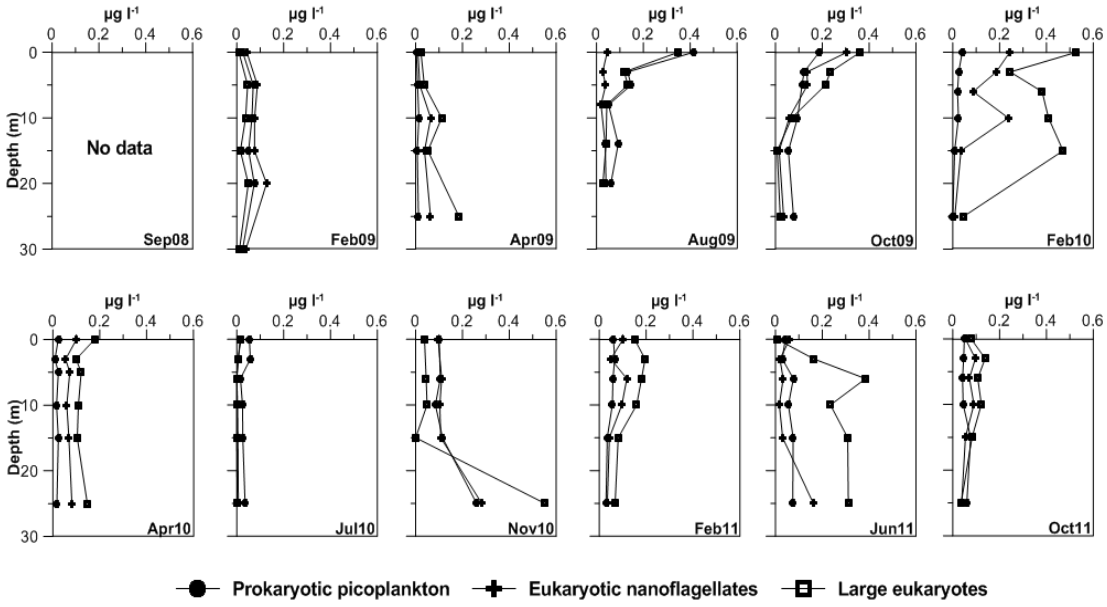


Figure 3.25. Changes in pigment based prokaryotic picoplankton (ZEA+DIV-A), eukaryotic nanoflagellate (BUT+HEX+CHL-B) and large eukaryote (FUC+PER) profiles from the shelf station T27.

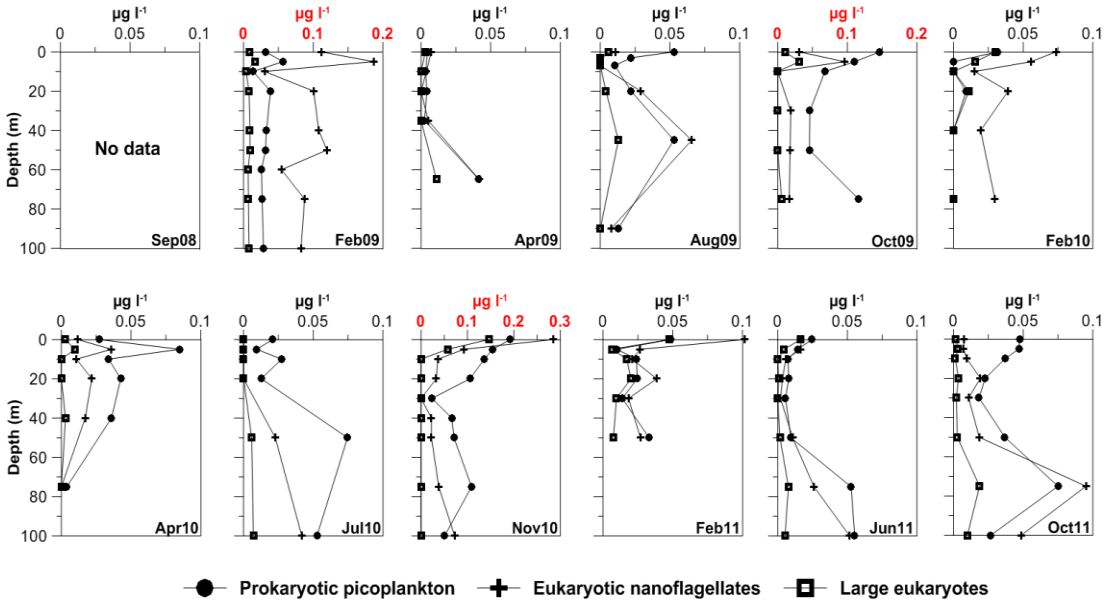


Figure 3.26. Changes in pigment based prokaryotic picoplankton (ZEA+DIV-A), eukaryotic nanoflagellate (BUT+HEX+CHL-B) and large eukaryote (FUC+PER) profiles from the offshore station T48.

3.3.2. Seasonal changes in biological parameters (size-based chlorophyll *a*, size-based primary production, phytoplankton pigment composition, bacterial carbon production, bacterial abundance (heterotrophic bacteria) in west side of the Mersin Bay.

3.3.2.1. Size-Based Chlorophyll *a*

Total chlorophyll concentrations fluctuated between 0.066 – 2.49 and 0.014 – 0.38 with water column mean levels of 0.46 and 0.12 mg m^{-3} in the shelf and offshore, respectively. Chlorophyll *a* concentrations were measured below 0.5 mg m^{-3} in the shelf whereas to the highest concentration was reached in March 2011. Low concentrations (below 0.1 mg m^{-3}) were observed in September 2011 in shelf waters. Chlorophyll yield of the year 2011 was higher than the previous 2010 for similar periods in the shelf except that observed in October. In August 2010, September 2010 and April 2011, concentrations peaked near bottom at around 30 m depth. Picoplanktonic chlorophyll dominated total chlorophyll from June to November and larger planktonic chlorophyll dominated from December to May in shelf waters. Larger plankton peak in March 2011 was followed by another peak in February 2011. Contribution of nanoplankton to the bulk was generally insignificant except observed high values in October 2010 in the shelf. Dominant groups shifted with each other in different depths in shelf waters.

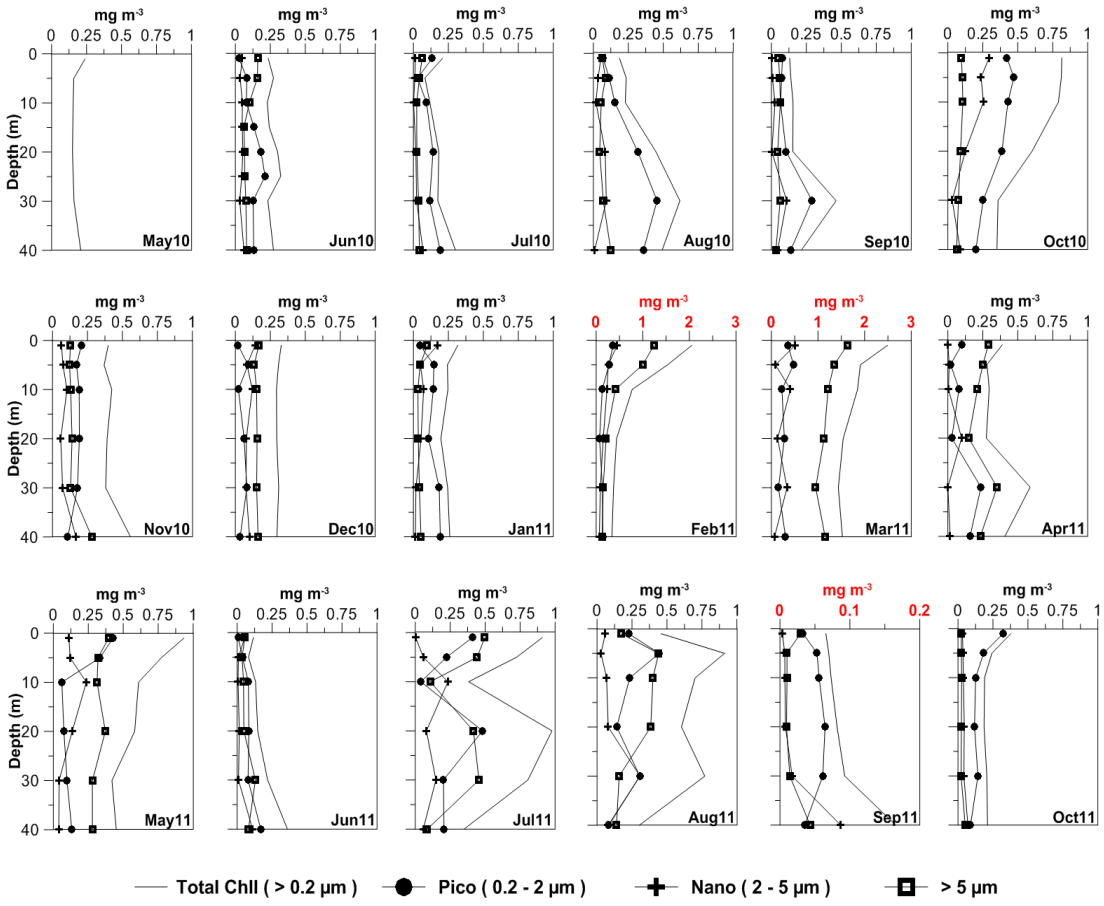


Figure 3.27. Size fractionated and total chlorophyll profiles at shelf station BAP1.

In offshore, the highest concentration was measured in May 2011 (0.38 mg m^{-3}). Picoplanktonic chlorophyll dominated total chlorophyll throughout the study. Larger plankton contributed more than nanoplankton to total chlorophyll in offshore waters. Also, these groups increased their contributions from December 2010 to March 2011. In general, concentrations peaked at mid and deeper depths (between 40 and 100 meters). Three peaks were observed in the water column in March and September 2011 in offshore waters (Figure 3.28). Also, high concentrations were measured from August 2010 to March 2011 and August and September 2011. Very low concentrations were observed at surface in offshore.

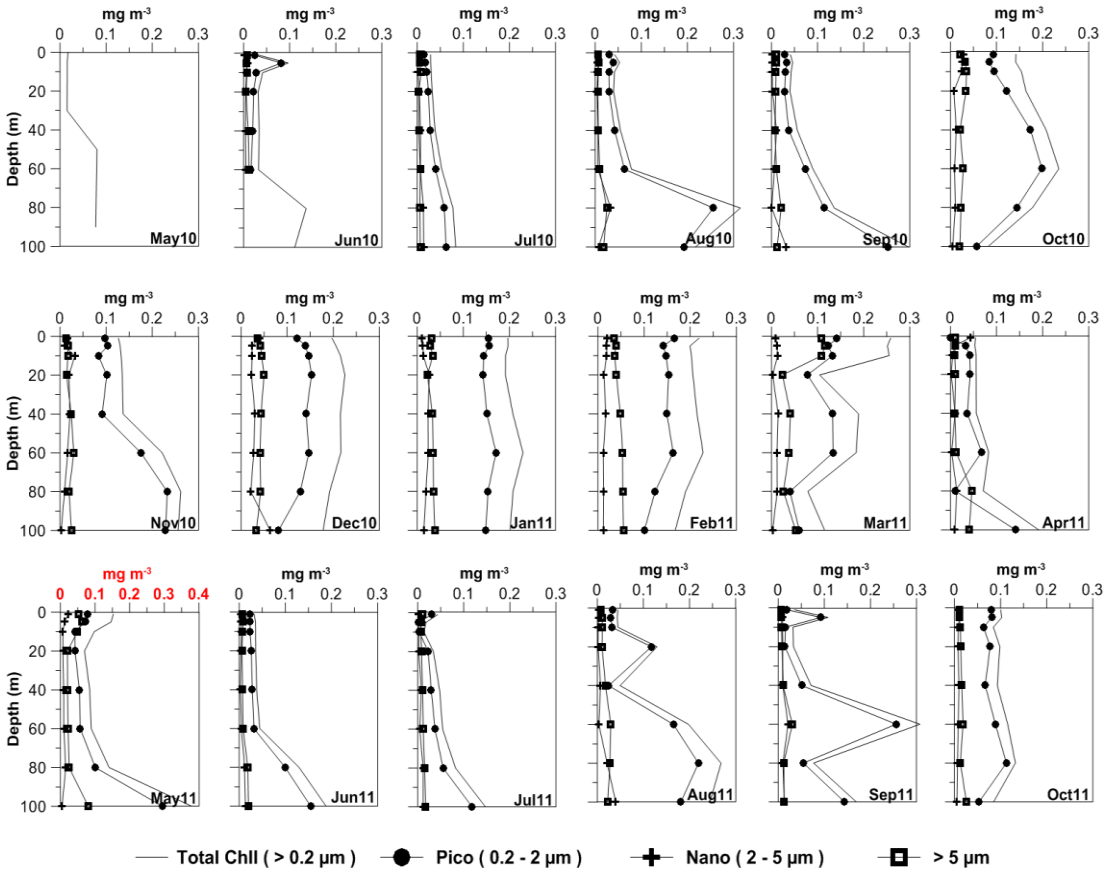


Figure 3.28. Size fractionated and total chlorophyll profiles at offshore station BAP3.

Depth integrated chlorophyll (ICHL) concentrations fluctuated between 3.6 – 67.3 and 4.60 – 20.8 with water column mean levels of 17.6 and 12.50 mg m^{-2} in the shelf and offshore, respectively (Figure 3.29). When these mean values were averaged for each m^{-2}, it can be seen that the concentration of chlorophyll in shelf waters (0.440 mg m^{-2}) was 3.5 times higher than the offshore waters (0.125 mg m^{-2}). ICHL concentrations peaked in March 2011 in parallel to increase in the amount of larger cells. While picoplanktonic ICHL dominated the total chlorophyll from June 2010 to November 2010, larger planktonic ICHL dominated the total from December 2010 to September 2011 in coastal waters. Nanoplanktonic ICHL concentration increased in February & March 2011 as well as earlier in October 2010 in the shelf. In offshore waters, ICHL concentrations were measured high from August 2010 to March 2011 (also, in August, September and October 2011). Dominated basically by picoplanktonic ICHL, larger cells also comprises the composition. Nanoplanktonic ICHL reached to a maximum in December 2010 in offshore (Figure 3.29.).

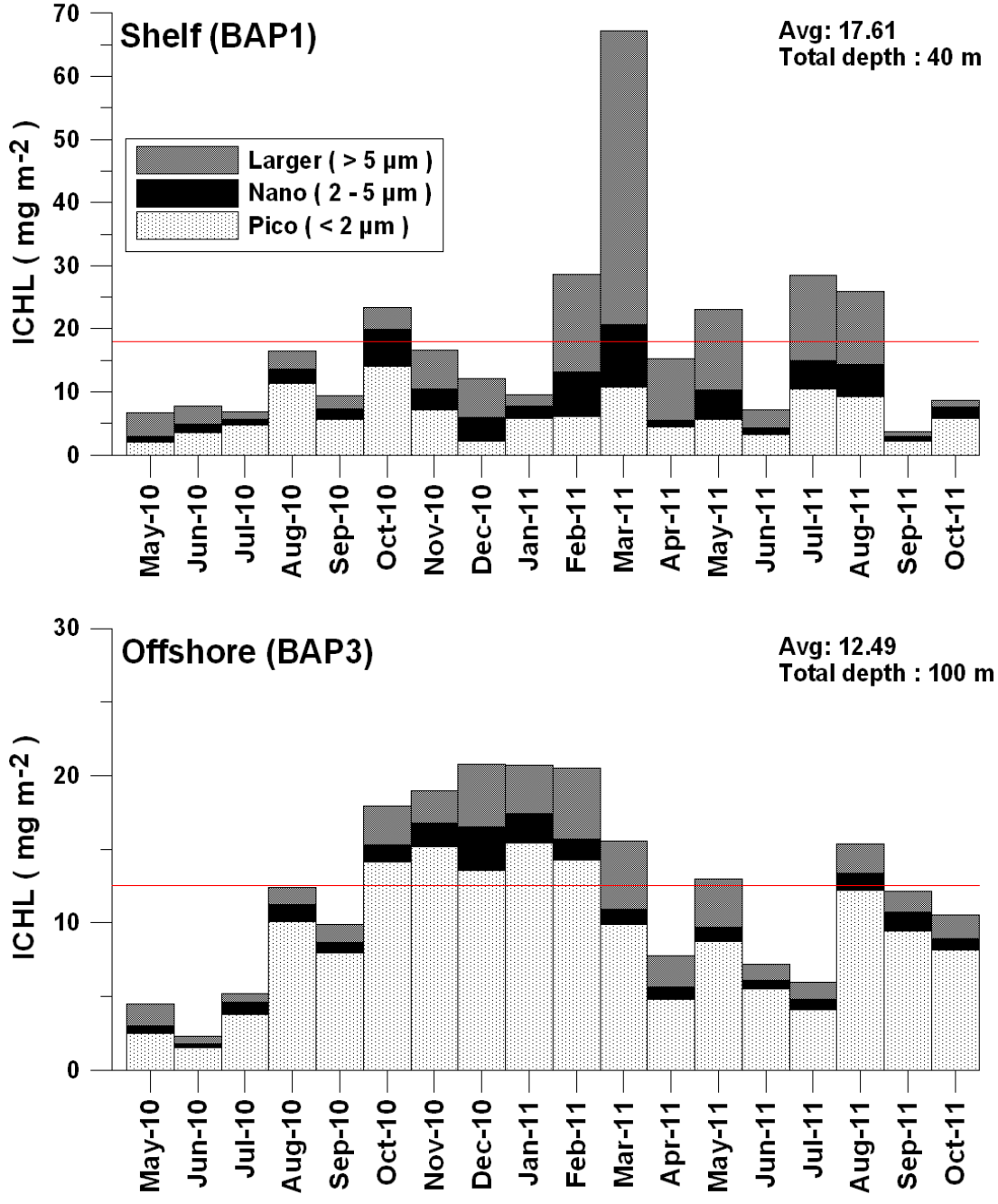


Figure 3.29. Depth integrated chlorophyll *a* (ICHL) rates at shelf station BAP1 (note that the total sampling depth = 40m) and offshore station BAP3 (total sampling depth = 100m).

3.3.2.2. Size-Based Primary Production

Rates of primary production fluctuated between 0.024 – 14.42 and 0.007 – 1.48 with water column mean levels of 1.52 and 0.25 $mgC.m^{-3}$ h^{-1} for the shelf and offshore, respectively. The highest rate was measured in March 2011 in shelf surface waters. PP decreased with depth in shelf waters. Very low values were measured near bottom. Top 20 meters were more productive than the deeper part. PP was generally below 2 $mgC.m^{-3}$ h^{-1}, with high turnover rates achieved especially during October 2010 and February, March & July 2011. Very low rates were measured in October 2011. The PP observed for the period May-October 2010 showed discrepancy from the same period of the following year. Rates measured during July 2011 exceeded those measured during July 2010, in shelf waters. Also, the rate measured in October 2010 was 55 times higher than that in October 2011, at station BAP1. PP had displayed two peaks in May 2010, one at surface which was mainly dominated by larger cells and the other one at 20 meters dominated mainly by picoplankton. Contribution of nanoplankton to total primary production (TPP) varied both in time and with depth. From June 2010 to January 2011, PP was dominated by picoplankton and from February to May 2011 by larger cells. Picoplankton and larger phytoplankton both competed for nutrients in the shelf. In cases where two different group peaks are present in the same water column, mostly larger cells dominate the surface and picoplankton the deeper part. Picoplankton was the major contributor to PP in October and November 2010 in coastal waters. Being the least active, nanoplankton dominated total PP only during May 2011 at surface.

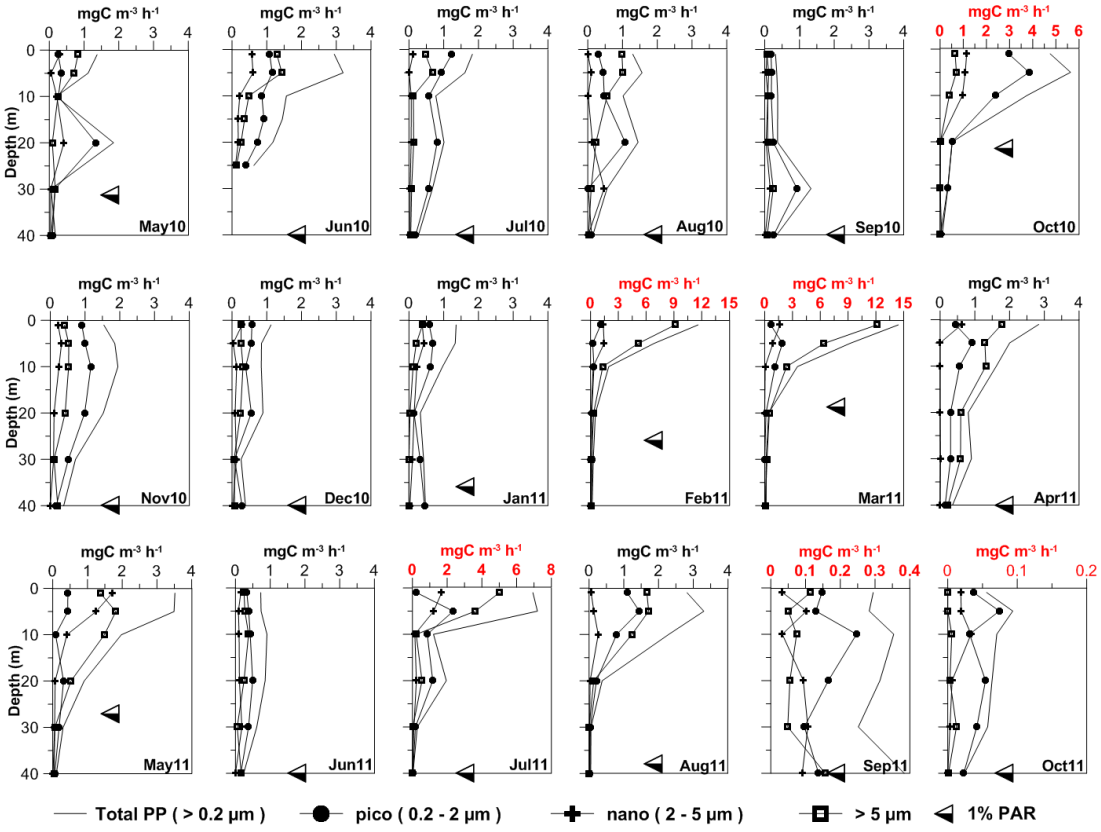


Figure 3.30. Size fractionated and total primary production profiles at shelf station BAP1.

Compared to shelf, low rates were measured in offshore waters (BAP3). The highest rate measurement was obtained at 10 m depth during March 2011 (1.48 mgC.m^{-3} h^{-1}). Near surface highs were also measured in January & May 2011. In some cases, PP peaks were observed at around 60 m during February, April, August & September 2011 in offshore waters. PP reduced as low as to a value of 0.007 mgC.m^{-3} h^{-1} with depth. Very low values were observed in October 2011 in the water column. The most dominant contributor was picoplankton in offshore waters. But, in March and May 2011, larger cells dominated PP at top 10 meters.

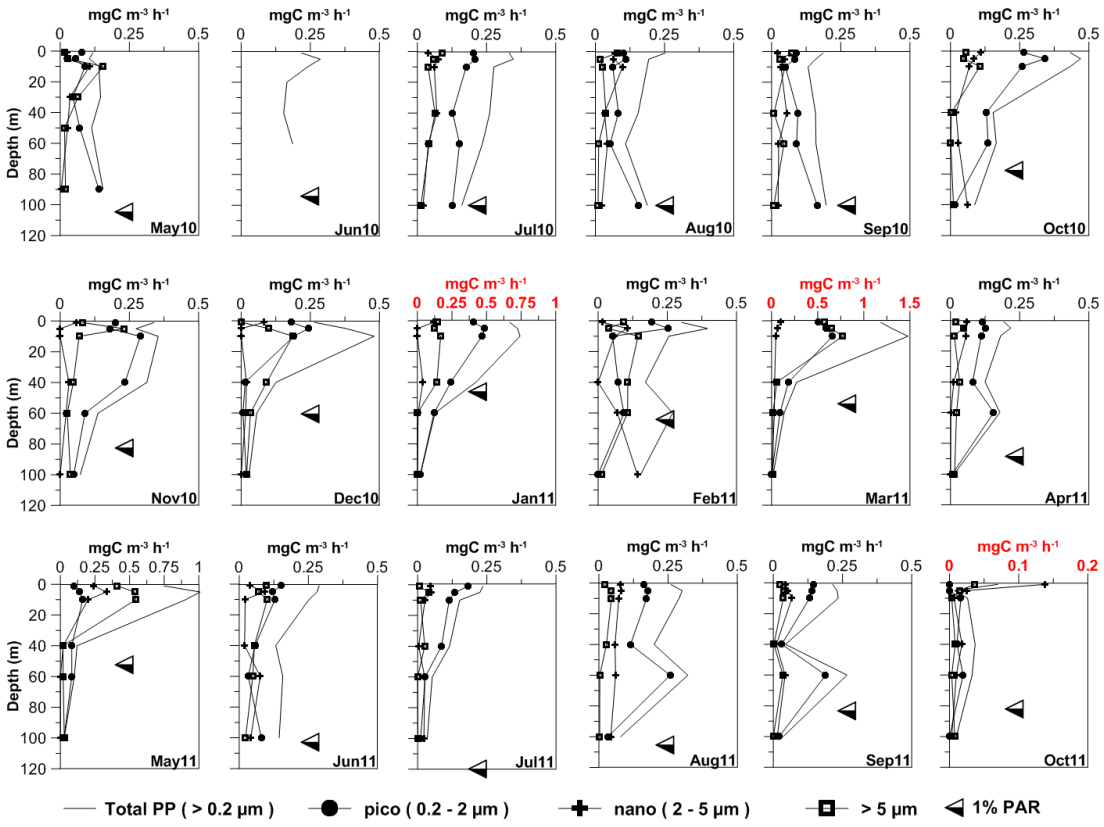


Figure 3.31. Size fractionated and total primary production profiles at offshore station BAP3.

Rates of Integrated primary production (IPP) fluctuated between 2.45 – 121 and 3.3 – 46.5 with mean levels of 48.6 and 20.2 mgC.m^{-2} h^{-1} in the shelf and offshore, respectively (Figure 3.32). The highest values were calculated for March 2011 in both stations. While larger cells (>5 µm) dominated phytoplankton composition in nutrient rich shelf waters from February 2011 to July 2011 (except June 2011), picoplankton dominated shelf waters in other months (Figure 3.32). In the nutrient-depleted Cilician basin offshore waters, IPP was dominated by picoplankton (except December 2010 and May 2011). Contribution of nanoplankton reached to 30 % of total IPP in February 2011 in offshore.

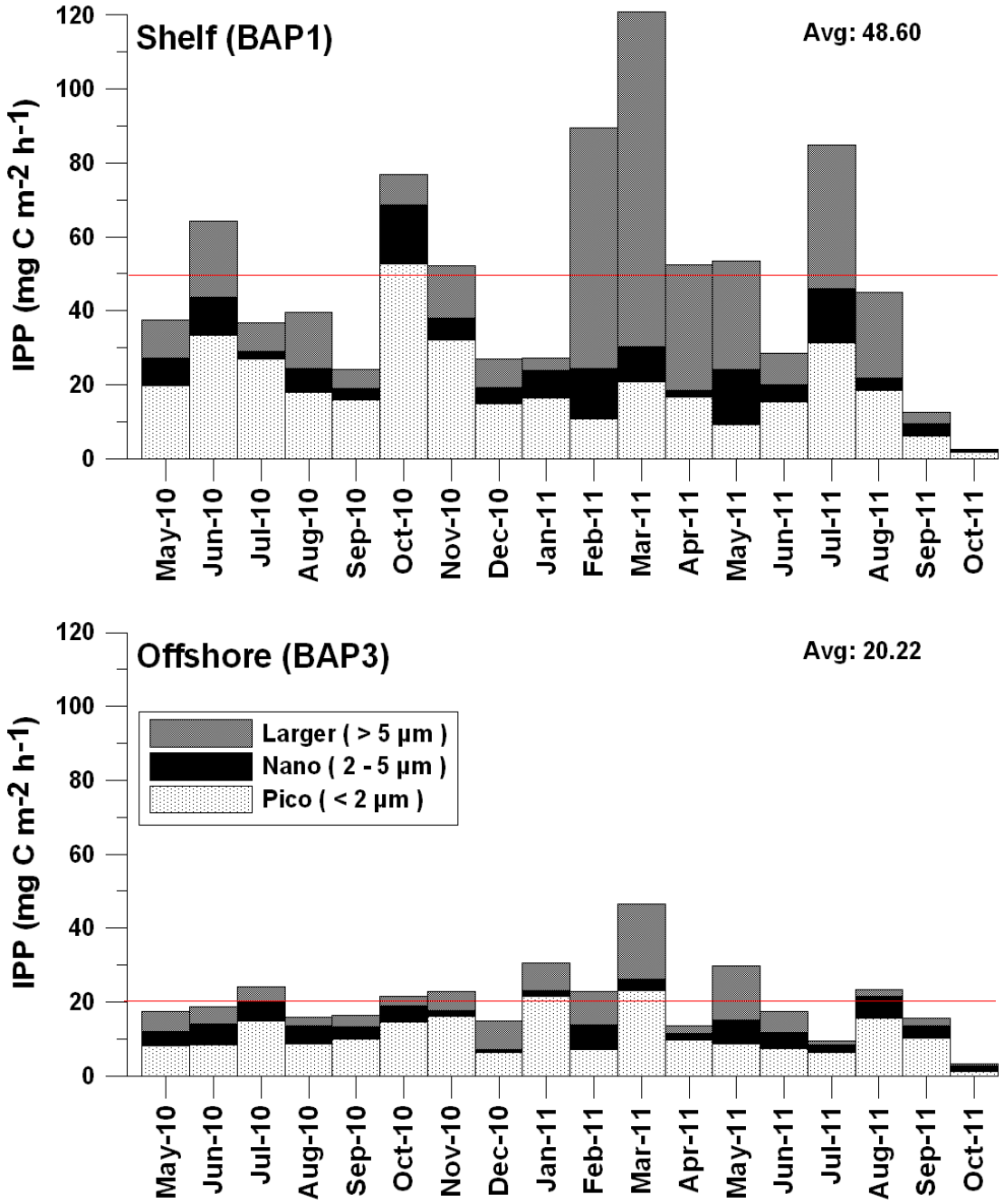


Figure 3.32. Depth integrated primary production rates at stations BAP1 (note that the total sampling depth = 40m) and BAP3 (total sampling depth = 100m).

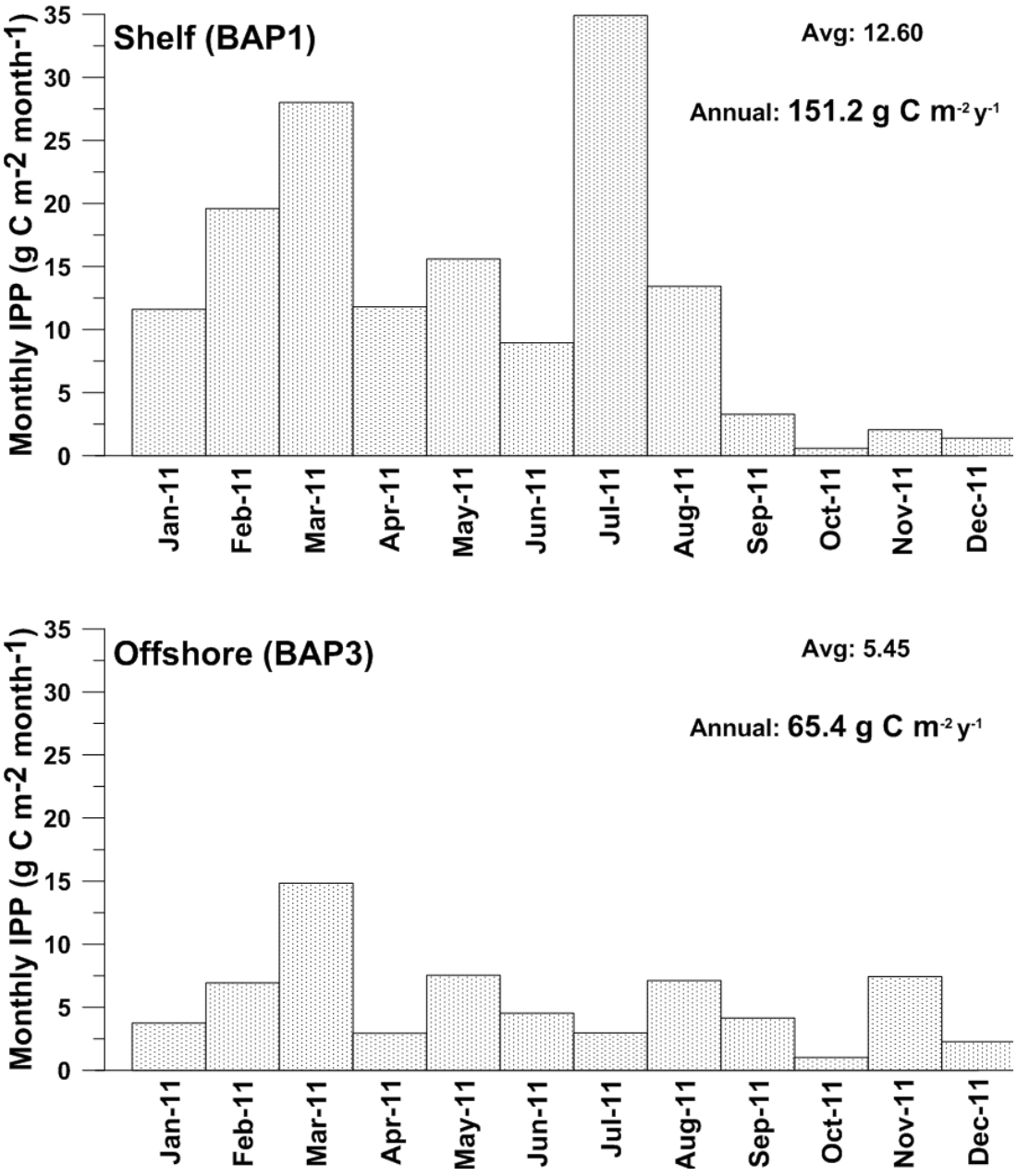


Figure 3.33. Depth integrated monthly primary production rates at stations BAP1 (note that the total sampling depth = 40m) and BAP3 (total sampling depth = 100m).

Monthly integrated primary production rates fluctuated between 0.60 – 34.90 and 1.01 – 14.83 with mean levels of 12.60 and 5.45 g $C.m^{-2}$ $month^{-1}$ in the shelf and offshore, respectively (Figure 3.33). Annual primary production rates were calculated as 65.4 for the offshore and 151.2 g $C.m^{-2}$ y^{-1} for the shelf in the Cilician basin. Among the most productive month were July 2011 and March 2011 for the

shelf and offshore, respectively. Productivity was least during October 2011 in the whole Cilician basin. Seasonal primary production was estimated as 32.6, 55.4, 57.3, 5.9 g $C.m^{-2}$ for shelf and 12.9, 25.3, 14.6 and 12.58 g $C.m^{-2}$ for offshore, in winter, spring, summer and autumn, respectively. Seasonal primary production was higher in summer in shelf and spring in offshore.

