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ANNUAL VARIATIONS IN BIOCHEMICAL COMPOSITION OF SESTON AND ZOOPLANKTON COMMUNITY IN MERSİN BAY-NORTHEASTERN MEDITERRANEAN

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ANNUAL VARIATIONS IN BIOCHEMICAL COMPOSITION OF SESTON AND ZOOPLANKTON COMMUNITY IN MERSİN BAY-NORTHEASTERN MEDITERRANEAN

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Approval of the Graduate School of Marine Sciences

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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Arife Zenginer-Yılmaz

ABSTRACT

ANNUAL VARIATIONS IN BIOCHEMICAL COMPOSITION OF SESTON AND ZOOPLANKTON COMMUNITY IN MERSİN BAY-NORTHEASTERN MEDITERRANEAN

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In this study, annual variations in biochemical composition of seston and zooplankton community were investigated to characterize the nutritional environment of zooplankton in the Mersin Bay, NE Mediterranean Sea. For this goal, seawater and zooplankton samples were collected at monthly intervals from two stations; one representing coastal and other representing open waters characteristics from November 2004 to January 2006. Seawater samples were collected with Niskin bottles from the sea surface. Zooplankton samples were collected both in the horizontal and vertical plane by towing a Nansen net (70 cm mouth diameter with 112 μm mesh). Surface seston chl-a, lipid, protein and carbohydrate concentrations were measured by fractionating seawater into three different size groups, 0.7-2.7, 2.7-18 and >18 μm representing pico, nano and micro particulates in the seston. Zooplankton biomass and abundance were determined at four size fractions: 112-200, 200-500, 500-1000 and >1000 μm; dry and organic weights were measured by gravimetric method and major taxonomic groups of zooplankton was identified under stereo-microscope.

The nearshore station was always more productive than the offshore station in terms of chl-a, particulate organic matter (POM: protein+lipid+carbohydrate), zooplankton abundance and biomass. Chl-a maxima occured in spring and autumn

at both stations. Very low chl-a concentrations at the offshore station (0.02-0.35 μg L^{-1}) confirmed oligotrophic character of the Northeastern Mediterranean. The highest chl-a concentration (2.4 μg L^{-1}) was observed in March 2005 at the nearshore station due to the input of Lamas River nearby. POM varied from 42.1 μg L^{-1} (in January 2006) to 1082 μg L^{-1} (in March 2005) and 53.7 μg L^{-1} (in January 2006) to 246 μg L^{-1} (in May 2005) at the nearshore and offshore stations, respectively. The oligotrophy of this system was indicated by the extremely low particulate lipid, protein and carbohydrate concentrations (1-3 times lower than in more productive systems). The most evident characteristic of this oligotrophic environment was the dominance of pico-POM throughout the study period, accounting for 31–65 % of the total carbohydrates, proteins, lipids and chl-a. The prt:cho ratio was generally lower than 1 (low in organic nitrogen). Carbohydrate was the dominant biochemical component at both stations.

Zooplankton varied during the sampling period, and they showed two peak abundances, in spring and autumn, with small increase in summer. The higher biomasses of zooplankton were observed in summer and autumn in the entire water column, but in spring and autumn periods in the surface water.

Zooplankton data showed that 200-500 and 112-200 μm size fractions were dominant in abundance at both stations. However, 200-500 μm size fraction was dominant in zooplankton biomass at nearshore, whereas >1000 μm size fraction was at offshore station. Copepods were the most abundant zooplankton group and dominated the distribution of total zooplankton, followed by crustace nauplii, appendicularia, cladocera and pteropoda.

Keywords: Zooplankton, POM, chl-a, size fraction, Northeastern Mediterranean

ÖZ

KUZEYDOĞU AKDENİZ, MERSİN KÖRFEZİ' NDE ZOOPLANKTON BOLLUK VE BİYOKÜTLESİ VE SESTONDAKİ BİOYOKİMYASAL KOMPOZİSYONUNUN YILLIK DEĞİŞİMİ

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Bu çalışmada, Mersin Körfezi'ndeki, Kuzeydoğu Akdeniz, zooplankton bolluk ve biyokütlesi ile sestonun biyokimyasal kompozisyonundaki yıllık değişimler araştırılmıştır. Bu araştırma ile, bu bölgedeki zooplanktonun besinsel çevresinin karakterize edilmesi amaçlanmıştır. Bu amaç doğrultusunda, deniz suyu ve zooplankton örneklemesi, biri kıyı ve diğeri açık olmak üzere iki istasyondan aylık olarak Kasım 2004 ve Ocak 2006 tarihleri arasında yapılmıştır. Deniz suyu örnekleri niskin şişeleri ile yüzeyden toplanmıştır. Zooplankton örnekleri Nansen ağı (çapı 70 cm, göz açıklığı 112 µm) ile yatay ve dikey çekimler yapılarak toplanmıştır. Yüzey sestonundaki klorofil-a, protein, yağ ve karbonhidrat ölçümleri piko (0.7-2.7 µm), nano (2.7-18 µm) ve mikro (>18 µm) boy gruplarında ayrı ayrı yapılmıştır. Bolluk ve biyokütle için zooplankton örnekleri dört farklı boy gruplarına (112-200, 200-500, 500-1000 ve >1000 µm) ayrılarak gravimetrik metod ile kuru ve organik ağırlıkları ölçülmüş ve stereo- mikroskop ile de grup kompozisyonu tayin edilmiştir.

Kıyı istasyonunun (istasyon 1) açık istasyona (istasyon 2) göre klorofil-a, partikül organik madde (POM=protein+yağ+karbohidrat), zooplankton bolluk ve biyokütle açısından her zaman daha üretken olduğu gözlenmiştir. Her iki istasyonda da, ilkbahar ve sonbahar dönemlerinde klorofil-a en yüksek değerlere ulaşmıştır. İstasyon 2' deki düşük klorofil-a konsantrasyonunun (0.02- 0.35 µg L^{-1}) istasyonun

oligotrofik olduğunu göstermiştir. İstasyon 1'de en yüksek klorofil-a değeri (2.4 µg L^{-1}) Mart 2005 de gözlenmiş olup Lamas nehrinin etkisinden kaynaklanmaktadır. İstasyon 1 ve 2'de POM değerleri sırasıyla 42.1 µg L^{-1} (Ocak 2006) -1082 µg L^{-1} (Mart 2005) ve 53.7 µg L^{-1} (Ocak 2006) - 246 µg L^{-1} (Mayıs 2005) aralıklarında değişmektedir. Düşük protein, yağ ve karbohidrat değerleri (üretken sistemlerden 1-3 kat daha az), buradaki sistemin oligotrofik olduğunu göstermiştir. Yıl boyunca piko boy grubunun baskın olması (toplam karbohidrat, yağ, protein ve klorofil-a'nın % 31-65' ni oluşturmakta) bölgenin oligotrofik olduğunun diğer bir göstergesidir. Her iki istasyonda da genellikle prt:cho oranı 1' den küçüktür. Her iki istasyonda da karbohidrat dominant biyokimyasal bileşendir.

Zooplankton bolluğunda ilkbahar ve sonbaharda olmak üzere iki pik ve ayrıca yaz döneminde küçük bir de artış gözlenmiştir. Su kolonundaki zooplanktonda en yüksek biyokütle artışı yaz ve sonbahar dönemlerinde gözlenirken, yüzey suyunda ilkbahar ve sonbahar dönemlerinde gözlenmiştir.

Her iki istasyonda da 200-500 ve 112-200 µm boy grupları zooplankton bolluğunun çoğunluğunu oluşturmuştur. Benzer şekilde, kıyı istasyonunda 200-500 µm boy grubu zooplankton biyokütlesinin çoğunluğunu oluştururken, açık istasyonda ise >1000 µm boy grubu oluşturmaktadır. Kürekayaklılar, zooplankton grupları arasında en fazla bolluğa sahip olan grup olmuştur ve böylece toplam zooplanktonun yıl içindeki dağılımını belirlemiştir. Kürekayaklılardan sonra kabuklu nauplii, apendikularia, kladosera ve pteropoda diğer önemli gruplardır.

Anahtar Kelimeler: Zooplankton, POM, klorofil-a, boy grubu, Kuzeydoğu Akdeniz

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1.1. General characteristics of particulates

In the marine environments, particulate matter is composed of organic and inorganic particles. Particulate organic matter (POM) is a mixture of living organisms and the dead particles in the sea (Figure 1.1). Living part of the POM is classified as pico-plankton (bacterioplankton and pico-phytoplankton), nano-plankton (flagellates and other protozoans), and micro-plankton (phytoplankton, eggs and early stages of crustacean plankton, meroplankton and micro-zooplankton) (Duursma, 1961; Wotton, 1994; Harris *et al*., 2000). Dead part of the particulate organic matter was classified as coarse particulate organic matter (CPOM), fine particulate organic matter (FPOM) and dissolved organic matter (DOM) (Wotton, 1994).

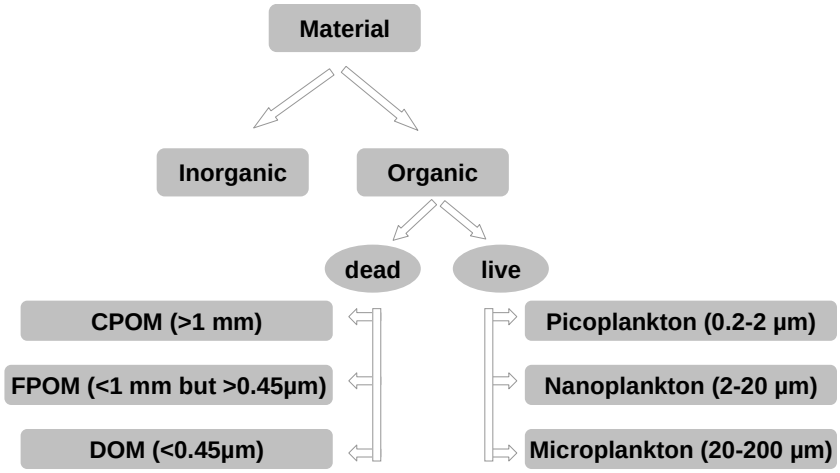

Figure 1.1. Classification of organic particles in the seawater (from Wotton, 1994).

The composition of cellular organic matter of phytoplankton and particulate organic matter was first determined on an elemental composition level, such as C, N, P and S. Then, new techniques were improved to separate, detect and examine the compounds (such as; carbohydrate, protein and lipid) in the seawater. However, chemical characterization of particulate matter allows neither the identification of its origin nor discriminates between living and detrital material (Danovaro *et al*., 2000). Carbohydrates are one of the most important macromolecules constituting the

energy reserve of many phytoplankton species. Proteins are used to promote growth in the body tissues. Lipids are used in generating energy for movement and metabolism and also for the production of eggs in females. Carbohydrates, proteins and lipids are investigated by calorimetric and fluorometric methods. For instance, direct estimations of the proteins are done by Lowry method, Biuret method, ninhydrin method, fluorescamine assay, the coomassive blue assay, and the bicinchoninic acid assay. Then, with the development of modern machine methods biomarkers are used to characterize the living organic matter at the molecular level. Amino acids, fatty acids and monosaccharides are the major detected biochemicals by gas and/or liquid chromatography (Tanoue, 1996 cited in Handa *et al*., 2000).

It is important to identify the origin of particles for understanding the ecosystem interaction. For example, particulate organic matter (POM) is an important energy source for many microbes and invertebrates. Riverine inputs are the dominant sources of particulates for coastal waters. Primary production by phytoplankton is another important source for organic matter in the sea. Organic matter which is produced photosynthetically in the photic zone is transferred to higher and lower trophic levels through marine food webs, and also transformed into detrital POM and DOM (Tanoue, 1996 cited in Handa *et al*., 2000).

Physical and biochemical processes, and nutrients supplies from sources are controlling the abundance and chemical composition of particulate organic matter in marine environments (Tselepides *et al*., 2000). Particulate organic matter plays a crucial role in many biogeochemical cycling of processes in the water column (Tselepides *et al*., 2000; Tanoue, 1996 cited in Handa *et al*., 2000; Wotton, 1994) and represents an important food source for planktonic consumers (Cauwet, 1978). Suspended particulate matter (seston) is crucial from bacteria to fish as an energy transfer (Diaz, 2007). Moreover, the POM content of the surface waters is a good indicator for determining not only the productivity, but also the magnitude of living/nonliving food resources of marine systems (Diaz, 2007).

The particulate organic matter in surface waters, together with measurements of chlorophyll-a define the trophic situations of the seas (Küçüksezgin *et al.,* 2005). Chlorophyll-a is the principal photosynthetic pigment of the plant kingdom both in terrestrial and marine environments. It is used as a biomass indicator for

phytoplankton for over 40 years. Estimation of phytoplankton biomass is very important in understanding the structure and dynamics of ecosystems.

1.2. General characteristics of zooplankton

Zooplankton is the heterotrophic component of the plankton that drift in the water column of oceans, seas, and bodies of fresh water and zooplankton has a key position in the pelagic food web which transfers organic energy produced by primary producers to higher trophic levels (Harris *et al*., 2000). Studying zooplankton communities are especially important for understanding the functioning of coastal ecosystems because of both land and ocean based environmental factors (Siokou-Frangou, 1996). Zooplankton have been divided into several categories, using different classification schemes to study. The most common classifications are the size and functional classifications (Harris *et al*., 2000).

1.2.1. Size classification

Zooplankton sizes range from tiny flagellates, a few µm large, up to giant jellyfish of 2 m diameter. Zooplankton sizes are classified in five order of magnitudes; nano-plankton (2.0-20 µm), micro-plankton (20-200 µm), meso-plankton (0.2-20 mm), macro-plankton (2-20 cm) and mega-plankton (20-200 cm) (Table 1.1). Nanozooplankton includes heterotrophic nanaoflagellates. Microzooplankton contains protozoans, eggs and early development stages of crustacean plankton and meroplanktonic larvae. Mesozooplankton is comprised of small hydromedusae, ctenophores, chaetognaths, appendicularians, doliolids, and larvae together with older stages of crustacean plankton and meroplankton larvae. Macrozooplankton consists of large hydromedusae, siphonophores, scyphomedisae, ctenophores, pteropods, mysids, amphipods, euphausiids, and salps. Finally, megazooplankton is mainly comprised of large jellyfish, siphonophoras and scyphozoan, and pelagic tunicates, pyrosomes and chain-forming salps (Lenz, 2000).

Table 1.1. Size classes of zooplankton based on classification (Lenz, 2000).

Size group	Size limit	Major organisms
Nanozooplankton	2-20 μm	heterotrophic nanaoflagellates
Microzooplankton	20-200 μm	protozoans, eggs and early development stages of crustacean plankton and meroplanktonic larvae
Mesozooplankton	0.2-20 mm	small hydromedusae, ctenophores, chaetognaths, appendicularians, doliolids, and larvae together with older stages of crustacean plankton and meroplankton larvae
Macrozooplankton	2-20 cm	large hydromedusae, siphonophores, scyphomedisae, ctenophores, pteropods, mysids, amphipods, euphausiids, and salps
Megazooplankton	20-200 cm	large jellyfish, siphonophoras and scyphozoan, and pelagic tunicates, pyrosomes and chain-forming salps

1.2.2. Functional classification

Functional classification is based upon the length of residency in the pelagic environment; holoplankton (spending their whole life in the water column) and meroplankton (spending only a part of the life cycle in the water column). Holoplanktonic and meroplanktonic groups commonly found in the Mediterranean Sea are described in Table 1.2 and Table 1.3, respectively.

Table 1.2. Major taxonomic groups of holoplanktonic zooplankton (Lenz, 2000; Özel, 2000; Lalli and Parsons 1994).

Phylum	Subgroups	Example
Protozoa	Foraminifera	*Globigerina*
	Ciliates	*Favella*
Cnidaria	Medusae	*Obelia*
	Siphonophora	*Nanomia*
Ctenophora	Tentaculate	*Pleurobranchia*
	Lobata	*Beroe*
Nemertea		*Nectonemertes*
Mollusca	Heteropoda	*Firoloida*
	Theocosomes	*Limacina*
Annelida	Polychaeta	*Tomopteris*
Arthopoda (Class crustacea)	Cladocera	*Evadne*
	Ostracoda	*Conchoecia*
	Copepoda	*Calanus*
	Mysidacea	*Lestrigonus*
	Amphipoda	*Boreomysis*
	Euphausiacea	*Euphasia*
	Decapoda	*Lucifer*
Chaetognatha		*Sagitta*
Chordata	Appendicularia	*Oikopleura*
	Salpida	*Salpa*
	Doliolida	*Doliolum*
	Cephalochordate	*Branchiostoma*

Table 1.3. Major taxonomic groups of meroplanktonic zooplankton (Lenz, 2000, Özel, 2000; Lalli and Parsons 1994).

Phylum	Subgroups	Example
Cnidaria		*Aurelia*
Mollusca		*Littorina*
Annelida	Polychaeta	*Nereis*
Arthopoda	Cirripedia	*Chthamalus*
	Stomatopoda	*Squilla*
	Isopoda	*Eurydice*
	Euphausiacea	*Styocheiron*
	Decapoda	*Callinectes*
Phoronida		*Actinotrocha*
Echinodermata		*Ophiothrix*
Chordate	Fish eggs and larvae	*Clupeidae*

It is important to describe the food and feeding mechanisms of groups to understand the food webs and energy transfer. Groups found in the Mediterranean Sea and that form the major part of the zooplankton are described below.

Among mesozooplanktonic groups copepods are numerous and abundant marine organisms and they sometimes form up to 90-97% of the biomass of marine zooplankton, therefore copepods are an important link in marine food webs and the marine economy (Boltovskoy, 1999). The main carbon flow from phytoplankton towards fish stocks is expected to be mediated via copepods, especially the calanoid copepods which are the most abundant mesozooplankton group (Cushing, 1975). Many copepod species are found over a wide range of depths; epipelagic, mesopelagic, bathypelagic and abyssal zones. A few epipelagic copepod species inhabit the neustonic environment and live in close association with the thin film at the very sea surface (Boltovskoy, 1999). Copepods feed on by filtering and ingesting particles. They have been found to feed on a wide range of particles of auto- and heterotrophic seston organisms (Hazzard, 2003) which can be selectively captured. Optimum particle sizes for copepods reported in the literature usually larger than 10 µm (Harris 1982; Vanderploeg, 1994 cited in Wotton, 1994; Berggreen *et al*., 1988). Chaetognaths are the best known and most abundant carnivorous planktonic

groups. They are found down to depths of several thousands meters. The diet of chaetognatha includes a wide range of organisms, reflecting the composition of the zooplanktonic community. Thus, it varies seasonally, but consists mainly of copepods, usually the dominant component of plankton (Boltovskoy, 1999). Reeve (1970) concluded that 30 % of the chaetognaths biomass came from copepods. Feigenbaum (1991) showed that the impact of chaetognatha predation on fish larvae could be exaggerated because of the scarcity of larvae in the plankton. Appendicularians are closely related to benthic tunicates and sea squirts. Generally, appendicularians are >200 μm in size and most abundant in coastal waters and continental shelves. They feed on materials ranging in size pico and nanoplankton. Appendicularians can feed on small particles (< 15 μm) (Alldredge, 1981) and present high grazing rates (Hopcroft and Roff, 1995). They secrete mucus called house and reside in it. As they move in the water the house functions as a filter and collect nanoplankton and bacteria. When the house clogs they discard them and they contribute to the formation of marine snow which is an important food source for other organisms (Boltovskoy, 1999). It is found that smallest seston particles (<2 μm) were exclusively ingested by appendicularians, whereas particles >5 μm were grazed upon by copepods, nauplii and larvae (Sommer, 2000). Doliolids are >1 mm in size (Özel, 2000) and feed on particles of wide-ranging size, from bacteria to flagellates, diatoms and other phytoplankton species. They are surface dwellers and preferably in the upper 100 m (Boltovskoy, 1999). Siphonophores range from about 1 mm to several tens of meters in length. They occur over quite wide depth ranges. They feed on primarily on small crustaceans, whereas some feed on soft-bodied animals. Pteropods include Gymnosomata and Theocosomata. They are mostly found in epipelagic zone. Gymnosomata are hunters, while Theocosomata consume microplankton. Sommer *et al.,* 2000 noted that 'the bivalvia larvae feed on as small as heterotrophic bacteria (Prieur 1983, Douillet 1993) or the cyanobacterium Synechococcus (Gallager *et al*. 1994), whereas Fritz *et al*. (1984) have found that bivalvia larvae feed on particles >10 μm or even >20 μm'. Cladocera are epiplanktonic animals, seasonally abundant in coastal, continental shelf and oceanic waters. They are capable of retaining particles as small as 2 μm (Boltovskoy, 1999). Cladocera are able to increase their numbers when the environmental conditions are favourable.

1.2.3. Ecological position

Lenz (2000) stated that zooplankton play a role in the pelagic food web by controlling phytoplankton production and shaping pelagic ecosystems. It is regarded as the most important biological factor controlling commercial fish stocks. Indeed, its grazing determines the amount and composition of vertical particle flux. It is important to study zooplankton for understanding and predicting the impact of environmental changes on fish stocks and for modeling the cycling of biogeochemical key elements such as carbon, nitrogen and phosphorous (Lenz, 2000). The life of the zooplankton depends on the compounds produced by phytoplankton (Cushing, 1975).

Ecological role of zooplankton is largely determined by its position and significance in the food web. Feeding is the main route for the transfer of energy and material from lower to higher trophic levels within communities; therefore its quantification will be a key factor when trophic interactions are studied. Zooplankton species differ in how their energy is obtained: some are herbivores which consume plants, some are carnivores which are capable of eating other animals; some are omnivores which feed on both plant and animal and others are detritivores which consume dead organic material. In eutrophic cold-water and upwelling regions, the classical food chain dominates the ecosystems; however, in oligotrophic warm-water ecosystems the microbial food web dominates the systems (Lenz, 2000) (Figure 1.2). Organic carbon and nutrients are remineralized and recycled efficiently within a complex microbial food web with little energy transfer to the higher trophic levels (Van Wambeke *et al*., 1996; Turley *et al*., 2000).

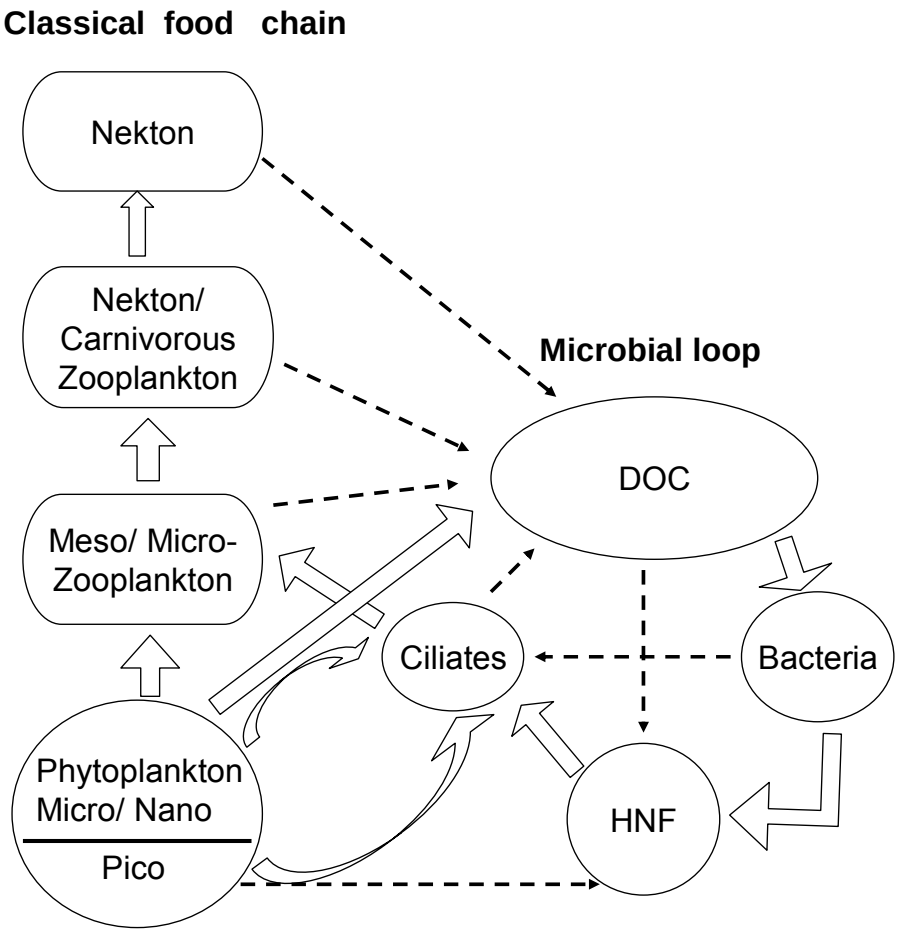

Figure 1.2. Simplified food web scructure with microbial loop. Microbial food web includes microbial loop and autotrophic picoplankton and nanoplankton.
(DOC= dissolved organic carbon and HNF= heterotrophic nanoflagellates.) (from Lenz, 2000)

1.2.4. Factors affecting zooplankton distribution

Studying zooplankton species prevails the planktonic ecosystems and communities. In order to determine the zooplankton community, the interaction between environmental parameters should be studied. Zooplankton distribution is generally affected by several physical (e.g.temperature, salinity, water circulations), biological (e.g. food availability, food quality, predation) and chemical (e.g. oxygen concentration, pollution) factors (Valiela, 1995).

Geographical environment of the region plays an important role on the distribution of planktonic organisms. Study done by Jespersen 1923 (cited in Özel, 1995) reveals that the zooplankton biomass decreases from west to the east of Mediterranean. The Strait of Gibraltar, which connects the Atlantic Ocean to the Medittereanean Sea, is not a barrier but isolate the transportation of Atlantic species into the Mediterrenean. However, it is known that the Atlantic species were seen in the Lebanese waters (Gücü, 1987; Lakkis, 1990, 1984, 1976a). The Strait of Gibraltar is shallow, therefore only the middle water Atlantic zooplankton species could pass the strait. Indeed, there are species which incoming to the Mediterrenean Sea from the Red Sea and the Indian Ocean by the Suez Canal and from the Black Sea by the Turkish Straits Systems (Özel, 1995). Water circulation system leads to the spreading of zooplankton species from open to shallow stations and vice versa (Siokou-Frongou *et al*., 1998). The distribution of zooplankton species are influenced by environmental conditions. When considering biogeographical classification of zooplankton, they are characterized in terms of offshore and nearshore occurences (Omori and Ikeda, 1992). When considering in terms of ocean circulation, in cyclonic gyres (cold surface waters, high nutrients and large seasonal changes) small number of zooplankton species but high zooplankton biomass are present, while in anticyclonic gyres (warm surface waters, low in nutrients and less seasonal variations) large number of species but the zooplankton biomass is low (Omori and Ikeda, 1992). Differentiation of species is more evident in coastal waters than the open waters due to the local geographical environment which affects the isolation of community (Omori, 1977 cited in Omori and Ikeda, 1992). According to the Amanieu *et al*. (1989) physical factors are the major factors affecting the zooplankton community in coastal areas (cited in Siokou-Frongou *et al*., 1998). Chl-a and nutrients can be regarded as other two important factors which determining distinctive characteristics between offshore and nearshore stations. Temperature was the main factor affecting zooplankton assemblages in the Saronikos Gulf (Siokou-Frongou *et al*., 1998). They have observed that the two important groups (cladocerans and appendicularia) are temperature dependent. On the other hand, salinity did not play a role in the distribution of zooplankton community because of narrow range of values. Large populations of cladocerans and appendicularians prevailed due to the favourable conditions happened in March with the development of thermocline. Therefore, increase of these two groups differentiates the nearshore regions from the offshore regions (Siokou-Frongou *et al*., 1998).

1.3. Physical oceanography of the Northeastern Mediterranean Sea

Mediterranean Sea is a semi-enclosed region which consists of Eastern and Western Mediterranean. Eastern Mediterranean Sea is comprised of four main basins called Ionian, Adriatic, Aegean and the Levantine basins (Özsoy *et al*., 1989; Demirov and Pinardi, 2002). Mediterranean Sea communicates with the Atlantic Ocean by the Strait of Gibraltar, the Red Sea and the Indian Ocean by the Suez Canal and the Black Sea by the Turkish Straits Systems (Dardanelle and Bosphorous Straits). Differences in the level between Mediterranean Sea and Atlantic Ocean lead to the formation of Atlantic Stream System (Demirov and Pinardi, 2002). Transportation of a branch of Atlantic Stream System into the Strait of Sicily leads to the formation of Ionian-Atlantic Stream. Then, travelling of Ionian-Atlantic Stream in the Levantine Sea forms the mid-Mediterranean Jet. The mid-Mediterranean Jet flows eastward between the Rhodes gyre on the north and the Mersa-Matruh gyre and the area of the Shikmona gyre on the south. The mid-Mediterranean Jet becomes the Asia Minor Current (AMC) when flowing along the Turkish coast (Demirov and Pinardi 2002). Salinity of the waters entering into the Mediterranean through the Gibraltar is about 36.15 psu, while the salinity in the Levantine Basin is 38.6 psu. Levantine Intermediate Waters (LIW) is produced by the intermediate convection during winter in the Levantine basin and transported westward in the layer between 300 and 500 m towards the Strait of Sicily and then towards Gibraltar (Özsoy *et al*., 1989). The Levantine deep water (LDW) is carrying relatively the highest nutrient content among other water bodies (Salihoğlu *et al*., 1990). The Eastern Mediterranean Deep Water is formed in the Adriatic (Roether and Schlitzer, 1991) or in the Aegean Sea (Roether, 1996) and then, sinks into the deeper parts of the basin through the relatively narrow and shallow straits. The eastern water is warmer and saltier than the western water. Levantine surface water is characterized by warmest (16-25^{o}C) and saltiest (38.8-39.4 psu) waters among the Mediterrenean surface waters (Malanotte-Rizzoli and Bergamasco, 1989). In winter, the LIW is mixed thoroughly with the saltier surface waters to form a vertically homogenous upper layer down to the LDW (Hecht *et al*., 1988; Özsoy *et al*., 1993).

Eastern Mediterranean receives relatively high irradiance throughout the year and the maximum irradiance is measured about 1750-1800 $\mu Em^{-2}s^{-1}$ at the surface during noon time. Therefore, the NE Mediterranean is quite oligotrophic and transparent (Berman *et al*., 1984; Sancak, *et al*., 2005; Yayla, 1999). The average depth of euphotic zone is 70 m in the Rhodes basin and 95 m in the anticyclonic eddies. Pelagic waters of NE Mediterranean are among the world's optical clearest waters. The Secchi Disc transparency range from 20-38 m and downward attenuation coefficient (Kd) is as low as $0.031m^{-1}$ (Ediger and Yılmaz 1996).

Ediger and Yılmaz (1996) divided the Levantine basin of the northeastern Mediterrenean into three regions according to the hydrodynamics and hydrochemistry: the cyclonic basin, the anticyclonic basin and the transitional between them. The anticyclonic basin (Cilician), the nutricline and the relatively nutrient-rich Levantine deep waters are able to supply sufficient amount of nutrient to the euphotic zone to maintain phytoplankton growth.

The eastern Mediterranean is oligotrophic because of the limited supply of nutrients to the euphotic zone (Bethoux, *et al*., 1992; Yılmaz, *et al*., 1994; Krom, *et al*., 1992). The distribution of nutrients in this area is strongly associated with the hydrographic features (Salioğlu, *et al*., 1990; Krom, *et al*., 1991; Krom, *et al*., 1993; Yılmaz and Tuğrul 1997).

1.4. Chemical oceanography of the Northeastern Mediterranean Sea

The Eastern Mediterranean Sea is one of the most oligotrophic sea among the world's ocean (Azov, 1986; Krom *et al*., 1993; Zohary and Robarts, 1998). Cretan Sea and Levantine Sea are the most transparent and least productive seas in the Eastern Mediterranean Sea. Nutrient concentrations in the western Mediterranean are higher than the eastern due to outflow of polluted rivers (Yılmaz and Tuğrul, 1998). Eastern Mediterranean has low nutrient concentration, plankton biomass and production (Stergiou *et al*., 1997). On the other hand, Northeastern Aegean Sea is more productive than the southern part (Siokou- Frongou *et al*., 2002) due to the input from Black Sea. The eastern Mediterranean upper layer waters receive limited nutrient supplies from both intermediate depths and external sources such as atmospheric input, riverine and waste discharges (Dugdale and Wilkerson, 1988).

Nitrate and phosphate concentrations in the eastern Mediterranean (NO_3 + NO_2 =5.5 µM, PO_4=0.2 µM, Si = 9.7µM) are lower than the deep waters of the western Mediterranean (NO_3 = 7.6 µM, PO_4 = 0.38 µM, Mc Gill, 1965; Bethoux *et al*., 1992) because of limited external inputs to the surface waters of eastern Mediterranean (Yılmaz and Tuğrul, 1998; Krom *et al*., 1993). The phosphate and nitrate concentrations in euphotic zone waters varied between <0.02-0.03 µM and 0.1-0.3 µM in most of the year in the Levantine Basin, except winter upwelling in the Rhodes cyclonic region (Yılmaz and Tuğrul, 1998). Surface water DIP (dissolved inorganic phosphate), nitrate and silicate concentrations varied between 0.018-0.230 µM, 0.06-19.9 µM and 0.91-26.71 µM at nearshore station and 0.012-0.036 µM, 0.07-0.94 µM and 0.64-2.88 µM at offshore station in the Mersin Bay during 2002-2003, respectively (Doğan-Sağlamtimur, 2006). The Lamas river close to the nearshore station in the Mersin Bay has high nitrate (78.1-92.1 µM) and silicate (62.2-79 µM) and low phosphate (0.27-0.81 µM) concentrations in which effecting the coastal waters (Doğan-Sağlamtimur, 2006). Tuğrul *et al*. (2006) reported that the Seyhan and Berdan rivers transports nutrient to the Mersin Bay which are high in nitrate and reactive silicate, and poor in phosphate. NE Mediterrenean circulation system carry discharges of Seyhan and Berdan rivers into the offshore station in the Mersin Bay which is located off Erdemli (Tuğrul *et al*., 2005). The majority of the nutrient comes from precipitation, river runoff and atmospheric input in the Mediterranean Sea. Coastal waters are often characterized by high concentrations of suspended organic and inorganic material derived from seabed resuspension or discharge of particle-laden rivers. The composition of suspended particulate matter shows high variability, with the inorganic fraction dominant over the organic fraction (Signoret *et al*., 2006).

