SPATIAL DISTRIBUTION, COMPOSITION AND DNA BARCODING OF ZOOPLANKTON IN THE SOUTHERN BLACK SEA (JULY 2013)

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Submitted by **İLAYDA DESTAN ÖZTÜRK** in partial fulfillment of the requirements for the degree of **Master of Science in Department of Marine Biology and Fisheries, Institute of Marine Sciences, Middle East Technical**

Prof. Dr. Ahmet Erkan Kıdeyş
Head of Institute, **Institute of Marine Sciences**

Prof. Dr. Zahit Uysal
Head of Department, **Marine Biology and Fisheries**

Prof. Dr. Ahmet Erkan Kıdeyş
Supervisor, **Marine Biology and Fisheries**

Examining Committee Members:

Prof. Dr. Ahmet Erkan Kıdeyş
Marine Biology and Fisheries Dept., METU

Prof. Dr. Zahit Uysal
Marine Biology and Fisheries Dept., METU

Assist. Prof. Dr. Bettina Fach Salihoğlu
Oceanography Dept., METU

University by,

Date: 10.09.2015

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

Name, Last name : İlayda Destan Öztürk

Signature :

ABSTRACT

SPATIAL DISTRIBUTION, COMPOSITION AND DNA BARCODING OF ZOOPLANKTON IN THE SOUTHERN BLACK SEA (JULY 2013)

Öztürk, İlayda Destan
M.Sc., Department of Marine Biology and Fisheries
Supervisor: Prof. Dr. Ahmet Erkan Kıdeyş

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Spatial distribution and composition of zooplankton was studied in the southern Black Sea at 46 stations in July 2013. The southern Black Sea was examined as three different study areas namely; western, central and eastern regions. Each region was also examined as inshore and offshore to determine the difference in zooplankton communities. Additionally a DNA barcoding study was also performed with samples collected from seven stations in the southern Black Sea to generate a gene library of zooplankton species of the Black Sea.

A total of 19 zooplankton species were identified at species level and a further 13 species at higher taxa levels.

The eastern region of the southern Black Sea displayed the lowest abundance values (average of 82,476 ind/m^2) of total zooplankton compared to the central (85,008 ind/m^2) and western Black Sea (average of 175,495 ind/m^2). 68% of the entire zooplankton community consisted of copepods, the dominant species being *Acartia clausi* (65%) in terms of abundance. Copepods were followed by *Noctiluca scintillans* (14%) and cladocerans (7%) in terms of abundance. The total absence of *N. scintillans* in the eastern region was striking in July 2013. Its abundance was rather high (39,495 ind/m^2) in the west decreasing towards the central southern Black Sea. Among cladoceran species *Penilia avirostris* was the most abundant (69%) for the entire southern Black Sea. Chaetognatha constituted 4% of the entire zooplankton community for the southern Black Sea in July 2013.

In terms of biomass, the central zone exhibited the lowest fodder zooplankton values (average of 4,882 mg/m^2) but the highest macro gelatinous organisms values (average of 581,329 mg/m^2). Despite higher abundance values in the west, the biomass values of fodder zooplankton were quite similar in western and eastern regions of the southern Black Sea, indicating the existence of larger individuals of fodder zooplankton in the eastern zone.

In this study DNA barcoding of many zooplankton species was obtained. It was found that DNA barcoding could help successful identification of 11 species of holo- and mero- zooplankton species.

Keywords: Southern Black Sea, zooplankton, DNA barcoding

ÖZ

GÜNEY KARADENİZ ZOOPLANKTON'UNUN MEKANSAL DAĞILIMI, KOMPOZİSYONU VE DNA BARKODLAMASI (TEMMUZ, 2013)

Öztürk, İlayda Destan
Yüksek Lisans, Deniz Biyolojisi ve Balıkçılık Bölümü
Tez Yöneticisi: Prof. Dr. Ahmet Erkan Kıdeyş

Eylül 2015, 253 sayfa

Zooplanktonun mekansal dağılımı ve kompozisyonu, Güney Karadeniz Bölgesi için 46 istasyonda 2013 yılının Temmuz ayı boyunca incelendi. Güney Karadeniz'in batı, orta ve doğu olmak üzere üç bölgesi ve bu üç bölgenin kıyı ve açık suları zooplankton komünitesindeki değişiklikleri görebilmek amacı ile ayrı ayrı araştırıldı. Ayrıca DNA barkodlama çalışması Güney Karadeniz'deki yedi istasyondan alınan örnekler ile, meroplanktonik bireylerin daha iyi tayin edilmesi ve Karadeniz zooplankton türlerinin gen bankasının oluşturulabilmesi için yapıldı.

2013 yılı Temmuz ayı boyunca yapılan bu çalışmada, toplamda 19 zooplankton tür seviyesinde ayırt edilirken, 13 grup tür seviyesinde ayırt edilemedi.

Güney Karadeniz'in doğu bölgesi (ortalama 82.476 birey/m^2) diğer bölgeler ile karşılaştırıldığına en düşük bolluk değerini sergiledi (orta bölge ortalama 85.008 birey/m^2 ve batı bölgesi ortalama 175.495 birey/m^2). Tüm komünitenin 68%'ini kopepodlar domine ederken, copepod türleri arasında bolluk bakımından en baskın tür *Acartia clausi* (65%), biyokütle bakımından en baskın tür ise *Calanus euxinus* (74%) olarak rapor edildi. Kopepodların *N. scintillans* (14%) ve kladoser türleri (7%) tarafından takip ettiği görüldü. 2013 yılı Temmuz ayında *Noctiluca scintillans* türünün doğu bölgede görülmemesi ilgi çekici idi. Batı bölgedeki bolluk değerinin (39, 495 ind/m^2) doğuya doğru azaldığı görüldü. Kladoser türleri arasından ise *Penilia avirostris* bolluk bakımından en baskın tür olarak rapor edildi. Güney

Karadeniz’in 2013 yılı Temmuz ayı zooplankton komünitesinin 4%’ünü ise *P. setosa*’nın oluşturduğu görüldü.

Güney Karadeniz’in orta bölgesinin biyokütle bakımından en yüksek jelimsi organizma değerlerini (ortalama 581.329 mg/m^2) sergilerken, besin zooplanktonunun en düşük (ortalama 4.882 mg/m^2) biyokütle değerini sergilediği rapor edildi. Batı bölgedeki yüksek bolluk değerine rağmen, batı ve doğu bölgelerdeki benzer besin zooplanktonu biyokütlesi, doğuda besin zooplanktonuna ait büyük bireylerin varlığına işaret ettiği gözlemlendi.

Bu çalışmada, birçok zooplankton türünün DNA barkodlama çalışması gerçekleştirdi. 11 holo ve meroplankton türünün tayininde DNA barkodlamanın başarılı sonuçlar verdiği görüldü.

Anahtar Kelimeler: Güney Karadeniz, zooplankton, DNA barkodlama

To My Family

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CHAPTER

1. INTRODUCTION

Zooplankton is one of the most important components of the marine ecosystem, and is also one of the most affected. Impacts of changes in the oceanographic characteristics effect the composition and structure of zooplankton. Due to the catastrophic conditions that the Black Sea ecosystem has experienced through the years (see 1.2), changes in the zooplankton have been clearly observed and studied by many researchers (see 1.3). Because of its key position in the marine ecosystem it is crucial to investigate the zooplankton to see the changes in structure, to understand the long-term variations and how they are related to the environmental parameters.

Studying zooplankton including larvae of meroplanktonic species by morphological identification requires much time, expertise and published data. Using DNA barcodes will accelerate analysis of species diversity of holo- and meroplankton in the Black Sea once a barcode library has been established and can help ensure timely recognition of shifts in species composition, richness and biogeographical distributions associated with environmental variability and climate change.

1.1 General characteristics of the Black Sea

With its limited size and almost complete enclosure, the Black Sea basin displays unique circulation characteristics and permanent stratification that divides the basin into upper aerobic and bottom anaerobic zones (Yunev *et al*., 2002). The Black Sea is located approximately between latitudes of 41° to 46°N and longitudes of 28° to 41.5°E. It is an elongated, nearly enclosed basin. The Black Sea’s surface area (420.000 km^2) is approximately 5 times smaller than the surface area of the Mediterranean. The Black Sea is a deep basin (maximum depth around 2200 m) with steep slopes in the order of 4-6°, and volume with 547,000 km^3 (Oğuz *et al.,* 2004).

The total Black Sea shoreline is about 4,340 km long while the Turkish coastline 1,400 km (Yunev *et al*., 2002). It contains narrow shelves and very strong topographic variations around its periphery. There is a one major shelf area in the northwestern part of this inland sea, comprising 27 % of the total area of the Black Sea (Niermann *et al*., 1999), with discharges from three of Europe's largest rivers, namely; Danube, Dniepr and Dniestr (Oğuz *et al*., 2004). Especially in the southeastern region of the Black Sea the shelf areas are very narrow.

The Black Sea communicates with the Aegean basin of the Mediterranean Sea through the Sea of Marmara and the Bosphorus and Dardanelles Straits in the southwestern end (Oğuz *et al*., 2004). The Kerch Strait connects the Black Sea to the Sea of Azov, which is a shallow channel about 45 kilometers (km) long in the north.

The Bosphorus Strait is a 31 km long channel, which is narrow, elongated, and shallow. Its width is around 1.3 km at the surface and varies between 0.7 and 3.5 km. The width becomes narrower at the bottom of the channel to an average of 500 m at a depth of 50 m. In this strait, the depth range is between 30 to 100 m with an average of 50 m along the central section of the channel (Zaitsev and Mamaev, 1997).

Major components for Black Sea water budget are precipitation, evaporation and river runoff (also exchange through the Bosphorus and the Kerch Straits. There is a net outflow from the Black Sea to the Bosphorus. The sum of fluxes due to precipitation (~300 km^3 yr^{-1}) and runoff (~350 km^3 yr^{-1}) exceeds that of evaporation (~350 km^3 yr^{-1}) (Unluata *et al*., (1989) (see also Ozsoy and Unluata, 1997). The difference between the transports of its two layers in the Bosphorus is the net outflow of the freshwater (300 km^3 yr^{-1}) from the Black Sea through the Bosphorus (Oğuz *et al*., 2004). In the open sea the maximum temperature above the thermocline is 27°C in summer and vary between 23-25°C while, the winter temperatures vary between 5-7°C.

In winter, in response to strong atmospheric cooling, evaporation and intensified wind mixing associated with a succession of strong, cold and dry continental wind events the northwestern shelf and near-surface levels on top of the thermohaline domes of the cyclonic cell exhibit vertically uniform conditions. The upper layer of the Black Sea is identified by T~5–6°C, S~18.5– 18.8 and s_t~14.5 kg m^{-3} and homogenized up to ~50 m depth, is (Oguz *et al.*, 1990b; Krivosheya *et al.*, 2002). The convectively generated cold water remains confined below the seasonal thermocline, and forms the CIL of the thermohaline structure, as the spring warming stratifies the surface water. The depths less than 20 m (the summer mixed layer) have typical characteristics of T~25°C, S~18 and s_t ~10.0–11.0 kg m^{-3} (Oğuz *et al.*, 2004).

The Mediterranean underflow enters the shelf with T~12-13 °C and S~28-30 while normally characterized typically by T~13-14 °C and S~35-36. Bosporus modifies the Mediterranean water considerably by mixing with the upper layer waters (Oğuz *et al*, 2004). It is diluted by entrainment of relatively colder and less saline CIL waters and is barely distinguished by its slight temperature and salinity differences from the ambient shelf waters up on issuing the shelf break, as it spreads out as a thin layer along the bottom (Oğuz *et al.*, 2004). At intermediate depths (150-250 m) the modified Mediterranean water is then injected in the form of thin multiple layers (Hiscock and Millero, 2006; Glazer *et al.*, 2006). Within the interior parts of the basin, signature of the Mediterranean inflow can be best monitored up to 500 m, where the residence time of the sinking plume varies from ~10 years at 100 m depth to ~400 years (Ivanov and Samodurov, 2001; Lee *et al.*, 2002).

In depth of 80-160 m a permanent halocline exists (Tuğrul *et al.*, 1992). The salinity varies between S=18- 18.5 ppt above the halocline, in the central Black Sea, while it drops below S=16 ppt in near shore areas in the western Black Sea due to the influence of the river Danube (Oğuz *et al.*, 1993). The intermediate and deep-water masses below a permanent halocline (at depths of 100–150 m) displays almost vertically uniform characteristics defined by T~9° C, S~22, s_t~17.0 kg m^{-3} (Murray *et al.*, 1991).

The volume of the 0- 200 m layer contains dissolved oxygen, which making up slightly more than 13% of the total sea volume (Zaitsev, 1992).

Due to the geothermal heat flux of about 40 W m^{-2} from the bottom, the deepest part of the water column that covers the entire abyssal plain of the sea, approximately below 1700m, involves a vertically homogeneous and horizontally uniform water mass formed during several thousands of years by convective mixing (Murray *et al.*, 1991).

In the Black Sea, characteristics of the upper layer waters are predominantly cyclonic, strongly time-dependent and spatially structured basin-wide (Oğuz *et al.*, 2004).

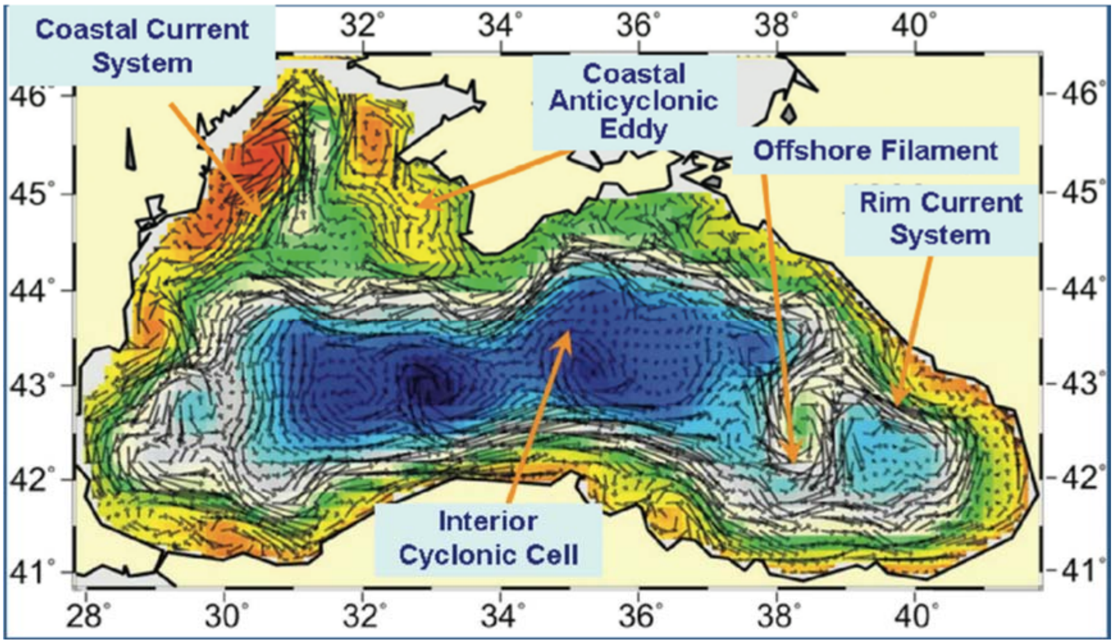
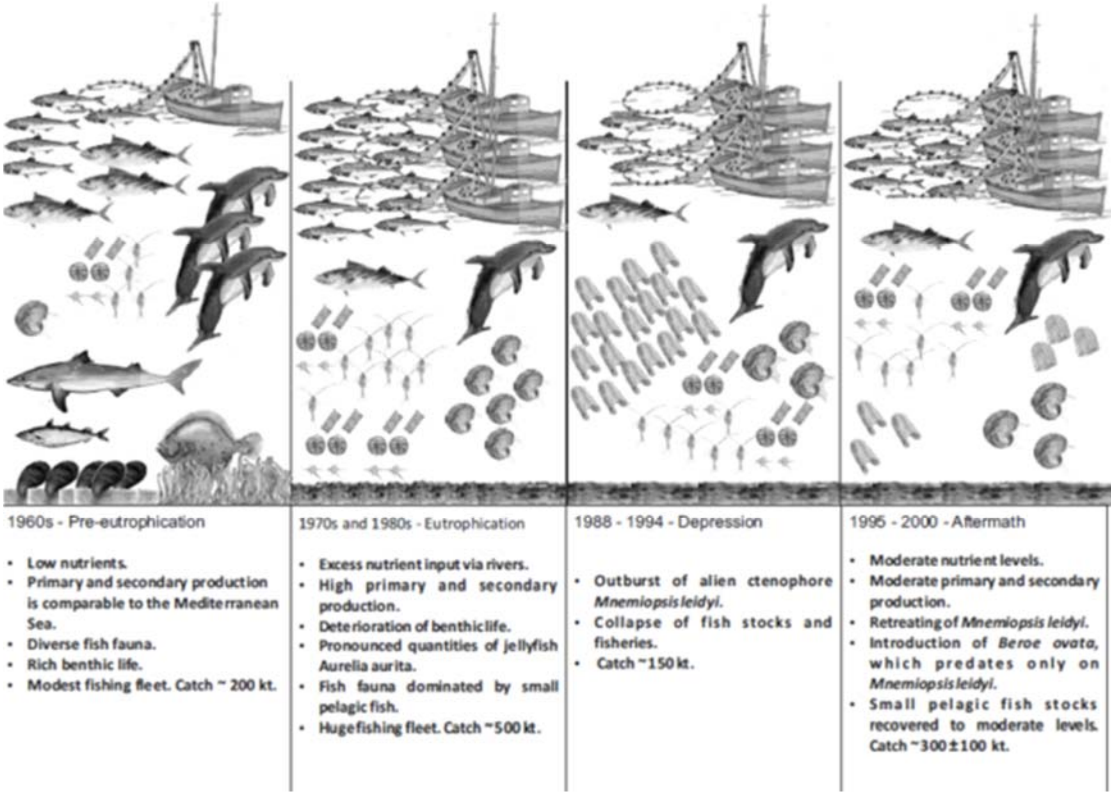


Figure 1 Upper layer circulation system of Black Sea (Korotaev *et al.*, 2003).

The rim current that cyclonically meandering, constituted the unique circulation feature of the Black Sea (Oğuz *et al.*, 2004). Interior part of the rim current constituted by two separate cyclonic cells namely; Western Gyre and Eastern Gyre. Mesoscale anticyclonic eddies are distributed between the rim current and at the coast (see Figure 1). Two of them are the most persistent eddies, the Batumi and the Sevastopol Eddies. From early summer to early fall eddy-induced upwelling occurs along the central part of the Anatolian coast.

1.2 Changes in the ecosystem characteristics of the Black Sea since the 1970s and their impact on zooplankton

During the past four decades, various human impacts and environmental conditions led to major changes in the structure and functioning of the ecosystem of the Black Sea. Kideys *et al*. (2000) stated several adverse events due to these changes. Increase in number and peak abundance of phytoplankton blooms including several red-tide events, modification of the phytoplankton composition in favor of flagellates, decreased oxygen concentration and expansion of hypoxia, reduced transparency of the water column, a decrease in non-gelatinous zooplankton, mass mortality among the entire benthos, demersal and pelagic fish populations, and decrease in overall biodiversity were the changes observed during the 1970s, 1980s and 1990s in the Black Sea. Changes in the Black Sea ecosystem between the 1960's and 2000's illustrated by Akoğlu (2014) are presented in Figure 2.



1960s - Pre-eutrophication

- Low nutrients.
- Primary and secondary production is comparable to the Mediterranean Sea.
- Diverse fish fauna.
- Rich benthic life.
- Modest fishing fleet. Catch ~ 200 kt.

1970s and 1980s - Eutrophication

- Excess nutrient input via rivers.
- High primary and secondary production.
- Deterioration of benthic life.
- Pronounced quantities of jellyfish Aurelia aurita.
- Fish fauna dominated by small pelagic fish.
- Huge fishing fleet. Catch ~500 kt.

1988 - 1994 - Depression

- Outburst of alien ctenophore *Mnemiopsis leidyi*.
- Collapse of fish stocks and fisheries.
- Catch ~150 kt.

1995 - 2000 - Aftermath

- Moderate nutrient levels.
- Moderate primary and secondary production.
- Retreating of *Mnemiopsis leidyi*.
- Introduction of *Beroe ovata*, which predates only on *Mnemiopsis leidyi*.
- Small pelagic fish stocks recovered to moderate levels. Catch ~300±100 kt.

Figure 2 Four phases of Black Sea ecosystem (pelagic-benthic) during 1960-2000 (Akoğlu, E., 2014)

During the agricultural revolution in Iron Curtain countries increased nutrient input via the major rivers resulted in strong eutrophication of the shallow northwestern/northern Black Sea in the 1970’s and 1980’s, (Kideys *et al*., 2000). Negative effects of increased eutrophication on the coastal ecosystem of the Black Sea has been reported by Tolmazin (1985); Bologa (1986); Chirea and Gomoiu (1986); Mee (1992); Tugrul *et al*. (1992); Saydam *et al*. (1993); Zaitsev (1993); Cociasu *et al*. (1996); Zaitsev and Aleksandrov (1997); Petranu *et al*. (1999) (Yunev *et al*., 2002).

According to Moncheva *et al*. (2000), the concentration of inorganic phosphorus and nitrogen measured at the mouth of the Danube increased from 0.3 µM and 1.6 µM, respectively, which was 6.4 µM between 1960s and1970s and 13.6 µM during 1976–1980.

Changes in the phytoplankton annual cycle stated by Oğuz *et al*. (2004), while the annuals cycle has 2 maxima (spring and autumn), it has been replaced by a pattern characteristics of eutrophicated waters identified by several exceptional maxima- the summer one being the most pronounced. At a lower trophic level, changes in the phytoplankton community and cycle effected zooplankton community and structure and also caused a decrease in non-gelatinous zooplankton.

Even though increased primary production resulted by producing higher mesozooplankton and fish stocks during the second half of the 1970’s and early 1980’s at first (Porumb, 1989), populations of many zooplankton species have become sparse or have even disappeared in NWS waters since the beginning of the phytoplankton blooming. Populations of the copepods *Calanus helgolandicus, Pseudocalanus elongatus, Paracalanus parvus, Centropages kroyeri, Pontella mediterranea*, and the cladoceran *Penilia avirostris* were effected (Zaitsev, 1992). Since the mid 1960’s Kovalev *et al.* (1998) observed that the biomass of other copepod species has decreased and indeed some (such as *Oithona nana*) have disappeared completely from the zooplankton community, while *Acartia clausi* (a species which prefers eutrophic conditions) became the most dominant copepod during the 1990’s forming up to 85% of total fodder zooplankton biomass in the shelf areas of the Black Sea. By the 1990's only six marine copepod species remained in Sevastopol Bay, while it was 13 in 1976.

Zaitsev (1992) stated that as a general rule, smaller species changed place with many large species of crustacean plankton and this resulted with increased numbers of species with mixed plant and animal diets, such as *Acartia clausi* and Oithona *minuta*. Konsulov and Kamburska (1998); Eker *et al*. (1999); Erkan and Gücü (2000) reported small and less commercially valuable species took the place of many dominant mesozooplankton species which support the fish stocks.

Due to their consumption by opportunistic species such as *Noctiluca scintillans*, *Aurelia aurita, Pleurobrachia rhodopis* and *Mnemiopsis leidyi,* total mesozooplankton biomass decreased around five-fold by the mid-1980s (Oğuz *et al*., 2004). "The total abundance of these new organisms reached 99% of the total zooplankton wet weight" (Kovalev *et al*., 1998; Shiganova, 1998; Kideys and Romanova, 2001).

Due to large amounts of phytoplankton, detritus, *Noctiluca*, jellyfish, ctenophores, and other suspended organisms and particles the transparency of water in the Black Sea has decreased significantly. Moreover, due to decreased oxygen concentrations in the near-bottom water layer the bottom fauna of the NWS underwent great changes. For a unit area of sea bottom surface more phytoplankton deposited during changes which resulted in higher amount of oxygen spent on the decomposition of this organic matter, and on the shelf regions of hypoxia and anoxia began to appear, at the end of the 1960s became a wide-scale phenomenon (Zaitsev, 1992). Only some polychaetes, nematodes, and other representatives of meiofauna could survive in these areas but bottom and near-bottom invertebrates and fishes fell victim to hypoxic conditions (Vorobyova, 1985). In the shelf area about 100-200 tonnes of benthic organisms (about 10% of this number included fish, both juveniles and adults) per km^2 died from hypoxia (Zaitsev, 1992).

Anninsky *et al*. (2013) stated that "Predatory gelatinous macroplankton is the main competitor of small pelagic fishes and consumer of their eggs in marine ecosystems.". As outbreaks of medusa and ctenophore negatively affecting the entire trophic levels in the pelagic zone it also lead to changes in the species composition and abundance of the zooplankton (Anninsky *et al*., 2013). All the unfavorable ecological situations such as eutrophication, overfishing, hypoxic and anoxic conditions became worse by the coincident invasion of an exotic ctenophore, *Mnemiopsis leidyi*, and there was a severe collapse in fisheries (Daskalov, 2002).

In the late 1980s, *Mnemiopsis leidyi,* a newly introduced species, appeared in the Black Sea in huge quantities (Kideys, 2002). According to Vinogradov (1990), a biomass of about 800 million tons wet weight of *M. leidyi* was estimated for the entire Black Sea in the autumn of 1989. Its appearance resulted with sudden decline in fish stocks thus many authors focused on possible predation by *M. leidyi* on pelagic eggs and larvae and sought correspondence with the collapse of the fisheries experienced in 1989 (Vinogradov, 1990; Zaika, 1992). The total catch of the Black Sea countries decreased by two-three fold, varied from to 363 and 284 thousand tons, respectively in 1990 and 1991 while, it was varied from 746 to 926 thousand tons in 1980–1988 (Lisovenko *et al*., 1997; Zaydiner and Popova, 1997).

According to Kideys (2002), the appearance of a predator of *Mnemiopsis* in 1997, the ctenophore *Beroe ovata* helped the ecosystem to recover. *B. ovata*'s existence resulted with precipitous decrease in the year-around abundance (apart from a brief peak in late summer) of *Mnemiopsis* (Finenko *et al*., 2001). *Beroe* itself almost disappeared from the water column of the Black Sea after the decline in *Mnemiopsis* which, indicating *Beroe*'s dependence on *Mnemiopsis* as a food supply (Kideys, 2002). Huge decline in *Mnemiopsis*'s population led to increases in nongelatinous zooplankton, anchovy landings (Kideys *et al*., 2000), egg densities of anchovy (Kideys *et al*., 1999), as well as increases in the biomass of two native gelatinous cnidarians (*Rhizostoma pulmo* and *Aurelia aurita*) (Kideys, 2002).

According to Oğuz *et al*. (2004), the intense winter cooling and reduction of the sea surface temperatures down to 5°C (unfavorable for survival of *Mnemiopsis*) was one of the main factors for reduction in the *Mnemiopsis* biomass during the 1992–1993 period. Kideys and Romanova (2001) stated that the gelatinous macrozooplankton community no longer reached a level critically competing for food with pelagic fish groups after 1993. Increase in fish stocks and reappearance of some zooplankton species (e.g. *Oithona nana, Parasagitta setosa*) characterized by some positive sign of recovery between 1993 and 1995 period (Oğuz *et al.*, 2004).