3.3.2.3. Carbon to Chlorophyll Ratio

Based on carbon to chlorophyll (C/CHLL) ratios different size groups appeared to be dominant for a particular period both in the shelf and in the offshore. In offshore waters highest C/CHLL ratio was observed in nanoplankton with two significant peaks in May & June 2010. C/CHLL ratio was also found high for the large phytoplankton in offshore waters. This is reversed in the shelf where C/CHLL ratios of picoplankton became more significant. This ratio was calculated lowest during October 2011 in the shelf. On the average C/CHLL ratios of the offshore phytoplankton was 1.90 which forms almost half the value obtained for shelf phytoplankton (3.26).

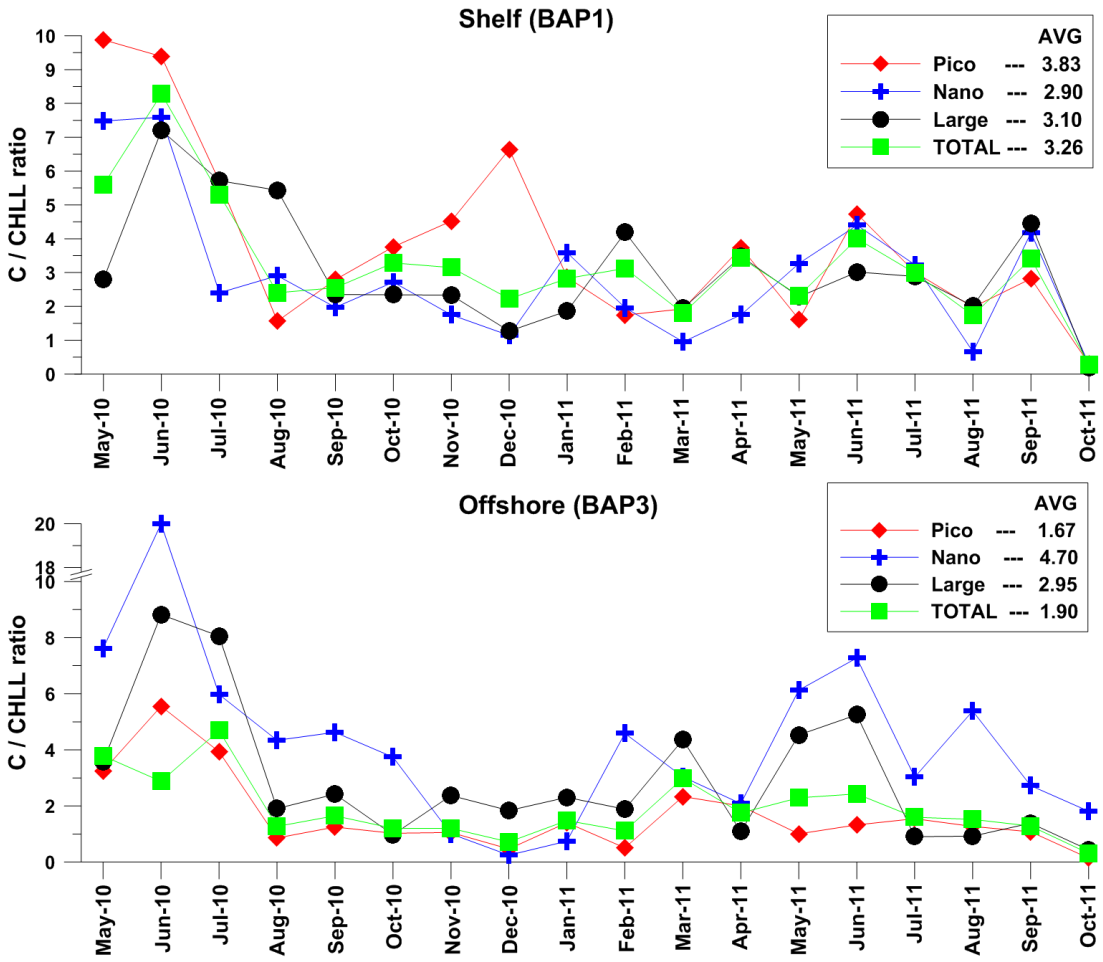


Figure 3.34. Changes in carbon to chlorophyll ratios in time at stations BAP1 and BAP3.

3.3.2.4. Phytoplankton Pigment Composition

Based on pigment composition, shelf waters were dominated by diatom (FUC) dominated large eukaryotes from February 2011 to May 2011. On the other hand, prokaryotic picoplankton dominated phytoplankton pigment composition from July 2010 to January 2011 and from June to October 2011. Eukaryotic nanoflagellates dominated flora during May and December 2010. They also shifted with other groups in October and November 2010 in the water column. In addition, high concentrations of eukaryotic nanoflagellates were found in May and October 2011. Large eukaryotes peaked two times in the water column in June 2010 and March & May 2011. Diatom dominated large eukaryotes reached to highest concentrations in March 2011. But, when individual pigments were checked, it was clear to see that phytoplankton pigment composition was dominated by four major pigments namely FUC (diatom), ZEA (cyanobacteria), HEX (prymnesiophytes) and DIV-A

(prochlorophytes) in shelf waters. FUC (diatom) dominated pigment composition from February to August 2011 and June 2010 in the shelf. Prymnesiophytes formed the major group in May, October and November 2010. Cyanobacteria dominated shelf waters in July, August, September 2010 and September and October 2011. Also, prochlorophytes dominated the bulk in December 2010 and January 2011, but replaced with prymnesiophytes in deeper parts of the water column in the shelf. Pigments were low and homogenously distributed in water column in May, July, December, 2010 and January 2011 in shelf waters.

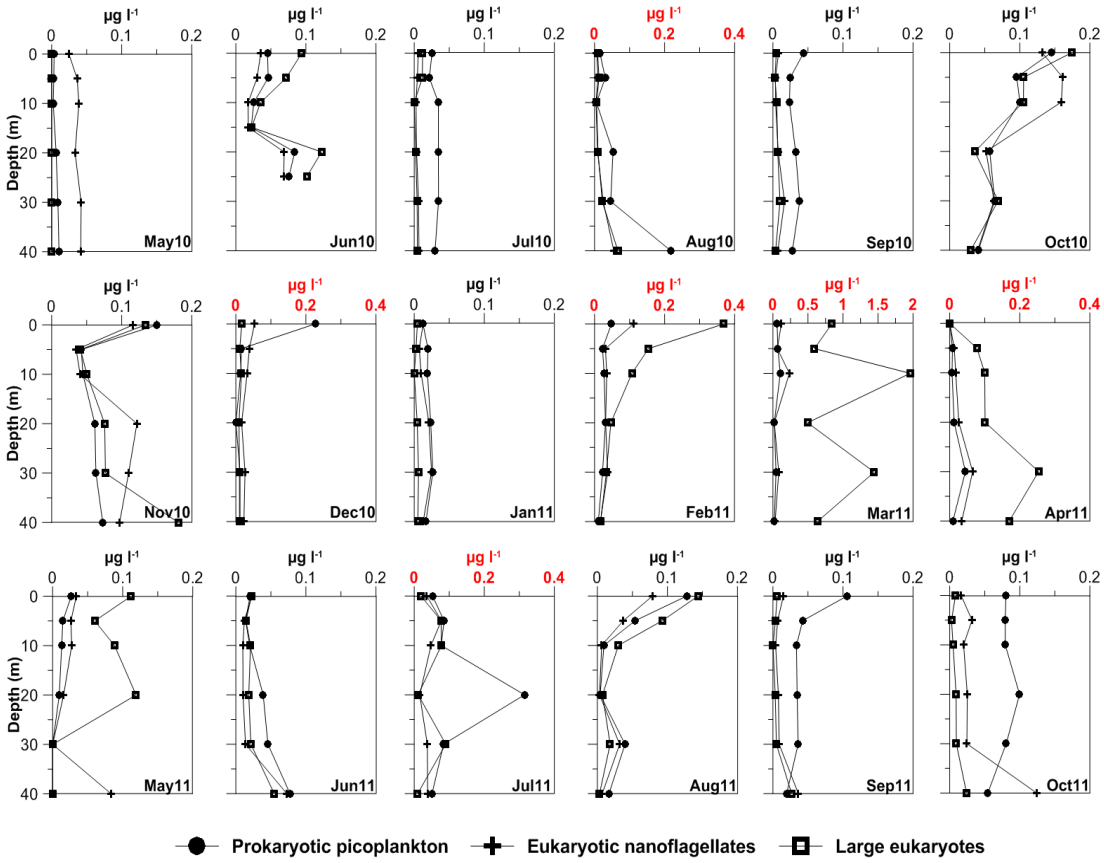


Figure 3.35. Changes in pigment based prokaryotic picoplankton (ZEA+DIV-A), eukaryotic nanoflagellates (BUT+HEX+CHL-B), large eukaryotes (FUC+PER) profiles from shelf station BAP1.

In offshore waters, prokaryotic picoplankton dominated phytoplankton pigment composition from June 2010 to November 2010 and April to October 2011 except August 2010 and May 2011. On the other hand, prymnesiophytes dominated

(especially coccolithophorid - *Emiliana huxleyi*) eukaryotic nanoflagellates in May and August 2010 and from December 2010 to February 2011. They also contributed to total pigment concentrations in September and October 2010 when prokaryotic picoplankton was the dominant group. Diatom dominated large eukaryotes dominated offshore waters in March and May 2011. In May 2011, prochlorophytes was also found as the second dominant group in the deeper part. In the meantime almost no accessory pigment except chlorophyll *a* was observed at depths of 40 and 60 meters. Prochlorophytes highly dominated the water column in November 2010 and October 2011 in offshore waters. Prymnesiophytes dominated eukaryotic nanoflagellates reached the highest concentration in the deepest sampling depth of 100 meters in October 2011. Diatom dominated large eukaryotes reached again their highest concentrations at top 10 meters in March 2011. Very low concentrations of large eukaryotes were measured in summer and autumn in offshore waters.

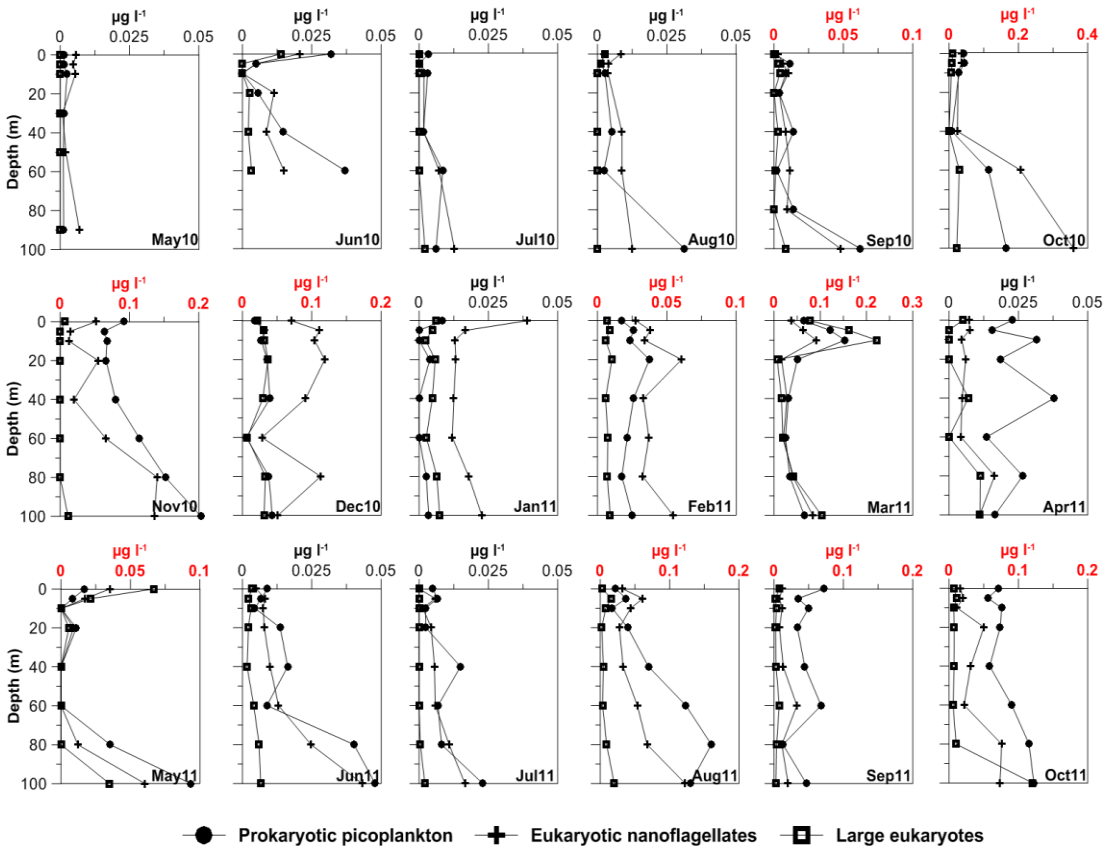


Figure 3.36. Changes in pigment based prokaryotic picoplankton (ZEA+DIV-A), eukaryotic nanoflagellates (BUT+HEX+CHL-B), large eukaryotes (FUC+PER) profiles from offshore station BAP3.

3.3.2.5. Bacterial Carbon Production

The mean bacterial carbon production (BCP) was 0.05 and 0.015 mgC.m^{-3} h^{-1} in the shelf and offshore, respectively. BCP varied between 0.002 and 0.270 mgC.m^{-3} h^{-1} in the shelf and 0.001 and 0.1 mgC.m^{-3} h^{-1} in offshore waters throughout the sampling period (Figure 3.37). Highest values were measured in February 2011 in shelf and in August 2011 in offshore surface waters (Figure 3.37). Rates of BCP decreased with depth in the shelf. Higher values were measured at top 20 m in coastal waters. In September 2011, very low rates were measured in the basin. Shelf was found 3 times more productive than offshore. Surface and mean BCP were higher in winter and summer seasons in shelf. Low surface and mean values were measured in March, April and September 2011 in offshore waters. Variations in BCP near bottom were minor in the shelf . BCP peaked at 5 meters in January and July 2011 in coastal waters. Mean BCP showed similar variation in both stations. Mean BCP of both stations were similar (0.008 mgC.m^{-3} h^{-1}) in September 2011.

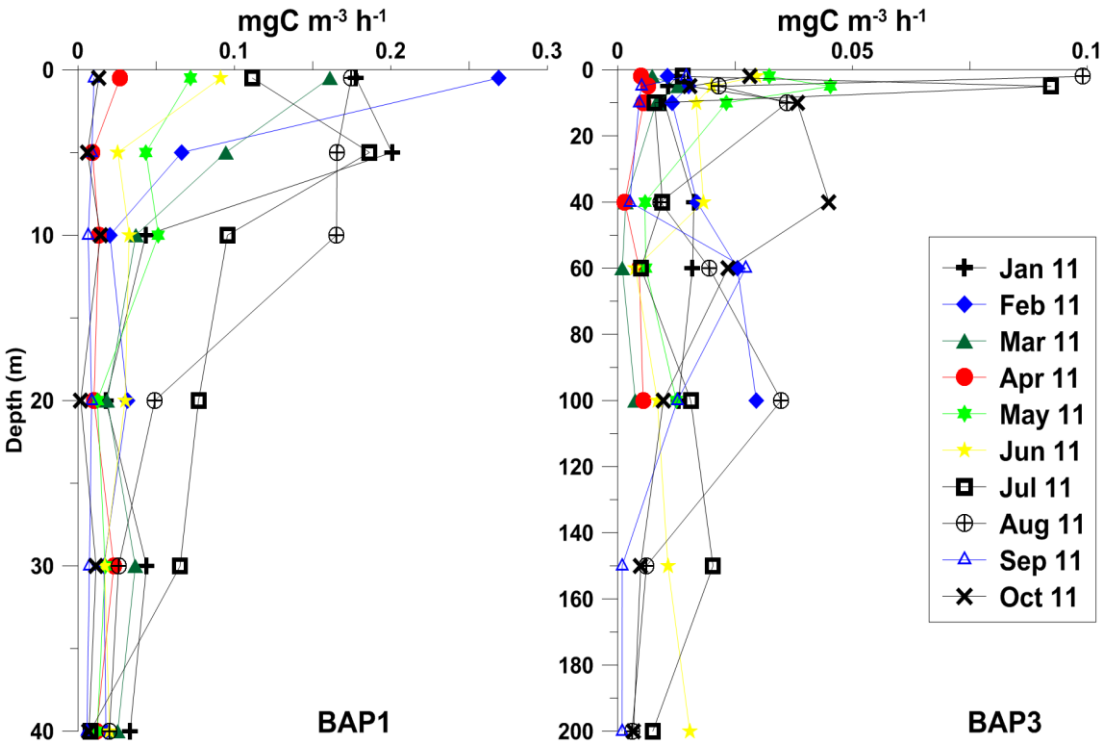


Figure 3.37. Monthly changes in bacterial carbon production (BCP) with depth and in time at stations BAP1 and BAP3.

Rates of Integrated bacterial carbon production (IBCP) fluctuated between 0.31 – 3.36 and 0.37 – 2.81 with mean values of 1.65 and 1.47 mgC.m^{-2} h^{-1} in the shelf and offshore, respectively (Figure 3.38). The highest values were observed in August 2011 in the shelf and in October 2011 in the offshore.

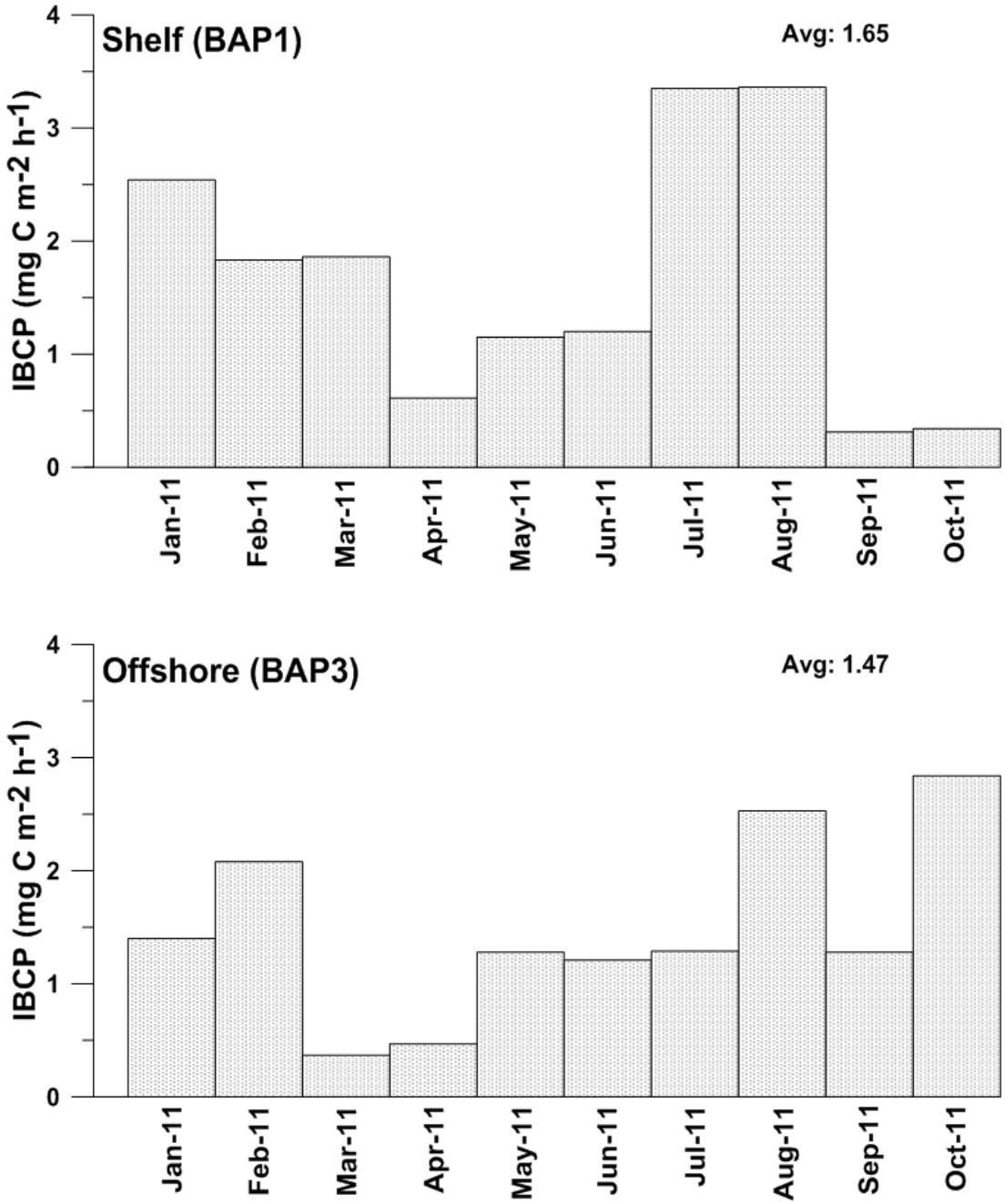


Figure 3.38. Depth integrated monthly bacterial carbon production rates at stations BAP1 (note that the total sampling depth = 40m) and BAP3 (total sampling depth = 100m).

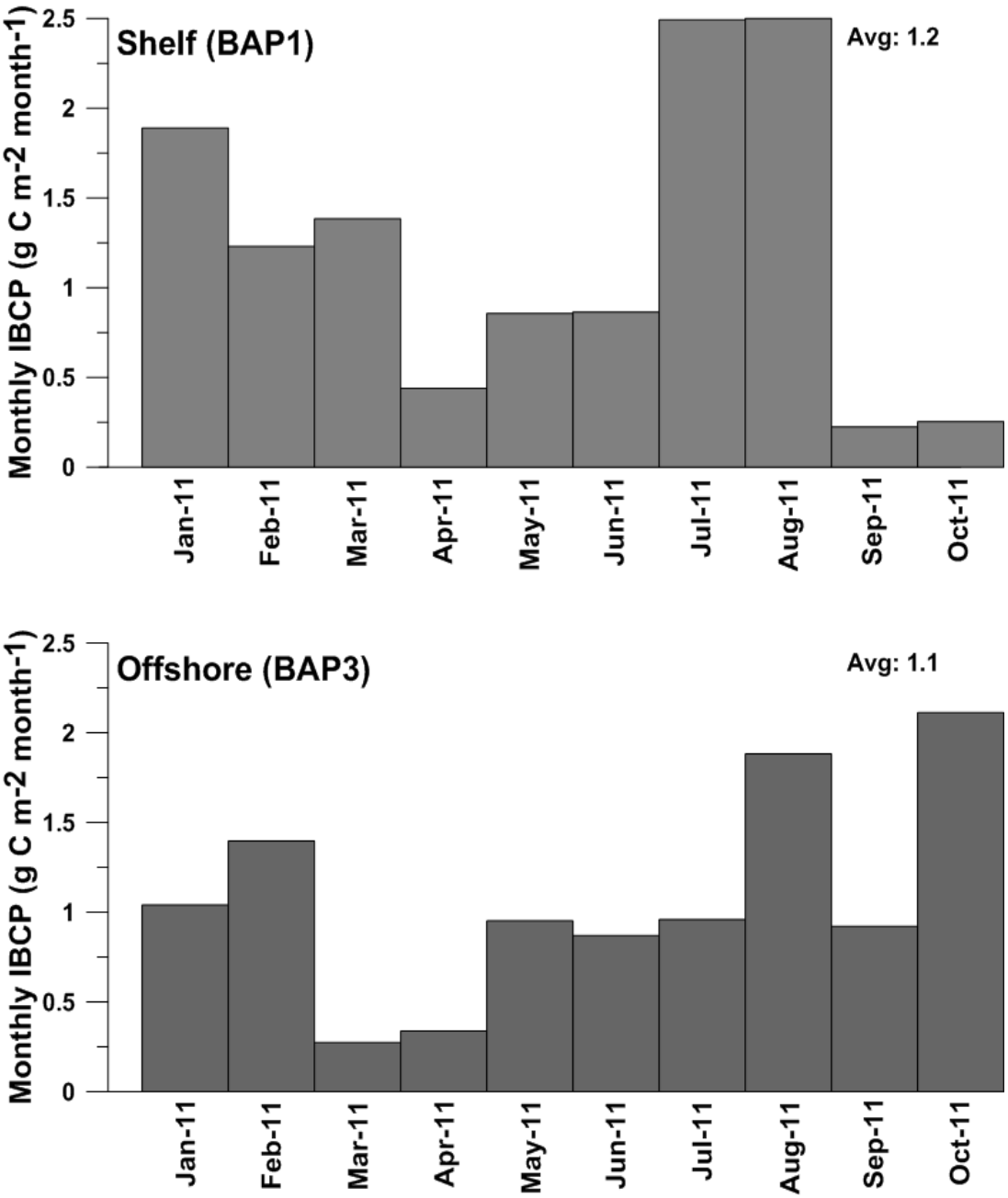


Figure 3.39. Depth integrated monthly bacterial carbon production rates at stations BAP1 (note that the total sampling depth = 40m) and BAP3 (total sampling depth = 100m).

Monthly integrated bacterial carbon production rates fluctuated between 0.2 – 2.5 and 0.3 – 2.1 with mean levels of 1.2 and 1.1 $gC.m^{-2}$ $month^{-1}$ in the shelf and offshore, respectively (Figure 3.39).

3.3.2.6. Bacterial Abundance (Heterotrophic Bacteria)

Heterotrophic bacterial abundance varied between 29686 and 1397129 cells ml^{-1} at the shelf and 11989 and 886253 cells ml^{-1} at the offshore station throughout the study period. Mean abundances for the shelf and offshore were 443306 and 233028 cells ml^{-1}, respectively. The population was found most abundant in July 11 in the shelf surface waters and in January 2011 at 150 m in the offshore. Bacteria also reached high abundances in the water column during June 2010 in the basin. Mean values were very low during July & August and November & December 2010 in coastal waters. Bacterial abundances were least during October 2011 in the shelf and during August 2010 and 2011 in the offshore. Bacterial abundance showed a sharp decrease below 5 m in July 2011 in the shelf. Deep maxima (≈ 160 m) were also recorded in few cases in the offshore. In general, abundance of heterotrophic bacteria decreased with increasing depth at both stations. Top 5 meters was found most abundant in shelf waters. Same trend was observed in offshore surface waters during July, August, September, and October (2010 and 2011). Summer values (2011) were found the highest in the shelf (seasonal mean was 523923 cells ml^{-1}). Also, higher abundance was observed in summer 2010 in BAP1. On the other hand, the highest seasonal abundance (seasonal mean 328305 cells ml^{-1}) was observed in winter in offshore waters. Mean bacterial abundance in 2010 (from May to October) was found 65 % and 35 % greater than 2011 (from May to October) in the offshore and shelf, respectively.

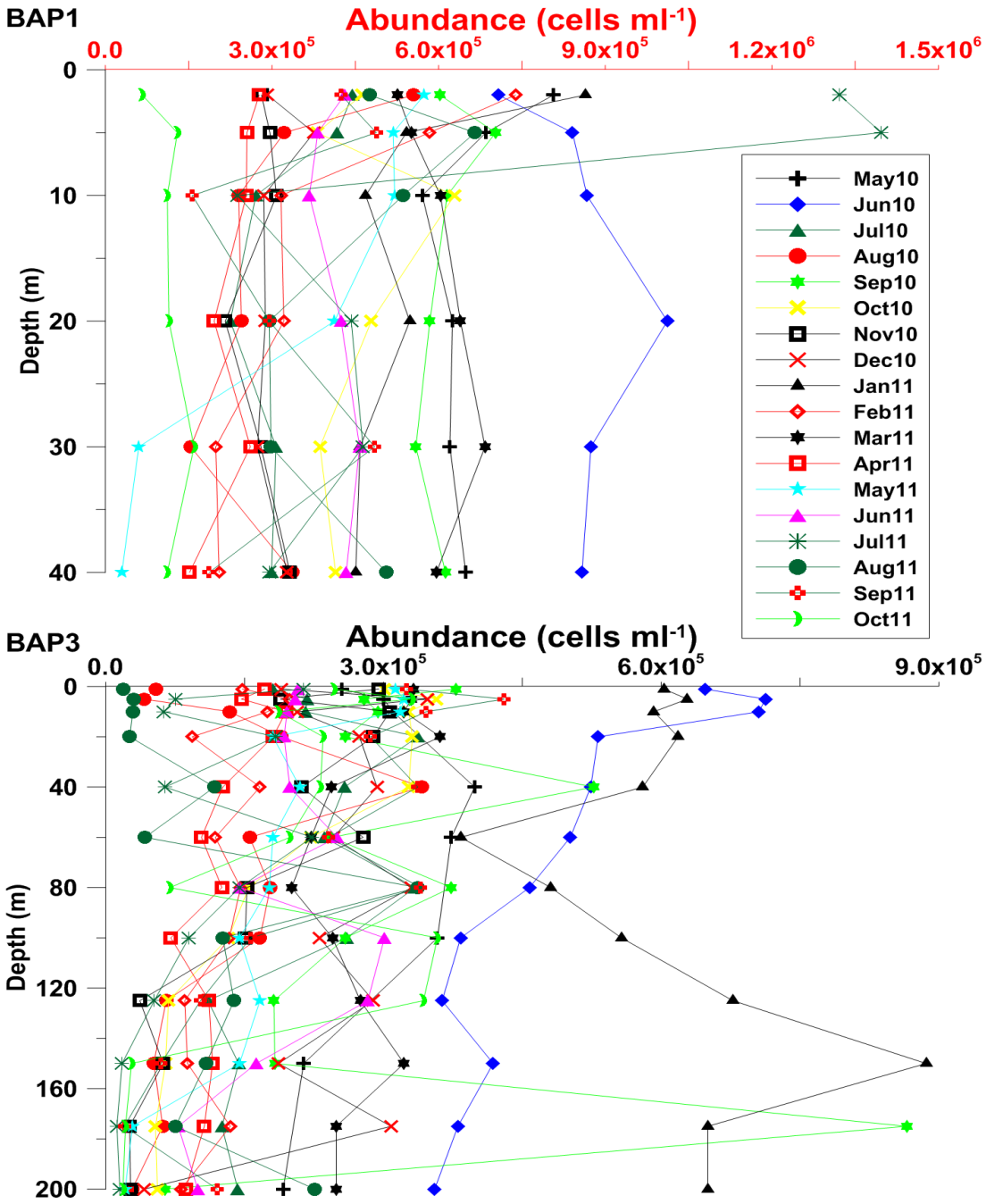


Figure 3.40. Monthly changes in heterotrophic bacterial abundance with depth at stations BAP1 and BAP3.

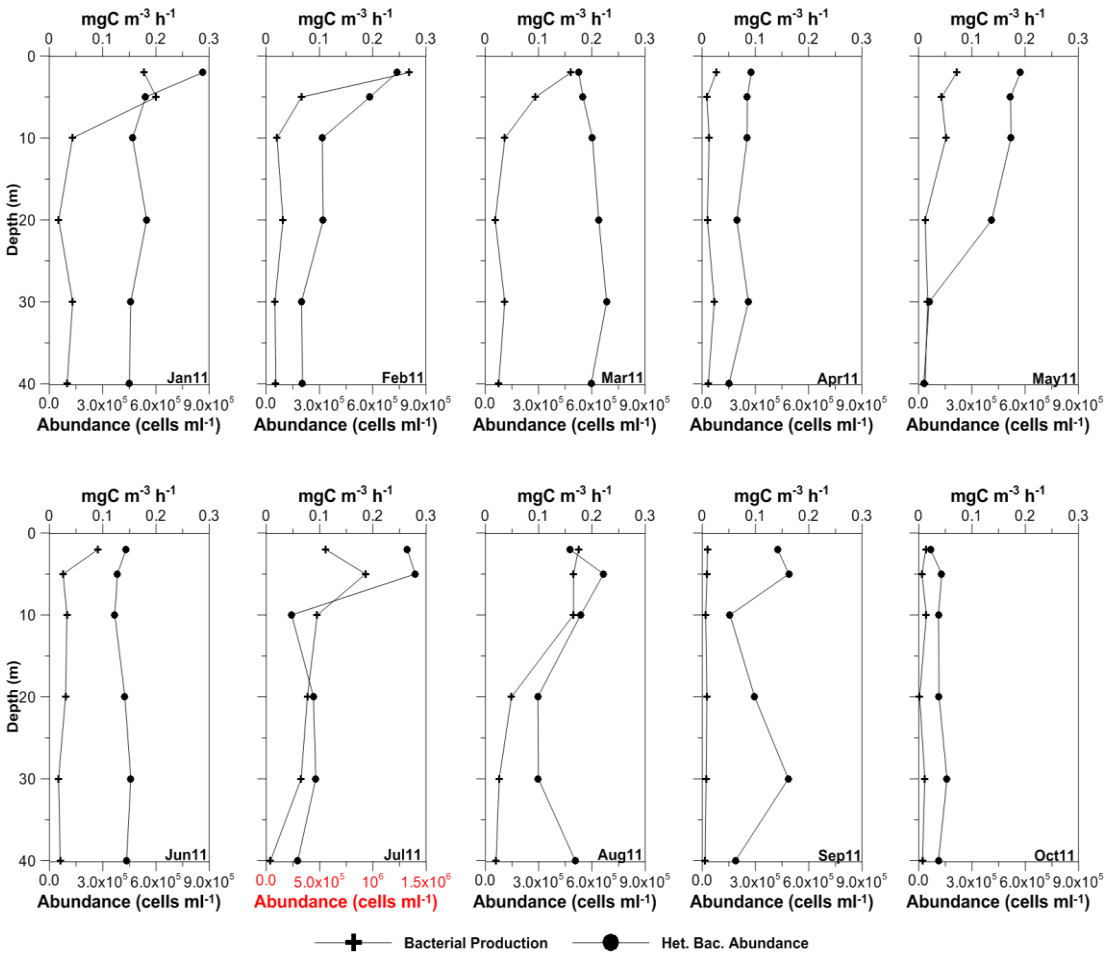


Figure 3.41. Bacterial carbon production and bacterial abundance profiles at station BAP1.

Bacterial carbon production (BCP) and bacterial abundance profiles mimicked the other in shelf waters. Highly significant positive correlations were observed between BCP and bacterial abundance (n: 60, r: 0.691, $P < 0.01$) in shelf waters. However, this close relationship was not true for the offshore profiles (Figure 3.42). High abundances did not yield high bacterial uptake as was the case in October 2011 in offshore waters. The maxima for production and abundance were observed at same depth (February and July 2011) in shelf waters (Figure 3.41). Although rate of BCP was distributed homogenously in the water column, abundance peaked two times in September 2011 in the shelf. BCP and abundance showed similar trends in the water column in February, April and May 2011 in coastal waters (Figure 3.41).