1.5. Biological oceanography of the Northeastern Mediterranean Sea

Vertical mixing and input of nutrients from the lower layers are the main factors controlling the occurrence of particulate organic matter in the open seas in the Mediterranean Sea. The particulate concentrations are higher in the surface layers in more productive western Mediterrenean (Rabitti *et al*., 1994; Socal *et al*., 1999). On the other hand, the particulate organic matter is in low concentrations at the upper layer waters in the oligotrophic eastern Mediterranean (Abdel-Moati, 1990; Ediger *et al*., 2005). The analysis of the biochemical composition of the particulate

organic matter has been used to provide information on the quantity of food material potentially available to consumers (Mayzaud *et al*., 1989; Navarro and Thompson, 1995). Biochemical composition of the particulate organic matter was referred to as the sum of lipids, proteins and carbohydrates (Mayzaud *et al*., 1989; Navarro and Thompson, 1995; Danovaro *et al*., 2000). Knowledge on the biochemical composition of POM, such as proteins, carbohydrates and lipids, is important to understand the energy transfer in the marine food chain (Tanoue, 1996, cited in Handa *et al*., 2000). Proteins, amino acids are the most abundant compounds in phytoplankton cells, accounting for 17-57 % of the total organic carbon. Carbohydrates are the second important compounds which ranged between 6.6-37 % and the lipids varied between 2.9-18 % of the total organic carbon (Hama, 1997 cited in Handa *et al*., 2000). Hazzard *et al.* (2003) found that proteins are the most abundant biochemical component followed by carbohydrates and then lipids in the suspended sediment in the Florida Bay. On the other hand, carbohydrates were the dominant biochemical component followed by proteins and then lipids in the Northeastern Mediterranean Sea (Danovaro *et al.*, 2000). Particulate carbohydrate, lipid and protein ranged between 10-75 μg L^{-1}, 10-103 μg L^{-1} and 12-76 μg L^{-1}, respectively in the mouth of the sea cave in France. Lower levels were observed from August to February and increasing concentrations to the end of the July in the mouth of the sea cave in France (Fichez, 1991). Carbohydrate, protein and lipid concentrations were varied between 33-88, 72-105 and 37-51 μg L^{-1} in the Northwestern Mediterranean (Fabiano *et al.,* 1984), 25-149, 28-111 and 18-74 μg L^{-1} in the Northwestern Mediterranean (Danovaro and Fabiano, 1997) and 13-149, 7-92 and 4-63 μg L^{-1} (Danovaro *et al.*, 2000) in the Northeastern Mediterranean Sea, respectively.

Bacteria include autotrophic and heterotrophic bacteria which are classified in picoplankton, varying from 0.2 to 2 μm in size (Van den Hoek, 1995). They have significant contribution to the plankton biomass and play a significant role in the planktonic microbial marine food web in the northeastern Mediterranean (Azam, 1998). The major consumers of the bacteria are small organisms like ciliates and flagellates. Indeed, zooplankton especially the protozoans are also feed on bacteria (Valiela, 1995). *Synechococcus* (autotrophic bacteria) is an important unicellular cyanobacteria for the oligotrophic northeastern Mediterrenean Sea (Li *et al*., 1993). It plays a significant role in the microbial loop by regulating the biogeochemical cycles in the northeastern Mediterrenean Sea (Burkill *et al*., 1993). *Synechococcus*

contribute from 15% to 25% and occasionally up to 45% of particulate organic carbon (POC) in the oligotrophic waters of the Arabian Sea (Burkill *et al*., 1993). Strong vertical water mixing, rapid freshwater intrusion and light inhibition are the major factors controlling the *Synechococcus* abundance in the coastal areas in the northeastern Mediterrenean Sea (Uysal and Köksalan, 2006). In addition to this, phosphorous limitation also plays a key role in the control of bacterial production in northeastern Mediterranean Sea (Thigstad and Rassoulzadegan, 1995). *Synechococcus* abundance is higher in the surface waters (Landry *et al*., 1996 cited in Uysal and Köksalan, 2006) related with their high phosphate affinity (Mountin and Raimbault, 2002) and near the deep chlorophyll maximum (Iturriaga and Marra, 1988 cited in Uysal and Köksalan, 2006). Uysal and Köksalan, (2006) observed that the influence of the Lamas River on the *Synechococcus* and the phytoplankton population during 1998-1999 in the nearshore station of Mersin Bay. Minimum and maximum phytoplankton and *Synechococcus* biomasses ranged between 3 and 1875 μgC L^{-1} and between 0.6 and 5.1 μgC L^{-1}, respectively in the Levantine shelf waters (Uysal, 2006). He showed that the contribution of *Synechococcus* to the total phytoplankton biomass may exceed 50 % under normal conditions in the Levantine Basin. Bayındırlı (2007) noted that the heterotrophic bacteria and cyanobacteria abundance and biomass in the nearshore station was higher than the offshore station and decreases with depth in the Mersin Bay during 2005-2006. Heterotrophic bacteria abundance always found to exceed *Synechococcus* abundance within the water column. *Synechococcus* were found more abundant during late summer and autumn in the stations (Bayındırlı, 2007). Bayındırlı (2007) also showed that there was a significant correlation between temperature and *Synechococcus* at offshore station. In addition to this, nitrate was found to negatively and salinity was positively correlated with *Synechococcus* at both stations.

Open waters have low nutrient concentrations and primary production (Krom *et al*., 1991; Kress and Herut, 2001; Psarra *et al*., 2005), and the phytoplankton community is dominated by the pico and nano fractions which are heavily grazed (Yacobi *et al*., 1995; Zohary *et al*., 1998; Christaki *et al*., 2001; Psarra *et al*., 2005). On the other hand, the coastal waters are characterized by higher nutrient and chlorophyll concentrations, higher primary production and high abundance of larger size phytoplankton (Berman *et al*., 1984; Azov, 1986; Kimor *et al*., 1987; Herut *et al*., 2000).

Chl-a concentrations were low, less than 1 μg L^{-1} in the Levantine Basin (Berman *et al*., 1984; Dowidar, 1984; Azov, 1986; Abdel-Moati, 1990; Salihoğlu *et al*., 1990; Yılmaz *et al*., 1994). Yacobi *et al.* (1995) observed that chl-a ranged between 0.01 and 0.42 μg L^{-1} in the Levantine Basin with an overall mean of 0.126 ± 0.086 μg L^{-1} in the upper 200 m. Ediger and Yılmaz (1996) found that chl-a ranged from 0.01-0.6 μg L^{-1} (in summer) to 0.1-1.7 μg L^{-1} (during late winter-early spring bloom period) during 1991-1994 in the northeastern Mediterranean. Ediger and Yılmaz (1996) noted that the deep chlorophyll maximum and nutricline coincided with each other and found at ~50 m depth in cyclonic regions, while deep chlorophyll maximum was located at the base of euphotic zone and found above the nutricline at ~600 m. Herut *et al.* (2000) found that chl-a concentrations ranged between 0.01 and 0.41 μg L^{-1} off Israel during 1996-1998. They observed autumn and winter peaks and a subsequent moderate spring peak were observed off Israel during 1996-1998. Yılmaz (2006) observed that the chl-a values were varied between 0.01-1.19 μg L^{-1} in the northeastern Mediterranean during 2001-2003.

Chl-a concentration values showed that the main phytoplankton bloom is seen in winter-spring period in the northeastern Mediterranean (Ediger *et al*., 2005; Gotsis-Skretas *et al*., 1999). Highest chlorophyll-a value was observed during late winter due to mixing of the upper water layers in the northeastern Mediterranean (Berman *et al*., 1984, 1986; Azov, 1986; Salihoğlu *et al*., 1990; Krom *et al*., 1991, 1992). Eker and Kıdeyş (2000) found that the main phytoplankton bloom was observed in February during 1985 and 1996 in the northeastern Mediterranean.

Zohary *et al*. (1998) noted that more than 90 % of the surface chl-a came from particles less than 10 μm in diameter and more than 64 % came from particles less than 2 μm in diameter in the eastern Mediterranean. Ignatiades *et al*. (2002) showed that the picoplankton fraction (0.2-1.2 μm) predominated and accounted for the 56-49 % followed by nano and microplankton (>3 μm) accounted for 21-31 % of the total chl-a in the north and south Aegean Sea, respectively. Ultraplankton (1.2-3 μm) were found in the lowest fraction contributing only 18-22 % of the total chl-a.

Among phytoplankton groups, diatoms were the most abundant group in the eastern Mediterranean (Gotsis- Skretas *et al*., 1999; Eker and Kıdeyş, 2000; Polat *et al*., 2000; Polat and Işık, 2002; Uysal *et al*., 2003; Yılmaz, 2006). It is also found that the phytoplankton abundance and biomass were generally higher in the nearshore

station compared to the offshore station (Yılmaz, 2006; Eker-Develi, 2004). Eker-Develi (2004) observed that the phytoplankton biomass was mainly controlled by vertical mixing in January-February, lateral transport and/or rain in March-April, dry atmospheric deposition at the end of the summer and by dry/wet deposition in autumn months.

There are several zooplankton studies concerning the distribution and composition in the eastern Mediterranean Sea (Uysal *et al*., 2002; Gücü, 1987; Isari *et al*., 2006; Kimor and Wood, 1975; Lakkis, 1976, 1984, 1990; Siokou-Frangou *et al*., 1996, 1998; El-Maghraby, 1965; Stamatina *et al*., 2006; Zervoudaki *et al*., 2006; Gotsis-Skretas *et al*., 1999; Mazzochi *et al*., 1997; Pancucci-Papadopoulou *et al*., 1992). Coastal areas of the northeastern Mediterranean are susceptable to anthropogenic impacts such as the severe eutrophication in the Iskenderun and Mersin Bays (Uysal *et al*., 2002). Migration of Lessepsian species from the Red Sea by the Suez Channel (Kimor and Wood, 1975; Lakkis, 1976; Gücü, 1987) can be an example to an anthropogenic effect (Uysal *et al*., 2002). Uysal *et al*. (2002) found that the existence of Indo-Pacific species in the Levantine Sea confirms the fact that the distribution of copepod species was related with the current regime in the region. Lakkis (1976, 1984) showed that there were species from Atlantic origin in which they play a role as hydrologic indicators of the current flowing into the eastern Mediterranean.

Study established by Gücü (1987) reported that the 75 % of the total zooplankton was comprised of copepods and a total of 56 species belonging to 34 genera have been recorded off the Erdemli-METU Campus in the Mersin Bay. He observed that the majority of copepod species were from Atlantic and Mediterranean origin. He noted that the copepod species were distributed evenly in the water column due to mixing process in winter, and they aggregated in the surface water down to 25 m depth where optimum temperature was present in spring and autumn. Lakkis (1990) stated that there was a negative relationship between copepod abundance and species diversity in the Lebanese waters in eastern Mediterranean. The highest copepod species diversity were observed in November- February, while the copepod abundance was the lowest when the sea water was unstable and there exist vertical homothermy. Siokou-Frangou *et al*. (1996) studied the similarities of the copepod community structure from Sicily to Cyprus (Eastern Mediterranean) in 1991. They observed that there were similarities between regions for the 0-50 m

layer, while dissimilarities between regions below 50 m and increased with depth; dissimilarities were related with the different hydrological features (cyclonic gyres or anticyclonic gyres) prevailing in the basin. Neritic mode of living seems to be the reason for the high abundance of copepod species in the inshore stations off the Egyptian coast in the eastern Mediterranean (El-Maghraby, 1965). El-Maghraby (1965) also showed that there was no any difference between day and night copepod samples.

Isari *et al*. (2006) studied the horizontal and vertical distribution of mesozooplankton assemblages in the northeastern Aegean Sea in 2003. Black Sea inflow into the northeastern Aegean Sea in July led to increase of mesozooplankton biomass and abundance in the 0-50 m layer. Distinctive copepod and cladoceran species were recorded in the region different from the other pelagic eastern Mediterranean. Filter-feeding organisms, appendicularia, cladoceran and doliolids are favoured with the Black Sea water which is rich in dissolved and particulate organic matter. Siokou-Frangou *et al*. (1998) stated that the zooplankton community composition was affected from environmental parameters such as, eutrophication-pollution, temperature, water mass circulation, hydrology and topography. For instance, cladocerans and appendicularians were found to increase under favourable conditions, when the temperature increases.

Study carried out in the Cretan Sea and the Straits of the Cretan Arc prevailed that the zooplankton shows a clear seasonal pattern, with highest abundance in autumn-winter and the lowest abundance in spring-summer (Gotsis-Skretas *et al*., 1999). They observed that the copepods always dominate the mesozooplankton assemblages, constituting 70 % of total abundance followed by chaetognaths.

Zooplankton abundance values varied in eastern Mediterranean; such as 684 ind m^{-3} in the Cretan Sea, at 100m (Gotsis- Skretas *et al*., 1999), 200 ind m^{-3} in the Sicily Channel (Mazzochi *et al*., 1997), 56 ind m^{-3} in the Cretan Passage (Mazzochi *et al*., 1997), 45 ind m^{-3} in the Cretan Sea (Mazzochi *et al*., 1997), 130-200 ind m^{-3} in the surface water of Levantine Basin (Pancucci-Papadopoulou *et al*., 1992) and 305-4662 ind m^{-3} in the frontal area of the Aegean Sea (Zervoudaki *et al*., 2006). Lakkis, (1990) recorded that the zooplankton biomass value reached to the 20 mg m^{-3} in the Lebanase waters.

1.6. Aim of the study

The size distribution of living particles is one of the main factors determining the tropic status of the ecosystem and the food web structure. Zooplankton feed on a wide range of particle types and sizes depending on the feeding methods and selectivity. Prey size is one of the major criteria for food selection of the zooplankton. There is positive correlation between the particle size and body size. For instance, Berggreen *et al*. (1988) determined the changes in the food size spectrum during the development of calanoid copepod *Acartia tonsa*. They showed that upper size limit for particle capture increased with stage from 10 to 15 μm for the youngest nauplii to 250 μm for the adults of copepods. Furthermore, Hansen *et al*. (1994) compared the size selectivity spectra of 28 planktonic predators from 18 literature studies. They found linear size ratio, 8:1 for ciliates, 18:1 for rotifers and copepods, and ~50:1 for cladocerans and meroplankton. In the case of zooplankton, several studies have shown that the biochemical composition of seston affects reproduction (Kleppel and Hazzard, 2000; Díaz *et al*., 2003), feeding (Roman, 1984; Huntley, 1985) and growth (Durbin *et al*., 1992; Hygum *et al*., 2000). A number of studies on the size fractionation of marine particles and zooplankton in the Mediterranean Sea have been documented in the literature and the importance of small size fractions have been reported (Danovaro, 2000; Fernandez de Puellez, 2003; Gotsis-Skretas-1999; Mazzocchi *et al*., 1997; Razouls, 1993; Siokou-Frangou, 1996; Tselepides, 2000). There are couple of investigations, demonstrate the significant contribution of pico and ultraplankton size fraction to the total chlorophyll-a and the primary production in the Turkish waters of the eastern Mediterranean Sea (Yayla, 1999; Polat and Işık, 2002). However, there is a lack of studies on the different size fractions of biochemical composition in the suspended matter and size fractionated zooplankton in both vertical and horizontal plane in the northeastern Mediterranean Sea.

The main purpose of this work was to characterize the nutritional environment of zooplankton in the Mersin Bay, NE Mediterranean Sea. The specific aims were to:

- identify the seasonal variations of chlorophyll-a and biochemical composition of suspended matter
- quantify the relative significance of the pico, nano and micro size fractions to the chlorophyll-a and the biochemical composition of the suspended matter

- examine the seasonal variations of size fractionated zooplankton in both vertical and horizontal plane

2. MATERIAL AND METHOD

Material and method used in the present study is described below under different headings such as: sampling area, CTD measurements, seston and its analysis; TSPM (total suspended particulate matter), chlorophyll-a, protein, lipid and carbohydrate, zooplankton composition and biomass including laboratory analysis. These comprised of spectrophotometric, spectrofluorometric and taxonomic measurements. Finally, statistical methods were described.

2.1. Sampling period and parameters measured

This study was performed in the Mersin Bay, Northeastern Mediterranean Sea from November 2004 to January 2006. Seawater and zooplankton samplings were collected at monthly intervals from two stations; one representing coastal, station 1 (36°33.580'N, 34°15.680'E; 20m depth) and other representing open waters, station 2 (36°26'N, 34°21'E; 200m depth) characteristics (Figure 2.1). Totally, 14 cruises were performed and details of the sampling are shown in Table 2.1. Crusises in December 2004, February 2005, March 2005, April 2005, May 2005, December 2005 and January 2006 were performed with R/V Lamas and the other months were performed with R/V Bilim-II. During January 2005, no cruise was accomplished because of severe weather conditions. Parameters measured in each sampling period are summarized in Table 2.2.

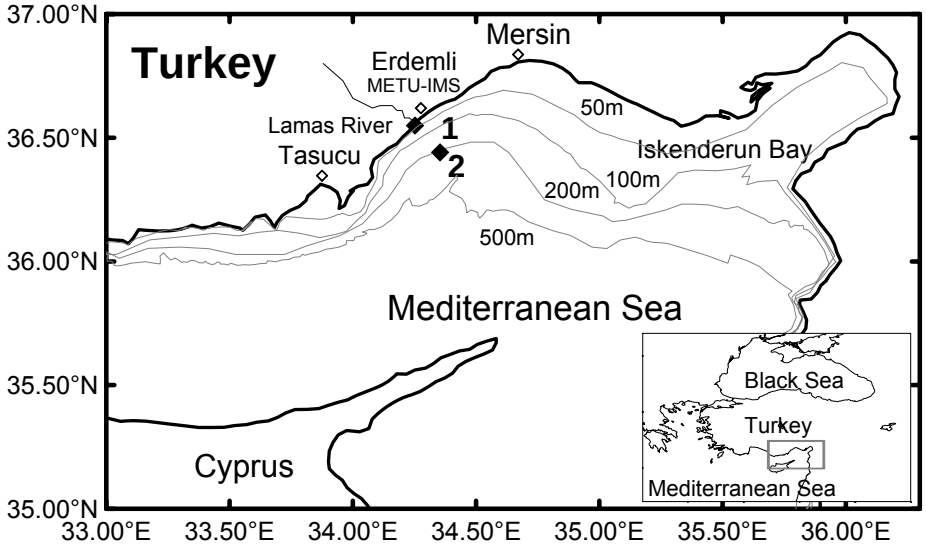

Figure 2.1. Location of sampling stations (Station 1: nearshore, Station 2: Offshore)

Table 2.1. Sampling protocol of the two stations in the Mersin Bay.
(Station 1: nearshore, Station 2: offshore)

			Water column zooplankton sampling		Surface water zooplankton sampling		Surface water sampling
Date	Station	Time	Total depth (m)	Haul depth (m)	Duration of towed net (min)	Speed of towed net (knot)	Time
04.11.04	1	14:10	20	15	-	-	-
	2	12:20	200	195	-	-	-
28.12.04	1	16:15	20	15	-	-	16:00
	2	12:30	200	195	-	-	12:00
10.02.05	1	17:30	20	15	-	-	17:00
	2	15:30	200	195	-	-	12:00
25.03.05	1	15:45	21	15	5	2.5	15:30
	2	13:30	195	190	5	2.5	10:00
21.04.05	1	16:20	21	15	5	2.5	16:40
	2	14:10	206	200	5	2.5	10:30
13.05.05	1	17:00	22	18	3	2	17:15
	2	14:45	206	200	5	2	11:45
12.06.05	1	15:25	21	17	4	3	15:30
	2	13:30	213	211	5	3	11:30
02.07.05	1	17:20	20	16	3	3	17:00
	2	14:50	212	207	5	3	13:20
02.08.05	1	14:40	25	18	3.5	3	14:30
	2	12:50	201	195	5	3	10:00
07.09.05	1	17:30	24	16	3	3	17:00
	2	15:10	207	199	3.5	3	13:20
27.10.05	1	16:00	23	18	3	3	15:45
	2	14:30	221	216	4	3	12:25
27.11.05	1	13:30	27	23	2.33	3	13:20
	2	10:30	220	211	3	3	10:00
29.12.05	1	14:10	24	20	-	-	14:10
	2	12:40	205	185	-	-	10:50
30.01.06	1	17:00	21	17	3	3	17:00
	2	14:50	204	200	4	3	11:40

Table 2.2. Parameters measured during the sampling periods. CTD: Conductivity, Temperature and Depth, TSPM: Total Suspended Particulate Matter
(+ sampling performed, - no sampling performed).

Parameters		Nov 04	Dec 04	Jan 05	Feb 05	Mar 05	Apr 05	May 05	Jun 05	Jul 05	Aug 05	Sep 05	Oct 05	Nov 05	Dec 05	Jan 06
CTD		-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
Surface seston																
TSPM	>0.7 µm	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
Chlorophyll-a	>0.7 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	>2.7 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	0.7-18 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
Protein	>0.7 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	>2.7 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	0.7-18 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
Carbohydrate	>0.7 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	>2.7 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	0.7-18 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
Lipid	>0.7 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	>2.7 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	0.7-18 µm	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
Zooplankton																
Water column zooplankton from ~200 m to the surface	Abundance															
	>1000 µm	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	500-1000 µm	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	200-500 µm	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	112-200 µm	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	Biomass															
	>1000 µm	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	500-1000 µm	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	200-500 µm	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
	112-200 µm	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
Surface water zooplankton	Abundance															
	>1000 µm	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+
	500-1000 µm	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+
	200-500 µm	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+
	112-200 µm	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+
	Biomass															
	>1000 µm	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+
	500-1000 µm	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+
	200-500 µm	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+
	112-200 µm	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+

2.1.1. CTD measurements

Temperature, salinity and depth profiles were recorded by using a Seabird sensor (Model SBE 19 plus). The CTD probe took records while traveling within the water column. The signals were transferred into the computer, calibrated and then the data is generated for use. Sensitivity of the probe is ±0.001 unit for both the temperature and salinity and 1% for the depth.

2.1.2. Seston sampling and measurements

Seawater samples were collected with niskin bottles from the sea surface for seston chlorophyll-a, total suspended particulate matter and the biochemical composition (protein, lipid and carbohydrate) analysis. Seawater samples were taken into the 25 L bottles and kept in dark until laboratory processes.

2.1.2.1. Total and organic suspended particulate matter

A well-mixed seawater sample was filtered onto pre-dried at 60^{o}C and pre-weight Whatman GF/F filters (0.7µm pore size and 47 mm diameter) and the filter was put into the Petri plate and then preserved at -20^{o}C in refrigerator for further analysis. The filters were dried at 60^{o}C in an oven for 24 hr for total suspended particulate matter (TSPM) measurement and put in a dessicator to reach the room temperature and then, were weighed with electronic balance. This process was repeated until a constant weight is obtained. About 3 to 5 liters of seawater was filtered for the nearshore station and about 5 to 10 liters of seawater was filtered for the offshore station. For the suspended particulate organic matter (SPOM) measurements, dried filters were combusted at 450^{o}C for 12 hr in a muffle furnace and weighed (Harris, *et al*., 2000). Then, SPOM is obtained by subtracting this value from the TSPM. The results were given in mg L^{-1}.

2.1.2.2. Seston chlorophyll-a, protein, lipid and carbohydrate

Total concentrations (>0.7 μm) of seston chlorophyll-a (chl-a), protein, lipid and carbohydrate and the contributions of pico (0.7-2.7 μm), nano (2.7-18 μm) and micro (>18 μm) size particles to the total concentrations were measured. For the analysis of total seston chl-a, protein, lipid ve carbohydrate, seawater were filtered through 0.7 μm Whatman GF/F filters (25 mm diameter). In order to measure the level of pico, nano and micro particles in the seawater, three types of filters were used; Whatman GF/F filters (0.7μm pore size and 25 mm diameter), Whatman GF/D filters (2.7μm pore size and 25 mm diameter) and nylon mesh (18μm pore size). Pre-combusted (at 450^{o}C for 6 h) Whatman filters were used to avoid contamination for the protein, lipid and carbohydrate measurements. About 1 to 2 L of seawater was filtered through Whatman GF/F filters and about 2 to 4 L of seawater was filtered through Whatman GF/D filters under low vacuum without causing any clogging. To obtain 0.7-18 μm size fraction, seawater sample were passed through 18 μm Nitex screen before filtration onto 0.7 μm GF/F filters. Another seawater sample were filtered onto 2.7 μm GF/D filters to obtain >2.7 μm size fraction. After filtration, filters were immediately frozen in liquid nitrogen prior to processing (Kleppel and Hazzard, 2000; Hazzard and Kleppel, 2003; Danovaro *et al*., 2000).

Chlorophyll-a and the biochemical components, i.e. protein, lipid and carbohydrate, concentrations in pico size fraction (0.7-2.7 μm) were estimated by difference between total concentrations (>0.7 μm) and that in the >2.7 μm size fractions. The concentrations in the nano size fraction (2.7-18 μm) were calculated as the difference between the concentrations in the <18 μm and that in the pico size fraction (0.7-2.7 μm). Similarly, the concentrations in the micro size fraction (>18 μm) were calculated as the difference between total concentrations (>0.7 μm) and that in the <18 μm size fraction (Kleppel and Hazzard, 2000; Hazzard and Kleppel; 2003 and Danovaro *et al*., 2000).

Chlorophyll-a measurements were analyzed by the method of fluorometric chlorophyll-a technique (Holm-Hansen *et al*., 1965) with a Hitachi F 3000 fluorometer. The samples on the filters were extracted with 5 ml of 90% acetone solution by using ultrasonicator (60 Hz for 1 min). Then, the samples were put into the refrigerator at 4°C for about 12 hours. After the extraction procedure, samples were centrifuged at 3500 rpm for 10 min to remove cellular debris. Prior to

measurement, fluorometer was set to zero with 90% acetone, than fluorescence intensity of 2 ml extract was measured before and after acidification with 2 drops of 1N HCl at 420 nm excitation and 669 nm emission wavelength (Strickland and Parsons, 1972). In order to determine the sample fluorescence concentration standard chlorophyll-a obtained from Sigma was used. Standard chlorophyll-a concentration were calculated by using following formula (Jeffrey and Humphrey, 1975);

$$\text{Chl-a} = 11.85 * A_{664-750} - 1.54 * A_{647-750} - 0.08 * A_{630-750} \quad \text{Eq. 1}$$

Chlorophyll-a and phaeopigment concentrations in the samples were calculated by using;

$$\text{Chl-a } (\mu g\ L^{-1}) = [F_m \times (F_o - F_a) \times V_{ext} \times K_s] / [(F_m - 1) \times V_{flt}] \quad \text{Eq. 2}$$

$$\text{Phaeo } (\mu g\ L^{-1}) = [F_m \times [(F_m \times F_a) - F_o] \times V_{ext} \times K_s] / [(F_m - 1) \times V_{flt}] \quad \text{Eq. 3}$$

where;

Fm, 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)

The detection limit was about 0.01 µg L^{-1}. The precision was better than 7% (relative standard deviation) (Jeffrey and Humphrey, 1975).

Protein analysis was performed with a modified Lowry method by using Helios type spectrophotometer (Clayton *et al*., 1988). The Lowry method consists of three parts: extraction, separation and measurement. Firstly, the filter with sample is put into the tissue-homogenizing tube containing 2.2 ml of 0.37M TCA (trichloroacetic acid, mol. Wt = 163.4; 6%w/v) for homogenization. After homogenizing for 1.5 min., the homogenate is mixed with 0.2 ml of DOC of 3.6 mM (sodium deoxycholate, mol. Wt=414.5; 0.15% w/v) and allowed to remain at room temperature for 10 min. Ice is

used to prevent the sample from heating, because heating of sample led to denaturation of the proteins. TCA (trichloroacetic acid) and DOC (sodium deoxycholate) are used to assist in the precipitation of proteins. The sample is centrifuged at 3000 g for 15 min and then, the supernatant is discarded and 1 ml of distilled, de-ionized water and 1 ml of reagent A are mixed with the pellet. After waiting 10 min. at room temperature, the sample is mixed with 0.5 ml of reagent B and allowed to remain at room temperature for an additional 30 min. The sample is again centrifuged at 3000 g for 15 min to remove residual cellular debris and filter material. To ensure that all the material in the solution is removed completely, the supernate is centrifuged couple of times at 3000 g for 15 min. Finally, the absorbance of supernate is measured with a spectrophotometer at 750 nm.

Preparation of reagents A and B are given below (Clayton *et al*., 1988):

Reagent A:

Equal volumes are prepared of the following solutions.

1. 0.1 % (w/v) copper sulfate (pentahydrate) $CuSO_4*5H_2O$
   0.2 % (w/v) potassium tartrate $C_4H_5O_6K$
   10% (w/v) sodium carbonate Na_2CO_3 in distilled, de-ionized water
2. 0.8 M NaOH in distilled, de-ionized water,
3. 10% (w/v) Sodium dodecyl sulfate $(CH_3(CH_2)_{11}OSO_3Na$
4. distilled, de-ionized water

Reagent B:

1:5 (v/v) ~ Folin-Ciocalteau phenol reagent : distilled, de-ionized water

Bovine serum albumin (BSA) is used as a standard to estimate the protein contents in the samples. BSA is prepared in 0.1 N NaOH (Clayton *et al*., 1988). The protein concentrations in the samples were calculated according to Kleppel and Hazzard (2000) and Hazzard and Kleppel (2003) by using;

$$\text{Protein } (\mu g\ L^{-1}) = [\mu g\ L^{-1} \times V_{ext}] / V_{flt} \qquad \text{Eq. 4}$$

where;

$\mu g\ L^{-1}$, concentration from the standard curve
V_{ext}, extraction volume (L)
V_{flt}, filtration volume (L)

Lipid analysis was performed with sulphophosphovanillin method by using Helios type spectrophotometer (Barnes and Blackstock, 1973). Firstly, sample on filter is put into a tube and dried under nitrogen gas. Secondly, 2 ml of 2:1 chloroform: methanol is put onto the sample in the tube and then extracted by using ultrasonicator at 60 Hz for 1 min. The outer part of the tube is covered with foil to prevent any light penetration and the tube is put into the refrigerator at 4^{o} C for 22-24 hours. After extraction, sample is centrifuged at 3000 g for 10 min and the supernatant is transferred to clean tube for evaporation process. This process is accomplished until all the supernatant evaporates under the nitrogen gas. 0.5 ml H_2SO_4 (99%) is added onto the sample and mixed. After that, the tube is placed into the water bath at 100^{o}C for 10 minutes. The tube is removed from the water bath and cooled under the tap water. The sample is shaked after adding 2.5 ml phospho-vanillin reagent onto the sample and then is allowed to stand at room temperature for 30 min. Finally, the absorbance of the sample is measured at 520 nm with the spectrophotometer.

Preparation of phospho-vanillin reagent (Barnes and Blackstock, 1973):

250 ml phosphoric acid
50 ml distilled, de-ionized water
0.5 g vanillin

Cholesterol is used as a standard to estimate the lipid contents in the samples. Cholesterol is prepared in chloroform:methanol (2:1; v/v). The lipid concentrations in the samples were calculated according to Kleppel and Hazzard (2000) and Hazzard and Kleppel (2003) by using;

$$\text{Lipid } (\mu g\ L^{-1}) = [\mu g\ L^{-1} \times V_{ext}] / V_{flt} \qquad \text{Eq. 5}$$

where;

$\mu g\ L^{-1}$, concentration from the standard curve
V_{ext}, extraction volume (L)
V_{flt}, filtration volume (L)

Carbohydrate analysis was performed with phenol-sulfuric acid method by using a Helios type spectrophotometer (Dubois *et al*., 1956). 1 ml of distilled de-ionized water is added onto the filter with sample on it and homogenized with the tissue-homogenizer. Then, 1 ml of phenol reagent A (5%) and 5 ml of concentrated H_2SO_4 are added immediately and the sample is allowed to remain at room temperature for 10 minutes. The sample is put into the water bath at 30^o C for 20 minutes and finally, it is measured at 490 nm with the spectrophotometer. Glucose is used as a standard to estimate the carbohydrate contents in the samples.

Phenol reagent A: 5.5 ml liquid phenol (90%) added to 94,5 ml water (5% final concentration) (Dubois *et al*., 1956).

The carbohydrate concentrations in the samples were calculated according to Kleppel and Hazzard (2000) and Hazzard and Kleppel (2003) by using;

$$\text{Carbohydrate } (\mu g\ L^{-1}) = [\mu g\ L^{-1} \times V_{ext}] / V_{flt} \qquad \text{Eq. 6}$$

where;

$\mu g\ L^{-1}$, concentration from the standard curve
V_{ext}, extraction volume (L)
V_{flt}, filtration volume (L)

2.1.3. Zooplankton sampling and measurements

To study the main zooplankton groups and biomass at nearshore and offshore stations, samples were collected by towing a Nansen net which has 70 cm mouth diameter with 112 μm mesh size. Lead pieces were attached onto the collector in order to increase the weight of the collector and therefore, the displacement of net

with the currents were minimized. At windy days, the vessel was drifted from the point where the net was lowered down, therefore it was not possible to keep the vessel stationary at a place. In that case, the net was not towed from the desired depth. Hence, wire angles were always taken into consideration and the length of the wire was corrected by the formula given below (Sameoto *et al*., 1980; Harrris *et al*., 2000; Omori and Ikeda, 1992);

$$Z_1=Z_2 \text{Cos } x \qquad \text{Eq. 7}$$

where Z_1 is the final wire length
Z_2 is the intended depth
X is the wire angle

Some animals can escape from the mouth opening of the net while hauling. In some cases animals can escape because of being smaller than the mesh opening (Harrris, *et al*., 2000; Omori and Ikeda, 1992). However, it is also possible that the animals may extrude from the mesh opening because of water pressure associated with water flow. As the speed of the net increases, the amount of animal extrusion through the mesh increases. On the contrary, towing speed may also led to spilling out of the water from the net. Therefore, hauls were made with a speed of 0.6 m/s to minimize the spilling out of the water.

For the water column zooplankton sampling, the net was towed vertically from 5-6 m above the bottom to the surface. For surface zooplankton sample collection, the net was towed horizontally from the sea surface about 2.5-3 knot for 2.5-5 min.

Material in the cod-end of the net was taken into the bucket by washing outer part of the net to get the material from the net. Zooplankton samples were fractionated into 4 size classes (112-200, 200-500, 500-1000 and >1000 μm) by filtering through mesh filters. For taxonomical identification and enumeration each size fraction was preserved with 5% borax-buffered formaldehyde in 250 ml bottles and kept in dark. Folsom splitter was used to divide samples into subsample and at least 400 organisms were counted for each sample under an Olympus SZX12 model stereo-microscope. Rare groups were counted by analyzing the whole sample (Harris *et al.,* 2000). The main references used for the identification of major zooplanktonic groups were Faune de France (Rose, 1933), Planktonoloji II. Denizel Zooplankton (Özel,

2000), South Atlantic Zooplankton (Boltovskoy, 1999), Guide to the coastal surface zooplankton of the South-western Indian Ocean (Conway *et al.,* 2003) and ICES (https://www.ices.dk/products/fiche/Plankton/INDEX.PDF). The abundance results were given in ind m^{-3}.