After the mid-1990s the Black Sea has been impacted by the adverse effects of climatic warming, which led to low nutrient levels in the surface layer and a subsequent decrease in phytoplankton abundance. Due to limited resource availability, all higher trophic levels have become less productive. The decline of *Mnemiopsis*, however, helped small pelagic fish to recover (Philippart *et al.*, 2014).

According to Oguz and Cokacar (2003), due to climate-induced warming that took place after 1993, these changes were shown to be triggered by the changes in the physical structure of the Black Sea.

During mid-1990s the timing of the climatic signal coincided with abrupt increases in the sea level rise and the net annual mean fresh water flux, as a consequence of the decadal scale climatic oscillations over the North Atlantic (Stanev and Peneva, 2002).

These changes are still affecting the entire marine ecosystem in the Black Sea such as composition, and in recent years many studies are carried out to understand these ongoing rapid changes.

1.3 Previous zooplankton studies in the Black Sea and in its southern part in particular and long term variations in the zooplankton

Due to the anthropogenic and environmental changes that the Black Sea experienced, zooplankton was the one of the most affected components thorough the years. Many investigations were done to understand the impacts of these changes on the fluctuation of the zooplankton communities. These investigations of zooplankton started in the mid-19th century by Ukranian scientists and followed by scientists from many institutes, namely; Ukraine- Karadag Reservation -Odessa branch of IBSS (Institute of Biology of Southern Seas), Southern Scientific Research Institute of Marine Fishery and Oceanography, Kerch Russia, -All-Russian Institute of Marine

Fishery and Oceanography, Moscow, Shirshov, Institute of Oceanology in Moscow and its Southern Department, in Gelendzhik - Biological Station of Krasnadar Univ, Novorossiysk. Georgia - Batumi Fisheries Station, Turkey - Institute of Marine Sciences and Geography İstanbul University, -Institute of Marine Sciences (IMS-METU), Erdemli/İçel, -Institute of Marine Sciences and Technology, İzmir, Bulgaria-Research Institute of Fisheries, Varna, - Institute of Oceanography, Varna, - Laboratory of Marine chemistry in Bourgas, Romania-Romanian Marine Research Institute, Constanza (Kovalev *et al*., 1999). At first (about 160 years ago) studies began with species descriptions (Kideys *et al*., 2000) and continued with more detailed and wider taxonomic studies such as meroplanktonic larvae (Kiseleva, 1957; Petran, 1980; Murina, 1993 and others), and the holoplanktonic larvae of copepoda were studied by Sazhina (1960, 1985). Results of all these taxonomic analyses are summarized in “Guidebook for the Marine Fauna of the Black Sea and Sea of Azov” (Dolgopolskaya *et al*., 1969). Taxonomic studies continued as focusing on feeding, growth, reproduction and other physiological parameters of zooplankton communities or species (Delalo, 1961; Petipa *et al*., 1970; Greze *et al*., 1971) and their temporal and spatial distributions were studied (Vinogradov *et al*., 1985; Konsulov, 1986, 1990) to understand the functioning of the ecosystem (Kideys *et al*., 2000).

Between 1991-1996, collaboration among the riparian countries, joint projects focused on long-term changes in zooplankton composition due to anthropogenic factors resulted in many studies (e.g. Konsulov and Kamburska, 1997; Niermann and Greve, 1997; Niermann *et al*., 1998; Shiganova, 1997, 1998; Shiganova *et al*., 1998; Kovalev *et al*., 1998a, b, c, d,) published in English, which provided knowledge about Black Sea zooplankton (Kideys *et al*., 2000).

To describe features of the horizontal and vertical distribution of zooplankton, quantitative studies have also been carried out in regions with different pollution and eutrophication levels (Zaitsev, 1993; Konsulov, 1993; Vinogradov *et al*., 1985; Polischuk *et al*., 1984; Koval, 1984; Kovalev, 1980; Petran, 1985; Porumb, 1992). Nikitin (1945), Kusmorskaya (1950), Petipa *et al*. (1963), Dimov (1960, 1966), Zogorodnyaya (1988), Koval (1984), Mashtakova (1985), Nikitin (1949), Petran and Moldoveanu (1997) studied the larger-scale horizontal and vertical distributions of zooplankton in the Black Sea (Kovalev *et al.*, 1999).

The food of higher trophic levels between the zooplankton groups, called fodder zooplankton, have a great importance, while feeding on primary producers, they filter suspended matter thus improving the water quality. Studies focused on fodder zooplankton are Konsulov and Kamburska, 1997; Niermann and Greve, 1997; Niermann *et al.*, 1998; Shiganova, 1997, 1998; Shiganova *et al.*, 1998; Kovalev *et al.*, 1998c, d) (Kideys *et al.*, 2000). Most of these studies were concentrated on copepods. While the taxonomic studies were done on copepods (Chichkoff, 1912; Dolgopolskaya, 1940; Galadzhiev, 1948; Karavaev, 1894; Klyucharev, 1952; Krichagin, 1873; Potemkina, 1940; Ulomskiy, 1940) at the end of the 19th and beginning of the 20th centuries (Gubanova *et al.*, 2014), impacts of previously mentioned dramatic changes were seen in plankton diversity, both in general as well as in the copepod community (Altukhov and Gubanova, 2006; Kamburska *et al.*, 2003). Due to the intensive anthropogenic and environmental impacts, serious changes were revealed in the copepod community (Belmonte *et al.*, 1994; Gubanova *et al.*, 2002). According to Kovalev *et al.* (1976) and Pavlova (1965), about 15 Mediterranean species were observed in the Black Sea, mostly near the Bosphorus during the 1960's. One of the reasons causing changes in the zooplankton biodiversity and one of the most important processes in the enrichment of Black Sea biodiversity was Mediterraneanization (transported by the lower Bosphorus flow through the Bosphorus Strait). Mordukhay-Boltovskoy (1972) and Zaika (2000) reported that species biodiversity of the Mediterranean is 3.5-4 times greater than the Black Sea. Studies for Mediterraneanization first began in the 1960`s (Bogdanova and Shmeleva, 1967; Porumb 1980 and Kovalev *et al.*, 1984, 1988, 1998, 1999).

One of the most affective anthropogenic impacts on the Black Sea zooplankton was the introduction of invasive ctenophore *Mnemiopsis leidyi* (which is according to Boxshall (2007) and Oğuz and Öztürk (2011) considered as one of the most catastrophic invasions known to date) (Gubanova *et al.*, 2014).

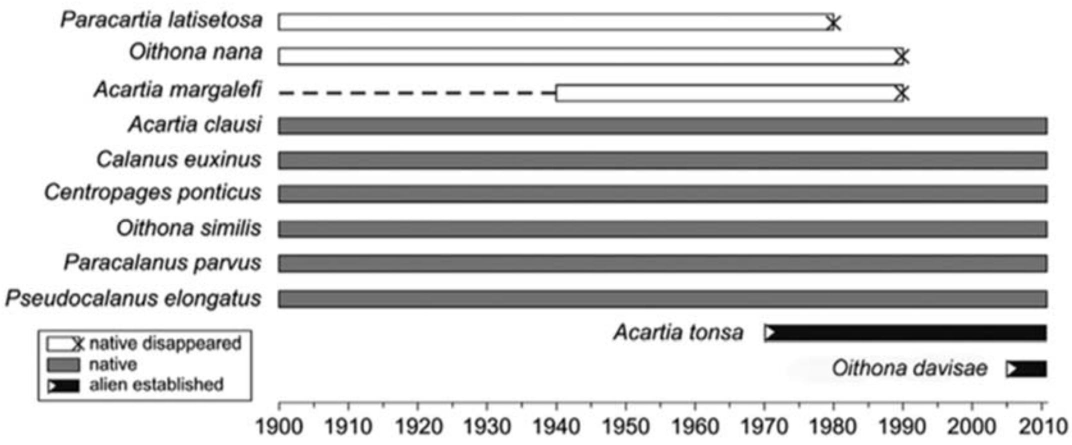


Figure 3 Changes in the species composition of the common copepod species of the Black Sea fauna from the beginning of the 20th century to present (Gubanova *et al*., 2014)

According to Figure 3, presented by Gubanova *et al*. (2014), between the 1980's and 1990's three copepod species disappeared, between the 1970's and 2000's two alien species were established, and the number of marine planktonic copepod species in the Black Sea remained almost the same as at the beginning of the 20th century. The most common and native copepod species in the Black Sea are *C. euxinus, Paracalanus parvus, Pseudocalanus elongatus, Centropages ponticus, A. clausi*, and *Oithona similis. A. tonsa* and *O. davisae* have enriched the assemblage of abundant copepod species of neritic zones, and individuals of Pontellidae (species that highly sensitive to pollution) are rare in the Black Sea (Gubanova *et al*., 2014).

Kideys *et al*. (2000) indicated long-term variation of fodder zooplankton have an increasing trend in the biomass of fodder zooplankton as a result of phytoplankton biomass in the deep eastern region of the Black Sea. According to Mee (1992), Zaitsev (1992), Kideys (1994) and Bologa *et al*. (1995) the reason of the decreasing trend seen in the fodder zooplankton of the coastal zone of the western Black Sea was worsening ecological conditions. Harmful levels of pollution and increasing eutrophication, which consequently result in an increase in the biomass of gelatinous organisms, can be among these conditions (Kideys *et al*., 2000)

In the last decade, Turkish scientists carried out many studies in the southern Black Sea in particular. Tarkan *et al*. (2005) and Işinibilir *et al*. (2011) studied abundance, biomass, and spatial and vertical structure of dominant mesozooplankton species in the northern part of the Bophorus to understand the exchange of the species. They also carried out experiments on salinity tolerance to determine the factors causing mortality. Beşiktepe (2001) reported the abundance diel vertical distribution and grazing pressure of common copepods in the southwestern part of Black Sea. Bat *et al*. (2007) studied abundance, biomass and species composition of zooplankton in the Sinop region of the southern Black Sea between 1990-2000. In the Sinop region the seasonality of zooplankton and seasonal mesozooplankton structure were evaluated by Üstün *et al*. (2007) and Ünal (2002). In the Samsun region, distribution and abundance of copepod species of coastal waters studied by Deniz and Gönülol (2014). Özdemir and Ak (2012) studied the seasonal qualitative and quantitative changes of zooplankton in the Trabzon region. Also in this region, Yıldız and Feyzioğlu (2014) defined the changes in the seasonal structure of mesozooplankton throughout the years in the coastal ecosystem and presented annual zooplankton abundance, diversity, species composition and differences between the southeastern and the southwestern Black Sea in terms of species composition from 1999 to 2006. Feyzioğlu and Sivri (2003) reported the seasonal variations of *Noctiluca scintillans* in the coastal waters of Trabzon between 1999 and 2000. Kopuz *et al*. (2014) used complementary environmental and meteorological data to understand the mechanisms that triggered the *Noctiluca scintillans* bloom, which was reported in the coastal waters of the Rize region in April 2011 and persisted for three days.

Satılmış *et al*. (2003, 2006 and 2014) evaluated the seasonal changes in the species composition, richness, diversity and distribution fish eggs and larvae and changes in the abundance gelatinous organisms in the Sinop region.

Studies focused on gelatinous zooplankton presented by Tunçer (1990), Mutlu *et al*. (1994), Mutlu and Bingel (1999), Mutlu (2001), Mutlu (2007), Kideys and Romanova (2001), Ünal (2002) and Bat *et al*. (2009) have reported spatial distribution, abundance and biomass, diameter distribution and morphometry, stomach contents, occurrence of parasites, abundance in relation to the abundance of other zooplankton species and reproduction period. Kideys and Romanova (2001) presented the results of seven cruises to evaluate the inter-annual changes in biomass, abundance levels of these gelatinous species in the southern Black Sea, including both vertical and horizontal distributions during 1996-1999.

1.4 DNA barcoding of zooplankton

"DNA barcoding is a novel system designed to provide rapid, accurate, and automatable species identifications by using short, standardized gene regions as internal species tags" (Hebert and Gregory, 2005). Specific DNA sequence from a standardized part of the genome can be used to differentiate organisms at a species level (Hebert *et al*., 2003). This DNA sequence is called as a barcode and for animal species generally Cytochrome C Oxidase 1 (COI) gene is used for this purpose.

For eukaryotic cells, DNA is located in the nucleus, and into the cytoplasm of prokaryotic cells. Furthermore, inside of some organelles such as mitochondria and chloroplast their own DNA molecule is located (Russell, 2001). Cells must be disrupted by physical or chemical methods, depending on the cell type and the expected DNA quality to extract the DNA from a cell or organelle. After the unwanted parts of the cell washed away, eluted DNA must be stored in a proper solution (Butler, 2011).

By using the pre-designed primers, polymerase chain reaction (PCR- an enzymatic reaction to produce millions of copies of specific sequences between two segments of template DNA) is performed to obtain the COI sequence from the mixture of genomic and mitochondrial DNA. By using the two short oligonucleotides called primers (complementary sequences for both sense and antisense strand of the DNA) the wanted region of the DNA is determined. Template DNA first heated enough to be single stranded, then temperature is decreased to let the primers bind their complementary sequences and finally the temperature is adjusted to the optimum for DNA polymerase enzyme to synthesize the new strand. This cycle repeats 30-50 times depending on the reaction quality. The number of the specific DNA sequence would be doubled after each of these cycles and this process called as DNA amplification (Dennis *et al*., 2006).

DNA sequencing gives precise knowledge about the order of the nucleotides in a DNA molecule. Making species identification is only possible by knowing the sequence of a barcode gene. The Chain-termination sequencing method was used in this research (Akeson *et al*., 2001). This method includes modifies nucleic acids to terminate the reaction to the classic polymerase chain reaction. Sequence data would be obtained by aligned the terminated sequence with electrophoresis (Work *et al*., 1983). Bioinformatics tools should be used to obtain useful results from the raw sequence data. At first, according to their quality score, sequence chromatograms must be cleaned up. Later on, by using a BLAST tool on the NCBI nucleotide database the clean sequence data should checked to find a match with a specific species. To proclaim the organism's species the similarity match should be higher than 97%.

1.5 Importance and purpose of the present study

The research undertaken for this thesis is important from several aspects. Due to the difficulties in financing cruises that provide samples from the entire Turkish Exclusive Economic Zone, studies which cover the mesozooplankton distribution for the whole southern Black Sea in a specific time period are rare. This study investigates samples from one cruise and 46 stations including samples from west to east and from inshore to offshore waters of the southern Black Sea.

Moreover, this study includes detailed taxonomic analyses of all groups of mesozooplankton (copepods, cladocerans, chaetognatha, appendicularia, *Noctiluca*, meroplankton and other mesozooplankton) and gelatinous zooplankton. This study details the distribution of these groups in the southern Black Sea not just at species level but also determines the developmental stage and size levels for certain groups in July 2013.

In this thesis, DNA barcoding of Black Sea zooplankton was studied for the first time in the southern Black Sea and provides accurate taxonomic information for the groups with difficult morphological characteristics for identification such as bivalvia and gastropoda. In addition to accurate identification, DNA barcoding of the zooplankton of the southern Black Sea provides a gene library.

The purposes of this study are as follows:

- To evaluate the abundance, biomass, species composition (stage and size frequencies for certain species) and spatial distribution of zooplankton species in July 2013 in the southern Black Sea (the area of the Turkish EEZ). Analyses to understand the differences in their distributions were carried out for fodder zooplankton, meroplankton, holoplankton, *N. scintillans* and gelatinous zooplankton.

- Comparison of the 3 different regions in the southern Black Sea namely; western, central and eastern to understand the differences in abundance, biomass, species composition (stage and size frequencies for certain species) and distribution of zooplankton species.

- Comparison of the inshore and offshore waters of the southern Black Sea in general in the three specified regions (western, central and eastern)in particular, to understand the differences in distribution for species and developmental stages.

-Evaluation of mesozooplankton with respect to the long-term changes in the Black Sea ecosystem.

-Molecular analyses for accurate taxonomic identification were performed by DNA barcoding to produce a gene library for marine planktonic organisms in the Black Sea. The result enables easier taxonomic identification for the Bivalve and Gasropod families, which are difficult to identify at the species level Creating a gene library for marine planktonic organisms in the Black Sea provides an easier, detailed and accurate identification of these species.

2. MATERIALS AND METHODS

2.1 Study Area and Sampling

The data presented in this study were obtained by R/V “Bilim 2” (Institute of Marine Sciences, Middle East Technical University, Turkey) from the southern Black Sea (Turkish Exclusive Economic Zone). The cruise was done between 12 July -25 July 2013. This cruise started with the joint project of Perseus (Perseus info at http://www.perseus-net.eu/site/content.php?locale=1&sel=402) (BSEX cruise) and continued with the project on anchovy larvae-egg survey (Anchovy project TUBITAK – KAMAG 110G124: Stock Assessment of Black Sea Anchovy Using Acoustic Method and Establishing a Monitoring Model for National Fisheries Data Collection Program: To observe anchovy stocks for fisheries management). During the cruise the data were collected from 46 different stations. These stations were defined with ecological properties of the study area. Information for each station is presented in Table 1 and these stations are shown in Figure 4.

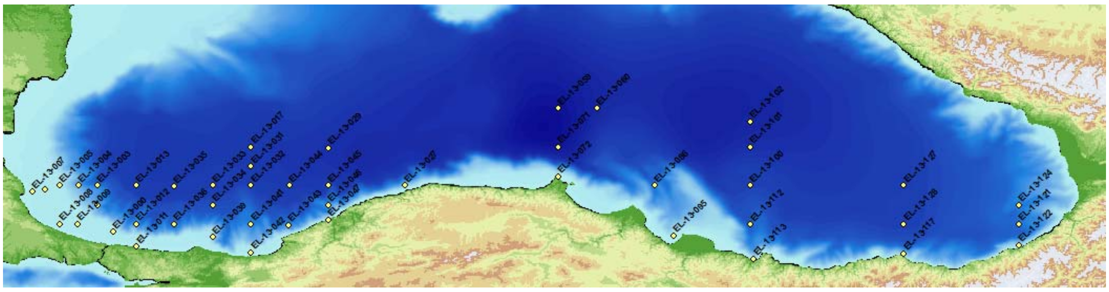


Figure 4 46 Sampling stations in the southern Black Sea in July 2013

Table 1 Information on 46 sampling stations of the present study in the southern Black Sea in July 2013

No	Station Name	Date	Time	Lat	Lon	Total Depth (m)	Haul Depth (m)	Position
1	EL-13-000	12.07.13	22:00	41,4	29,2	95	90	Inshore
2	EL-13-002	12.07.13	02:40	41,75	29	990	120	
3	EL-13-003	13.07.13	05:20	42	29	1330	178	
4	EL-13-004	13.07.13	07:20	42	28,75	778	192	Offshore
5	EL-13-005	13.07.13	10:05	42	28,5	94	80	
6	EL-13-006	13.07.13	11:45	41,95	28,32	70	65	
7	EL-13-007	13.07.13	13:30	41,92	28,15	77	70	
8	EL-13-008	13.07.13	17:30	41,5	28,5	79	76	
9	EL-13-009	13.07.13	19:25	41,5	28,74	83	75	Inshore
10	EL-13-011	13.07.13	00:45	41,21	29,5	36	30	
11	EL-13-012	14.07.13	05:30	41,5	29,5	840	166	
12	EL-13-013	14.07.13	10:10	42	29,5	2084	125	Offshore
13	EL-13-017	14.07.13	22:00	42,5	31	2068	110	
14	EL-13-027	16.07.13	07:30	42	33	340	156	
15	EL-13-029	16.07.13	20:00	42,49	32	2195	119	Offshore
16	EL-13-031	17.07.13	03:40	42,25	31	2142	107	
17	EL-13-032	17.07.13	06:10	42	31	2045	120	Offshore
18	EL-13-033	17.07.13	09:20	42	30,5	2020	115	
19	EL-13-034	17.07.13	12:15	41,75	30,5	1869	114	
20	EL-13-035	17.07.13	17:00	41,99	30	2085	120	
21	EL-13-036	17.07.13	22:00	41,5	30	1160	167	
22	EL-13-039	18.07.13	06:10	41,33	30,5	109	105	
23	EL-13-041	18.07.13	11:20	41,5	31	1310	160	
24	EL-13-042	18.07.13	15:05	41,13	31	67	60	Inshore
25	EL-13-043	18.07.13	20:15	41,49	31,49	1524	150	

26	EL-13-044	18.07.13	00:50	42	31,5	2108	125	
27	EL-13-045	19.07.13	05:20	42	32	2107	130	
28	EL-13-046	19.07.13	08:00	41,75	32	973	135	
29	EL-13-047	19.07.13	10:10	41,56	32	222	100	Inshore
30	EL-13-059	21.07.13	08:45	43	35	2198	112	Offshore
31	EL-13-060	21.07.13	11:40	43	35,5	2200	108	
32	EL-13-071	23.07.13	06:00	42,5	35	2169	133	
33	EL-13-072	23.07.13	09:30	42,12	35	71	65	Inshore
34	EL-13-086	25.07.13	04:00	42	36,25	887	133	
35	EL-13-095	25.07.13	14:45	41,35	36,5	60	56	
36	EL-13-100	26.07.13	05:40	42	37,5	1951	128	
37	EL-13-101	26.07.13	10:00	42,5	37,5	2142	132	
38	EL-13-102	26.07.13	13:30	42,83	37,5	2154	117	Offshore
39	EL-13-112	27.07.13	01:30	41,5	37,5	1791	175	
40	EL-13-113	28.07.13	05:50	41,05	37,54	509	155	Inshore
41	EL-13-117	28.07.13	18:50	41,12	39,5	570	163	Inshore
42	EL-13-121	29.07.13	09:00	41,5	41	1568	184	
43	EL-13-122	29.07.13	12:05	41,23	41	675	157	Inshore
44	EL-13-124	29.07.13	20:10	41,75	41	1322	198	Offshore
45	EL-13-127	30.07.13	08:30	42	39,5	2010	132	Offshore
46	EL-13-128	30.07.13	14:50	41,5	39,5	1962	150	

According to the research objective, 46 stations were chosen covering almost the entire southern Black Sea from west to east including stations from inshore and offshore waters. These stations also represent the different physical characteristics of the Black Sea, by the reason of sampling in cyclonic, peripheral and anticyclonic regions, as well as inshore and offshore. Vertical hauls were performed from the bottom to the surface at shallow stations (less than 16.2 sigma-theta) and from the anoxic layer to the surface at deep stations. The beginning of the anoxic water layer was determined according to sigma-theta values. It is known that this value corresponds to the lower boundary of the oxic layer and its depth changes with respect to circulation direction (Vinogradov *et al.*, 1992, Murray *et al.*, 1995, Saydam *et al.*, 1993). A □t = 16.2 value is indicative of the cyclonic region at a depth of 100-120 m and the anticyclonic region at a depth of 160-200 m.

Sampling stations are presented in three different colors in Figure 5. Both gelatinous zooplankton and mesozooplankton were sampled from stations shown in red color. Additional gelatinous samples were obtained from stations shown in black color. For all analyses, results are shown as three areas, namely; west, middle, east region. There were 24 stations in the west, 11 stations in the middle and 11 stations in the east region for gelatinous zooplankton, whilst there were 11 stations in the west, 8 stations in the middle and 11 stations in the east region for mesozooplankton. Within these stations, inshore and offshore stations were chosen to see the difference between the inshore and offshore waters in selected transects. Due to the lack of proper inshore stations in some regions (total depth less than 100 m) definition of inshore and offshore stations were made by choosing closest stations as inshore waters and choosing the farthest stations as offshore for one transect. Overall there were three transects in the west, 2 transects in the middle and 3 transects in the east, comprising 8 inshore and 8 offshore stations. For these stations shown in Table 1, red color representing stations in the west, green for middle and blue for east.

2.2 Hydrographic measurements

Physical and chemical parameters of environment, which included temperature, salinity, pH, DO (dissolved oxygen) and chlorophyll-a (chl-*a),* were measured *in situ* on board R/V Bilim 2 by a SEABIRD CTD probe fitted to a 12-bottle Rosette system. CTD data were gathered from downcast. Sensitivities of salinity and temperature measurements were 0.001 psu and 0.0005 °C, respectively. DO sub-samples were also collected in 100-ml Pyrex bottles.

In order to estimate chl-a concentration, water samples were collected from several depth strata according to the CTD profile and the *in situ* fluorometric readings were made. Chl-a samples were collected in dark colored Nalgene containers. Appropriate amount of water (1-2 liter) were filtered through the 47 mm GF/F filters. In order to have a view of the chl-a distribution over the entire Black Sea, satellite images for surface chl-a concentration obtained from http://gdata1.sci.gsfc.nasa.gov for July 2013.

2.3 Zooplankton sampling

All samples were collected from the southern Black Sea during July 2013 at 46 geographical locations onboard R/V Bilim 2. Samples were collected both during day and night by a single vertical tow using WP-2 type plankton net of 0.57 m diameter mouth opening and 200 mikron mesh size.

Hauls were performed at a speed of 1m/s to minimize spillage at each station from the bottom to the surface for inshore stations and from anoxic boundary (16.2 sigma theta) to the surface for the deep stations. The sampling depths were estimated from the angle and length of the hauling wire.

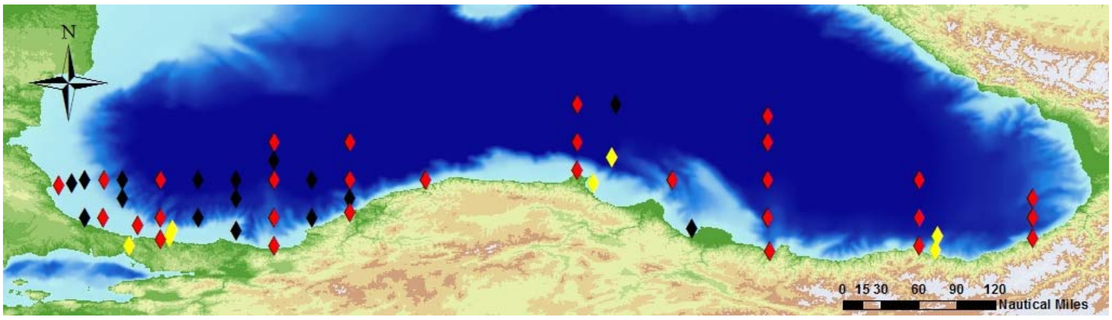


Figure 5 Zooplankton sampling stations (off southern Black Sea). Red color represents stations for mesozooplankton and gelatinous zooplankton, black color represents stations only for gelatinous zooplankton and yellow colored stations represents genetic study.

At the end of each haul, nets were exteriorly washed and their cod end contents were washed through a 2 mm sieve to retain gelatinous organisms (Figure 6). The mesozooplankton part of the sample washed with sea water and fixed immediately in a buffered formaldehyde-sea water solution with a final concentration of 4% and brought to METU-IMS for qualitative and quantitative analyses of mesozooplankton.