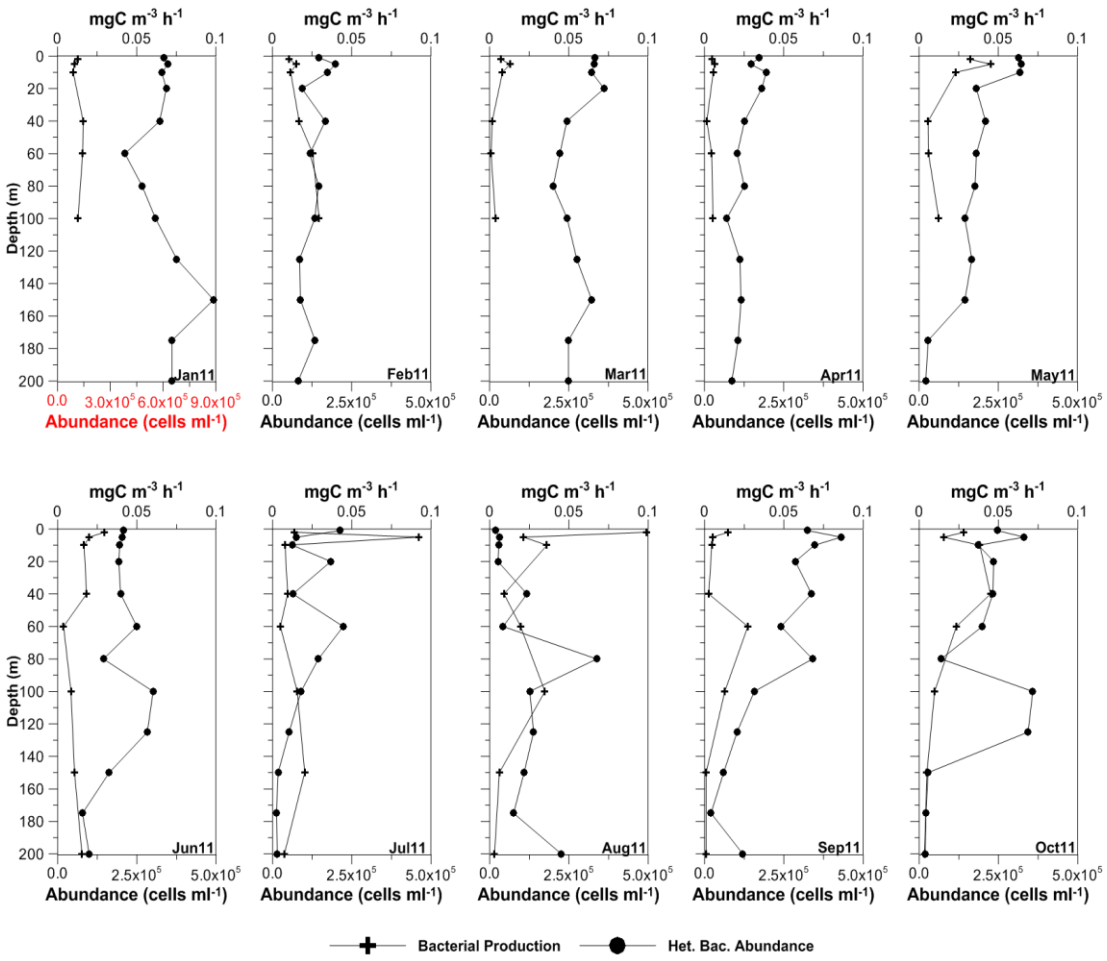


Figure 3.42. Bacterial carbon production and bacterial abundance profiles at station BAP3.

3.4. Limiting Nutrient Experiment Results

Limiting Nutrient experiments were accomplished monthly from January 2011 to October 2011.

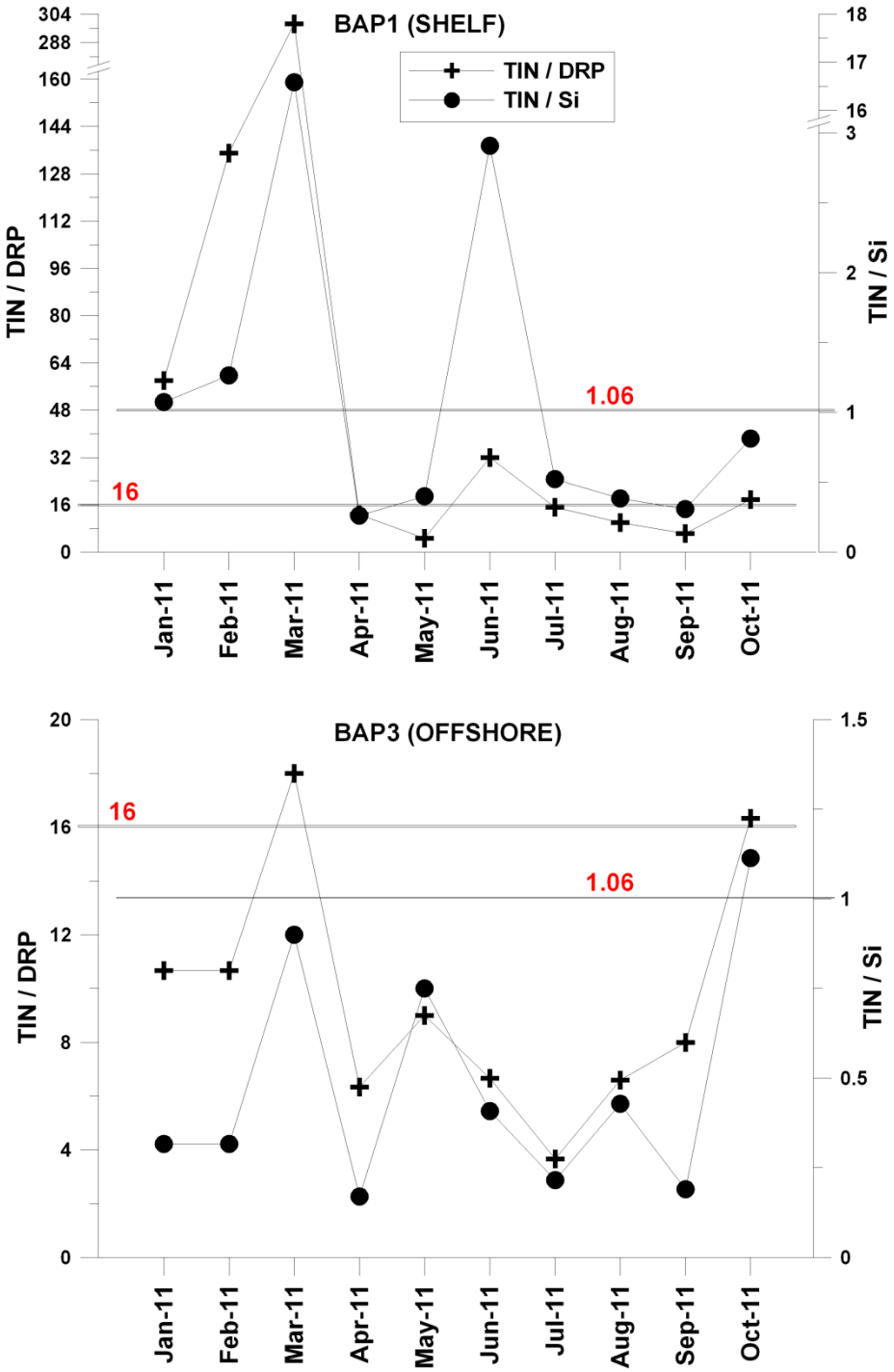


Figure 3.43. Changes in surface TIN/DRP and TIN/Si ratios at stations BAP1 and BAP3.

N/P (TIN/DRP) ratios were generally higher than 16 from January to October 2011 in shelf surface waters. This ratio increased to a peak value of 298 during March 2011 and a high value of 135 during February 2011. Very low N/P values were observed in May, August and September 2011 in coastal surface waters. N/Si (TIN/Si) ratios generally stayed below 1.06 (given Redfield ratio) at the shelf station with an extraordinary high value recorded in March 2011 (16.6). In offshore surface waters, N/P ratios were mostly found below 10 (except March and October 2011 during which the value increased to 16). Mean N/Si ratio was found below 0.5 in offshore surface waters.

Note: Cell counts, pigment concentrations and isotop activity in PP and BCP experiments were not converted to real or final values.

Primary Production was found to be P and N+P co-limited in the Cilician basin.

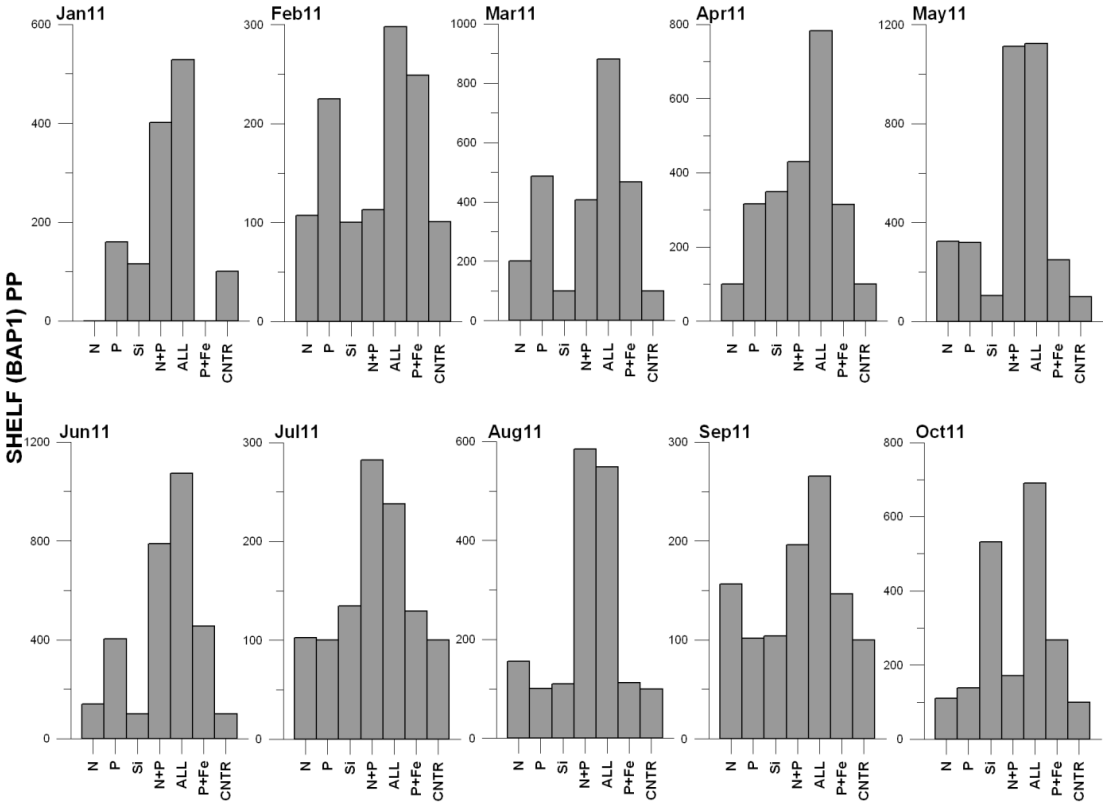


Figure 3.44. Primary production rates obtained at limiting nutrient experiments (2nd day) for the shelf waters.

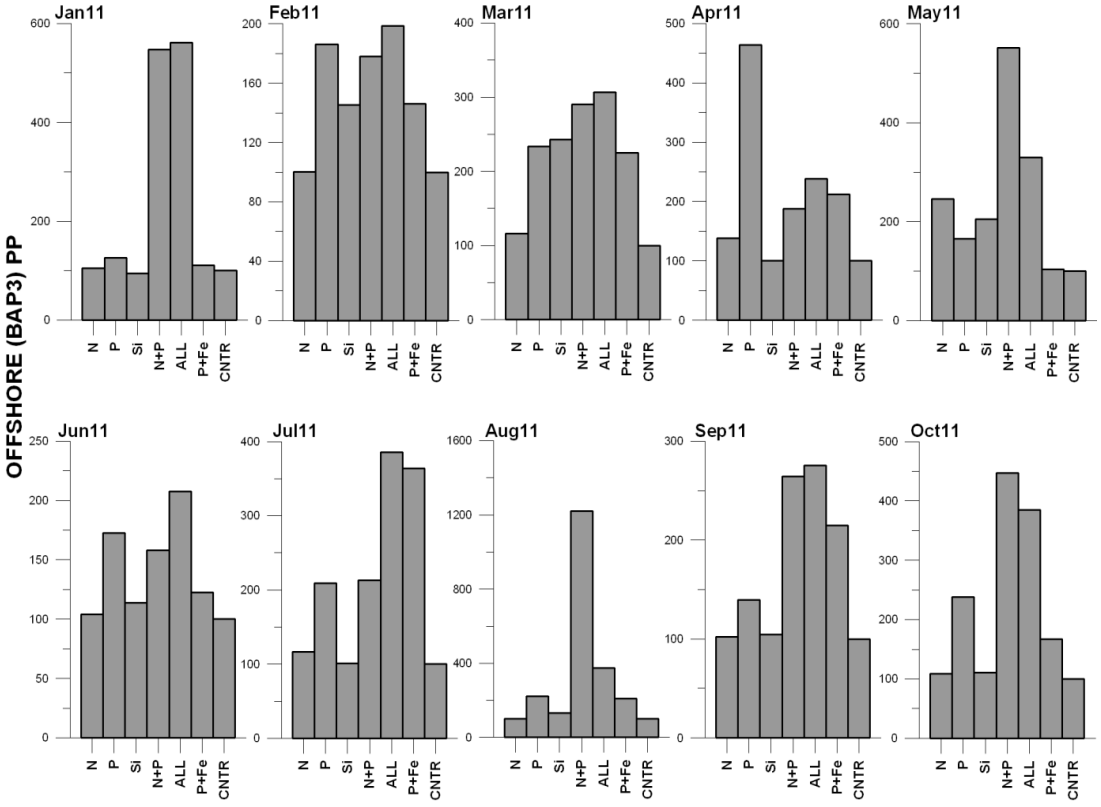


Figure 3.45. Primary production rates obtained at limiting nutrient experiments (2ndday) for the offshore waters.

The content of chlorophyll *a* was directly related to the presence of N+P, P and P+Fe in the basin.

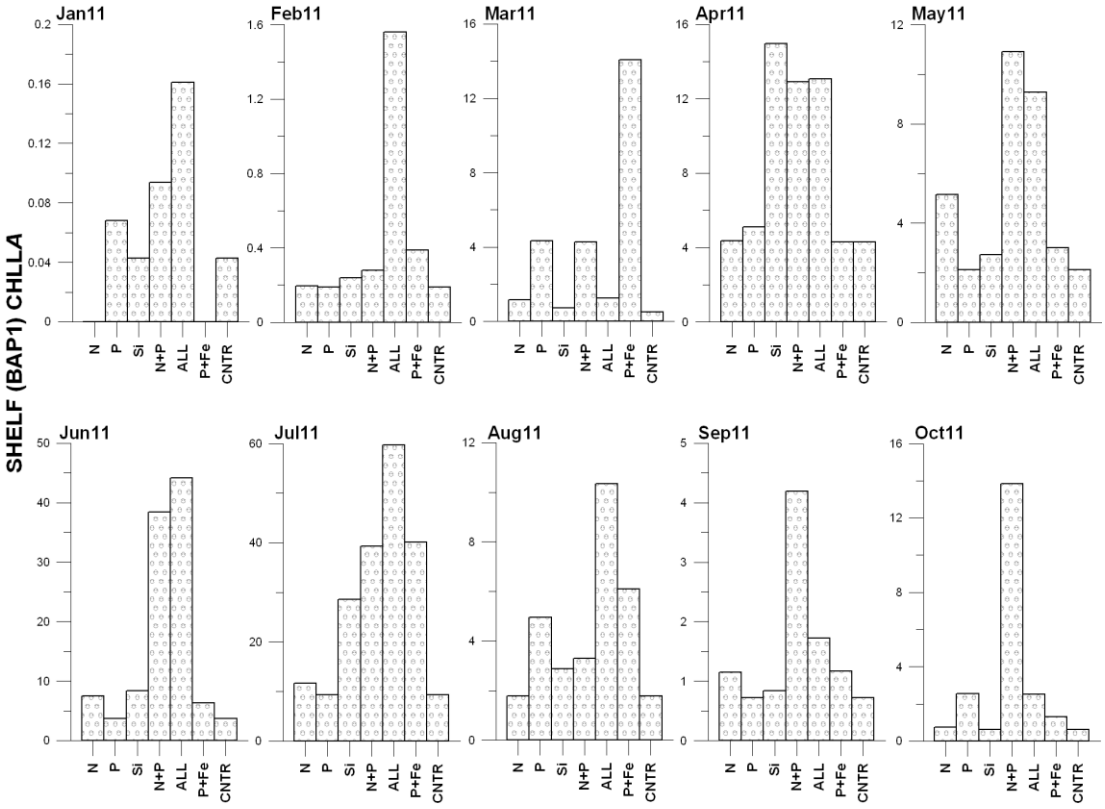


Figure 3.46. Changes in the amount of chlorophyll *a* during limiting nutrient experiments (3rd day) for the shelf waters.

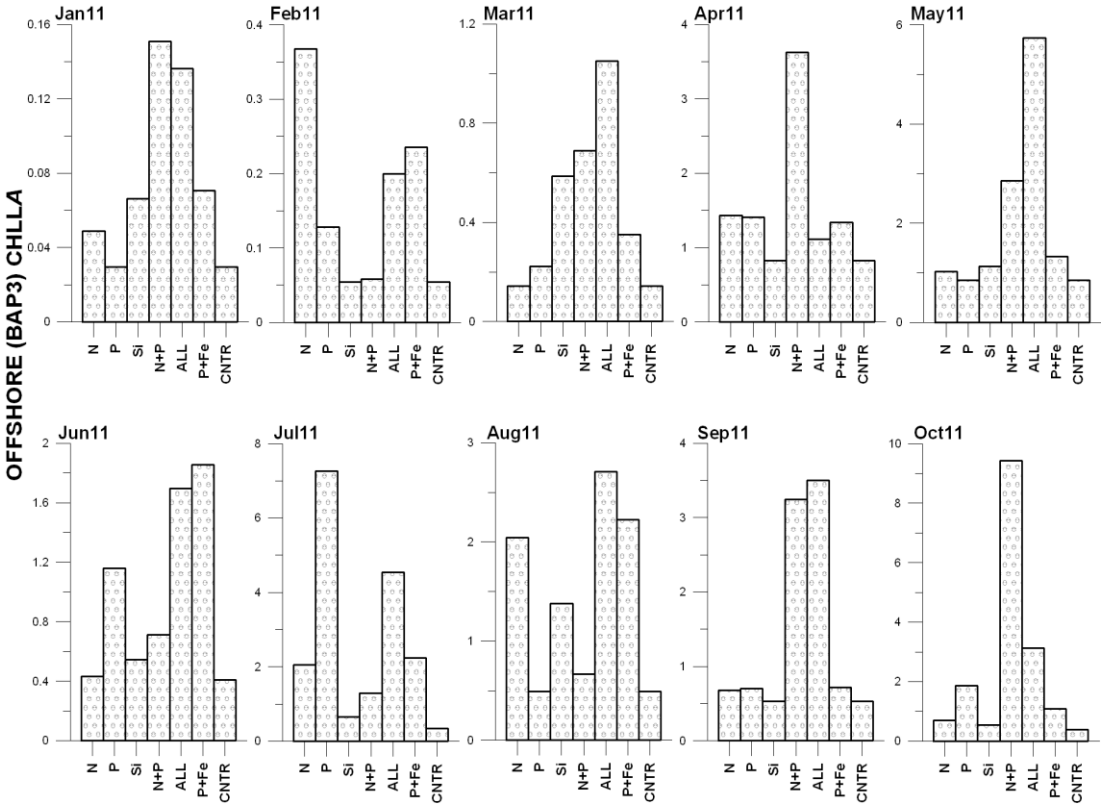


Figure 3.47. Changes in the amount of chlorophyll *a* during limiting nutrient experiments (3rdday) for the offshore waters.

Responses of different size classes of shelf and offshore phytoplankton to various nutrient types ((N+P, N, Si, P+Fe, P) are given in Figure 3.48 and 3.49. It is clearly seen from the figures that shelf and offshore phytoplankton respond differently to given nutrient recipes.

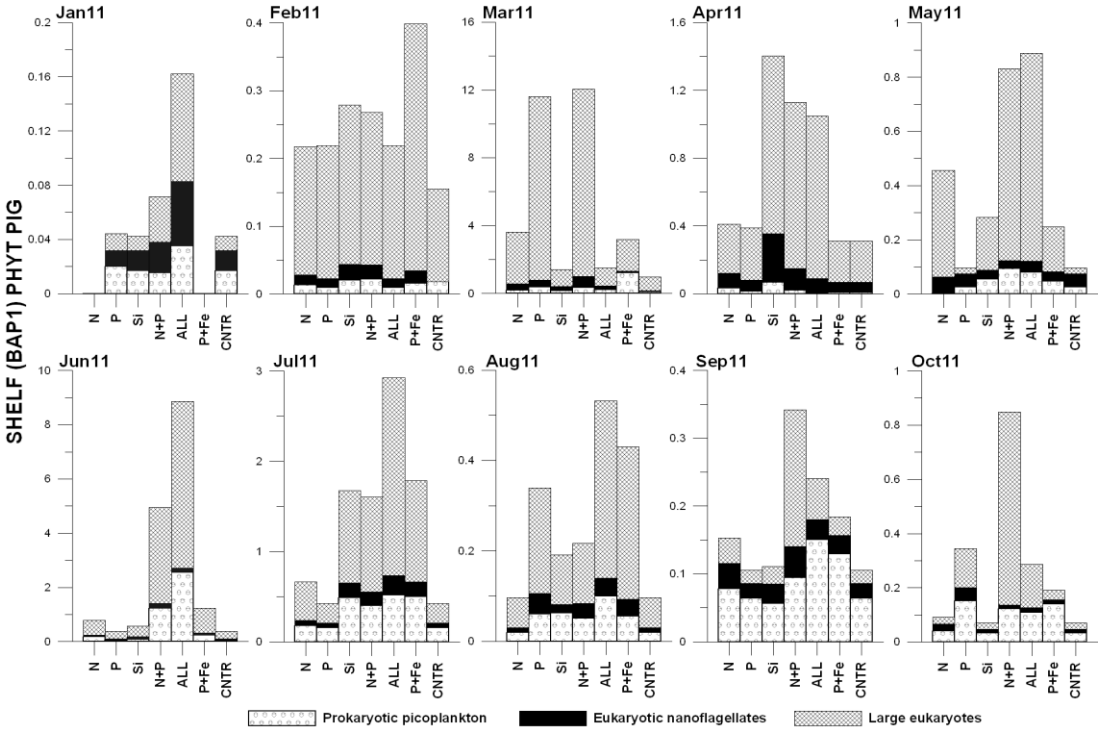


Figure 3.48. Success in different size classes (based on pigment concentrations) following nutrient enrichment for 3 days in shelf waters.

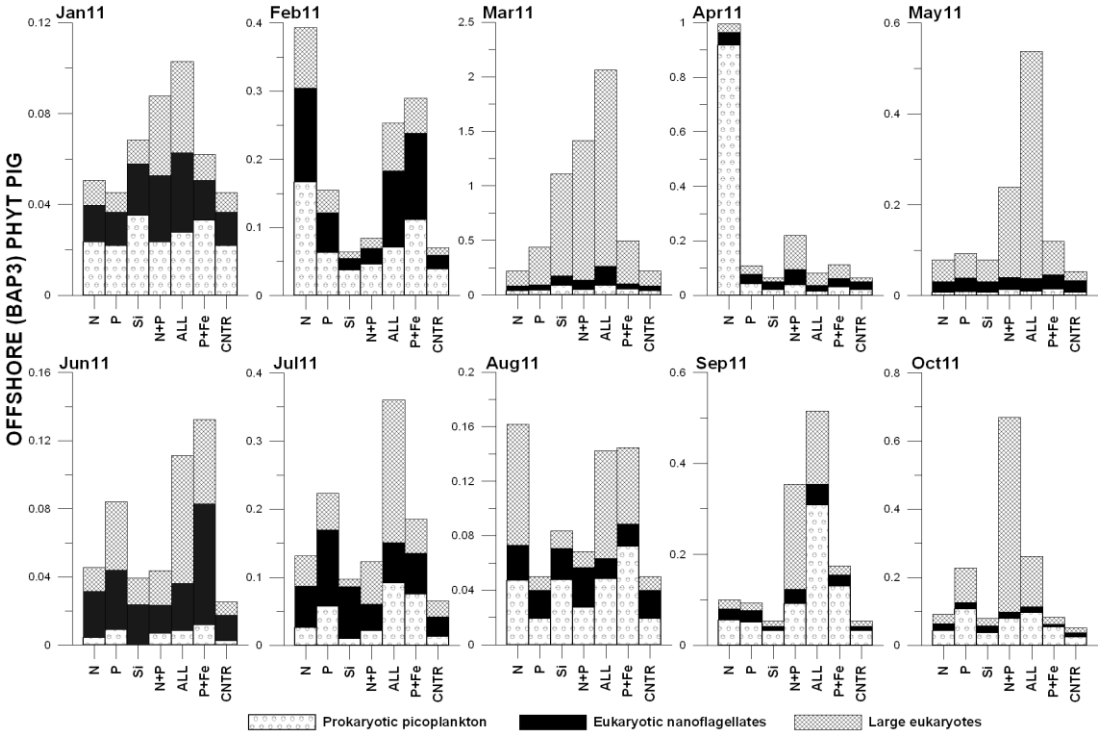


Figure 3.49. Success in different size classes (based on pigment concentrations) following nutrient enrichment for 3 days in offshore waters.

Bacterial Production was found to be N+P, P and P+Fe co-limited in the shelf and P+Fe and P co-limited in the offshore waters in the basin.

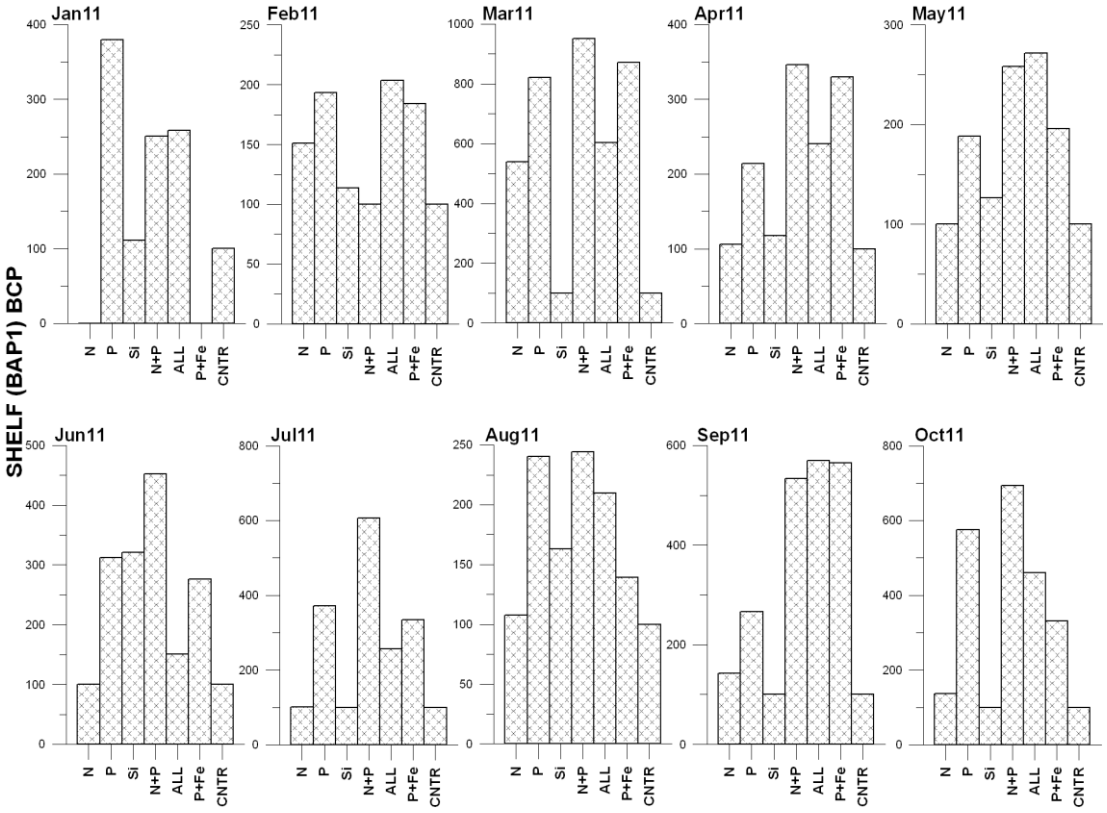


Figure 3.50. Bacterial carbon production rates measured during limiting nutrient experiments (2ndday) for shelf waters.

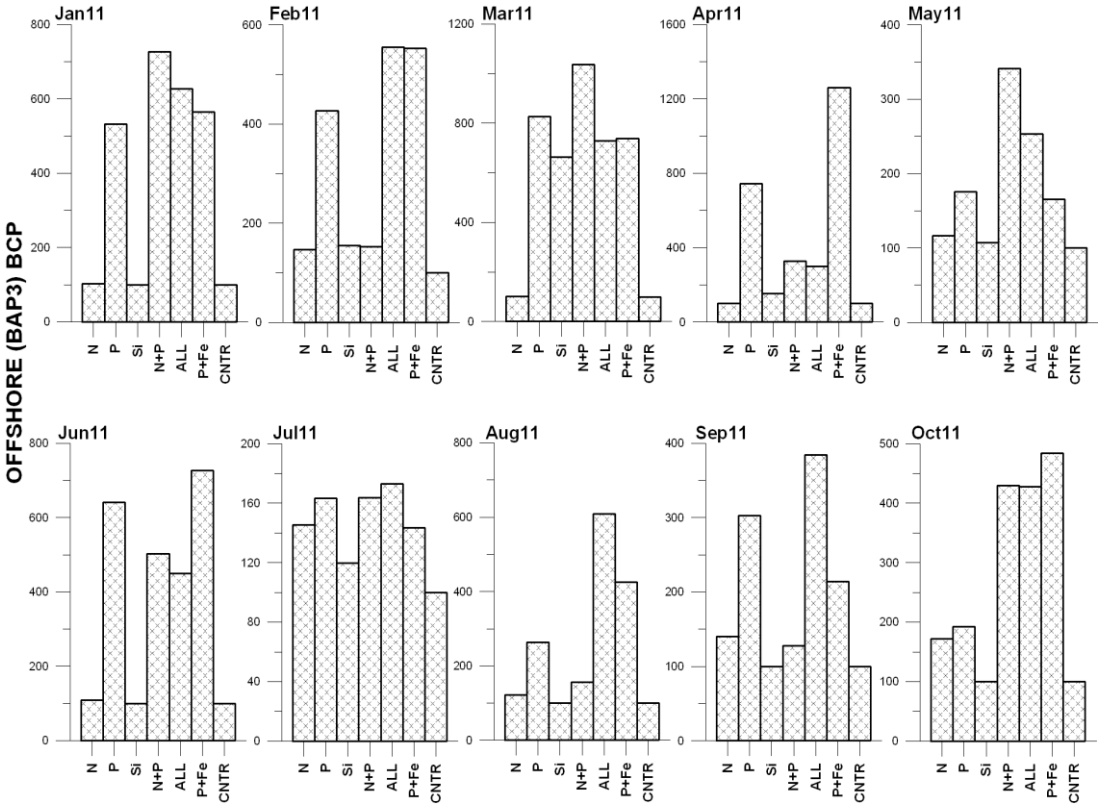


Figure 3.51. Bacterial carbon production rates measured during limiting nutrient experiments (2ndday) for offshore waters.

Growth of heterotrophic bacteria seemed to be controlled more by N+P and P in the shelf and by N+P and P+Fe in offshore waters.

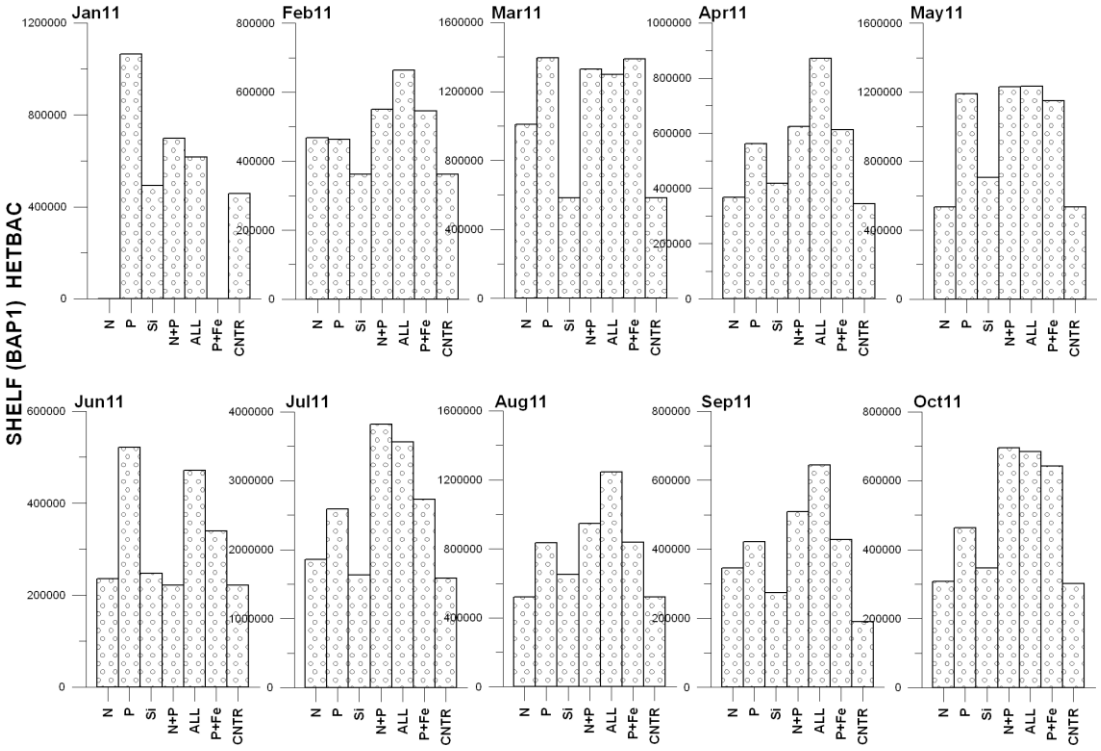


Figure 3.52. Changes in abundance of heterotrophic bacteria during the limiting nutrient experiments held for 3 days in the shelf.

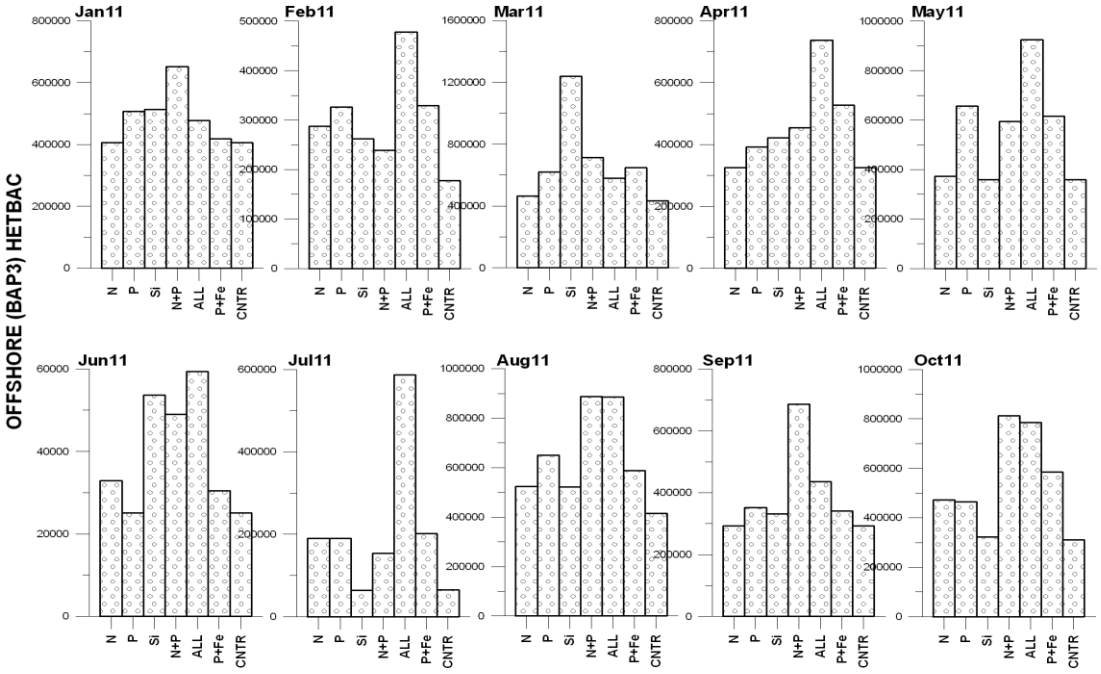


Figure 3.53. Changes in abundance of heterotrophic bacteria during the limiting nutrient experiments held for 3 days in the offshore.