For zooplankton biomass estimation, each size fractions were filtered onto pre-dried and pre-weighed Whatman GF/C filters (1.2 µm pore size and 47mm diameter) and put into the Petri plate and then preserved at -20^{o}C in refrigerator for further analysis. In the laboratory, zooplankton on GF/C filters were dried at 60^{o}C for 24 hr and weighed for dry weight. Afterwards, dried samples were combusted at 450^{o}C for 12 hr and weighed for ash weight. Zooplankton organic dry weight (ash free dry weight) was calculated as the difference between dry weight and ash weight (Harris *et al.,* 2000). Dry weight results were given in mg m^{-3}.

In this study, abundance and biomass values were expressed in unit volume. In order to compare the offshore and inshore stations with the environmental parameters measured, the differences in the depths of stations are important. Therefore, the differences in the depth should be ignored when using unit volume. Use of unit volume will be useful when comparing the results with other studies. Hence, comparison of the water column and surface water zooplankton will be expressed with unit volume, not with the unit area (Harrris *et al*., 2000; Omori and Ikeda, 1992).

Filtration volume of the net was calculated by the following formula;

$$V=\pi r^2 L \qquad \text{Eq. 8}$$

where V is the volume of the filtered water

r is the radius of the mouth of the net

L is the wire length

2.2. Statistical analysis

Spearman Rank correlation test was used to examine the relationships between zooplankton and environmental parameters measured. Mann-Whitney Rank Sum Test was used to determine the difference between stations.

3. RESULTS

3.1. Physical parameters

Temperature and salinity data were obtained from nearshore (station 1) and offshore (station 2) stations in the Mersin Bay, NE Mediterranean Sea, from February 2005 to January 2006. Due to technical problems, no data were obtained in November and December 2004.

Throughout the study period, the surface temperature ranged between 16 - 29.4 ^{o}C being lowest in February 2005 and highest in August 2005 at station 1 (offshore station) (Figure 3.1). The surface salinity varied between 37 (in March 2005) and 39.5 psu (in October 2005) at station 1, shown in Figure 3.2. A well-mixed water column was observed throughout the sampling period, except in February, March, May and July 2005. Low surface salinity observed in February 2005 and March 2005 can be explained by Lamas River influence. In May 2005, surface mixed layer thickness was around 14 m. In July 2005, surface temperature decreased sharply from 28.09 to 26.6 ^{o}C between 2-4 m depths.

At station 2, surface temperature ranged from 17.2 - 29.18 ^{o}C being coldest in January 2006 and hottest in August 2005 (Figure 3.3). Surface salinity ranged from 38.96 (in June 2005) to 39.48 psu (in October 2005) (Figure 3.4). Throughout the sampling period, temperature of the deep water (below 80 m) was not changed much, only between 16 and 18 ^{o}C. On the contrary, in the upper 80 m, there were apparent monthly changes. Due to winter mixing, reasonably well-mixed water column was observed in February, March, April, December 2005 and January 2006. Surface warming started in April 2005. Strong stratification was observed during June, July, August, September and October 2005.

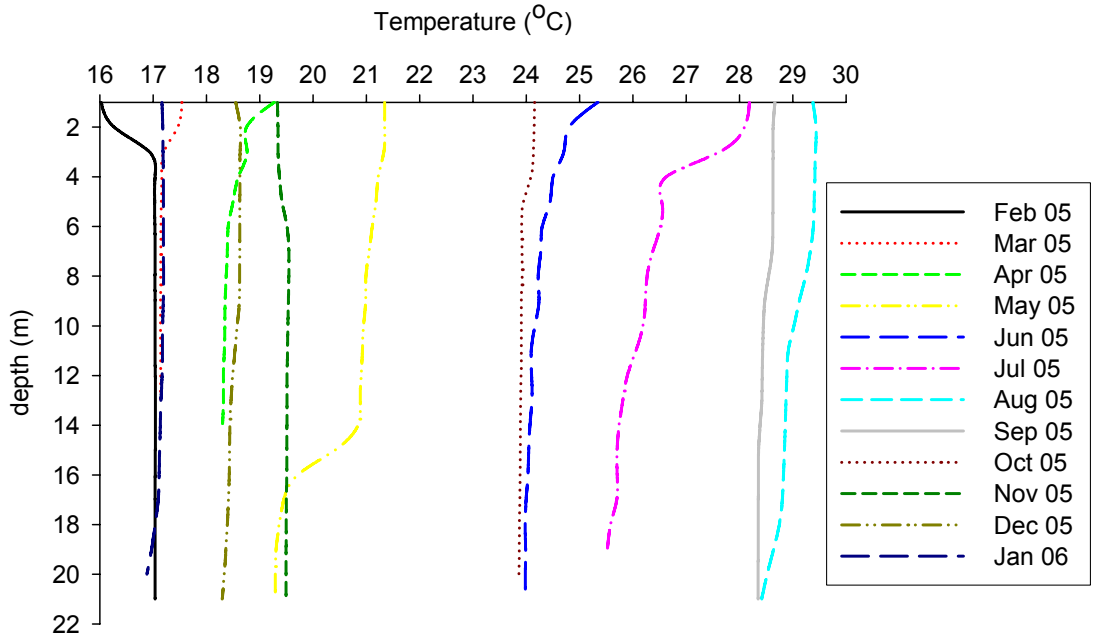

Figure 3.1. Temperature profiles obtained during the study period from station 1.

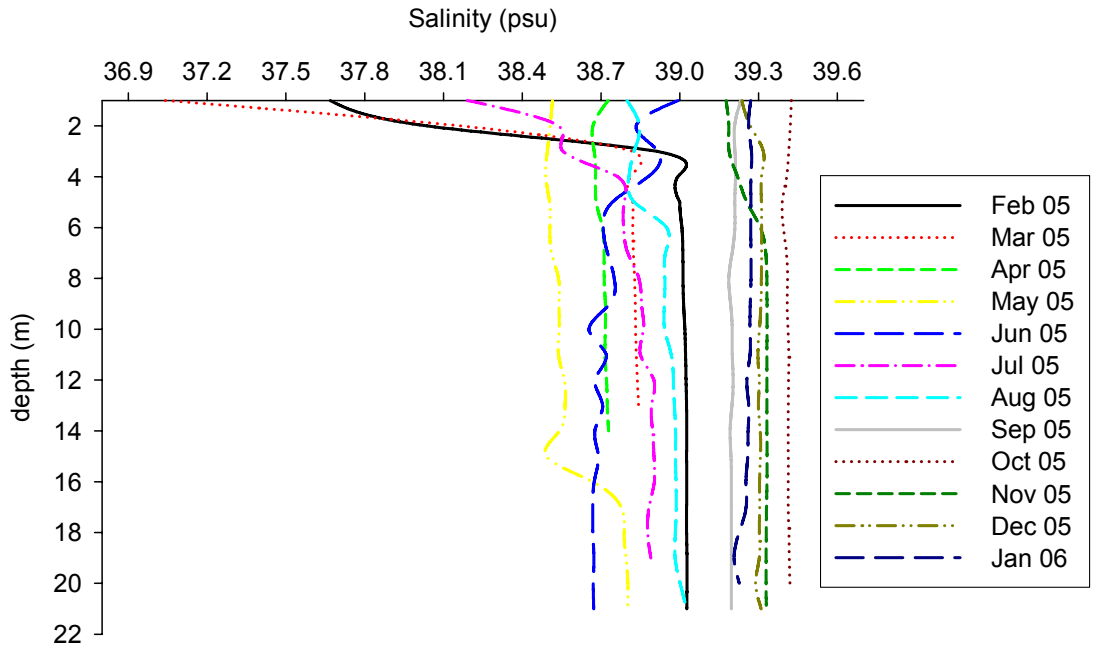

Figure 3.2. Salinity profiles obtained during the study period from station 1.

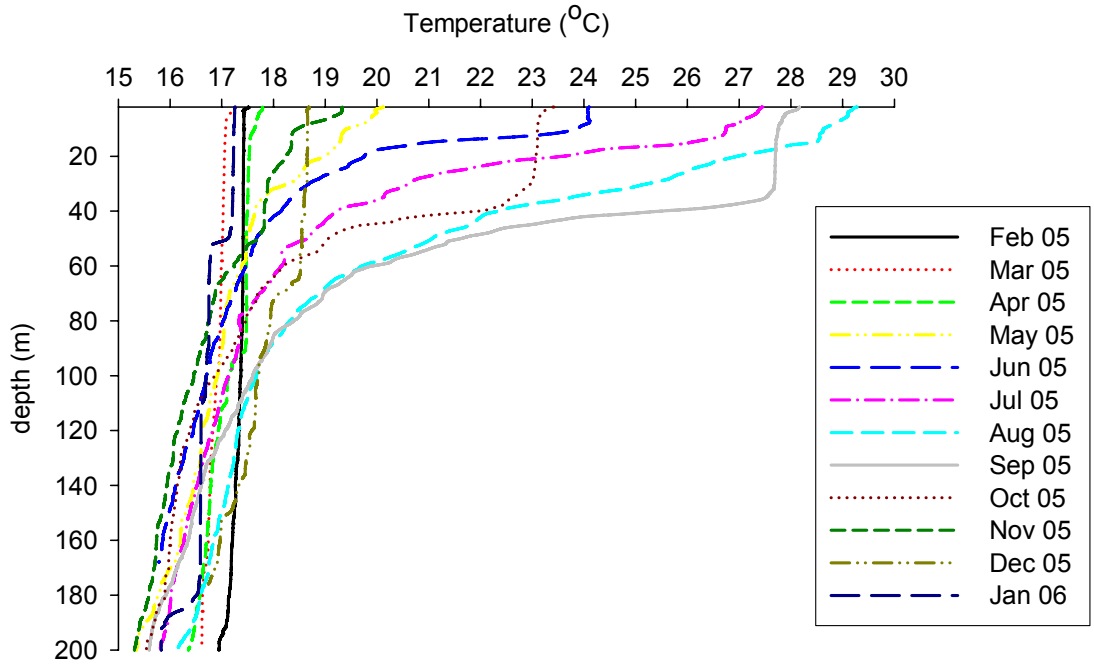

Figure 3.3. Temperature profiles obtained during the study period from station 2

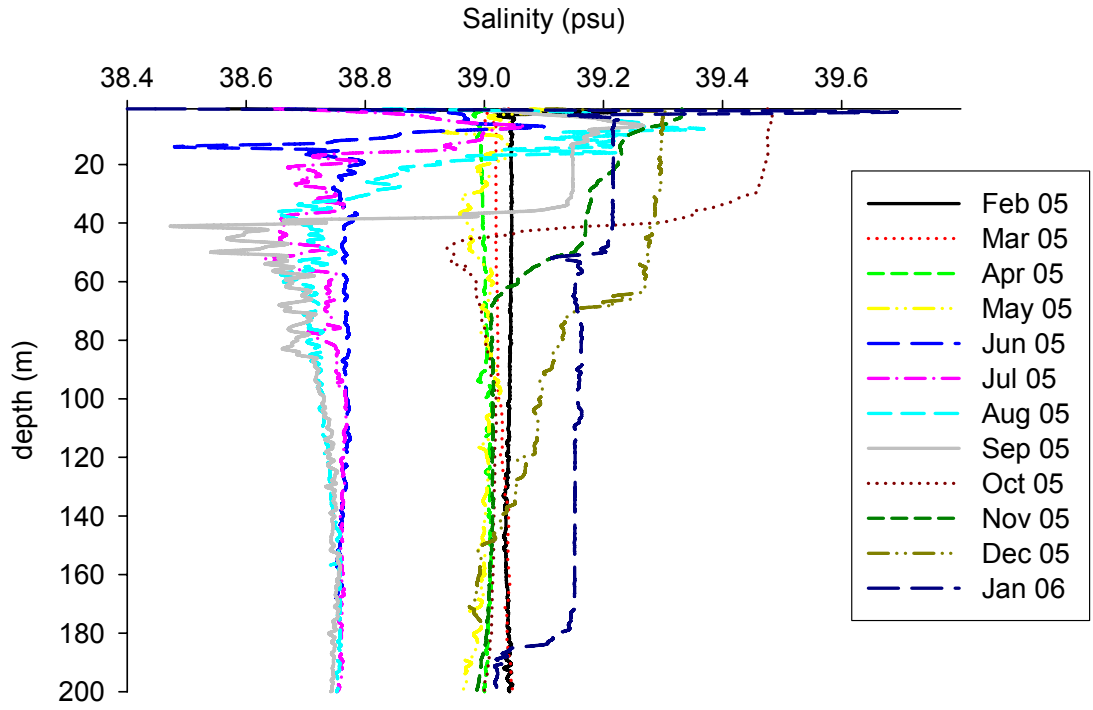

Figure 3.4. Salinity profiles obtained during the study period from station 2.

3.2. Surface seston composition

Under this heading the components related to total and organic suspended particulate matter, total and size fractionated chl-a, carbohydrate, protein and lipid will be presented in the following.

3.2.1. Total and organic suspended particulate matter

Monthly changes in total suspended particulate matter (TSPM) and suspended particulate organic matter (SPOM) and 3X running averages of them at station 1 were shown in Figure 3.5. TSPM values were varied between 5.9 mg L^{-1} (in August 2005) and 14.4 mg L^{-1} (in March 2005) and SPOM values were ranged from 1.4 mg L^{-1} (in June 2005) to 4.6 mg L^{-1} (in March 2005). During the sampling period, they showed seasonal pattern with primary peak in March 2005. On annual average, SPOM content accounted for 28 % of the TSPM and ranged from 24 % to 35 %. 3X running averages of TSPM and SPOM showed that the important increase was that of during March and April. Smoothed curve reveal a decreasing values from April 2005 until to the autumn period (Figure 3.5).

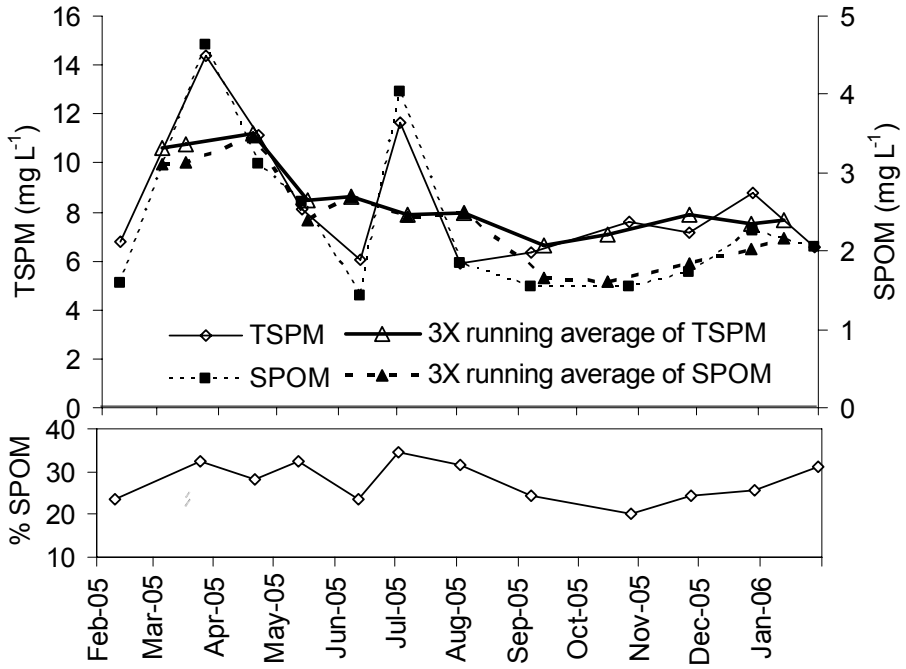

Figure 3.5. Monthly changes in concentrations of TSPM, SPOM and percentage of SPOM in TSPM measured during sampling period at station 1.

Figure 3.6 shows the monthly changes in TSPM and SPOM with 3X running averages at station 2. TSPM and SPOM showed seasonal pattern during the sampling period, the highest value was observed in March and April 2005, respectively. TSPM values ranged from 3.4 mg L^{-1} (in April 2005) to 7.4 mg L^{-1} (in March 2005), and SPOM ranged from 0.9 (in October) to 2.4 mg L^{-1} (in April). On annual average, SPOM accounted for 33 % of TSPM and ranged from 25 % to 70 %. 3X running averages of TSPM and SPOM showed that after an increase in April, the TSPM and SPOM values slightly fluctuated at a certain level within the year.

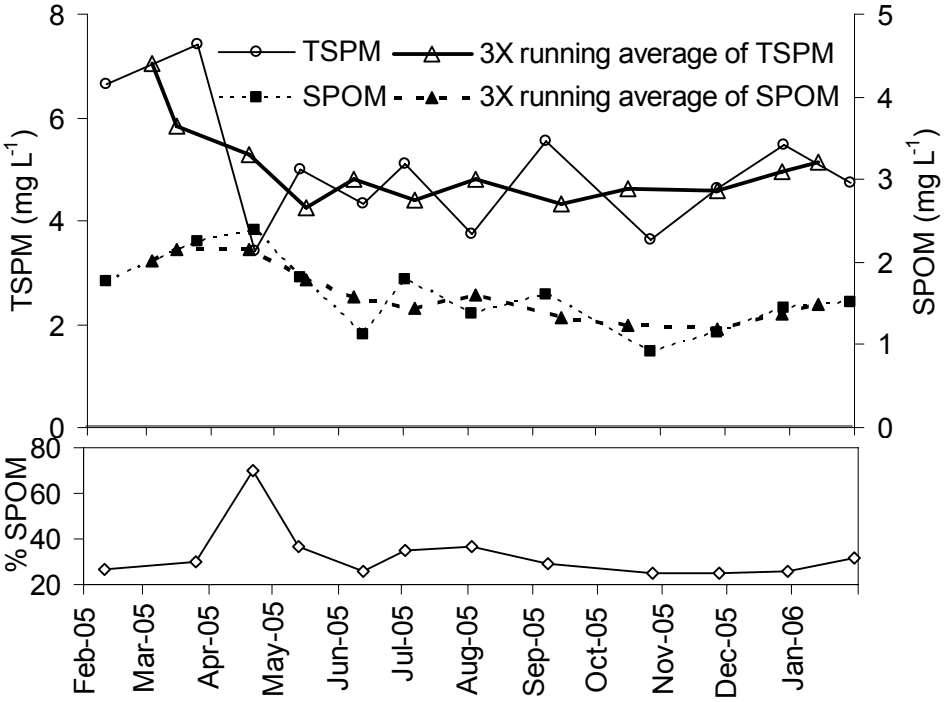

Figure 3.6. Monthly changes in concentrations of TSPM, SPOM and percentage of SPOM in TSPM measured during sampling period at station 2.

3.2.2. Total and size fractionated chlorophyll-a

Temporal distributions of total and size fractionated chl-a at station 1 are presented in Figure 3.7. Total chl-a concentrations ranged between 0.1 µg L^{-1} (June 2005) - 2.4 µg L^{-1} (March 2005). Chlorophyll-a concentration exhibited primary maximum in spring (March 2005). This is followed by summer increase in May and July 2005. A small broad raise was observed in autumn (October and November 2005). Nano

size fraction predominated and accounted for around 94 % of spring chl-a maximum. Chlorophyll-a concentration in nano size fraction was very low during summer and steadily increased in October and November 2005, contributing 37 % and 42 % of total chl-a, respectively. Pico size fraction was dominant in most of the sampling period. In May and July 2005, micro size fractions had higher contribution to total chl-a than the nano size fraction.

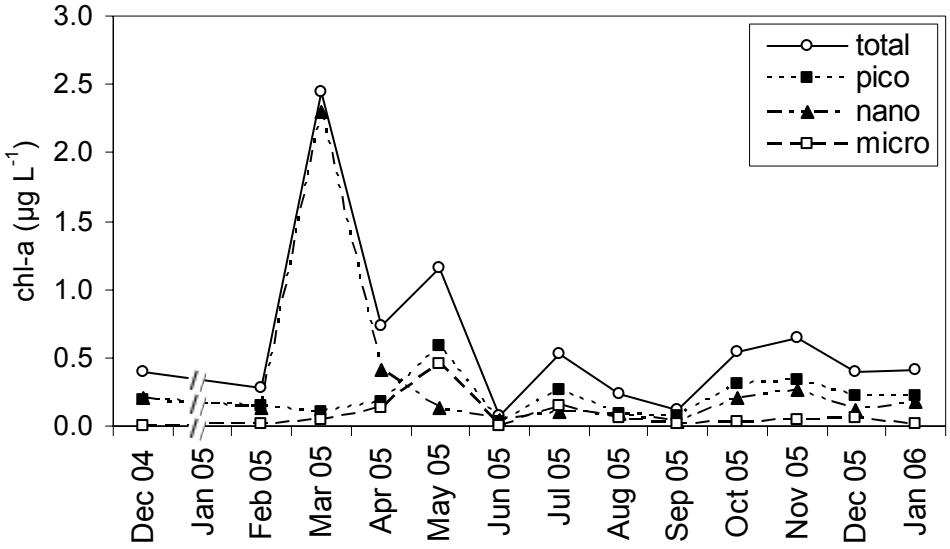

Figure 3.7. Total and size fractionated chl-a concentrations during the sampling period at station 1 (total: >0.7 µm, pico: 0.7-2.7 µm, nano: 2.7-18 µm, micro: >18 µm).

Total chl-a concentrations ranged between 0.03 µg L^{-1} (July 2005) - 0.35 µg L^{-1} (January 2006) at station 2 (Figure 3.8). There were two obvious maxima in total chl-a concentration; the first one was in spring (March 2005) and the other was in winter (January 2006). The relative contribution of three size fractions to total chl-a was different during the sampling period. This reveal that pico fraction dominate the system while showing significant increase in winter and early spring months. Pico size fraction constituted the majority (54- 80 %) of the total chl-a throughout the year. While the micro size fraction was relatively important in spring (February and March 2005) (37-27 % contribution), nano size fraction contribution to the total chl-a was important in July 2005, December 2005 and January 2006 (36-37 % contribution).

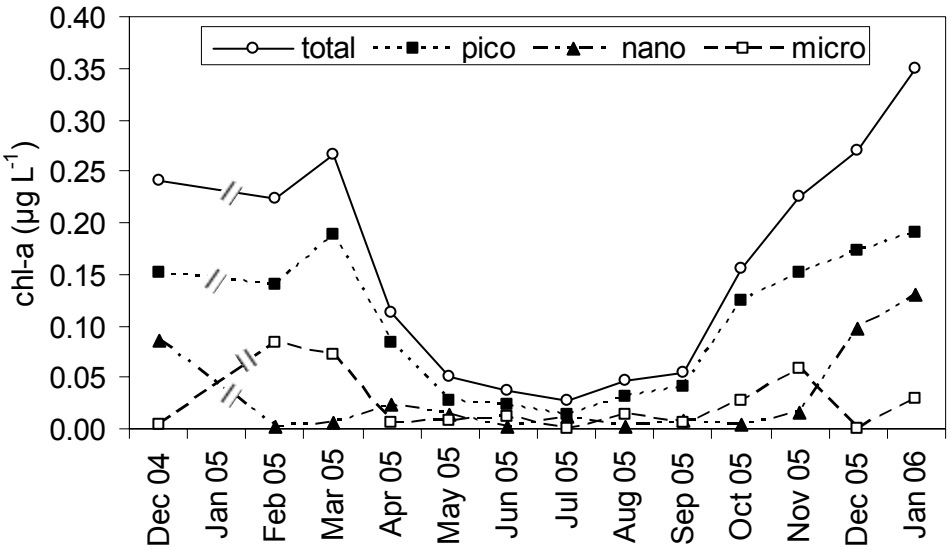

Figure 3.8. Total and size fractionated chl-a concentrations during the sampling period at station 2 (total: >0.7 µm, pico: 0.7-2.7 µm, nano: 2.7-18 µm, micro: >18 µm).

3.2.3. Total and size fractionated protein

At station 1, the maximum value of total protein was observed in March 2005, decreasing progressively afterwards (Figure 3.9). Total protein concentrations ranged between 5.4 µg L^{-1} in January 2006 and 348 µg L^{-1} in March 2005. In March 2005, pico size fraction was responsible for around 58% of the total protein, and being generally the dominant fraction. On annual average, the contribution of pico size fraction was 43 % to the total chl-a concentration. The highest concentration (113.1 µg L^{-1}) of protein in micro size fraction was found in March 2005, while the highest concentration (50.5 µg L^{-1}) of nano size fraction was in April 2005. On annual average, the contributions of nano and micro size fractions to the total protein were 25 and 32 %, respectively.

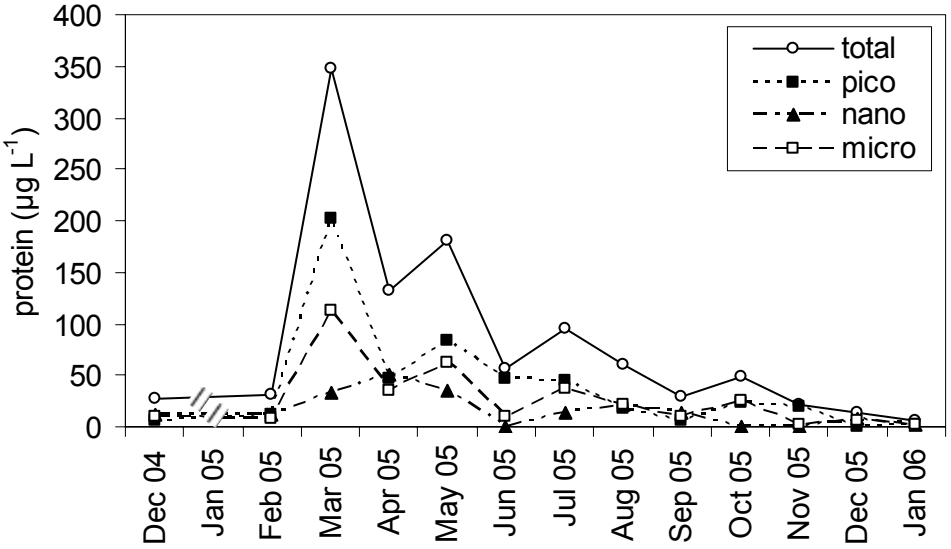

Figure 3.9. Total and size fractionated protein concentrations during the sampling period at station 1 (Total: >0.7 µm, pico: 0.7-2.7 µm, nano: 2.7-18 µm, micro: >18 µm).

At station 2, total protein concentrations ranged between 2.5 µg L^{-1} in January 2006 and 101 µg L^{-1} in June 2005. At this station, three peaks of total protein were observed, with the values of 65 µg L^{-1} in spring (March 2005), 101 µg L^{-1} in summer (June 2005) and 55.4 µg L^{-1} in autumn (November 2005) (Figure 3.10). Pico size fraction was the main contributor to the summer peak (in June 2005), constituting 76%. In spring maximum (March 2005), >80% of the total protein was in the pico (41%) and nano (47%) size fractions. However in November, the micro size fraction accounted for 68% of the total.

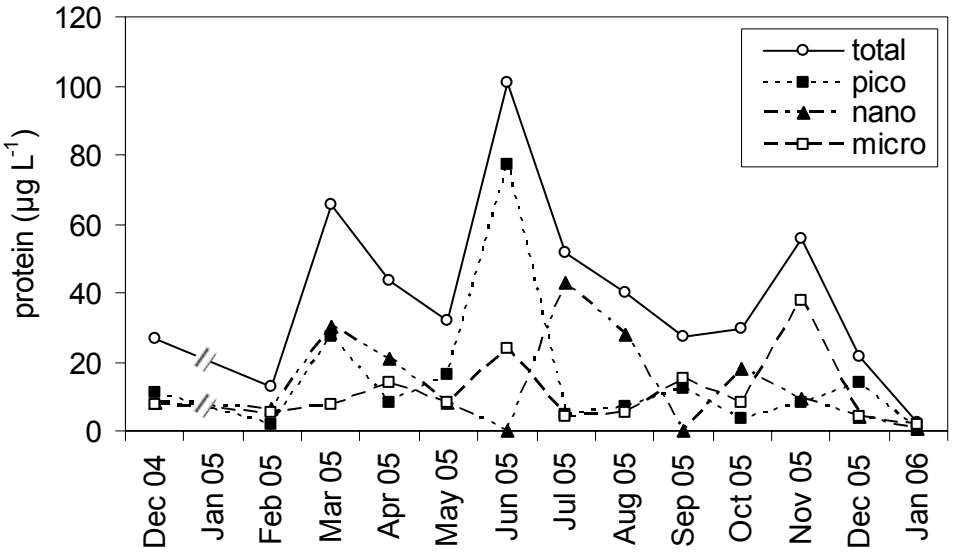

Figure 3.10. Total and size fractionated protein concentrations during the sampling period at station 2 (total: >0.7 µm, pico: 0.7-2.7 µm, nano: 2.7-18 µm, micro: >18 µm).

3.2.4. Total and size fractionated lipid

At station 1, the highest concentration of total lipid was found in March 2005 (315.2 µg L^{-1}) (Figure 3.11). In this peak, 68% and 31% of the lipid lay in the nano and micro size fractions, respectively. The concentration of total lipid decreased drastically after the March peak through April 2005 and remained at levels lower than 100 µg L^{-1} for the rest of the survey. The relevance of the pico size fraction increased during the period of low lipid content.

At station 2, total lipid concentration exhibited a pronounced spring maximum (83 µg L^{-1} in March 2005 and 97.8 µg L^{-1} in April 2005) and decreased drastically after May 2005 till October 2005; it increased again to around 30 µg L^{-1} in winter 2006 (Figure 3.12). In April 2005, >90% of the total lipid was in the pico (47%) and micro (50%) size fractions. Nano size fraction did not show any clear seasonal trend. However, it was responsible for around 70% of the total lipid in August 2005 and December 2005. On annual average, the contributions of pico, nano and micro size fractions to the total lipid were 49, 27 and 24 %, respectively.

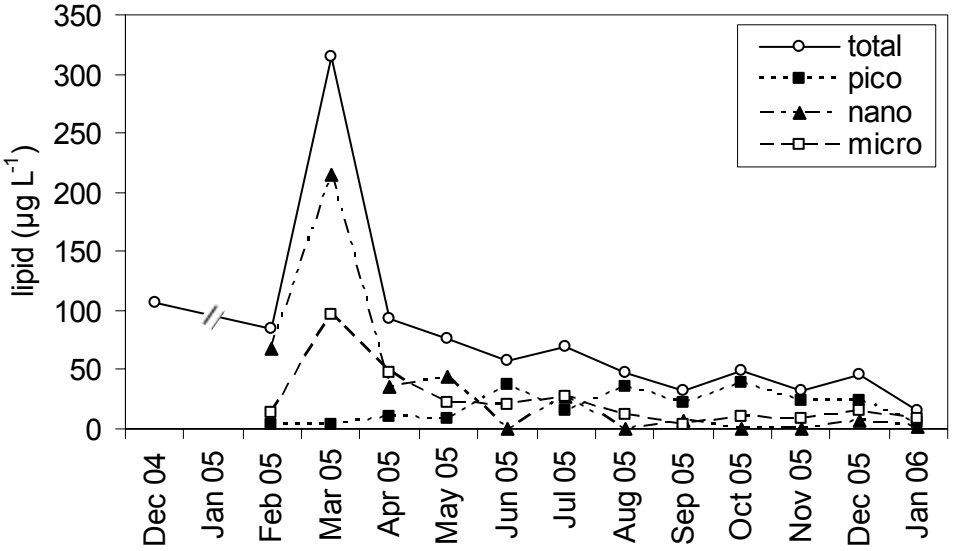

Figure 3.11. Total and size fractionated lipid concentrations during the sampling period at station 1 (total: >0.7 µm, pico: 0.7-2.7 µm, nano: 2.7-18 µm, micro: >18 µm).

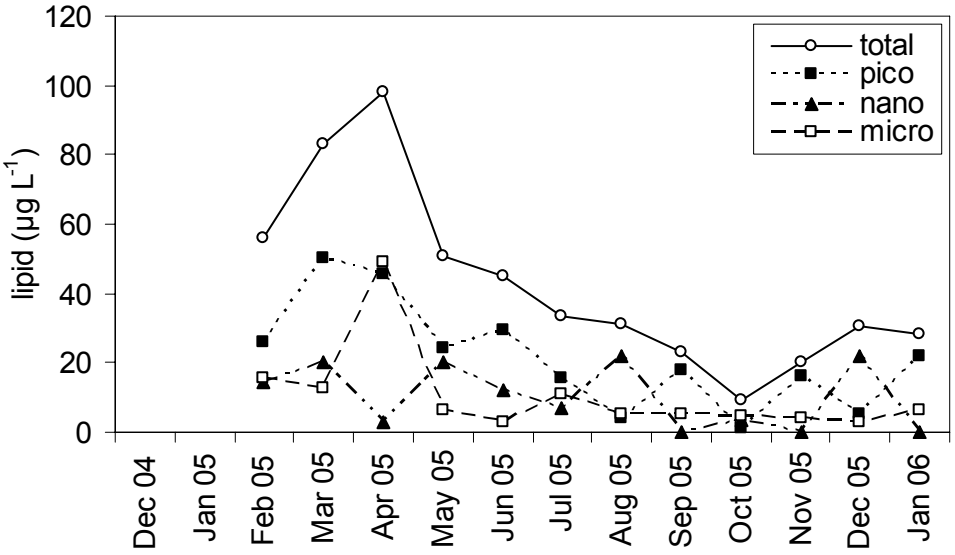

Figure 3.12. Total and size fractionated lipid concentrations during the sampling period at station 2 (total: >0.7 µm, pico: 0.7-2.7 µm, nano: 2.7-18 µm, micro: >18 µm).

3.2.5. Total and size fractionated carbohydrate

Total carbohydrate concentrations ranged between 21.4 μg L^{-1} in January 2006 and 419.5 μg L^{-1} in March 2005 at station 1 (Figure 3.13). Two peaks of total carbohydrate were observed, with values of 419.5 μg L^{-1} in March 2005 and 227.6 μg L^{-1} in August 2005. In March 2005, nano and micro size fractions accounted for 49 and 31% of the total carbohydrate, respectively. However, in August 2005 carbohydrate concentration in pico size fraction was more dominant, accounted for 75% of the total carbohydrate. On annual average, the contributions of pico, nano and micro size fractions to the total carbohydrate were 31, 47 and 22 %, respectively.

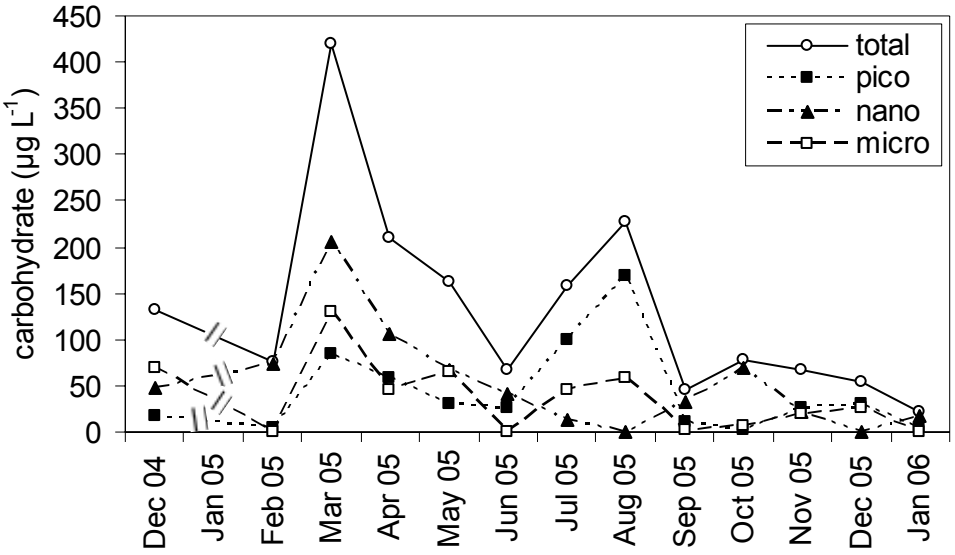

Figure 3.13. Total and size fractionated carbohydrate concentrations during the sampling period at station 1 (total: >0.7 μm, pico: 0.7-2.7 μm, nano: 2.7-18 μm, micro: >18 μm).