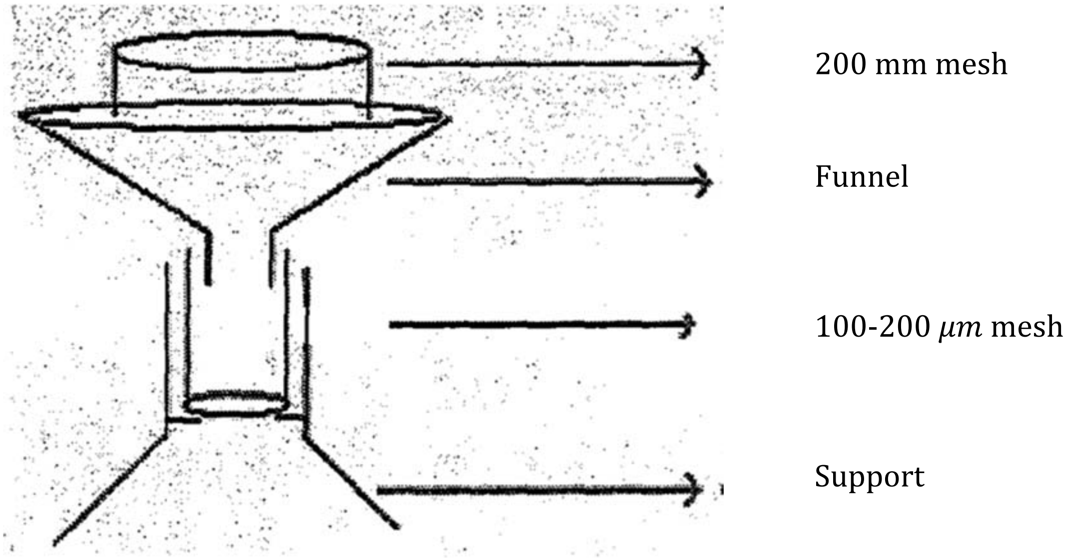


Figure 6 Schematic drawing of the sieving system to separate mesozooplankton and gelatinous macrozooplankton.

Samples already fixed onboard were examined in sub-samples by using Folsom splitter depending on the abundance of individuals in the samples. The average number of individuals that were identified and counted for each subsample was approximately 400, larger and rare animals counted without sub-sampling. For analysis of 400 individuals, precision in % of count was ± 10 and the range was between 360-440 (Harris *et al*., 2000).

For the qualitative and quantitative analysis of the mesozooplankton, individuals in subsample were counted under stereomicroscope (Olympus SZX12) and identified at a species level; and at age stages for copepods. A total of 30 samples were analyzed. Copepods (I–VI copepodites) were identified according to certain characteristics such as general anatomy, a1, a2, p5 and structure of organs (urosome, prosome). Appendages were dissected under a stereomicroscope and mounted on microscope slides for detailed examination (Figure 7). The identification of zooplankton groups was made according to Boltovskoy (1999), Dussart and Defaye (1995), Bradford *et al*. (1999), Özel (2003), Boxshall and Halsey (2004), Tregouboff and Rose (1957), Özel (1992, 1996), Larink and Westheide (2006) and Vershinin (2005), Smith and Johnson (1996), Guglielmo and Ianora (1995), Todd *et al*. (1996).

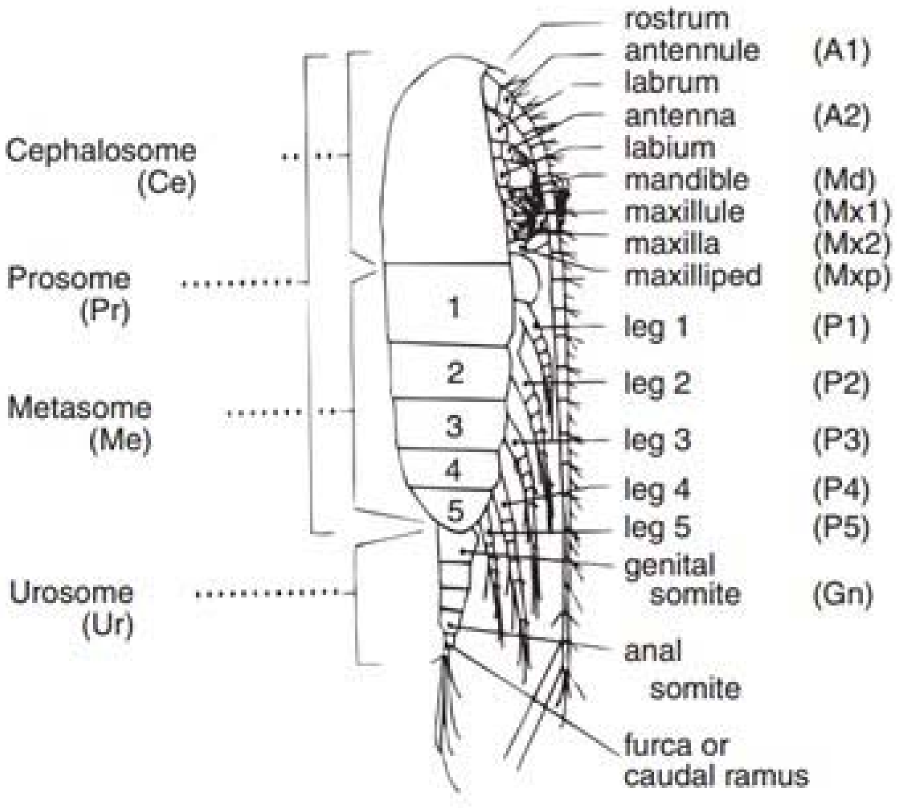


Figure 7 Generalized anatomy of a copepoda (Steele and Thorpe *et al*., 2010)

As *Oithona similis* has a relatively small body size, its early stages (I–III copepodites) can be underestimated when using a net equipped with 200 mm mesh size. For this reason, only adults and the copepodites V were counted whilst the I–IV stages of copepodites were ignored.

Organisms smaller than 200 mikron (nauplii of copepods *Paracalanus parvus* and *Oithona similis*) were not considered in the above analyses. Chaetognaths and Appendicularians were enumerated and their total lengths were measured for size classes. Mesozooplankton biomass in terms of carbon was estimated based on the individual weight of organisms. Earlier stages of gelatinous zooplankton were identified upon microscopic examination in the preserved samples. Small gelatinous plankton do not preserve well in formaldehyde-sea water solution and therefore underestimation of small size groups is possible in the present study. Biomass of mesozooplankton was calculated by using the individual wet weight (Petipa, 1957). The results were presented in terms of surface area (m^2) rather than volume (m^3) because of the characteristics of the Black Sea.

Larger gelatinous organisms separated from the other mesozooplankton by using 2 mm mesh sieve were immediately identified to a species level and the number of individuals was counted. Individual weighing of these animals was not practical on board and hence the weight of these animals was calculated from size measurements using a conversion formula. Therefore, length of *Pileurobrachia pileus*, umbrella diameter of *Aurelia aurita* and volume of *Mnemiopsis leidyi* and *Beroe ovata* were calcutaled individually.

For the measurement of individual volume of *M. leidyi* and *B. ovata*, 2, 5, 10, 20 and 50 ml capacity cylinders were used depending on the size of the animal. Measurement was made on 3526 individuals collected from 46 stations during the cruise in July 2013.

Length and volume of three species converted to biomass using equations below, which were obtained by Mutlu (1996).

1. Wet Weight (mg) =0.682 + Length (mm) X 2.522

for *Pleurobrachia pileus*

2. Wet Weight (mg) =- 0.249 + Volume (ml) X 0.886

for *Mnemiopsis leidyi*

3. Wet Weight (mg) =0.12+ Umbrellar Diameter (cm) X 2.582

for *Aurelia aurita*

The total biomass was calculated as the sum of the biomasses of all the size groups in the population. The density of gelatinous macrozooplankton was calculated from the diameter of the net without taking the tow depth into account to express results per unit surface area. This type of presentation is suitable for the Black Sea, as a permanent anoxic zone exists below 150±200 m.

2.4. Genetic analyses

Sampling for genetic analyses was carried out at seven stations (shown in Table 2 and Figure 5) as a part of previously mentioned the Perseus project as well as the CoCoNet project (http://www.coconet-fp7.eu/index.php/about-coconet). This was also a part of another MSc study (of Mr Ibrahim Halil Miraoğlu) on developing methods for quick identification of all zooplankton.

For each tow, after sieving thorough the 2 mm mesh, the individuals that passed the sieve were fixed with ethanol (70%), and the gelatinous zooplankton that was over the sieve was identified, enumerated and their morphological calculations were done. The temperature at which the samples were stored was important, which should be less than 25°C (Goswami, 2004). Photographs of each macrogelatinous individual were taken. After all the examination, they were stored in the freezer at -20 °C until their genetic analyses in the laboratory.

For the mesozooplankton, three individuals of each species (if the identification at a species level was not possible, then at a genus level, and if it is not possible, then a class level) were photographed individually under the microscope and each sample was placed in a separate eppendorf tube in order to ease DNA extraction, after fixation with ethanol. These samples were kept in the freezer until the genetic analyses, maximum one day to prevent the unwanted changes in the organisms. All the materials were sterilized within that period.

Benthic zooplanktonic organisms were collected from the Turkish coasts of the Black Sea for identification of earlier stages of meroplankton. For ichthyoplankton, some species, namely turbot, anchovy, horse mackerel, perch, haddock, goby and scorpion fish, were obtained from local fishermen with İbrahim Halil Miraoğlu. The species of the samples were morphologically identified. All individuals were labeled and photographs were taken. Either tissue (1-2 cm^3) or the whole organism was stored for the molecular analysis. Samples were stored as a museum samples.

Primers were designed or taken from the related articles by İbrahim Halil Miraoğlu in order to amplify the COI gene of the zooplankton and fish species. Different primer pairs were prepared in case of failure in amplification step. These were mainly, degenerate primers, species-specific primers and the primers chosen for relative studies. The sequences of zooplankton, benthic organisms and individuals of fish were obtained from NCBI and BOLD databases. The COI gene sequences of these individuals are given in the appendix A.

Molecular extraction and amplification were performed in the laboratories of Institute of Marine Sciences of Middle East Technical Universitiy. This section of study (genetic analyses) was a part of TUBITAK project No: 113Y179.

Table 2 Information on 7 stations from the southern Black Sea for the genetic analyses

No	Cruise	Station	Lat	Long	Date	Depth (m)	Type
1	Perseus	L095K153	41,12	29,09	13.06.13	50	Vertical
2	Coconet	CTD_23	41,24	29,6	5.08.13	0	Horizontal
3	Coconet	Sile_acik	41,34	29,65	5.08.13	0	Horizontal
4	Perseus	EL-13-071	41,95	35,2	23.07.13	133	Vertical
5	Perseus	EL-13-072	42,3	35,45	23.07.13	65	Vertical
6	Perseus	EL-13-117	41,25	39,75	28.07.13	163	Vertical
7	Perseus	EL-13-128	41,06	39,73	30.07.13	175	Vertical

2.5 Statistical analysis

For the analysis of multispecies copepod data and the associated environmental variables both STATGRAPHICS (Univariate Statistics Package) and PRIMER (Multivariate Analyses Package - Plymouth Routines in Multivariate Ecological Research), a number of PC programs written at the Plymouth Marine Laboratory, UK were used. Net zooplankton samples consisted mainly of copepods and other groups. Zooplankton counts required root-root transformation to adjust the weight of abundant (groups) species. To calculate similarities between samples the Bray-Curtis coefficient is used. Similarity between j^{th} and k^{th} samples is given by;

$$S_{jk} = 100 \{1 - \Sigma_i \mid y_{ij} - y_{ik} \mid / \Sigma_i (y_{ij} + y_{ik})\}$$

where
y_{ij} = score (count) for i^{th} species in the j^{th} sample,
y_{ik} = score for the i^{th} species in the k^{th} sample.

Then the similarity matrix was formed between every pair of samples in a lower triangular array for further clustering and ordination. For a graphic representation of relations among samples, a dendogram showing clustered groups at an arbitrary cut-off level was constructed. Among the various hierarchical sorting strategies the group-average sorting was preferred to produce a dendogram from the similarity matrix. This joins 2 groups of samples together at the average level of similarity between all members of one group and all members of the other. In order to visualize sample relationships, ordination was done by delineating dendogram classes on the corresponding ordination via Multi-Dimensional Scaling (MDS).

Spearman Rank Correlation is used to see the relation between temperature, salinity and abundance of Noctiluca.

3. RESULTS

3.1. Physical and biochemical characteristics of the southern Black Sea

Basin averaged distribution of Black Sea chl-a, obtained from http://gdata1.sci.gsfc.nasa.gov for July 2013 is shown in Figure 8. The results show high chl-a values at the coastal region with a substantial decrease towards the offshore waters. Moreover the highest chl-a concentration is observed in the inshore waters of the southwestern region. Offshore waters of the eastern region showed also high *chl*-a values compared to the other regions in the southern Black Sea. In the Figure 8, the deep sea displays the lowest chl-a concentrations.

Fluorescence values from CTD probe corresponding to 5 m depth is also higher in the inshore and offshore waters of the western region, as well as in the region between Samsun and Ordu and around the Batumi eddy (Figure 9). The lowest fluorescence readings correspond to off the coast of Sinop region.

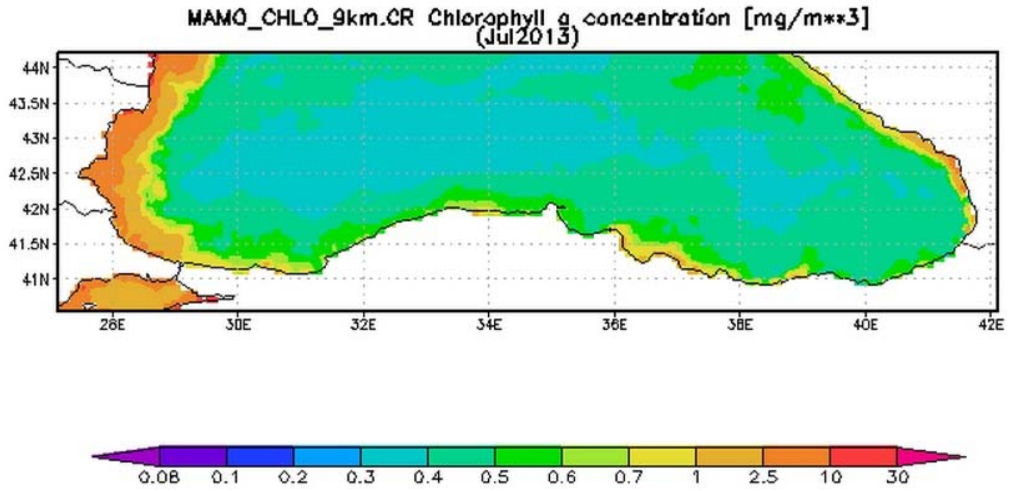


Figure 8 Chlorophyll-a surface average concentration (mg/m^3) for the entire southern Black Sea in July 2013

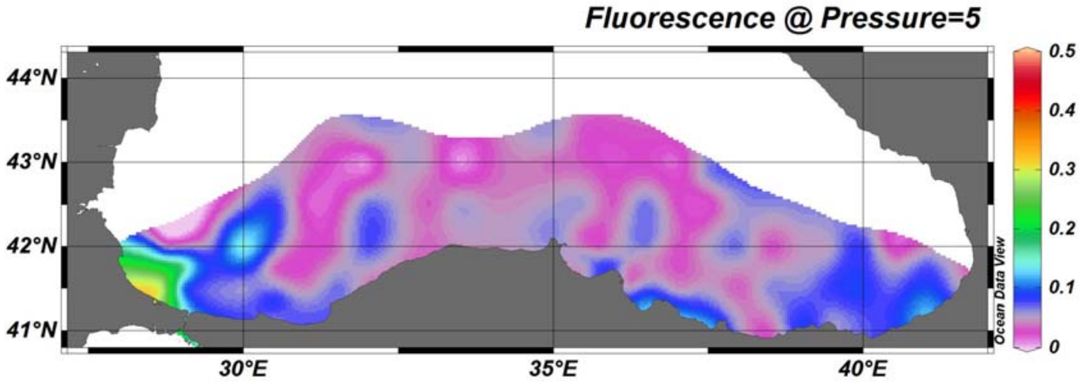


Figure 9 Fluorescence values of 46 stations at 5 m depth for the southern Black Sea in July 2013

Spatial distribution of sea surface temperature (SST) at 5 m depth reveals significant characteristics for the southern region of the Black Sea for July 2013 (Figure 10). Offshore waters of the middle part in the middle of the two cyclonic gyres are the area with the highest SST values, whereas in the western region where the Danube River plume effects dominate, SST was the lowest. Moreover, inshore waters of the southwestern region and offshore waters of the far east region near the Batumi eddy display the lowest SST values.

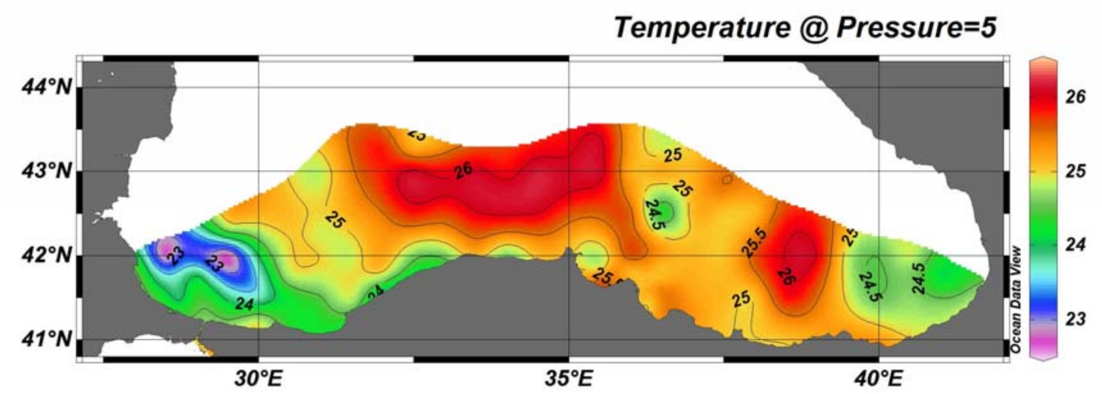


Figure 10 Temperature values (°C) of 46 stations at 5 m depth in the southern Black Sea in July 2013

Figure 11 shows the 16.2 sigma theta density levels in the southern Black Sea in July 2013. The deeper depths wherein 16.2 density occur denote the regions of anti-cyclonic activity. These regions are in the easternmost part of the southern Black Sea that are located nearby the Batumi eddy, as well as inshore waters of Ordu and Kocaeli region. The minimum depths at which 16.2 sigma theta occurs is measured in the offshore waters of the southern Black Sea, in the middle of two mesoscale cyclonic gyres.

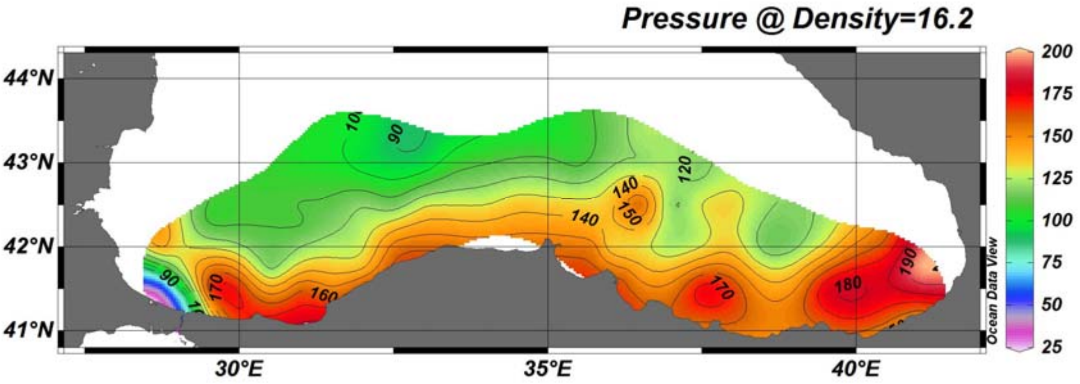


Figure 11 Depth levels (m), where density equals 16.2 sigma-theta, of 46 stations in the southern Black Sea in July 2013

Salinity distribution at 5 m depth clearly shows the effect of Danube River plume on the southwestern region of the Black Sea (Figure 12). This effect can be tracked also in the inshore waters until the middle part (with a decreasing trend) from west to the east. The highest density measurements are observed around the cyclonic gyres in the central part of the southern Black Sea in July 2013.

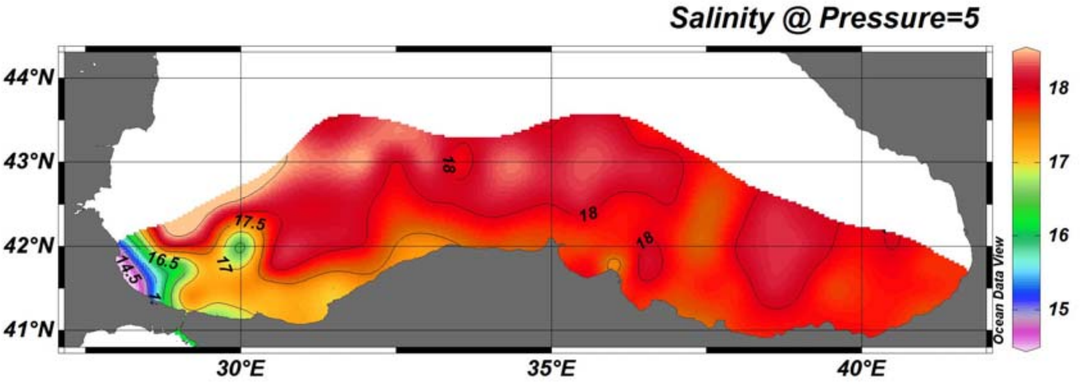


Figure 12 Salinity values (PSU) of 46 stations at 5 m depth in the southern Black Sea in July 2013

Vertical profiles of density, salinity and temperature measured in 3 stations reveals significant characteristics.

In the cyclonic gyre, the depth corresponding to the 16.2 density level is measured as 100 m (Figure 13). The temperature is~ 26°C at the surface which decreases down to the 8 °C at 50 m depth (which is the Cold Intermediate Layer -CIL), from where it increases maximum to 10 °C with depth. Salinity is 18 PSU at the surface and increases to the 20.5 PSU at 100 m depth (corresponding to 16.2 density level).

In the peripheral zone the depth where the 16.2 sigma theta occurs is at around 150 m. (Figure 14) Temperature of the water is 25 °C at the surface and decreases to its lowest value (8 °C) at 70 m. Salinity is measured 17.5 PSU at the surface and increases to 21 PSU at 150 m.

The vertical profiles of the density, salinity and temperature in the anticyclonic region show different characteristics. The depth equaling to the 16.2 sigma theta is located at 200 m (Figure 15). Temperature was 24 °C at the surface and decreased to its minimum value of 7.5 ^{0}C at 150 m depth. Salinity is almost 18 PSU at the surface and increases up to 21 PSU at 16.2 sigma theta level at the anticyclonic regions.