The growth of coccoid cyanobacterium *Synechococcus spp.* was limited by N+P and P+Fe in the basin.

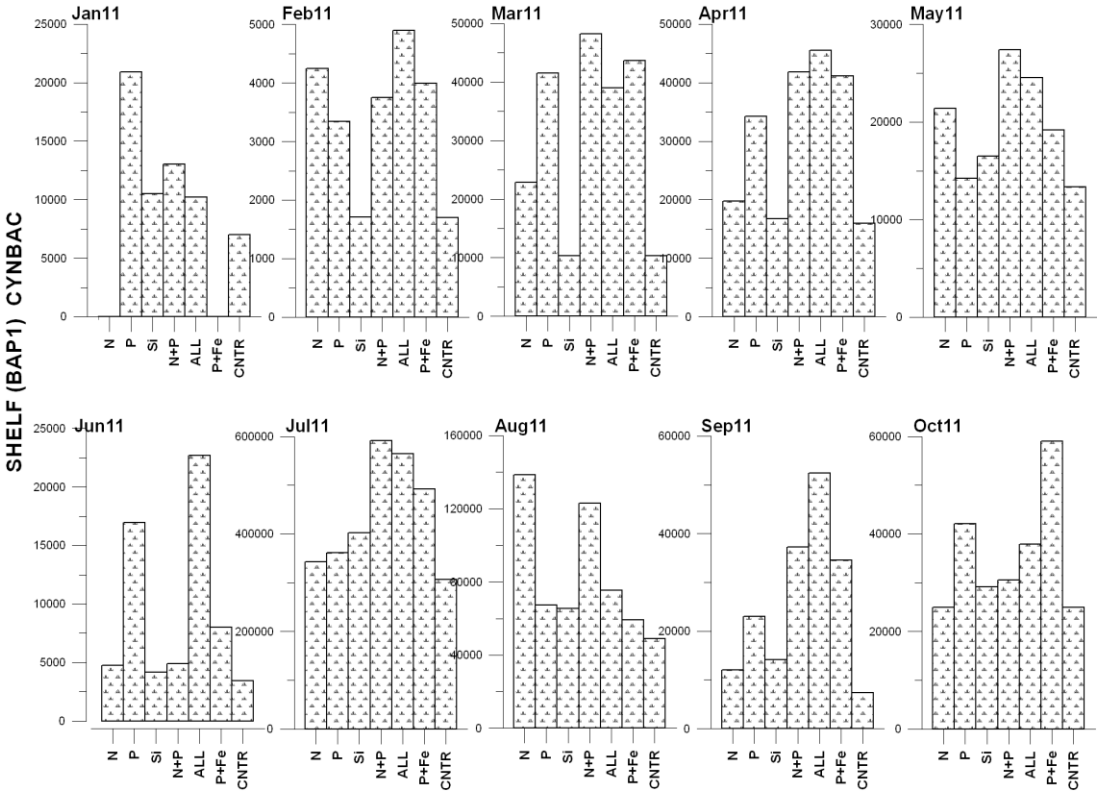


Figure 3.54. Changes in abundance of S*ynechococcus spp.* during limiting nutrient experiments held for 3 days in the shelf.

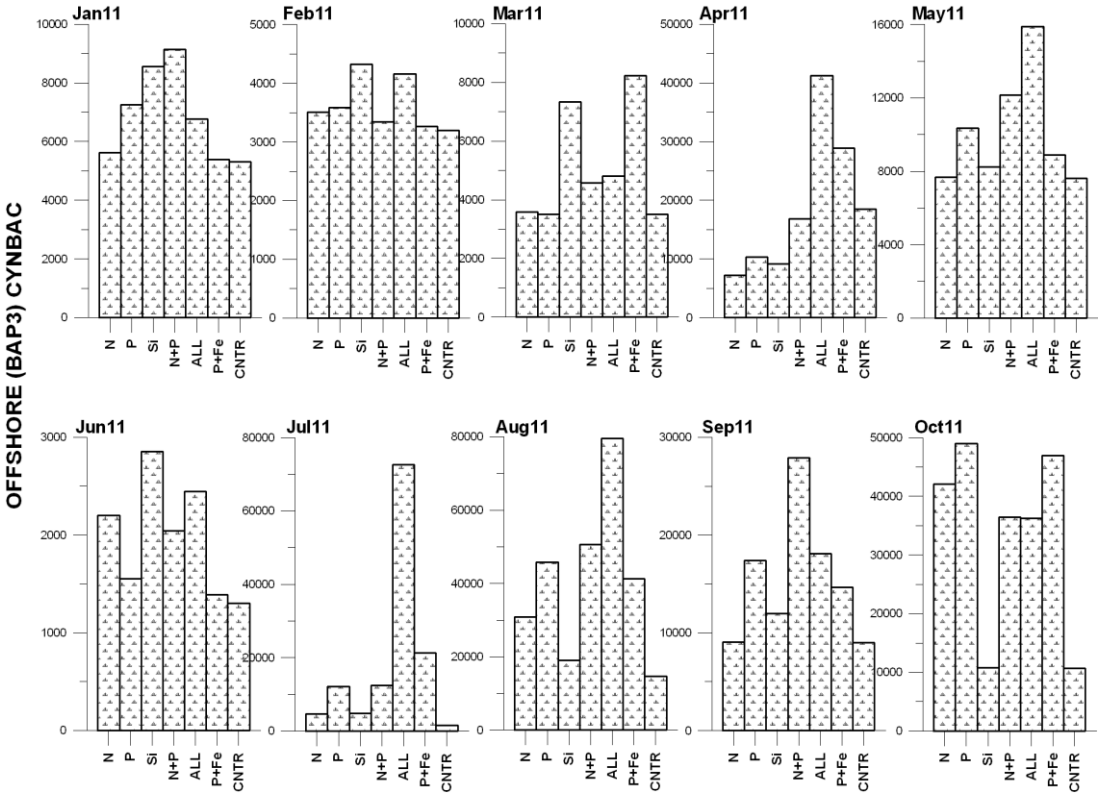


Figure 3.55. Changes in abundance of S*ynechococcus spp.* during limiting nutrient experiments held for 3 days in the offshore.

Table.3.1. List of limiting nutrients.

Months	PP		CHL-*a*		Tot-Pigment		BCP		HET-BAC		CYN-BAC	
	Shelf	Off	Shelf	Off	Shelf	Off	Shelf	Off	Shelf	Off	Shelf	Off
Jan11	**N+P**	**N+P**	**N+P**	**N+P**	**N+P**	**N+P**	**P**	**P**	**P**	**N+P**	**P**	**N+P**
Feb11	**P**	**P**	**P+Fe**	**N**	**Si**	**N**	**P**	**P+Fe**	**N+P**	**P+Fe**	**N**	**Si**
Mar11	**P**	**N+P**	**P**	**N+P**	**N+P**	**N+P**	**P+Fe**	**N+P**	**P**	**Si**	**P+Fe**	**P+Fe**
Apr11	**N+P**	**P**	**Si**	**N+P**	**Si**	**N**	**N+P**	**P+Fe**	**N+P**	**P+Fe**	**N+P**	**P+Fe**
May11	**N+P**	**N+P**	**N+P**	**N+P**	**N+P**	**N+P**	**N+P**	**N+P**	**N+P**	**P**	**N+P**	**N+P**
Jun11	**N+P**	**P**	**N+P**	**P+Fe**	**N+P**	**P+Fe**	**N+P**	**P+Fe**	**P**	**Si**	**P**	**Si**
Jul11	**N+P**	**P**	**N+P**	**P**	**P+Fe**	**P**	**N+P**	**P**	**N+P**	**P+Fe**	**N+P**	**P+Fe**
Aug11	**N+P**	**N+P**	**P**	**P+Fe**	**P+Fe**	**N**	**N+P**	**P+Fe**	**N+P**	**N+P**	**N**	**N+P**
Sep11	**N+P**	**N+P**	**N+P**	**N+P**	**N+P**	**N+P**	**P+Fe**	**P**	**N+P**	**N+P**	**N+P**	**N+P**
Oct11	**Si**	**N+P**	**N+P**	**N+P**	**N+P**	**N+P**	**P**	**P+Fe**	**N+P**	**N+P**	**P+Fe**	**P**

3.5. Statistical Analysis

Spearman rank-order correlation was done to search for any possible relationships that may exist between biological (size fractioned primary production and chlorophyll *a*, phytoplankton pigment composition, bacterial carbon production, heterotrophic bacteria), chemical (phosphate, nitrite+nitrat, nitrite, ammonium, silicate) and physical (temperature, salinity and density, Secchi depth) parameters. (Bacterial carbon production and heterotrophic bacteria were not measured at stations T27 and T48.) Highly significant ($p < 0.01$) and significant ($p < 0.05$) correlations (negative or positive) were found between parameters given both for the shelf and offshore.

Table.3.2. List of Abbreviations and Parameters used on correlation analysis.

PARAMETERS	ABBREVIATIONS	PARAMETERS
Physical	**TEMP**	Temperature
	SAL	Salinity
	DENS	Density
	SDD	Secchi Disc Depth
Chemical	**PO4**	Phosphate
	NO2+NO3	Nitrite+Nitrate
	NO2	Nitrite
	NH4	Ammonium
	Si	Silicate
Biological	**CHL-L**	Larger cells Chlorophyll a (larger than 5µm)
	CHL-P	Picoplanktonic Chlorophyll a (0.2-2µm)
	CHL-N	Nanoplanktonic Chlorophyll a (2-5µm)
	CHL-T	Total Chlorophyll a
	PP-L	Larger cells Primary Production (larger than
	PP-P	Picoplanktonic Primary Production (0.2-2µm)
	PP-N	Nanoplanktonic Primary Production (2-5µm)
	PP-T	Total Primary Production
	LARG	Large eukaryotes
	NANO	Eukaryotic Nanoplankton
	PROK	Prokaryotic Picoplankton
	BCP	Bacterial Production
	HET-BAC	Heterotrophic Bacterial Abundance
	PER	Peridinin
	BUT	19-butanoyloxyfucoxanthin
	FUC	Fucoxanthin
	HEX	19-hexanoyloxyfucoxanthin
	ZEA	Zeaxanthin
	CHL-B	Chlorophyll-*b*
	DIV-A	Divinyl chlorophyll-a
	POC	Particulate Organic Carbon

Table.3.3. List of correlations between physical, chemical and biological data for T27.

T-27

CC: Correlation Coefficient

Sig: Sig. (1-tailed)

N: Number of Data

** Correlation is significant at the 0.01 level (1-tailed).

* Correlation is significant at the 0.05 level (1-tailed).

		TEMP	SAL	DEN	PO4	NO2+NO3	NO2	NH4	Si	CHL-L	CHL-P	CHL-N	CHL-T	PP-L	PP-P	PP-N	PP-T	LARG	NANO	PROK	PER	BUT	FUC	HEX	ZEA	CHL-B	DIV-A
SAL	CC	.456(**)																									
	Sig	0																									
	N	73																									
DEN	CC	-.925(**)	-.212(*)																								
	Sig	0	0.036																								
	N	73	73																								
PO4	CC	-0.15	-.339(**)	0.104																							
	Sig	0.103	0.002	0.191																							
	N	73	73	73																							
NO2+NO3	CC	-.388(**)	-.226(*)	.246(*)	0.113																						
	Sig	0	0.027	0.018	0.17																						
	N	73	73	73	73																						
NO2	CC	-.430(**)	-0.144	.285(**)	.242(*)	.564(**)																					
	Sig	0	0.112	0.007	0.02	0																					
	N	73	73	73	73	73																					
NH4	CC	0.063	.329(**)	0.005	0.005	.572(**)	.380(**)																				
	Sig	0.297	0.002	0.482	0.484	0	0																				
	N	73	73	73	73	73	73																				
Si	CC	-.261(*)	-.307(**)	0.064	.382(**)	.557(**)	.760(**)	.320(**)																			
	Sig	0.013	0.004	0.296	0	0	0	0.003																			
	N	73	73	73	73	73	73	73																			
CHL-L	CC	-.481(**)	-.545(**)	.323(*)	.493(**)	.382(*)	.685(**)	0.304	.505(**)																		
	Sig	0.004	0.001	0.041	0.003	0.019	0	0.051	0.002																		
	N	30	30	30	30	30	30	30	30																		
CHL-P	CC	-0.216	-0.143	0.001	0.029	.402(*)	.372(*)	0.23	.306(*)	0.231																	
	Sig	0.126	0.226	0.497	0.44	0.014	0.021	0.111	0.05	0.11																	
	N	30	30	30	30	30	30	30	30	30																	
CHL-N	CC	-.332(*)	-0.193	0.167	.318(*)	.600(**)	.694(**)	.386(**)	.623(**)	.381(*)	.696(**)																
	Sig	0.036	0.153	0.188	0.043	0	0	0.018	0	0.019	0																
	N	30	30	30	30	30	30	30	30	30	30																
CHL-T	CC	-.233(*)	-.313(**)	0.17	.559(**)	0.057	0.164	-0.062	0.166	.830(**)	.590(**)	.748(**)															
	Sig	0.024	0.003	0.075	0	0.317	0.083	0.302	0.081	0	0	0															
	N	73	73	73	73	73	73	73	73	30	30	30															
PP-L	CC	-0.035	-.480(**)	-0.15	0.12	-0.021	0.001	-.243(*)	0.023	0.26	0.135	0.132	0.202														
	Sig	0.392	0	0.118	0.173	0.435	0.497	0.026	0.429	0.083	0.239	0.243	0.055														
	N	64	64	64	64	64	64	64	64	30	30	30	64														
PP-P	CC	.354(**)	0.148	-.430(**)	-0.126	-.361(**)	-0.096	-0.176	-0.087	-.628(**)	-0.088	-0.218	-0.186	.540(**)													
	Sig	0.002	0.122	0	0.161	0.002	0.225	0.082	0.247	0	0.322	0.124	0.071	0													
	N	64	64	64	64	64	64	64	64	30	30	30	64	64													
PP-N	CC	0.18	-0.126	-.293(**)	0.1	-0.193	-0.07	-.293(**)	-0.049	0.15	0.208	0.219	.212(*)	.718(**)	.569(**)												
	Sig	0.078	0.161	0.009	0.216	0.064	0.292	0.009	0.35	0.215	0.135	0.122	0.046	0	0												
	N	64	64	64	64	64	64	64	64	30	30	30	64	64	64												
PP-T	CC	0.133	-.227(*)	-.268(*)	0.067	-.275(*)	-0.096	-.331(**)	-0.038	-0.026	0.043	-0.013	0.092	.873(**)	.830(**)	.819(**)											
	Sig	0.136	0.03	0.012	0.291	0.011	0.239	0.003	0.378	0.445	0.41	0.473	0.224	0	0	0											
	N	70	70	70	70	70	70	70	70	30	30	30	70	63	63	63											
LARG	CC	-.291(**)	-.462(**)	0.068	0.122	.383(**)	.442(**)	0.012	.473(**)	.694(**)	.394(*)	.568(**)	.312(**)	.505(**)	0.034	.256(*)	.238(*)										
	Sig	0.01	0	0.295	0.168	0.001	0	0.464	0	0	0.017	0.001	0.006	0	0.396	0.022	0.033										
	N	64	64	64	64	64	64	64	64	29	29	29	64	62	62	62	61										
NANO	CC	-.367(**)	-0.163	.212(*)	-0.162	.410(**)	.364(**)	.262(*)	.270(*)	.391(*)	.452(**)	.555(**)	.284(*)	.261(*)	-0.001	0.174	0.122	.466(**)									
	Sig	0.001	0.099	0.046	0.1	0	0.002	0.018	0.016	0.018	0.007	0.001	0.011	0.02	0.497	0.089	0.175	0									
	N	64	64	64	64	64	64	64	64	29	29	29	64	62	62	62	61	64									
PROK	CC	.427(**)	.435(**)	-.399(**)	-0.031	-.325(**)	0.089	0.171	0.074	0.055	.412(*)	.360(*)	0.134	0.122	.415(**)	.336(**)	.317(**)	0.119	.289(*)								
	Sig	0	0.001	0	0.404	0.004	0.242	0.088	0.28	0.388	0.013	0.027	0.146	0.173	0	0.004	0.006	0.174	0.01								
	N	64	64	64	64	64	64	64	64	29	29	29	64	62	62	62	61	64	64								
PER	CC	.395(**)	-0.078	-.516(**)	.265(*)	-0.068	0.131	0.07	.303(**)	.544(**)	.497(**)	.607(**)	.427(**)	.383(**)	.276(*)	.398(**)	.384(**)	.482(**)	.251(*)	.628(**)							
	Sig	0.001	0.271	0	0.017	0.298	0.152	0.292	0.008	0.001	0.003	0	0	0.001	0.014	0.001	0.001	0	0.024	0							
	N	64	64	64	64	64	64	64	64	29	29	29	64	63	63	63	62	63	63	63							
BUT	CC	-.486(**)	-0.127	.446(**)	-0.003	.412(**)	.229(*)	.335(**)	0.105	.475(**)	.337(*)	.444(**)	.288(*)	0.175	-0.095	0.041	0.009	.289(*)	.760(**)	0.033	0.036						
	Sig	0	0.158	0	0.49	0	0.034	0.003	0.204	0.005	0.037	0.008	0.01	0.084	0.23	0.376	0.473	0.011	0	0.399	0.387						
	N	64	64	64	64	64	64	64	64	29	29	29	64	63	63	63	62	63	63	63	64						
FUC	CC	-.331(**)	-.419(**)	0.131	0.093	.396(**)	.458(**)	0.062	.471(**)	.668(**)	.373(*)	.550(**)	.295(**)	.466(**)	-0.037	0.204	0.2	.992(**)	.468(**)	0.099	.444(**)	.318(**)					
	Sig	0.004	0	0.152	0.233	0.001	0	0.312	0	0	0.023	0.001	0.009	0	0.387	0.054	0.06	0	0	0.221	0	0.005					
	N	64	64	64	64	64	64	64	64	29	29	29	64	63	63	63	62	63	63	63	64	64					
HEX	CC	-.369(**)	-0.058	.262(*)	-.224(*)	.393(**)	.387(**)	.304(**)	.298(**)	0.244	.479(**)	.509(**)	.262(*)	0.203	0.077	0.126	0.104	.423(**)	.856(**)	.285(*)	0.166	.627(**)	.457(**)				
	Sig	0.001	0.324	0.018	0.038	0.001	0.001	0.007	0.008	0.101	0.004	0.002	0.018	0.055	0.276	0.163	0.211	0	0	0.012	0.095	0	0				
	N	64	64	64	64	64	64	64	64	29	29	29	64	63	63	63	62	63	63	63	64	64	64				
ZEA	CC	.461(**)	.257(*)	-.521(**)	-0.031	-.264(*)	0.152	0.113	0.155	0.145	.493(**)	.412(*)	.221(*)	.226(*)	.415(**)	.322(**)	.356(**)	.283(*)	.365(**)	.924(**)	.745(**)	0.083	.274(*)	.367(**)			
	Sig	0	0.02	0	0.405	0.017	0.115	0.188	0.111	0.226	0.003	0.013	0.04	0.037	0	0.005	0.002	0.012	0.002	0	0	0.257	0.014	0.001			
	N	64	64	64	64	64	64	64	64	29	29	29	64	63	63	63	62	63	63	63	64	64	64	64			
CHL-B	CC	-0.111	-.325(**)	-0.135	0.024	.440(**)	.373(**)	0.155	.422(**)	0.087	.557(**)	.514(**)	0.182	0.087	-0.064	-0.04	-0.022	.393(**)	.450(**)	0.034	.317(**)	0.162	.381(**)	.364(**)	.217(*)		
	Sig	0.192	0.004	0.144	0.425	0	0.001	0.111	0	0.326	0.001	0.002	0.075	0.248	0.308	0.379	0.434	0.001	0	0.397	0.005	0.1	0.001	0.002	0.042		
	N	64	64	64	64	64	64	64	64	29	29	29	64	63	63	63	62	63	63	63	64	64	64	64	64		
DIV-A	CC	0.054	.722(**)	0.167	-0.103	-.224(*)	-0.067	.211(*)	-0.184	-0.306	0.05	0.033	-0.074	-.416(**)	0.098	-0.151	-0.161	-.508(**)	-0.031	.419(**)	-0.164	0.136	-.471(**)	0.141	0.195	-.267(*)	
	Sig	0.335	0	0.209	0.038	0.301	0.047	0.073	0.053	0.139	0.433	0.282	0	0.222	0.119	0.105	0	0.405	0	0.098	0.143	0	0.133	0.061	0.016		
	N	64	64	64	64	64	64	64	64	29	29	29	64	63	63	63	62	63	63	63	64	64	64	64	64		
SDD	CC	0.041	-0.115	-0.111	-0.041	-0.4	-0.48	-0.221	-0.198	0	-0.2	-0.4	-0.3	0.055	0.275	-0.165	0.185	-0.257	0.404	0.239	-0.359	0.379	-0.318	0.33	0.306	-0.367	0.17
	Sig	0.452	0.368	0.373	0.453	0.112	0.067	0.257	0.28	0.5	0.4	0.3	0.185	0.44	0.221	0.324	0.305	0.237	0.124	0.253	0.154	0.14	0.185	0.176	0.195	0.149	0.32
	N	11	11	11	11	11	11	11	11	4	4	4	11	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Table.3.4. List of correlations between physical, chemical and biological data for T48.

T-48

CC: Correlation Coefficient

Sig: Sig. (1-tailed)

N: Number of Data

** Correlation is significant at the 0.01 level (1-tailed).

* Correlation is significant at the 0.05 level (1-tailed).

		TEMP	SAL	DEN	PO4	NO2+NO3	NO2	NH4	Si	CHL-L	CHL-P	CHL-N	CHL-T	PP-L	PP-P	PP-N	PP-T	LARG	NANO	PROK	PER	BUT	FUC	HEX	ZEA	CHL-B	DIV-A
SAL	CC	.384(**)																									
	Sig	0																									
	N	73																									
DEN	CC	-.930(**)	.219(*)																								
	Sig	0	0.032																								
	N	73	73																								
PO4	CC	0.121	-0.11	-.219(*)																							
	Sig	0.155	0.177	0.032																							
	N	73	73	73																							
NO2+NO3	CC	-0.115	0.064	0.127	.336(**)																						
	Sig	0.167	0.295	0.143	0.002																						
	N	73	73	73	73																						
NO2	CC	-.397(**)	0.084	.337(**)	0.192	.397(**)																					
	Sig	0.002	0.24	0.002	0.052	0																					
	N	73	73	73	73	73																					
NH4	CC	.280(**)	-0.082	-.266(*)	.244(*)	0.153	-0.162				**																
	Sig	0.008	0.244	0.012	0.019	0.098	0.086																				
	N	73	73	73	73	73	73																				
Si	CC	-0.071	0.025	0.094	-0.166	0.055	-0.003	0.118																			
	Sig	0.276	0.417	0.215	0.08	0.322	0.491	0.161																			
	N	73	73	73	73	73	73	73																			
CHL-L	CC	-.665(**)	0.187	.692(**)	-.309(*)	0.253	.648(**)	-.449(**)	.427(**)																		
	Sig	0	0.161	0	0.048	0.089	0	0.006	0.009																		
	N	73	73	73	73	73	73	73	73																		
CHL-P	CC	-0.134	0.212	0.055	-0.126	0.196	0.215	0.044	.309(*)	.383(*)																	
	Sig	0.24	0.13	0.386	0.253	0.15	0.126	0.409	0.048	0.018																	
	N	30	30	30	30	30	30	30	30	30																	
CHL-N	CC	-.489(**)	0.012	.482(**)	-0.249	0.264	.397(*)	-0.158	.333(*)	.505(**)	0.288																
	Sig	0.003	0.476	0.004	0.092	0.079	0.015	0.203	0.036	0.002	0.061																
	N	30	30	30	30	30	30	30	30	30	30																
CHL-T	CC	-.582(**)	-0.121	.482(**)	-0.006	.206(*)	.386(**)	-0.162	0.025	.706(**)	.882(**)	.570(**)															
	Sig	0	0.155	0	0.481	0.041	0	0.086	0.418	0	0	0.001															
	N	73	73	73	73	73	73	73	73	30	30	30															
PP-L	CC	0.132	.311(**)	-0.11	-0.157	-0.145	-0.032	-.229(*)	.505(**)	.382(*)	-0.022	0.272	-0.007														
	Sig	0.145	0.005	0.19	0.104	0.122	0.401	0.032	0	0.019	0.454	0.073	0.476														
	N	66	66	66	66	66	66	66	66	30	30	30	66														
PP-P	CC	0.094	.447(**)	-0.063	-.268(*)	0.058	.243(*)	-.295(**)	.335(**)	.448(**)	0.142	.339(*)	0.191	.681(**)													
	Sig	0.226	0	0.309	0.015	0.322	0.024	0.008	0.003	0.007	0.227	0.034	0.062	0													
	N	66	66	66	66	66	66	66	66	66	30	30	66	66													
PP-N	CC	-0.062	0.183	0.054	-0.099	0.028	-0.129	-0.157	.345(**)	.438(**)	-0.018	0.243	0.052	.484(**)	.378(**)												
	Sig	0.31	0.071	0.334	0.215	0.411	0.151	0.104	0.002	0.008	0.463	0.098	0.338	0	0.001												
	N	66	66	66	66	66	66	66	66	66	30	30	66	66	66												
PP-T	CC	0.021	.337(**)	-0.006	-0.098	-0.009	.233(*)	-.385(**)	.380(**)	.390(*)	0.014	0.259	0.155	.789(**)	.943(**)	.591(**)											
	Sig	0.429	0.002	0.48	0.205	0.469	0.023	0	0	0.017	0.472	0.083	0.096	0	0	0											
	N	73	73	73	73	73	73	73	73	30	30	30	73	66	66	66											
LARG	CC	-.223(*)	0.078	.213(*)	0.042	0.135	0.065	-0.184	-0.197	.465(**)	0.015	0.225	.235(*)	0.003	0.021	.318(**)	0.114										
	Sig	0.037	0.268	0.044	0.37	0.142	0.302	0.071	0.057	0.005	0.47	0.116	0.03	0.49	0.434	0.005	0.183										
	N	65	65	65	65	65	65	65	65	30	30	30	65	65	65	65	65										
NANO	CC	-.423(**)	0.119	.383(**)	-0.071	0.042	.225(*)	-.329(**)	-0.162	.641(**)	.443(**)	.468(**)	.526(**)	-0.058	0.069	0.147	0.082	.721(**)									
	Sig	0	0.172	0.001	0.288	0.369	0.036	0.004	0.088	0	0.007	0.005	0	0.324	0.294	0.121	0.258	0									
	N	65	65	65	65	65	65	65	65	30	30	30	65	65	65	65	65	65									
PROK	CC	.213(*)	.334(**)	-0.164	-0.064	0.133	0.075	-0.029	0.024	.330(*)	.762(**)	.358(*)	0.071	-0.028	0.086	0.125	0.102	.361(**)	.478(**)								
	Sig	0.044	0.003	0.096	0.307	0.146	0.275	0.41	0.425	0.037	0	0.026	0.287	0.413	0.248	0.16	0.21	0.002	0								
	N	65	65	65	65	65	65	65	65	30	30	30	65	65	65	65	65	65	65								
PER	CC	-0.083	-0.163	0.061	0.172	.310(**)	0.091	-0.032	-0.113	.412(*)	0.158	.315(*)	0.185	0.056	0.019	0.146	0.062	.575(**)	.343(**)	.250(*)							
	Sig	0.254	0.098	0.316	0.086	0.006	0.236	0.399	0.185	0.012	0.202	0.045	0.071	0.33	0.439	0.122	0.311	0	0.003	0.022							
	N	65	65	65	65	65	65	65	65	30	30	30	65	65	65	65	65	65	65	65							
BUT	CC	-.358(**)	0.149	.336(**)	-0.087	0.063	.212(*)	-.327(**)	-0.122	.662(**)	.435(**)	.419(*)	.450(**)	-0.058	0.035	0.187	0.065	.746(**)	.957(**)	.515(**)	.353(**)						
	Sig	0.002	0.118	0.003	0.244	0.31	0.045	0.004	0.167	0	0.008	0.011	0	0.322	0.392	0.068	0.304	0	0	0.002							
	N	65	65	65	65	65	65	65	65	30	30	30	65	65	65	65	65	65	65	65							
FUC	CC	-.216(*)	0.115	0.204	0.034	0.088	0.048	-0.205	-.233(*)	.448(**)	-0.042	0.163	.230(*)	-0.011	0.008	.296(**)	0.101	.980(**)	.730(**)	.384(**)	.449(**)	.756(**)					
	Sig	0.042	0.182	0.052	0.395	0.244	0.353	0.051	0.031	0.007	0.412	0.195	0.033	0.464	0.474	0.008	0.213	0	0	0.001	0	0					
	N	65	65	65	65	65	65	65	65	30	30	30	65	65	65	65	65	65	65	65	65	65					
HEX	CC	-.439(**)	0.113	.382(**)	-0.072	0.003	.227(*)	-.351(**)	-0.145	.666(**)	.427(**)	.437(**)	.540(**)	-0.022	0.104	0.17	0.121	.708(**)	.988(**)	.454(**)	.325(**)	.931(**)	.721(**)				
	Sig	0	0.184	0.001	0.284	0.49	0.034	0.002	0.124	0	0.009	0.008	0	0.431	0.206	0.088	0.168	0	0	0	0.004	0	0				
	N	65	65	65	65	65	65	65	65	30	30	30	65	65	65	65	65	65	65	65	65	65	65				
ZEA	CC	.412(**)	.333(**)	-.371(**)	0.018	0.067	-0.122	0.034	-0.057	0.038	.566(**)	0.173	-0.068	0.026	0.143	0.112	0.167	.295(**)	.289(**)	.901(**)	.271(*)	.325(**)	.296(**)	.265(*)			
	Sig	0.003	0.007	0.001	0.443	0.298	0.166	0.394	0.327	0.422	0.001	0.181	0.297	0.419	0.128	0.186	0.092	0.009	0.01	0	0.015	0.004	0.008	0.016			
	N	65	65	65	65	65	65	65	65	30	30	30	65	65	65	65	65	65	65	65	65	65	65	65			
CHL-B	CC	-0.099	0.18	0.116	0.06	0.111	0.017	-0.111	-.429(**)	-0.164	0.174	-0.097	.246(*)	-0.182	-0.122	-0.133	-0.162	.317(**)	.430(**)	0.196	0.162	.386(**)	.337(**)	.355(**)	0.173		
	Sig	0.217	0.075	0.179	0.317	0.19	0.448	0.19	0	0.193	0.179	0.305	0.024	0.073	0.167	0.145	0.098	0.005	0	0.059	0.098	0.001	0.003	0.002	0.084		
	N	65	65	65	65	65	65	65	65	30	30	30	65	65	65	65	65	65	65	65	65	65	65	65	65		
DIV-A	CC	0.03	.314(**)	0.015	-0.153	0.11	0.172	-0.109	0.103	.439(**)	.772(**)	.429(**)	0.159	-0.031	0.084	0.175	0.097	.340(**)	.576(**)	.938(**)	0.194	.602(**)	.344(**)	.554(**)	.728(**)	.227(*)	
	Sig	0.407	0.005	0.453	0.112	0.191	0.085	0.194	0.208	0.008	0	0.009	0.104	0.405	0.253	0.081	0.222	0.003	0	0	0.061	0	0.003	0	0	0.034	
	N	65	65	65	65	65	65	65	65	30	30	30	65	65	65	65	65	65	65	65	65	65	65	65	65	65	
SDD	CC	-0.198	-0.018	0.244	0.376	0.353	-0.267	0.12	-0.346	-0.564	-0.718	0.632	-0.321	-.659(*)	-.745(**)	-0.086	-.724(**)	0.043	0.049	0.065	-0.121	0.13	0.043	-0.043	0.16	-0.145	0
	Sig	0.28	0.479	0.235	0.127	0.144	0.213	0.383	0.149	0.161	0.086	0.127	0.168	0.019	0.007	0.406	0.006	0.453	0.446	0.429	0.369	0.361	0.453	0.453	0.329	0.345	0.5
	N	11	11	11	11	11	11	11	11	5	5	5	11	11	10	10	11	10	10	10	10	10	10	10	10	10	10

Table.3.5. List of correlations between physical, chemical and biological data for BAP1.

Table.3.6. List of correlations between physical, chemical and biological data for BAP3.