At station 2, the highest concentrations of total carbohydrate were found in December 2004 and May 2005 (around 164 μg L^{-1}) (Figure 3.14). In December 2004, >70% of the total carbohydrate was in the pico (31%) and micro (44%) size fractions. In May 2005, approximately half of the total carbohydrate was contributed by nano size fraction constituting the 53 % of the total. On annual average, the contributions of pico, nano and micro size fractions to the total carbohydrate were 38, 34 and 28 %, respectively.

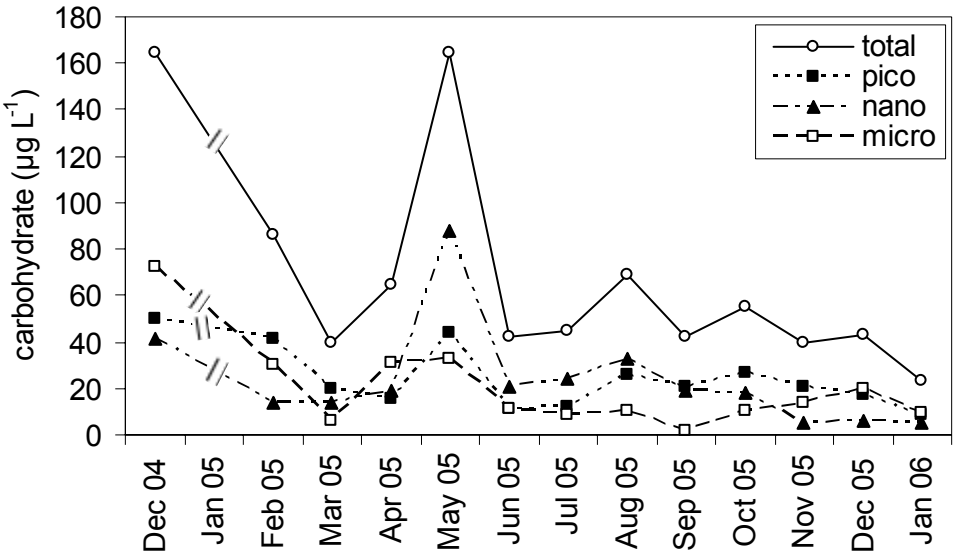

Figure 3.14. Total and size fractionated carbohydrate concentrations during the sampling period at station 2 (total: >0.7 µm, pico: 0.7-2.7 µm, nano: 2.7-18 µm, micro: >18 µm).

3.3. Zooplankton composition and biomass in the water column

In this section, the results of the zooplankton composition and the biomass from the two stations studied are presented as the total and size fractionated zooplankton composition and annual variations of holoplankton and meroplankton in the water column and surface water.

3.3.1. Zooplankton composition in the water column

Total zooplankton abundance (ind m^{-3}) differed between two stations with the almost eight times more value at station 1 than station 2. Zooplankton abundance varied from 1648 (in November 2004) to 14198 ind m^{-3} (in March 2005) at station 1 shown in Figure 3.15. Three main increases were observed in March, August and October 2005. >1000 µm and 500-1000 µm size fractions displayed maximum values in spring. They varied between 24 ind m^{-3} (in September 2005) -705 ind m^{-3} (in April 2005) and 30 ind m^{-3} (in September 2005) - 4570 ind m^{-3} (in March 2005), respectively (Figure 3.15). Contribution of >1000 µm and 500-1000 µm size fractions to the total zooplankton was lower than other size fractions, constituting only 3 and

11 %, respectively. 200-500 µm and 112-200 µm size fractions exhibited the same seasonal trend with the total zooplankton abundance (Figure 3.15). They varied between 304 ind m^{-3} (in September 2005) - 5768 ind m^{-3} (in October 2005) and 360 ind m^{-3} (in November 2004) - 5191 ind m^{-3} (in March 2005), respectively. On annual average, the contribution of these two fractions to the total zooplankton was higher and same, with 43 %. 200-500 µm size fraction were dominant in April, May, August 2005, autumn and winter periods, while 112-200 µm size fraction were dominant in December 2004, February, March, June, July and September 2005.

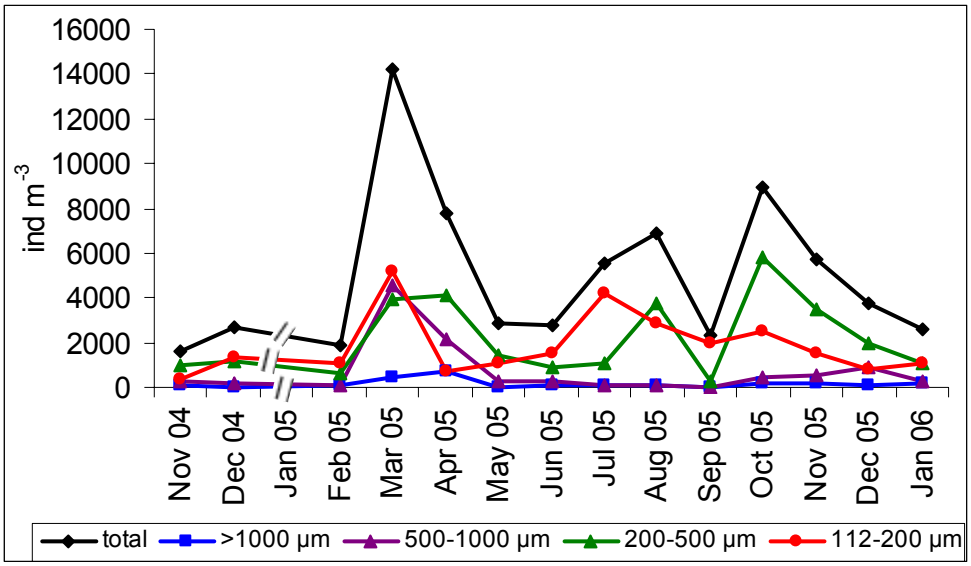

Figure 3.15. Temporal variations of total and size fractionated zooplankton in the water column at station 1.

Total zooplankton abundance varied from 238 (in July 2005) to 1556 ind/m^3 (in November 2005) at station 2, shown in Figure 3.16. At station 2, the primary peak of zooplankton abundance was observed in autumn period (November), with secondary peak in spring and small increases in summer months. >1000 µm and 500-1000 µm size fractions varied between 3 ind m^{-3} (in September 2005) - 115 ind m^{-3} (in November 2005) and 10 ind m^{-3} (in June 2005) - 307 ind m^{-3} (in November 2005), respectively (Figure 3.16). These two size fractions slightly fluctuated throughout the year with a small peak in November 2005. They contributed only 5 and 8 % to the total zooplankton abundance, respectively. 200-500 µm size fraction varied between 69 ind m^{-3} (in May 2005) and 916 ind m^{-3} (in November 2005). 112-200 µm size fraction ranged from 81 ind m^{-3} (in November 2004) to 483 ind m^{-3} (in February 2005). 200-500 µm size fraction was dominant in autumn and winter

periods among other size fractions, whereas 112-200 µm size fraction was dominant in spring and summer periods. Average contribution of 200-500 µm and 112-200 µm size fractions to total zooplankton were higher than other two size fractions with 41 % and 46 %, respectively.

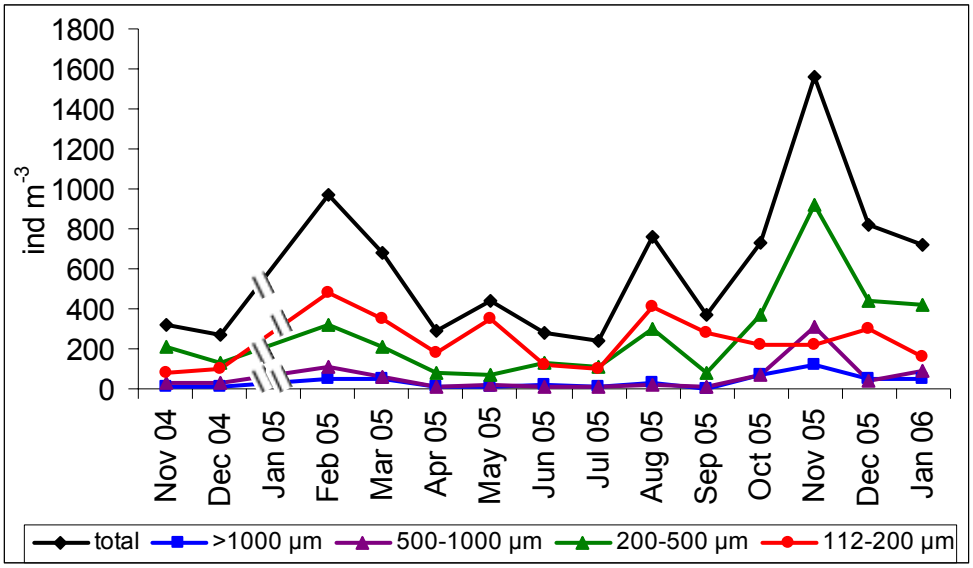

Figure 3.16. Temporal variations of total and size fractionated zooplankton in the water column at station 2.

Temporal variations in size fractionated zooplankton group composition in percentages at stations 1 and 2 are given in Figure 3.17 and Figure 3.18. The main taxonomic groups were protozoa, siphonophora, cladocera, ostracoda, copepoda, chaetognatha, doliolida, appendicularia, crustacean nauplii, polychaeta larvae, gastropoda larvae, bivalvia larvae and echinodermata larvae at both stations.

As the magnitude of size fractions increases, zooplankton group diversity increases at both stations (Figure 3.17 and Figure 3.18). Copepods constituted the majority of the total zooplankton in all size fractions at both stations. Crustacea nauplii was the second dominant group in smaller size fractions (112-200 and 200-500 µm), whereas appendicularia was the second dominant group in the larger two size fractions (500-1000 and >1000 µm) at both stations (Figure 3.17 and Figure 3.18). The level of contribution of appendicularia was higher at station 1 than at station 2. Highest contribution of cladocera was observed at station 1, especially during spring and summer periods in all size fractions except the smallest size fraction (Figure 3.17). Contribution of chaetognatha to the total zooplankton was higher in >1000

and 500-1000 µm size fractions at both stations (Figure 3.17 and Figure 3.18 c, d). The level of contribution was higher at station 2 compared to station 1. Echinodermata larvae showed the highest contribution in August at station 1, even exceeded the copepod contribution in 500-1000 µm size fraction (Figure 3.17 c). Contribution of siphonophora was highest throughout the year at 500-1000 and >1000 µm size fractions at both stations (Figure 3.18 c, d). Contribution of polychaeta larvae was found at higher values in July at station 1 (Figure 3.17).

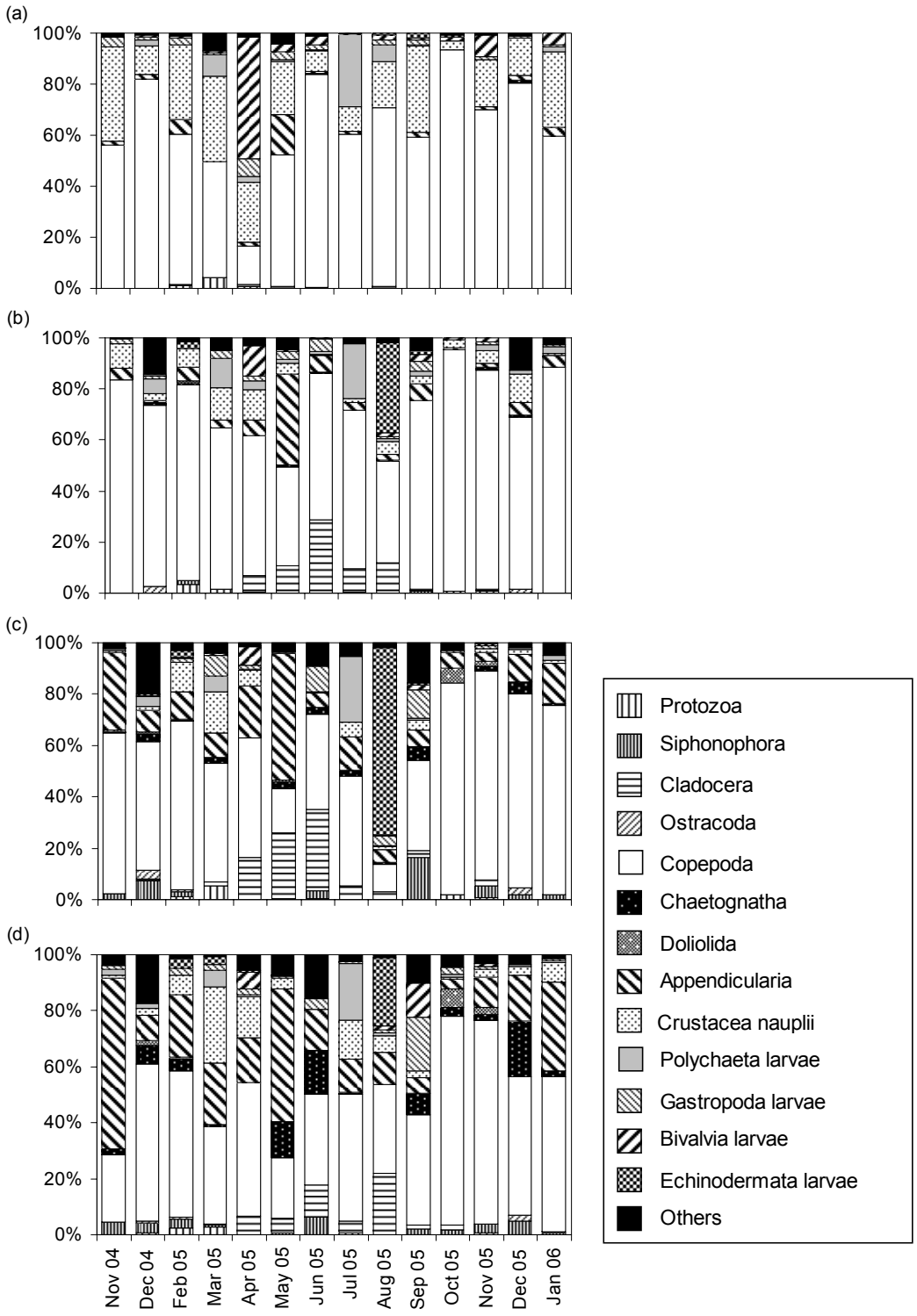

Figure 3.17. Temporal variations in size fractionated zooplankton composition in the water column at station 1, a) 112-200 µm, b) 200-500 µm, c) 500-1000 µm and d) >1000 µm. (Others: Jelly organisms, Pteropoda, Cumacea, Isopoda, Amphipoda, Mysidacea, Euphasidacea, Decapoda, Salpida, cirripedia larvae, Stamopoda larvae, Decapoda larvae, Phoronida larvae, Fish eggs and larvae, and unidentified organisms)

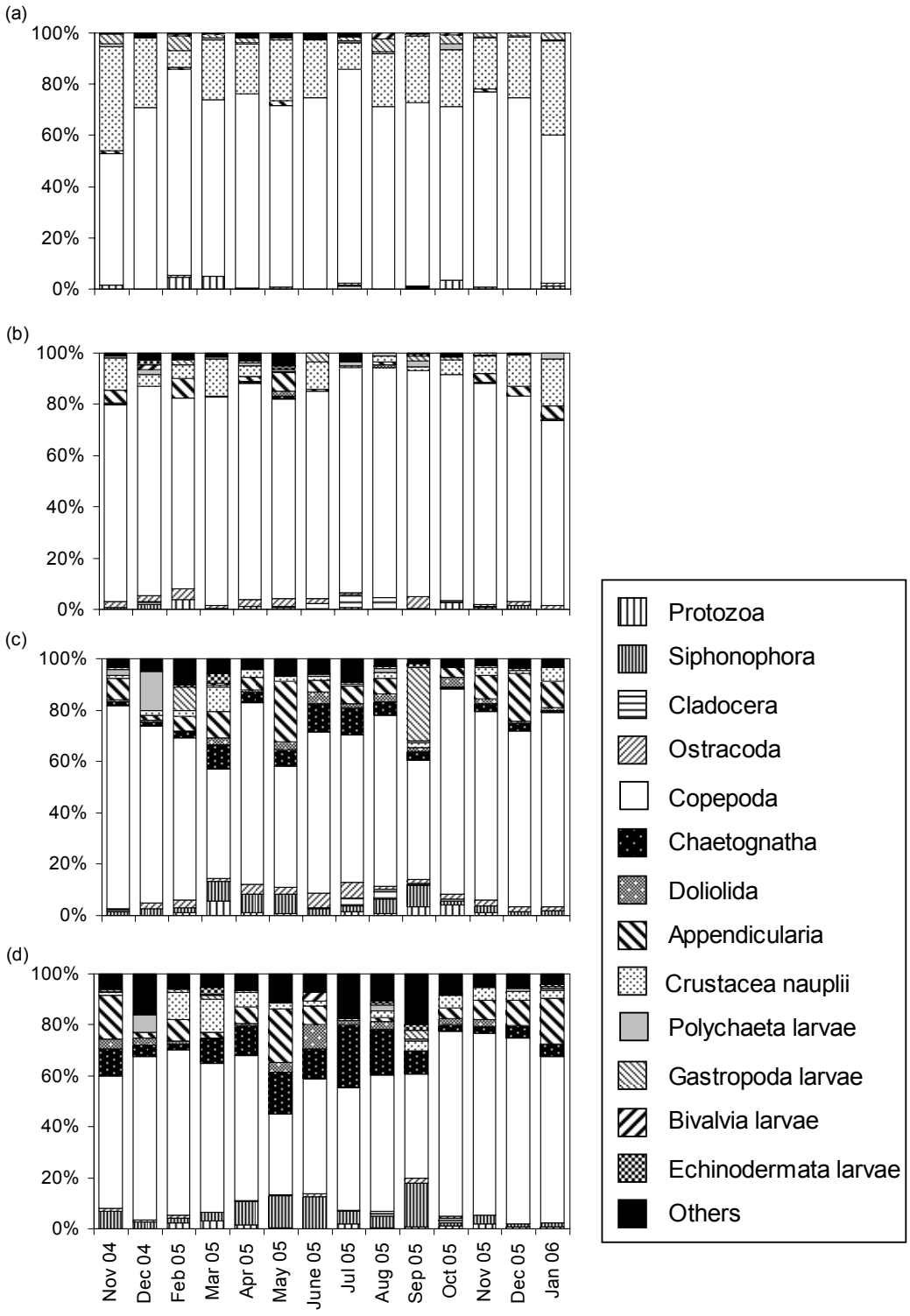

Figure 3.18. Temporal variations in size fractionated zooplankton composition in the water column at station 2, a) 112-200 µm, b) 200-500 µm, c) 500-1000 µm and d) >1000 µm. (Others: Jelly organisms, Pteropoda, Cumacea, Isopoda, Amphipoda, Mysidacea, Euphasidacea, Decapoda, Salpida, cirripedia larvae, Stamopoda larvae, Decapoda larvae, Phoronida larvae, Fish eggs and larvae, and unidentified organisms)

3.3.2. Annual variations of zooplankton groups in the water column

A total of 19 holoplankton and 9 meroplankton groups were present in the sampling period. During the study period, holoplankton groups were comprised of copepoda, crustacean nauplii, appendicularia, cladocera, chaetognatha, siphonophora, jelly organisms, polychaeta, doliolid, pteropoda, salp, protozoa, decapoda, euphasidae, ostracoda, mysidacea, amphipoda, cumacea and isopoda. Meroplankton groups were consisted of larvae of polychaeta, gastropoda, bivalvia, cirripedia, stamopoda, decapoda, echinodermata, phoronida, and fish eggs and larvae.

Annual variations of holoplankton and meroplankton in the water column were shown in Figure 3.19 and Figure 3.20 at station 1 and 2, respectively. Throughout the study period, holoplanktonic groups dominated the meroplanktonic groups at both stations. At station 1, holoplankton abundance values ranged between 1610 and 12326 ind m^{-3}, recorded in November 2004 and March 2005, respectively (Figure 3.19). Meroplankton abundance values varied from 38 ind m^{-3}in November 2004 to 1971 ind m^{-3}in August 2005. Holoplanktonic organisms had two pronounced peaks in March 2005 and October 2005 with a small increase in August 2005. Two main abundance peaks were observed in March and August 2005 for meroplankton and there was a gradual increase in November and December 2005.

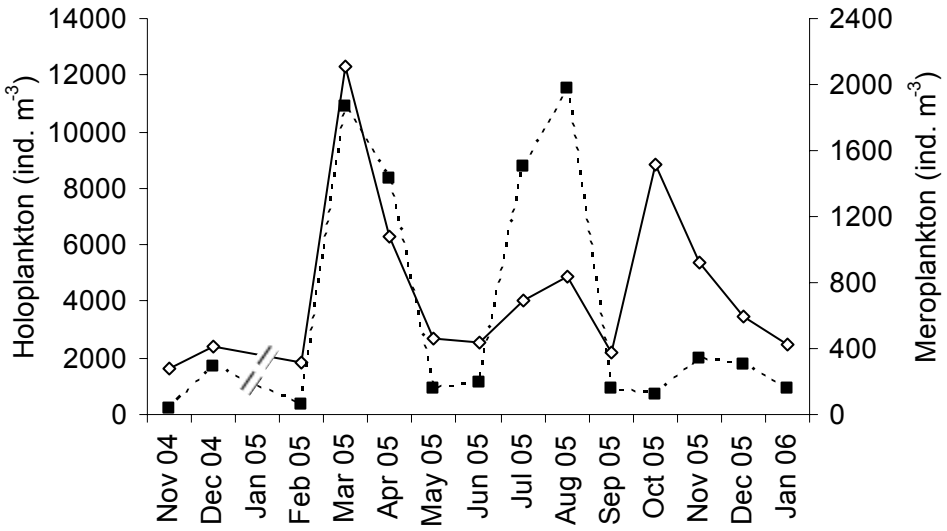

Figure 3.19. Temporal variations of holoplankton (solid line) and meroplankton (dashed line) in the water column at stations 1.

At station 2, holoplankton abundance values ranged between 233 and 1536 ind m^{-3}, recorded in July 2005 and November 2005, respectively (Figure 3.20). Meroplankton abundance values varied from 4.9 ind m^{-3} (in July 2005) to 51.8 ind m^{-3} (in February 2005). The two main peaks for the holoplankton were observed in February and November 2005. Two small increases were also recognizable in May and August 2005. The high values of meroplankton were in February, August and October 2005. There was a small increase in January 2006.

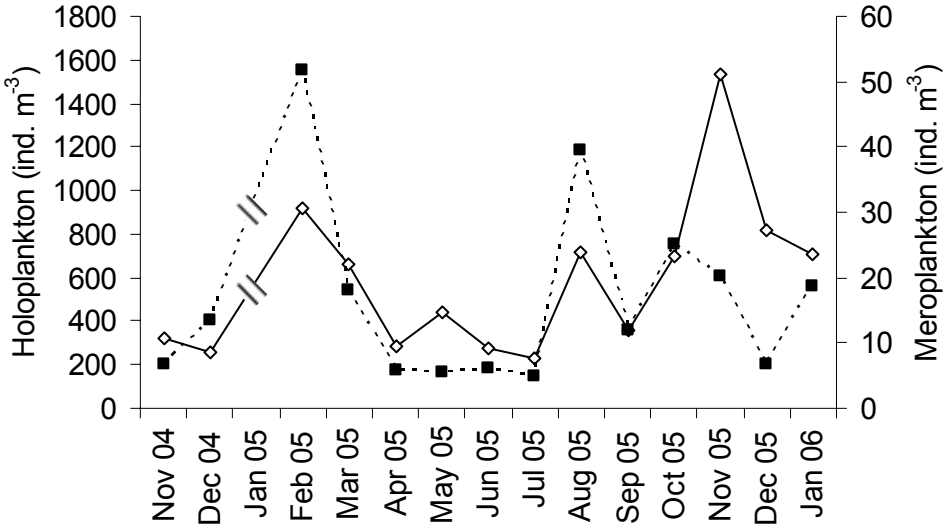

Figure 3.20. Temporal variations of holoplankton (solid line) and meroplankton (dashed line) in the water column at stations 2.

Holoplankton comprised 90 % of the total zooplankton at station 1 and 97 % at station 2, respectively. Meroplankton comprised 10 % and 3 % of the total zooplankton at stations 1 and 2, respectively. Among holoplankton groups, copepoda, crustacea nauplii and appendicularia were the dominant groups throughout the year at both stations 1 and 2 (Table 3.1 and Table 3.2). Copepoda made up 65% and 75 % of the total zooplankton at stations 1 and 2, respectively. Crustacea nauplii contributed 12 % to the total zooplankton at station 1 and 14 % at station 2. Appendicularia constituted 6 % and 2 % of the total zooplankton at both stations 1 and 2, respectively.

Copepods dominated the total zooplanktonic organisms. The percent composition of copepods ranged between 41.5 % in May 2005 and 93.4 % in October 2005 at

station 1 (Table 3.1), and between 69.1 % in January 2006 and 82.4 % in July 2005 at station 2 (Table 3.2). This group dominated the seasonal distribution of the total zooplankton (Figure 3.21 a). They showed spring, summer and autumn peaks. There was a shift in abundance of copepods between two stations. The spring peak was one month later (in March 2005) at station 1 than at station 2 (in February 2005), while autumn peak was one month earlier (in October 2005) at the station 1 than at station 2 (in November 2005). Copepod abundance at station 1 was significantly higher than at station 2 (Mann-Whitney Rank Sum Test $p<0.001$).

Crustacea nauplii contained all the nauplii of crustacean groups. Crustacea nauplii were the second dominant group in the total zooplankton and their abundance varied from 129 to 3083 ind m^{-3}at station 1 and from 11 to 140 ind m^{-3}at station 2 (Figure 3.21 b). They contributed between 3 and 29 % (Table 3.1) at station 1 and between 5 and 20 % (Table 3.2) to the total zooplankton at station 2. At station 1, the primary peak was in March 2005, and second peak was rather small and broad covering August and September 2005. At station 2, the crustacean nauplii showed different distribution pattern than at station 1. They consisted of two pronounced peaks in spring and winter with fluctuations in summer. Abundance of crustacean nauplii at station 1 was significantly higher than at station 2 (Mann-Whitney Rank Sum Test $p<0.001$).

Appendicularia was the third dominant group throughout the year, constituting 6.2 % and 2.2 % of the annual zooplankton abundance at the stations 1 and 2, respectively (Table 3.1 and Table 3.2). The seasonal distribution of appendicularia is presented in Figure 3.21 c. At station 1, abundance values ranged between 51 and 826 ind m^{-3}, observed in December 2004 and May 2005, respectively. A remarkable peak was found throughout the spring, covering March, April and May 2005 period. The abundance decreased drastically after May 2005, remaining at levels not higher than 200 ind m^{-3}during the summer and autumn period. A slight increase was observed in December 2005 and January 2006. At station 2, abundance values varied from 0 in September 2005 to 70.2 ind m^{-3}in November 2005 (Figure 3.21 c). Two main peaks were observed in February and November 2005. Besides these main peaks, the abundance remained at low level between May and October 2005.

Table 3.1. Percent composition of major zooplanktonic groups in the water column at station 1.

Major taxonomic groups	Nov 04	Dec 04	Feb 05	Mar 05	Apr 05	May 05	Jun 05	Jul 05	Aug 05	Sep 05	Oct 05	Nov 05	Dec 05	Jan 06	Average
Holoplankton															
Protozoa	0	0.013	1.904	3.848	0.358	0	0.044	0.106	0	0	0.515	0.585	0	0	0.527
Jelly organisms	0.189	2.117	0.083	0.156	0.072	0.015	0.155	0.106	0	0.328	0.013	0.016	0.014	0.282	0.253
Siphonophora	0.526	0.516	0.773	0.020	0.004	0.031	0.421	0	0	0.328	0.039	0.538	0.542	0.235	0.284
Polychaeta	0	0.019	1.214	1.094	0	0	0	0	0.006	0.012	0	0.008	0.445	0	0.200
Pteropoda	0.694	0.181	0	0	2.183	4.367	0.952	0.352	0	0.012	0.296	0.285	0.042	0	0.669
Cladocera	0	0.052	0	0.488	8.697	8.117	13.045	1.995	7.248	0.140	0.039	0.696	0	0.012	2.895
Ostracoda	0	1.459	0.350	0	0	0.01532	0	0	0	0	0	0	1.598	0	0.244
Copepoda	72.150	74.6999	65.271	50.098	48.137	41.467	69.402	60.014	51.789	60.700	93.356	80.781	71.665	72.868	65.171
Cumacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0	0.013	0	0	0	0.010	0	0	0	0	0	0	0	0	0.002
Amphipoda	0	0.006	0	0	0	0	0	0	0	0	0	0	0	0	0.000
Mysidacea	0	0	0	0	0	0	0	0	0.006	0	0	0	0	0	0.000
Euphausiacea	0.063	0.052	0.009	0	0	0	0	0	0	0.023	0	0	0	0	0.011
Decapoda	0	0	0.037	0	0	0	0	0	0	0	0	0	0	0	0.003
Chaetognatha	0.168	0.723	0.442	0.801	0	0.919	0.720	0.070	0.206	0.152	0.064	0.759	2.168	0.235	0.530
Doliolida	0.084	0.077	0.313	0	0	0.061	0.177	0	0	0	0.464	0.253	0	0	0.102
Salpida	0	0.026	0.018	0	0	0.010	0	0	0	0.012	0	0	0.014	0	0.006
Appendicularia	9.886	1.898	6.191	4.824	10.486	29.228	3.311	1.948	1.372	2.482	0.798	1.897	5.878	6.897	6.221
Crustacea nauplii	13.925	6.751	19.991	21.719	11.560	10.385	4.651	8.201	10.724	29.291	3.103	8.301	9.394	13.279	12.234
Unidentified organisms	0	0.413	0.018	3.770	0	0	0	0	0	0	0	0	0	0	0.300
Meroplankton															
Polychaeta larvae	0.168	4.002	0	8.477	2.434	0.991	0.709	26.634	3.307	0.667	0.026	1.518	1.126	2.111	3.726
Gastrapoda larvae	1.998	0.833	1.628	3.828	2.112	2.815	3.699	0.023	1.245	2.306	0.103	0.917	0.222	0.798	1.609
Bivalvia larvae	0	0.413	0.607	0.625	13.349	1.476	1.949	0.375	1.566	1.276	0.824	3.320	0	1.877	1.976
Cirripedia larvae	0	5.228	0	0	0	0.010	0	0	0.967	0.187	0	0	6.893	1.408	1.049
Stamopoda larvae	0	0	0	0	0	0	0	0	0	0.047	0.013	0	0	0	0.004
Decapoda larvae	0.084	0.045	0	0	0	0.005	0.100	0.023	0.024	0.304	0.142	0.063	0	0	0.057
Echinodermata larvae	0	0.465	1.132	0.254	0.501	0.020	0	0	21.527	1.697	0.206	0.063	0	0	1.848
Phoronida larvae	0	0	0	0	0.072	0	0	0	0	0	0	0	0	0	0.005
Fish eggs & larvae	0.063	0	0.018	0	0.036	0.056	0.664	0.153	0.012	0.035	0	0	0	0	0.074
Total (ind m^{-3})	**1648**	**2685**	**1884**	**14198**	**7748**	**2828**	**2762**	**5539**	**6881**	**2338**	**8973**	**5719**	**3742**	**2607**	

Table 3.2. Percent composition of major zooplanktonic groups in the water column at station 2.