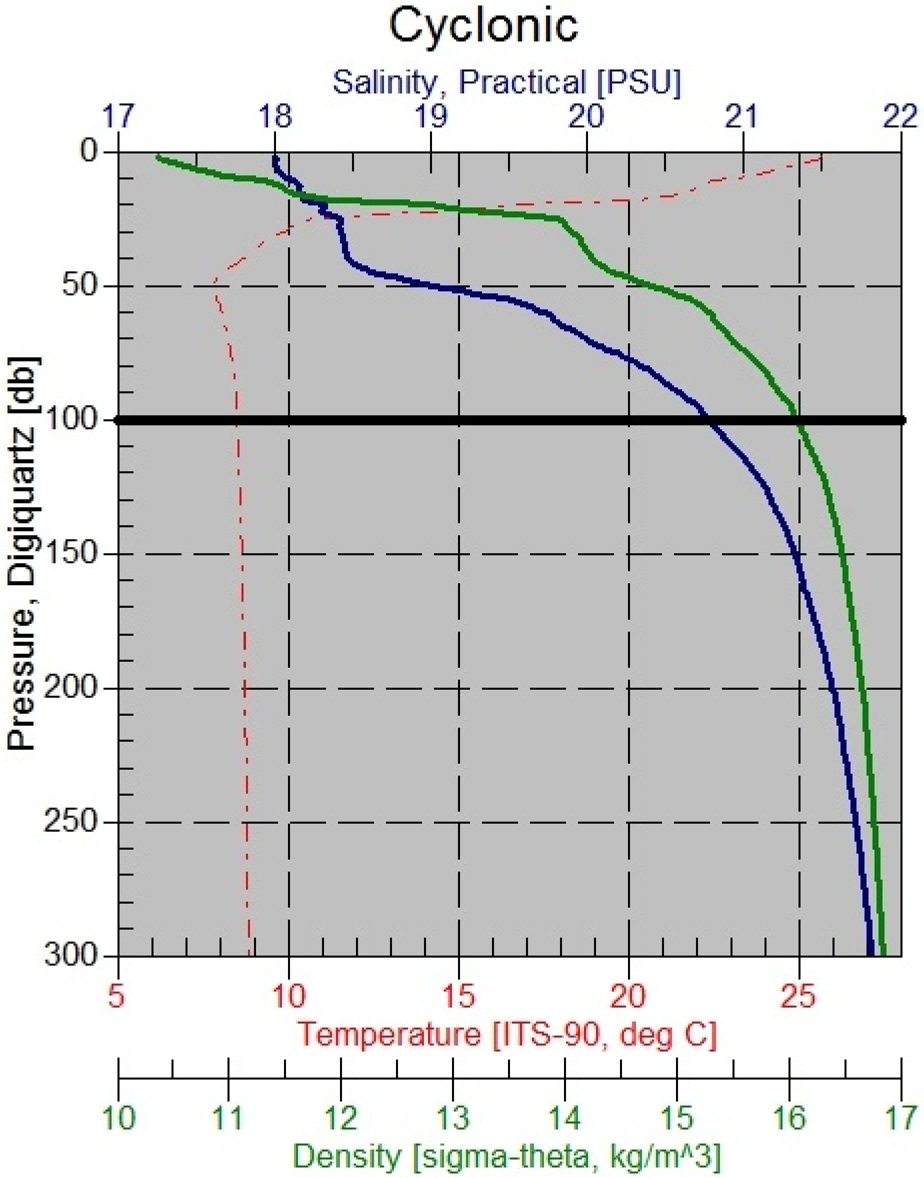


Figure 13 Temperature (°C), salinity (PSU) and density (sigma-theta) profiles plotted against depth in cyclonic region. Black line represents the depth where the density is equal 16.2 sigma theta

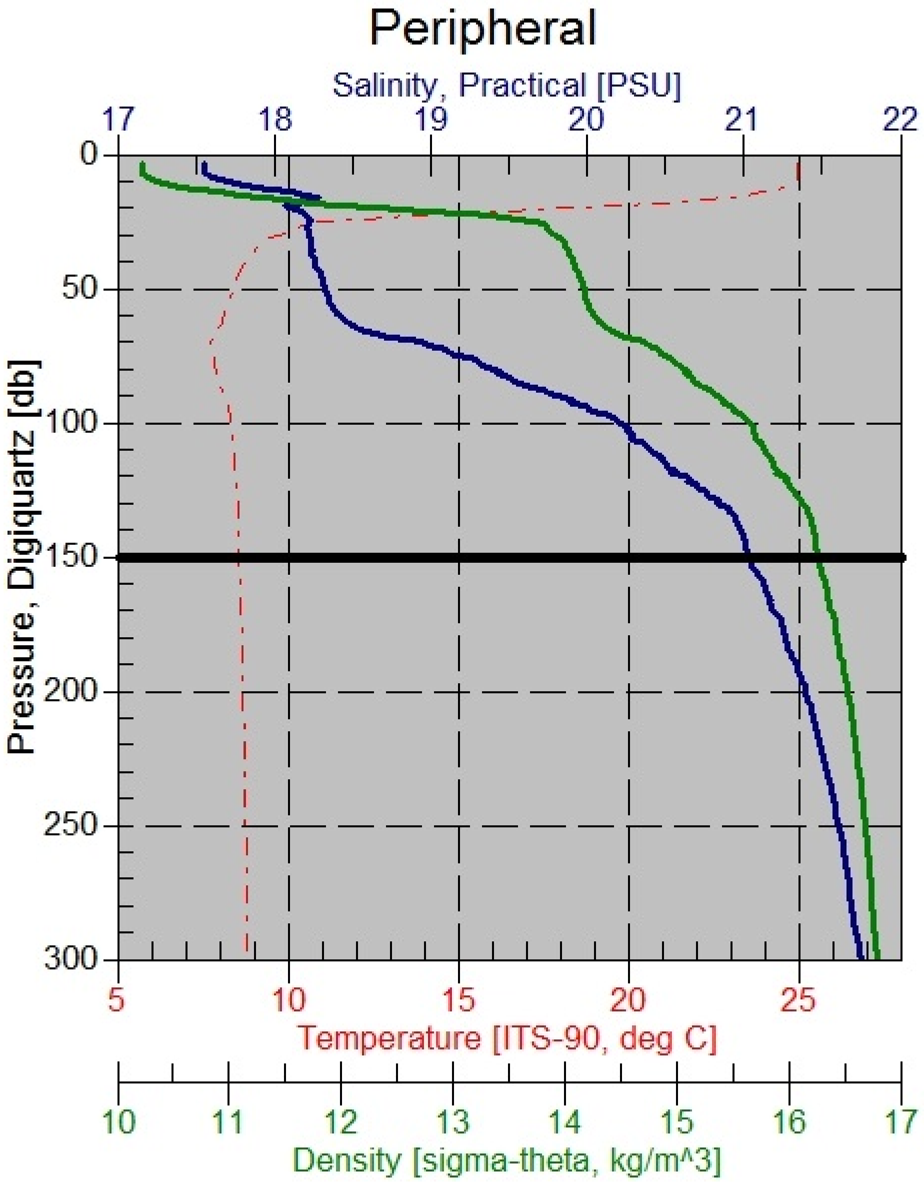


Figure 14 Temperature (°C), salinity (PSU) and density (sigma-theta) profiles plotted against depth in peripheral region. Black line represents the depth where the density is equal 16.2 sigma theta

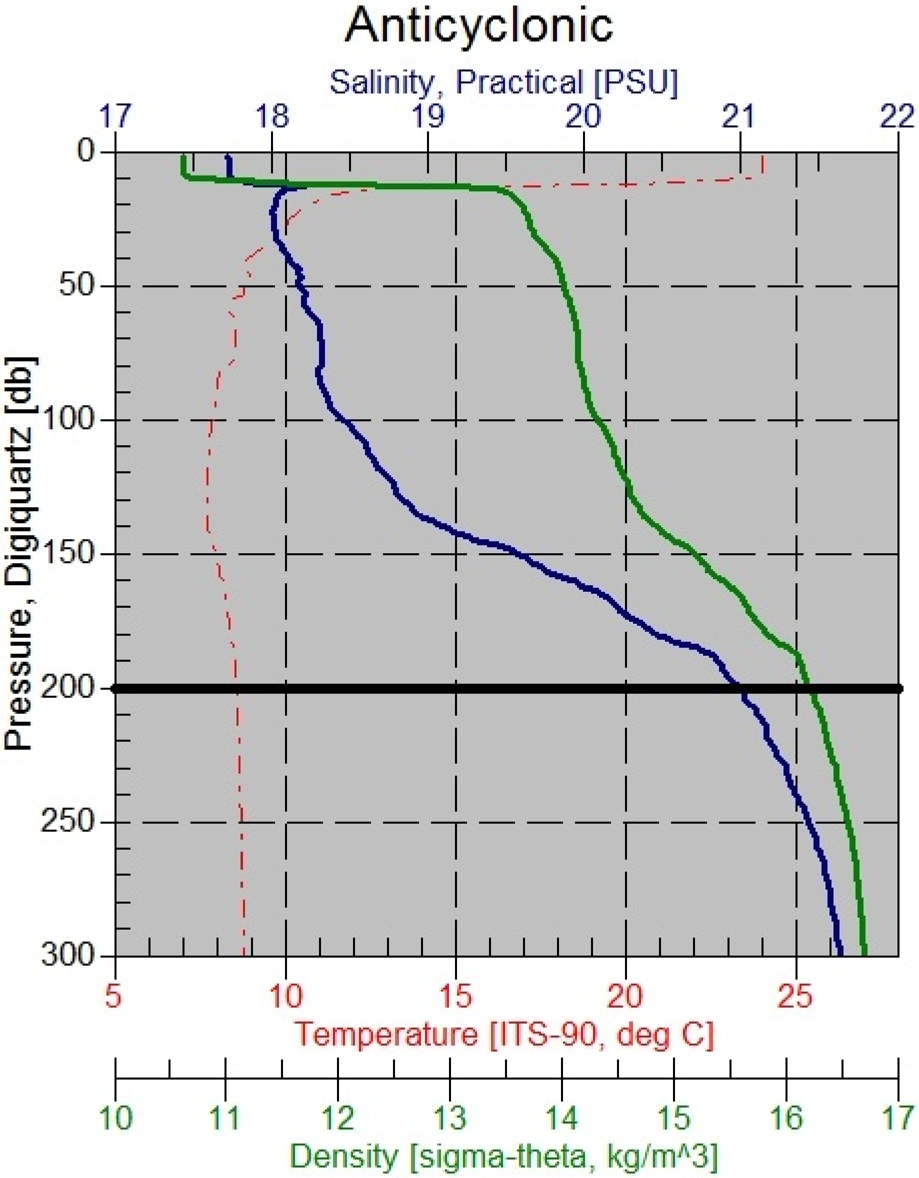


Figure 15 Temperature (°C), salinity (PSU) and density (sigma-theta) profiles plotted against depth in anticyclonic region. Black line represents the depth where the density is equal 16.2 sigma theta

3.2 Species biodiversity of zooplankton

In the Southern Black Sea, a total of 19 mesozooplanktonic species belonging to 13 classes were identified during July 2013. The species number is clearly an underestimate, since some zooplankton groups (in particular meroplankton) could not be identified to the species level (i.e. Cirripedia, Bivalvia, Gastropoda, Polychaeta, Decapoda, Isopoda, Nematoda, Cumacea and Ostracoda). Some species are the sole representative of their groups, like *Noctiluca scintillans* (Dinophyceae), *Parasagitta setosa* (Chaetognatha), and *Oikopleura dioica* (Appendicularia), while others are less known groups in the Black Sea (i.e. Nematoda, Isopoda). Some of these individuals that photographed under microscope are shown in Appendix D. The systematic groups to which these species belong are shown below:

Kingdom: Chromista
Phylum: Myzozoa
Class: Dinophyceae
Order: Noctilucales
Family: Noctilucaceae
Genus: *Noctiluca*
Species: *Noctiluca scintillans*, Kofoid & Swezy, 1921
Kingdom: Animalia
Phylum: Chordata
Subphylum: Tunicate
Class: Appendicularia
Family: Oikopleuridae
Genus: *Oikopleura*
Species: *Oikopleura dioica*, Fol, 1872
Subphylum: Vertebrata
Superclass: Pisces
Unidentifies egg
Unidentified larvae
Class: Actinopterygii
Order: Clupeiformes
Family: Engraulidae
Genus: *Engraulis*
Species: *Engraulis encrasicolus*, Linnaeus, 1758
Phylum: Mollusca
Class: Bivalvia

Undintified species

Class: Gastropoda

Unidentified species

Phylum: Chaetognatha

Class: Sagittoidea

Family: Sagittidae

Genus: *Parasagitta*

Species: *Parasagitta setosa*, Müller, 1847

Phylum: Arthropoda

Subphylum: Crustacea

Class: Branchiopoda

Infraorder: Cladocera

Family: Podonidae

Genus*:* *Evadne*

Species: *Evane spinifera*, P.E. Müller, 1867

Genus: *Pseudevadne*

Species: *Pseudevadne tergestina*, Claus, 1877

Genus: *Pleopis*

Species: *Pleopis polyphaemoides*, Leuckart, 1859

Family: Sididae

Genus: *Penilia*

Species: *Penilia avirostris*, Dana, 1849

Class: Maxillopoda

Subclass: Copepoda

Superorder: Gymnoplea

Order: Calanoida

Family: Calanidae

Genus: *Calanus*

Species: *Calanus euxinus*, Hulsemann, 1991

Family: Acartiidae

Genus: *Acartia*

Species: *Acarita clausi*, Giesbrecht, 1889

Species: *Acartia tonsa*, Dana, 1849

Family: Centropagidae

Genus: *Centropages*

Species: *Centropages ponticus*, Karavaev, 1895

Family: Paracalanidae

Genus: *Paracalanus*

Species: *Paracalanus parvus*, Claus, 1863

Family: Clausocalanidae

Genus: *Pseudocalanus*

Species: *Pseudocalanus elogatus*, Boeck, 1865

Family: Pontellidae

Genus: *Pontella*

Species: *Pontella mediterranea*, Claus, 1863

Superorder: Podoplea

Order: Cyclopoida

Family: Oithonidae

Genus: *Oithona*

Species: *Oithona similis*, Claus, 1866

Subclass: Thecostraca

Infraclass: Cirripedia

Unidentified cypris larvae

Unidentified nauplius larvae

Class: Malacostraca

Superorder: Peracarida

Order: Isopoda

Unidentified species

Order: Cumacea

Unidentified species

Superorder: Eucarida

Order: Decapoda

Unidentified species

Unidentified brachyuran zoae

Unidentified zoae

Class: Ostracoda

Unidentified species

Phylum: Nematoda

Unidentified species

Phylum: Annelida

Class: Polychaeta

Unidentified species

Phylum: Cnidaria

Class: Scyphozoa

Order: Semaeostomeae

Family: Ulmaridae

Genus: *Aurelia*

Species: *Aurelia aurita*, Linnaeus, 1758

Phylum: Ctenophora

Unidentified ctenophora larvae

Class: Tentaculata

Subclass: Typhlocoela

Order: Cydippida

Family: Pleurobrachiidae

Genus: *Pleurobrachia*

Species: *Pleurobrachia pileus*, O. F. Müller, 1776

Order: Lobata

Family: Bolinopsidae

Genus: *Mnemiopsis*

Species: *Mnemiopsis leidyi*, A. Agassiz, 1865

Class: Nuda

Order: Beroida

Family: Beroidae

Genus: *Beroe*

Species: *Beroe ovata*, Bruguiere, 1789

Species composition

The comparison of the number of individuals for 3 different regions in the Black Sea showed that the western part was the most abundant area with an average of 175,495 individuals per m^2 (Figure 17) and followed by middle part of the Black Sea in July 2013, which was 85,008 ind/m^2. The lowest number was observed in the eastern region that was 82,476 ind/m^2. The overall mean value for abundance of zooplankton of the entire southern Black Sea was 117,258 ind/m^2 (Figure 16) and this mean value decreased from west to the east. The highest abundance was attained by Copepoda (68%), which was followed by *Noctiluca scintillans* (14%), and Cladocera (7%), while Chaetognatha formed only 4% of the total. Abundance of copepods was highest in the western part of the Black Sea while its percentage was lowest. The second most abundant *Noctiluca scintillans* was highly abundant in the western part with decreasing number in the middle part of the southern Black Sea. Abundance of Cladocerans was also the highest in the western part and lowest in the eastern part.

The comparison of the number of individuals for inshore and offshore stations (only 6 inshore stations and 6 offshore stations) showed that the mean abundance was higher in the offshore stations (123,418 ind/m^2 in the inshore and 130,937 ind/m^2 for the offshore stations). Copepods were dominating the total abundance with 83% of total for the offshore stations and with 53% for the inshore stations. Abundance of individuals belonging to Cladocera, Bivalvia , Gastropoda, Cirripedia and Decapoda, were higher in the inshore stations compared to those in the offshore.

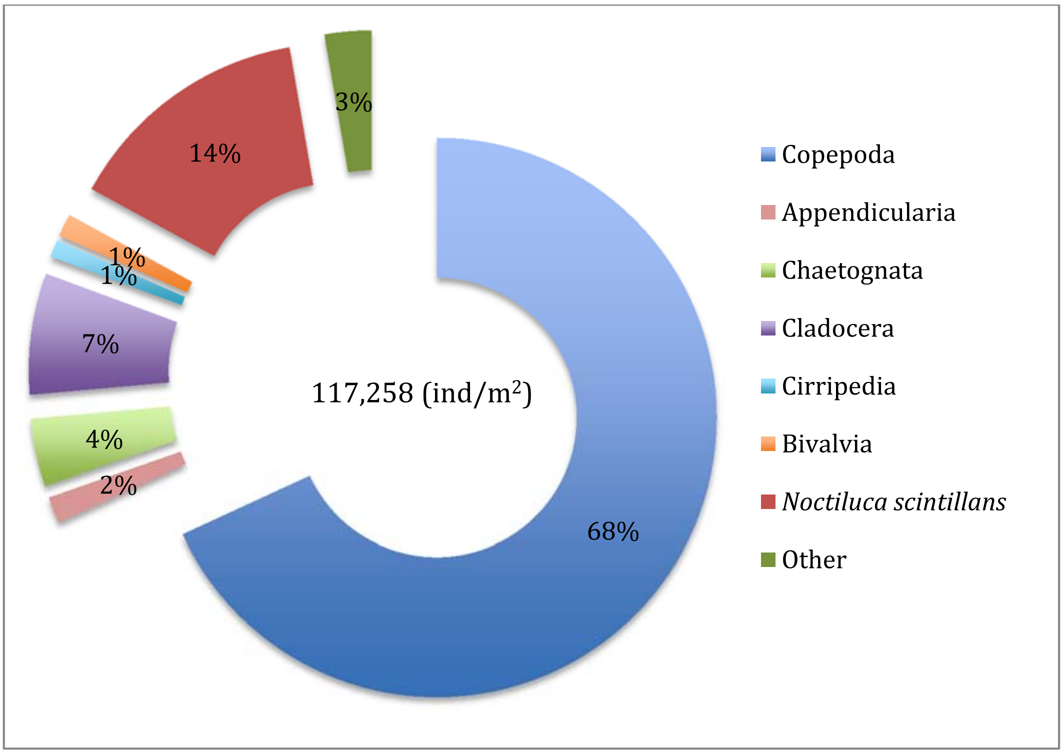
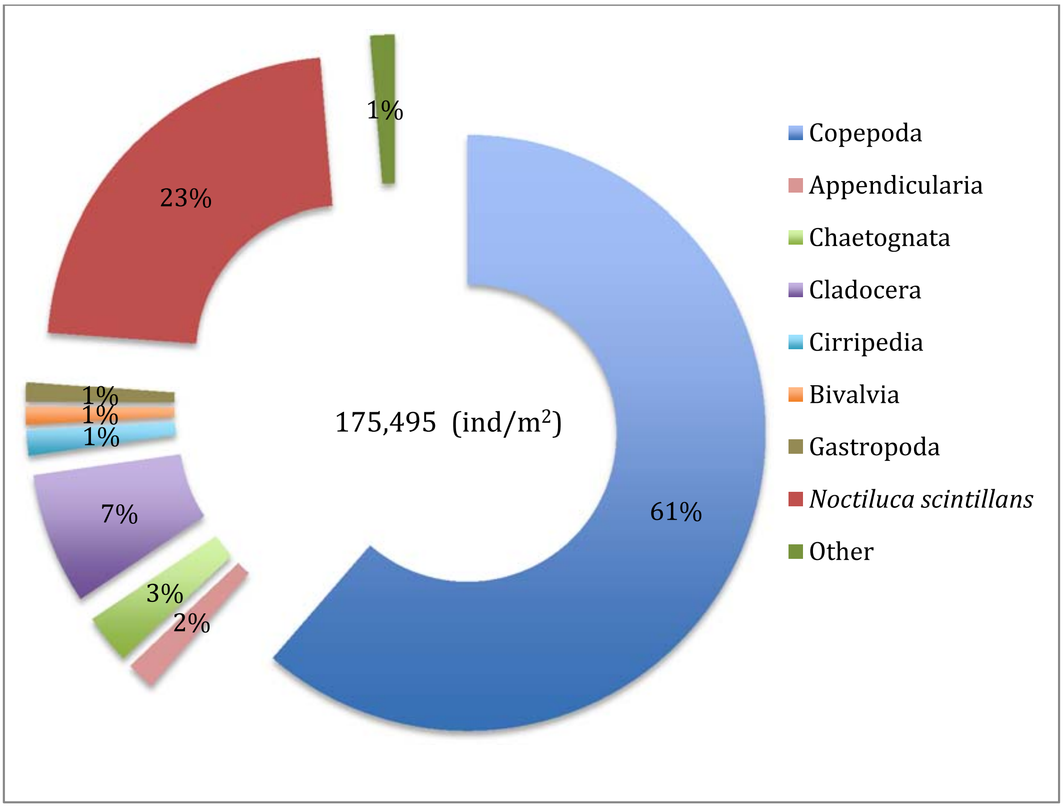


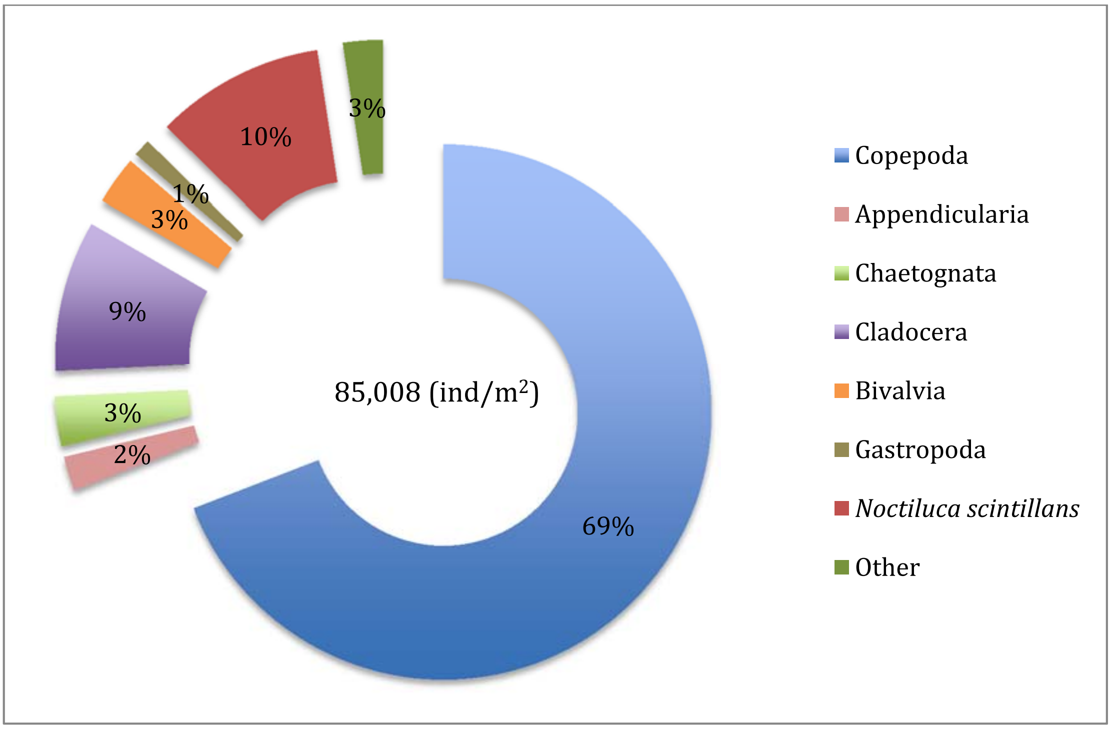
Figure 16 Abundance (ind/m^2) percentages of main zooplankton groups in the southern Black Sea in July 2013.

A



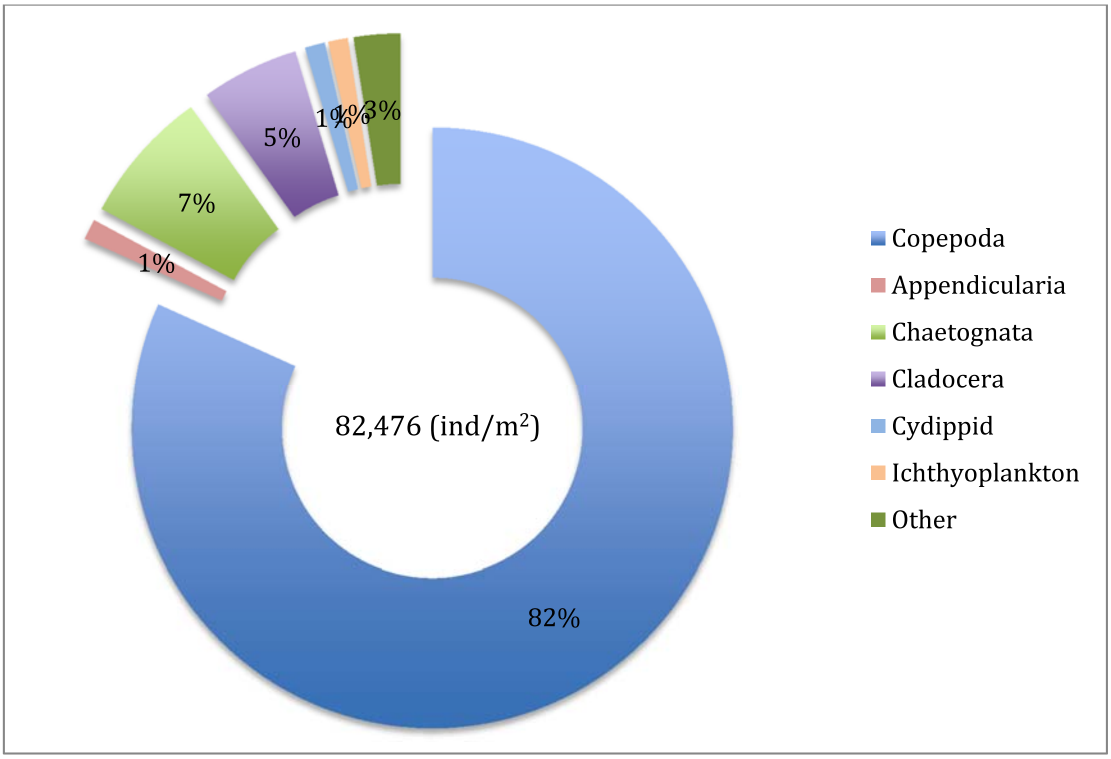
1%
23%
1%
1%
1%
7%
3%
2%
175,495 (ind/m2)
61%
Copepoda
Appendicularia
Chaetognata
Cladocera
Cirripedia
Bivalvia
Gastropoda
Noctiluca scintillans
Other

B



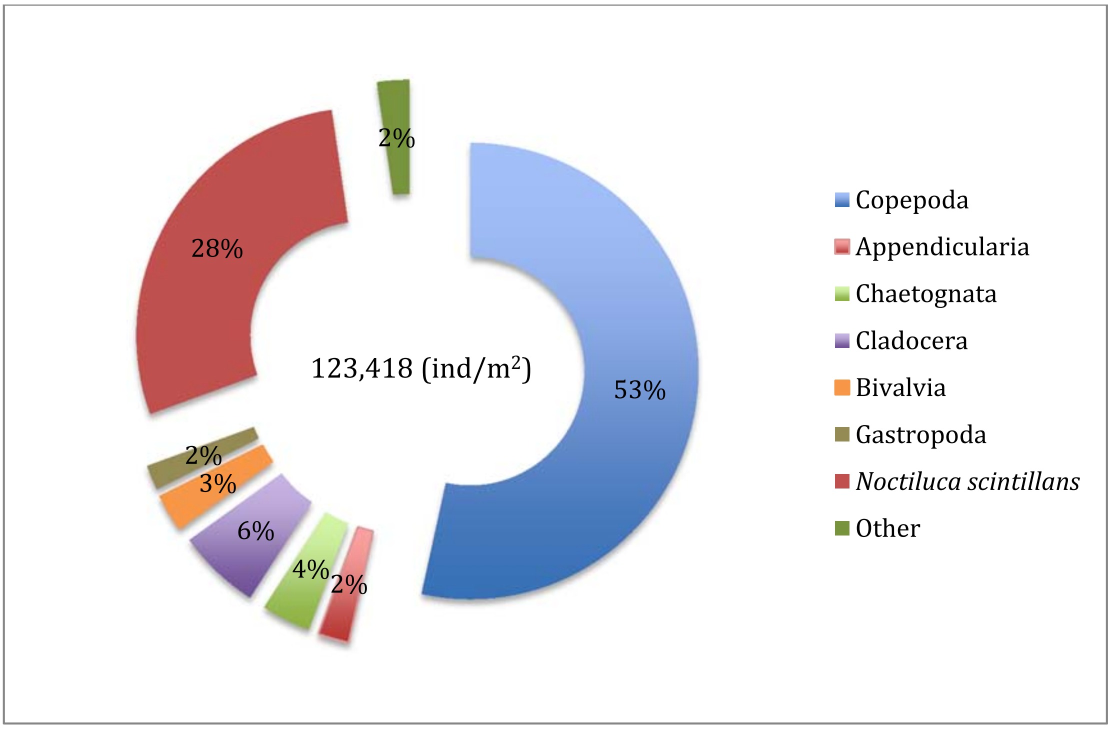
10%
3%
1%
3%
9%
3%
2%
85,008 (ind/m2)
69%
Copepoda
Appendicularia
Chaetognata
Cladocera
Bivalvia
Gastropoda
Noctiluca scintillans
Other

C



82,476 (ind/m²)
82%
1%
7%
5%
1%
1%
3%
Copepoda
Appendicularia
Chaetognata
Cladocera
Cydippid
Ichthyoplankton
Other

D



123,418 (ind/m²)
53%
28%
2%
2%
3%
6%
4%
2%
Copepoda
Appendicularia
Chaetognata
Cladocera
Bivalvia
Gastropoda
Noctiluca scintillans
Other

E

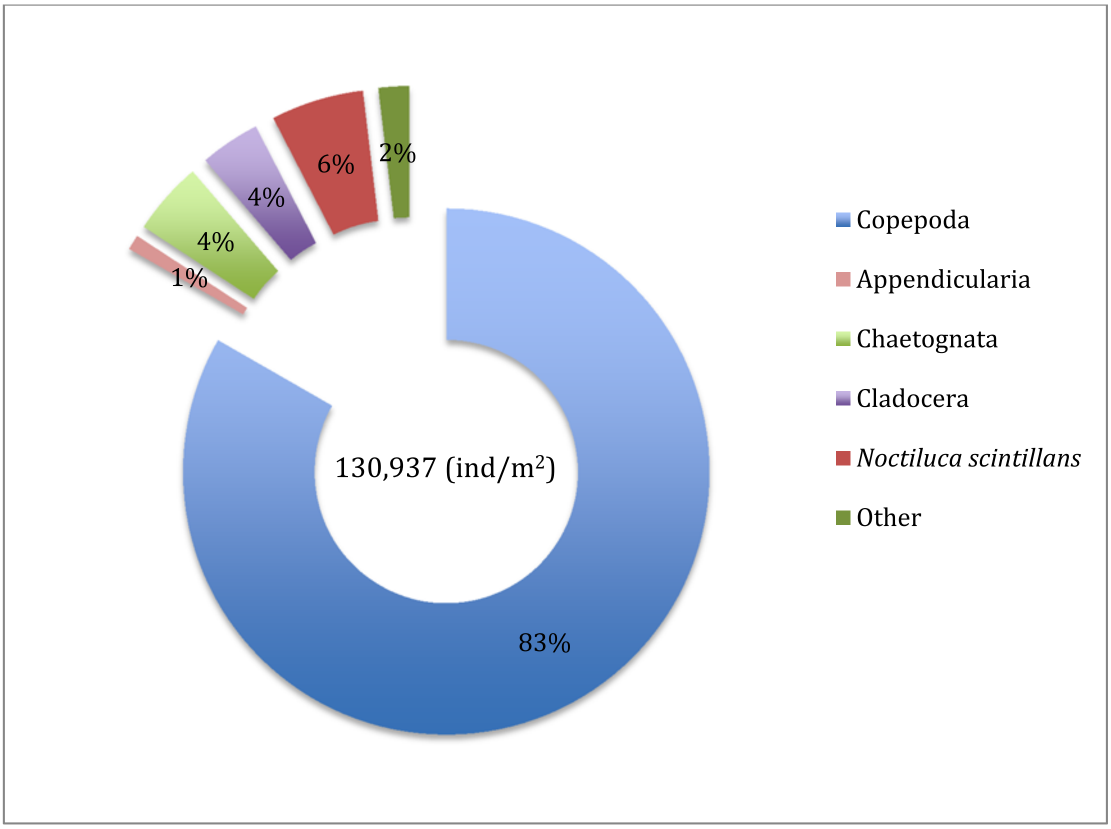


Figure 17 Species composition (in terms of abundance (ind/m^2)) of zooplankton groups that identified in the southern Black Sea in July 2013. (A. West stations B. Middle stations C. East stations E. Inshore stations F. Offshore stations)

Holoplankton and meroplankton

The comparison of abundance values of holoplankton and meroplankton showed domination of holoplankton (96%) by former over meroplankton (4%). The mean value for holoplankton was 112,489 ind/m^2, while it was only 4,768 ind/m^2 for meroplankton (Figure 18).