BAP-3

CC: Correlation Coefficient
Sig: Sig. (1-tailed)
N: Number of Data

** Correlation is significant at the 0.01 level (1-tailed).
* Correlation is significant at the 0.05 level (1-tailed).

		TEMP	SAL	DEN	PO4	NO2+NO3	NO2	NH4	Si	CHL-L	CHL-P	CHL-N	CHL-T	PP-L	PP-P	PP-N	PP-T	LARG	NANO	PROK	BCP	HET-BAC	PER	BUT	FUC	HEX	ZEA	CHL-B	DIV-A	SDD
SAL	CC	.425(**)																												
	Sig	0																												
	N	108																												
DEN	CC	-.981(**)	-.296(**)																											
	Sig	0	0.001																											
	N	108	108																											
PO4	CC	-.07	0.045	0.087																										
	Sig	0.234	0.321	0.184																										
	N	108	108	108																										
NO2+NO3	CC	-.405(**)	-.323(**)	.377(**)	.169(*)																									
	Sig	0	0	0	0.04																									
	N	108	108	108	108																									
NO2	CC	-.411(**)	-0.069	.432(**)	.252(**)	.344(**)																								
	Sig	0	0.239	0	0.004	0																								
	N	108	108	108	108	108																								
NH4	CC	-0.035	-.333(**)	0.008	-0.043	.202(*)	-0.108																							
	Sig	0.361	0	0.468	0.328	0.018	0.133																							
	N	108	108	108	108	108	108																							
Si	CC	-.228(**)	0.014	.221(*)	-0.039	0.157	.166(*)	-.201(*)																						
	Sig	0.009	0.443	0.011	0.343	0.053	0.043	0.018																						
	N	108	108	108	108	108	108	108																						
CHL-L	CC	-.490(**)	-0.054	.506(**)	.210(*)	.184(*)	.466(**)	-.172(*)	-0.146																					
	Sig	0	0.294	0	0.017	0.032	0	0.042	0.072																					
	N	102	102	102	102	102	102	102	102																					
CHL-P	CC	-.627(**)	-0.11	.653(**)	0.068	.231(**)	.386(**)	-0.052	-0.058	.730(**)																				
	Sig	0	0.135	0	0.249	0.01	0	0.303	0.28	0																				
	N	102	102	102	102	102	102	102	102	102																				
CHL-N	CC	-.432(**)	0.078	.476(**)	0.047	0.134	.300(**)	-.174(*)	-0.072	.508(**)	.637(**)																			
	Sig	0	0.217	0	0.32	0.09	0.001	0.04	0.236	0	0																			
	N	102	102	102	102	102	102	102	102	102	102																			
CHL-T	CC	-.551(**)	-0.111	.573(**)	0.123	.244(**)	.413(**)	-0.109	-.162(*)	.824(**)	.965(**)	.702(**)																		
	Sig	0	0.126	0	0.103	0.005	0	0.13	0.047	0	0	0																		
	N	108	108	108	108	108	108	108	108	102	102	102																		
PP-L	CC	0.12	.326(**)	-0.09	-0.015	-0.012	-0.032	-.171(*)	-0.086	0.139	-0.007	.203(*)	0.002																	
	Sig	0.114	0	0.184	0.441	0.454	0.374	0.043	0.196	0.088	0.475	0.024	0.491																	
	N	102	102	102	102	102	102	102	102	96	96	96	102																	
PP-P	CC	0.162	.200(*)	-0.143	0.16	0.154	-0.007	-0.051	0.041	-0.008	-0.054	0.029	-0.019	.486(**)																
	Sig	0.052	0.022	0.076	0.054	0.062	0.474	0.306	0.341	0.47	0.302	0.389	0.426	0																
	N	102	102	102	102	102	102	102	102	96	96	96	102	102																
PP-N	CC	.339(**)	0.074	-.372(**)	-0.018	-0.152	-.255(**)	0.048	-0.081	-.258(**)	-.286(**)	-.212(*)	-.256(**)	.262(**)	.295(**)															
	Sig	0	0.231	0	0.428	0.064	0.005	0.316	0.208	0.006	0.002	0.019	0.005	0.004	0.001															
	N	102	102	102	102	102	102	102	102	96	96	96	102	102	102															
PP-T	CC	.245(**)	.312(**)	-.218(*)	0.099	0.039	-0.111	-0.076	-0.053	-0.006	-0.081	0.088	-0.041	.737(**)	.880(**)	.534(**)														
	Sig	0.005	0.001	0.012	0.153	0.346	0.127	0.217	0.295	0.477	0.208	0.19	0.335	0	0	0														
	N	108	108	108	108	108	108	108	108	102	102	102	108	102	102	102														
LARG	CC	-.266(**)	0.031	.265(**)	0.109	.215(*)	.176(*)	-0.094	-.210(*)	.392(**)	.333(**)	.254(**)	.384(**)	0.081	-0.029	0.038	0.041													
	Sig	0.003	0.374	0.003	0.132	0.013	0.034	0.167	0.014	0	0	0.005	0	0.208	0.385	0.353	0.336													
	N	108	108	108	108	108	108	108	108	102	102	102	108	102	102	102	108													
NANO	CC	-.350(**)	-0.023	.358(**)	0.132	.282(**)	.162(*)	-0.067	-0.139	.354(**)	.446(**)	.332(**)	.455(**)	0.015	0.039	-0.026	0.052	.810(**)												
	Sig	0	0.408	0	0.087	0.002	0.047	0.245	0.075	0	0	0	0	0.441	0.35	0.399	0.295	0												
	N	108	108	108	108	108	108	108	108	102	102	102	108	102	102	102	108	108												
PROK	CC	-.168(*)	-0.151	0.133	0.096	.282(**)	0.077	-0.054	-.194(*)	.311(**)	.351(**)	0.101	.369(**)	-0.134	-0.045	-0.041	-0.072	.607(**)	.723(**)											
	Sig	0.041	0.059	0.085	0.161	0.002	0.213	0.291	0.022	0.001	0	0.156	0	0.09	0.326	0.343	0.23	0	0											
	N	108	108	108	108	108	108	108	108	102	102	102	108	102	102	102	108	108	108											
BCP	CC	.338(**)	.274(*)	0.065	-.320(**)	-0.209	-.575(**)	-0.062	-.372(**)	-.319(**)	-0.144	0.004	-.223(*)	0.105	0.023	.320(**)	0.208	0.118	.237(*)	0.018										
	Sig	0.004	0.017	0.506	0.312	0.055	0	0.32	0.002	0.006	0.136	0.488	0.043	0.213	0.43	0.006	0.056	0.184	0.034	0.446										
	N	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60										
HET-BAC	CC	-0.013	0.132	0.059	0.011	.159(*)	0.001	0.123	0.021	-0.037	-0.019	0.044	-0.052	.221(*)	.176(*)	-0.031	.162(*)	0.012	-0.038	-.171(*)	-0.178									
	Sig	0.447	0.086	0.271	0.457	0.05	0.498	0.103	0.414	0.355	0.426	0.33	0.297	0.013	0.044	0.38	0.047	0.45	0.346	0.039	0.086									
	N	108	108	108	108	108	108	108	108	102	102	102	108	102	102	102	108	108	108	108	60									
PER	CC	0.113	0.009	-0.114	0.093	0.025	-0.035	0.079	-.384(**)	0.085	0.061	.211(*)	0.124	-0.051	-0.099	-0.032	-0.062	.575(**)	.468(**)	.411(**)	0.181	0.02								
	Sig	0.13	0.462	0.126	0.175	0.403	0.363	0.216	0	0.205	0.278	0.02	0.106	0.313	0.169	0.378	0.269	0	0	0	0.095	0.42								
	N	102	102	102	102	102	102	102	102	96	96	96	102	96	96	96	102	102	102	102	54	102								
BUT	CC	-.432(**)	-0.091	.438(**)	0.1	.320(**)	.176(*)	0.016	-0.077	.305(**)	.410(**)	.298(**)	.395(**)	0.02	0.031	-0.007	0.044	.729(**)	.914(**)	.617(**)	.246(*)	-0.012	.357(**)							
	Sig	0	0.174	0	0.153	0.04	0.07	0.433	0.214	0.001	0	0.001	0	0.421	0.379	0.472	0.324	0	0	0	0.029	0.449	0							
	N	108	108	108	108	108	108	108	108	102	102	102	108	102	102	102	108	108	108	108	60	108	102							
FUC	CC	-.329(**)	0.007	.327(**)	0.14	.255(**)	.217(*)	-0.093	-.176(*)	.441(**)	.359(**)	.260(**)	.412(**)	0.13	0.025	0.049	0.09	.972(**)	.801(**)	.582(**)	0.069	0.054	.441(**)	.758(**)						
	Sig	0	0.47	0	0.074	0.004	0.012	0.17	0.034	0	0	0.004	0	0.097	0.401	0.311	0.178	0	0	0	0.3	0.288	0	0						
	N	108	108	108	108	108	108	108	108	102	102	102	108	102	102	102	108	108	108	108	60	108	102	108						
HEX	CC	-.357(**)	-0.01	.359(**)	.184(*)	.246(**)	.176(*)	-0.134	-0.145	.395(**)	.456(**)	.292(**)	.473(**)	0.062	0.066	-0.007	0.097	.817(**)	.962(**)	.725(**)	.218(*)	-0.083	.457(**)	.873(**)	.815(**)					
	Sig	0	0.46	0	0.028	0.005	0.034	0.083	0.068	0	0	0.001	0	0.267	0.254	0.472	0.16	0	0	0	0.047	0.196	0	0	0					
	N	108	108	108	108	108	108	108	108	102	102	102	108	102	102	102	108	108	108	108	60	108	102	108	108					
ZEA	CC	-0.024	-0.105	-0.022	0.09	.184(*)	-0.002	-0.13	-.221(*)	.260(**)	.209(*)	0.046	.272(**)	-0.017	-0.303	-.585(**)	-.532(*)	-.735(**)	-.478(**)	-0.389	0.167	-0.236	-.585(**)	-.551(*)	-.706(**)	-.618(**)	-.470(*)			
	Sig	0.402	0.132	0.409	0.177	0.029	0.493	0.09	0.011	0.004	0.018	0.323	0.002	0.433	0.269	0.172	0.267	0	0	0	0.48	0.092	0	0	0	0	0.028			
	N	108	108	108	108	108	108	108	108	102	102	102	108	102	102	102	108	108	108	108	60	108	102	108	108	108	102			
CHL-B	CC	0.048	0.014	-0.041	0.036	0.089	-0.035	0.044	-.185(*)	0.063	0.142	0.135	-.213(*)	-0.143	-0.094	-0.157	.475(**)	.569(**)	.483(**)	.325(**)	-0.133	.486(**)	.400(**)	.428(**)	.491(**)	.398(**)				
	Sig	0.314	0.446	0.342	0.361	0.245	0.363	0.332	0.031	0.27	0.084	0.094	0.074	0.019	0.082	0.182	0.058	0	0	0	0.008	0	0	0	0	0				
	N	102	102	102	102	102	102	102	102	96	96	96	102	96	96	96	102	102	102	102	54	102	102	102	102	102	102			
DIV-A	CC	-.303(**)	-0.153	.286(**)	0.135	.374(**)	0.166(*)	0.002	-0.139	.335(**)	.448(**)	0.141	.433(**)	.192(*)	-0.079	-.175(*)	-0.142	.557(**)	.699(**)	.937(**)	-0.046	-0.13	.327(**)	.814(**)	.543(**)	.698(**)	.793(**)	.483(**)		
	Sig	0.001	0.057	0.001	0.082	0	0.043	0.493	0.075	0	0	0.079	0	0.027	0.215	0.04	0.072	0	0	0	0.364	0.09	0	0	0	0	0	0		
	N	108	108	108	108	108	108	108	108	102	102	102	108	102	102	102	108	108	108	108	60	108	102	108	108	108	102	102		
SDD	CC	.494(*)	0.354	-.468(*)	0.106	-0.273	0.023	0.053	0.2	-0.227	-0.17	-0.325	-0.362	-0.373	-0.303	-.585(**)	-.532(*)	-.735(**)	-.478(**)	-0.389	0.167	-0.236	-.585(**)	-.551(*)	-.706(**)	-.618(**)	-.470(*)	0.135	-0.312	
	Sig	0.022	0.081	0.029	0.343	0.144	0.465	0.419	0.221	0.198	0.265	0.11	0.077	0.078	0.127	0.009	0.014	0	0.026	0.061	0.333	0.179	0.009	0.011	0.001	0.004	0.028	0.309	0.111	
	N	17	17	17	17	17	17	17	17	16	16	16	17	16	16	16	17	17	17	17	9	17	16	17	17	17	16	17	17	
POC	CC	-0.258	-.624(**)	0.095	0.172	0.032	-0.025	-0.123	-0.193	.492(*)	0.359	0.072	0.25	-0.032	-0.132	-0.179	-0.172	0.01	-0.24	0.172	-.588(*)	-0.071	0.001	-0.148	-0.016	-0.109	0.232	-0.372	0.017	-0.069
	Sig	0.151	0.003	0.354	0.247	0.449	0.46	0.314	0.221	0.022	0.078	0.391	0.159	0.452	0.306	0.246	0.247	0.484	0.169	0.247	0.037	0.389	0.498	0.278	0.475	0.333	0.177	0.071	0.474	0.396
	N	18	18	18	18	18	18	18	18	17	17	17	18	17	17	17	18	18	18	18	10	18	17	18	18	18	17	18	18	17

4. DISCUSSION

Changes in physical, chemical and biological parameters for the east and west coast of Mersin Bay will be discussed separately.

4.1. Seasonal variation in physical, chemical and biological parameters in the east coast of the Mersin Bay.

4.1.1. Hydrography:

Physical, chemical and biological properties of the eastern shelf area of the bay are controlled extensively by the intermittent rivers namely Seyhan and Tarsus (Berdan) and to a less extent by the Ceyhan River discharging to the shallow shelf. The impact of freshwater is most pronounced at the top 10 m of the shelf waters (Uysal et al., 2008; Yücel, 2008). Secchi depths varied from a low level of 3 m during August 2009 to a high level of 10.5 m during November 2010 in the east coast. Highest PP was measured at surface during August 2009 during which PAR was reduced to 1% of its surface intensity at around 15 m. Invasion of top few meters with river waters containing both the dissolved and particulate matter might have also block penetration of light sufficient enough to lower depths during this month. In the meantime, chlorophyll and pigment concentrations were also measured at peak levels. A sharp decline in all related parameters in parallel to PP with depth is observed in August 2009. In contrast, both the PP and chlorophyll tend to increase with increasing depth during November 2010, which enable the penetration of incident light to lower depths. SDD was measured as high as 29 m during June & October 2011 during which PP and chlorophyll content started to increase below 30 m with low levels above it. It is for this reason that SDD was measured minimal during this period.

Salinities as low as 36 was also recorded near the river outlets. Intense river discharge coupled with immense precipitation during winter and spring (in some cases during late spring and early summer) desalinate surface waters of the eastern coast significantly. Surface salinity peaks mostly during late summer early autumn period (Uysal et al., 2008). On their way towards eastern Mediterranean Atlantic waters warms up and become more saltier (increase from 36.15 to 38.6 salinity,

Hecht et al., 1988; Özsoy et al., 1989; Kress and Herut, 2001). Surface and near surface water temperatures are solely controlled by rivers in areas under freshwater influence. Water column temperature values varied in the range of 15 – 30.2^{o}C in the east coast of the bay over the year.

Seasonal thermocline was formed at around 50 meters in the offshore waters during autumn. This then was followed by a strong convectional mixing during winter. Highly significant positive correlation (n: 73, r: 0.384, $P < 0.01$) was observed between temperature and salinity.

4.1.2. Dissolved Nutrients:

Eastern Mediterranean is a good example for low nutrient low chlorophyll (LNLC) ecosystem (Krom et al., 1991; Ediger and Yılmaz, 1996; Yılmaz and Tuğrul, 1998; Kress and Herut, 2001; Eker-Develi 2004; Psarra et al., 2005; Yücel, 2008; Koçak et al., 2010). Krom et al., (2005) reported that eastern Mediterranean surface waters have extremely low nutrient content. The nutricline is located at around 300-500 m in the anticyclonic regions (Yılmaz and Tuğrul, 1998). However, despite its oligotrophic nature, the northeastern sector of the eastern Mediterranean receives substantial amounts of river waters which further enhance the nutrient content of the shallow shelf areas (Yücel, 2008; Koçak et al., 2010). Interactions between coastal shelf and offshore waters determine the trophic status of the water masses in the shelf region. High concentration of nitrogen (nitrite+nitrate) and silicate were observed in less saline surface shelf waters in different seasons (Uysal and Köksalan, 2006; Doğan-Sağlamtimur, 2007). The majority of these nutrients are introduced by Seyhan and Ceyhan rivers (Koçak et al., 2010). During this study, nitrogen was generally found below 1 μM in the coastal waters for most of the year. In February 2009 and 2010, peak values of 4.6 and 10.2 μM were recorded. Intense river discharges observed during winter and spring enhance significantly the nitrogen content of the receiving shelf waters in the east coast. Overall, concentrations tend to decrease with depth in shallow areas. Conversely, nitrogen concentrations tend to increase with increasing depth in offshore waters. Nitrogen concentrations varied between 0.05 and 2.06 μM in the offshore water column. Previous studies also

indicate low nitrogen concentrations within the euphotic layer of the eastern Mediterranean (Krom et al., 1993; Tuğrul and Yılmaz, 1998; Eker-Develi, 2004).

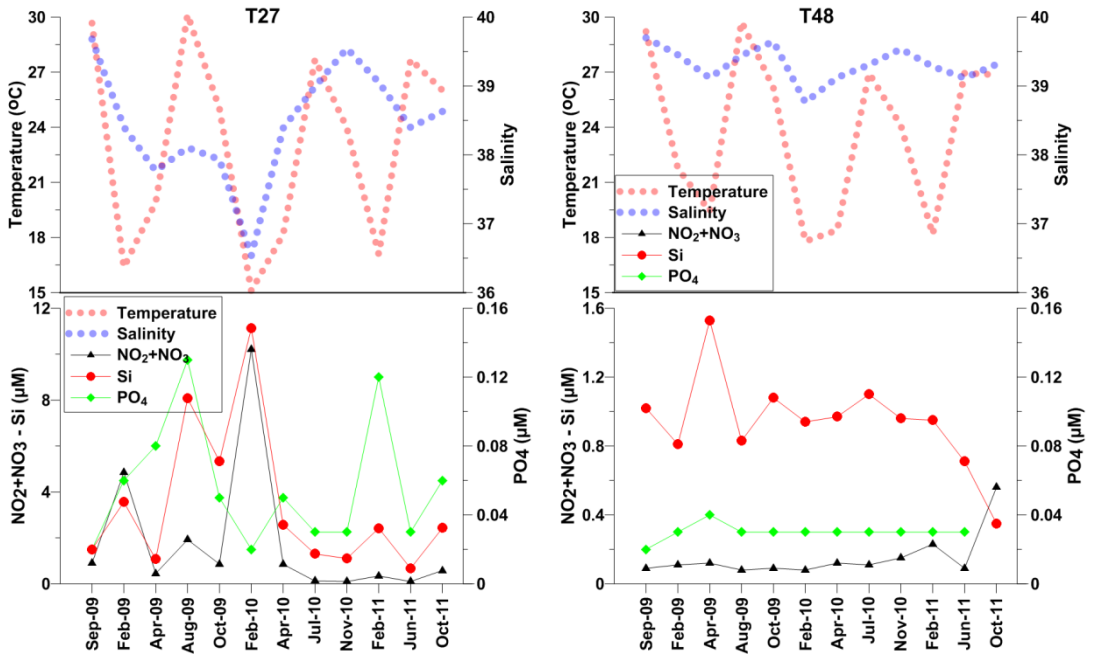


Figure 4.1. Surface distribution of physical and chemical parameters in eastern side of the Mersin Bay.

Much higher levels were also measured in the offshore station in February 2011. In the mean time, a very pronounced convective mixing occurred in the area possibly leading to upward nutrient entrainment from deeper depths towards the sunlit euphotic layer. N/P (TIN/DRP) varied between 3 and 75 in the offshore station which further increase with increasing depth. The Levantine deep waters have higher N/P ratios (25-28) than the well known Redfield ratio of 16 which is common for most of the oceans (Redfield et al., 1963; Krom et al., 1991; Yılmaz and Tuğrul, 1998; Ediger et al., 2005).

However a co-limitation of both N and P may occur in the nutrient depleted Levantine surface water (Yılmaz and Tuğrul, 1998; Thingstad et al., 2005; Zohary et al., 2005; Tanaka et al., 2011). N/Si ratios were generally below 0.5 in coastal waters. Rivers carry dissolved nutrients to coastal areas where concentrations of silicate exceed that of nitrogen (Koçak et al., 2010).

Silicate concentrations in most cases have exceeded nitrogen concentrations in the shelf waters. However, they both displayed similar profiles in the water column. Silicate concentrations increased from 0.67 to maximum level of 11.1 μM in the surface layer in the shelf during the study period. Higher silicate concentrations were mostly due to higher freshwater discharge from the nearby rivers (Uysal et al., 2004; Doğan-Sağlamtimur, 2007; Bayındırlı, 2007; Koçak et al., 2010). Consequently, a highly significant negative correlation was found between the silicate content and salinity of the coastal waters (n: 73, r: -0.307, $P < 0.01$). Silicate concentration decreased to a low level of 0.25 μM in offshore waters during October 2011. Also, mean value was calculated as 1.05 μM which almost makes half the value observed for the shelf. Silicate concentrations increased with depth below the euphotic zone in the offshore station. In the euphotic zone, the average concentration was found as 0.95 μM. In addition, N/Si ratios calculated for the euphotic layer (0.3) and for the water column (0.4) remain far below than the given Redfield ratio of 1.06 (Redfield et al., 1963). In general, silicate concentrations increased with depth below the euphotic zone reaching to a maximum at 200 m (2.64 μM) in April 2009. Low N/Si ratios can be attributed to rapid utilization of available nitrogen by non-silicious picoplankton (cyanobacteria and prochlorophytes) in offshore waters. It is well known that pico and nanoplankton forms the major part of the phytoplankton in oligotrophic eastern Mediterranean. Especially cyanobacterium *Synechococcus* displays a special affinity to nitrogen species (Karl et al., 1997; Pantoja et., al., 2002; Moore et al., 2002). Scarce amount of nitrogen and phosphorus available in surface waters are utilized immediately by these groups. It is for this reason that such water bodies display low N/P and N/Si ratios (Uysal and Köksalan, 2010; Krom et al., 2010).

Phosphate concentrations were consistently low slightly varying between 0.02 – 0.05 μM in eastern shelf waters of the Mersin Bay. In the study area, most of the phosphate is supplied by the regional and domestic wastewater discharges (Doğan-Sağlamtimur, 2007; Koçak et al., 2010). Therefore, a highly significant positive correlation was found between phosphate and chlorophyll (n: 73, r: 0.559, $P < 0.01$). A negative correlation did exist between salinity and phosphate (n: 73, r: - 0.339, $P < 0.01$). Phosphate is considered as the potential limiting factor for algal production in the upper layer in northeastern Mediterranean (Yılmaz and Tuğrul, 1998; Ediger et

al., 2004). Also, it is consumed prior to nitrate in surface waters which is characteristic for the phosphorus limited systems (Krom et al., 2005). N/P ratios were found lower than 16 in half of the sampling periods (April, August 2009, July, November 2010, February, June 2011). Phosphate concentrations in the euphotic zone generally ranged between 0.02 – 0.04 μM in the offshore station. Phosphate profiles exhibited an increasing trend below the euphotic zone reaching peak values near bottom in offshore waters.

4.1.3. Chlorophyll *a*:

Total chlorophyll concentrations fluctuated between 0.06 – 1.07 and 0.02 – 0.25 mg m^{-3} with water column mean levels of 0.40 and 0.08 mg m^{-3} in the shelf and offshore, respectively. High surface chlorophyll content of this particular shelf station with values ranging between 0.02 and 0.76 mg m^{-3} was determined previosly for the period November 2005 to September 2007 (Uysal et al., 2008; Yücel, 2008). Relatively, higher concentrations were met both during April 2007 (Yücel, 2008) and April 2009 (0.80 mg m^{-3}). Homogenous chlorophyll profiles were observed during February 2009 and February – April 2010 in the shallow station. The highest concentration was measured in shelf waters in February 2011 during which very high concentrations of phosphate and low concentrations of nitrogen and silicate were measured in the water column indicating a phosphate favoured primary production. Larger cells (> 5 μm) dominated the bulk chlorophyll during this period. Expectedly, a highly significant positive correlation did exist between silicate and chlorophyll contents of larger cells in the shelf waters (n: 30, r: 0.505, $P < 0.01$). Pigment compositions as well as bulk chlorophyll were dominated by large eukaryotes composed primarily of diatoms in February 2011. Despite the high chlorophyll levels retained in February 2011 very low concentrations were measured during former February 2009 & 2010 in the shelf. N/P ratios calculated for the February 2009 and 2010 (122 and 414) were much higher than that calculated for February 2011 (almost below 6 for the top 10 m) which is also true for the observed low N/Si ratio of 0.3. Based on these ratios, we can conclude that production was mainly controlled by phosphorus during February 2009 and 2010 and to a less extend by N during February 2011. However, estimates of unit carbon produced per unit chlorophyll

(C/CHLL) for February 2010 exceeds that of February 2011. Such ratios together with available nutrient concentrations all indicate that a post bloom event was persistent during February 2011 (most cells were inactive).

Both the content and variations in chlorophyll were almost the same in February 2009 and 2010 in the shelf. However a four fold PP and twice as much C/CHLL were observed during February 2010 compared to February 2009. This probably is due to presence of three fold nutrient (N and silicate) content in February 2010 than February 2009.

Top ten meters had higher chlorophyll contents in shelf (Yücel, 2008). In some cases, two peaks, one at surface and the other at the bottom were also observed during April – August 2009 and November 2010. While the discrete near bottom flora observed in April 2009 contain active cells (high PP) rich in chlorophyll, those that occupy similar depths during November 2010 with high chlorophyll contents displayed low PP.

While picoplankton derived chlorophyll dominated total chlorophyll in July and November 2010, contribution of larger plankton to total chlorophyll was excess during February and June 2011 in shelf waters. Although contribution of pico and larger phytoplankton to total chlorophyll were almost the same in the water column in October 2011 picoplankton have been found to be more active based on size fractionated PP rate estimates. Contribution of nanoplankton to total chlorophyll has always been least in shelf waters except February 2011. Although the highest concentration was observed in February 2011, contribution of pico and nanoplankton to total chlorophyll were measured very low near bottom being 0.003 and 0.002 mg m^{-3}, respectively. Share by pico and larger plankton of total chlorophyll was almost equal for the water column during October 2011 in the shelf. Dominant groups changed with depth both in shelf and offshore waters. Mean surface concentration of shelf waters (0.52 mg m^{-3}) was found 7.5 times higher than offshore waters (0.068 mg m^{-3}). Shelf and offshore waters showed opposite trends when taking into account the surface concentrations. Chlorophyll concentration suddenly decreased in October 2009 in shelf waters in parallel to PP and nutrients at top 10 m.

Very low chlorophyll concentrations were measured in offshore station throughout this study. Earlier findings in the same site also indicate presence of very low

concentrations ranging between 0.02 and 0.23 mg m^{-3} (Yücel, 2008). In addition, a deep chlorophyll maximum taking place between 60 and 120 m has been pronounced formerly by others (Ediger and Yılmaz, 1996; Eker-Develi, 2004; Yılmaz, 2006). During this study, subsurface chlorophyll peaks were observed at different depths in offshore waters with a highly significant one observed in October 2011. However this sub peak did not show any impact on PP. Activity of cells (C/CHLL) has been found least during October 2011.

Total chlorophyll increased with increasing depth in June 2011 with no direct impact on PP. Total chlorophyll was dominated by picoplankton where contributions from nanoplankton and larger phytoplankton were minor at the offshore station. Concentrations of all groups increased at 75 m in October 2011. Contribution of larger cells to total chlorophyll increased with increasing N in February 2011 in offshore waters. Similar concentrations (0.18 mg m^{-3}) were measured at 5 m in February 2009 and 2010. Total chlorophyll concentration was dominated by picoplanktonic chlorophyll in the offshore. Generally, cyanobacteria was found as the dominant group followed by prymnesiophytes (coccolithophorids) in the offshore (Yücel, 2008). Contributions of larger cells and nanoplanktonic forms to total chlorophyll remained very low. A highly significant positive correlation was found between chlorophyll content of large cells and nitrite & silicate (n: 30, r: 0.648, $P < 0.01$ & n: 30, r: 0.427, $P < 0.01$). Larger cells (especially diatom) require more nitrogen and silicate in offshore waters (Fogg, 1991; Sin et al., 2000; Kormas et al. 2002).

Depth integrated chlorophyll (ICHL) concentrations fluctuated between 3.7 – 17.04 and 2.37 – 11.73 with water column mean levels of 9.63 and 8.45 mg m^{-2} at the shelf and offshore stations, respectively. This difference may rise to almost 5 fold if the shelf (0.385 mg m^{-2}) and offshore (0.08 mg m^{-2}) mean values are converted to values per m^{-2}. According to ICHL, while larger cells dominate chlorophyll composition in shelf waters, picoplankton replaces this group in offshore waters in east coast of Mersin Bay. Relatively a much higher contribution to total chlorophyll was made by picoplankton (73%) than those >5 microns in size (16%) in offshore. This figure increase from 16% to 44% in shallow coastal station where the bulk chlorophyll is dominated by larger forms. Contribution of near shore picoplankton to total chlorophyll drops almost to its half value retained in offshore. Contribution of

nanoplankton to total chlorophyll and PP tend to decrease in the near shore – offshore extent. In contrast to the west coast, nanoplankton contribute twice as much to PP in the east coast.

4.1.4. Primary Production:

Water column primary production rates varied between 0.005 – 13.23 and 0.007 – 0.952 mgC. m^{-3} h^{-1} with mean levels of 1.773 and 0.246 mgC. m^{-3} h^{-1} for the shallow shelf and offshore stations, respectively. The highest concentration was measured in August 2009 in shelf surface waters. PP decreased with depth in shelf waters. Top 10 meters were found more eutrophic than the deeper part. Because of the higher PP at surface, light did not penetrate to lower depths. PP rates dropped suddenly to lower values below 10 meters in shelf. Pronounced freshwater input carrying ample amount of dissolved nutrients from the nearby Seyhan and Tarsus rivers enhance both the algal standing stock and productivity of the surrounding water masses westward towards the inner Mersin Bay. Increased freshwater discharge during winter and spring lead to formation of high algal standing biomass at top few meters and delimit significantly penetration of light to lower depths. Low productivity rates observed mostly at lower depths during August 2009, October 2009, February 2010, February and June 2011 were mainly due to the insufficient PAR levels at these depths. Both the algal standing stock and chlorophyll have been found plenty at near surface waters during these periods. Rates were measured minimum in general at the depth of 25 m where the incident PAR level was also measured lowest. A secondary peak or relatively much higher chlorophyll content compared to upper layer was also observed at around 25 m or near bottom. Such high chlorophyll contents and low productivity rates observed at lower depths are mainly due to sinking diatom cells (post bloom events) which are physiologically inactive although they contain significant amount of chlorophyll within their cells. Unit carbon assimilated per unit chlorophyll was calculated to be very low at lower depths. An inverse relationship between PP and chlorophyll with depth was observed during November 2010. Sinking of live diatom cells from surface towards depths due to ongoing convectional mixing in the meantime could possibly result in such case. Phytoplankton cell counts (Tuğrul et al. 2010) and pigment analysis (observed high

FUC concentration near bottom) as well as profiles of physical and chemical parameters all support this phenomenon clearly.

In contrast to high chlorophyll content very low PP was measured at top 15 m during October 2011. Size fractionated chlorophyll and PP results clearly indicate that while large eukaryotes (diatom dominated) contribute relatively much more to the chlorophyll than the pico and nanoplankton, picoplankton dominates the PP relative to nanoplankton and large eukaryotes in the water column. In general pico and nanoplankton replace large eukaryotes during late summer and autumn in shelf waters denuded of necessary nutrients (especially of silicate) for larger cells composed of diatoms and dinoflagellates. Ambient conditions favor smaller ones over larger ones during this period. PP was generally below 3 mgC. m^{-3} h^{-1}, but found much higher in August & October 2009 and February 2011, during which surface salinity and secchi disc (about 4 m) decreased considerably. Significant negative correlation was found between salinity and primary production of larger cell (n: 64, r: - 0.480, $P < 0.01$) which are dominant group in coastal waters. Shelf surface waters were directly affected from the nearby rivers. Also, Ceyhan River located southeast of the shelf station influences considerably the coastal shelf waters. These shallow shelf waters enriched with river water held much higher concentrations compared to areas beyond the shelf break (Yücel, 2008).

High PP levels observed during August and October 2009 at surface waters are mainly promoted by river discharges. It is clearly evident from figure 3.2 that freshwater occupy the near surface waters with ample amount of nutrients (see figure 3.10). During winter nutrient provision to the sunlit surface waters is not only through the rivers but also significant amount of nutrients are provided from lower depths via convectional mixing. The only limitation to enhanced PP levels seems to be the light during this period. Despite the low PP rates observed during February 2009 and 2010 much higher rates are measured during February 2011. This could possibly evolve from the low phosphorus content of the water column during February 2009 and 2010 relative to February 2011 (Figure 3.10). All the above mentioned high PP rates are mainly regulated by phytoplankton greater than 2 μm in size. Previous studies also denote signification contribution of large sized phytoplankters composed primarily of diatoms to bulk chlorophyll near river drainage areas. Based on Redfield Ratio, N was suggested to be the limiting nutrient

(N/P < 16 and N/Si <1.1) during August and October 2009 and February 2011. Concentration of N was found very low especially during summer in the water column below 5 m.

In February 2010 and 2011, PP was found higher than February 2009 in shelf waters. Although chlorophyll concentrations were almost equal in February 2009 and February 2010, phytoplankton was found more active in February 2010 than others. Phosphate concentration was found near detection limits at near surface during February 2010. Despite the high levels of N and silicate, lower P content of the water column delimited PP significantly during February 2010. All the available P was utilized by diatom dominated large cells prior to N and silicate. PP rates could have been retained at much higher levels if there had been extra P available for the flora.

Almost three fold chlorophyll content and PP rate were measured during April 2009 compared to April 2010. Although both periods were dominated by diatoms and unit carbon produced per unit chlorophyll was almost equal for both, this threefold difference could be related to differences in abundance of phytoplankters. Both the presence of almost 5.3 fold cells and enriched P levels favored April 2009 over April 2010.

Contribution of size groups to total primary production (TPP) varied greatly in time. Groups shifted with each other in the water column. Picoplankton in February 2009, larger plankton in February 2010 and larger and nanoplankton in February 2011 dominated total primary production in the shelf. Picoplankton was the major contributor to PP in July and November 2010 in coastal waters. Nanoplankton, being least active overall, was the dominant group at surface in front of the Seyhan River only during August 2009. While larger cells dominated total PP at surface, it shifted with picoplankton below surface during October 2009. The type and availability of nutrients may help shape the algal composition in time and space (Sin et al., 2000; Kormas et al., 2002; Lomas et al., 2012).

PP was measured 20 times higher in October 2009 than October 2011 although the chlorophyll and nutrient contents were similar with almost equal visibility. Differences in C/CHLL ratios imply presence of pre or post-bloom scenarios for these periods. During the onset of a bloom cells are more active than those that exist during the termination of the bloom. In other words, high biomass may not yield high

PP rates, especially during the post bloom events. This situation underlies how significant it is to carry out frequent PP observations for a better description of the productivity of a certain water body.

Compared to others, picoplankton made a pronounced contribution to PP in July and November 2010 in coastal waters. In addition, a highly significant positive correlation was found between picoplanktonic PP and ambient temperature (n: 64, r: 0.354, $P < 0.01$). Cyanobacterium *Synechococcus* sp form the major part of picoplankton with an apparent peak during summer in the area (Uysal et al., 2004). They contain photoprotectant pigments to survive excess light conditions (Stuart et al., 1998; Gibb et al., 2001). Significant negative correlations have been found between picoplankton and N (n: 64, r: -0.361, $P < 0.01$). Cyanobacterium *Synechococcus* sp has special affinity to N compounds (Karl et al., 1997; Pantoja et., al., 2002; Moore et al., 2002). Since the ambient waters are devoid of silicate, P and N (compared to winter and spring) during summer, smaller cells like *Synechococcus* become more favoured due to their high surface to volume ratio. Even, scarce amounts of N species may support cyanobacterial growth significantly.

Nanoplankton was the dominant group at surface near Seyhan River in August 2009. But, they generally remained less active. Changes in light, nutrients, temperature and competition result in shifts from one group to another with depth. Nanoplankton has been found less competitive against pico and larger phytoplankton in nutrient rich shelf waters. Although nanoplankters dominate PP at top 5 m in August 2009 pigment results indicate picoplankton to be the most abundant group at this depth. Similar results have also been obtained during February 2011. Nanoplankters have been found more active (high PP rates) although they formed a small portion of the bulk algal biomass during winter.

In compliance with previous works, very low PP rates were measured in offshore. To a highest rate was met at DCM layer (at 90 m) in August 2009. Almost an equal rate was also measured in July 2010 at near surface (top 10 m). PP decreased with depth except August and October 2009. In contrast to observed high biomass at 45 m, cells at 90 m seemed to be more active in August 2009. Although PP decreases with depth in most cases, two PP sub peaks parallel to chlorophyll were also seldom observed. There were two peaks present in the water column in February and October 2009. In

both Februaries, surface waters were more productive than deeper part of the water column in offshore waters. Since the water column is rich in nutrients due to convectional mixing during winter phytoplankton require more of the incident PAR to carry out photosynthesis efficiently. Near surface waters become more productive during winter as they receive more light compared to lower depths. Although cells greater than 2 μm are most abundant in biomass, PP was dominated by picoplankton. The most dominant contributor was picoplankton in offshore waters. A highly significant negative correlation was found between picoplanktonic PP and ammonium (n: 66, r: -0.295, $P < 0.01$). Picoplankton use ammonium as primary nitrogen source in offshore waters (Moore et al., 2002; Wheeler, 2007). There exist a significant negative correlation between picoplankton PP and dissolved reactive phosphate (n: 66, r: -0.268, $P < 0.05$). Moutin et al. (2002) suggest that picoplankton (*Synechococcus* sp.) display high affinity for orthophosphate and significantly higher maximum uptake rates than heterotrophic bacteria and eukaryotic cells. Results from the mesoscale Lagrangian phosphate-enrichment experiment also support this conclusive remark (Psarra et al., 2005). As reported earlier by many, picoplankton is the most dominant group in the eastern Mediterranean (Raimbault et al., 1988; Chisholm 1992; Magazzu and Decembrini 1995; Li et al., 1993; Agawin and Agusti, 1997; Uysal, 2006). Contribution of nano and larger phytoplankton remained almost the same. PP rates of nanoplankton and larger phytoplankton shifted with each other in offshore waters. For this reason, a highly significant positive correlation did exist between them (n: 66, r: 0.484, $P < 0.01$).