Major taxonomic groups	Nov 04	Dec 04	Feb 05	Mar 05	Apr 05	May 05	Jun 05	Jul 05	Aug 05	Sep 05	Oct 05	Nov 05	Dec 05	Jan 06	Average
Holoplankton															
Protozoa	0.394	0	3.872	3.482	0.690	0.123	0	0.507	0.041	0.147	2.812	0.834	0.051	0.288	0.946
Jelly organisms	0.074	0.634	0.269	0.470	0.336	0.062	0.318	1.246	0.138	0.042	0.371	0.343	0.025	0.058	0.313
Siphonophora	0.781	1.368	0.319	0.891	0.649	0.634	0.936	0.359	0.332	0.706	0.265	1.226	0.963	0.346	0.698
Polychaeta	0.008	1.090	1.034	0.259	0.350	0.388	0.212	0.274	0.014	0.035	0.159	0.123	0.228	0.173	0.311
Pteropoda	1.142	0.734	0.308	0	1.617	1.760	0.901	0.866	0.041	0.042	0.106	0.294	0.025	0.029	0.562
Cladocera	0.066	0.634	0	0	0	0	1.148	3.230	1.964	0.587	0.690	0	0	0	0.594
Ostracoda	1.405	1.209	2.128	0.518	1.072	1.328	1.113	1.013	0.041	1.189	0.212	0.785	0.887	1.386	1.020
Copepoda	70.184	75.829	75.723	69.555	77.378	70.246	75.274	82.415	77.867	73.842	79.788	81.104	77.457	69.078	75.410
Cumacea	0	0	0.005	0	0	0	0	0	0	0	0	0	0	0	0.000
Isopoda	0	0.020	0.176	0	0.005	0	0	0	0	0	0	0	0	0	0.014
Amphipoda	0.008	0.005	0.000	0.016	0.027	0.032	0.018	0.718	0	0.014	0.053	0	0.051	0	0.067
Mysidacea	0	0	0.005	0	0	0	0	0	0	0	0	0	0	0	0.000
Euphausiacea	0.016	0.030	0.192	0.146	0.086	0.015	0.124	0.021	0.014	0.014	0.053	0.012	0.051	0.043	0.058
Decapoda	0.008	0.010	0.082	0.032	0	0	0	0	0	0	0.053	0.049	0.025	0	0.019
Chaetognatha	0.592	0.317	0.451	1.555	0.890	0.761	1.148	1.731	0.775	0.217	0.318	0.785	0.431	0.923	0.778
Doliolida	0.403	0.178	0.044	0.291	0.059	0.476	0.795	0.148	0.636	0.056	0.584	0.981	0.051	0.115	0.344
Salpida	0.016	0.377	0.077	0.194	0.014	0.144	0	0.253	0.083	0.098	0.106	0.049	0	0.058	0.105
Appendicularia	4.520	0.317	3.921	1.344	1.036	3.927	0.936	0.380	0.692	0	0.743	4.513	3.470	5.420	2.230
Crustacea nauplii	18.302	12.291	5.868	18.559	13.712	18.638	14.889	4.729	12.132	19.702	10.239	7.603	15.451	19.489	13.686
Unidentified organisms	0	0	0.176	0.016	0	0.200	0	0.063	0.028	0.119	0	0	0	0	0.043
Meroplankton															
Polychaeta larvae	0.994	2.934	0	0.518	0.586	0.097	0.018	1.056	0.996	0.930	0.690	0.490	0.279	1.557	0.796
Gastrapoda larvae	0.994	0.020	4.603	1.101	1.490	0.846	1.713	0.760	2.711	1.846	1.538	0.785	0.431	0.634	1.391
Bivalvia larvae	0	0.952	0.638	0.340	0	0	0.212	0	1.328	0	0.212	0	0	0	0.263
Cirripedia larvae	0	0	0	0.065	0	0	0	0.021	0	0	0	0	0.101	0	0.013
Stamopoda larvae	0	0	0	0	0	0	0	0.063	0	0	0	0	0	0	0.005
Decapoda larvae	0.082	0.089	0.011	0	0	0.135	0.247	0.148	0.111	0	0.955	0.025	0	0.288	0.149
Echinodermata larvae	0	0.952	0.093	0.648	0	0.188	0	0	0.041	0.413	0.053	0	0	0.058	0.175
Phoronida larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fish eggs & larvae	0.008	0.010	0	0	0.005	0	0	0	0.014	0	0	0	0.025	0.058	0.009
Total (ind m^{-3})	**324**	**269**	**970**	**676**	**286**	**443**	**279**	**238**	**759**	**372**	**726**	**1556**	**821**	**721**	

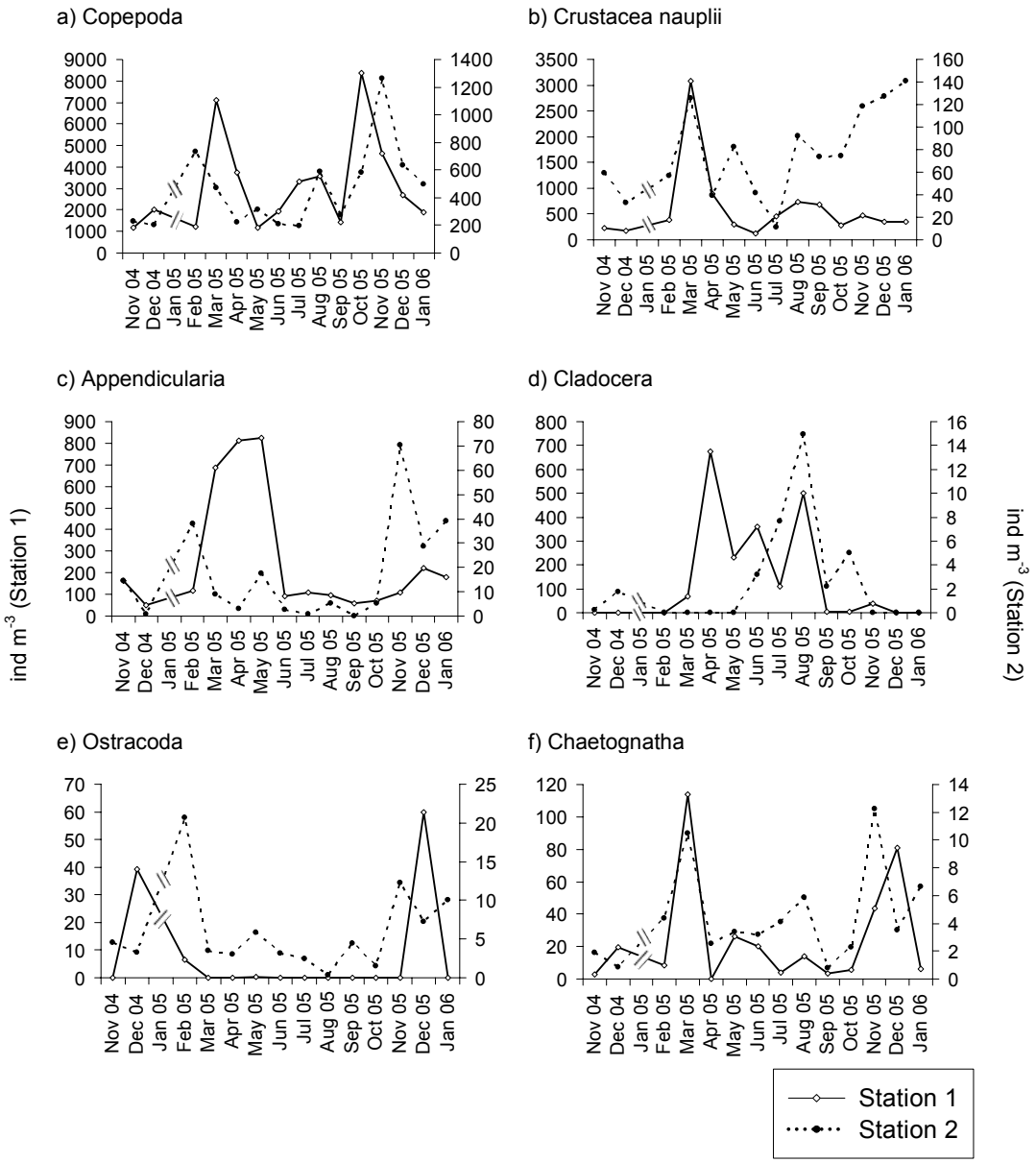

Figure 3.21 Temporal variations of major holoplanktonic groups in the water column at stations 1 and 2. a) Copepoda, b) Crustacea nauplii, c) Appendicularia, d) Cladocera, e) Ostracoda and f) Chaetognatha

Temporal distributions of **cladocerans** at stations 1 and 2 are presented in Figure 3.21 d. Cladocerans followed a rather regular trend throughout the sampling period, with high values from late spring to end of autumn. At station 1, a broad distribution pattern was observed from April to August 2005. At station 2, highest value was observed in August 2005. On annual average, they constituted around 2.9 % of the total zooplankton at station 1 (Table 3.1), however only 0.6 % at station 2 (Table 3.2).

Ostracods abundance value varied from 0 to 59 ind $m^{-3}$and from 0.3 to 21 ind m^{-3}at stations 1 and 2, respectively (Figure 3.21 e). The bulk of the ostracods occurred during the winter months. Two peaks were observed in December 2004 and 2005 at station 1. At station 2, in spite of oscillations in abundance throughout the year, high values were observed during winter months (Figure 3.21 e). Their contributions to the total zooplankton abundance were very low, contributed only 0.2 % and 1 % to the total zooplankton at stations 1 and 2, respectively (Table 3.1 and Table 3.2).

The seasonal distribution of **Chaetognaths** is given in Figure 3.21 f. Even though they were observed throughout the year at both stations, their maximum values were in March, November 2005 and December 2005. They also showed remarkable existence all over the summer period. The most pronounced contribution to the overall zooplankton was 0.5 % in December 2005 at station 1 (Table 3.1), while only 0.8 % in July 2005 at station 2 (Table 3.2).

Other holoplanktonic groups contributed less than 1 % to the total zooplankton (Table 3.1 and Table 3.2). The distributional pattern of **Protozoa** displayed the same trend at both stations. Protozoa population reached remarkably high values in spring (546 ind m^{-3}, at station 1; 38 ind m^{-3}, at station 2) and in autumn (46 ind m^{-3}, at station 1; 20 ind m^{-3}, at station 2). Its estimated average contribution to the total zooplankton at both stations was lower than 1 % (Table 3.1 and Table 3.2). **Siphonophora** reached the highest values in November 2005 at both stations (31 ind/m^3, at station 1; 19 ind/m^3, at station 2) with fluctuations throughout of the year. Average contribution to total zooplankton was higher at station 2 than station 1. **Jelly organisms** showed the highest abundance values in winter (57 ind m^{-3}) at station 1, while in autumn (5 ind/m^3) at station 2. Moderate peaks were observed during other seasons at both stations. Maximum abundance values of **Polychaeta** were observed in March (155 ind/m^3) and February 2005 (10 ind m^{-3}) at stations 1 and 2, respectively. Abundance values at both stations were below 30 ind m^{-3}at station 1 and 3 ind m^{-3} at station 2, in the rest of the year. Maximum **Doliolid** population was observed during autumn periods at both stations (42 ind/m^3, at station 1; 15 ind m^{-3}, at station 2). They slightly fluctuated in the remaining part of the year. **Salp** population did not exceed 0.7 and 1.3 ind m^{-3}at stations 1 and 2, respectively, throughout the year they did not show any important annual variation. **Pteropoda** contain Theocosomata and Gymnosomata. They showed their

maximum values in spring and autumn at both stations. **Decapoda** were observed only in February 2005 (0.7 ind m^{-3}) at station 1. At station 2, they were observed in February, March, October, November and December 2005 with its maximum values in February (0.8 ind m^{-3}) and November 2005 (0.8 ind m^{-3}). **Euphasidae** were observed from November 2004 to February 2005 and in September 2005 at station 1. They made a peak in February 2005 (1.9 ind m^{-3}) and remained below 0.5 ind m^{-3} in the rest of the sampling period at station 2. **Mysidacea** were found only in February 2005 at station 1 and in August 2005 at station 2. **Amphipoda** were found only in December 2004 at station 1. At station 2, maximum value was recorded in July 2005 (1.7 ind m^{-3}). **Cumacea** was observed only in February 2005 at station 2 and was not found at station 1. **Isopoda** was observed only in December 2004 and May 2005 at station 1 and in February 2005 at station 2.

Among meroplankton, the highest number of individuals was represented by polychaeta larva (3.7 %), which was followed by bivalvia larvae (1.9 %) and echinodermata larvae (1.8 %), while gastrapoda larvae formed only 1.6 % of the total zooplankton groups at station 1 (Table 3.1). Other five groups constituted less than 1 % of the total zooplankton within the year. At station 2, except gastropoda larvae (1.4 %), other groups constituted less than 1 % of the total zooplankton (Table 3.2).

Polychaeta larvae showed two peaks in March (1204 ind m^{-3}) and July 2005 (1475 ind m^{-3}) at station 1 (Figure 3.22 a). At station 2, polychaeta larvae fluctuated during the sampling period and reached its maximum in January 2006 (11.2 ind m^{-3}). They contributed 24.6 % and 29.6 % to the annual total meroplankton at stations 1 and 2, respectively.

Gastropoda larvae varied between 1.3 and 544 ind m^{-3} and between 0.1 and 44.6 ind m^{-3} at stations 1 and 2, respectively (Figure 3.22 b).They exhibited highest value in March 2005 and then, showed a decreasing trend at station 1. At station 2, the highest abundance was observed in February 2005. Low number of individuals was observed in summer and autumn. They contributed 26.1 % to the annual total meroplankton at stations 1. Gastropoda larvae constituted the majority of the meroplanktonic groups at station 2, with 51.5 %.

Bivalvia larvae were abundant in April 2005 at station 1 and in February and August 2005 at station 2 (Figure 3.22 c). They contributed 23.5 % and 6.1 % to the annual total meroplankton at stations 1 and 2.

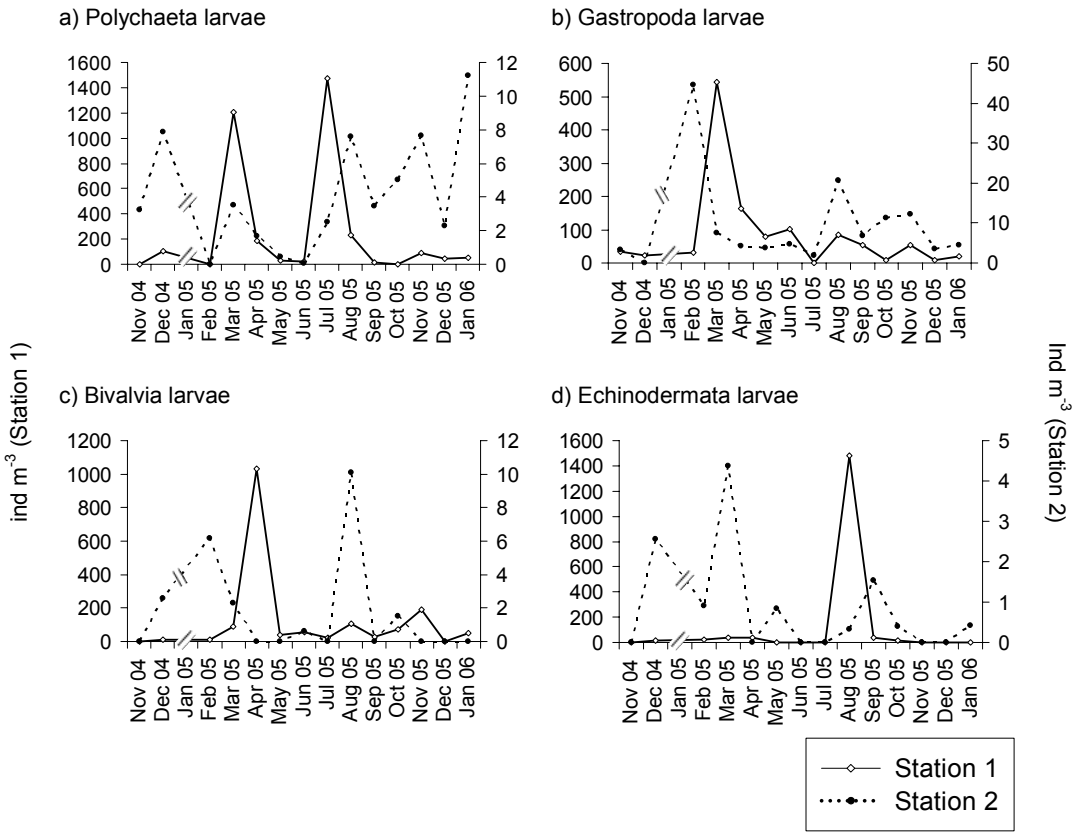

Figure 3.22 Temporal variations of major meroplanktonic groups in the water column at both stations. a) Polychaeta larvae, b) Gastropoda larvae, c) Bivalvia larvae and d) Echinodermata larvae

Highest abundance value of **Echinodermata larvae** was recorded in August 2005 with the value of 1481 ind m^{-3} at station 1 (Figure 3.22 d). In the remaining part of the sampling period, abundance was below 40 ind m^{-3}. At station 2, the high values were observed in December 2004 and March 2005, with small increases in May and September 2005. The contribution of them to the annual total meroplankton was 11.5 and 5.5 % at stations 1 and 2, respectively.

Cirripedia larvae were observed only in March, July and December 2005 at station 2. On annual average, they formed only 1.1 % of the meroplankton. At station 1, maximum value was observed in December 2005 (258 ind m^{-3}), with small increases in December 2004 and August 2005. Their contribution to the total meroplankton

was important in December 2004 and 2005, with 47.6 % and 83.6 %, respectively. **Stamopoda larvae** showed two maximum in autumn months (September and October 2005) at station 1. They were observed only in July 2005 at station 2. Their contribution was less than 0.3 % to the total meroplankton at both stations. **Decapoda larvae** exhibited the highest value in October 2005 at both stations. Their contribution was 1.6 and 5.6 % to the annual total meroplankton at stations 1 and 2, respectively. **Phoronida larvae** were observed only in April 2005 at station 1. On the other hand, it was not observed at station 2. The highest abundance of **Fish eggs and larvae** was observed in June (18.4 ind m^{-3}) at station 1. At station 2, the high values were in December 2005 (0.21 ind m^{-3}) and January 2006 (0.4 ind m^{-3}).

3.3.3. Zooplankton biomass in the water column

Total zooplankton biomass at station 1 was always much higher than at station 2 (Figure 3.23 and Figure 3.24). The dry weight values at station 1 ranged between 5.3- 68.2 mg m^{-3}, being highest in June 2005 and the minimum in September 2005. The bulk of the biomass was in spring and summer season (Figure 3.23) and a considerable amount of biomass was observed in October. The dry weight of organisms in >1000 µm size fraction varied between 0.4 mg m^{-3} (in September 2005) - 29.5 mg m^{-3} (in June 2006). Two peaks were observed; major in June 2005 and minor in October 2005, which were also the dominant periods for the >1000 µm size fraction among other size fractions. Other three size fractions (500-1000, 200-500 and 112-200 µm) showed similar trend throughout the year with high values in spring and summer (Figure 3.23). 500-1000 µm size fraction ranged between 1 mg m^{-3} (in September 2005) and 13.6 mg m^{-3} (in April 2005). 200-500 µm size fraction varied between 1.5 mg m^{-3} (in September 2005) and 28.6 mg m^{-3} (in April 2005), and 112-200 µm size group ranged from 0.9 mg m^{-3} (in November 2004) to 11.2 mg m^{-3} (in March 2005). 200-500 µm size fraction was dominant through March to July. 112-200 µm size fraction was dominant through March to July as well. Highest contribution to the total dry weight was that of 200-500 µm size fraction with 34 %. Other size fractions contributed more or less same with 22 % (>1000 µm), 21 % (500-1000 µm) and 24 % (112-200 µm).

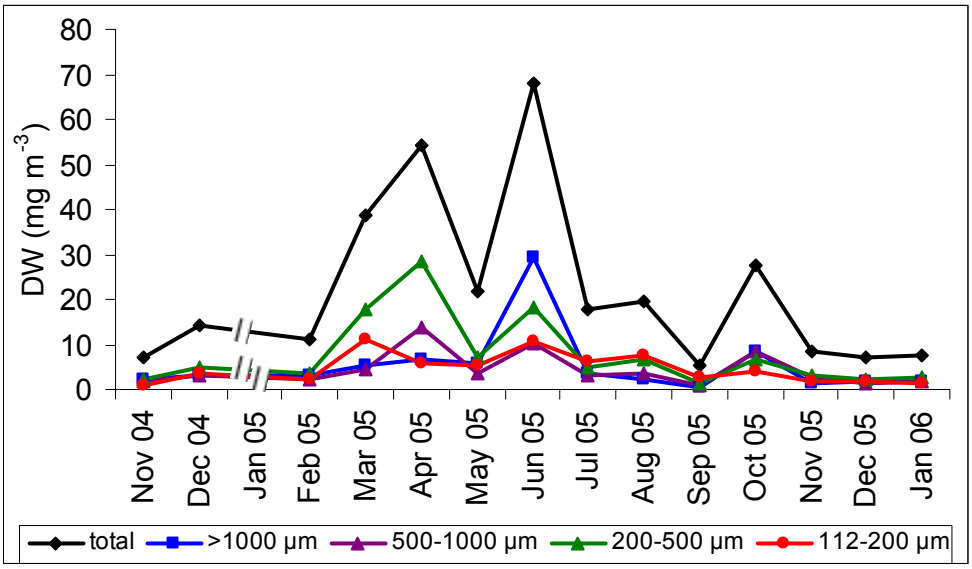

Figure 3.23. Temporal variations of total and size fractionated zooplankton dry weight in the water column at station 1.

At station 2, total dry weight values varied between 1.4 (both in December 04 and May 2005) and 4.6 mg m^{-3} (in November 2005) (Figure 3.24). Two main peaks were observed in July and November 2005, followed by a broad increase in spring. The dry weight of >1000 µm size fraction varied between 0.3 mg m^{-3} (in December 2004) - 1.8 mg m^{-3} (in November 2005). It displayed almost same distribution pattern as total zooplankton dry weight. This group was dominant throughout the year, except in December 2004, February 2005 and in September 2005 (Figure 3.24). Contribution of >1000 µm size fraction to the total zooplankton dry weight was highest than other size fractions with 36 %. The dry weight of the organisms in 500-1000 µm size fraction ranged between 0.2 mg m^{-3} (in May 2005) and 1.2 mg m^{-3} (in November 2005). 500-1000 µm size fraction fluctuated within the year with the maximum value in November 2005 and was the dominant size fraction among others in September 2005. This size fraction contributed 21 % to the total zooplankton dry weight. 200–500 µm size fraction varied between 0.4 mg m^{-3} (in December 05 and May 2005) and 1.4 mg m^{-3} (in July 2005). Their biomass was higher in July and November 2005. Average contribution of 200-500 µm size fraction was 29 % to the total zooplankton dry weight, and they are the second dominant size group. 112-200 µm size fraction ranged from 0.2 mg m^{-3} (in most of the periods) to 0.8 mg m^{-3} (in July 2005). Average contribution of this size fraction was the lowest with only 14 %.

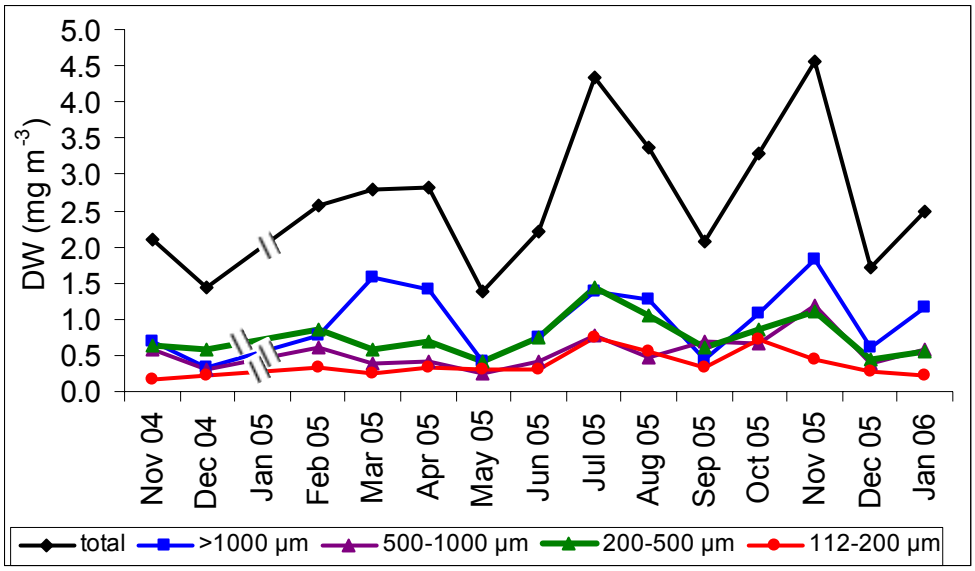

Figure 3.24. Temporal variations of total and size fractionated zooplankton dry weight in the water column at stations 2.

Ash-free dry weight (organic content) of the total zooplankton group varied between 4.1 mg m^{-3} (in September 2005) and 35 mg m^{-3} (in April 2005) at station 1 (Figure 3.25), and between 0.9 mg m^{-3} (in December 2004) and 3.3 mg m^{-3} (in November 2005) at station 2 (Figure 3.26). At station 1, the contribution of 200-500 µm size fraction to total zooplankton organic content was highest among other size fractions, especially in April. At station 2, high contribution of organic weight to the total dry weight came from >1000 and 200-500 µm siz fractions. On the annual average, organic content of the total zooplankton constituted 64 and 63 % of the total zooplankton dry weight at stations 1 and 2, respectively.

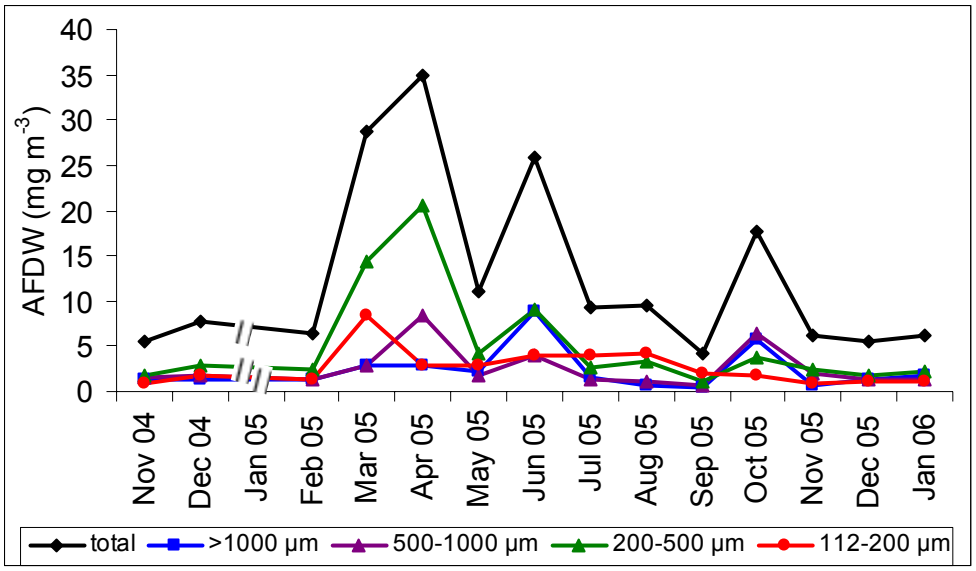

Figure 3.25. Temporal variations of zooplankton ash-free dry weight (AFDW) in the water column at station 1.

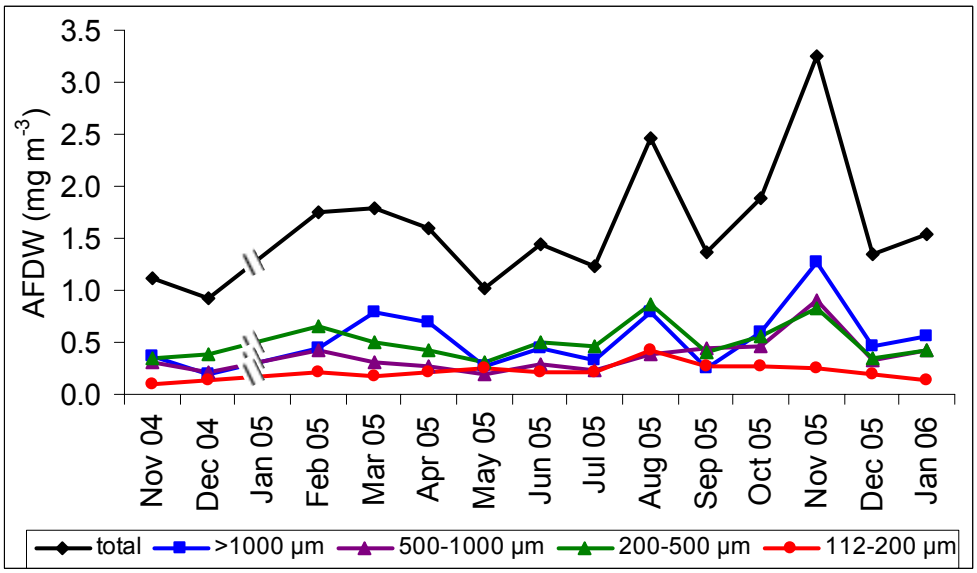

Figure 3.26. Temporal variations of zooplankton ash-free dry weight (AFDW) in the water column at station 2.

3.4. Zooplankton composition and biomass in the surface water

In this session, the results of the total and size fractionated zooplankton composition, biomass, and annual variations of holoplankton and meroplankton from the surface waters at the two stations studied will be presented.

3.4.1. Zooplankton composition in the surface water

Zooplankton abundance in the surface waters was almost three times higher at station 1 than at station 2 (Figure 3.27 and Figure 3.28). Total zooplankton abundance varied from 356 to 8904 ind m^{-3}, being lowest in September 2005 and highest in March 2005 at station 1 (Figure 3.27). Two peaks were observed; in March and November 2005. A small increase was observed in July 2005. >1000 µm size fraction varied between 1.46 ind m^{-3} (in September 2005) and 549 ind m^{-3} (in April 2005). Their highest values were observed in April and October 2005. The abundance of 500-1000 µm size fraction ranged from 4.06 ind m^{-3} (in September 2005) to 424 ind m^{-3} (in November 2005). Both >1000 and 500-1000 µm size fractions contributed 6 % to the total zooplankton abundance by forming the lowest contributions. 200–500 µm size fraction varied between 60.5 ind m^{-3} (in September 2005) and 6342 ind m^{-3} (in November 2005). Next highest value was observed in March 2005 (6044 ind m^{-3}) and a slight increase in July 2005 (Figure 3.27). 200-500 µm size fraction was the dominant fraction among others at station 1 by constituting 57 % of the total zooplankton abundance. It was dominant during almost all of the year except in July and September, when the 112-200 µm size fraction showed dominancy. 112-200 µm size fraction ranged between 54.6 ind m^{-3} (in April 2005) and 2339 ind m^{-3} (in March 2005). This fraction constituted 32 % of the total zooplankton abundance.

At station 2, zooplankton abundance varied from 12 to 3678 ind m^{-3} in June and November 2005, respectively (Figure 3.28). At station 2, the primary peak of zooplankton abundance was observed in autumn period (October-November), with secondary peak in spring and small increases in summer months. Maximum values of >1000, 500-1000 and 200-500 µm size fractions were in November 2005 with the values of 489, 788 and 2156 ind m^{-3}, respectively. 112-200 µm size fraction varied between 9.16 ind m^{-3} (in June) and 338 ind m^{-3} (in March 2005). The smallest two

size fractions (200-500 and 112-200 µm) together contributed >80 % to the total zooplankton abundance at this station.

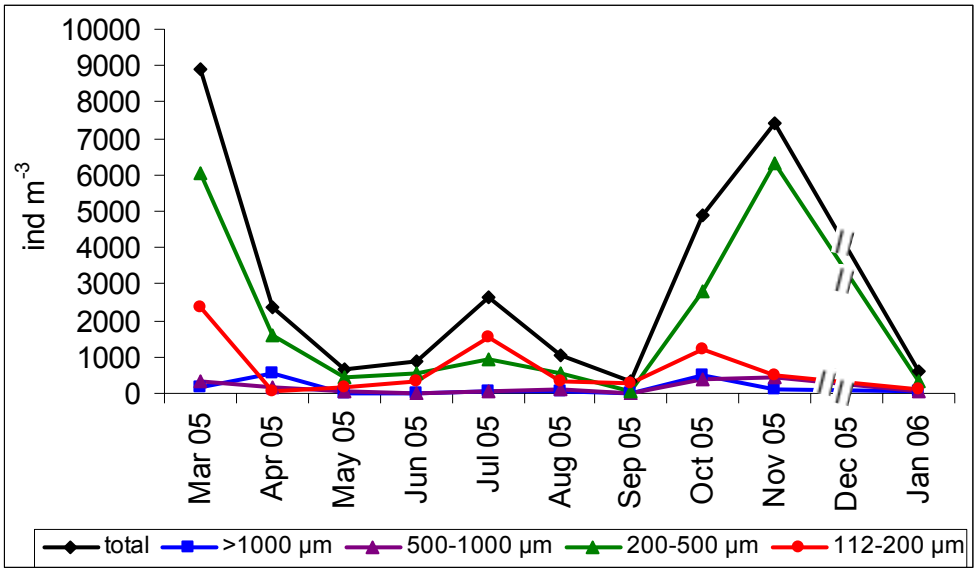

Figure 3.27. Temporal variations of total and size fractionated zooplankton in the surface water at station 1.

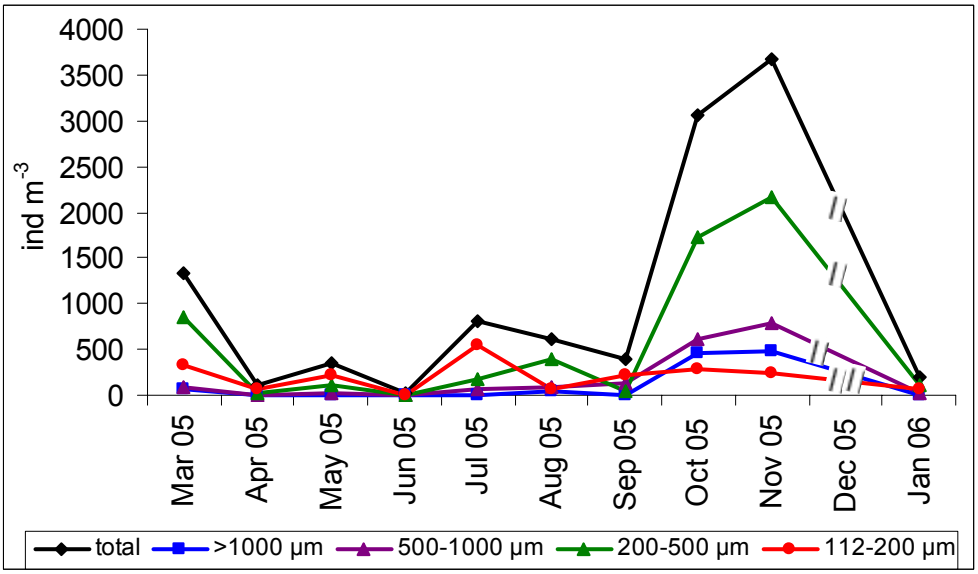

Figure 3.28. Temporal variations of total and size fractionated zooplankton in the surface water at station 2.

Temporal variations in size fractionated zooplankton group composition in percentages in the surface waters at stations 1 and 2 are given in Figure 3.29 and Figure 3.30, respectively. During the sampling period, the main zooplankton

taxonomic groups were protozoa, siphonophora, cladocera, ostracoda, copepoda, chaetognatha, doliolida, appendicularia, crustacean nauplii, polychaeta larvae, gastropoda larvae, bivalvia larvae and pteropoda.

In surface water, copepods constituted the majority of the total zooplankton in all size fractions at both stations (Figure 3.29 and Figure 3.30). Crustacea nauplii were the second dominant group, especially in smaller size fractions (112-200 and 200-500 μm) at both stations. Cladocera was abundant in 200-500 μm and 500-1000 μm size fractions during spring and summer periods at both stations. They suprisingly exceeded the number of copepods in July at 200-500 and 500-1000 μm size fractions at station 2. Siphonophora were observed much higher at station 2 than station 1, especially in larger size fractions during most of the year. Chaetognaths were confined to 500-1000 and >1000 μm size fractions, contribution was much higher at station 2. Contribution of appendicularia was higher in 500-1000 μm size fraction at both stations. Contribution of bivalvia larvae was much higher in 112-200 μm size fraction at station 1. Pteropoda contribution to total zooplankton abundance was higher at station 2 than station 1, especially in two small size fractions at station 2.