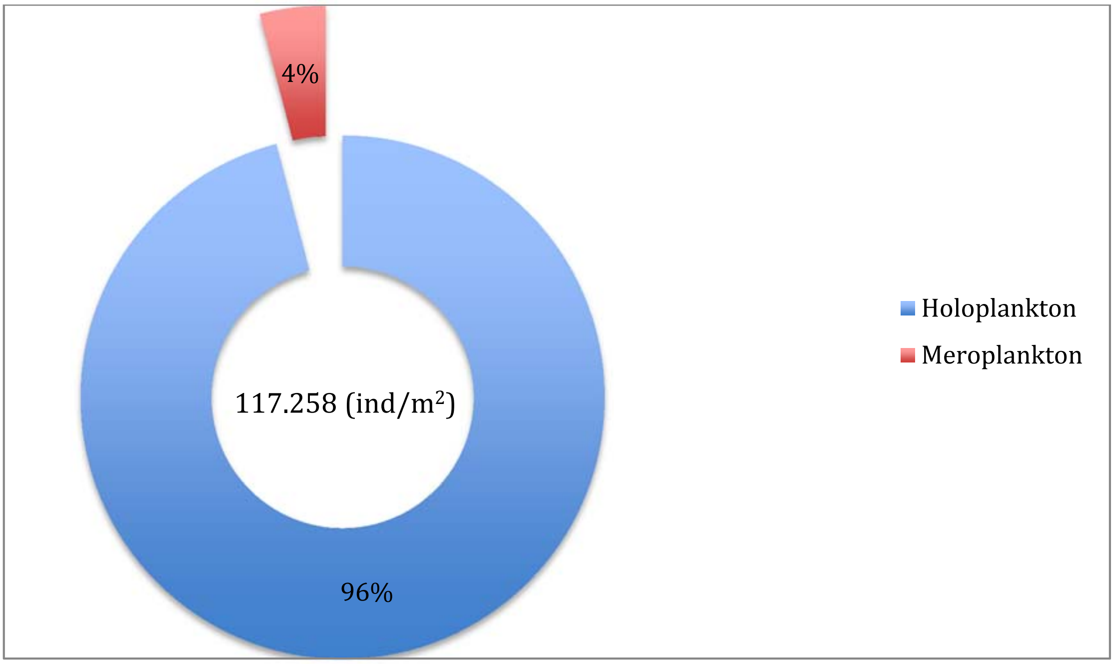


Figure 18 Mean abundance (ind/m^2) percentages of holoplankton and meroplankton in the southern Black Sea in July 2013. Blue color represents holoplankton and red color represents meroplankton

The number of individuals and species clearly increased from east to west for both holoplankton and meroplankton. The abundance of holoplanktonic individuals was highest in the west (168,155 ind/m^2, being almost double of that in the middle and east parts of the southern Black Sea). For meroplanktonic individuals the abundance was also highest in the west (7,341 ind/m^2) and followed by middle part (4,633 ind/m^2). The lowest meroplankton value was recorded in the east, which was only 2,296 ind/m^2 (Figure 19).

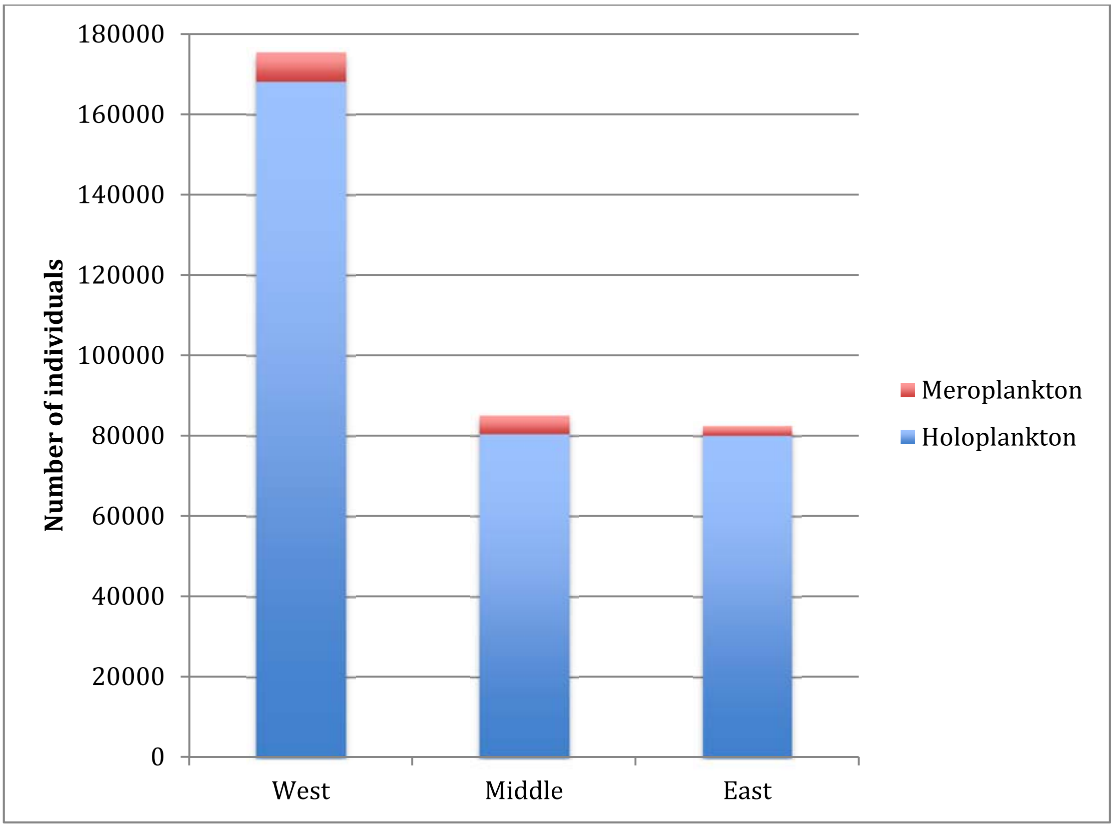


Figure 19 Mean abundance (ind/m^2) values of holo- and meroplankton in 3 different regions in the southern Black Sea in July 2013. Blue color represents holoplankton and red color represents meroplankton

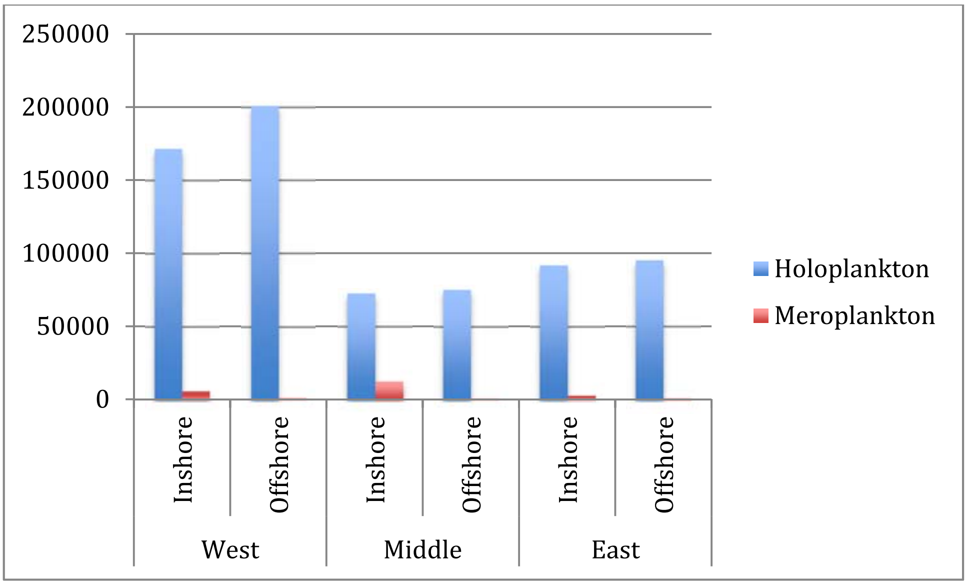


Figure 20 Mean abundance (ind/m^2) values of holoplankton and meroplankton for inshore and offshore waters of the 3 different regions of the southern Black Sea in July 2013. Blue color represents holoplankton and red color represents meroplankton

The comparison of inshore and offshore waters in the 3 mentioned regions for holoplankton and meroplankton showed that the highest abundance of individuals of holoplankton was observed in the offshore waters (201,003 ind/m^2) of the western part of the southern Black Sea, while the abundance of meroplanktonic individuals was highest (12,578 ind/m^2) in the inshore waters of middle part. The number of holoplankton was always higher in the offshore stations for the 3 mentioned regions (Figure 20).

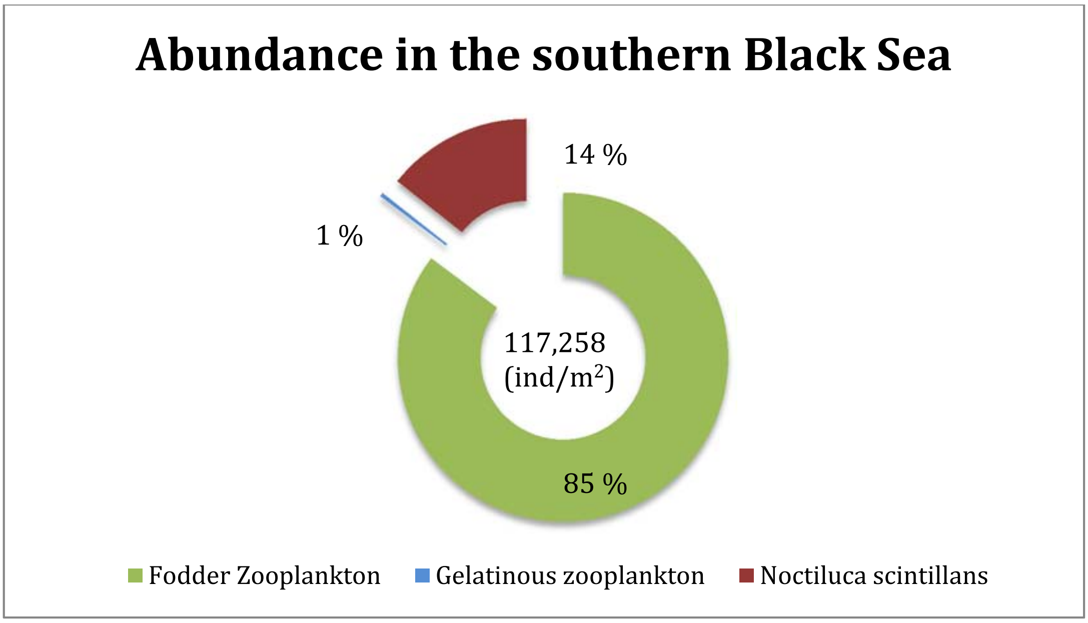
In general, highest numbers were observed in the inshore stations for meroplankton species, while highest numbers were observed in the offshore stations for holoplankton species. The maximum number of meroplankton obtained from inshore stations of the middle part of the Black Sea, while the offshore waters of the west were the regions with high abundance values of holoplanktonic individuals for the selected transects.

3.3 Composition and regional variability of major zooplankton groups

Zooplankton was examined in three groups, namely fodder zooplankton, gelatinous zooplankton and the heterothrophic dinoflagellate *Noctiluca scintillans*, due to the mass existence of the latter two. Mesozooplankton is the group having a size range of 0.2-20 mm and normally includes most zooplankton except large gelatinous individuals. Althougt majority of *Pleurobrachia* fall to this category, here we treated this species under large gelatinous zooplankton. However the *N. scintillans (*0.2-2 mm size range) was included within mesozooplankton.

Fodder zooplankton was found to be the most abundant group (average of 100,013 ind/m^2) constituting as much as 85% of the total zooplankton. Even though the fodder zooplankton and *N. scintillans* constituted almost all the zooplankton (116,812 ind/m^2) in the southern Black Sea in terms of abundance, the two together could only constitute 2% of the total in terms of biomass, due to their much smaller sizes as compared to gelatinous organisms (Figure 21). On the contrary, even if the abundance of gelatinous organisms was negligible (1%), they formed the majority part (98%) of the total biomass in all regions and both inshore and offshore waters.

A



B

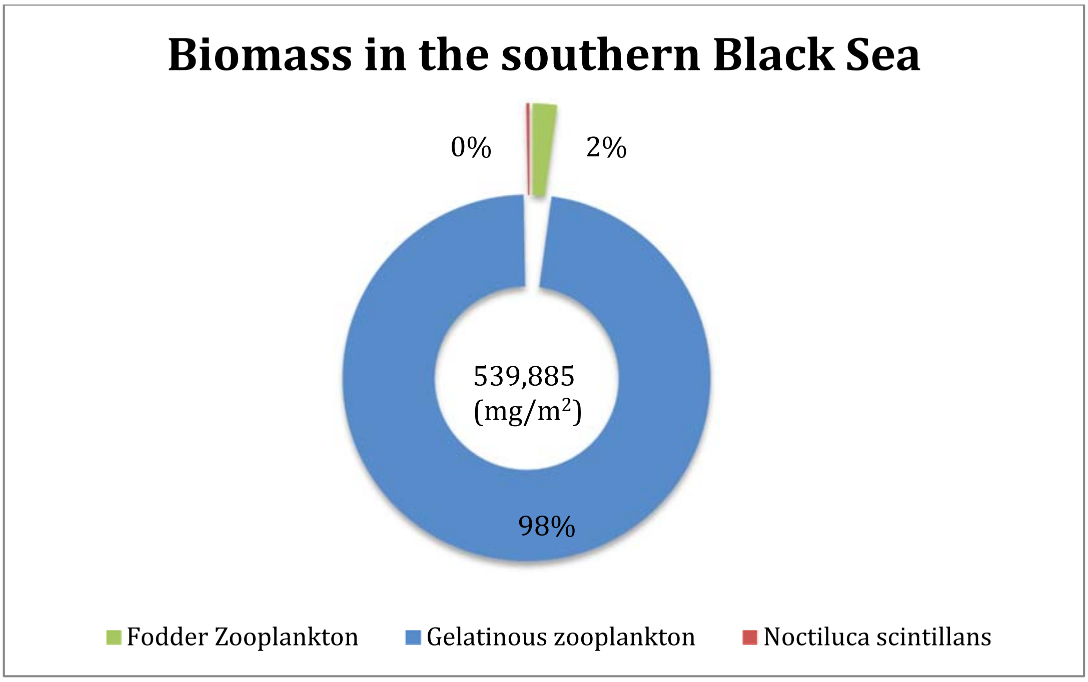


Figure 21 Percent composition of total abundance and biomass of the three main groups of zooplankton (i.e. fodder zooplankton, gelatinous zooplankton and *Noctiluca scintillans*) in the southern Black Sea A. Abundance (ind/m^2) B. Biomass (mg/m^2)

The comparison of the main zooplankton groups for 3 regions did reveal a significant overall difference among them in terms of abundance. *Noctiluca scintillans* (39,495 ind/ m^2) and fodder zooplankton (135,611 ind/ m^2) displayed high values in terms of abundance in the western part of the southern Black Sea (Table 3). Fodder zooplankton showed the lowest abundance values in the middle part, with an average abundance value of only 75,997 ind/m^2. The mean abundance values for fodder zooplankton were also lower in the east (81,881 ind/m^2) compared to west. On contrary, the highest value in terms of abundance for gelatinous zooplankton (595 ind/ m^2) was observed in the eastern region of the southern Black Sea, and lower values were observed in the western and middle parts (Figure 22). *N. scintillans* was only found in the west and middle parts of the southern Black Sea.

Table 3 Mean abundance values (ind/m^2) of the 3 main zooplankton groups namely; Fodder zooplankton, Gelatinous zooplankton and Noctiluca scintillans in 3 regions off southern Black Sea in July 2013

	Fodder Zooplankton (ind/m^2)	**Gelatinous zooplankton (ind/m^2)**	***Noctiluca scintillans*** **(ind/m^2)**
West	135,611	389	39,495
Middle	75,997	321	8.690
East	81,881	595	0

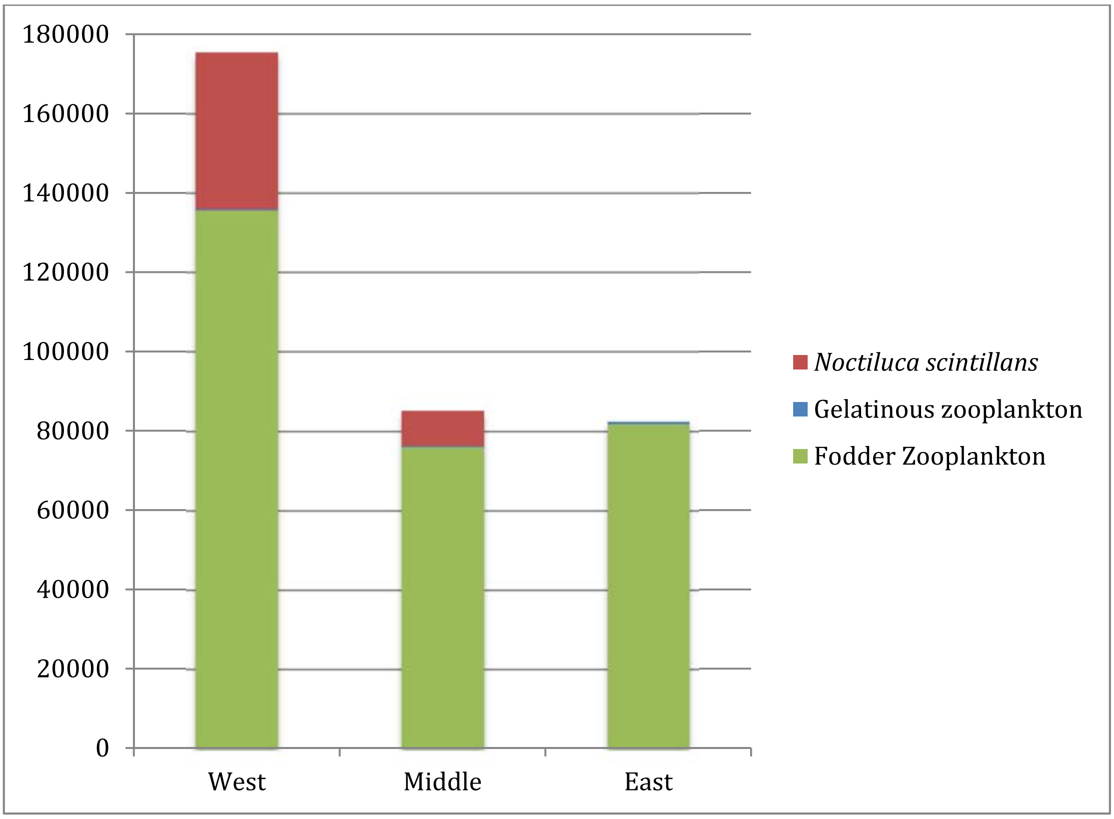


Figure 22 Relative abundance values (ind/m^2) of 3 major zooplankton groups namely; Fodder zooplankton, Gelatinous zooplankton and Noctiluca scintillans in 3 regions of the southern Black Sea in July 2013.

The comparison of the main zooplankton groups for the 3 regions did reveal a significant overall difference between them in terms of biomass (Table 4). In terms of biomass gelatinous zooplankton was dominating for all regions (526,792 mg/m^2). Biomass value of gelatinous zooplankton was followed by fodder zooplankton, which was an average of 11,614 mg/m^2 and *N. scintillans* displayed the lowest biomass value (1,478 mg/m^2) compared to other main groups.

Table 4 Biomass values (mg/m^2) of 3 main zooplankton groups namely; Fodder zooplankton, Gelatinous zooplankton and Noctiluca scintillans in 3 regions off southern Black Sea

	Fodder Zooplankton (mg/m^2)	**Gelatinous zooplankton (mg/m^2)**	***Noctiluca scintillans*** **(mg/m^2)**
West	14,290	501,592	3,476
Middle	4,882	581,329	765
East	13,834	512,330	0

The comparison of mean biomass value of 3 main groups showed that the highest value was observed in the middle part of the southern Black Sea in July 2013 as a result of highest biomass value of gelatinous zooplankton compared to other regions (Table 4).

Biomass value of fodder zooplankton was highest in the west (14,290 mg/m^2) and followed by eastern region. The lowest value was recorded in the middle part. While the abundance value of fodder zooplankton was similar in the middle and east parts, the high difference between biomass value indicates the difference of the size groups that constitutes fodder zooplankton, which indicates high number of larger individuals in the eastern region (Figure 23).

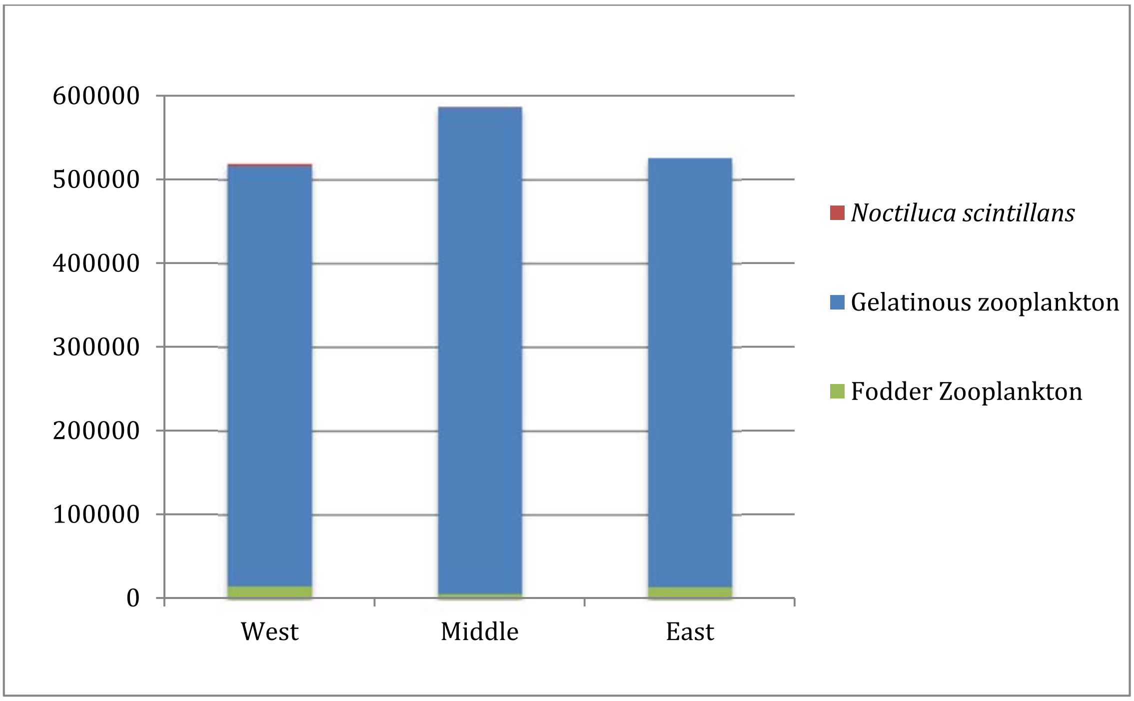


Figure 23 Relative biomass values (mg/m^2) of 3 major zooplankton groups namely; Fodder zooplankton, Gelatinous zooplankton and Noctiluca scintillans in 3 regions of the southern Black Sea in July 2013

While the number of fodder zooplankton was higher in the western part of the Black Sea, the percentage is lowest in the west. The highest percent of fodder zooplankton observed in the eastern part of the Black Sea. Also for gelatinous zooplankton while the abundance is higher in the eastern part, the percentage in terms of biomass is higher in the middle part (99%) of the southern Black Sea, which displayed the lowest gelatinous zooplankton value in terms of abundance.