Integrated primary production (IPP) rate was as low as 2.05 $mgC.m^{-2}\ h^{-1}$ in the offshore and increased to 72.2 $mgC.\ m^{-2}\ h^{-1}$ in the near shore waters enriched by river discharges in eastern part of the Mersin Bay. The mean IPP was 33.58 and 19.29 $mgC.m^{-2}\ h^{-1}$ in shelf and offshore, respectively. In the nutrient-depleted Cilician basin offshore waters, PP was dominated by picoplankton (0.2-2.0 μm). Larger cells (>5 μm) dominated phytoplankton composition in nutrient rich shelf waters according to season, especially during the winter. Picoplankton dominated shelf waters during summer and fall. Nanoplankton was found as the major contributor in April 2009 in shelf waters. Very low values were calculated for October 2011 in both stations. In general, picoplankton competes with larger phytoplankton throughout the year while nanoplankters display temporary highs in shelf waters.

Picoplankton dominated total primary production in shelf and offshore waters in eastern side of the Mersin Bay. Their average contribution reached to 71 % of total primary production in offshore waters. Previous studies indicate picoplankton as the major contributor to primary production in oligotrophic waters (Raimbault et al., 1988; Chisholm 1992; Magazzu and Decembrini 1995; Li et al., 1993; Agawin and Agusti, 1997; Uysal, 2006).

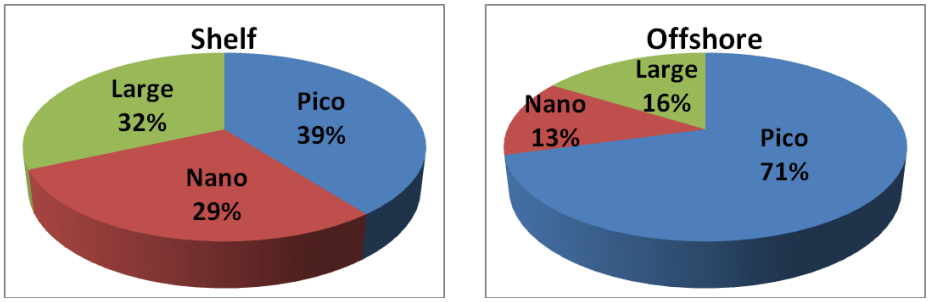


Figure 4.2.% contribution of groups to total primary production in eastern side of the Mersin Bay.

Carbon to chlorophyll (C/CHLL) ratio can change according to light, temperature and nutrient (Finenko et al., 2003) availability. It was shown that C/CHLL ratios increase with increasing temperature. In this study, C/CHLL ratios increased in summer and autumn in shelf (except October 2011). Picoplankton was found more active in July and November 2010. Nanoplanktonic C/CHLL increased in February 2011 in the shelf. Several peaks were observed in different seasons in offshore (August 2009, April 2010 and February 2011). Mean values indicate picoplankton (3.9) as the most active group in shelf and nanoplankton (2.43) in the offshore.

4.1.5. Phytoplankton Pigments:

In previous studies, diatoms were reported as the most abundant group in the Cilician Basin shelf waters (Lakkis and Lakkis, 1981; Kideys et al., 1989; Eker et al., 2003; Koray, 1995; Eker and Kıdeys, 2000; Polat et al., 2000; Polat and Işık, 2002; Uysal et al., 2003). According to results of our pigment analysis diatoms were found to be the most dominant group in coastal waters except the summer period (July & August) during which elevated phosphate and N/P and reduced N/Si (ammonia dominated N) levels is observed. Diatom flora is replaced by prokaryotic picoplankton

(Cyanobacteria dominated) during summer. Cyanobacteria can develop different strategies to survive against harsh conditions (Tandeau de Marsac and Houmard, 1993). Larger cells composed mainly of diatoms and dinoflagellates in shelf waters are more tolerant (opportunistic) to enriched nutrient levels compared to smaller ones (Fogg, 1991). Increased temperatures as well as light (PAR) levels favour smaller individuals against larger ones since prokaryotic picoplankton retains photoprotective pigment (ZEA) to stand high light conditions. Being able to regulate their pigment concentration, picoplankton is also able to grow faster under high light and temperature (Postius et al. 1998). Prokaryotic picoplankton occasionally may become more abundant in nutrient rich waters (Partensky et al. 1999; Polat and Uysal, 2009) and contribute significantly to primary production during the warm period (Weisse 1993; Kormas et al. 2002). There exist a significant positive correlation between prokaryotic picoplankton and temperature (n: 64, r: 0.427, $P < 0.01$). The observed high positive correlation between cyanobacteria (ZEA) and dinoflagellate (PER) (n: 64, r: 0.745, $P < 0.01$) in this study may be either linked to prey-predator relationship (Christaki et al. 1999; 2001) or their tolerance to increased temperature. Dinoflagellates can be autotrophic, heterotrophic, parasitic or endosymbionts of marine animals and protozoa (Tomas et. al.1997). They may act as producers or consumers or both in the same time in the food web (Gaines and Elbrächter, 1987). It is widely accepted that phosphorus is the limiting nutrient in primary production for the northeastern Mediterranean (Yılmaz and Tuğrul, 1998; Krom et al., 2005). Despite the higher N/P ratios, phosphorus was not utilized completely in shelf waters. Large eukaryotes especially diatoms were limited by nitrogen in shelf waters fed by rivers ($N/Si < 1.1$ and $N/P < 16$). On the other hand, diatom production was limited by phosphorus in February 2010 during which N and Si supply was higher. Similarly concentration of large eukaryotes was found small in shelf in February 2009 while the ratio of N to Si was greater than 1.1. Significant correlation between ammonia, eukaryotic nanoflagellates (n: 64, r: 0.262, $P< 0.05$) and prokaryotic picoplankton (n: 64, r: 0.289, $P< 0.05$) was also observed in the study area. Growth of diatoms seemed to rely much on silicate as the nitrogen increase and phosphorus decrease in shelf waters. Green algae seemed to be most favoured at elevated nitrogen and silicate levels. Prymnesiophytes including coccolithophorids (*Emiliania huxleyi*) were present consistently at both stations throughout the sampling period with remarkably higher contribution to total chlorophyll in shelf than the offshore

where they shifted with prokaryotic picolankton in the latter. Eukaryotic nanoflagellates were mostly dominated by coccolithoporids except in February 2010 when the shelf waters contained surplus amounts of nitrogen and silicate. Enrichment with nutrients of shelf waters during winter also promoted growth of chlorophytes as observed elsewhere (Mackey et al., 2002). Silicate was preferentially consumed by diatoms which further help shape the phytoplankton composition in coastal waters (Ludwig et al., 2009).

Although, shelf waters receive significant amount of freshwater from the surrounding major rivers and brooks, offshore waters receive very limited input. Atmospheric deposition and small scale upwelling events supply a certain amount of nutrients to the oligotrophic offshore waters (Krom et al., 2004; Koçak et al., 2010). Phytoplankton composition is dominated by small sized organisms in offshore waters in the eastern Mediterranean (Li et al., 1993; Yacobi et al., 1995; Ignatides, 1998; Psarra et al., 2005). Prokaryotic picoplankton (cyanobacteria and prochlorophytes) and prymnesiophytes comprise the dominant groups while shifting in time in offshore waters. Prokaryotic picoplankton dominates the bulk in dry seasons and coccolithoporids in cold seasons in the offshore. N/P and N/Si ranged between 5 - 27.5 and 0.02 0.96 in the euphotic zone. In general, N/Si remained below 0.5. Nitrogen was found to be limiting autotrophic production in offshore waters especially during summer (Thingstad et al., 2005; Lagaria et al., 2010). Eukaryotic nanoflagellates dominated by coccolithophorids became excessively important in offshore flora in February and April 2009. Flora further dominated by prokaryotic picoplankton from August 2009 till November 2010 in offshore waters. Cyanobacteria dominated prokaryotic picoplankton in shelf, but, prochlorophytes and cyanobacteria shifted according to seasons and depth in offshore waters. Prochlorophytes were observed as the dominant group in colder deep waters. Conversely, cyanobacteria dominated the warmer upper layer waters in the offshore (n: 65, r: 0.412, $P < 0.01$). Prochlorophytes seemed to be more adapted to oligotrophic conditions than other groups (Dandonneau et al., 2006) in offshore waters. No significant relationship between prokaryotic picoplankton and nutrients were observed in offshore waters.

4.2. Monthly variation in physical, chemical and biological parameters in west side of the Mersin Bay.

Prior to this study, several time series (weekly or monthly) studies had been conducted in almost the same spot in front of IMS-METU in the past (Köksalan, 2000; Eker-Develi, 2004; Yılmaz, 2006; Bayındırlı, 2007; Doğan-Sağlamtimur, 2007.

4.2.1. Hydrography:

During this study, secchi disc depth (SDD) varied between 3 and 34 meters in western part of the Mersin Bay. These values varied between 3 and 41 m in the previous studies (Köksalan, 2000; Yılmaz, 2006; Bayındırlı, 2007; Doğan-Sağlamtimur, 2007). The highest values were recorded in summer (Köksalan, 2000; present study) for the period January 1998 to October 2011 in the study area. Extreme high values observed during summer 1998 were due to invasion of shelf with modified deep Atlantic waters (Uysal and Koksalan, 2006; 2010). Lower SDD values were measured in winter and spring periods. The shelf station was affected greatly from the nearby Lamas River which carries particulate and dissolved humic substances as well as dissolved nutrients to receiving waters during winter and spring. In cases where mud is transported enormously the surface layer becomes very turbid which further delimits incident light to enter lower depths. It may either promote or limit productivity of surrounding waters depending on the quality and quantity of the runoff. The lowest SDD was recorded in March 2011 when particulate organic carbon (POC), primary production (PP) and chlorophyll *a* reached their peak levels in the shelf station. Surface salinity dropped below 36 in that time. Highly significant negative correlations were found between SDD and POC (n: 18, r: -0.724, $P < 0.01$), PP (n: 18, r: -0.811, $P < 0.01$) and chlorophyll *a* (n: 18, r: -0.799, $P < 0.01$). Low SDD's were measured in coastal station in July 2011. Köksalan (2000), Yılmaz (2006) and Bayındırlı (2007) also recorded low SDD in July.

Surface salinity decreased significantly during winter and spring with lowest levels retained in March 2011. Similar lower values were also observed in May 2011 at surface (Köksalan, 2000). This is mainly due to increasing freshwater runoff supplied

by melting snow in Taurus Mountains that occur late spring. Direction of the coastal currents and prevailing winds as well as intensity of runoff shape the salinity profile in the shelf station. Salinity was found low from May 2011 to October 2011 compared to the previous year (May 2010 to October 2010). Short term changes in near surface salinity and temperature delimit formation of a well defined thermocline, halocline or pycnocline in the shallow shelf station (Bayındırlı, 2007). Temperature start to increase beginning with April from surface towards lower depths and continue to increase till late August forming a wide temperature gradient from surface to bottom. With the onset of cooling and convectional mixing during autumn and winter, thermocline migrates from near surface to bottom till December. Highly significant positive correlations ((n: 108, r: 0.415, $P < 0.01$) and (n: 108, r: 0.425, $P < 0.01$)) were observed between temperature and salinity in both stations. Salinity increased with increasing temperature, due to intense evaporation.

PAR has been measured since December 2010 in IMS-METU. Daily and monthly measurements are presented in this section. Surface photosynthetically active radiation (PAR) has reached to high levels (3500 μEinsteins/m^2/s) at midday during sampling period (from January 2011 to October 2011). Monthly mean PAR results indicate plenty of light available from May to September in the region (Figure 3.9) with very low levels during winter. Extreme light during late summer may also limit near surface PP as a result of photo inhibition.

4.2.2. Dissolved Nutrients:

Impact of Lamas River to the surrounding may extend as far as 1055 km^2 (Okyar (1991) with pronounced signals on the particular station for most of the time (Uysal et al., 2004). Compared to larger rivers in the region (Seyhan, Ceyhan, Göksu, Berdan rivers) input from Lamas river remains minor (Koçak et al., 2010). Annual mean water discharge of Lamas River was calculated as 6.7 m^3 s^{-1} (Okyar, 1991) and 3 m^3 s^{-1} (Koçak et al., 2010). Despite its low phosphorus content, Lamas River retains high nitrogen and silicate and high N/P and Si/P ratios (Tuğrul et al., 2006; Uysal and Köksalan, 2006; Doğan-Sağlamtimur, 2007; Koçak et al., 2010). Nitrogen concentration started to increase in September 2010 in shelf surface waters with decreasing salinity which recall freshwater intrusion from the nearby Lamas River to

that particular station. It reached to a peak level of 11.56 μM in March when salinity dropped to a minimum of 35.9 at surface. With increasing salinity in time nitrogen concentration dropped again to low levels below 0.3 μM with a mean concentration of 0.5 μM in coastal waters. High nitrogen concentrations were observed near surface in winter and early spring. Nitrogen concentration was found higher in winter and early spring than summer and autumn. Highly significant negative correlations were found between nitrogen and salinity & temperature ((n: 108, r: -0.247, $P < 0.01$) & (n: 108, r: -0.616, $P < 0.01$)). Silicate concentrations fluctuated throughout the year with a peak level of 4.27 μM in February 2011. Surface highs were observed during winter (January and February 2011). Previously, higher silicate concentrations were also measured in winter (Eker-Develi, 2004), in autumn and spring (Yılmaz, 2006) and in late winter and spring (Bayındırlı, 2007) in shelf waters. Phosphate has also found to fluctuate between 0.02 and 0.08 μM with a mean concentration of 0.04 μM. A gradual decrease in phosphate concentration was observed from January to May 2011. Despite this no seasonality in phosphate concentration was observed earlier (Yılmaz, 2006). N/P (TIN/DRP) ratios were generally higher than 16 from November to April in the shelf station. Increase in N/P starting from November has been related to rainy season (Eker-Develi, 2004; Köksalan, 2000). In general, rainy season start with November in the region (Köksalan, 2000; Koçak et al., 2010). But, N/P and N/Si (TIN/Si) reached to 298 and 17 in surface waters in March 2011, respectively. Mean N/P and N/Si were calculated as 38 and 1.5 in coastal surface waters. N/Si ratios were generally below 1.1 (Redfield) in the shelf station. Mean surface N/Si was found 0.6 (omitting the highest concentration recorded in March 2011). Higher N/P and N/Si ratios were observed in winter and early summer.

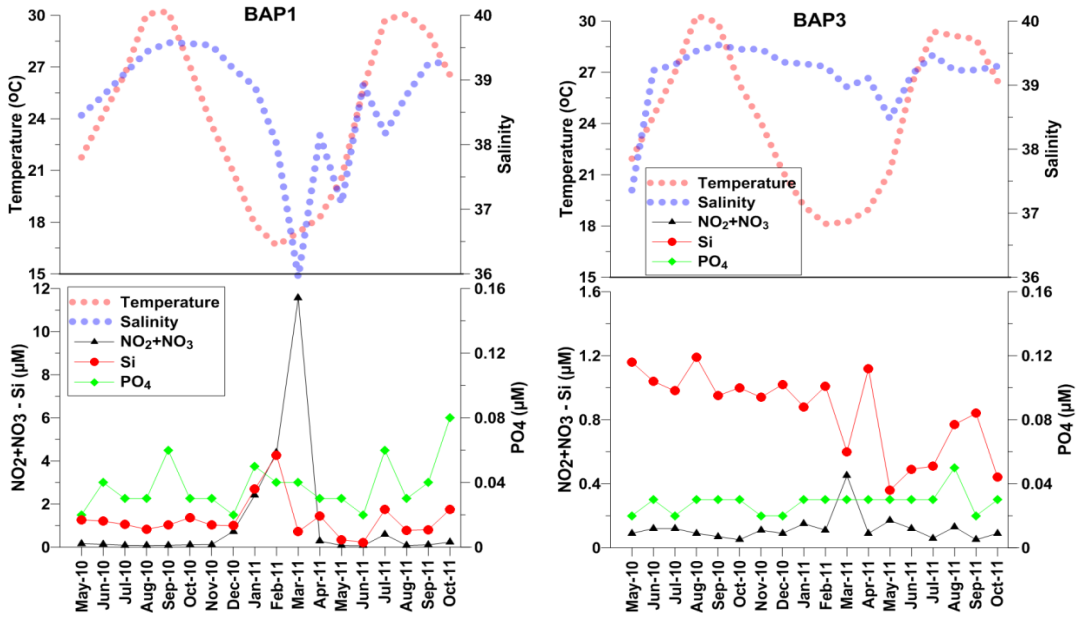


Figure 4.3. Surface distribution of physical and chemical parameters in western side of the Mersin Bay.

Offshore station is located far (10 nautical miles, >200 m) from the effect of the Lamas river. Nitrogen concentration was generally below 0.2 µM within the euphotic zone (top 100 meters). Concentrations increased with increasing depth below the euphotic zone with a near bottom peak in September 2010. Conversely, higher values were measured within the euphotic zone as well as at surface in March 2011. The whole basin was rich in nitrogen in March 2011. Köksalan (2000), Bayındırlı (2007) and Doğan-Sağlamtimur (2007) have also found surface water with high nitrogen content in the whole basin during March. Minimum concentrations were observed at the top 60 meters of the water column. Mean concentrations of nitrogen were higher during the first year (May 2010 – October 2010) than the second year (May 2011 – October 2011). Silicate concentrations ranged between 0.14 - 2.69 µM with a mean value of 1.02 µM in the offshore. To a highest concentration was met near bottom in September 2010. Doğan-Sağlamtimur (2007) declared that higher silicate concentrations were observed in autumn and spring in offshore waters. Mean concentrations of silicate were higher during the first year (May 2010 – October 2010) than the second year (May 2011 – October 2011). Average concentrations were highest in summer than rest of the year. In spring, concentrations increased below 80 meters, but, lower values were observed in upper parts throughout the

sampling period. Concentration of silicate tended to decrease in surface during the study period. A negative relationship between nitrogen and silicate does exist in offshore surface waters, since silicate is less preferred compared to nitrogen & phosphorus by offshore flora dominated by picoplankters (Li et al., 1993; Magazzu and Decembrini, 1995; Uysal, 2006; Yücel, 2008). Flora in offshore waters relies much on nitrogen and phosphorus relative to silicate. N/Si values remained below 0.5 in the offshore. N/Si values increased with depth and reached to 1.1 (Redfield, 1963) in deeper parts in the offshore. Mean phosphate concentration was calculated as 0.03 μM in the offshore during the study period. Phosphate concentrations increased near bottom. Phosphate was measured near detection limits (0.02 μM) in the offshore except January and August 2011. N/P ratios were found below 16 at top 80 meters, and then increased with depth. To a highest value of 106 was met in October 2010.

4.2.3. Chlorophyll *a*:

Total chlorophyll concentrations fluctuated between 0.066 – 2.49 and 0.014 – 0.38 with water column mean levels of 0.46 and 0.12 mg m^{-3} in the shelf and offshore, respectively. Chlorophyll concentrations were measured below 0.5 mg m^{-3} in shelf where to highest concentration was reached in March 2011. Also, higher concentrations were measured in March in previous studies (Eker-Develi, 2004; Yılmaz, 2006; Yücel, 2008). Presence of surplus amount of nutrients as a result of increasing anthropogenic inputs and winter convectional mixing provide optimum conditions for a healthy growth of flora in shelf waters during late winter early spring.

Chlorophyll content of shelf waters for 2011 was 30 % higher than 2010 for the same period (from May to October) except October. More phosphate was supplied to water column and lower salinity was measured during 2011. In August 2010, September 2010, April 2011 and August 2011 concentrations peaked at 30 m depth layer with some more increases at lower depths. Total chlorophyll and PP was mainly controlled by cells greater than 5 microns during May 2011 when the phosphorus loads via rivers was maximum. Similarly contribution of larger cells to total chlorophyll at top 10 meters was highest during June 2010. Picoplankton was the

major contributor of depths below 10 m in June 2010 and of the whole water column during June 2011. Probably larger cells (diatoms) that are not tolerant of warmer waters are replaced by picoplankton that can tolerate higher temperatures.

Chlorophyll tend to increase with depth during July 2010 with two sub peaks in the following year. However the flora at top 10 meters have responded more significantly to PP than those below, possibly as a result of elevated nutrient concentrations introduced by local rivers. Reduced amounts of silica also lowered the chlorophyll content and PP potential of larger cells at near surface. Afterwards, with increasing silica an increase in both is observed. Although the total chlorophyll is enhanced mainly by picoplankton and by large eukaryotes in August 2010 and 2011, respectively, large cells have been the most active group in PP at top ten meters. The second chlorophyll sub peak formed mainly by pico and nanoplankters had no impact on PP at all. They remained inactive and contributed solely to chlorophyll at this depth. Near bottom increases in chlorophyll match well with nutrient profiles during September. PP and total chlorophyll is mainly controlled by picoplankton in October when the nutrients were depleted significantly from the water column.

Picoplanktonic chlorophyll dominated total chlorophyll from June to November and larger planktonic chlorophyll dominated from December to May in shelf waters. There seemed to exist a strong competition between pico and larger plankton in shelf waters based on chlorophyll results. Also, a highly significant positive correlation was found between them (n: 102, r: 0.305, $P < 0.01$). Chlorophyll of larger cells peaked in March 2011 and February 2011. Highly significant negative correlations between larger cell chlorophyll and temperature and salinity ((n: 102, r: -0.401, $P < 0.01$) & (n: 102, r: -0.487, $P < 0.01$)) were found. Contribution of nanoplankton to total chlorophyll was insignificant. However, considerable input has been made to chlorophyll by nanoplankters in October 2010 in the shelf.

In offshore, the highest concentration was measured in May 2011 (0.38 mg m^{-3}) at 100 meters. Very low concentrations were measured in summer and autumn in offshore waters, especially at top 60 meters and inversely with increasing nutrient levels an increase in biomass is observed below it. Low PP rates retained indicate presence of inactive cells in this depth range.

Homogenous chlorophyll profiles observed during winter as a result of convectional mixing have been replaced by deeper highs with the onset of thermal stratification towards summer. Very low chlorophyll levels were retained during summer and autumn in the upper layers. Contribution of cells larger than 5 microns dominated mainly by diatoms to total chlorophyll was highly significant during winter and spring. Contribution of picoplankton to total chlorophyll exceeds those of nanoplankton and large eukaryotes during summer and autumn.

Contribution of larger cells dominated primarily by diatoms to total chlorophyll was greater during March 2011 as a result of increased nutrient concentrations at surface. The observed high in nutrient concentrations and low in surface salinity in offshore surface waters indicate wind or current induced drifting of coastal surface waters towards offshore. Large diatoms most of which drifted from coastal waters temporarily inhabit offshore waters during winter and spring. River discharges are so intense during this period that freshwater may expand towards offshore carrying both the dissolved and particulate matter with it.

Highly significant negative correlations have been found between temperature and total chlorophyll (n: 108, r: -0.551, $P < 0.01$) and contribution of chlorophyll from different groups ((n: 102, r: -0.627, $P < 0.01$) pico; (n: 102, r: -0.432, $P < 0.01$) nano; (n: 102, r: -0.490, $P < 0.01$) large cell). A deep chlorophyll maximum was found between 60 and 120 meters during the study period. Presence of a deep chlorophyll maximum was reported earlier between 50 and 130 m in the northeastern Mediterranean (Ediger and Yılmaz, 1996; Eker-Develi, 2004; Yılmaz, 2006). Picoplanktonic chlorophyll dominated total chlorophyll during the sampling period. Zohary et al., (1998) declared that picoplankton was the major contributor to chlorophyll in eastern Mediterranean. Highly significant positive correlation was found between picoplanktonic chlorophyll and nitrogen (n: 102, r: 0.231, $P < 0.01$) in offshore waters. Larger plankton contributed more than nanoplankton to total chlorophyll in offshore waters for the period December 2010 to March 2011. In general, concentrations made peaks at middle or deeper depths (between 40 and 100 meters).

Depth integrated chlorophyll (ICHL) concentrations fluctuated between 3.6 – 67.3 and 4.60 – 20.8 with water column mean levels of 17.6 and 12.50 mg m^{-2} in the shelf

and offshore, respectively. When averaged for each m^{-2} the chlorophyll content of shelf waters (0.440 mg m^{-2}) exceeds 3.5 times more the content in offshore waters (0.125 mg m^{-2}).

Contribution of picoplankton to total chlorophyll (%72) exceeded those provided by larger cells (%18). Almost similar ratios have been observed at station T48, with a slight increase in nano's contribution (%11) to the bulk. These values indicate that flora shift from larger cells to smaller ones towards offshore where pico and nanoplankters form the only opposing groups. It is well known that nanoplankters may sometimes react as mixotrophs over picoplankters. These shifts in trophic states as well as lack of necessary nutrients determine much their contribution to total chlorophyll in offshore waters.

4.2.4. Primary Production:

Rates of primary production (PP) fluctuated between 0.024 – 14.42 and 0.007 – 1.48 with water column mean levels of 1.52 and 0.25 mg C. m^{-3} h^{-1} in the shelf and offshore, respectively. The highest rate was measured in March 2011 in shelf surface waters. Intense freshwater input in the meantime decreased surface salinity to a low level of 36 and increased significantly the chlorophyll and nitrogen contents of the water. Secchi depth was measured lowest (3 m) in this month. Highly significant negative correlations were found between PP and salinity (n: 108, r: -0.282, $P < 0.01$), phosphate (n: 108, r: -0.236, $P < 0.01$) and ammonium (n: 108, r: -0.260, $P < 0.01$). Silicate was depleted by larger cells, especially by diatoms rapidly. It is interesting to note here that phosphorus has been found to be the precursor of PP relative to silicate as a result of the nutrient enrichment experiment done in March. Diatom cells that are already developed in the water column require phosphorus to continue dividing (Egge, 1998).

PP decreased with increasing depth during autumn and winter in shelf waters. Low light intensities at depths eventually delimit PP in the shelf. In addition self-shading by high algal biomass developed at upper depths of incident light limit sharing of enough light by cells inhabiting lower depths. As a result, the top 20 meters remains more productive compared to lower depths. Except October 2010, February, March

and July 2011, PP was generally below 2 mgC. m^{-3} h^{-1} for the rest of the period. Secchi disc depth was measured very low in these months. Carbon produced per unit chlorophyll (C/CHLL) was lowest during March 2011 indicating presence of a post bloom event.

Despite the high phosphorus content, very low PP values were observed in October 2011. C/CHLL was also found very low. Although almost similar conditions were present both the PP and C/CHLL values were significantly lower compared to those measured in October 2010. In addition, the chlorophyll content of the water was also found very low in October 2011.

No similarities among revisited months were observed for the period May to October in the shelf. May, July, August 2011 were found more productive than 2010 (same months) in shelf waters. River impact was more significant during 2011 than the previous year. Diatoms became more active during this period as a result of increased silicate concentrations in the shelf. Both the apparent contribution of diatoms to total chlorophyll and high PP rates controlled mainly by large cells (mainly diatoms) has been found parallel to each other.

PP is controlled mainly by nutrient availability and temperature. PP simply shows the carbon assimilation capacity of the flora while chlorophyll designates the size of the standing stock. Since the metabolic efficiencies differ from one cell to another depending on the physiological state of an individual cell, high biomass may not yield high PP as desired always. Smaller cells have better metabolic activity and assimilate carbon more efficiently compared to larger cells (Raven, 1984; Finkel et al. 2005; Falkowski and Knoll, 2007).

In June 2010, PP was found higher than June 2011 in shelf surface waters. PP was dominated by large cells during June 2010 and by picoplankton in the following year. Relatively colder waters enriched with plenty of silicate favored diatoms over others during June 2010 which further had an apparent effect on PP.

River discharges have increased phosphate and silicate content of surface waters in July 2011. High PP rate retained near surface was mainly supported by cells greater than 5 microns. An abrupt decline in silicate as well as in nitrate (below detection limits) reduced to almost nill the PP and contribution from this size group. Below it,

picoplankters that are usually dominant during summer formed the most efficient group. Shelf (coastal) waters are in general dominated by picoplankters during July. With increasing silicate concentrations larger cells again became more active at lower depths although their carbon assimilation efficiencies remained below those of picoplankters.

PP had displayed two peaks in May 2010, one at surface which is primarily dominated by larger cells and the other at 20 m which is mainly supported by picoplankters. Increased river input with high phosphate content promoted PP significantly in May 2011. Compared to May 2010, silicate could have been depleted more quickly and efficiently in May 2011. This eventually will limit the production of larger cells mainly the diatoms. Carbon to chlorophyll ratios designate a more active flora in May 2010 compared to the following year. This shows us that all the available silicate has been fully consumed by diatoms in May 2011. The observed N/P and N/Si ratios were <7.5 and <0.4, respectively.

August 2011 has been found more productive than the previous year. All algal groups were favored by lateral nutrient inputs from the surface. Among these groups contribution from larger cells were most significant at the top ten meters. Based on the C/CHLL ratios larger cells have been found most active among all. In general picoplankton was defined as the most dominant group in shelf waters during hot summer periods (Yılmaz, 2006; Yücel, 2008). However, although limited, even small amount of nutrient provision to the surface waters from perennial rivers during summer may promote larger cells inhabiting near surface waters in the inner bay. In this case, success of larger cells (composed primarily of diatoms) is likely to rely much on silica availability than nitrogen & phosphorus availability.

Contribution to total primary production (TPP) of certain algal groups differs in time and with depth. From June 2010 to January 2011, PP was dominated by picoplankters and from February to May 2011 by larger cells. Picoplankton and larger phytoplankton remained in competition in shelf waters for most of the year. In the presence of both, larger cells usually have dominated the near surface and smaller ones the lower depths. Larger cells mostly bloom and dominate in coastal waters enriched with riverine inputs (Agawin et al., 2000; Ning et al., 2000; Ansotegui et al., 2003). Picoplankton was the major contributor to PP in October and November 2010

in coastal waters. Nanoplankters forming the smallest portion in overall composition have dominated total primary production in surface waters during May 2011. Based on C/CHLL ratios, picoplankton seemed to be the most active group among all in shelf waters with a high ratio of 3.8, with nanoplankton being the least active with a low ratio of 2.9. However, overall contribution of larger cells (%44) to PP is almost equal to those of picoplankters (%41) in shelf waters.

Very low PP values were measured in the offshore. To a highest value was met at 10 m depth in March 2011 (1.48 mgC. m^{-3} h^{-1}). Higher rates were also measured in January (dominated by picoplankton) and May 2011 (dominated by larger cells) at the same depth.

Near surface waters were enriched with P and N during January & March 2011 which further enhanced PP. Low salinities observed at surface offshore waters indicate enhanced river input in the meantime. Expansion of freshwater towards offshore has favored cells larger than 5 microns to dominate PP at top 10 m of the water column. Large cells with slightly lesser contribution to total chlorophyll were observed to be the most active group due to their high C/CHL ratio. However PP was found to be dominated by picoplankton below 10 m. Depth integrated PP results clearly designate picoplankton as the most efficient producer group.

Almost all parameters displayed a homogenous profile from surface to bottom in the shelf due to winter convectional mixing with an apparent increase in nutrient content of the euphotic layer during January 2011. Slight increase in PAR levels promoted PP during this period. PP was dominated by picoplankton when biomass and activity are taken into consideration. On the other hand, carbon assimilated per unit chlorophyll has been found most efficient in large cells. Near surface PP made peaks during December 2010. Although contribution of nanoplankton to PP and total chlorophyll was minor during December 2010 and January 2011, contribution of eukaryotic nanoplankton to marker pigment composition was found high during this period. Apart from the eukaryotic coccolithophorids that dominate the nanoplankton, the rest of the nanoplankton could be of either mixotrophic or heterotrophic origin (Gaines and Elbrächter, 1987; Tomas et al., 1997)

PP decreased to a low level of 0.007 mgC. m^{-3} h^{-1} in October 2011. Low light levels during winter enable only the top few meters to be most productive. PP profiles have

been found more homogenous at optimum light levels retained at lower end of the euphotic layer during summer and fall with decreasing nutrient levels at surface compared to winter and spring surface & subsurface maximas (Armbrust et al., 1989). In some cases, secondary PP peaks that match with the DCM were observed at mid-depths during August and September 2011. Observed sudden decrease in PP and total chlorophyll content at 40 m depth coinciding with the thermocline during August and September 2011 imply low tolerance of the existing flora to such thermal shocks. Very low values were observed in October 2011 in the water column. Despite the reasonable chlorophyll and marker pigment concentrations, PP and carbon assimilated per unit chlorophyll were measured too low in this month.

The most dominant contributor was picoplankton in offshore waters. But, in March and May 2011, larger cell dominated PP at top 10 meters. Earlier studies also indicate domination of PP by picoplankters in offshore waters in the region (Zohary et al., 1998; Li et al., 1993; Magazzu and Decembrini, 1995; Yücel, 2008; Siokou-Frangou et al. 2010). In addition nanoplankters were found more efficient during warm periods. A highly significant positive correlation (n: 102, r: 0.534, $P < 0.01$) was found between nanoplankton chlorophyll and PP. Moreover, highly significant positive correlation did exist between nanoplanktonic PP and picoplanktonic PP (n: 102, r: 0.295, $P < 0.01$) and negative correlation between nanoplanktonic PP and picoplanktonic chlorophyll (n: 96, r: -0.286, $P < 0.01$), all implying a close contact between both groups.

Rates of Integrated Primary Production (IPP) fluctuated between 2.45 – 121 and 3.3 – 46.5 with mean levels of 48.6 and 20.2 $mgC.m^{-2}\ h^{-1}$ in the shelf and offshore, respectively. While larger cells (>5 μm) dominated phytoplankton composition in nutrient rich shelf waters from February 2011 to July 2011 (except June 2011), picoplankton dominated shelf waters for the rest of the year. Observed highly significant negative correlation between larger cells and salinity (n: 108, r: -0.415, $P < 0.01$) indicate direct impact of freshwater on the success of diatom dominated larger cells in coastal areas. Intrusion of freshwater with high phosphorus and silica content promotes the growth of diatoms in receiving waters. With decreasing anthropogenic inputs a shift from larger cells to smaller ones (picoplankters) is observed with the onset of summer and during fall. Nanoplankters have been found to be the least efficient in PP in the region.

In the nutrient-depleted Cilician Basin offshore waters, IPP was dominated by picoplankton (except May 11). Their average contribution increased from 41 % to 54 % of total primary production in shelf and offshore waters, respectively. Contributions from the nanoplankters have also increased from inshore to offshore. Even small amount of ammonium supply from inshore may inhibit nitrite uptake by coccolithophorids (Varela and Harrison, 1999; Lewitus et al., 1998). A gradual decrease in ammonium occurs from inshore towards offshore. On the average, nanoplankters have been found to be the most efficient group in terms of carbon assimilation per unit chlorophyll (C/CHLL 4.70) in offshore waters. Almost all previous studies do indicate that with increasing oligotrophy there is a shift from large to pico and nano fractions of the flora (Peeken, 1997; Tremblay et al., 1997; Gibb et al., 2000; Gin et al., 2000; Christaki et al., 2001; Pitta et al., 2001; Van Wambeke et al., 2002; Ansotegui et al., 2003).