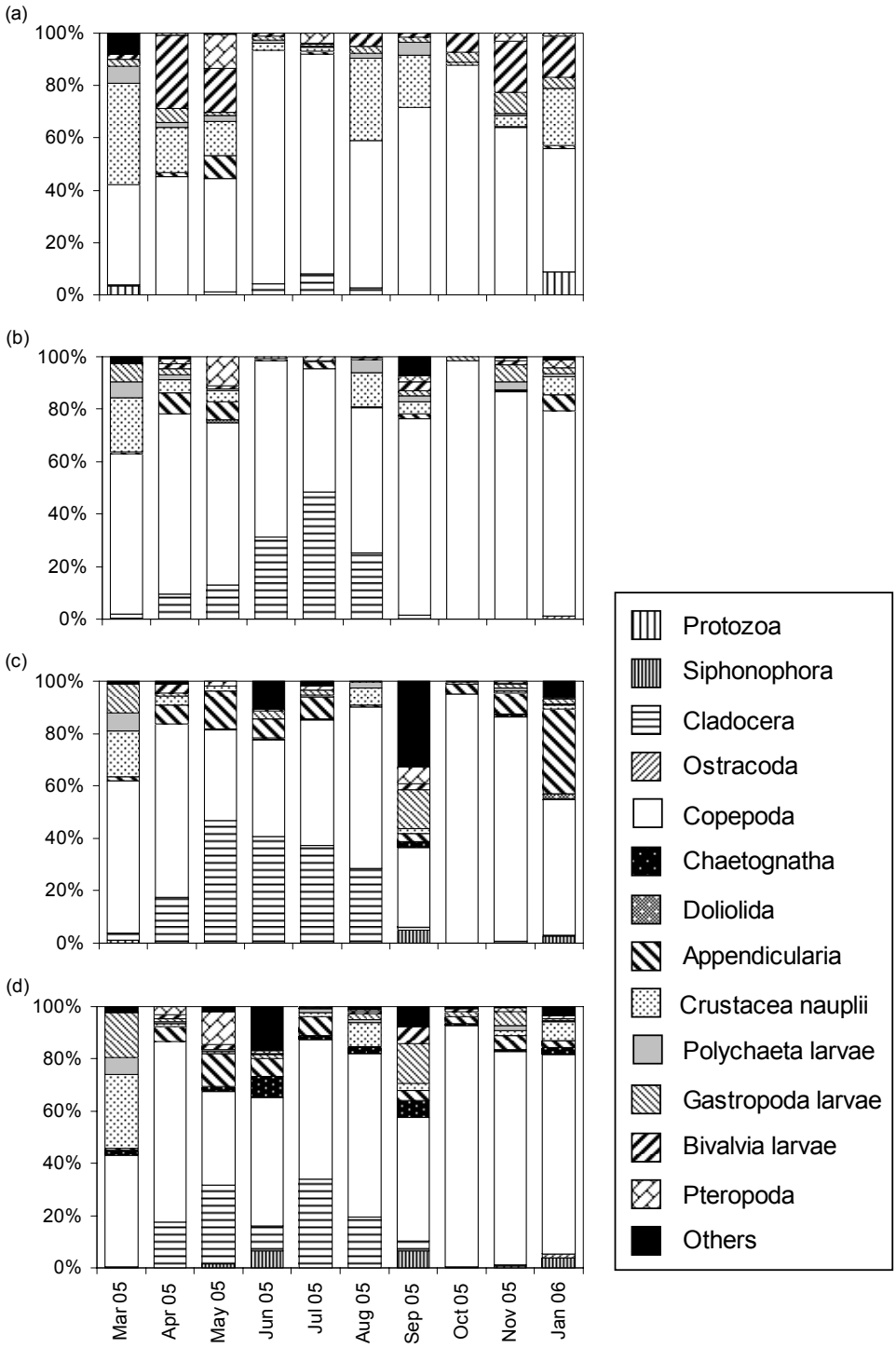

Figure 3.29. Temporal variations in size fractionated zooplankton composition in the surface water at stations 1, a) 112-200 µm, b) 200-500 µm, c) 500-1000 µm and d) >1000 µm. (Others: Jelly organisms, Pteropoda, Cumacea, Isopoda, Amphipoda, Mysidacea, Euphasidacea, Decapoda, Salpida, cirripedia larvae, Stamopoda larvae, Decapoda larvae, Phoronida larvae, Fish eggs and larvae, and unidentified organisms)

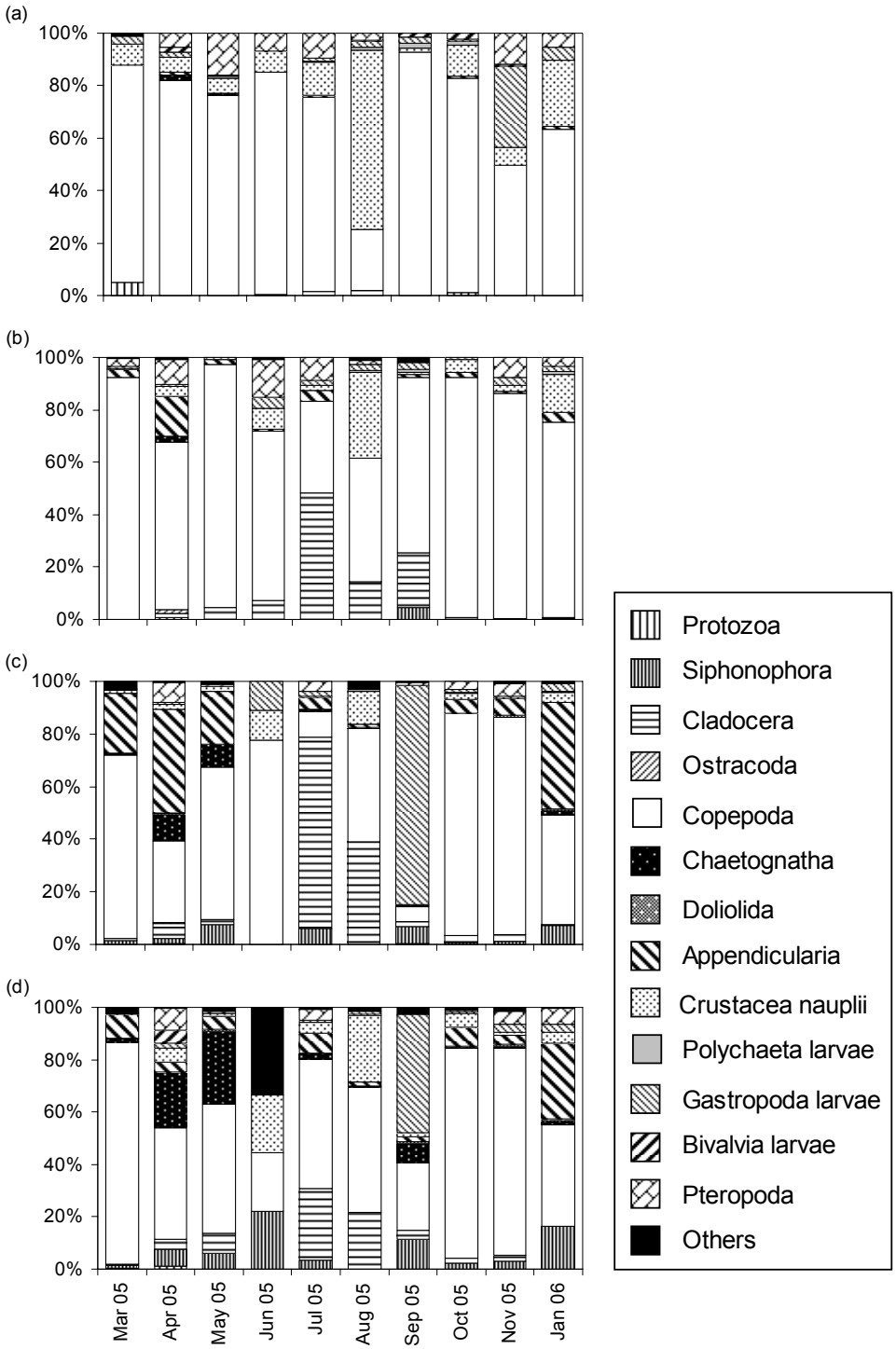

Figure 3.30. Temporal variations in size fractionated zooplankton composition in the surface water at stations 2, a) 112-200 µm, b) 200-500 µm, c) 500-1000 µm and d) >1000 µm. (Others: Jelly organisms, Pteropoda, Cumacea, Isopoda, Amphipoda, Mysidacea, Euphasidacea, Decapoda, Salpida, cirripedia larvae, Stamopoda larvae, Decapoda larvae, Phoronida larvae, Fish eggs and larvae, and unidentified organisms).

3.4.2. Annual variations of zooplankton groups in the surface water

Annual variations of holoplankton and meroplankton at stations 1 and 2 are shown in Figure 3.31 and Figure 3.32. Similar to the water column zooplankton, surface holoplanktonic groups dominated the meroplanktonic groups at both stations throughout the study period. At station 1, holoplankton and meroplankton groups showed two peaks during spring and autumn. At station 2, holoplankton reached the highest values in autumn. The high abundance of meroplankton was observed in September and November 2005. Holoplankton comprised 93 % and 95 % of the total zooplankton at stations 1 and 2, respectively. Meroplankton comprised only 7 % and 5 % of the total zooplankton at stations 1 and 2, respectively.

Copepoda, crustacea nauplii and cladocera were the dominant groups among the holoplankton groups throughout the year at both stations (Table 3.3, Table 3.4). Copepoda made up around 70 % and 72 % of the total zooplankton at stations 1 and 2, respectively. Crustacea nauplii made up around 8 % of the total zooplankton at both stations 1 and 2. Cladocera constituted 8.7 % and 4.6 % of the total zooplankton at stations 1 and 2, respectively. Pteropoda had considerable contribution to the total zooplankton, with 2 % at station 1 and 4.8 % at station 2.

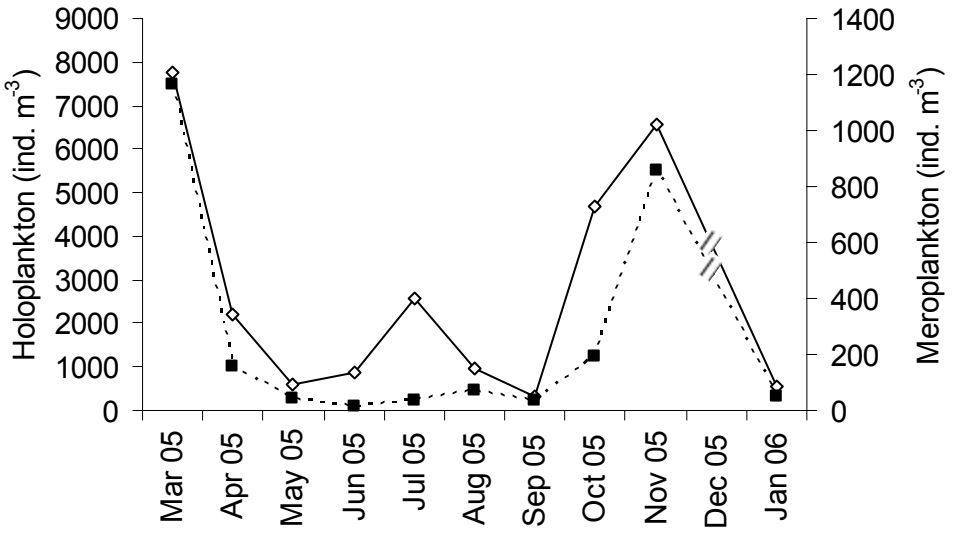

Figure 3.31. Temporal variations of holoplankton (solid line) and meroplankton (dashed line) in the surface waters at station 1.

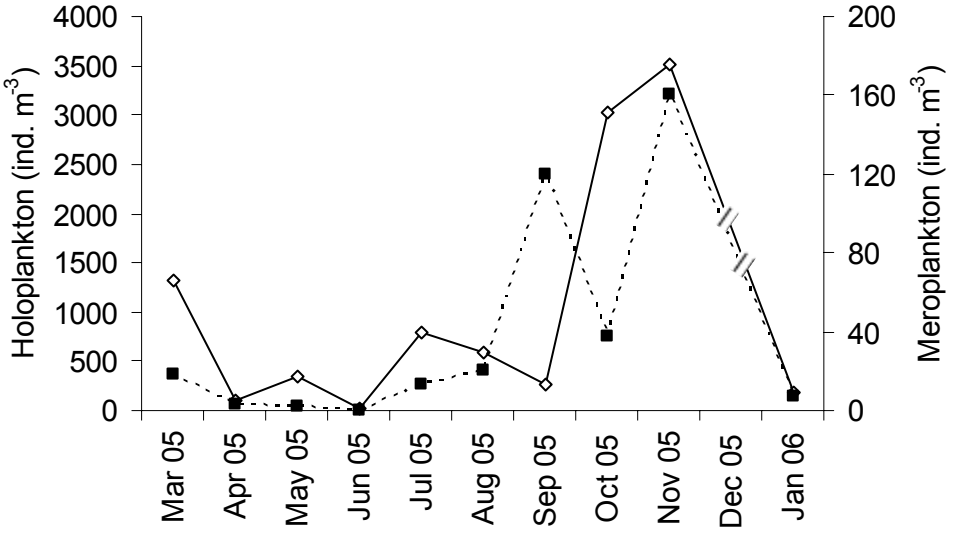

Figure 3.32. Temporal variations of holoplankton (solid line) and meroplankton (dashed line) in the surface waters at station 2.

Copepoda ranged between 254 and 6296 ind m^{-3}, recorded in September 2005 and November 2005, respectively at station 1 (Figure 3.33 a). At station 2, copepod abundance varied from 9.5 to 3008 ind m^{-3}, in June and November 2005, respectively. Two peaks were observed in March and November 2005 at both stations. They showed a small increase in July 2005. Similar to the water column copepoda, maximum copepod abundance was observed during autumn at both stations.

Crustacea nauplii were the other dominant group in the total zooplankton and their abundance varied from 13 (in June 2005) to 2255 ind m^{-3} (in March 2005) at station 1 and varied from 1 (in June 2005) to 201 ind m^{-3} (in August 2005) at station 2 (Figure 3.33 b). They showed maximum abundance in March 2005 at station 1. At station 2, maximum crustacea nauplii values were in August and in October 2005. They contributed 8.4 % (Table 3.3) and 8.7 % (Table 3.4) to the total zooplankton at stations 1 and 2, respectively.

Table 3.3. Percent composition of major zooplanktonic groups in the surface waters at station 1.

Major taxonomic groups	Mar 05	Apr 05	May 05	Jun 05	Jul 05	Aug 05	Sep 05	Oct 05	Nov 05	Jan 06	Average
Holoplankton											
Protozoa	1.279	0	0	0	0	0	0	0.024	0.010	1.952	0.327
Jelly organisms	0	0	0.140	0	0	0	0.011	0.001	0.339	0.049	0.054
Siphonophora	0.000	0.001	0.013	0.023	0	0	0.084	0.003	0.004	0.634	0.076
Polychaeta	0	0	0	0	0	0	0	0.000	0	0.067	0.007
Pteropoda	0	1.928	11.135	0.010	2.776	0.220	0.410	0.049	1.276	2.196	2.000
Cladocera	1.095	11.694	11.568	20.882	23.755	18.461	0.279	0.024	0.047	0.006	8.781
Ostracoda	0.001	0	0	0	0	0	0	0	0	0.781	0.078
Copepoda	54.724	68.202	55.023	75.443	69.219	56.704	71.475	94.828	85.047	68.133	69.880
Cumacea	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	0	0	0	0	0	0	0	0	0	0.195	0.020
Mysidacea	0	0	0	0	0	0	0	0	0	0	0
Euphausiacea	0	0.001	0	0	0	0	0.084	0.000	0	0.015	0.010
Decapoda	0	0	0	0	0	0.024	0	0	0	0.012	0.004
Chaetognatha	0.029	0	0.018	0.034	0.040	0.122	0.053	0.076	0.052	0.293	0.072
Doliolida	0.005	0	0.595	0	0	0	0	0.013	0.021	0.201	0.083
Salpida	0.000	0	0	0	0	0	0	0.002	0.001	0.049	0.005
Appendicularia	0.736	7.091	7.915	0.511	2.109	0.318	0.389	0.759	0.932	7.760	2.852
Crustacea nauplii	25.320	4.448	6.554	1.444	0.855	17.679	17.281	0.294	0.719	9.712	8.431
Unidentified organisms	3.734	0.074	0	0	0	0	0	0	0	0.006	0.381
Meroplankton											
Polychaeta larvae	6.165	1.370	1.264	0.413	0.428	3.448	4.460	0.003	2.474	0.683	2.071
Gastrapoda larvae	6.069	1.963	0.280	0.656	0.410	0.954	1.914	2.007	6.391	2.587	2.323
Bivalvia larvae	0.823	2.637	5.478	0.414	0.365	2.005	1.988	1.884	2.688	3.465	2.175
Cirripedia larvae	0.000	0	0	0	0	0	1.036	0	0	1.025	0.206
Stamopoda larvae	0	0	0	0	0	0	0.011	0.024	0	0	0.003
Decapoda larvae	0.000	0.001	0.013	0.003	0.012	0.032	0.379	0.007	0.000	0.006	0.045
Echinodermata larvae	0.019	0.588	0	0	0	0	0	0	0	0	0.061
Phoronida larvae	0	0	0	0	0	0	0	0	0	0	0
Fish eggs and larvae	0.000	0.003	0.004	0.168	0.030	0.032	0.147	0.001	0	0.171	0.056
Total (ind m^{-3})	**8904**	**2345**	**642**	**871**	**2627**	**1050**	**356**	**4895**	**7403**	**614**	

Table 3.4. Percent composition of major zooplanktonic groups in the surface waters at station 2.

Major taxonomic groups	Mar 05	Apr 05	May 05	Jun 05	Jul 05	Aug 05	Sep 05	Oct 05	Nov 05	Jan 06	Average
Holoplankton											
Protozoa	1.321	0.275	0	0	0	0	0.098	0.088	0	0.235	0.202
Jelly organisms	0.347	0	0.048	0	0	0.296	0.115	0	0.147	0	0.095
Siphonophora	0.161	0.288	0.370	0.189	0.527	0	2.806	0.470	0.651	1.063	0.652
Polychaeta	0.297	0.236	0	0.189	0.001	0	0	0	0	0	0.072
Pteropoda	1.832	6.511	9.885	8.302	8.875	1.243	0.328	0.647	6.905	3.840	4.837
Cladocera	0.046	0.838	1.691	1.698	18.442	17.457	3.544	1.176	1.107	0	4.600
Ostracoda	0.006	0.445	0	0	0	0	0	0	0	0.029	0.048
Copepoda	88.099	73.182	80.889	79.906	59.566	43.716	60.965	87.606	81.791	67.343	72.306
Cumacea	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0.001	0	0	0	0	0	0.008	0	0	0	0.001
Amphipoda	0.038	0	0	0	0	0	0	0.001	0.130	0	0.017
Mysidacea	0	0	0	0	0	0	0	0	0	0	0
Euphausiacea	0	0	0	0	0	0	0	0.001	0	0	0.000
Decapoda	0	0	0	0	0	0	0	0	0	0	0
Chaetognatha	0.103	3.066	0.937	0	0.087	0.104	0.139	0.059	0.147	0.139	0.478
Doliolida	0.013	0.026	0.005	0	0	0.004	0.008	0.077	0.195	0.073	0.040
Salpida	0.042	0.013	0.005	0	0	0	0	0.118	0.065	0.007	0.025
Appendicularia	3.886	7.035	1.475	0.189	1.779	0.266	0.246	3.262	2.410	6.347	2.690
Crustacea nauplii	2.419	5.109	4.083	8.208	9.116	33.094	1.001	5.260	2.085	17.237	8.761
Unidentified organisms	0	0	0	0.283	0.006	0.518	0.197	0.001	0	0	0.100
Meroplankton											
Polychaeta larvae	0	0	0.307	0	0.359	0.740	1.181	0.235	0.001	0.528	0.335
Gastrapoda larvae	1.336	1.559	0.307	1.038	1.241	2.086	28.411	0.793	4.267	3.093	4.413
Bivalvia larvae	0.002	1.415	0	0	0	0.074	0.886	0.206	0.065	0	0.265
Cirripedia larvae	0	0	0	0	0	0	0	0	0	0	0
Stamopoda larvae	0	0	0	0	0	0	0	0	0	0	0
Decapoda larvae	0.006	0	0	0	0	0.015	0	0.001	0.016	0.059	0.010
Echinodermata larvae	0.004	0	0	0	0	0	0.033	0	0	0	0.004
Phoronida larvae	0	0	0	0	0	0	0	0	0	0	0
Fish eggs and larvae	0.042	0	0	0	0	0.388	0.033	0	0.017	0.007	0.049
Total (ind m^{-3})	**1331**	**103**	**351**	**12**	**801**	**607**	**391**	**3057**	**3678**	**192**	

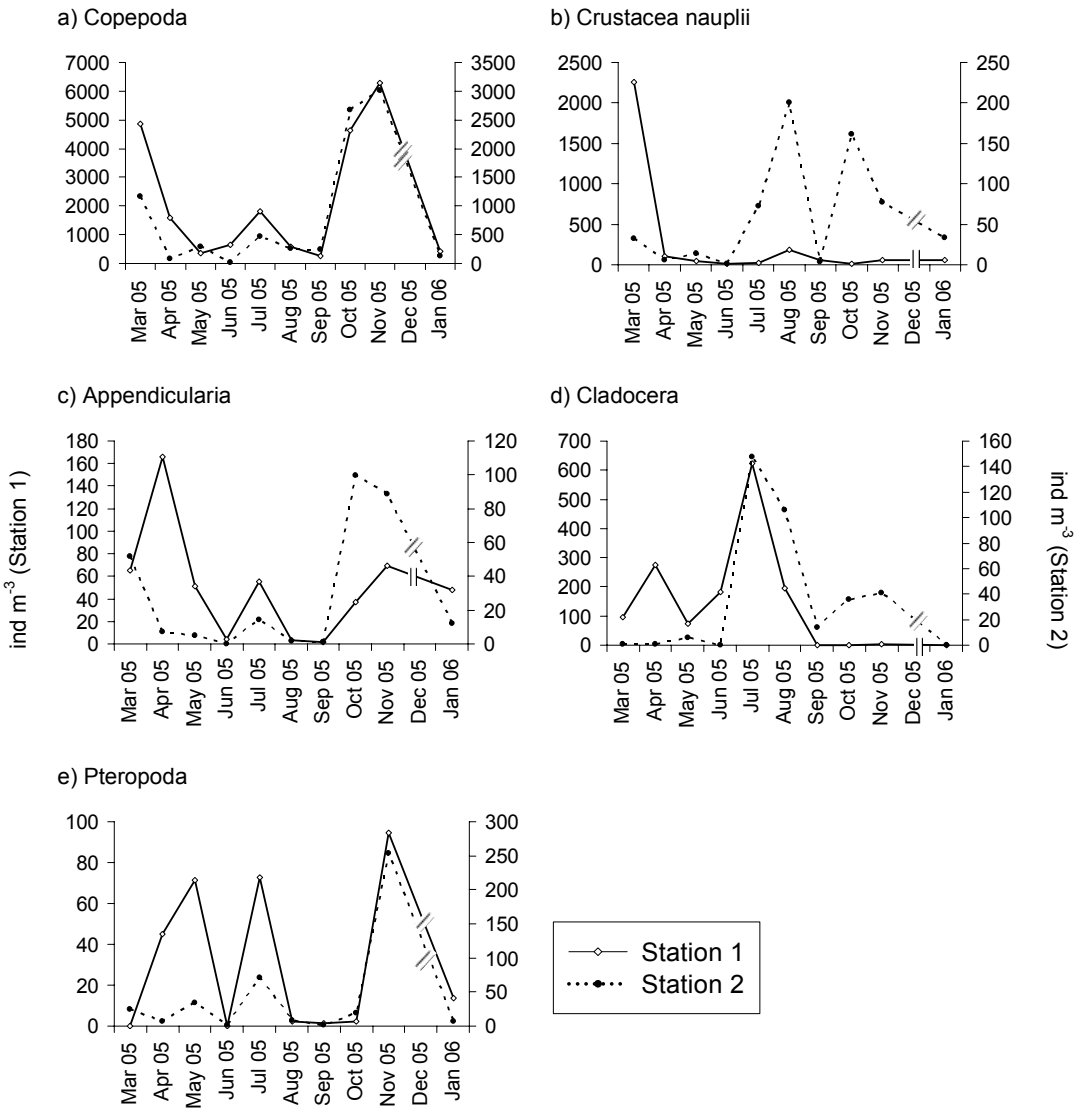

Figure 3.33. Temporal variations of major holoplanktonic groups in the surface waters at both stations. a) Copepoda, b) Crustacea nauplii, c) Appendicularia, d) Cladocera and e) Pteropoda

Appendicularia varied between 1.4 and 166 ind m^{-3}at station 1 and between 0.02 and 98 ind m^{-3}at station 2 (Figure 3.33 c). They were abundant in spring and autumn periods at both stations. Similar to the water column appendicularia distributions, they were dominant in spring at station 1, while dominant in autumn at station 2. They contributed 2.8 % and 2.7 % to the total zooplankton at stations 1 (Table 3.3) and 2 (Table 3.4), respectively.

Cladocera varied between 0 (in January 2006) and 624 ind m^{-3} (in July 2005) at station 1 and 0 (in January 2006) and ind m^{-3} (in July 2005) at station 2 (Figure 3.33

d). Cladocera were observed mostly in summer at both stations. Similar to the water column Cladocera, their contribution to total zooplankton was higher at station 1 (8.7 %) (Table 3.3), but lower at station 2 (4.6 %) (Table 3.4). They were the third dominant group at station 1.

Pteropoda ranged between 0 (in March 2005) and 95 ind m^{-3} (in November) at station 1 and varied from 1 (in June) to 254 ind m^{-3} (in November) at station 2 (Figure 3.33 e). Spring, summer and autumn peaks were observed at station 1. Their peak was in November with increases in spring and summer. At station 2, main peak was in November, however peaks observed in spring and summer period is much smaller and are only indicative. Pteropoda contributed 2 % (Table 3.3) and 4.8 % (Table 3.4) to the total zooplankton at stations 1 and 2, respectively. They were the third dominant group at station 2.

Other holoplanktonic groups contributed less than 1 % to the total zooplankton, abundance. **Chaetognaths** were abundant in autumn at both stations. **Chaetognaths** and **jelly organisms** showed similar distribution trend with the copepods. **Siphonophora** were abundant in autumn and winter periods. **Polychaeta** were abundant in January 2006 and March 2005 at stations 1 and 2, respectively. **Doliolids** showed maximum values in spring and autumn. **Salps** were abundant during autumn. The high abundance of **Protozoa** was in March 2005 with the value of 114 ind m^{-3} at station 1 and 17.6 ind m^{-3} at station 2. **Decapoda** were observed only in August 2005 and January 2006 at station 1. They were not found in the surface waters of the station 2 during the study period. **Euphasidae** were observed only in October 2005 at station 2, while at station 1, they were identified in spring, autumn and winter. **Ostracoda** were found only in spring and winter at both stations. **Mysidacea** and **cumacea** were not observed in the surface waters of both stations.

Among meroplankton, highest number of individuals was represented by gastropoda larva which was followed by bivalvia larvae and polychaeta larvae (Table 3.3 and Table 3.4). On annual average, they contributed 2.3, 2.2 and 2.1 % to the total zooplankton, respectively, at station 1 and 4.4, 0.26 and 0.34 %, respectively, at station 2. The contribution of other groups to the total zooplankton was less than 0.1 %.

Gastropoda larvae varied between 6 and 540 ind m^{-3} at station 1 and between 0.1 and 157 ind m^{-3} at station 2 (Figure 3.34 b). Two maxima were observed at station 1, in March and November 2005. At station 2, the high values were recorded in September and November 2005. Gastropoda larvae constituted the majority of the meroplanktonic groups at both stations. On annual average, they contributed 32.6 % and 77.8 % to the total meroplankton at stations 1 and 2, respectively.

Polychaeta larvae varied between 0.13 and 549 ind m^{-3} at station 1 and between 0 and 7.2 ind m^{-3} at station 2 (Figure 3.34 a). They were abundant in spring and autumn at station 1, but they were observed in high numbers in summer and early autumn at station 2. Their contribution to the total meroplankton ranged between 0.1 % in October and 53.3 % in August 2005 at station 1. At station 2, their contribution varied between 0 to 50 % (May 2005) to the total meroplankton.

Bivalvia larvae abundance varied between 3.6 and 199 ind m^{-3} at station 1, and between 0 and 6.3 ind m^{-3} at station 2, respectively (Figure 3.34 c). They were abundant in autumn period at both stations. Some individuals were also observed during spring (~50 ind m^{-3}). On annual average, they contributed around 34.5 and 7 % to the total meroplankton at stations 1 and 2, respectively.

Other meroplanktonic groups contributed less than 0.1 % to the total zooplankton. **Cirripedia larvae** were observed only in September 2005 and January 2006 at station 1. **Stamopoda larvae** were observed only in September and October 2005 at station 1. Individuals from the last two larval groups were not observed at station 2 during the study period. **Decapoda larvae** were higher in summer and autumn periods at station 1 and in November at station 2. **Echinodermata larvae** were abundant in April 2005 at station 1 and in September 2005 at station 2. **Phoronida larvae** were not observed at both stations. The maximum value of **Fish eggs and larvae** was observed in June 2005 (1.46 ind m^{-3}) at station 1 and in August (2.36 ind m^{-3}) at station 2.

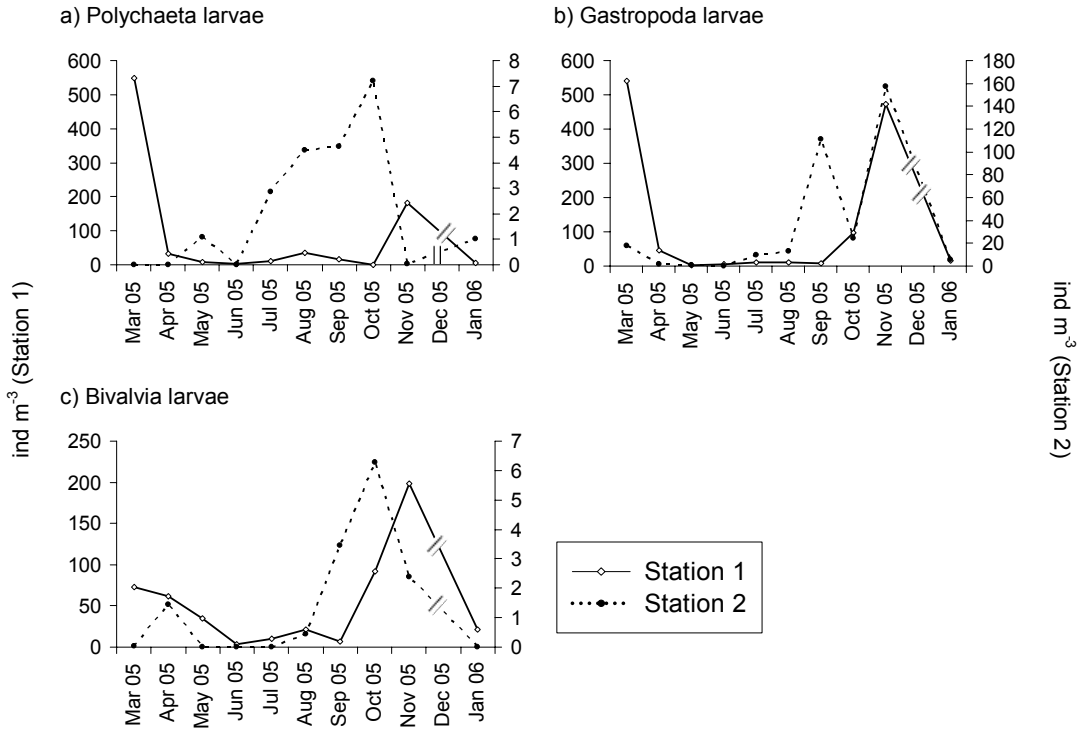

Figure 3.34. Temporal variations of major meroplanktonic groups in the surface water at both stations. a) Gastropoda larvae, b) Polychaeta larvae and c) Bivalvia larvae

3.4.3. Zooplankton biomass in the surface water

Dry weight of total zooplankton ranged between 0.9 mg m^{-3} (in September 2005) and 14.3 mg m^{-3} (in April 2005) at station 1 (Figure 3.35). >1000 µm size fraction varied between 0.05 mg m^{-3} (in September 2005) and 4.35 mg m^{-3} (in October 2005). Maximum values were observed in April and October 2005. 500-1000 µm size fraction varied from 0.39 mg m^{-3} (in January 2006) to 4.04 mg m^{-3} (in April 2005). Contribution of >1000 and 500-1000 µm size fractions was same, 20 %. 200–500 µm size fraction varied between 0.31 mg m^{-3} (in September 2005) and 5.78 mg m^{-3} (in March 2005). The contribution of 200-500 µm size fraction to the total zooplankton biomass was high during most of the year, contributing 41 % to the annual total zooplankton DW. Its annual trend was similar to the total zooplankton DW (Figure 3.35). 112-200 µm size group ranged between 0.27 mg m^{-3} (in January 2006) and 2.42 mg m^{-3} (in April 2005).

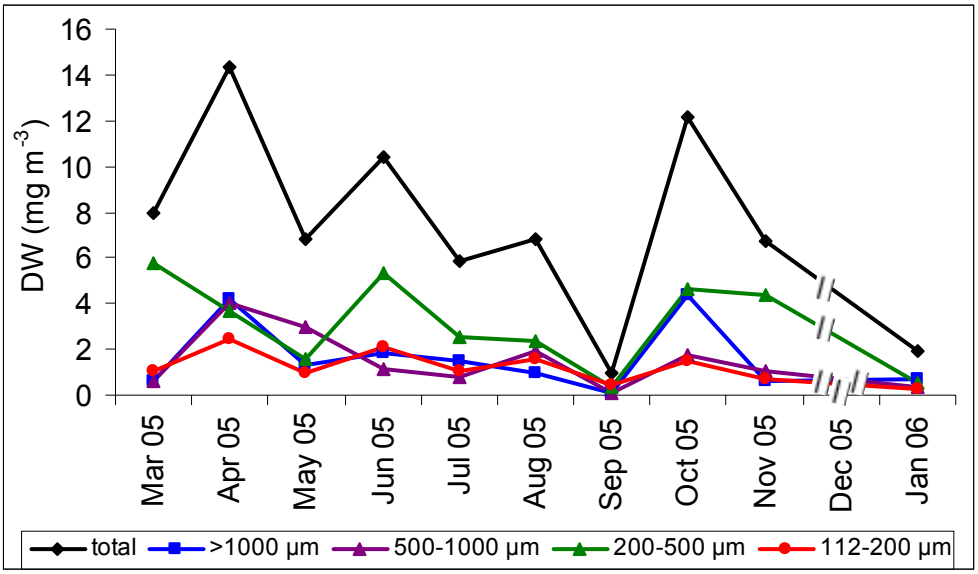

Figure 3.35. Temporal variations of total and size fractionated zooplankton dry weight in the surface water at station 1.