The comparison of the main zooplankton groups for inshore and offshore stations reveals a significant overall difference for *Noctiluca scintillans* in terms of abundance and biomass (Table 5). *Noctiluca scintillans* was clearly higher (100,978 ind/m^2 and 8,886 mg/m^2) in the inshore waters of the western region while higher (17,820 ind/m^2 and1,568 mg/m^2) in the offshore waters in the middle part of the Black Sea. Fodder zooplankton was also clearly higher in terms of abundance in the offshore waters of the western Black Sea, while higher values were observed in the inshore waters of the middle part (Figure 24). In terms of biomass fodder zooplankton was higher in the offshore waters of the eastern region, while the abundance value was almost same for inshore and offshore waters according to selected transects (Table 6 and Figure 25) .

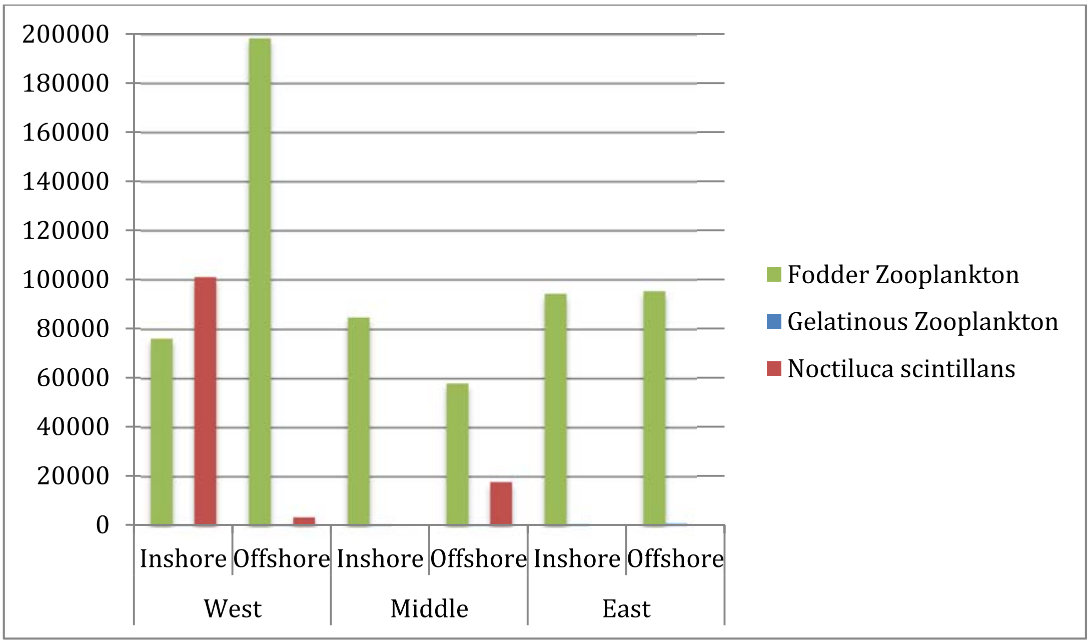


Figure 24 Abundance values (ind/m^2) of 3 major zooplankton groups namely; Fodder zooplankton, Gelatinous zooplankton and Noctiluca scintillans in inshore and offshore waters of 3 different regions in the southern Black Sea in July 2013

The comparison of the main zooplankton groups for inshore and offshore stations showed that in terms of biomass, gelatinous zooplankton was dominating the inshore stations while the fodder zooplankton was consistently higher in the offshore waters for all 3 regions.

Table 5 Abundance values (ind/m^2) of 3 major zooplankton groups namely; Fodder zooplankton, Gelatinous zooplankton and Noctiluca scintillans in inshore and offshore waters of 3 different regions in the southern Black Sea in July 2013

	West		Middle		East	
	Inshore	Offshore	Inshore	Offshore	Inshore	Offshore
Fodder Zooplankton	76224	198303	84894	57918	94293	95410
Gelatinous Zooplankton	281	433	237	208	503	875
Noctiluca scintillans	100978	3514	125	17820	0	0

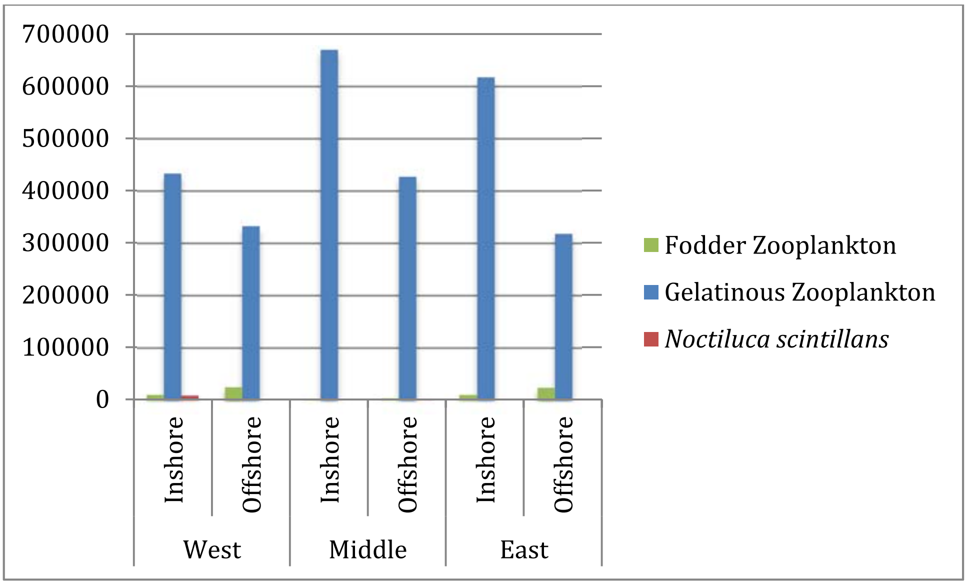


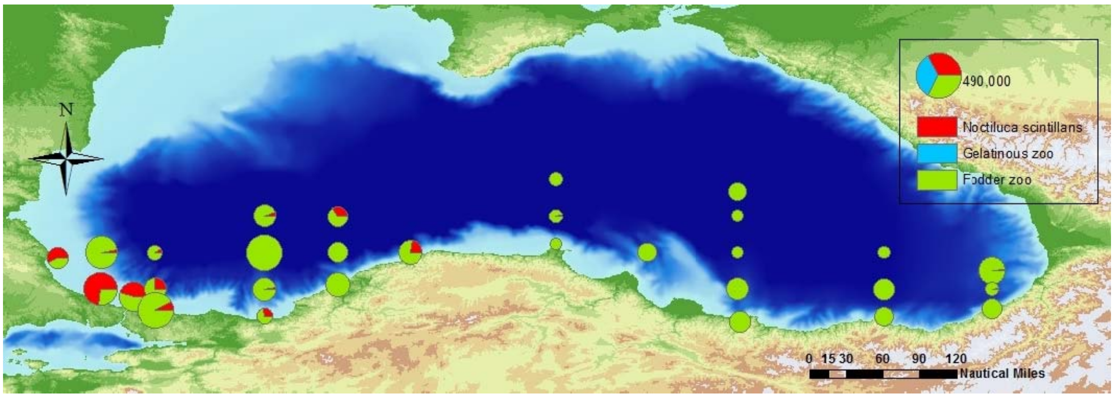
Figure 25 Biomass values (mg/m^2) of 3 major zooplankton groups namely; Fodder zooplankton, Gelatinous zooplankton and Noctiluca scintillans in inshore and offshore waters of 3 different regions in the southern Black Sea in July 2013

Table 6 Biomass values (mg/m^2) of 3 major zooplankton groups namely; Fodder zooplankton, Gelatinous zooplankton and Noctiluca scintillans in inshore and offshore waters of 3 different regions in the southern Black Sea in July 2013

	West		Middle		East	
	Inshore	Offshore	Inshore	Offshore	Inshore	Offshore
Fodder Zooplankton	9565	24659	2124	3395	9973	24030
Gelatinous Zooplankton	432978	332295	669402	427756	616630	318439
Noctiluca scintillans	8886	309	11	1568	0	0

The percentage of the fodder zooplankton was higher in the offshore stations, while *Noctiluca scintillans* was lower in terms of abundance.

A



B

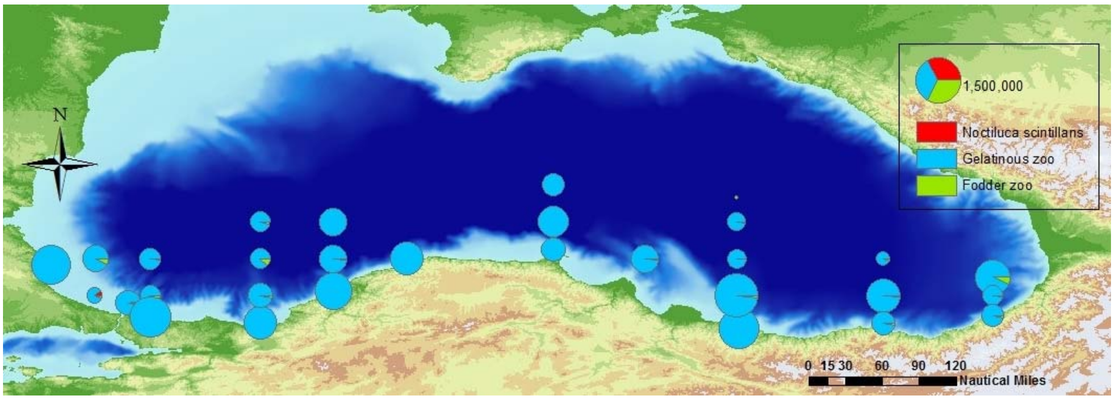
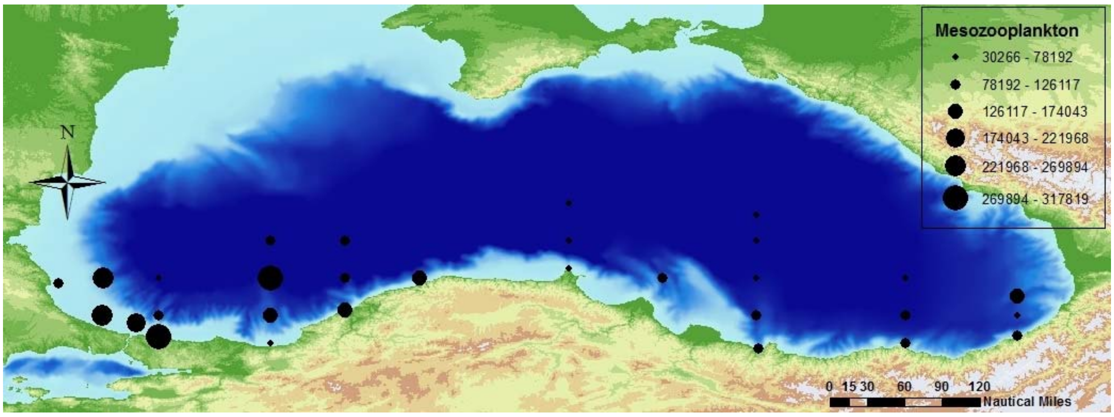


Figure 26 Spatial changes in abundance (ind/m^2) and biomass (mg/m^2) distributions of the main zooplankton groups namely; Fodder zooplankton, Gelatinous zooplankton and Noctiluca scintillans A. Abundance (ind/m^2), B. Biomass (mg/m^2).

As it is shown in Fig 27, the mesozooplankton abundance (ind/m^2) and biomass (mg/m^2) off the southern Black Sea displayed difference in the 3-metioned regions. In terms of abundance (ind/m^2) mesozooplankton was dominant in the inshore waters of the western part of the southern Black Sea, while it was higher in the offshore waters in the western and eastern part in terms of biomass (mg/m^2).

A



B

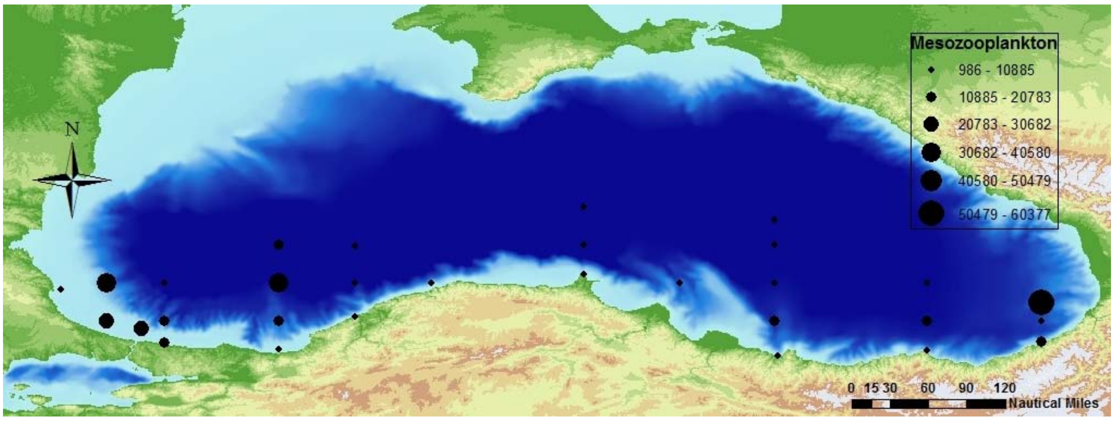


Figure 27 Spatial distribution of mesozooplankton in the southern Black Sea. A. Abundance (ind/m^2), B. Biomass (mg/m^2).

Total mesozooplankton was also examined in five groups, namely *Noctiluca scintillans*, Copepoda, Meroplankton, Cladocera and *Parasagitta setosa*. The mesozooplankton communities also differ in terms of group composition in different regions and in inshore and offshore waters (Figure 28, Figure 29 and Table 7).

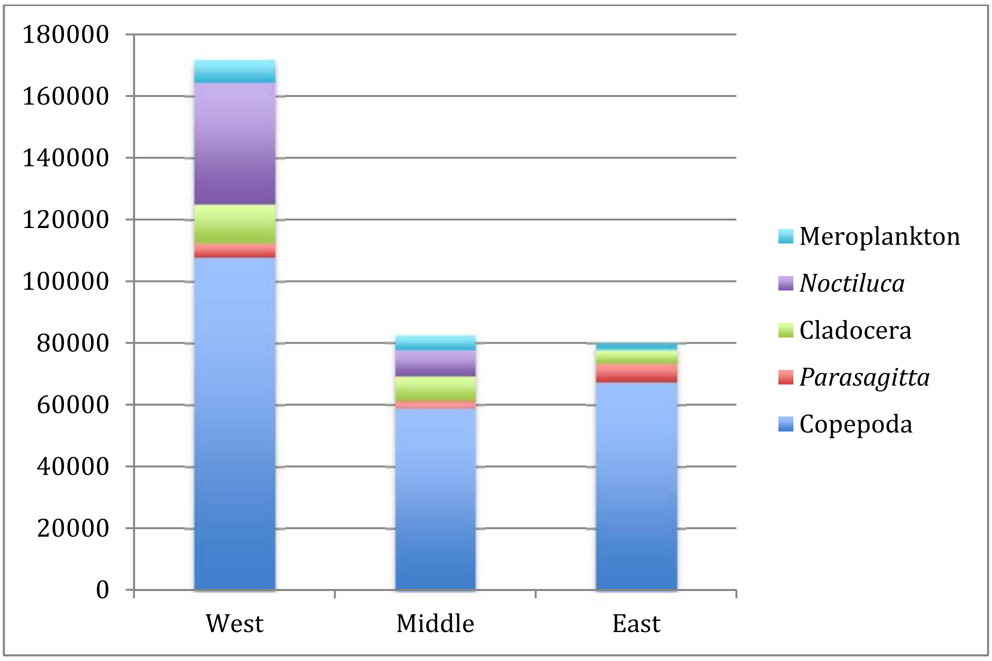


Figure 28 The spatial abundance values (ind/m^2) of the main mesozooplankton groups, namely *Noctiluca scintillans*, Copepoda, Meroplankton, Cladocera and *Parasagitta setosa* in 3 different region of the southern Black Sea in July 2013

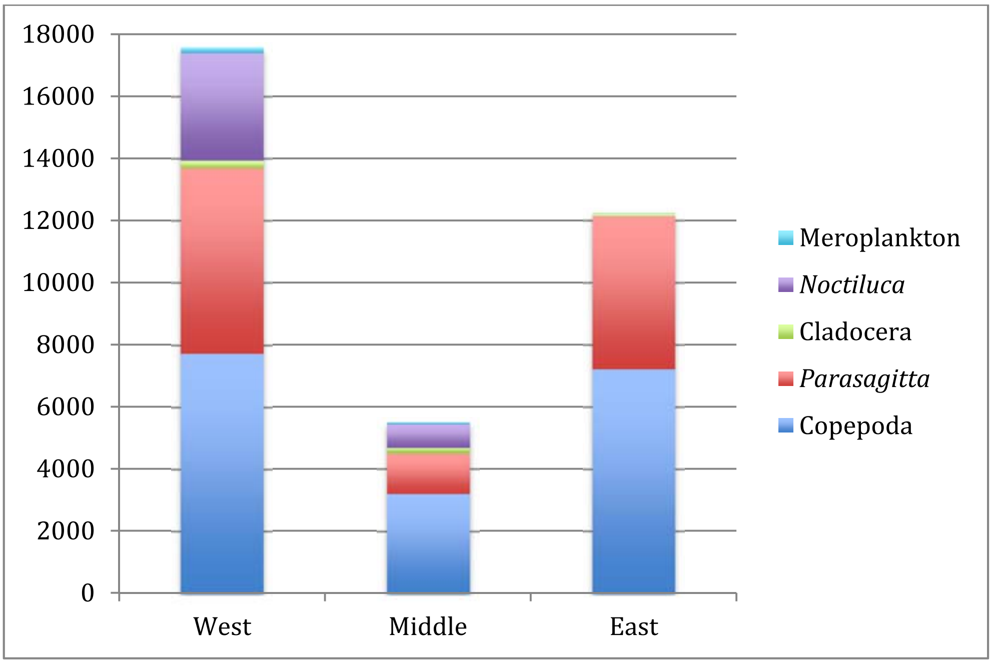


Figure 29 The spatial biomass values (mg/m^2) of the main mesozooplankton groups, namely *Noctiluca scintillans*, Copepoda, Meroplankton, Cladocera and *Parasagitta setosa* in 3 different region of the southern Black Sea in July 2013

Table 7 Mean abundance (upper section, (ind/m^2)) and biomass (lower section, (mg/m^2)) values of 5 main mesozooplankton groups namely *Noctiluca scintillans*, Copepoda, Meroplankton, Cladocera and *Parasagitta setosa* in 3 different regions of the southern Black Sea in July 2013

	Copepoda	***Parasagitta***	**Cladocera**	***Noctiluca***	**Meroplankton**
West	107,682	4,723	12,531	39,495	7,341
Middle	58,773	2,565	7,782	8,690	4,633
East	67,424	5,972	4,328	0	2,296
	Copepoda	**Parasagitta**	**Cladocera**	**Noctiluca**	**Meroplankton**
West	7,717	5,960	251	3,476	182

Middle	3,194	1,286	190	765	74
East	7,210	4,923	81	0	30

In terms of abundance, copepoda was the most dominant group of the main mesozooplankton for all regions, which is highest (107,682 ind/m^2) in the west and lowest (67,424 ind/m^2) in middle part of the southern Black Sea. The second most abundant group was *Noctiluca*, which was more dominant in the west and its abundance value was almost 5 times greater than middle part. Cladocerans was dominant in the west (12,531 ind/m^2) and its abundance value decreased from west to east. Meroplankton displayed similar preference as Cladocerans. The highest value was 7,341 ind/m^2 that was observed in the western region. *P. setosa* was the only group with a highest abundance value in the eastern region. All these groups were existed in both regions except *Noctiluca*. It is especially interesting to note the decline in the abundance of the *N. scintillans* in the eastern Black Sea.

In terms of biomass, copepod was the most dominant group of mesozooplankton for all the 3 regions. Even the number of copepods was clearly high in the western regions, in terms of biomass there was not big difference between eastern and western Black Sea. The highest biomass value (7,717 mg/m^2) was in the western Black Sea, while the lowest e was higher in the middle part of the southern Black Sea. The highest biomass value (5,960 mg/m^2) for *P. setosa* was observed in the west, while the highest abundance value was in the east. This indicates bigger individuals were existed in the western region. In terms of biomass, the highest value (182 mg/m^2) for meroplankton was in the western region, which was almost 6 times greater than eastern region.

For both abundance and biomass values the comparison of inshore and offshore waters (for selected stations from mentioned transects) for five major groups of mesozooplankton showed preference of inshore waters for Cladocerans, *Noctiluca* and Meroplankton and preference of offshore waters for Copepoda and *Parasagitta*.

3.3.1 Fodder Zooplankton

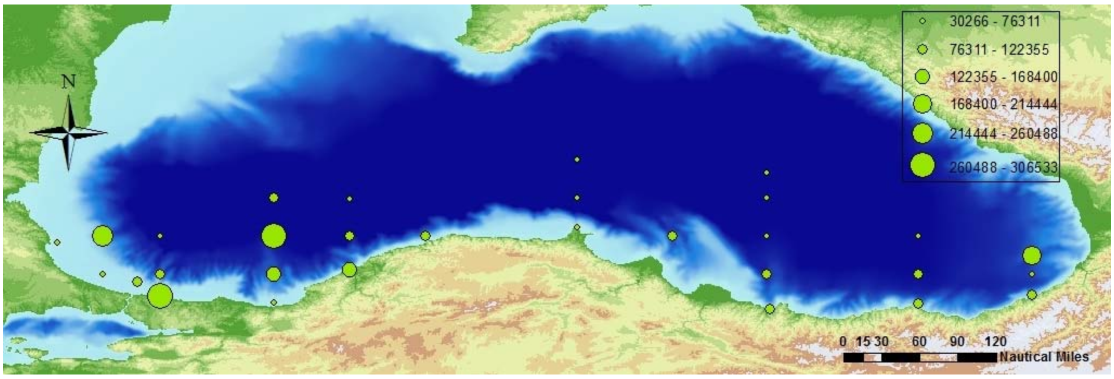
Spatial Abundance and biomass distribution

The fodder zooplankton consisted of all the mesozooplankton groups other than *Noctiluca*, i.e. Copepoda, Cladocera, Meroplankton, Chaetognatha and Appendicularia (Ünal, 2002). Their total abundance and biomass plots were quite different that those of the mesozooplankton (which includes *N. scintillans*), to see the difference so it can be attributed to this sole species of *Noctiluca*.

The mean abundance value of fodder zooplankton was 100,013 ind/m^2 in the southern Black Sea. The comparison of 3 mentioned region for abundance value of fodder zooplankton displayed its highest value in the west (135,611 ind/m^2), which followed by eastern region (81,881 ind/m^2). The lowest value was observed in the middle part (75,997 ind/m^2). The comparison of inshore and offshore waters showed higher fodder zooplankton values in offshore compared to inshore.

In terms of abundance, four stations showed higher values compared to all other stations. 3 of them were in the western Black Sea, which includes 1 inshore station (near to Bosphorus) and 2 offshore stations. The only abundant station for fodder zooplankton in the eastern Black Sea was in Batumi Gyre (Figure 30).

A



B

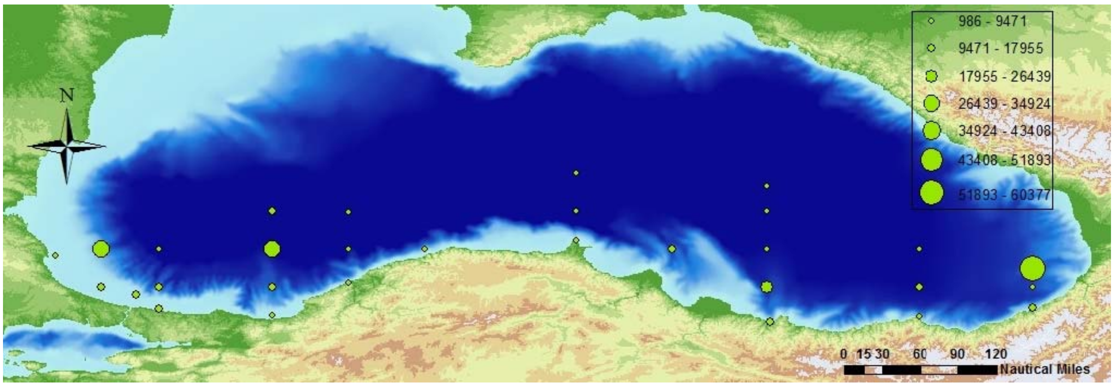


Figure 30 Spatial changes in the abundance and biomass of fodder zooplankton (which excludes *Noctiluca*) in the southern Black Sea in July 2013. A. Abundance (ind/m^2) B. Biomass (mg/m^2)

The average biomass value of fodder zooplankton was 11,614 mg/m^2 in the southern Black Sea. Western region displayed its highest value (average of 14,290 mg/m^2), which was almost similar with eastern region. The lowest value recorded in the middle part. The comparison of inshore and offshore water for fodder zooplankton showed that the biomass value was more than 2 times greater in the offshore waters.

In terms of biomass, 3 stations with high values observed in the southern Black Sea. The highest biomass value was in the in Batumi Gyre and the others were in the western region.

For both abundance and biomass, lowest values were observed in the middle part of the southern Black Sea and abundance and biomass values for offshore stations of the 3 regions were higher. Near the Bosphorus the biomass was low while in terms of abundance this stations value was one of the highest, due to high numbers of small individuals.

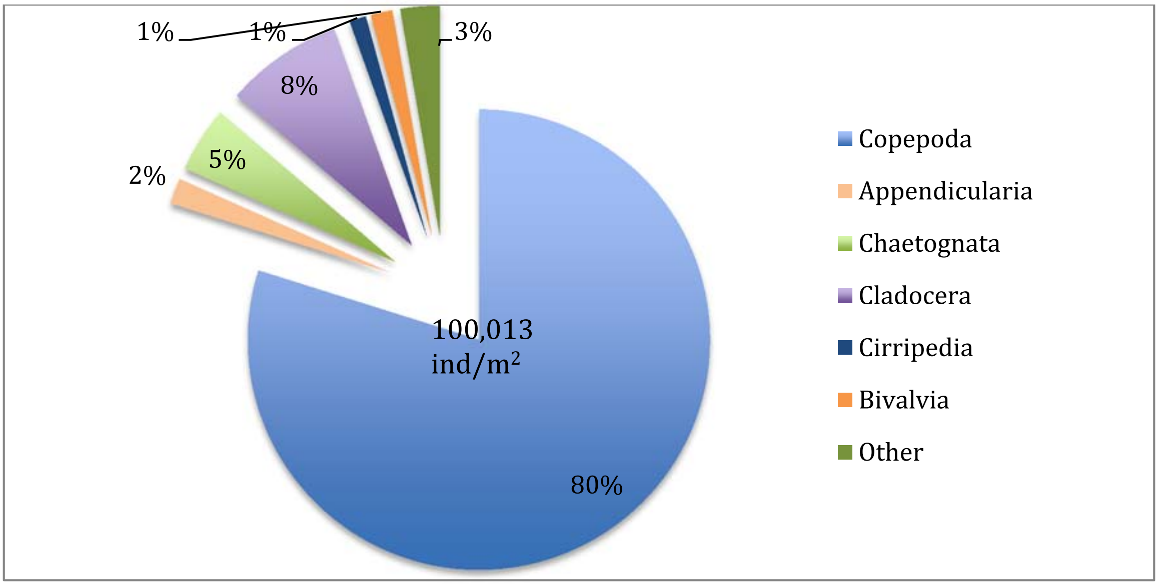
Group composition

Copepods were dominating the fodder zooplankton in terms of both biomass and abundance. 80% of the total fodder zooplankton was copepods in terms of abundance and 54% in terms of biomass.