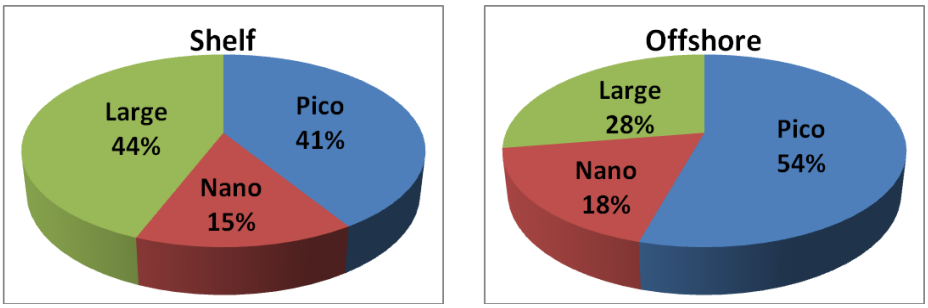


Figure 4.4.% contribution of groups to total primary production in western side of the Mersin Bay.

Monthly integrated primary production rates fluctuated between 0.60 – 34.90 and 1.01 – 14.83 with mean levels of 12.60 and 5.45 g $C.m^{-2}$ $month^{-1}$ in the shelf and offshore, respectively. The most productive months were found as July 2011 in the shelf and March 2011 in the offshore. The lowest values were calculated in October 2011 in the basin. These daily, monthly and annual rates were based on daily photosynthetically active radiation (DPAR). Depth integrated primary production (DIPP) rates were extrapolated to the whole day time by using DPAR data. These daily rates were converted to monthly primary production by using DPAR data. For this reason, monthly production was calculated highest for July during which the

sunlight is most efficient and long lasting instead of March 2011 when the highest PP rates were measured.

Annual primary productivity was estimated to be 65.4 for the offshore and 151.2 g $C.m^{-2}$ y^{-1} for the shelf in the Cilician basin for this study. These rates varied in the range 14 and 425 mg $C.m^{-3}$ d^{-1} for the shelf and in the range 1.5 and 9.5 mg $C.m^{-3}$ d^{-1} in the offshore in a previous study conducted for surface waters only (for the period May, July, November and December 2002 and March 2003; Yilmaz, 2006). Yılmaz (2006) estimated annual production as 110 g $C.m^{-2}$ y^{-1} for the offshore. Seasonal primary productivity was estimated as 32.6, 55.4, 57.3, 5.9 g $C.m^{-2}$ for shelf and 12.9, 25.3, 14.6 and 12.58 g $C.m^{-2}$ for offshore, for winter, spring, summer and autumn, respectively. Seasonal primary productivity was found higher during summer in the shelf and during spring in the offshore.

Previous annual primary productivity estimates varied in the range 20,3 and 232 g $C.m^{-2}$ y^{-1} in the Mediterranean (Sournia, 1973; Dugdale and Wilkerson, 1988; Lefévre et al., 1997; Ignatiades et al., 1998; Conan et al., 1998; Psarra et al. 2000; Boldrin et al., 2002; Boldrin et al., 2002; Marty and Chiaverini 2002. Moutin and Raimbault, 2002; Yılmaz, 2006)

Based on carbon to chlorophyll (C/CHLL) ratios different size groups appeared to be dominant for a particular period both in the shelf and in the offshore. In offshore waters highest C/CHLL ratio was achieved in nanoplankton (4.7) with two significant peaks observed in May & June 2010. C/CHLL ratio was also found high for the large phytoplankton in offshore waters (Finenko et al., 2003). This is reversed in the shelf where C/CHLL ratios of picoplankton (3.83) became more significant. This ratio was calculated lowest during October 2011 in the shelf. On the average C/CHLL ratios of the offshore phytoplankton was 1.90 which makes almost half the value obtained for shelf phytoplankton (3.26).

4.2.5. Phytoplankton Pigments:

Based on pigment composition, shelf waters were dominated by diatom (FUC) dominated large eukaryotes from February 2011 to May 2011. In previous studies, diatoms were reported as the most abundant group in the Cilician basin shelf waters (Lakkis and Lakkis, 1981; Kideys et al., 1989; Eker et al., 2003; Koray, 1995; Eker and Kıdeys, 2000; Polat et al., 2000; Polat and Işık, 2002; Uysal et al., 2003; Uysal et al., 2004). On the other hand, prokaryotic picoplankton dominated phytoplankton pigment composition from July 2010 to January 2011 and from June to October 2011. Diatom flora was replaced by prokaryotic picoplankton (Cyanobacteria dominated) during these months. Cyanobacteria can develop different strategies to survive against harsh conditions (Tandeau de Marsac and Houmard, 1993). Larger cells composed mainly of diatoms and dinoflagellates in shelf waters are more tolerant (opportunistic) to enriched nutrient levels compared to smaller ones (Fogg, 1991). Increased temperature as well as light (PAR) level favors smaller individuals against larger ones since prokaryotic picoplankton retains photoprotective pigment (ZEA) to resist high light conditions. Being able to regulate their pigment concentration, picoplankton is also able to grow faster under high light and temperature (Postius et al. 1998). Prokaryotic picoplankton occasionally may become more abundant in nutrient rich waters (Partensky et al. 1999; Polat and Uysal, 2009; Uysal et al., 2004) and contribute significantly to primary production during the warm period (Weisse 1993; Kormas et al. 2002). There exist a significant positive correlation between prokaryotic picoplankton and temperature (n: 108, r: 0.236, $P < 0.05$), salinity (increase in summer time) (n: 108, r: 0.251, $P < 0.01$), phosphate (n: 108, r: 0.370, $P < 0.01$) & ammonium (n: 108, r: 0.227, $P < 0.05$). Moutin et al. (2002) suggest that prokaryotic picoplankton (*Synechococcus* sp.) display high affinity for orthophosphate and significantly higher maximum uptake rates than heterotrophic bacteria and eukaryotic cells. Results from the mesoscale Lagrangian phosphate-enrichment experiment also support this conclusive remark (Psarra et al., 2005). The observed highly significant positive correlation between cyanobacteria (ZEA) and dinoflagellate (PER) (n: 102, r: 0.314, $P < 0.01$ in shelf and n: 102, r: 0.397, $P < 0.01$in offhore) in this study may be either linked to prey-predator relationship (Christaki et al. 1999; 2001) or their tolerance to increased temperature. Dinoflagellates can be autotrophic, heterotrophic, parasitic or endosymbionts of

marine animals and protozoa (Tomas et. al., 1997). They may act as producers or consumers or both in the same time in the food web (Gaines and Elbrächter, 1987). It is widely accepted that phosphorus is the limiting nutrient in primary production for the northeastern Mediterranean (Yılmaz and Tuğrul, 1998; Krom et al., 2005). Eukaryotic nanoflagellates dominated in May and December 2010. They also shifted with other groups in October and November 2010 in the water column. In addition, high concentrations of eukaryotic nanoflagellates were found in May and October 2011. Highly significant negative correlation was found between eukaryotic nanoflagellates and temperature in shelf (n: 108, r: -0.334, $P < 0.01$). Eukaryotic nanoflagellates were mostly dominated by coccolithoporids (Uysal et al., 2004). Diatom dominated large eukaryotes became most abundant during March 2011 in shelf waters due to Lamas River discharges of necessary dissolved nutrients. Large eukaryotes especially diatoms were limited by silicate and phosphate availability in shelf waters ($N/Si > 1.1$ and $N/P > 16$). But, when individual pigments were checked, it was clear to see that phytoplankton pigment composition was composed of four major pigments namely; FUC (diatom), ZEA (cyanobacteria), HEX (prymnesiophytes) and DIV-A (prochlorophytes) in shelf waters. Diatoms (FUC) were dominated pigment composition from February to August 2011 and during June 2010 in the shelf. Prymnesiophytes were found as the major group in May, October and November 2010. Cyanobacteria was dominated shelf waters during July, August, September 2010 and September and October 2011 (Köksalan, 2000; Uysal et al., 2004; Uysal 2006; Bayındırlı, 2007). Also, prochlorophytes dominated composition in December 2010 and January 2011, but replaced with prymnesiophytes in deeper parts of the water column in shelf waters. Silicate was preferentially consumed by diatoms which further help shape the phytoplankton composition in coastal waters (Ludwig et al., 2009). Although, shelf waters receive significant amount of freshwater from the surrounding major rivers and brooks, offshore waters receive very limited input. Atmospheric deposition and small scale upwelling events supply a certain amount of nutrients to the oligotrophic offshore waters (Krom et al., 2004; Koçak et al., 2010). In previous studies it was shown that the eastern Mediterranean offshore waters' phytoplankton composition was dominated by small sized organisms (Li et al., 1993; Yacobi et al., 1995; Ignatides, 1998; Uysal et al., 2004; Psarra et al., 2005). In the offshore waters, prokaryotic picoplankton dominated phytoplankton pigment composition from June 2010 to November 2010 and April to

October 2011 except August 2010 and May 2011. On the other hand, eukaryotic nanoflagellates (mainly the coccolithophorid *Emiliana huxleyii*) dominated flora in May and August 2010 and from December 2010 to February 2011 (Uysal et al., 2004). They also contributed significantly to total pigment concentrations in September and October 2010 during which the prokaryotic picoplankton was the dominant group. Prokaryotic picoplankton (cyanobacteria and prochlorophytes) and prymnesiophytes comprise the dominant groups while shifting in time in offshore waters. Diatom dominated large eukaryotes have flowered in offshore waters during March and May 2011 due to expansion of freshwater towards offshore. In May 2011, prochlorophytes formed the second dominant group especially in the deeper parts. But, in that time, we were unable to detect this particular pigment at 40 and 60 meters except chlorophyll *a*. Prochlorophytes dominated the water column mostly during November 2010 and October 2011 in offshore waters. Eukaryotic nanoflagellates dominated by coccolithophorids reached the peak concentration in the deepest sampling depth of 100 meters during October 2011. Diatom dominated large eukaryotes reached again their highest concentrations at top 10 meters in March 2011. Nitrogen seemed to be the limiting nutrient for autotrophic production in offshore waters especially during summer (Thingstad et al., 2005; Lagaria et al., 2010). Eukaryotic nanoflagellates became excessively important in offshore flora. Although prochlorophytes were present in the water column throughout the study period in shelf, they could not be detected above thermocline. Prochlorophytes were observed as the dominant group in colder deep waters in the eastern Mediterranean (Mella-Flores et al., 2011). Conversely, cyanobacteria dominated the warmer upper layer waters in the offshore. Prochlorophytes seemed to be more adapted to oligotrophic conditions than other groups (Dandonneau et al., 2006) in offshore waters.

4.2.6. Bacterial Production:

To date only few studies dealt with the bacterial production in the northeastern Mediterranean (Zoppini et al., 2008; Amalfitano et al., 2009; Zoppini et al., 2010). Previous studies have focused mainly the western Mediterranean, Aegean Sea, and Levantine basin of the eastern Mediterranean (Zohary and Robarts, 1992; Robarts et

al., 1996; Wambeke et al., 2000, 2002; Turley et al., 2000; Christaki et al., 2003; Tanaka and Rassoulzadegan, 2004). There is a gradual decrease in bacterial and PP from west to east in the Mediterranean. Rates of bacterial production vary between 1 and 468 mg C m^{-2} d^{-1} for the western and between 7 and 131 mg C m^{-2} d^{-1} for the eastern Mediterranean (Siokou-Frangou et al. 2010).

In the present study, bacterial carbon production (BCP) varied between 0.002 and 0.270 mg C.m^{-3} h^{-1} in the shelf and 0.001 and 0.1 mg C.m^{-3} h^{-1} in offshore waters throughout the sampling period. Mean bacterial carbon production (BCP) rates were calculated as 0.05 and 0.015 mgC. m^{-3} h^{-1} for the shelf and offshore, respectively. Daily BCP rate varied in the range 7.4 - 39.7 at top 50 m in the shelf and 8.9 - 35.4 mg C m^{-2} d^{-1} for the 200 m water column in the offshore. BCP has been found to decrease with depth in the offshore (Winter et al., 2009). Our findings also support this eastward decrease in BCP rates. BCP measurements provided with this study may be considered preliminary for the Cilician Basin.

Highest values were measured in February 2011 in the shelf and in August 2011 in offshore surface waters. BCP has been found maximum during winter (January & February) and summer (July & August) compared to the rest of the year in shelf waters. Similar winter high is also observed in the offshore with a relatively deeper maximum during summer. Offshore BCP profile mimicked those of chlorophyll, POM and DOM during July. Summer lows in the upper part of the euphotic layer were replaced by higher BCP rates during October in offshore waters, all in concordance with the PP and chlorophyll profiles.

Highly significant negative correlation was observed between BCP and salinity (n: 60, r: -0.535, $P < 0.01$) in shelf waters. Also, highly significant positive correlation was found between BCP and all size classes of chlrorophyll *a* (n: 60, $r > 0.381$ in all size groups, $P < 0.01$) and primary production (n: 60, $r > 0.580$ in all size groups, $P < 0.01$) in eutrophic coastal waters. Enhanced phytoplankton biomass retained during winter & spring in shelf waters promotes bacterial production to a certain degree while temperature acts as an overall key parameter regulating bacterial growth. Dissolved substances carried by rivers as well as decaying of the already formed phytoplankton support DOC pool necessary for bacterial growth (Fuhrman and Azam 1982; Cole et al. 1988; White et al. 1991; Jenkinson and Biddanda, 1995;

Gasol et al. 1998; Nagata 2000; Chrost et al., 2000; Tsai et al., 2011). Increase in PP simultaneously result in an increase in DOC content of the water. Highly significant correlation was found between BCP and large cells (CHLL, n: 60, r: 0.574, $P < 0.01$ and PP, n: 60, r: 0.580, $P < 0.01$) at shelf near surface waters. Large cells flowered during excess nutrient cases form the basic source of DOC in shelf waters (Amon and Benner, 1994). PP and BCP have been found to mimic the other in shelf waters (Gasol et al. 1998; Tsai et al., 2011). BCP increase with increasing eutrophication in areas receiving extensive river discharge. BCP rates tend to decrease with increasing depth in the shelf. Highest BCP rates were retained at top 20 m of shelf, which itself is almost 3 times more productive than the offshore.

Mean BCP for the water column at both stations were similar (0.008 $mgC.m^{-3}\ h^{-1}$) in September 2011. The difference between both stations will be most pronounced if the BCP rates are integrated to depth.

The observed significant positive correlation between BCP and temperature (n: 60, r: 0.338, $P < 0.01$) in the offshore was not found for the shelf. BP increases in parallel to nutrient enrichment during winter and spring in the shelf. Nutrient deficiency during summer indirectly lowers BP rates although the ambient temperature is optimal for bacterial growth in the shelf. It is highly probable that nutrient availability could mask statistically the temperature effect on BP.

In general procaryotes do better at elevated temperatures. Previous studies showed that BCP and abundance increase with increasing temperature (Shiah and Ducklow, 1994; Carlson et al., 1998; Tsai et al., 2008; Solic et al., 2008; Winter et al., 2009; Azaro et al., 2012). However in our case nutrients are only available during the cold season (winter and spring). As a result of this statistically no relationship was observed between BCP and temperature in the shelf. BCP rates were only measured high during July & August in the water column. Bacterial abundance was also found high during summer, early autumn in shelf waters (Uysal et al, 2004). Bacterial activity is strongly limited in the eastern Mediterranean offshore waters by lacking necessary sources (DOC pool) while the uptake and removal of such sources by bacteria are intense in eutrophic coastal areas (Ducklow, 2000).

Unit carbon produced per bacterial cell was highest during July and August both in the shelf and offshore in parallel to high chlorophyll & particle content of the water column. Winter & spring bacterial flora rely mostly on dissolved organic substances that are produced through excretion, exudation and diffusion of recent phytoplankton blooms where summer flora rely mostly on easily degradable DOM sources of winter & spring remnants of the phytoplankton flora (Hobbie and Williams, 1981; Azam et al., 1983; Jumars et al. 1989; Bergström & Jansson, 2000). Unit carbon produced per bacterial cell was found least during September & October in the shelf. In contrast, bacterial activity was found high in offhore waters above thermocline in the meantime due to accumulation of particles within the surface mixed layer.

Maximum BCP was measured in July and August 2011 in offshore surface waters. In these months, temperature was measured maximum at surface. Significant positive correlation was found between BCP and nanoplanktonic primary production (n: 60, r: 0.320, $P < 0.05$) which might be related to possible prey-predator relationship that exist between bacteria and nanoplankton (Solic et al., 2008). Increase in heterotrophic activity and bacterial abundance result in an increase in nanoplankton production and biomass which further recalls prey-predator relationship. (E. Sherr et al. 1986, Sanders & Porter 1988, Pace et al. 1990, Proctor & Fuhrman 1990; Caron et al., 1991; Sanders et al., 1992; Stickney et al., 2000; Boissonneault-Cellineri et al. 2001; Schultz et al. 2003; Solic et al., 2008; Tsai et al., 2011). In search of a possible relationship between bacteria and heterotrophic nanoplankton, Sanders et al., (1992) have pointed out bottom-up control in oligotrophic systems whereas a top-down control mechanism is evident in eutrophic coastal waters (Ducklow, 2000).

Negative correlation between bacterial abundance and autotrophic procaryotes (n: 108, r: - 0.171, $P < 0.05$) recall competition for available food sources (Currie and Kalff, 1984; Kirchman, 1994; Thingstad, 2000; Michelou Vanessa K., 2009; Michelou et al., 2011). Affinity of procaryotic picoplankton is greater and its' uptake is faster compared to heterotrophic bacteria (Van Wambeke et al., 2002; Moutin et al., 2002 Michelou et al., 2009, 2011). On the other hand, heterotrophic bacteria with a greater surface to volume ratio rely mostly on DOM that originates from phytoplankton to grow. Heterotrophic bacteria are known to be efficient recyclers (Currie and Kalff, 1984; Tranvik, 1988; Valiela, 1995; Munn, 2004; Michelou et al., 2011). For this reason there exists a mutualistic competition in between both groups.

Despite the general tendency that bacterial productivity is limited by phosphate in the eastern Mediterranean no significant relationship has been observed in between both parameters (Siokou-Frangou et al., 2010). However, results of our recent limiting nutrient addition experiments point out phosphate as the limiting factor for bacterial production. However in nature changes in type of limiting nutrient may occur within short intervals (Sala et al., 2002). For this reason, typical short term experiments may not give the truth always. In order to understand such a dynamic system satisfactorily all other ambient parameters should be simulated efficiently throughout the experiment.

Overall, a decline at around 20 m depth in almost all BCP profiles is observed in the shelf. This then followed by a slight increase at 30 m depth. Although it had no impact over PP, all nutrients (N, Si and PO_4) and chlorophyll displayed similar profiles. Despite the overall decreasing trend in carbon assimilated per cell with depth, a sudden increase in it was observed below 20 m in May 2011 towards bottom. Normally, bacterial production was found low in such depths in May. Observed significant fluctuations in cell numbers also imply presence of very active cells in the water column.

Rates of integrated bacterial carbon production (IBCP) fluctuated between 0.31 – 3.36 and 0.37 – 2.81 with mean levels of 1.65 and 1.47 mgC. m^{-2} h^{-1} in the shelf and offshore, respectively. Monthly integrated bacterial carbon production rates fluctuated between 0.2 – 2.5 and 0.3 – 2.1 with mean levels of 1.2 and 1.1 g $C.m^{-2}$ $month^{-1}$ in the shelf and offshore, respectively. The highest values were observed in August 2011 in the shelf and in October 2011 in the offshore. Finally, annual bacterial carbon production was estimated as 14.6 g $C.m^{-2}$ y^{-1} for the shelf and 12.9 g $C.m^{-2}$ y^{-1} for offshore waters.

Table 4.1. Bacterial Production measurements from the Mediterranean (modified from Siokou-Frangou et al. 2010).

Referances	Bacterial Production (PP)	Location	Period
Present Study	0.31 - 3.36 (coastal) 0.37 - 2.81 (offshore) mg C m^{-2} h^{-1}	NE Mediterranean Sea	Jan - Oct 2011 (monthly)
Zohary and Robarts (1992)	0.2-0.4 pmol TdR l^{-1} h^{-1} 0.2-0.48 106 cells l^{-1} h^{-1}	Levantine Basin, Cyprus eddy, core and boundary	Sep

Robarts et al. (1996)	0.04-0.2 µg C l^{-1} d^{-1} 0-3.9, avg: 0.3 pmol TdR l^{-1} h^{-1} 8-43, avg 24 mg C m^{-2} d^{-1} (200 m)	Levantine basin	Oct - Nov
Zohary et al. (1998)	0.0-0.2 average 0.1 pmol TdR l^{-1} h^{-1}	Cyprus eddy	Mar
Van Wambeke et al. (2000)	0.45-1.96 µg C l^{-1} d^{-1} 7-131, avg 45 mg Cm^{-2} d^{-1} (100 m)	S. Aegean Sea (transect off-shore)	Sep, Mar
Christaki et al. (2003), Siokou-Frangou et al. (2002)	0.22-0.94 µg C l^{-1} d^{-1} 48-110 mg Cm^{-2} d^{-1} (10 m)	North and South Aegean	Sep, Mar
Christaki et al. (2001), Van Wambeke et al.	0.0048-1.3 µg C l^{-1} d^{-1} 13-75 mg Cm^{-2} d^{-1} (200 m)	East-west transect (Med Sea)	Jun - Jul
Fernández et al. (1994)	0.04-3.26 µg C l^{-1} d^{-1} 124-199 mg Cm^{-2} d^{-1} (150 m)	Almeria-Oran font (Alboran Sea)	May
Christaki et al. (1996, 1998)	1.2-7.2 µg C l^{-1} d^{-1} (5 and 40 m) 1.0-2.1 pmol TdR l^{-1} h^{-1}	NW Mediterranean current	May and Jun
Gasol et al. (1998)	0.5-3.0 pmol l^{-1} h^{-1} 20-360 mg C m^{-2} d^{-1} (60-80 m)	Barcelona: In-Offshore transect	Jun
Pedrós-Alió et al. (1999)	0.02-2.5 µg C l^{-1} d^{-1} 1-104 mg C m^{-2} d^{-1} (200 m)	Barcelona Balearic Islands	Stratification period (3yr)
Moran et al. (2001)	0.3-4.5 µg C l^{-1} d^{-1} 33-384 mg C m^{-2} d^{-1} (120 m)	Algerian current	Oct
Vaqué et al. (2001)	0.09-5.9 µg C l^{-1} d^{-1}	NW Mediterranean: transects off-shore	Mar
Lemée et al. (2002)	undetectable-4.8 µg C l^{-1} d^{-1} 60-468 mg Cm^{-2} d^{-1} (130 m)	NW Mediterranean: station off-Nice	Monthly (one year)
Van Wambeke et al. (2004)	0.1-5.5 µg C l^{-1} d^{-1} 68-215 mg C m^{-2} d^{-1} (200 m) Atl. Jet 52-70 mg C m^{-2} d^{-1} (200 m) Med water	Almeria-Oran front (Alboran Sea)	Nov, Jan

4.2.7. Heterotrophic Bacterial Abundance:

In the present study, heterotrophic bacterial abundance varied in the range 29686 and 1397129 cells ml^{-1} in the shelf and 11989 and 886253 cells ml^{-1} in the offshore

throughout the study period. Mean abundances for the shelf and offshore were 443306 and 233028 cells ml^{-1}, respectively. Mean values were very low during July & August and November & December 2010 in coastal waters. Bacterial abundances were least during October 2011 in the shelf and during August 2010 and 2011 in the offshore. In addition, PP, chlorophyll and floral activity were also measured very low in October 2011 in the shelf. This eventually had a negative impact on the success of bacterial community. However, in a similar study conducted on the same site, bacterial abundance was found much higher at surface during October 2005 (Bayındırlı, 2007).

In addition, low surface values in bacterial abundance coincided with lower PP and chlorophyll concentrations in offshore during August. Nitrate deficiency (N/P is calculated to be below 7) as well as photoinhibition possibly supressed algal growth (low chlorophyll & phytoplankton biomass). On the other hand, bacterial production reached peak levels at surface waters during August 2011 with a maximal carbon assimilated per cell output. This clearly indicates that bacterial activity is efficient at surface waters in this month. It is highly probable that physiological activity increase with increasing surface temperature (Vázquez-Domínguez et al., 2012). Similarly higher bacterial abundance was found before in the same site and time period (Bayındırlı, 2007).

The population was found most abundant in July 2011 in the shelf surface waters and in January 2011 at 150 m in the offshore. Bacterial abundance showed a sharp decrease below 5 m in July 2011 in the shelf. PP and chlorophyll content of the top 5 m was also found high during July 2011 in shelf waters which further promoted bacterial growth. A 6 fold sudden drop in bacterial abundance was observed just below 5 m at 10 m depth. Similar drops are also observed in PP and chlorophyll levels. Observed highly significant negative correlation between salinity and bacterial abundance (n: 108, r: -0.247, $P < 0.05$) clearly indicate the direct impact of the river sources on the success in PP levels and eventually on healthy bacterial growth (Valiela, 1995).

In general, heterotrophic bacterial abundance decreased with increasing depth at both stations. Since their presence is strictly bounded to availability of dissolved organics, a positive correlation does exist between producers and bacteria (n: 102, r >0.282 in

all size of PP, $P < 0.01$) in the water column. Bacteria also reached high abundances in the water column during June 2010 at both stations in the basin. Winter & spring algal blooms provide plenty of dissolved organics for bacterial populations to consume in early summer.

Higher abundances were observed in summer in shelf and summer and winter in offshore (Bayındırlı, 2007). Uysal et al., (2004) declared that maximum HBAs were found in September and March. Low abundances were observed during winter convectional mixing (Uysal et al., 2004). Bacterial carbon production (BCP) and HBA showed highly significant positive correlation (n: 60, r: 0.691, $P < 0.01$) in shelf. Also, highly significant positive correlation was found between primary production (with all groups) and HBA (n: 102, $r > 0.282$ in all size of PP, $P < 0.01$). HBA increased with increasing productivity and increase in amount of particulate matter in coastal waters. The mean abundance in shelf waters was 4.4×10^5 (443306) and in offshore was 2.3×10^5 (233028) cells ml^{-1}. Very low values were observed in shelf in October and in offshore in Augusts (2010 and 2011). Higher abundances were also observed above thermocline in offshore waters (Uysal et al., 2004). HBA decreased with increasing depth in September (Uysal et al., 2004). Abundance reached maximum numbers in deeper part (≈ 160 m). A significant negative correlation is present between HBA and prokaryotic picoplankton in offshore waters (n: 108, r:-0.171, $P < 0.05$). Rates of bacterial carbon production and bacterial abundance displayed similar profiles in shelf waters.

Bacterial abundance was maximal during summer 2011 in the shelf (seasonal mean was 523923 cells ml^{-1}). Similarly, higher abundance was also met in summer 2010 in BAP1. On the other hand, to the peak abundance was met in winter (seasonal mean 328305 cells ml^{-1}) in offshore waters. Except July & August 2011, bacterial abundance was found higher during 2010 compared to 2011 which contrasts with the present PP and chlorophyll levels. In the offshore, comparison of repeated monthly means (May to October 2010 and 2011) clearly indicate higher values in 2010 than 2011.

In January 2011, bacterial abundance decreased suddenly at 60 m depth and below it tends to increase again with increasing depth in offshore parallel to PP. Despite the

low abundance bacterial activity was measured highest at 60 m in parallel to chlorophyll profile.

Bacterial carbon production (BCP) and bacterial abundance profiles mimicked the other in shelf waters. Highly significant positive correlations (n: 60, r: 0.691, $P < 0.01$) were observed between BCP and bacterial abundance in shelf waters. However, this close relationship was not true for the offshore profiles. High abundances did not yield high bacterial uptake as was the case in October 2011 in offshore waters. The maxima for production and abundance were observed at the same depth (February and July 2011) in shelf waters. Although rate of BCP was distributed homogenously in the water column, abundance peaked two times in September 2011 in the shelf. BCP and abundance have displayed similar trends in the water column in February, April and May 2011 in coastal waters.

4.3. Limiting Nutrient Experiment:

Limiting nutrient experiments were accomplished monthly from January 2011 to October 2011 in western stations (Shelf-BAP1 and Offshore-BAP3) and the results are provided in section 3.3.2.

Primary production is known to be limited mainly by phosphorus in the eastern Mediterranean (Krom et al., 1991, 1993; Thingstad and Rassoulzadegan, 1995; Yılmaz and Tuğrul, 1998; Zohary and Robarts, 1998; Ediger et al., 2005; Thingstad et al., 2005; Doğan-Sağlamtimur, 2007). According to some others, primary production is limited by N and P (Pitta et al., 2005; Thingstad et al., 2005; Zohary et al., 2005) and the bacterial production by mainly phosphorus (Siokou-Frangou et al., 2010). In the shelf, phosphate (P) concentration decreased from January to June, and then increased in shelf surface waters.

P was found 0.03 μM from January to October except August (maximum) and September (minimum) in offshore surface waters. Higher nitrogen (N) concentrations were observed in winter and early spring in the Cilician basin. Very low concentrations were measured after April in the shelf. Silicate (Si) was highly available in winter at both stations. N/P and N/Si ratios were generally below 16 and 1.1, respectively, from April to October 2011 in shelf surface waters except June.

N/P and N/Si were calculated to be higher than Redfield ratio (1963) during winter and in June. Ratios (N/P and N/Si) reached to highest levels of 298 and 18 in shelf surface waters where a sharp decline in surface salinity (36.2) in March 2011 was observed. Also, higher N/P was found in offshore in March, which was generally remained below 16 in offshore waters. N/Si was calculated below 1.1 in offshore surface waters. Primary production (PP) was measured highest in March in the Cilician basin. PP decreased from winter to autumn in offshore waters with a minimum in September in the basin. Chlorophyll concentrations remained in harmony with primary production in shelf and offshore. Chlorophyll content of the shelf waters almost ten fold those in the offshore. Bacterial carbon production (BCP) made two peaks in shelf, one in winter and the other in summer. Higher values were observed in summer in offshore waters. No correlation was existed between bacterial abundance and BCP where the former made a peak in July and the latter a peak in February in the shelf. Cyanobacterial abundance and chlorophyll concentrations displayed similar profiles in offshore waters.

4.3.1. Primary Production and Chlorophyll *a*:

PP was limited by N+P in shelf surface waters. Also, PP was limited by P in February and March 2011 when N concentration made a peak in the shelf. Silicate promoted PP in October 2011 in the shelf. On the other hand, PP was limited by N+P and P in offshore waters (Krom et al., 1991, 1993; Thingstad and Rassoulzadegan, 1995; Yılmaz and Tuğrul, 1998; Zohary and Robarts, 1998; Ediger et al., 2005; Thingstad et al., 2005; Doğan-Sağlamtimur, 2007). Chlorophyll *a* (CHLA) concentrations were measured at the end of the experiments. CHLA was limited by N+P and P and P+Fe co-limited in the Cilician Basin.

4.3.2. Phytoplankton Pigments:

Response of different phytoplankton groups to various nutrient combinations (N+P, N, Si, P+Fe, P) differ in time in the Cilician basin. Total contribution of pigments to CHLA was measured very high in March. Large eukaryotes have responded more efficiently than any other group to nutrient additions in shelf. Larger cells grew much faster than smaller cells in nutrient rich shelf waters. Their response to nutrient additions was even more remarkable during summer. In fact, primary producers are dominated by prokaryotic picoplankters during summer in shelf waters.

Offshore waters generally contain low nitrogen with lower N/P and N/Si ratios. Offshore phytoplankton is usually dominated by smaller cells, mainly by picoplankton and coccolithophorids (Li et al., 1993; Yacobi et al., 1995; Ignatides, 1998; Psarra et al., 2005; Yılmaz, 2006; Yucel, 2008). Results of enrichment experiments clearly indicate that, if proper nutrients are provided large cells could have been flowered significantly in offshore waters for certain time period. Total pigment concentrations showed that pigment syntheses were limited by N, P and their combination in offshore waters. Nitrogen was found to be limiting element during winter, spring and summer. Highly significant positive correlation was found between nitrogen and smaller cells (prokaryotic picoplankton (n: 108, r: 0.282, $P < 0.01$) and eukaryotic nanoplankton (n: 108, r: 0.282, $P < 0.01$)) in offshore waters. Prokaryotic picoplankton has responded strongly to nitrogen enrichment in April in offshore.

4.3.3. Bacterial Production and Heterotrophic Bacterial Abundance:

Bacterial production was limited by N+P, and observed to be P and P+Fe co-limited in shelf and offshore waters in the Cilician basin. Heterotrophic bacteria were limited by N+P and P in shelf and by N+P and P+Fe in offshore waters. Silicate was observed to be the limiting element in March and June for heterotrophic bacteria although there exist no direct relationship in between both parameters. In silicate enriched bottles larger cells composed mainly of diatoms flower rapidly while releasing (excrete) dissolved substances (organics) necessary for bacterial growth.

4.3.4. *Synechococcus spp.* Abundance:

Based on the nutrient concentrations and N/P and N/Si ratios, *Synechococcus* sp. was limited by N, P, N+P and P+Fe in the Cilician basin.

4.4. Overall Discussion:

Basin waters exert both eutrophic and extreme oligotrophic conditions within and beyond the shelf (Uysal et al., 2008). Coastal waters receive significant amount of fresh water from the surrounding major rivers and brooks. Further, present Asia Minor current which affects permanently Cilician basin squeezes shelf waters

enriched with nutrients and phytoplankton to coastal areas or separates by moving towards west along the Turkish coast. This mechanism creates highly contrasting water masses with very low and very high production capacities within the basin.

Table 4.2. Minimum, maximum and average levels observed for physical, chemical and biological parameters in Mersin Bay.

	Eastern Part				Western Part			
Parameters	Coastal-T27		Offshore-T48		Coastal-BAP1		Offshore-BAP3	
	min-max	avg	min-max	avg	min-max	avg	min-max	avg
Secchi DD	3-10.5	6	18-29	23	3-20	10.5	15-34	26
Temperature	15.0-30.17	23.06	15.96-29.73	18.91	16.63-30.23	23.44	16.10-30.32	19.37
Salinity	36.53-39.68	39.06	38.39-39.99	39.26	35.39-39.58	39.14	37.36-39.63	39.18
Thermocline				50				60
NO_2+NO_3	0.06-10.22	0.96	0.05-2.06	0.34	0.05-11.56	0.5	0.05-3.06	0.38
Si	0.43-11.14	2.20	0.25-2.64	1.05	0.22-4.27	1.26	0.14-2.69	1.02
PO_4	0.02-0.13	0.05	0.02-0.07	0.03	0.02-0.08	0.04	0.02-0.07	0.03
Chlorophyll-*a*	0.06-1.07	0.40	0.02-0.25	0.08	0.06-2.49	0.46	0.014-0.38	0.12
DIChll-*a*	3.7-17.04	9.63	2.37-11.73	8.45	3.6-67.3	17.6	4.6-20.8	12.50
DIChll-		0.385		0.084		0.440		0.125
Primary Production (PP)	0.005-13.23	1.773	0.007-0.952	0.266	0.024-14.42	1.52	0.007-1.48	0.25
DIPP	5.24-72.2	33.58	2.05-40.4	19.29	2.45-121	48.6	3.3-46.5	20.2
DIPP/depth		1.343		0.193		1.215		0.202
C/Chll-a		4.12		2.49		3.26		1.90
% Contribution								
Picoplankton		39		71		41		54
Nanoplankton		29		13		15		18
Larger cells		32		16		44		28

Eastern coastal sector of the Mersin Bay is highly influenced from the Seyhan and Tarsus Rivers relatively resulting in highly turbid & productive water body either rich in particles, plankton and rich in dissolved organic substances – humic matter etc than the offshore waters. This part of the basin contains substantial amount of N & Si (twice as much) and P (25 % more) compared to the western sector of the basin

(Table 4.2). The thickness of the top layer that is directly affected from the river inputs drops from 10 m in the east coast to 5 meters in the west coast. Offshore waters of the bay displayed similar physicochemical and biological properties in the basin. Phytoplankton at east coast was more active (higher carbon to chlorophyll ratio) although they hold slightly less chlorophyll content than those in the west coast (shallow stations only). On a much wider range, rates of primary production tend to decrease from west to east in the Mediterranean (Table 4.3.). A gradual decrease in production capacity towards offshore is clearly evident from the results obtained on a transect formed of stations BAP1, BAP3 and T48 (48.6>20.22>19.29 mg C $m^{-2}h^{-1}$) (Figure 4.5.).