At station 2, dry weight of the total zooplankton varied between 0.3 mg m^{-3} (in June 2005) and 7.1 mg m^{-3} (in September 2005) shown in Figure 3.36. The dry weight of >1000, 500-1000, 200-500 and 112-200 µm size fractions varied between 0.07 mg m^{-3} (in June 2006) and 1.24 mg m^{-3} (in November 05), 0.06 mg m^{-3} (in June 2006) and 1.59 mg m^{-3} (in November 2005), 0.07 mg m^{-3} (in June 2006) and 1.93 mg m^{-3} (in November 2005) and between 0.06 mg m^{-3} (in June 2006) and 0.44 mg m^{-3} (in July 2005), respectively (Figure 3.36). All size fractions showed similar annual trend except 500-1000 µm size fraction which exhibited high value in September 2005. Contribution of >1000 and 200-500 µm size fraction were more or less same, 30 and 31 %, respectively. 112-200 µm size fraction contribution was lower with only 14 %.

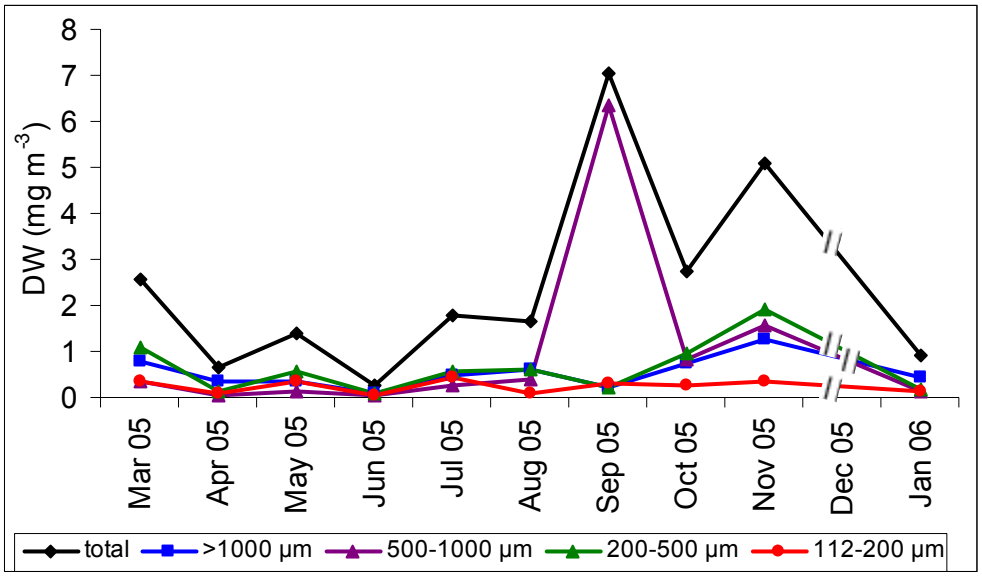

Figure 3.36. Temporal variations of total and size fractionated zooplankton dry weight in the surface water at station 2.

Ash-free dry weight of the total zooplankton varied between 0.6 mg m^{-3} (in September 2005) and 9.1 mg m^{-3} (in April 2005) at station 1 (Figure 3.37) and between 0.2 mg m^{-3} (in June 2005) and 4.2 mg m^{-3} (in November 2005) at station 2 (Figure 3.38), respectively. Ash-free dry weight constituted 70 % and 71 % of the total zooplankton dry weight at stations 1 and 2, respectively

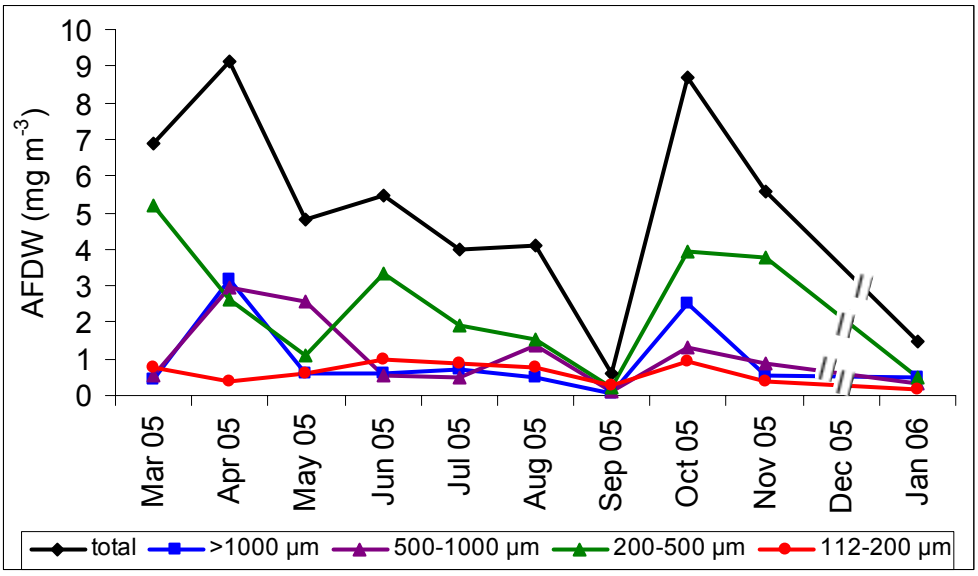

Figure 3.37. Temporal variations of zooplankton ash-free dry weight in the surface water at station 1.

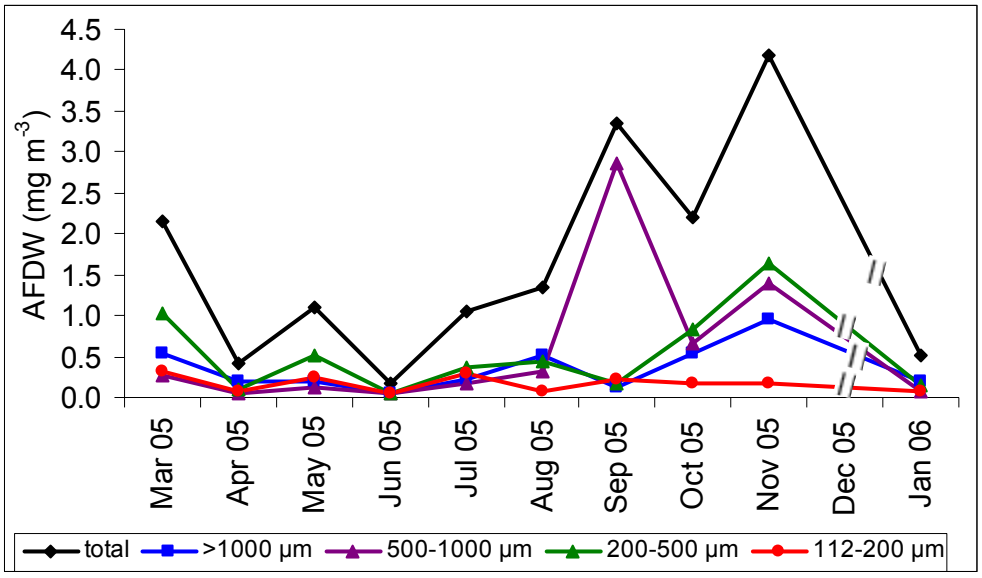

Figure 3.38. Temporal variations of zooplankton ash-free dry weight in the surface water at station 2.

3.5. Statistical analysis

Spearman rank correlation analysis was applied for examining the relationships between environmental parameters and zooplankton. Table 3.5 and Table 3.6 show the correlations between environmental parameters at stations 1 and 2, respectively.

During the study period, any of the seston parameters were not dependent on temperature, but pico-size fraction of lipid at station 1 (Table 3.5). Negative effects of salinity on almost all seston parameters were observed. However, significant negative relationships were found between salinity and all protein fractions, total, nano and micro lipid fractions, and total carbohydrate (Table 3.5). TSPM was not related to the protein content of seston. On the other hand, positive correlations were observed between nano, micro and total chl-a, nano and micro fractions of lipid and micro carbohydrate fraction. When all seston biochemical compounds data were polled, the correlation between TSPM and total biochemical compounds was weak and insignificant (r_s=0.47, P>0.05). Interestingly, insignificant weak correlation was also observed between SPOM and total seston biochemical compounds. TSPM and SPOM were dependent on total chl-a (r_s=0.78 and 0.68, respectively). Total protein and carbohydrates correlated with micro size fraction of chl-a.

At station 2, temperature showed strong negative correlation with total and pico fraction chl-a and positive correlation with nano fraction of carbohydrate (Table 3.6). However, no significant correlation was found with the salinity and TSPM. SPOM correlated only with seston lipid (total, pico and micro size fractions). Total chl-a showed strong negative correlation with nano fraction of carbohydrate.

Table 3.7 shows the relationship between zooplankton abundance and dry weight with environmental parameters in the water column at station 1. No correlation was detected between temperature, salinity and zooplankton abundance and biomass. Total zooplankton abundance correlated with total chl-a, total carbohydrate and micro fraction of protein (Table 3.7). Except 112-200 μm size fraction, other three size fractions of zooplankton abundance correlated with total and nano fraction of chl-a. >1000 and 500-1000 μm size fractions of zooplankton abundance were also found to correlate with TSPM. However, 112-200 μm size fraction did not show any correlation. All size fractions of zooplankton dry weight were correlated with pico and micro size fractions of protein, micro fraction of lipid and total sum of protein, lipid and carbohydrate. Indeed, 112-200 size fraction zooplankton biomass was also correlated with pico fraction of carbohydrate, and >1000 and 200-500 μm size fractions were also correlated with nano carbohydrate. Finally, total zooplankton dry weight showed significant correlation ($p<0.01$) with total sum of protein, lipid and carbohydrate. Among size fractions in organic weight of zooplankton, 200-500 μm size fraction correlated with total sum of protein, lipid and carbohydrate and 112-200 μm size fraction correlated with carbohydrate and protein. Other two size fractions showed no correlation. Total organic weight showed significant relation with protein and lipid. However, no correlation were observed between zooplankton biomass and chl-a. Except >1000 μm size fraction, total zooplankton abundance showed correlation with other three size fractions of zooplankton dry weight. However, no any correlation was observed between zooplankton dry weight with any size fractions of zooplankton abundance. Zooplankton abundance and dry weight of 112-200 μm size fractions showed correlation within them.

In the surface water at station 1, except 112-200 μm size fraction, other size fractions of zooplankton abundance showed significant correlation ($p<0.01$) with nano fraction of chl-a. 200-500 μm size fraction of zooplankton dry wieght correlated with pico fraction of protein. Other fractions did not exhibit any correlation. On the other hand, 500-1000 μm size fraction of zooplankton organic weight correlated with

total carbohydrate while total organic weight correlated with nano fraction of carbohydrate. In addition, total zooplankton organic weight showed relation with nano fraction of chl-a. Only, 200-500 µm size fraction of zooplankton abundance and dry weight was found to correlate in the surface water at station 1.

In the water column at station 2, 200-500 and 500-1000 µm size fractions of zooplankton abundance were correlated with pico fraction of chl-a, while 500-1000 and >1000 µm size fractions were correlated with micro fraction (Table 3.8). Overall, total zooplankton abundance was found to correlate with micro fraction of chl-a. Strong negative correlation was observed between 200-500, 500-1000 and >1000 µm size fractions of zooplankton abundance with nano fraction of carbohydrate. >1000 µm size fraction of zooplankton dry weight was found to correlate with the same size fraction of zooplankton abundance.

In the surface water at station 2, 200-500 and >1000 µm size fractions of zooplankton abundance were found to correlate with salinity (Table 3.9). Strong negative correlation was observed between 500-1000 µm size fraction of zooplankton abundance and total and pico fraction of lipid. Total zooplankton dry weight and total lipid showed negative correlation. Interestingly, significant correlation was observed in the similar size fractions between zooplankton abundance and dry weight. Therefore, significant relation was found between total zooplankton abundance and dry weight.

Table 3.5. Spearman rank correlation between environmental parameters in each size fraction at station 1 (n=12- 13) * p<0.05, ** p<0.01
TSPM: Total suspended particulate matter; SPOM: Suspended particulate organic matter; prt: protein; lip: lipid; cho: carbohydrate.

Station 1		Temperature	Salinity	TSPM	SPOM	total chl-a	total prt	total lip	total cho	total (prt+cho+lip)
chl-a	total	-0.371	-0.326	**0.783****	**0.678***		0.429	0.319	0.451	0.524
	pico	-0.196	0.125	0.459	0.284	**0.635***	-0.118	-0.151	-0.049	-0.035
	nano	-0.615	-0.161	**0.608***	0.455	**0.791****	0.143	0.412	0.352	0.357
	micro	0.168	-0.459	**0.594***	**0.727****	**0.571***	**0.593***	0.154	**0.560***	**0.636***
prt	total	0.210	**-0.722****	0.455	0.503	0.429		**0.670***	**0.863****	**0.944****
	pico	0.126	**-0.574***	0.413	0.315	0.505	**0.885****	0.522	**0.665***	**0.790****
	nano	0.038	**-0.620***	0.395	**0.698****	0.360	**0.689****	0.545	**0.694****	**0.720***
	micro	0.28	**-0.578***	0.552	0.517	0.505	**0.912****	**0.692****	**0.852****	**0.818****
lip	total	-0.203	**-0.809****	0.552	0.441	0.319	**0.670***		**0.742****	**0.881****
	pico	**0.664***	**0.602***	-0.364	-0.545	-0.399	-0.196	-0.413	-0.126	-0.287
	nano	-0.445	**-0.681***	**0.616***	**0.616***	0.469	0.504	**0.718****	0.410	0.532
	micro	-0.154	**-0.743***	**0.699****	**0.671***	0.497	**0.804****	**0.860****	**0.727****	**0.839****
cho	total	0.147	**-0.683***	0.406	0.503	0.451	**0.863****	**0.742****		**0.958****
	pico	0.308	-0.511	0.357	**0.706****	0.264	0.538	0.231	**0.632***	**0.601***
	nano	-0.399	-0.405	0.350	0.063	0.443	0.503	**0.713****	0.410	**0.511***
	micro	0.13	-0.537	**0.581***	**0.743****	0.528	**0.547***	**0.616***	**0.792****	**0.767***
TSPM		-0.357	-0.42		**0.776****	**0.783****	0.455	0.552	0.406	0.469
SPOM		-0.266	-0.557	**0.776****		**0.678***	0.503	0.441	0.503	0.559
total (prt+lip+cho)		0.021	**-0.809****	0.469	0.559	0.524	**0.944****	**0.881****	**0.958****	

Table 3.6. Spearman rank correlations between environmental parameters in each size fraction at station 2 (n=12-13) * p<0.05 ** p<0.01
TSPM: Total suspended particulate matter; SPOM: Suspended particulate organic matter; prt: protein; lip: lipid; cho: carbohydrate.

Station 2		Temperature	Salinity	TSPM	SPOM	total chl-a	total prt	total lip	total cho	total (prt+cho+lip)
Chl-a	total	**-0.762****	0.186	0.280	0.000		-0.505	-0.175	-0.330	-0.420
	pico	**-0.741****	0.144	0.273	0.000	**0.984****	-0.412	-0.154	-0.418	-0.420
	nano	-0.301	0.161	-0.083	0.213	**0.544***	-0.319	-0.154	-0.192	-0.259
	micro	-0.510	-0.119	0.112	-0.112	0.258	0.082	0.062	-0.264	0.042
Prt	total	0.315	0.172	-0.203	0.021	-0.505		0.287	-0.214	0.538
	pico	0.203	0.329	0.154	0.154	-0.137	0.505	0.350	-0.054	0.531
	nano	0.077	0.160	-0.119	0.354	-0.212	0.451	0.284	0.173	0.287
	micro	0.294	0.459	-0.343	-0.252	-0.280	**0.566***	-0.119	-0.093	0.252
Lip	total	-0.371	-0.382	0.189	**0.755****	-0.175	0.287		0.350	**0.832****
	pico	-0.524	-0.350	0.259	**0.615***	0.083	0.308	**0.776****	-0.133	**0.608***
	nano	0.042	-0.017	0.224	0.112	-0.112	0.042	0.434	0.434	0.420
	micro	-0.413	-0.403	0.217	**0.853****	-0.049	-0.049	**0.692***	0.273	0.406
Cho	total	0.161	0.021	-0.224	0.175	-0.330	-0.214	0.350		0.531
	pico	0.105	0.431	0.133	0.000	-0.005	-0.275	-0.049	**0.714****	0.182
	nano	**0.699****	-0.087	-0.203	0.154	**-0.709****	0.198	0.280	**0.720****	0.517
	micro	-0.322	0.119	-0.301	0.119	0.087	-0.192	0.371	**0.720****	**0.580***
TSPM		-0.294	-0.126		0.385	0.280	-0.203	0.189	-0.224	-0.097
SPOM		-0.364	-0.228	0.385		0.000	0.021	**0.755****	0.175	0.476
total (prt+lip+cho)		-0.083	-0.056	-0.097	0.476	-0.420	0.538	**0.832****	0.531	

Table 3.7. Spearman rank correlations between water column zooplankton and surface environmental parameters at station 1 (n=12-13) * p<0.05 ** p<0.01 TSPM: Total suspended particulate matter; SPOM: Suspended particulate organic matter; prt: protein; lip: lipid; cho: carbohydrate.

St 1	Abundance					Dry Weight				
water column	total	>1000 µm	500-1000 µm	200-500 µm	112-200 µm	total	>1000 µm	500-1000 µm	200-500 µm	112-200 µm
total chl-a	**0.621***	**0.626***	**0.637***	**0.643***	0.022	0.297	0.258	0.363	0.319	0.087
pico chl-a	0.198	0.223	0.226	0.322	-0.146	-0.151	-0.013	-0.046	-0.173	-0.413
nano chl-a	0.505	**0.626***	**0.681****	**0.659***	-0.098	0.275	0.192	0.335	0.319	-0.054
micro chl-a	0.527	0.302	0.187	0.418	0.022	0.220	0.154	0.269	0.269	0.308
total cho	**0.637***	0.258	0.181	0.533	0.302	**0.698****	0.522	**0.687****	**0.769****	**0.780****
pico cho	0.533	0.231	0.225	0.313	0.262	0.280	0.002	0.275	0.368	**0.571***
nano cho	0.190	0.228	0.303	0.242	-0.113	0.545	**0.583***	0.523	**0.547***	0.292
micro cho	0.523	0.074	0.234	0.506	0.209	0.286	0.102	0.300	0.410	0.454
total prt	0.522	0.203	0.143	0.308	0.308	**0.760****	**0.665***	**0.736****	**0.791****	**0.086****
pico prt	0.538	0.308	0.341	0.308	0.319	**0.830****	**0.731****	**0.808****	**0.802****	**0.764****
nano prt	0.216	-0.002	-0.052	0.169	-0.024	0.243	0.113	0.232	0.396	0.462
micro prt	**0.555***	0.165	0.121	0.379	0.385	**0.632***	**0.571***	**0.626***	**0.648***	**0.775****
total lip	0.225	0.038	0.159	0.176	-0.016	**0.604***	**0.593***	**0.544***	**0.659***	**0.593***
pico lip	0.259	-0.042	0.055	0.238	0.182	0.119	0.133	0.196	0.006	0.119
nano lip	-0.014	0.021	0.014	-0.059	-0.102	0.070	0.112	0.000	0.158	0.186
micro lip	0.441	0.315	0.476	0.287	-0.006	**0.671***	**0.608***	**0.615***	**0.734****	**0.685***
total (prt+lip+cho)	0.538	0.238	0.259	0.413	0.161	**0.727****	**0.573***	**0.692***	**0.825****	**0.762****
TSPM	0.510	**0.538***	**0.594***	0.406	0.028	0.203	0.224	0.231	0.244	0.168
SPOM	0.406	**0.420**	**0.385**	0.308	0.069	0.090	0.000	0.090	0.201	0.238
Temperature	0.119	-0.350	-0.413	-0.069	0.048	0.083	0.035	0.126	0.076	0.420
Salinity	-0.105	0.045	0.010	0.084	-0.133	-0.382	-0.252	-0.277	-0.494	-0.560

Table 3.8. Spearman rank correlations between water column zooplankton and surface environmental parameters at station 2 (n=12-13) * p<0.05 **p<0.01 TSPM: Total suspended particulate matter; SPOM: Suspended particulate organic matter; prt: protein; lip: lipid; cho: carbohydrate.

St 2	Abundance					Dry Weight				
water column	total	>1000 µm	500-1000 µm	200-500 µm	112-200 µm	total	>1000 µm	500-1000 µm	200-500 µm	112-200 µm
total chl-a	0.451	0.440	**0.736****	**0.593***	0.082	-0.214	0.038	-0.22	-0.495	**-0.632***
pico chl-a	0.511	0.533	**0.780***	**0.648***	0.132	-0.071	0.187	-0.121	-0.379	**-0.566***
nano chl-a	-0.137	-0.198	0.087	0.098	-0.500	-0.297	-0.087	-0.269	**-0.549***	-0.538
micro chl-a	**0.566***	**0.703****	**0.654***	0.423	0.456	0.363	0.462	0.258	0.247	0.033
total cho	-0.165	-0.363	-0.198	-0.396	0.104	0.209	-0.258	-0.478	-0.407	-0.011
pico cho	0.187	-0.104	0.264	-0.181	0.385	-0.269	-0.462	-0.236	-0.088	0.159
nano cho	**-0.610***	**-0.725****	**-0.676****	**-0.764****	-0.126	-0.28	-0.484	-0.341	0.005	0.198
micro cho	0.044	-0.154	0.044	-0.071	-0.054	-0.374	-0.363	**-0.560***	-0.264	-0.209
total prt	-0.280	0.022	-0.418	-0.214	-0.143	0.44	0.511	0.099	0.418	0.264
pico prt	-0.319	-0.418	-0.478	-0.396	0.022	-0.489	-0.275	**-0.566***	-0.429	-0.39
nano prt	-0.0605	0.184	-0.019	-0.077	0.107	**0.646***	**0.633***	0.074	0.435	0.465
micro prt	-0.033	-0.060	-0.165	-0.198	-0.065	0.0769	0.0714	0.137	0.159	0.165
total lip	-0.357	-0.315	-0.35	-0.503	0.21	-0.168	0.105	**-0.580***	-0.175	-0.301
pico lip	-0.350	-0.196	-0.175	-0.406	0.006	-0.287	0.112	-0.399	-0.322	**-0.580***
nano lip	0.119	-0.042	-0.133	-0.049	**0.587***	-0.238	-0.21	**-0.664***	-0.203	-0.14
micro lip	-0.287	-0.210	-0.049	-0.483	0.161	0.119	0.273	-0.0769	0.014	0.014
total (prt+lip+cho)	-0.308	-0.294	-0.399	-0.531	0.182	-0.097	0.035	-0.559	-0.063	-0.084
TSPM	0.105	0.006	0.189	-0.049	0.406	-0.364	-0.21	-0.056	-0.252	-0.294
SPOM	-0.378	-0.455	-0.231	-0.580	0.154	-0.161	0.126	-0.364	-0.301	-0.245
Temperature	-0.357	-0.455	-0.566	-0.364	-0.175	0.154	-0.203	0.266	0.343	0.545
Salinity	0.312	0.221	0.214	0.172	0.186	0.045	0.003	-0.077	-0.144	0.161

Table 3.9. Spearman rank correlations between surface zooplankton and surface environmental parameters at station 2 (n=12-13) * p<0.05 ** p<0.01 TSPM: Total suspended particulate matter; SPOM: Suspended particulate organic matter; prt: protein; lip: lipid; cho: carbohydrate.

St 2	Abundance					Dry Weight				
surface water	total	>1000 µm	500-1000 µm	200-500 µm	112-200 µm	total	>1000 µm	500-1000 µm	200-500 µm	112-200 µm
total chl-a	0.273	0.248	0.321	0.345	0.018	0.236	0.479	0.139	0.345	0.139
pico chl-a	0.297	0.285	0.370	0.370	-0.006	0.248	0.527	0.176	0.358	0.079
nano chl-a	-0.152	-0.224	-0.164	-0.127	-0.079	-0.115	-0.006	-0.297	-0.164	0.273
micro chl-a	0.418	0.418	0.345	0.576	0.055	0.139	**0.661***	0.176	0.576	0.030
total cho	-0.164	-0.042	-0.212	-0.091	-0.006	-0.248	-0.236	-0.164	-0.067	-0.248
pico cho	0.430	0.527	0.479	0.455	0.358	0.479	0.188	0.552	0.564	0.139
nano cho	-0.273	-0.212	-0.321	-0.273	0.006	-0.224	-0.467	-0.115	-0.200	-0.115
micro cho	-0.273	-0.176	-0.358	-0.091	-0.333	-0.503	-0.115	-0.442	-0.079	-0.333
total prt	0.079	0.115	-0.212	0.067	0.152	-0.188	0.176	-0.212	0.115	0.115
pico prt	-0.309	-0.236	-0.382	-0.358	-0.139	-0.164	-0.394	-0.164	-0.139	-0.042
nano prt	0.480	0.505	0.158	0.505	**0.650***	0.109	**0.632***	0.006	0.450	0.438
micro prt	0.018	0.103	0.152	-0.091	-0.176	0.200	-0.152	0.224	0.006	-0.164
total lip	-0.527	-0.467	**-0.770****	-0.467	-0.139	**-0.624***	-0.309	**-0.721***	-0.358	-0.042
pico lip	-0.527	-0.503	**-0.648***	-0.503	-0.297	-0.467	-0.333	-0.588	-0.358	-0.042
nano lip	-0.091	-0.030	-0.321	0.042	0.103	-0.345	0.006	-0.248	0.103	-0.115
micro lip	-0.139	-0.139	-0.333	-0.152	0.273	-0.152	0.006	-0.370	-0.103	0.382
total (prt+lip+cho)	-0.358	-0.248	-0.612	-0.261	-0.079	-0.539	-0.248	-0.552	-0.139	-0.115
TSPM	0.200	0.079	0.115	0.079	0.442	0.406	-0.006	0.297	0.200	0.697
SPOM										
Temperature	0.055	0.103	0.212	-0.067	0.055	0.236	-0.261	0.406	-0.055	-0.164
Salinity	**0.638***	**0.705***	0.590	**0.620***	0.511	0.608	0.450	0.559	**0.711***	0.353

4. DISCUSSION

4.1. Total and organic suspended particulate matter

Highest TSPM values were observed in spring at both stations (Figure 4.1 c, 4.2 c). TSPM values were varied between 5.9 mg L^{-1} and 14.4 mg L^{-1} in the nearshore station. Maximum TSPM value was observed in March 2005 due to input from Lamas river nearby at station 1 (Figure 4.1 c). Uysal and Köksalan (2006) revealed that the TSPM value varied between 1.76 and 17 mg L^{-1} in the studied region with the highest value in spring, similar to the present study. Higher TSPM values were observed when the nutrients increased in the area (Uysal and Köksalan, 2006). At station 2, highest value of TSPM observed in March 2005 could be the result of mixing process. The organic content of TSPM were low and almost constant during the sampling period at station 1 (ranged from 24 to 35 %), while at station 2, the organic matter contribution to the total suspended particulate matter were between 25 and 70 %. Spring (March and May), summer (July), autumn (September) and winter (December) periods were well related to the physical forces in the environment; winter-spring mixing, summer stratification and autumn when the re-mixing starts with the south- westerly winds at station 2.

TSPM showed strong correlation with total chl-a at station 1 ($p<0.05$). This suggests that TSPM distribution was coupled with phytoplankton distribution at this station, and chl-a explained 62.7% of the variance in TSPM (Linear Regression, $r^2= 0.627$, $p<0.01$, $n=12$). There is a statistically significant difference between station 1 and 2 in terms of surface TSPM amount (Mann-Whitney Rank Sum Test $p<0.001$).

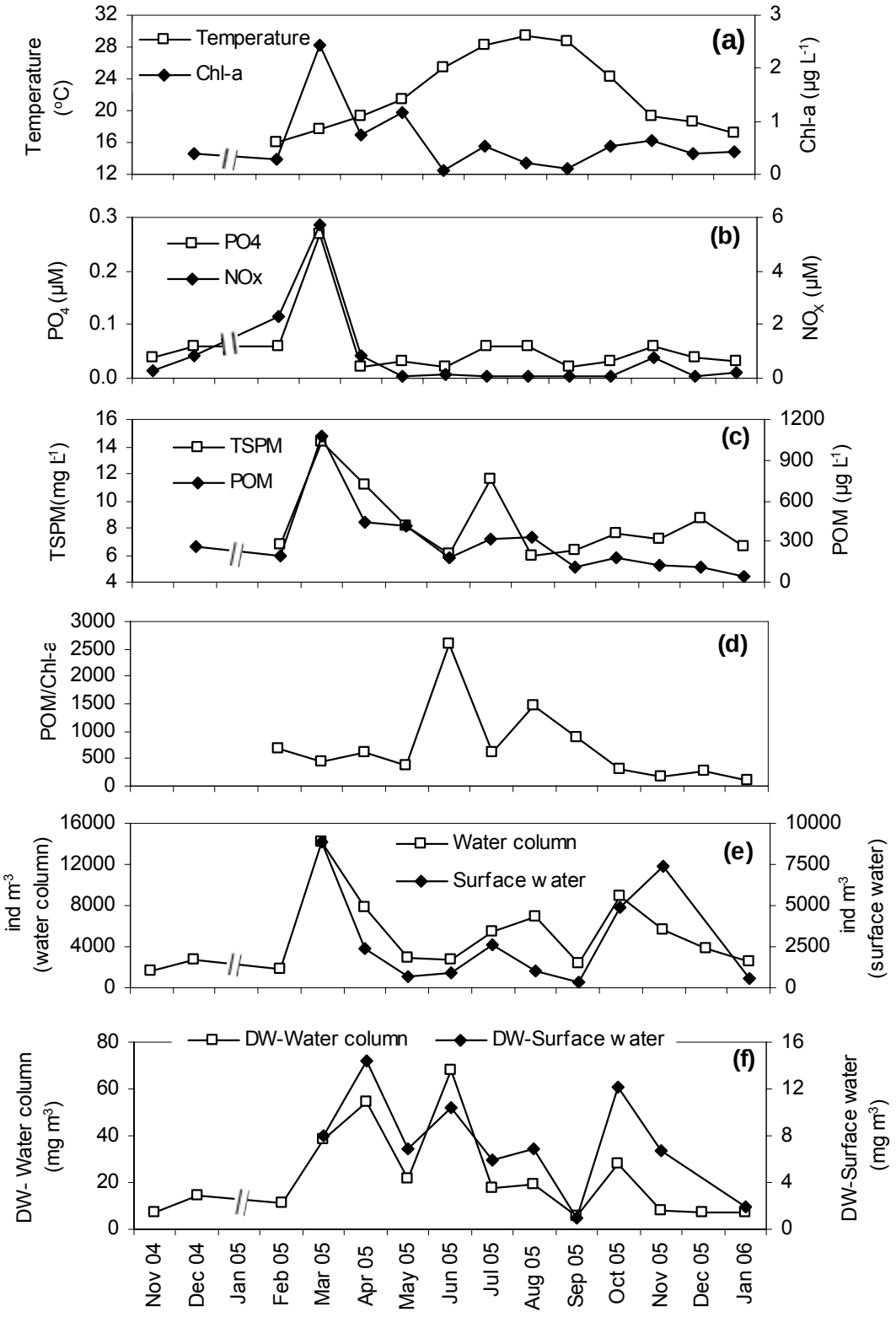

Figure 4.1 Temporal changes of some parameters at station 1. a) Temperature and total chl-a, b) PO_4 and NOx, c) TSPM and total POM, d) POM/Chl-a ratios, e) total zooplankton abundance in water column and surface, f) total zooplankton biomass in the water column and surface.

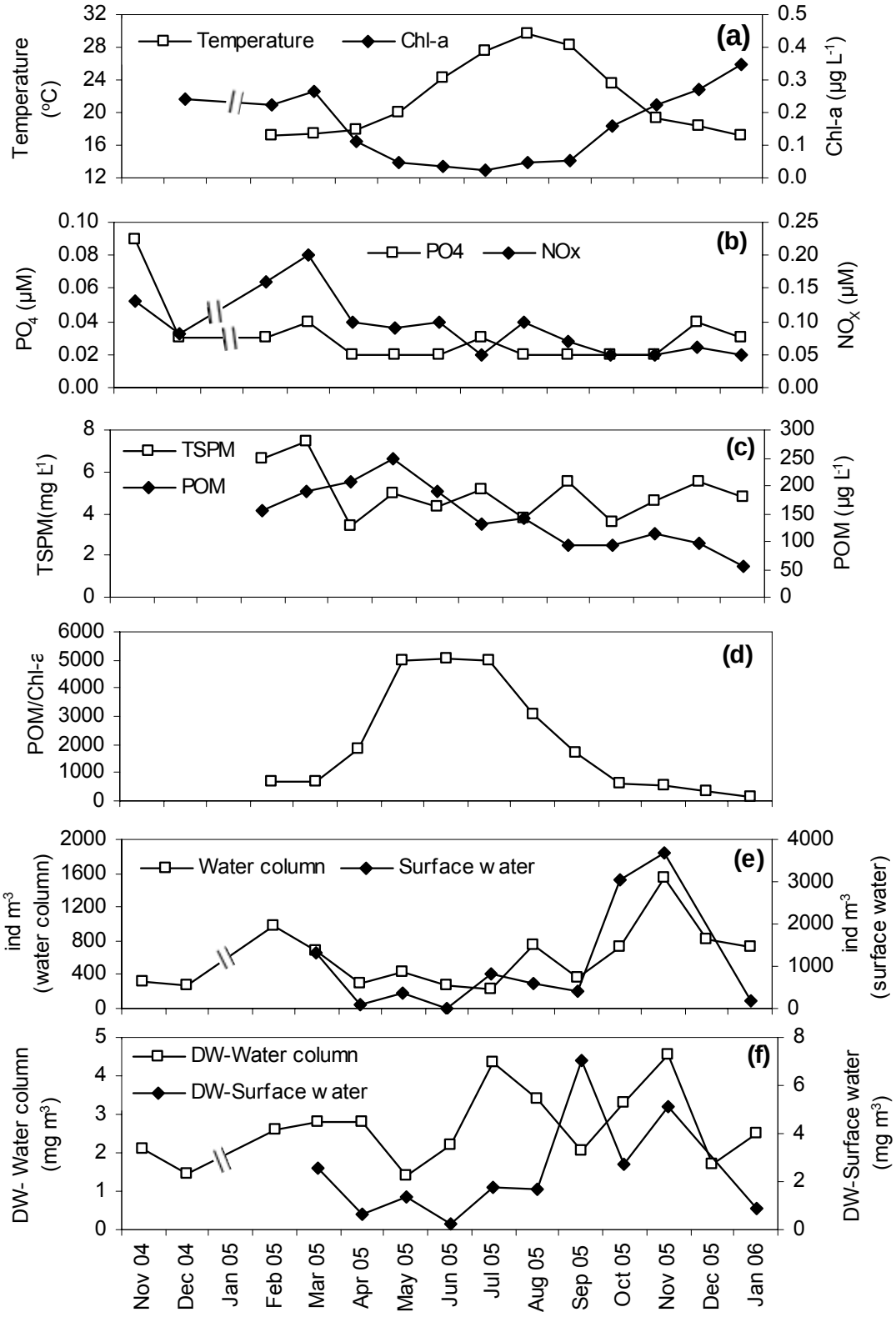

Figure 4.2 Temporal changes of some parameters at station 2. a) Temperature and total chl-a, b) PO_4 and NOx, c) TSPM and total POM, d) POM/Chl-a ratio, e) total zooplankton abundance in water column and surface, f) total zooplankton biomass in the water column and surface

4.2. Chlorophyll-a

Total chl-a concentrations varied between 0.1 - 2.4 μg L^{-1} and 0.03 μg L^{-1} - 0.35 μg L^{-1} at stations 1 and 2, respectively (Figure 4.1 a, 4.2 a). Yılmaz (2006) obtained similar chl-a values at the same stations during 2001-2003, which varied between 0.03-8.0 μg L^{-1} and 0.01-1.19 μg L^{-1} at stations 1 and 2, respectively. Uysal and Köksalan, (2006) revealed that the chl-a concentration in the station 1 varied between 0.12 and 2.93 μg L^{-1} during 1998-1999. There were low chlorophyll-a concentrations in the eastern Ionian Sea (0.16-0.26 μg L^{-1}, Gotsis- Skretas *et al*.,1986), offshore Israeli waters (0.06–0.12 μg L^{-1}, Berman *et al*., 1986), offshore in Egyptian waters (0.09–0.79 μg L^{-1}, Dowidar, 1984), the NW Levantine Sea (0.10–0.47 μg L^{-1}, Ediger & Yilmaz, 1996), in the NE Mediterranean Sea (0.02-1.0 μg L^{-1}, Ediger *et al.,* 2005), in the northern Levantine basin (0.02-0.3 μg L^{-1}, Çoban, 1997) and in the core of the Cyprus eddy (0.16–0.23 μg L^{-1}, Krom *et al.,* 1993). Lower chl-a value in the eastern Mediterranean are in accordance with the values in the offshore station in the study area. In contrast to these low values Küçüksezgin *et al.* (2005) found that the chl-a concentrations varied between 0.46 and 10 μg L^{-1} at the inner bay in İzmir Bay. The two studies carried in the study area by Yılmaz (2006) and Uysal and Köksalan (2006) confirmed that the nearshore station is more productive than the offshore station.