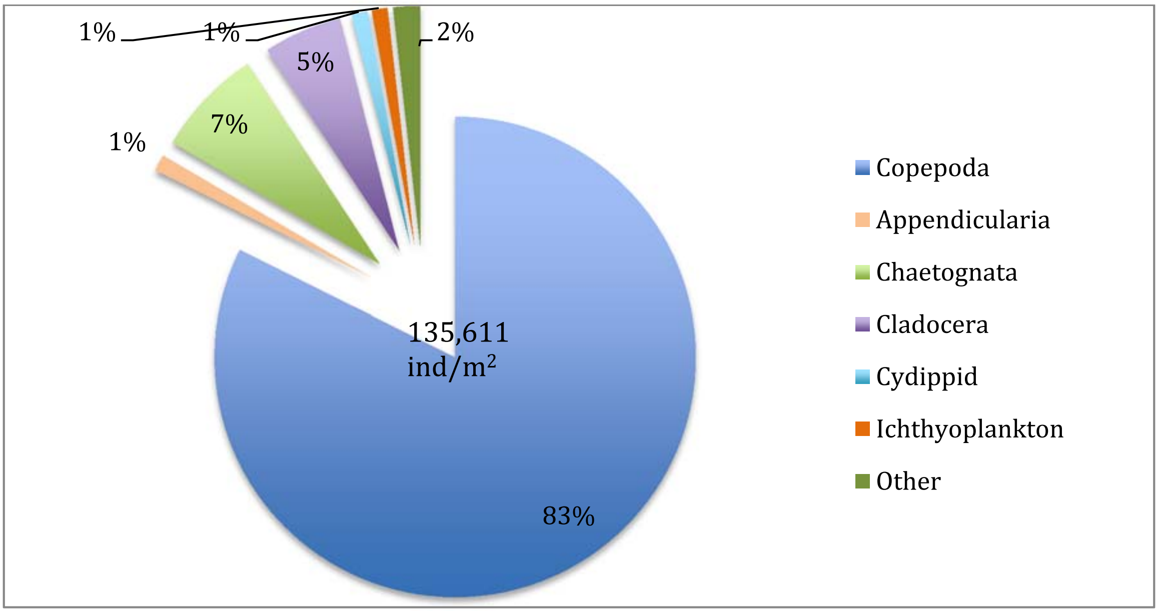
In terms of abundance cladocerans was the second group and followed by chaetognatha in the southern Black Sea. Comparing the percentage of abundance for copepods in 3 regions, highest values shown in the western part and similar percentage with middle and east parts of the Black Sea, which is also same for chaetognaths. Appendicularians' percentage was lower in the western and eastern parts comparing to the middle part of the Black Sea. Cladocerans' abundance was also highest in the middle part and followed by eastern and western parts of the southern Black Sea (Figure 31).

The comparison of the percentage of abundance of the fodder zooplankton for inshore and offshore waters showed that appendicularians, cladocerans , cirripedia, bivalvia and gastropoda were higher in the inshore stations while copepoda and chaetognatha was higher in the offshore stations.

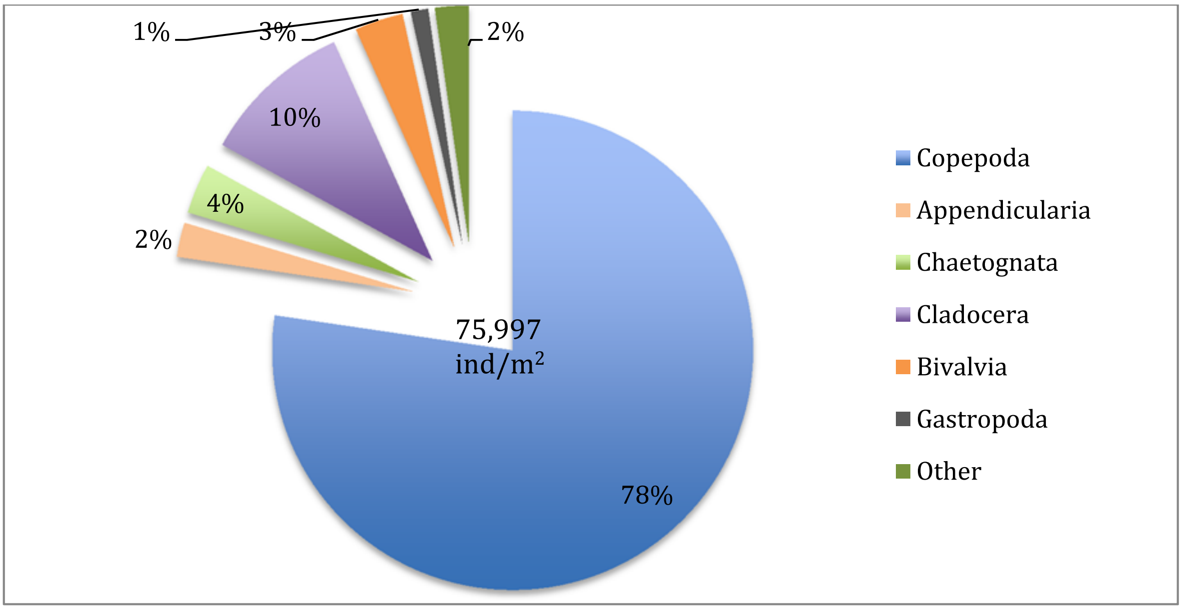
A


1%
1%
3%
8%
5%
2%
100,013 ind/m²
80%
Copepoda
Appendicularia
Chaetognata
Cladocera
Cirripedia
Bivalvia
Other

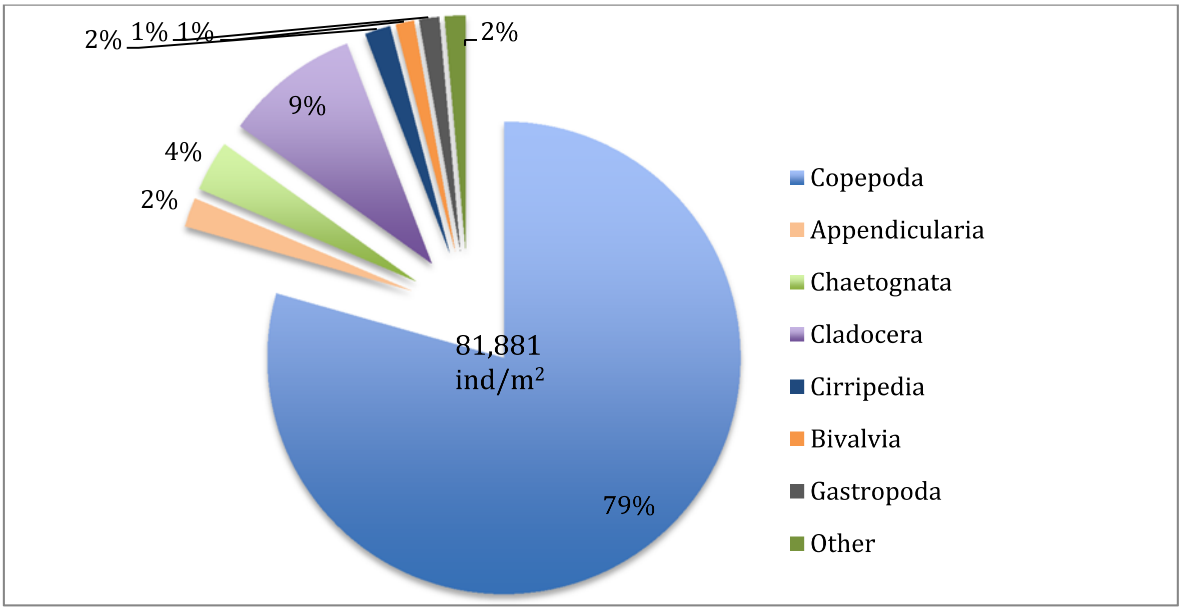
B


1%
1%
2%
5%
7%
1%
135,611 ind/m²
83%
Copepoda
Appendicularia
Chaetognata
Cladocera
Cydippid
Ichthyoplankton
Other

C


1%
3%
2%
10%
4%
2%
75,997 ind/m²
78%
Copepoda
Appendicularia
Chaetognata
Cladocera
Bivalvia
Gastropoda
Other

D


2%
1%
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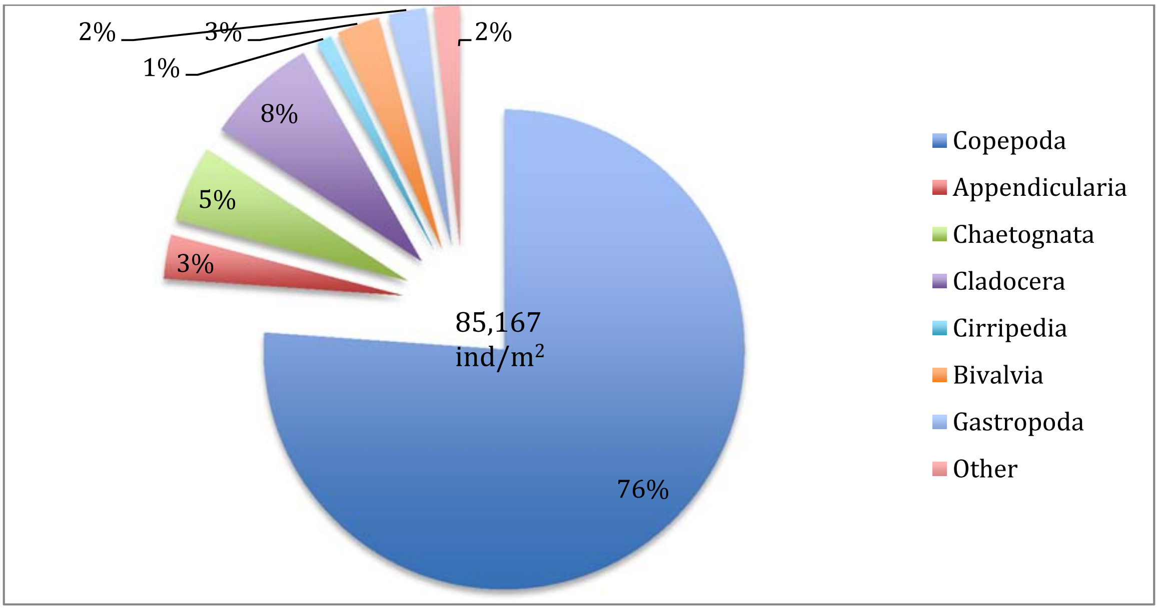
9%
4%
2%
81,881 ind/m²
79%
Copepoda
Appendicularia
Chaetognata
Cladocera
Cirripedia
Bivalvia
Gastropoda
Other

E



F

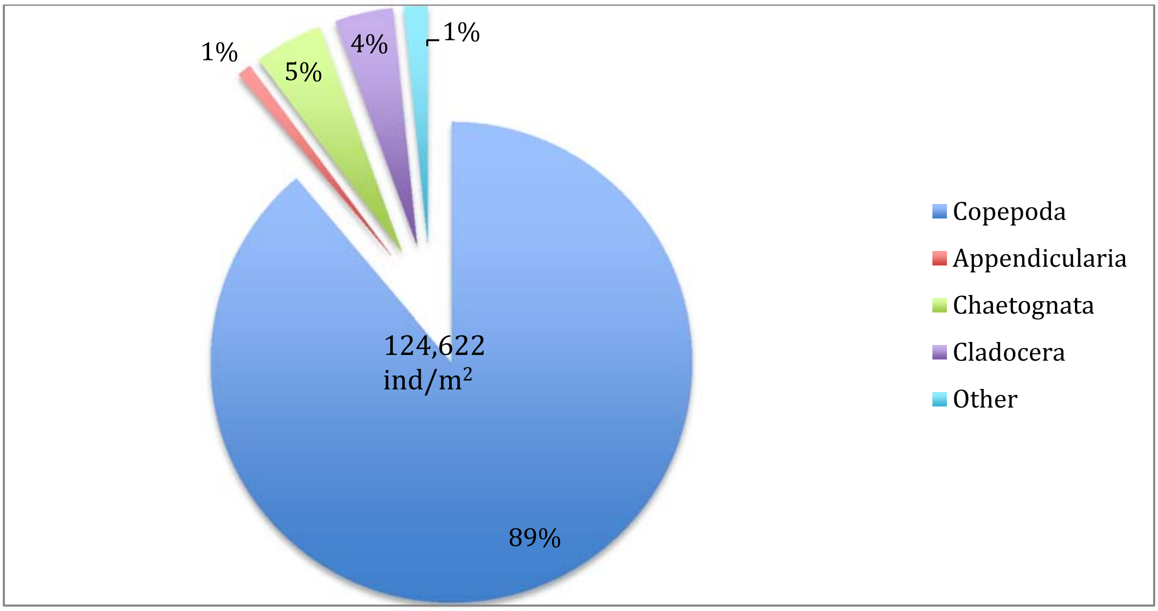


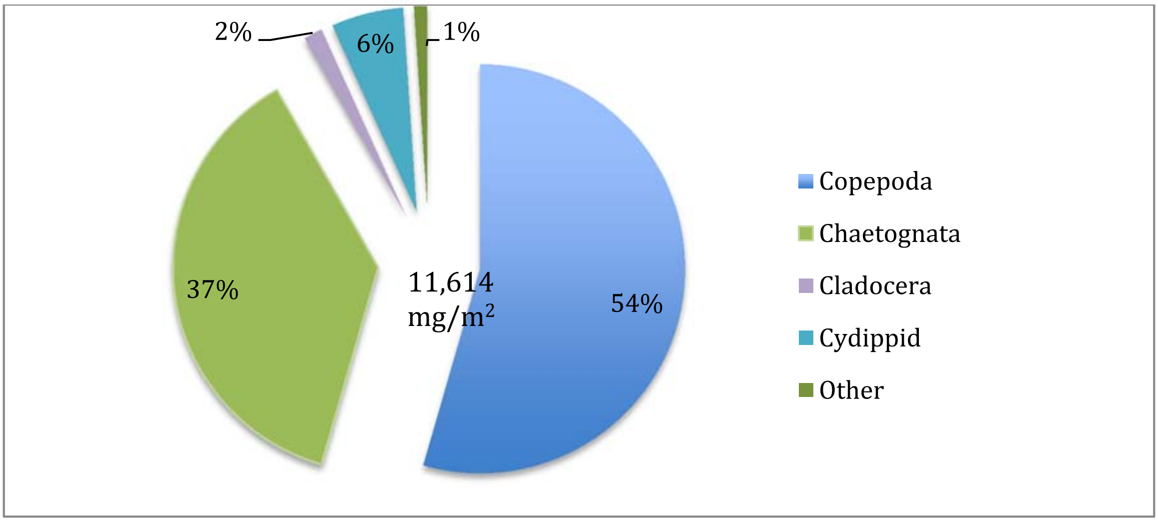
Figure 31 Percent composition of the main fodder zooplankton groups in terms of abundance (ind/m^2). A. Abundance in the southern Black Sea B. Abundance in the west C. Abundance

in the middle D. Abundance in the east E. Abundance in inshore stations F. Abundance in offshore stations

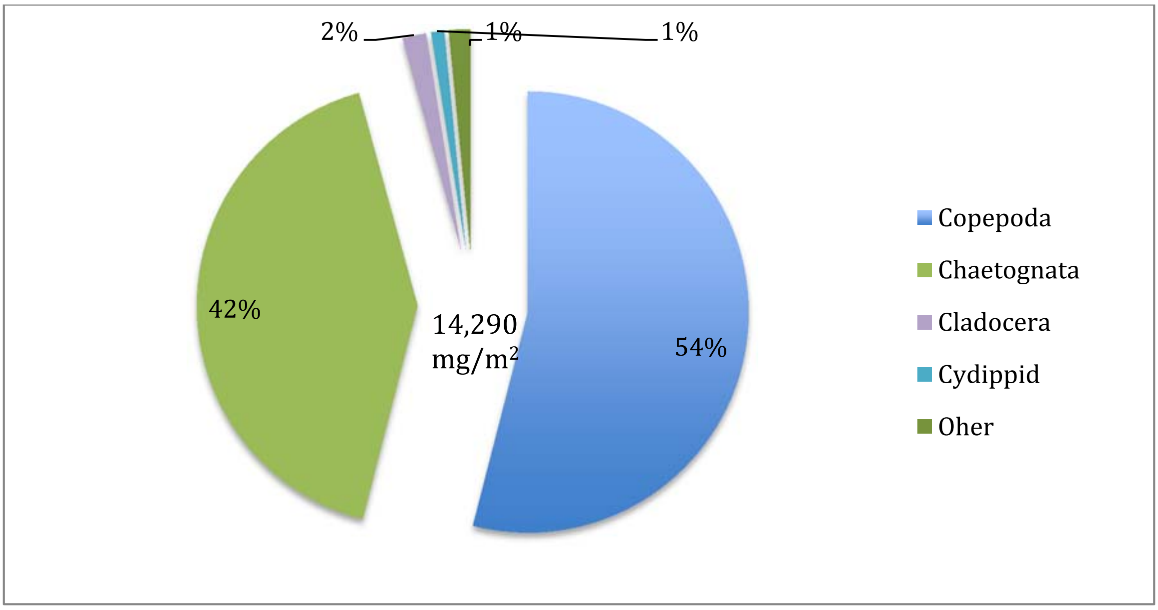
In terms of biomass, copepods were the most dominant group with similar values of chaetognatha and followed by ctenophora larvae and cladocera in the southern Black Sea. Comparing the percentage of biomasses of copepods for the three regions of the Black Sea showed the middle part having the highest value, which is reverse for chaetognatha.

The comparison of the percentage of biomass of the fodder zooplankton for inshore and offshore waters showed that biomass values for copepods and ctenophore larvae were higher in the inshore stations, while chaetognaths and cladocerans were higher in the offshore stations (Figure 32).

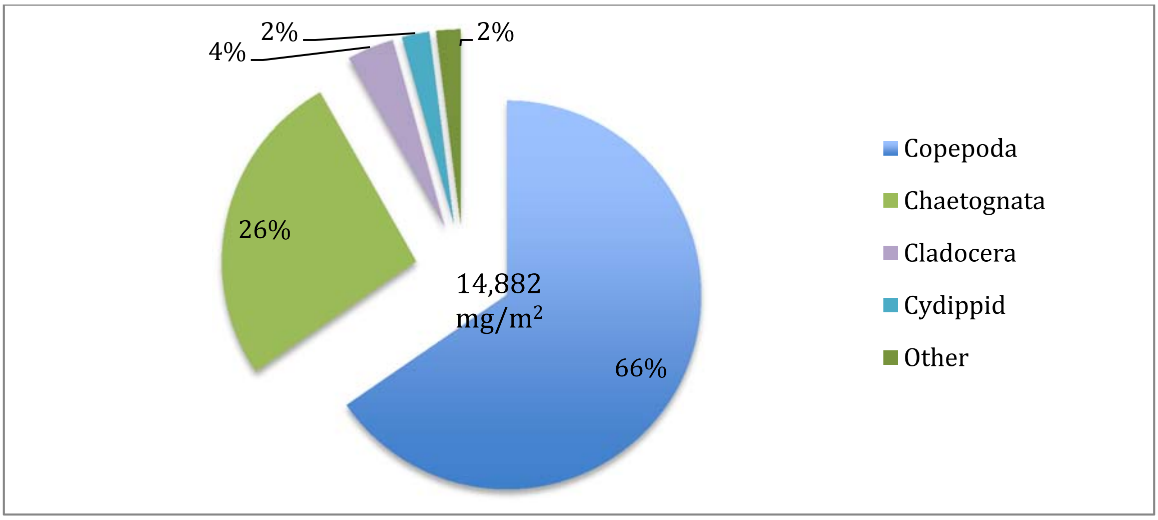
A



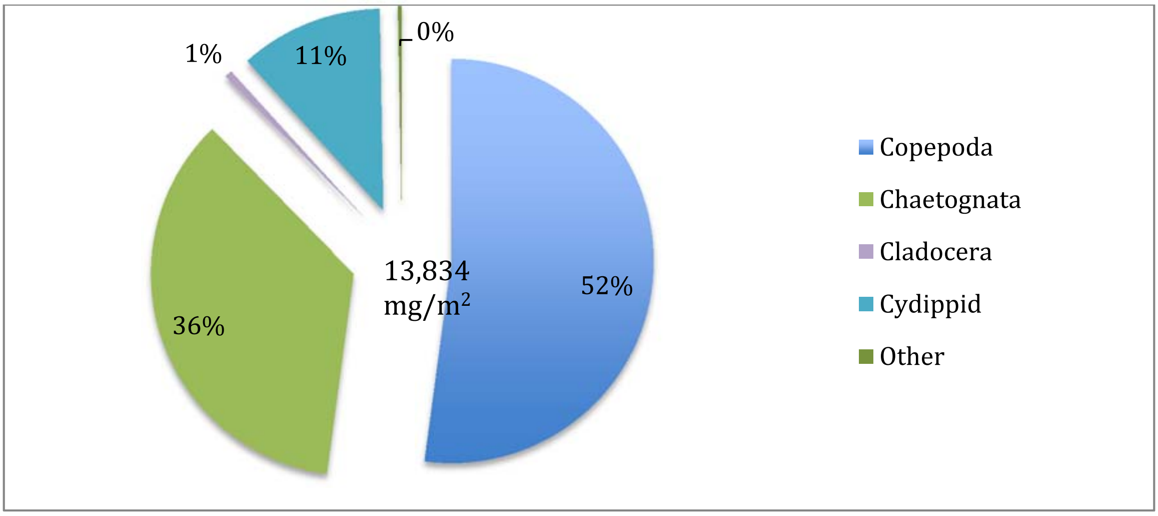
B


2%
1%
1%
42%
14,290
mg/m²
54%
Copepoda
Chaetognata
Cladocera
Cydippid
Oher

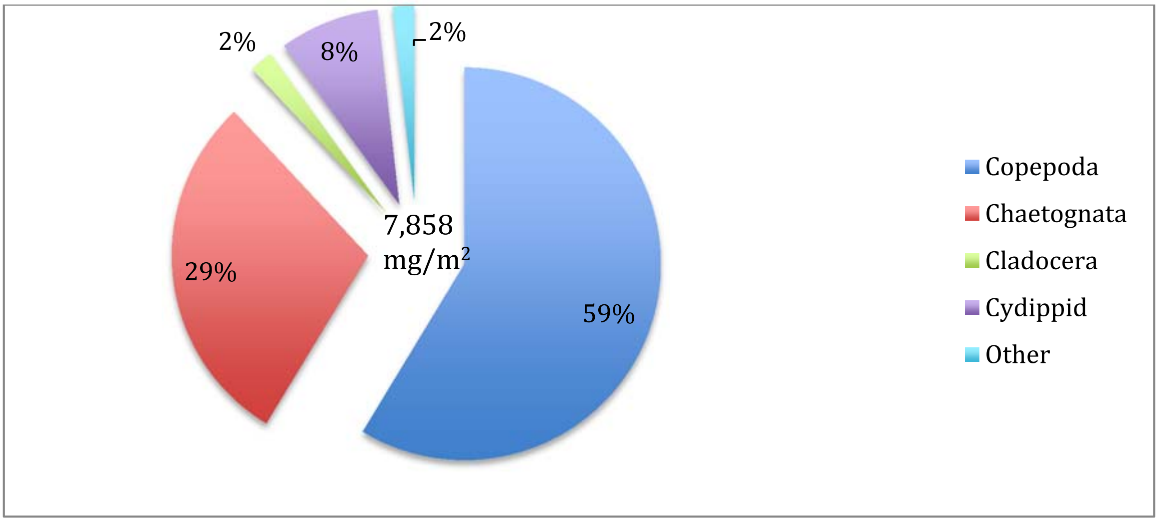
C


4%
2%
2%
26%
14,882
mg/m²
66%
Copepoda
Chaetognata
Cladocera
Cydippid
Other

D


1%
11%
0%
13,834 mg/m²
52%
36%
Copepoda
Chaetognata
Cladocera
Cydippid
Other

E


2%
8%
2%
7,858 mg/m²
29%
59%
Copepoda
Chaetognata
Cladocera
Cydippid
Other

F

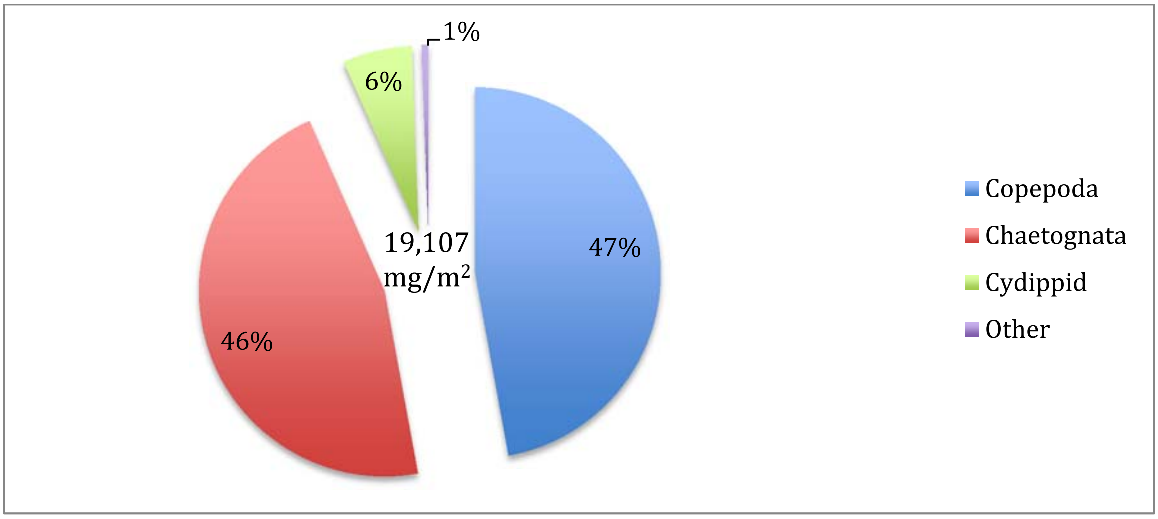
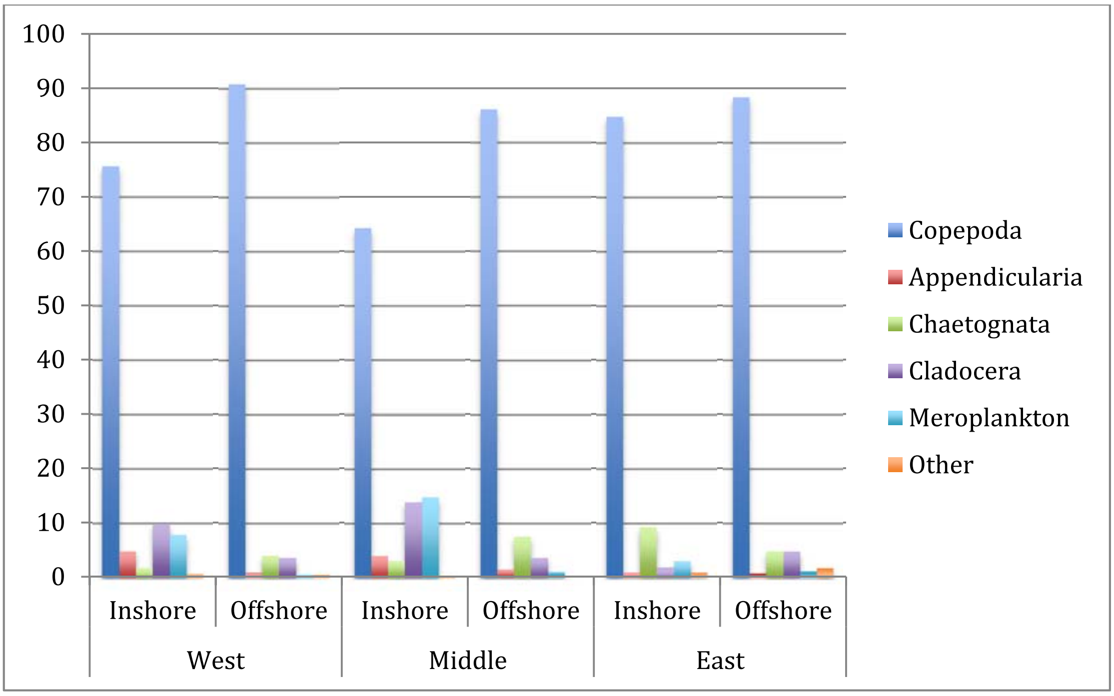