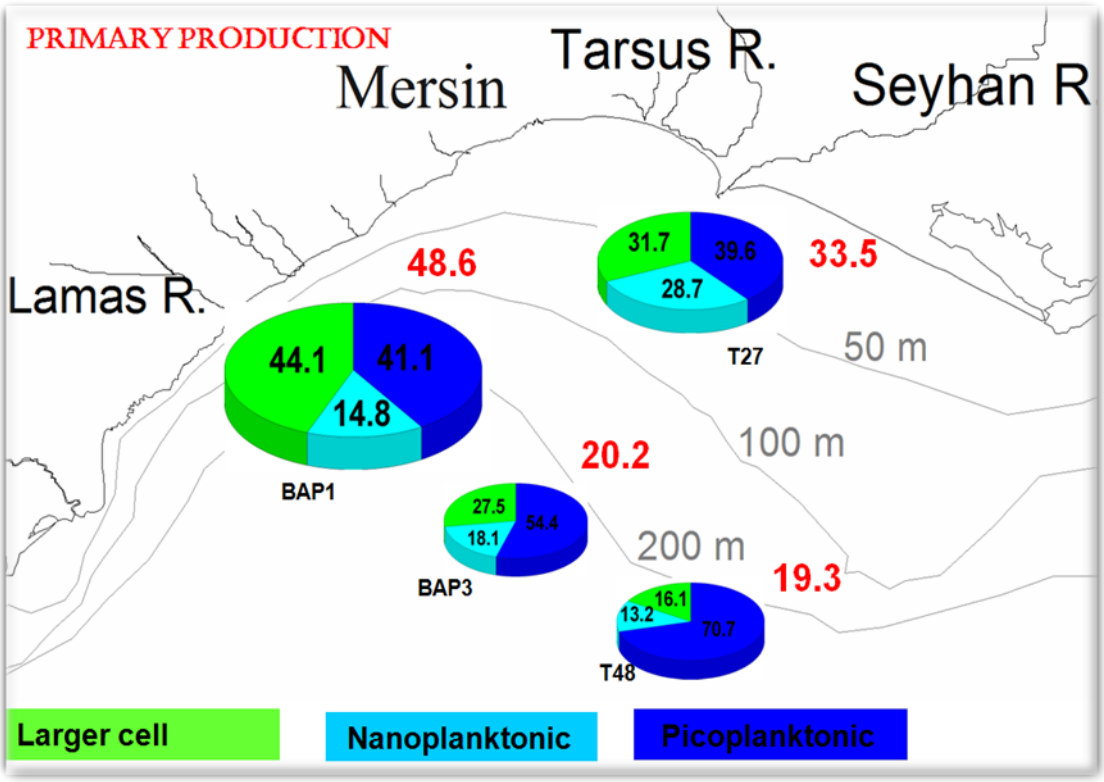


Figure 4.5. % contribution of groups to total primary production and mean depth integrated primary production values obtained in the Mersin Bay.

In the Cilician basin, larger cells (>5µm) have been found to dominate primary production in the western shelf and picoplankton to dominate PP in the eastern coastal waters of the bay. However, in the east, the top 10 m that is effected greatly from the river inputs was dominated by cells larger than 5 microns. From inshore to offshore a gradual increase in picoplankton contribution to the total was observed (% 41.1 to 54.4 to 70.7) (Figure 4.5). Inversely a gradual decrease in the contribution of

larger cells to total phytoplankton abundance was also observed towards offshore (44.1, 27.5, 16.1). Contribution of nanoplankton peaked (% 28.7) in the coastal waters near Seyhan River and decreased to as low as % 13.2 in the offshore zone. In general, oligotrophic offshore waters of the eastern Mediterranean are known to be dominated by picoplankton.

While large eukaryotes (diatoms and dinoflagellates) dominate the population in the eastern coastal waters, all groups seem to contribute evenly to the bulk throughout the study period in western shelf in the Mersin Bay. Prokaryotic picoplankton (Prochlorophyta and Cyanophyta) and eukaryotic nanoflagellates (Chrysophyta, Chlorophyta and Prymnesiophyta) dominate the offshore population. Observed significant negative correlation between salinity and PP (n: 108, r: -0.281, $P < 0.01$) clearly indicate that the success in PP is strictly related to the extend of river input in coastal shelf waters.

Table 4.3. Primary Production measurements in the Mediterranean (modified from Siokou-Frangou et al. 2010).

Referances	Primary Production (PP)		Location	Period
	mg C m^{-2} d^{-1}	g C m^{-2} y^{-1}		
Present Study	2.05 mgC.m^{-2} h^{-1} (coastal - 25m) 72.2 mgC. m^{-2} h^{-1}(offshore-100m)		East side of the Cilician Basin	Sep 2008 - Oct 2011 (seasonal)
	18.9 - 1126 (coastal - 40m) 32.7 - 478.5 (offshore-100m)	151.2 (shelf) 65.4 (offshore)	NE Mediterranean	May 2010 - Oct 2011 (monthly)
Yılmaz, (2006)	1.5 - 9.5 (offshore surface) 14 - 425 mg C.m^{-3} d^{-1} (shelf surface waters)	110 (offshore)	NE Mediterranean	May, Jul, Nov and Dec 2002 and Mar 2003
Yayla, (1999)	153		Finike Trough	May, Nov 1996
	236		Rhodes Gyre	Sep, 1997
Ediger, (1995)	38.5 - 457		Rhodes Gyre	1991-1992
	250		Cilician Basin	
Robarts et al. (1996)	45		Levantine Basin (between Israel and Crete)	1991
Moutin and Raimbault, (2002)	168-221		Mediterranean	May - June 1996
		99	E Mediterranean	
	119-419		Ionian Sea	
	419		Straits of Sicily	
	353-996	145	W Mediterranean	
	398		Tyrrhenian Sea	

Sournia, (1973)		80-90	Mediterranean	
Dugdale and Wilkerson, (1988)		20.3	E Mediterranean Sea	
Boldrin et al. (2002)		97.3	South Adriatic	1997-1999
Bianchi et al. (1999) in Boldrin et al. (2002)	297±56		South Adriatic	Mar (avg 1997-1999)
Bianchi et al. (1999) in Boldrin et al. (2002)	186±65		Ionian Sea	Aug (avg 1997-1999)
Boldrin et al. (2002)		61.8	Ionian Sea	(1997-1999)
Casotti et al. (2003)	208-324.5		Ionian Sea	Apr-May 1999
Ignatiades et al. (2002)	81.36		North Aegean	Mar 1997-1998,
	38.88		South Aegean	Mar 1997-1998, Sep 1997
Ignatiades et al. (1998)		24.79		1994 (four seasons)
Zervoudaki et al. (2007)	232±45 (non-front) 326±97(front)		North Aegean	Sep 1999
Zervoudaki et al. (2007)	256±62 (non-front) 245±27(front)		North Aegean	Apr 2000
Psarra et al. (2000)		59	Cretan Sea	1994-1995
Lohrenz et al. (1988)	330-600 (avg. 480)		Alboran Sea	May. 1986 (non-front)
	500-1300 (avg. 880)			May. 1986 (front)
Moran and Estrada (2001)	632, 388 and 330		Alboran Sea	May 1988
Macias et al. (2009)	6.15- 643.9 (avg. 142.4)		Alboran Sea	Nov 2003
Estrada et al. (1993)	160-760		Catalan-Balearic	May-Jul 1982-1987
Granata et al. (2004)	150-900		Catalan-Balearic	Apr 1991
	450, 700			Jun 1993
	210, 250			Oct 1992
Moran and Estrada (2005)	1000±71 (max 1700)		Catalan-Balearic	Mar 1999
	404±248 (max 1000)			Jan-Feb 2000
Moran et al. (2001)	186-636 (avg. 440)		Algerian Basin	Oct 1996
Gaudy et al. (2003)	401		Gulf of Lion	Mar-Apr 1998
	166			Jan-Feb 1999
Lefévre et al. (1997)		78-106	South Gulf of Lion	
Conan et al. (1998)		140-150	South Gulf of Lion	
Decembrini et al. (2009)	273		Tyrrhenian Sea	Jul 2005
	429			Dec 2005
Marty and Chiaverini (2002)		86-232 (avg. 156)	Ligurian Sea (DYFAMED)	1993-1999
Vidussi et al. (2000)	240-716		Ligurian Sea (DYFAMED)	May 1995

5. CONCLUSIONS AND FUTURE RECOMMENDATIONS

Although the eastern Mediterranean is known to be a highly oligotrophic water body among the world seas, its coastal waters have high production capacity in the river fed northeastern shelf zone. Pronounced anthropogenic input from the local perennial rivers (Asi, Ceyhan, Seyhan, Tarsus, Lamas and Göksu) enhance greatly the microbial flora in receiving waters. Strong seasonality is observed in almost all biological, chemical and physical properties of the shelf waters. Among these, nutrient availability and temperature are of prime importance as they control the success of pelagic flora in time and space relative to other ambient factors. Highly eutrophic and oligotrophic water bodies coexist in the area where exchange between the shelf and offshore is quite limited.

Primary production rates varied in the range 0.005 – 13.23 and 0.007 – 0.952 with mean values of 1.773 and 0.266 mg C m^{-3} h^{-1} in the shelf and offshore waters of the eastern Mersin Bay. On the other hand, these values fluctuated between 0.024 – 14.42 and 0.007 – 1.48 with mean levels of 1.52 and 0.25 mg C m^{-3} h^{-1} in the shelf and offshore waters of the west coast of the bay. Overall, depth integrated primary production varied between 2.05 and 121 mg C m^{-2} h^{-1} in the basin. Annual primary productivity is estimated as 151.2 for the shelf and 65.4 g C m^{-2} y^{-1} for offshore waters of the Cilician basin. Depth integrated primary production results indicate a much more efficient water exchange between shelf and offshore in the west than the east coast of the bay. Larger cells (>5μm) have been found to dominate total primary production (PP) in the western shelf and picoplankton to dominate total PP in the eastern shelf. However, in the east, the top 10 m that is affected greatly from the river inputs was dominated by cells larger than 5 microns. From inshore to offshore a gradual increase in picoplankton contribution to the total PP was observed (% 41.1 to 54.4 to 70.7). Inversely a gradual decrease in % contribution of larger cells to total was also observed towards offshore (44.1, 27.5, 16.1). Contribution of nanoplankton to total PP peaked (% 28.7) in shelf near Seyhan River and dropped to as low as % 13.2 in the offshore. In general oligotrophic offshore waters are known to be dominated by picoplankton in the Mediterranean.

Rates of integrated bacterial production fluctuated between 0.31 – 3.36 and 0.37 – 2.81 with mean values of 1.65 and 1.47 mgC.m^{-2} h^{-1} in the shelf and offshore areas of the western Mersin Bay, respectively. Monthly integrated bacterial carbon production rates varied in the range 0.2 – 2.5 and 0.3 – 2.1 with mean levels of 1.2 and 1.1 g C.m^{-2} month^{-1} in the western coastal and offshore, respectively. Finally, annual bacterial carbon production is estimated as 14.6 g C.m^{-2} y^{-1} for the shelf and 12.9 g C.m^{-2} y^{-1} in the offshore waters of the west coast. Highly significant positive correlations were found among bacterial production, primary production and chlorophyll. Since their presence is strictly bounded to availability of dissolved organics, a positive correlation does exist between producers and bacteria (n: 102, r >0.282 in all size of PP, $P < 0.01$) in the water column. Bacteria also reached high abundances in the water column during June 2010 at both stations in the basin. Winter & spring algal blooms provide plenty of dissolved organics for bacterial populations to consume in early summer. Bacterial carbon production and abundance displayed a highly significant positive correlation (n: 60, r: 0.691, $P < 0.01$) in the shelf. HBA increased with increasing productivity and increase in amount of particulate matter in western coastal waters. A close link between primary and heterotrophic production does exist in the western basin. Bacterial production peaked during summer in western shallow waters. The observed significant positive correlation between bacterial production and temperature (n: 60, r: 0.338, $P < 0.01$) in western offshore (higher abundances were observed above thermocline in offshore) was not found for the shelf. Bacterial production increases in parallel to nutrient enrichment during winter and spring in the shelf. Nutrient deficiency during summer indirectly lowers bacterial production rates although the ambient temperature is optimal for bacterial growth in the shelf. It is highly probable that nutrient availability could mask statistically the temperature effect on bacterial production in western shelf. Observed highly significant negative correlation between salinity and bacterial abundance (n: 108, r: -0.247, $P < 0.05$) clearly indicate the direct impact of the river sources on the success in PP levels and eventually on healthy bacterial growth. Bacterial carbon production (BCP) and bacterial abundance profiles mimicked the other in shelf waters. Highly significant positive correlations (n: 60, r: 0.691, $P < 0.01$) were observed between BCP and bacterial abundance in western shelf waters. However, the relationship weakened in the offshore. High

abundances did not yield high bacterial uptake as was the case in October 2011 in western offshore waters.

Total chlorophyll concentrations fluctuated between 0.06 – 1.07 and 0.02 – 0.25 with water column mean levels of 0.40 and 0.08 mg m^{-3} in the coastal and offshore parts of the eastern bay, respectively. Larger cells (> 5 μm) dominated the total chlorophyll in February 2011. Highly significant positive correlation was found between phosphate and chlorophyll content of larger cells. Similar correlation is also observed between silicate and chlorophyll content of larger cells. On the other hand, total chlorophyll concentrations fluctuated between 0.066 – 2.49 and 0.014 – 0.38 with water column mean levels of 0.46 and 0.12 mg m^{-3} in shallow and deep waters of the west coast, respectively. Chlorophyll content of the flora in 2011 was found 30 % higher than that measured for 2010 for the period May to October in western shelf except October. Reduced salinities indicate efficient river runoff during 2011 which, as a result, increase the phosphate content of the western basin waters. Picoplanktonic chlorophyll dominated total chlorophyll from June to November and larger planktonic chlorophyll dominated the bulk from December to May in western shelf waters. Chlorophyll of larger cells peaked in February & March 2011 in the western shelf. Highly significant negative correlations are observed between larger cell chlorophyll and temperature & salinity in the west shelf. Very low chlorophyll concentrations were measured during summer and autumn in offshore waters, especially, at top 60 meters of the water column. A deep chlorophyll maximum was found between 60 and 120 meters in the basin during the study period. Picoplanktonic chlorophyll dominated total chlorophyll during the sampling time in western offshore waters. Highly significant positive correlation was found between picoplanktonic chlorophyll and nitrogen in the offshore waters. Larger plankton contributed more than nanoplankton to total chlorophyll in offshore waters. Depth integrated chlorophyll (ICHL) concentrations fluctuated between 3.6 – 67.3 and 4.60 – 20.8 with water column mean levels of 17.6 and 12.50 mg m^{-2} in the western coastal and offshore waters, respectively. When averaged for each m^{-2} the coastal chlorophyll (0.440 mg m^{-2}) was 3.5 times the content in offshore waters (0.125 mg m^{-2}) in the western basin.

Phytoplankton at east coast of Mersin Bay had displayed higher carbon to chlorophyll ratio than those in the west although they hold slightly less chlorophyll content than those in the west coast (shallow stations only). Based on carbon to chlorophyll (C/CHLL) ratios different size groups appeared to be dominant for a particular period both in the shelf and in the offshore. This ratio can change according to light, temperature and nutrient availability. Mean values indicate picoplankton as the most active group in shelf and nanoplankton in the offshore.

While large eukaryotes (diatoms and dinoflagellates) dominate the population in eastern shelf, all groups seemed to contribute evenly to the bulk throughout the study period in western shelf of the Mersin Bay. Prokaryotic picoplankton (Prochlorophyta and Cyanophyta) and eukaryotic nanoflagellates (Chrysophyta, Chlorophyta and Prymnesiophyta) have dominated the offshore population. Observed significant negative correlation between salinity and PP (n: 108, r: -0.281, $P < 0.01$) clearly indicate that the success in PP is strictly related to the extend of river input in coastal shelf waters.

P was found to be the limiting nutrient for bacterial production, while P, N and N+P have displayed seasonal impact on the success of primary producers in the basin. However in nature changes in type of limiting nutrient may occur within short intervals (Sala et al., 2002). For this reason, typical short term experiments may not give the truth always. In order to understand such a dynamic system satisfactorily all other ambient parameters should be simulated efficiently throughout the experiment.

Response of different phytoplankton groups to various nutrient combinations (N+P, N, Si, P+Fe, P) differ in time in the Cilician basin. Large eukaryotes have responded more efficiently than any other group to nutrient additions in the shelf. Larger cells grew much faster than smaller cells in nutrient rich shelf waters. Their response to nutrient additions was even more remarkable during summer. In fact, primary producers are dominated by prokaryotic picoplankters during summer in shelf waters. Offshore waters generally contain low nitrogen with lower N/P and N/Si ratios. Offshore phytoplankton is usually dominated by smaller cells, mainly by

picoplankton and coccolithophorids. Results of enrichment experiments clearly indicate that, if proper nutrients are provided large cells could have been flowered significantly in offshore waters for certain time period. Total pigment concentrations showed that pigment syntheses were limited by N, P and their combination in offshore waters. Nitrogen was found to be limiting element during winter, spring and summer. Highly significant positive correlation was found between nitrogen and smaller cells (prokaryotic picoplankton (n: 108, r: 0.282, $P < 0.01$) and eukaryotic nanoplankton (n: 108, r: 0.282, $P < 0.01$)) in offshore waters.

Dissolved organic substances produced and released by cell following cell lyses accumulate in seawater. These substances are necessary for bacterial growth). Increase in PP simultaneously result in an increase in DOC content of the water. In this study, highly significant correlation was found between bacterial carbon production (BCP) and chlorophyll content and PP of large cells (CHLL, n: 60, r: 0.574, $P < 0.01$ and PP, n: 60, r: 0.580, $P < 0.01$) in the shelf. Large cells flowered during excess nutrient cases form the basic source of DOC in shelf waters. PP and BCP have been found to mimic the other in shelf waters. BCP increases with increasing eutrophication in areas receiving extensive river discharge. BCP rates tend to decrease with increasing depth in the shelf. Highest BCP rates were retained at top 20 m of the shelf, which itself is almost 3 times more productive than the offshore. Bacterial activity is strongly limited in the eastern Mediterranean offshore waters by lacking necessary sources (DOC pool) while the uptake and removal of such sources by bacteria are intense in eutrophic coastal areas. For this reason, it is highly recommended that DOC measurements should be undertaken in parallel to primary and bacterial productivity measurements.

In reality, nanoplankton involves different kind of organisms including autotrophs, heterotrophs and mixotrophs. Observed high positive correlations between cyanobacteria (ZEA) and dinoflagellate (PER) (n: 64, r: 0.745, $P < 0.01$) and bacterial production and nanoplanktonic primary production (n: 60, r: 0.320, $P < 0.05$) during this study may be either linked to prey-predator relationship or their tolerance to increased temperature. Dinoflagellates can be autotrophic, heterotrophic,

parasitic or endosymbionts of marine animals and protozoa. They may act as producers or consumers or both in the same time in the food web. Therefore prey predator relationships within individual groups that form nanoplankton should be studied in detail.

Results of size fractionated primary production and phytoplankton pigment measurements should somehow be correlated with those of epifluorescent microscope and flow-cytometer. Response of individual cells (or any group) to changing nutrient, light, temperature conditions may vary from one cell to another. For a better discription of the bulk parameters like chlorophyll, one should describe contribution of individual species belonging to different taxon to the bulk. Flow cytometry is a good tool to follow physiology of individual cells (groups) in a mixture. It may help us to compare pre or post-bloom conditions of a cell within a short time interval.

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Zoppini, A., Amalfitano, S., Fazi, S., Tuğrul, S., Uysal, Z., Puddu, A., 2010. Carbon flow mediated by microbial communities in the eastern Mediterranean Sea. 39th CIESM Congress – Venice, Italy, 10-14 May 2010 (Oral Pres).

CURRICULUM VITAE

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EDUCATION:

B.Sc.	Çukurova University, Dept. of Biology,	2001-2005
M.Sc.	METU-IMS, Dept. of Marine Biology & Fisheries,	2006-2008
Ph.D.	METU-IMS, Dept. of Marine Biology & Fisheries,	2008-2013

RESEARCH INTERESTS:

Marine Microbiology, Primary and Bacterial Production, Phytoplankton Composition, Limiting Factors and Productivity, Heterotrophic and Autotrophic Bacteria, Radiometric and Chromatographic Techniques.

THESIS:

M.Sc.:Phytoplankton Pigment Distribution in the Cilician Basin (North-eastern Mediterranean) (Advisor: Prof. Dr. Zahit UYSAL).

Ph.D.:Monthly Changes in Primary and Bacterial Productivity in the North-Eastern Mediterranean Shelf Waters (Advisor: Prof. Dr. Zahit UYSAL).

PUBLICATIONS - INTERNATIONAL

Journal Papers:

1. Zervoudaki S., Christou E.D., Assimakopoulou G., Örek H, Gucu A.C., Giannakourou A. ,Pitta P., Terbiyik T , **Yücel N.,** Moutsopoulos T., Pagou K., Psarra S., Ozsoy E., Papathanassiou E, 2011. Copepod communities, production and grazing in the Turkish Straits System and the adjacent northern Aegean Sea during spring. Journal of Marine Systems. Vol - 86, Issues 3 - 4, Pages 45 - 56.

2. Saygideger, S., Gulnaz, O., Istifli, E.S., **Yücel, N.,** 2005. Adsorption of Cd(II), Cu(II) and Ni(II) ions by Lemna minor L.: Effect of physicochemical environment, Journal of Hazardous Materials, Vol-126, Issue 1 - 3, Pages 96 – 104

Conference Papers:

1. **Yücel**, **N.,** Uysal, Z., Tuğrul, S., 2013. Temporal Changes in Size-Based Primary Productivity and Chlorophyll Content of the Cilician Basin. 40th CIESM Congress – Marseille, France, 28 Oct - 2 Nov 2013 (accepted).

2. **Yücel**, **N.,** Uysal, Z., Tuğrul, S., 2013. Heterotrophic Microbial Activity in the Cilician Basin (Northeastern Mediterranean). 40th CIESM Congress – Marseille, France, 28 Oct - 2 Nov 2013 (accepted).

3. Kurtay, G., **Yücel, N**., Uysal, Z., Tuğrul, S., 2013. Changes in Pico-Nanoplankton Assemblages on Gradient in the NE Mediterranean. 40th CIESM Congress – Marseille, France, 28 Oct - 2 Nov 2013 (accepted).

4. **Yücel**, **N.,** Uysal, Z., Tuğrul, S., 2012. Phytoplankton pigment partitioning in shelf waters of the oligotrophic north eastern Mediterranean – Contribution of 19'-Butanoyloxyfucoxanthin to the bulk. Eight International Chrysophytes Symposium 12 – 17 Aug 2012, Prague, Chez Republic (Oral Pres).

5. Tuğrul, S., Kaptan, M.S., **Yücel, N.,** Uysal, Z., Doğan-Sağlamtimur, N., 2011. The use of TRIX INDEX for scaling trophic status of coastal waters: A case study in the Mersin Bay (2010–2011). 6. International Symposium on Ecology and Environmental Problems, 17 – 20 Nov 2011, Antalya, Turkey (Oral Pres).

6. **Yücel**, **N.,** Erdogan, E., Uysal, Z., Tugrul, S., Özsoy, E., 2010. Primary production in the shelf waters of the Cilician basin. 39th CIESM Congress – Venice, Italy, 10-14 May 2010 (Oral Pres).

7. Gazihan Akoğlu, A., **Yücel, N.,** Uysal, Z., Tuğrul, S., 2010. Picoplankton abundance and biomass distribution in Turkish seas. 39th CIESM Congress – Venice, Italy, 10-14 May 2010 (Oral Pres).

8. Uysal, Z., Tuğrul, S., **Yücel, N.,** Sert, F., Gazihan, A., Ak Örek, Y., Terbiyik, T., Örek, H., Özsoy, E. 2010. An Assessment of the State of Marine Ecosystems Around Turkey during SESAME (Black Sea, Turkish Straits System and the Levantine basin). 39th CIESM Congress – Venice, Italy, 10-14 May 2010 (Poster Pres).

9. Borges, A., Commarieu, M., Ozsoy, E., Sancak, S., Tugrul, S., **Yücel, N.,** Uysal, Z., Krasakopoulou, E., Huertas, E., Chasovnikov, V., Arashkevich, A., Catalano, G., Luchetta, A., Goyet, C., Grégoire, M., 2010. Carbon Dioxide Dynamics and Air-Sea CO Fluxes in the SES: Synthesis of the SESAME Cruises. 39. CIESM Congress - Venice, Italy, 10-14 May 2010 (Oral Pres).

10. Zoppini, A., Amalfitano, S., Bayındırlı, C., Puddu, A., Tuğrul, S., Uysal, Z., **Yücel, N.,** 2008. Carbon uptake and release by plankton community in the Cilician Basin (Eastern Mediterranean). Congress of the Italian Society for Ecology Parma, Italy. 1 – 3 Sep 2008 (Oral Pres).

PUBLICATIONS - NATIONAL

Journal Papers:

1. Tuğrul, S., Uysal, Z., Erdoğan, E., **Yücel, N.,** 2011. Changes of Eutrofication Indicator Parameters (TP, DIN, Chl-a and TRIX) in the Cilician Basin (Northeast Mediterranean). Ekoloji 20 (80): 33 – 41.

Conference Paper:

1. Tuğrul, S., Kaptan, M.S., Doğan-Sağlamtimur, N., Uysal, Z., **Yücel, N.,** 2012. Mersin Körfezi'nde (Kuzeydoğu Akdeniz) 2009 – 2010 Döneminde Ötrofikasyon İzleme ve Değerlendirme Çalışması. FABA 2012, Fisheries and Aquatic Sciences, Eskişehir, 21 – 24 Nov 2012 (Poster Pres- Oral Discussion).

2. Tuğrul, S., **Yücel, N.,** Uysal, Z., Sert, F., Kaptan, M.S., Doğan-Sağlamtimur, N., 2011. Monitoring and Assessment of Eutrophication: Mersin Bay, The Northeastern Mediterranean (2008-2009). Ecology Symposium - Düzce-Turkey, 5 – 7 May 2011 (Oral Pres).

3. **Yücel, N.,** Uysal, Z., Tuğrul, S., Özsoy, E., 2009. In-situ Chlorophyll Distribution in the Surface waters in the Cilician Basin (Northeastern Mediterranean). IX. National Ecology and Environment Congress. Ürgüp, Nevşehir, 7 – 10 Oct 2009 (Oral Pres).

4. **Yücel, N.,** Uysal, Z., 2009. Phytoplankton Pigment Distribution in the Cilician Basin (Northeastern MEditerranean). 15. National Fisheries Symposium, Rize, 1 – 4 July 2009 (Oral Pres).

5. **Yücel, N.,** Uysal, Z., Tuğrul, S., Özsoy, E., 2009. Chlorophyll distribution in the surface waters in the Cilician basin (Northeastern Mediterranean). 15. National Fisheries Symposium, Rize, 1 – 4 July 2009 (Poster Pres).

6. Uysal, Z., Gazihan, A., **Yücel, N.,** 2009. Distribution of abundance and biomass of the heterotrophic bacteria and cyanobacteria-*Synechococcus* in Turkish seas. 15. National Fisheries Symposium, Rize, Turkey 1 - 4 July 2009 (Oral Pres).

7. **Yücel, N.**, 2003. Ecology, physiology, morphology and the use of *Capparis spinosa* and *C. ovata*, 10th National Biology Student Congress, Istanbul, Turkey (Oral Pres).

Meeting Organization & Conference:

1. **Yücel, N.,** Uysal, Z., Tugrul, S., Assimakopoulou, G., Ozsoy, E., Erdogan, E., 2011. Primary production and phytoplankton composition in the southern Black Sea. SESAME Final Scientific Conference, Athens, Greece 4-8 April 2011.

2. Gogou, A., Krasakopoulou, E., Tugrul, S., **Yücel, N.,** Pavlidou, A., Sert, F.M., Papathanassiou, E., 2011. Dissolved and particulate C, N and P in the SW Black Sea, Marmara Sea and the NE Aegean Sea: production and cycling. SESAME Final Scientific Conference, Athens, Greece 4-8 April 2011.

3. Lagaria, A., Psarra, S., Gogou, A., Krasakopoulou, E., Pavlidou, E., Tugrul, S., **Yücel, N.,** Christaki, U., 2011. Particulate and dissolved primary production along a gradient of hydrographic and trophic regimes. SESAME Final Scientific Conference, Athens, Greece 4-8 April 2011.

4. Puddu, A., Psarra, S., Amalfitano, S., Assimakopoulou, G., Christaki, U., Giannakourou, A., Lagaria, A., Magiopoulos, I., Mara, P., Pagou, K, Pitta, P., Varkitzi, I., **Yücel, N.,** Zoppini, A., 2011. Spatial and seasonal variability of primary production, bacterial production, community respiration and community trophic level in the Eastern Mediterranean. SESAME Final Scientific Conference, Athens, Greece 4-8 April 2011.

5. Tugrul, S., Akoglu, G.A., Uysal, Z., **Yücel, N.,** Erdogan, E., and Sert, M.F., 2011. Effect of riverine and domestic discharges on the biogeochemical properties of Mersin Bay ecosystem (Northeastern Mediterranean). SESAME Final Scientific Conference, Athens, Greece 4-8 April 2011.

6. **Yücel**, **N.,** Uysal, Z., Tuğrul, S., Assimakopoulou, G., Özsoy, E., Örek, H., 2011. Primary production and phytoplankton composition in the black sea and oligotrophic Cilician Basin (NE-Mediterranean). SESAME's 2nd Scientific Workshop, Villefranche, France, Nov, 9 – 11, 2009.

7. **Yücel, N.,** Örek, H., Uysal, Z., Özsoy, E., Tuğrul, S., 2011. Temporal and spatial distribution of chlorophyll in Turkish seas. SESAME's 2nd Scientific Workshop, Villefranche, France, Nov, 9 – 11, 2009.

8. Borges, A.V., Commarieu, M.V., Özsoy, E., Sancak, S., Tuğrul, S., **Yücel, N.,** Uysal, Z., Krasakopoulou, E., Hurtas, E., Arashkevich, A., Catalano, G., Goyet, C., 2011. Carbon dioxide dynamics and air-sea CO_2 fluxes in the SES: Synthesis of the SESAME cruises. SESAME's 2nd Scientific Workshop, Villefranche, France, Nov, 9 – 11 2009.

9. Gazihan, A., **Yücel, N.,** Uysal, Z., and Tuğrul, S., 2009. Picoplankton abundance and biomass distribution in Turkish Seas. SESAME's 2nd Scientific Workshop, Villefranche, France, Nov, 9 – 11, 2009.

RESEARCH PROJECTS (ONGOING AND COMPLETED PROJECTS):

1. Researcher, (Jan 2013 – ----) MENAPHY (Mediterranean Network for Automated High Frequency Monitoring of Phytoplankton) Projesi". ENVI-MED Regional Programme.

2. Researcher, (May 2012 – ----) PERSEUS (Policy-oriented Marine Environmental Research in the Southern European Seas) Projesi" EU Project (287600).

3. Project Assistant, (Oct 2011 – ----) Dynamics and bacterial and primary production potential of distinct ecosystems composed of upwelling regions, shelf and offshore waters in the eastern Mediterranean, reflections on higher trophic levels (111Y023 coded TUBITAK project).

4. Researcher, (Jan 2011 – Dec 2011) Limiting nutrients and their role on regulating primary and bacterial production in Mersin Bay (northeastern Mediterranean) (BAP-07-01-2011-001).

5. Researcher, (Jan 2009 – May 2011) Seasonal changes in primary production rates in Mersin Bay (northeastern Mediterranean) (BAP-07-01-2009-01).

6. Project Assistant, (Nov 2008 - Apr 2011) "Urban Wastewater Management Along Coastal Areas of Turkey: Reidentification of Hot Spots & Sensitive Areas, Determination of Assimilation Capacities by Monitoring and Modeling and Development of Sustainable Urban Wastewater investment Plans", (107G066 coded TUBITAK project).

7. Researcher, (Mar 2009 – Feb 2010) Biocide Anti-fouling Agents Menadione (bis) Piperazine Bisulfite (MPB) Menadione Triazine Bisulfite (MTB) Anti-fouling Experiment.

8. Researcher, (Mar 2008 - Oct 2008) MOMA - The Meteorology and Oceanography Network of Excellence MONOE.

9. Project Assistant, (Mar 2008 – Apr 2011) SESAME "Southern European Seas: Assessing and Modeling Ecosystem change" under Framework Programme 6 of European Commission (project no: 036949).

10. Project Assistant (Oct 2006 – Dec 2007) "The Circulation, Removal, and Eutrophication of the Coastal Ecosystem in the Cilician Basin" (YDABAG104Y277 coded TUBITAK project).

TRAINING COURSES:

1. Flow Cytometry Training. 26th May – 2nd June 2013. Mediterranean Institute of Oceanology, CNRS, Marseille, France.

2. Marine Carbon Cycle - Dissolved organic matter dynamics and marine ecosystem health. May 2013/2014, Three Weeks. Biophysics Institute, CNR, Pisa, Italy.

3. BD Accuri C6 Flow Cytometry User Training, 20-23th Nov 2012. Karadeniz Technical University, Trabzon, Turkey.

4. ATMOMED – The impact of atmospheric deposition on the microbial food web of the Eastern Mediterranean Sea, 3rd - 31th May 2012, Hellenic Centre for Marine Research (HCMR-CRETACOSMOS), Crete, Greece.

5. Mesocosms in aquatic ecology: use, problems and potentials, 29th August – 2nd September 2011, Leibniz Institute of Marine Sciences (IfM-GEOMAR), Kiel, Germany.

6. Experimental Design and Data Analysis for Marine Biologist" 4th - 13th August 2010. University of Gothenburg, Sven Lovén Centre - Tjärnö, Strömstad, Sweden.

7. Perkin Elmer-TRICARB 2810 scintillation counting device operating principles and practices course, 27th April 2009, Mersin.

8. SESAME-Training Workshop ”Methods on Plankton Production” (Lab/Field Training) 2nd – 6th July, 2007, HCMR, Anavyssos GREECE

9. Applied Project Writing Course, IV. National Congress of Neurological Sciences, 29th March - 2nd April, 2005. Mersin University, Mersin, Turkey.

AWARDS:

1. The best M.Sc thesis awards in Department of Marine Biology & Fisheries, IMS-METU between 2007-2008 periods (May 27, 2009).

SHIP TIME:

203 days (38 days Chief Scientist - R/V Bilim – 2, METU-IMS)