The maximum chl-a concentration was observed in March 2005 at station 1 (Figure 4.1 a). Eker-Develi (2004) and Uysal and Köksalan (2006) observed that the highest chl-a concentration were observed in spring due to the excess nutrient input from Lamas River at station 1. Therefore, the increase in March could be the result of river effect at station 1 in the present study. Temperature played a role in the concentration of chl-a in summer, eventhough any statistically significant correlation was not found. At station 2, the highest chl-a concentration was observed in spring and autumn-winter periods with a maximum in January 2006 (Figure 4.2 a). In Northeastern Mediterranean, the highest chl-a concentration was observed in autumn and winter due to winter mixing (Berman *et al*., 1984, 1986; Azov, 1986; Salihoğlu *et al.,* 1990; Krom *et al.,* 1991, 1992; Ediger *et al*., 2005; Gotsis-Skretas *et al*., 1999). Therefore, this gradual increase in chl-a value in winter period could be a result of nutrient transport to the upper layers from lower layers by mixing processes at station 2 (Berman *et al*., 1984, 1986; Azov, 1986; Salihoğlu *et al.,* 1990; Krom *et al.,* 1991, 1992; Ediger *et al*., 2005; Gotsis-Skretas *et al*., 1999; Çoban, 1997).

The lowest chl-a concentration (0.05 μg L^{-1}) was observed during summer period in which the highest temperature values were recorded at station 2 (Figure 4.2 a). Strong negative correlation ($p<0.01$) is evident between chl-a and temperature at station 2. Low chl-a concentrations during the summer months could be due to the photoinhibition and/or the nutrient limitation. During the summer, because of the strong stratification, recycled nutrient in the upper mixed layer is the main source of nutrients. Phytoplankton cells decrease the synthesis of chl-a in order to protect themselves from excessive light inhibition when the surface temperature increases especially at noon during summer periods (Gibb *et al.*, 2000). Effects of grazing on phytoplankton can not be ruled out during the summer period, because of the increase in temperature, grazers become more active, and increase their reproductive and feeding activities.

The eastern Mediterranean coastal waters are characterized by larger size phytoplankton; however the open waters are characterized by pico and nano size phytoplankton community (Yacobi *et al*., 1995; Zohary *et al*., 1998; Christaki *et al*., 2001; Psarra *et al*., 2005; Berman *et al*., 1984; Azov, 1986; Kimor *et al*., 1987; Herut *et al*., 2000). At station 1, pico and nano size fractions shared the highest contributions to the annual total chl-a, with around 40% each. In spring, nano size fraction (2.7-18 μm) made up the bulk of the spring bloom, constituting 94% of the total chl-a. Nutrient concentrations were very low in the rest of the year (Figure 4.1 b) and pico size fractions took the advantage, and became dominant in the rest of the year at station 1. Pico size fraction was always dominant at station 2 throughout the year and constituting 65 % of total annual chl-a. The results of the present study are in accordance with earlier findings and showed the oligotrophic character of the eastern Mediterranean Sea because of low chl-a concentrations and the dominancy of pico size fraction as this was also stated by Danovaro *et al*. (2000). On the other hand, high chl-a concentration were observed in near coastal areas, receiving nutrient input from rivers. A significant difference in total chl-a concentration between station 1 and station 2 was observed (Mann-Whitney test, $p<0.02$).

4.3. Biochemical composition

Total POM (sum of the total carbohydrate, protein and lipid) varied between 42 and 1083 μg L^{-1} at station 1 (nearshore) and between 54 and 247 μg L^{-1} at station 2 (offshore), respectively in the study area (Figure 4.1 c, 4.2 c and Table 4.1). On annual average, station 1 had higher total POM concentrations compared to station 2. Total POM values of the offshore station were very low. Similar results were observed in the Cretan Sea (northeastern Mediterranean) by Danovaro *et al*. (2000) (Table 4.1). Total POM values at station 1 were similar to more productive systems (Table 4.1). Danovaro *et al*. (2000) have found that the total POM concentration was decreasing from coast to open waters, similar to the results of the present study. There have been no quantitative studies of total POM (in terms of sum of the total carbohydrate, protein and lipid) in the Turkish waters of the NE Mediterranean. However, there are couple studies of POM (sum of POC, PON and TPP) in the area (Çoban, 1997; Dogan-Saglamtimur, 2007; Yılmaz, 2006). Doğan-Sağlamtimur (2007) showed that the POM concentration showed decreasing trend from the river-bed to the shelfbreak zone. Çoban (1997) and Yılmaz (2006) noted that the POM values were higher in the coastal regions in the northern Levantine basin.

The total POM was higher in spring at both stations in the study area (Figures 4.1 c, 4.2 c). No clear seasonality was observed in the Cretan Sea (Danovaro *et al.*, 2000). Doğan-Sağlamtimur (2006) showed that the POM was higher in spring and summer periods, implying the input from river runoff in the nearshore station. Çoban (1997) observed that the highest POM was observed in May and the lowest values were observed in September-October in the northeastern Mediterranean. Yılmaz (2006) showed that the maximum POM values were in late winter-early spring in the northeastern Mediterranean.

Table 4.1. Comparison of particulate organic matter concentration, as carbohydrates (cho), proteins (prt) and lipids (lip) from different areas. POM is defined as the total sum of carbohydrate, lipid and protein (modified from Danovaro *et al*., 2000).

Area (depth)	cho (µg L^{-1})	prt (µg L^{-1})	lip (µg L^{-1})	POM (µg L^{-1})	Authors
Bedford Basin, Canada (eutrophic)	160-630	200-650	130-440	660-1570	Mayzaud *et al*. (1989)
Ross Sea, Antarctica (eutrophic)	22-251	40-406	18-115	110-660	Fabiano *et al.* (1999)
Terra Nova Bay, Antarctica (eutrophic)	8-144	10-620	2-77	19-885	Fabiano *et al.* (1999)
Pacific Sector Antarctic Ocean (oligotrophic)	3-66	14-100	3-60	25-220	Tanoue (1985)
W. Mediterranean (oligotrophic)	33-88	72-105	37-51	143-246	Fabiano *et al.* (1984)
W. Med. submarine cave (oligotrophic)	1-75	4-77	4-104	15-220	Fichez (1991b)
Mediterranean seagrass (eutrophic)	40-110	25-135	50-180	125-395	Danovaro *et al*. (1998)
Ligurian Sea, W. Med. (oligotrophic)	25-130	28-111	18-74	105-335	Danovaro & Fabiano (1997)
Yaldad Bay, Chile , south America (eutrophic)	50-1050	300-2250	30-560	310-2960	Navarro *et al.* (1993)
Newfoundland, Atlantic Ocean (eutrophic)	8-120	80-740	20-75	130-1030	Navarro & Thompson (1995)
Cretan Sea (oligotrophic)	13-149	7-92	4-63	54-200	Danovaro *et al.* (2000)
Florida Bay (eutrophic)	17-335	90-939	20-157	127-1431	Hazzard *et al.* (2003)
Off Rankin Key (Florida Bay) (eutrophic)	84.7 ± 51.0	435 ± 251	25 ± 13	547	Kleppel and Hazzard (2000)
Off Duck Key (Florida Bay) (oligotrophic)	8.9 ± 5.8	76.7 ± 19	8.9 ± 3.9	95	Kleppel and Hazzard (2000)
Bay of Biscay (2000) (eutrophic)	2.09-345	156-2425	54-2037	315-4587	Diaz *et al*. (2007)
Bay of Biscay (2001) (eutrophic)	12-83	109-721	25-360	234-1012	Diaz *et al.* (2007)
NE Mediterranean - nearshore	21-419	5-348	15-315	42-1083	present study (2007)
NE Mediterranean - offshore	23-164	2.5-101	9-98	54-247	present study (2007)

No significant relationship was observed between total POM and chl-a at both stations. Yılmaz (2006) did not also found any significant relationship between POM and chl-a which indicates that POM pool is dominated by detritus, bacteria and zooplankton. Total POM to chl-a ratios are given in Figure 4.1 d for station 1, and in Figure 4.2 d for station 2. Total POM to chl-a ratio increased in summer periods at stations 1 and 2, comparing the ratios with other periods. Increasing ratio of POM to chl-a is an indication of high amount of non-phytoplanktonic material (Küçüksezgin *et al.*, 2005). Çoban (1997) showed that the POC to Chl-a ratio was ranged between 200 and 3558 in the northern Levantine basin with the lowest values in spring and summer. Yılmaz (2006) observed that POC:chl-a ratio at the surface varied between 58-4500 and 97-4000 for nearshore and offshore stations, respectively. Ratios were generally high during spring and summer seasons. Ediger *et al.* (2005) noted high ratio of POC:chl-a in the NE Mediterranean and they concluded that the particles could be dominated by detritus and bacteria .

In the present study, seston carbohydrate, protein and lipid concentrations varied between 21-419 μg L^{-1}, 5-348 μg L^{-1} and 15-315 μg L^{-1}, respectively at station 1 (Table 4.1) and 23-164 μg L^{-1}, 2.5-101 μg L^{-1} and 9-98 μg L^{-1}, respectively at station 2 (Table 4.1). Carbohydrate, protein and lipid concentrations varied between 33-88, 72-105 and 37-51 μg L^{-1} in the western Mediterranean (Fabiano *et al.,* 1984), 25-149, 28-111 and 18-74 μg L^{-1} in the western Mediterranean (Danovaro and Fabiano, 1997) and 13-149, 7-92 and 4-63 μg L^{-1} in the Cretan Sea (western Mediterranean) (Danovaro *et al.*, 2000), respectively (Table 4.1). These results are in accordance with the results of the present study at station 2. However, station 1 is more productive than the Cretan Sea in terms of protein, carbohydrate and lipid. No statistical significant difference was observed in total POM between stations; however, carbohydrate exhibited significant difference ($p<0.05$) between the stations (ANOVA). Carbohydrate was much higher at station 1 than station 2.

Distribution of biochemical components was variable at the stations. Carbohydrates were the dominant biochemical component at both stations. Similar to the present study, Danovaro *et al.* (2000) found that the carbohydrate was the dominant biochemical components of POM followed by proteins and then lipids in the Northeastern Mediterranean Sea.

Among three size fractions, pico size fraction was the dominant fraction of total POM, followed by nano-particulate and then micro-particulate fraction at both stations. Dominancy of size fractions varied in each biochemical component; pico size fraction was dominant in protein and lipid, while nano size fraction was dominant in carbohydrate at station 1. On the other hand, at station 2 pico size fraction was dominant in lipid and carbohydrate, whereas nano size fraction was dominant in protein. These results were similar to the findings in the Cretan Sea (Danovaro *et al*., 2000). Dominancy of pico size fraction is a characteristic of the oligotrophy in the northeastern Mediterranean as stated by Danovaro *et al*. (2000).

Using seston lipid, carbohydrate and protein concentrations, the biopolymeric carbon concentrations (BPC: as the sum of the carbohydrate, lipid and protein carbon) were estimated for two stations shown in Figure 4.3. Conversion factors were used as 0.75, 0.4 and 0.49 g C g^{-1} for particulate lipids, carbohydrates and proteins, respectively (Danovaro *et al*., 2000). At station 1, BPC ranged between 23 (January 06) and 575 (March 05) µg C L^{-1}. It was generally higher in spring and summer period. At station 2, it varied from 32 (January 06) to 120 (April 05) µg C L^{-1}, and it was always higher than 100 µg C L^{-1} during the spring period. These results are similar to reported by Danovaro *et al*. (2000) for the Cretan Sea, they found between 24.2 and 113.7 µg C L^{-1}. BPC implies the autochtonous origin of the particles (Danovaro and Fabiano, 1997). Generally, it is estimated that BPC forms 40 to 80 % of the particulate organic carbon (POC). But this contribution depends on the source of POM. Low contribution was observed in the areas under terrestrial influence (Pusceddu *et al*., 1996). In the Cretan Sea, the contribution of BPC to the total POC pool was high, 80-100 % (Danovaro *et al*., 2000). This high contribution implies that the origin of POM is autochtonous in the Cretan Sea. Unfortunately, we do not have POC measurements in the present study. So, to obtain a precise picture of the origin of the POM in the studied area, a comprehensive series of measurements containing POC concentrations over different seasons should be carried out.

Annual changes in protein to carbohydrate ratio (prt:cho) at stations 1 and 2 are illustrated in Table 4.2. Generally, total protein to carbohydrate ratio was lower than 1 at both stations in the study area. The total POM was highly dominated by carbohydrates and characterized by very low prt:cho ratios. At station 1, highest prt:cho ratios were observed in micro and pico size fractions, on annual average 4.3

and 2, respectively. On the other hand, the prt:cho ratio in the nano fraction was on annual average 0.3 (Table 4.2). The prt:cho ratio of micro fraction was much higher (34.8) in Febuary 2005. This is because of the low concentration of micro size fraction of carbohydrate at that period. At station 2, high prt:cho value was found in micro size fraction (on annual average 1.3), but in the pico and nano size fractions, the ratios were <1 (Table 4.2). This condition was also reported by Danovaro *et al*. (2000) in the Cretan Sea with low prt:cho ratios (on average <1). These findings are in contrast with the POM values observed in more productive protein-dominated systems (Navarro & Thompson, 1995; Navarro *et al*., 1993; Hazzard *et al*., 2003; Kleppel and Hazzard, 2000, Fabiano *et al*., 1992 and Diaz *et al*., 2007). Fabiano *et al*. (1984) observed that the prt:cho ratio increased during the phytoplankton bloom in the Ligurian Sea. On the contrary, the prt:cho ratio did not increase with the increase of chl-a (as a phytoplankton biomass indicator) or vice versa in the study area. The prt:cho ratio was lower than 1, indicating that particulate matter was mainly composed of carbonaceous compounds (low in organic nitrogen). It is already stated that the oligotrophic systems are characterized by very low prt:cho ratios (on average <1) by Danovaro *et al.* (2000). When prt:cho ratios are <1, conditions are considered to be as N limited (Mayzaud *et al.,* 1989). Therefore, the studied region was nutrient limited in most of the year, and nutrient deficiency was severe especially for nano size fraction.

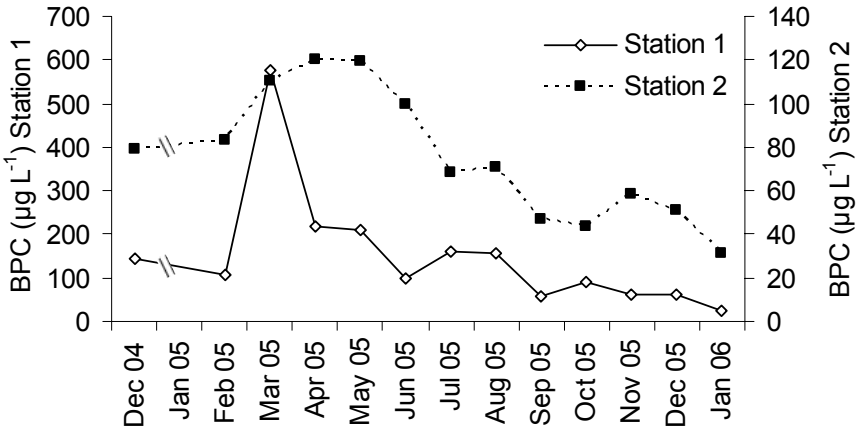

Figure 4.3. Temporal variations of BPC (Biopolymeric carbon) concentrations at both stations.

Table 4.2 Temporal changes in protein (Prt) and carbohydrate (Cho) ratios during sampling period at stations 1 and 2. T= total, P= pico factions, N= nano fractions, M= Micro fractions.

Months	Station 1				Station 2			
	Prt_T: Cho_T	Prt_P: Cho_P	Prt_N: Cho_N	Prt_M: Cho_M	Prt_T: Cho_T	Prt_P: Cho_P	Prt_N: Cho_N	Prt_M: Cho_M
Nov 04	-	-	-	-	-	-	-	-
Dec 04	0.2	0.3	0.2	0.1	0.2	0.2	0.2	0.1
Jan 05	-	-	-	-	-	-	-	-
Feb 05	0.4	3.1	0.1	34.8	0.1	0	0.4	0.2
Mar 05	0.8	2.4	0.2	0.9	1.6	1.4	2.2	1.4
Apr 05	0.6	0.8	0.5	0.8	0.7	0.5	1.1	0.5
May 05	1.1	2.8	0.5	1	0.2	0.4	0.1	0.2
Jun 05	0.8	1.8	0		2.4	7	0	2.1
Jul 05	0.6	0.4	1	0.8	1.1	0.4	1.8	0.5
Aug 05	0.3	0.1		0.4	0.6	0.3	0.8	0.5
Sep 05	0.7	0.7	0.4	4	0.6	0.6	0	7.2
Oct 05	0.6	12	0	4.4	0.5	0.1	1	0.8
Nov 05	0.3	0.7	0	0.1	1.4	0.4	1.7	2.7
Dec 05	0.2	0		0.2	0.5	0.8	0.6	0.2
Jan 06	0.3	0.5	0.1		0.1	0	0.1	0.2
Average	**0.5**	**2**	**0.3**	**4.3**	**1**	**0.9**	**0.8**	**1.3**

4.4. Zooplankton composition and biomass

Three main increases in zooplankton abundance (spring, summer & autumn) were observed at station 1, with primary peak in spring and secondary peak in autumn, and a small increase in summer (Figure 4.1 e). Zooplankton abundance significantly correlated with chl-a, and zooplankton biomass significantly correlated with POM at this station. Increase in phytoplankton in spring (Figure 4.1 a) supplied more food for zooplankton, and zooplankton responded by increasing their grazing and reproduction. In spring, zooplankton maximum, 500-1000 (32%) and 112-200 (37 %) µm size fractions together made up the majority of the zooplankton abundance in the water column. While 200-500 µm size fraction itself formed about 68 % of the total surface water zooplankton abundance in March. The growth efficiency of larger individuals decreases as temperature increase. Small organisms can be more efficient during the warmer periods (Valiela, 1995). This may cause the higher contribution of small size fractions to the total zooplankton in the region. Therefore, contribution of 112-200 µm size fraction to the total water column and surface zooplankton was >50 % during the summer months (June, July, August, September). It is known that microzooplankton and heterotrophic nanoflagellates are the important food sources for zooplankton (Harris, 2000; Omori and Ikeda, 1992; Saiz *et al*., 2007; Turner and Graneli, 1992; Boltovskoy, 1999). In South Aegean waters, high ciliates and heterotrophic nanoflagellates were observed in September than in March (Siokou-Frangou *et al*., 2002). Broglio *et al*. (2004) observed high abundance of ciliates in the plankton during summer period in the oligotrophic coastal waters off Masnou, Spain (NW Mediterranean). Additionally, they showed that copepods selectively feed on ciliates. In the present study, although we have protozoa abundance, because of the large mesh size (112 µm) of the net for protozoa collection, their abundance could be under estimated. But using the literature knowledge these micro-organisms possibly supported the summer and autumn zooplankton abundance in the study area. When photoperiod becomes shorter (especially during winter time), most of the grazers begin to die or migrate downward, and become the inhabitants in deeper waters (Valiella, 1995). This can be an explanation for the low abundance in winter months, especially for the surface water zooplankton (Figure 4.1 e).

At station 2, the primary peak of zooplankton abundance was observed in autumn period (November), with secondary peak in spring and small increases in summer months (Figure 4.2 e). Chl-a formed two peaks, in spring and autumn (Figure 4.2 a), and it correlated negatively with surface temperature. In the open waters, generally, due the meteorological processes, mixing occurs and nutrient concentrations in the surface water increase. At station 2, strong mixing was observed in winter, spring and late autumn, and almost whole water column became mixed (Figure 3.3 and Figure 3.4). During the mixing period chl-a concentration were high, and bulk of the chl-a was from the pico size fraction. In the oligotrophic open systems, the microbial loop has been found to dominate the system (Lenz, 2000). Copepods were the abundant group, constituting >70 % of the total zooplankton in the water column and in the surface water at station 2. Copepods have the poor ability to feed directly on picoplankton, and they mainly feed on protozoans and larger algae. In the present study, there was a positive significant correlation between micro size chl-a and total zooplankton abundance in the water column. However, micro size fraction (>18 µm) formed only 17 % of total annual chl-a concentration. Therefore, micro size fraction can not be the only food sources to support annual zooplankton population. Zooplankters should rely on the other source of food, like protozoan. Thingstad *et al*. (2005) carried out a Phosphorous-addition experiment in the eastern Mediterranean in May 2002, and after Phosphorous-addition, they observed a decreasing trend in phytoplankton growth, but an increase in bacterial and ciliate biomass, and copepod egg production. They concluded that, phytoplankton is colimited by N and P in the area. Dissolved organic carbon and nitrogen pools supported the increase in bacterial production. Ciliates responded to high bacterial production by increase in biomass, and the egg production of copepods increased as response to high ciliate biomass, and they consumed ciliates rapidly (Thingstad *et al*., 2005).

Invertebrates such as, predaceous chaetognaths, ctenophores and carnivorous copepods and, fish and fish larvae may be the more important predators, controlling the mesozooplankton production. Even though, predators are present throughout the year, their abundance showed seasonality in the area. Chaetognaths were dominant in spring and autumn, jelly organisms were abundant in spring, and the highest abundance of fish egg and larvae were observed in summer at station 1. At station 2, jelly organisms showed their peak abundance in autumn, chaetognaths

were abundant in autumn and spring, and fish egg and larvae were very low at this station, with peak abundance in winter.

The highest zooplankton abundance was found in spring and autumn at both stations in the present study. The highest zooplankton biomass was observed in summer and autumn in the water column, while in spring and autumn in the surface waters. Data from the straits of the Cretan Arc showed that the highest mesozooplankton abundance was in autumn-winter periods and the highest biomass was in spring and autumn (Gotsis- Skretas *et al*., 1999). Scotto di Carlo and Ianora, (1983) and Estrada *et al*., (1984) stated that the Mediterranean zooplankton is characterized by two abundance maxima: the first one in late winter or early spring and a second peak in autumn.

Zooplankton abundance and biomass values were always higher at station 1 (nearshore) than station 2 (offshore) in the study area ($p<0.001$) shown in Table 4.3. The zooplankton abundance values at the offshore station are in accordance with the studies done at the offshore stations in the Aegean Sea, the Cretan Sea, the Sicily Channel, the Cretan Passage, the Lebanase waters, the South-eastern Mediterranean and the Levantine basin (Table 4.3). On the other hand, zooplankton abundance values at the coastal station are similar to the values observed in the coastal stations of the Egypt, the Eastern Harbour-Alexandria, the Lebanase waters, the Kastella Bay, the Trieste Bay, the Naples, the Balearic Sea and the Saronicos Gulf (Table 4.3). Champalbert (1996) stated that the zooplankton biomass values are in 2-20 mg m^{-3} range and there is a clear uniformity of zooplankton composition in the western and eastern Mediterranean, similar to the results in the Balearic Sea, Lebanase waters and the present study. Indeed, biomass values were always found to be higher at coastal waters (Gaudy *et al.,* 2003; Lakkis, 1990; Champalbert, 1996).

Table 4.3 Comparison of total zooplankton abundance and biomass from different regions in the Mediterranean Sea. (modified from Kovalev *et al.*, 2003) EM: Eastern Mediterranean; WM: Western Mediterranean

Region	Abundance (ind m^{-3})	Dry weight (mg m^{-3})	Reference
Egypt, Coastal (EM)	3695-44330	-	El-Maghraby and Halim (1965)
Eastern Harbour, Alexandria, Coastal (EM)	10340-82700	-	Khalil *et al.* (1983)
Lebanase, Coastal (EM)	269-1900	-	Lakkis and Zeidane (1983)
Kastella Bay, Coastal (EM)	1930-6450	-	Vucetic and Regner (1973)
Triest Bay, Coastal (EM)	100-10000	-	Specchi *et al*. (1981)
Saronicos Gulf, Coastal (EM)	300-6000	-	Siokou-Frongou (1996)
Balearic Sea, Coastal (WM)	328- 2010	1.4- 16.9	Fernandez de Puelles *et al.* (2003)
Naples, Coastal (WM)	223-11148	-	Mazzocchi and Ribera (1995)
Aegean Sea, Coastal & Offshore (EM)	305-4662	-	Zervoudaki *et al*. (2006)
Cretan Sea, Offshore (EM)	684	-	Gotsis- Skretas *et al.* (1999)
Sicily Channel, Offshore (EM)	200	-	Mazzochi *et al. (*1997)
Cretan Sea, Offshore (EM)	45	-	Mazzochi *et al. (*1997)
Cretan Passage, Offshore (EM)	56	-	Mazzochi *et al. (*1997)
Lebanase waters, Offshore (EM)	-	0-20	Lakkis (1990)
South-Eastern Mediterranean, Offshore	211-373	-	Porumb *et al.* (1982)
Levantine Basin, Offshore (EM)	130-200	-	Pancucci-Papadopoulou *et al.* (1992)
NE Mediterranean - Nearshore	614-14198	1.4-68.2	present study (2007)
NE Mediterranean - Offshore	12-3678	0.3-14.3	present study (2007)

In spite of zooplankton abundance values were similar in the surface waters at stations 1 and 2 (Figure 4.1 and Figure 4.2) during September 2005, the dry weight value was much higher at station 2. The dry weight value was the lowest value at station 1, while it was the highest value at station 2. This high dry weight value came from the gastropoda larvae in the surface waters at station 2. Gastropoda larvae were much higher in terms of dry weight than other groups because of having calcium carbonate shell. It even constituted the 83 % one of the largest size fraction (500-1000 µm) of zooplankton abundance in September 2005. On the other hand, gastropoda larvae had much higher inorganic content comparing to the other zooplankton groups. Therefore, the organic weight constituted the ~50 % of the dry weight in September 2005, decreasing from 7.1 to 3.4 mg m^{-3}.

The percentage organic weight of zooplankton varied between 38 and 83 % at station 1 and between 28 and 82 % at station 2 in the study area. A study carried out off the Angola, Namibia reported that the average organic weight of zooplankton ranged between 77 and 84 % (Harris *et al.,* 2000). Average organic weight of zooplankton at both stations was almost similar with the results off the Angola, Namibia (Harris *et al.,* 2000).

Among four different size groups, 200-500 µm size fraction was the dominant fraction in terms of both zooplankton abundance and biomass at station 1, while >1000 and 500-1000 µm size fractions were found in lower values. At station 2, >1000 µm and 200-500 µm size fractions were dominant in terms of zooplankton biomass, whereas 112-200 and 200-500 µm size fractions were dominant in zooplankton abundance. Dominancy of >1000 µm size fraction at station 2 came from appendicularia, chaetognaths, siphonophora, doliolid, and cladocera. 112-200 and 200-500 µm size fractions were mainly composed of copepoda and crustacea nauplii. Similar results were obtained in 200-500 µm size fraction in western Mediterranean by Champalbert (1996). He found that this size fraction was mainly composed of small crustaceans. Considering the abundance values, 112-200 µm size fraction is important in number, but its contribution to the total community in terms of biomass is small.

Copepods and crustacea nauplii were the most abundant zooplankton groups, followed by appendicularia, cladocera, pteropoda in the study area. These results are in accordance with studies performed in the Balearic Sea (Fernandez de Puellas

et al., 2003), the straits of the Cretan Arc (Gotsis- Skretas *et al*., 1999), the northern Aegean Sea (Zervoudaki *et al*., 2006) and the Aegean Sea (Siokou- Frongou *et al*., 2002). Champalbert (1996) noted similar standing stocks in the western and the eastern parts of the Mediterranean Sea, most species were found in both basins. Sommer, (2000) observed that the mesozooplankton (>200 μm) were dominated by nauplii and copepods, which together accounted for more than 73% of zooplankton composition in the Kiel Bight, Baltic Sea. The region with higher abundance of nauplii and copepodites indicates high reproduction rate of copepods stated by the Zervoudaki *et al*. (2006).

Among zooplanktonic groups cladocera, gastropoda larvae and pteropoda were found to be more abundant in the surface water than the entire water column at both stations. On the contrary, crustacea nauplii, polychaeta larvae, bivalvia larvae, chaetognatha, protozoa, ostracoda and doliolida were more abundant in the water column. Cladocera exceeded the number of copepods not in the total zooplankton abundance but in some size fractions in the study area at certain periods. Chaetognaths and ostracods were found in water column as previously reported in Rhodes island waters by Kimor and Wood (1975) and Siokou-Frangou and Pancucci-Papadopoulou (1988). Small organisms such as meroplanktonic larvae and crustacean nauplii were more abundant in the coastal waters, similar to the results of Gaudy *et al*. (2003) in the Gulf of Lions (northwestern Mediterranean). High numbers of cladocerans was observed by Siokou-Frangou (1996) in Sarokinos Gulf having neritic character and close to the sewage outfall and small pollutant sources. In Northeastern Aegean Sea, cladocerans abundance exceeded copepods in July (Isari *et al*., 2006), but generally, cladocera and copepoda comprised the largest part of the total zooplankton abundance. Cladocerans are found to be important group especially in the regions close to the land in these studies; therefore presence of high numbers of cladocerans indicates some coastal and local influence (Fernandez de Puellas *et al*., 2003). Presence of appendicularia and cladocerans is an important aspect for the carbon flux, because these two groups have high population growth rate and therefore contribute to a high carbon turnover (Hopcroft & Roff 1995; Rose *et al*. 2004).

5. Extended Summary

This study aimed to improve our knowledge on the seasonality of particulate organic matter and zooplankton abundance and biomass in the Turkish waters of the NE Mediterranean Sea. Furthermore, size fractionations were studied in order to understand relative importance of small and large sizes for each parameter, which are lack for the area.

The two stations performed in the study area have different water characteristics, one representing coastal and the other representing open water characteristics. The nearshore station has highly variable and complex water characteristics and exposed to different intensities of anthropogenic and land-related influences. However, the offshore station is more stable and shows oligotrophic character of the northeastern Mediterranean. Lamas River close to the nearshore station effected the concentrations of nutritional environment especially in March with high values. On the other hand, mixing processes due to the meteorological processes were an important factor in the high concentrations of nutrients in the offshore station. Therefore, the zooplankton inhabiting at these different areas was affected by changing environmental factors, in which they modified their feeding behaviour and reproductive pattern. Indeed, the parameters in terms of chl-a, POM and zooplankton abundance and biomass measured in the nearshore station were always much higher than the offshore station.

Size structure of the chl-a and particulate organic matter in the study area, is strongly dominated by the pico-particulate (0.7-2.7 μm) fraction, and so is different from that in more productive areas. This is followed by nano and micro fractions in the study area. Nano size fraction of chl-a became important in March at nearshore station, when high amounts of nutrients were introduced by Lamas river. The prt:cho ratio less than 1 at the two stations revealed that the studied area was under the nutrient limitation, and nutrient deficiency was severe especially for nano size farction. Dominancy of pico size fraction and prt:cho <1 are an indication of oligotrophy as found by other studies in the northeastern Mediterranean.

The data on the seasonal distribution of zooplankton abundance and biomass obtained in this study are in good agreement with the results cited in the literature. Zooplankton abundance varied during the sampling period, and they showed two

peak abundances, in spring and autumn, with small increase in summer. The high biomasses of zooplankton were observed in summer and in autumn in the water column, whereas in spring and autumn in the surface waters.

Particulate organic matter seemed to play a significant role in growth of zooplankton at nearshore station, while phytoplankton biomass appeared to be important in the zooplankton abundance in the area.

Copepods are always the dominant group among other zooplanktonic groups in the study area. This group is the most important group in determining the distribution of the total zooplankton in the area, by constituting about 65-75 % of the total zooplankton. Cladocera is another important group which becomes abundant under favorable conditions. Zooplankton groups have different distribution pattern in the water column. Cladocera, pteropods and gastropoda were more abundant in the surface waters. It could be related to the temperature and feeding preference of these groups.

Food size is an important factor shaping the trophic interactions in the marine ecosystems. Dominancy of pico size fraction in the particulate organic matter in the area showes that the microbial loop is dominated the system. Some of the meso-zooplanktonic organisms can feed directly on pico size particles, like cladocerans, appendicularians. However, copepods are the main zooplankton component in the study area and they can not feed directly on the pico size fractions. So they are forced to rely on protozoans that can consume pico size particles efficiently.

Among four different size fractions, 200-500 and 112-200 μm size fractions were dominant in zooplankton abundance in the study area. The most abundant two groups; copepods and crustacean nauplii are responsible for the dominancy of these size fractions. The organisms found in the water column at offshore station were much larger than those at the nearshore station. This was stated by the high contribution of >1000 μm size fraction biomass to the total zooplankton biomass at offshore station, while 200-500 μm size fraction contribution was high to the total zooplankton biomass at the nearshore station. This could be possible due to the existence of deep-living or migrating zooplankton individuals at the offshore station. Since, the vertical distribution and migration of zooplankton is related to the body length.

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