Figure 32 Percent composition of the main fodder zooplankton groups in terms of biomass (mg/m^2). A. Biomass in the southern Black Sea B. Biomass in the west C. Biomass in the middle D. Biomass in the east E. Biomass in inshore station F. Biomass in offshore station

A



B

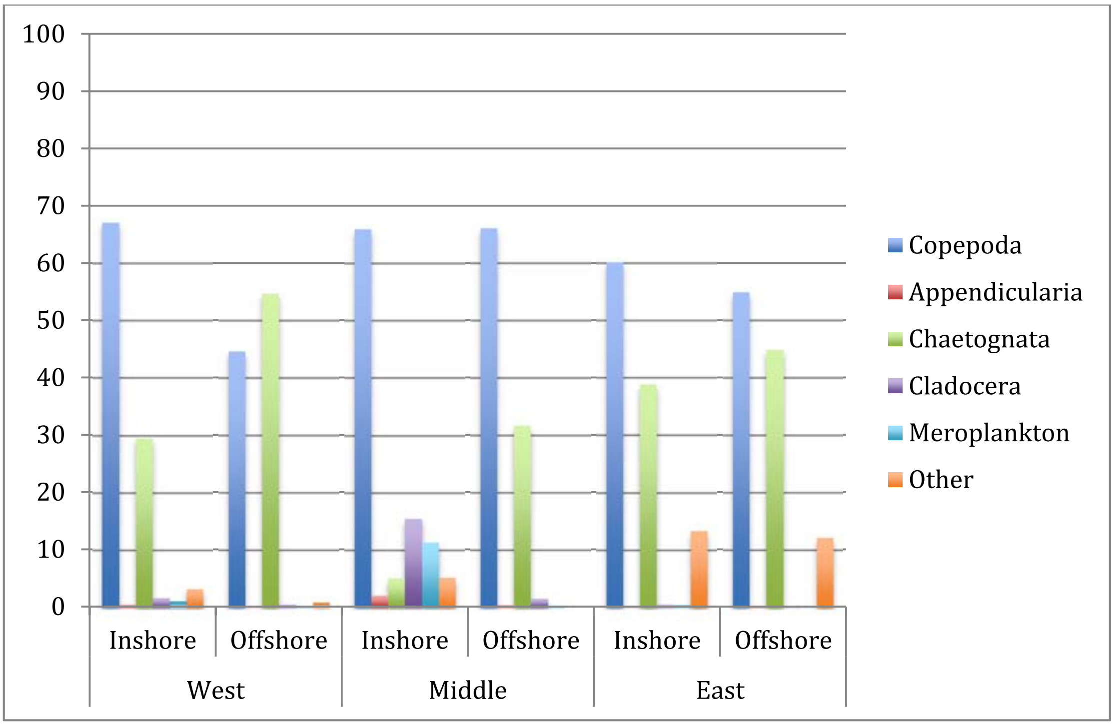


Figure 33 Percent composition of abundance and biomass values of the main mesozooplankton groups, namely *Noctiluca scintillans*, Copepoda, Meroplankton, Cladocera and *Parasagitta setosa* in inshore and offshore waters of 3 regions of the southern Black Sea in July 2013 A. Abundance (ind/m^2) B. Biomass (ind/m^2)

Abundance values of different fodder zooplankton groups, such as copepoda, appendicularia, cladocera, cirripedia, gastropoda, isopoda, decapoda, eggs of fish, cumacean and ostracoda, were found to be more dominant in the west, while planktonic stages of bivalvia were more dominant in the middle and *P. setosa*, polychaeta, nematoda and larvae of fish and ctenophora more dominant in the east.

In terms of biomass, individuals of copepoda, appendicularia, P. setosa, cladocera, cirripedia, gastropoda, isopoda, and ostracoda were more dominant in the west, while bivalvia was more dominant in the middle and individuals of polychaeta, nematoda and larvaes of ctenophora were more dominant in the east (Figure 33).

In terms of abundance comparison of inshore and offshore waters for major fodder zooplankton groups showed higher values of appendicularia, cladocera, cirripedia, bivalvia, gastropoda, decapoda, eggs and larvaes of fish, cumacean and ostracoda individuals in inshore waters, while copepod, *P. setosa*, polychaeta, isopoda, nematode and larvaes of fish displayed higher preference for offshore waters in the southern Black Sea. In terms of biomass, appendicularia, cladocera, cirripedia, bivalvia, gastropoda, decapoda and ostracoda individuals displayed higher values in inshore waters, while copepod, *P. setosa*, polychaeta, isopoda, nematoda and larvaes of ctenophora showed higher values in offshore waters (Figure 33).

Spatial abundance of the 5 main fodder zooplankton groups namely, Copepoda, *Oikopleuro dioica*, Meroplankton Cladocera, and *Parasagitta setosa* were presented in the Figures 34 and Figure 35. The copepods dominated the fodder zooplankton groups. The cladocerans were more abundant in terms of abundance in the inshore waters of the western region and both inshore and offshore waters of the middle part of the Black Sea. In terms of abundance, meroplankton was largely confined to the inshore stations and was identified to be more abundant in the inshore waters of the western region. Meroplankton was also high in the inshore waters of the middle and eastern parts of the southern Black Sea.

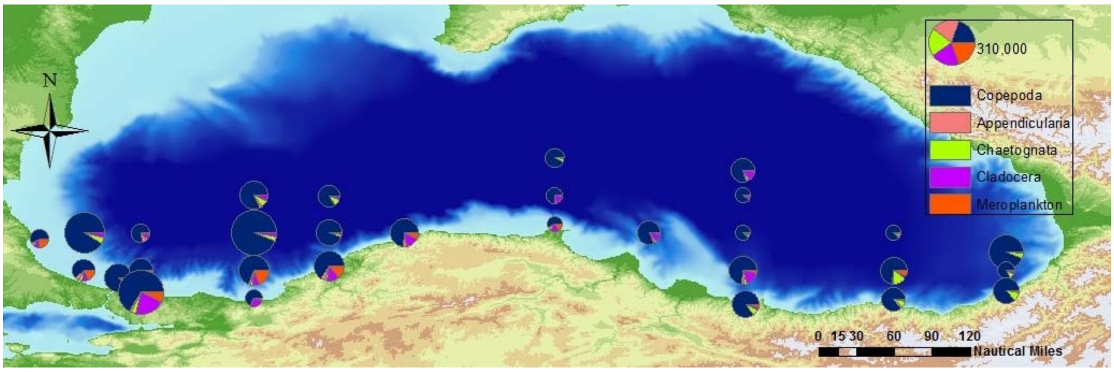


Figure 34 The spatial distributions of the abundance (ind/m^2) values for the main fodder zooplankton groups: Copepoda, *Oikopleuro dioica*, Meroplankton, Cladocera and *Parasagitta setosa* in southern Black Sea in July 2013

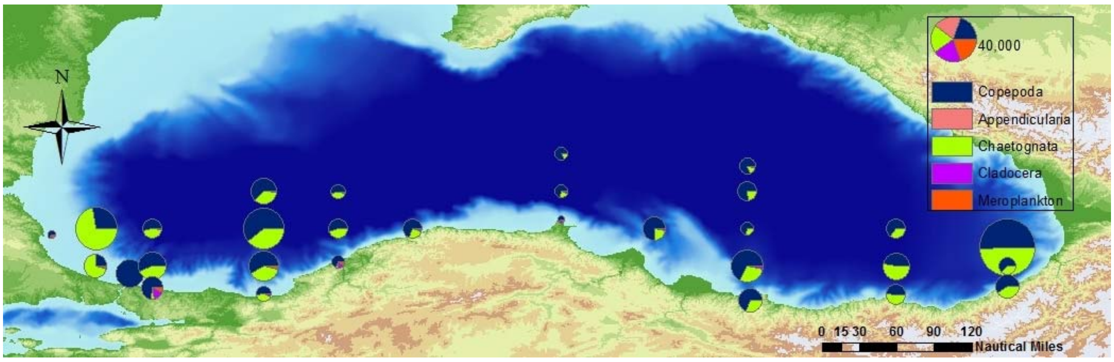


Figure 35 The spatial distributions of the biomass (mg/m^2) values for the main fodder zooplankton groups: Copepoda, *Oikopleuro dioica*, Meroplankton, Cladocera and *Parasagitta setosa* in southern Black Sea in July 2013

Parasagitta setosa was the second most abundant group after copepods in terms of biomass in the southern Black Sea (Figure 35), while its value higher than copepods in the western region. Meroplankton biomass was also higher in the west than the 2 other regions.

3.3.1.1 Copepoda

Spatial abundance and biomass distribution

Copepods were the most important group in mesozooplankton, consisting of 8 species (i.e. *Calanus euxius, Acartia clausi, Acartia tonsa, Pseudocalanus elongates, Centropages ponticus, Paracalanus parvus, Oithona similis, Pontella mediterranea*). The copepod species identified in the southern Black Sea consisted of mainly the calanoid copepods except *Oithona similis*, which was the sole representative of the cyclopoid copepods.

The copepod quantity changed among the 3 different regions and between the inshore and offshore stations. The mean abundance value of copepods was 79,878 ind/m^2. Copepod abundance value was also higher in the western region (ranges between 26,604 ind/m^2 and 286,118 ind/m^2 compared to the middle and eastern regions of the southern Black Sea. In the eastern region, especially stations in the

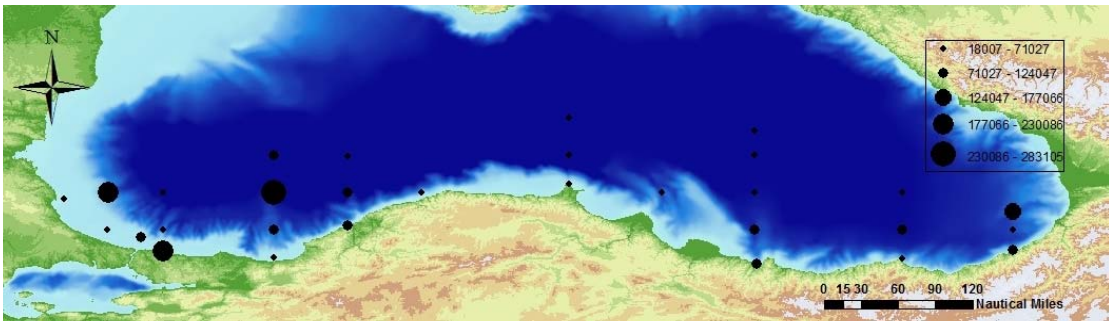
Batumi Gyre displayed high values of abundance for copepods (Figure 36). Minimum abundance values were observed in the middle part of the southern Black Sea ranging between 19,078 ind/m^2 and 89,851 ind/m^2 (Table 8).

Table 8 Min, max and mean abundance (ind/m^2) and biomass (mg/m^2) values of copepods in the southern Black Sea and in 3 different regions of it in July 2013.

	Black Sea	**West**	**Middle**	**East**
Min Abundance (ind/m2)	19,078	26,604	19,078	26,353
Max Abundance (ind/m2)	286,118	286,118	89,851	155,608
Mean Abundance (ind/m2)	79,878	107,682	58,773	67,424
Min Biomass (mg/m2)	416	796	416	2,052
Max Biomass (mg/m2)	26,566	19,644	7,270	26,566
Mean Biomass (mg/m2)	6,325	7,717	3,194	7,210

The mean biomass value was 6,325 mg/m^2 for the entire southern Black Sea. In terms of biomass, most fertile regions were the Batumi gyre in the east, stations near the Bosphorus and offshore waters in the west. Even both min and max biomass values are higher in the eastern area, average biomass values for the western (7,717 ind/m^2) and eastern regions (7,210 ind/m^2) were almost similar due to the high abundance in the western region. Lowest biomass value was seen in the middle part of the Black Sea, which was only 3,194 mg/m^2 (Table 8).

A



B

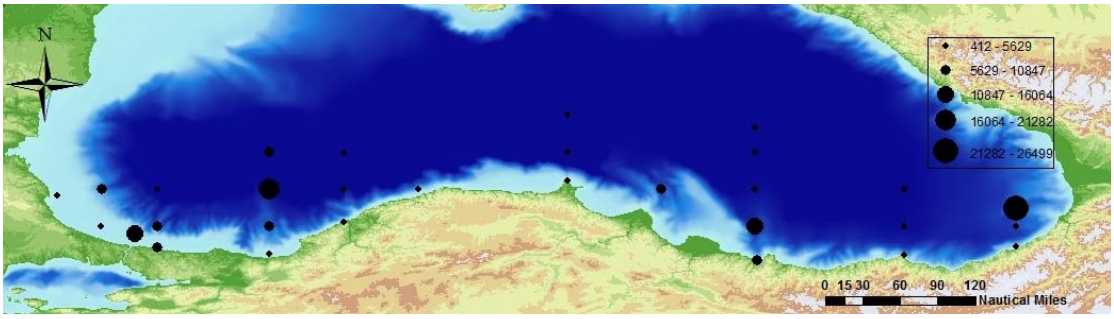


Figure 36 Abundance and biomass distributions of the copepoda in the southern Black Sea in July 2013. A. Abundance (ind/m^2) B. Biomass (mg/m^2)

Group composition

In terms of group abundance, the most abundant species was found to be *Acartia clausi* (49,673 ind/m^2), constituting 65% of the total copepod abundance in the southern Black Sea in July 2013. Abundance of the *A. clausi* was different in 3 regions of the Black Sea. The maximum value was in the western Black Sea (67,137 ind/m^2), being almost 2 times greater than that in the eastern region, where the lowest abundance value was observed. In the middle part of the southern Black Sea, the mean abundance value of *A. clausi* was 41,576 ind/m^2. *A. clausi* was followed by *Pseudocalanus elongatus* (10,556 ind/m^2), making up the 14% of the Black Sea populations, respectively. This species displayed the least abundance value (5,365 ind/m^2) in the middle part of the Black Sea, while highest abundance (13,775 ind/m^2) was in the eastern part. The third most abundant species was *Calanus euxinus* (5,260 ind/m^2), which constitutes 74% of the total copepod biomass and followed by *Centropages ponticus* (3,424 ind/m^2), *Paracalanus parvus* (3,093 ind/m^2), *Oithona similis* (2,554 ind/m^2) and *Acartia tonsa* (1,514 ind/m^2). On the other hand, *Pontella mediterranea* was identified to be the least abundant copepod species in the southern Black Sea with only 21 ind/m^2. Abundance of *C. euxinus, A. clausi, C. ponticus, P. parvus, O. similis* and *A. tonsa* were higher in the western region of the southern

Black Sea, while *P. elongatus* and *P. mediterranea* was only species that were more abundant in the southeastern Black Sea (Table 9).

When the biomass composition of the copepods was considered, the mass species was identified to be *C. euxinus* (4,700 mg/m^2), constituting 74% of the total biomass. *C. euxinus* was followed by *A. clausi* (1,037 mg/m^2), making up the 16% of the total biomass. *P. elongatus* was the third species that displayed highest biomass with 367 mg/m^2 and constituting the 6%. The contribution of *C. ponticus* was 115 mg/m^2 and followed by *A. tonsa* (44 mg/m^2), *P. parvus* (34 mg/m^2), *Oithona similis* (13 mg/m^2) and *P. mediterranea* (0.05 mg/m^2). In terms of biomass both *A. clausi* (1,427 mg/m^2), *C. ponticus* (154 mg/m^2), *P. parvus* (67 mg/m^2), *O. similis* (24 mg/m^2) and *A. tonsa* (120 mg/m^2) showed higher biomass values in the western region of the southern Black Sea, while higher biomass values for *C. euxinus* (5,822 mg/m^2), *P. elongatus* (488 mg/m^2) and *P. mediterranea* (0.14 mg/m^2) were higher in the eastern region. The lowest biomass values for each species were observed in the middle part (Table 9).

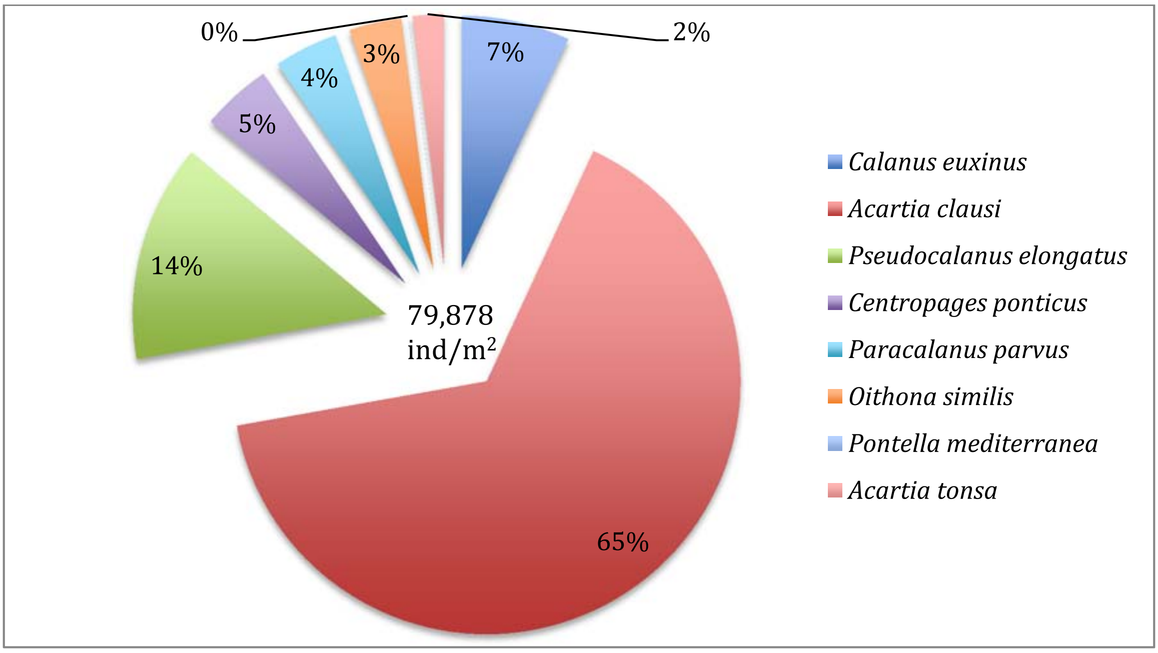
Table 9 Mean abundance (ind/m^2) and biomass (mg/m^2) values of 8 copepod species in west, middle and east parts of the southern Black Sea in July 2013

		C. euxinus	***A. clausi***	***P. elongatus***	***C. ponticus***	***P. parvus***	***O. similis***	***Pontella***	***A. tonsa***	**Total**
Abu	**W**	6.548	67.137	11.112	4.769	5.909	4.917	0	4.130	104.750
	M	2.643	41.576	5.365	1.059	3.090	1.506	0	0	55.318
	E	5.875	38.098	13.775	3.799	280	953	57	0	63.310
	BS	5.260	49.673	10.556	3.424	3.093	2.554	21	1.514	76.373
Bio	**W**	5.531	1.427	381	154	67	24	0	120	7.710
	M	2.015	906	182	40	34	7	0	0	3.187
	E	5.822	741	488	130	3	4	0	0	7.200
	BS	4.700	1.037	367	115	34	13	0	44	6.316

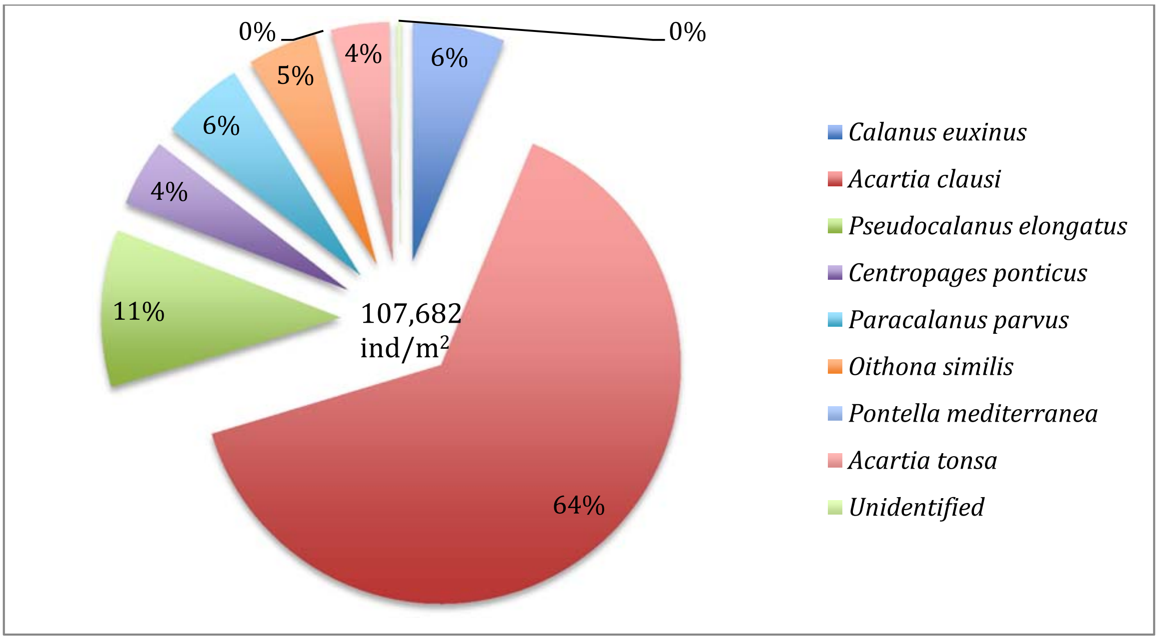
Table 10 Abundance (ind/m^2) and biomass (mg/m^2) values of 8 copepod species in inshore and offshore waters of the southern Black Sea in July 2013

	Abundance (ind/m^2)		**Biomass** (mg/m^2)	
	Inshore	**Offshore**	**Inshore**	**Offshore**
Calanus euxinus	4,019	6,142	2,925	6,254
Acartia clausi	38,724	69,996	820	1,388
Pseudocalanus elongatus	9,990	8,833	361	283
Centropages ponticus	1,719	6,581	68	200
Paracalanus parvus	3,102	2,538	34	28
Oithona similis	3,528	1,610	17	8
Pontella mediterranea	0	0	0	0
Acartia tonsa	167	2,454	5	70

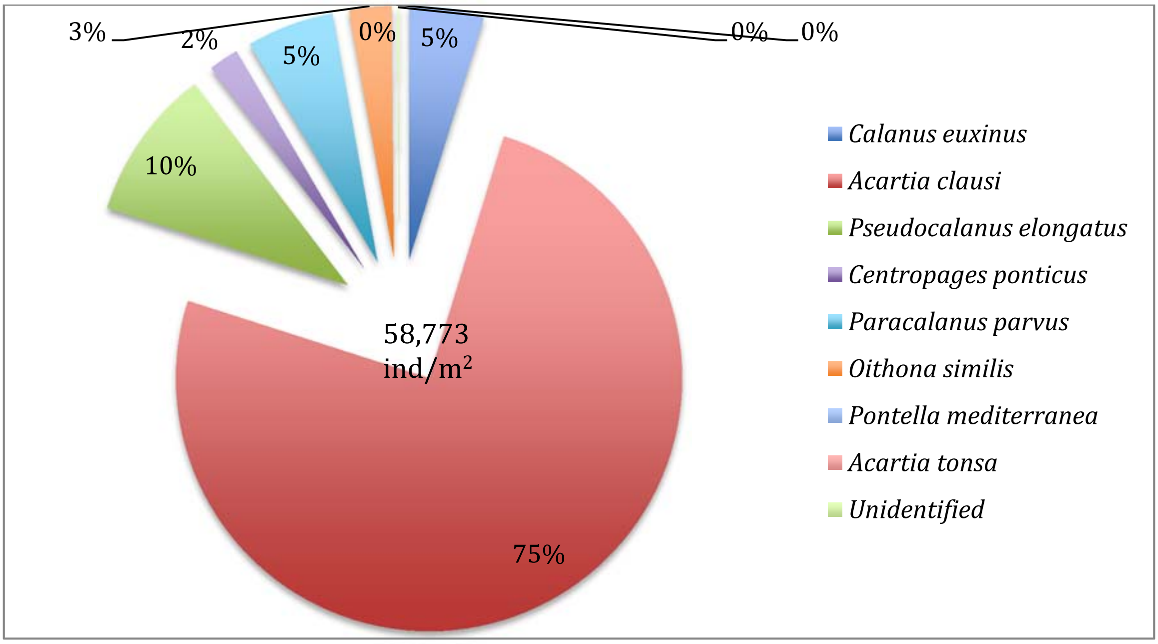
A



B


0%
4%
0%
5%
6%
6%
4%
11%
107,682
ind/m²
64%
Calanus euxinus
Acartia clausi
Pseudocalanus elongatus
Centropages ponticus
Paracalanus parvus
Oithona similis
Pontella mediterranea
Acartia tonsa
Unidentified

C


3%
2%
5%
0%
5%
0%
0%
10%
58,773
ind/m²
75%
Calanus euxinus
Acartia clausi
Pseudocalanus elongatus
Centropages ponticus
Paracalanus parvus
Oithona similis
Pontella mediterranea
Acartia tonsa
Unidentified

D

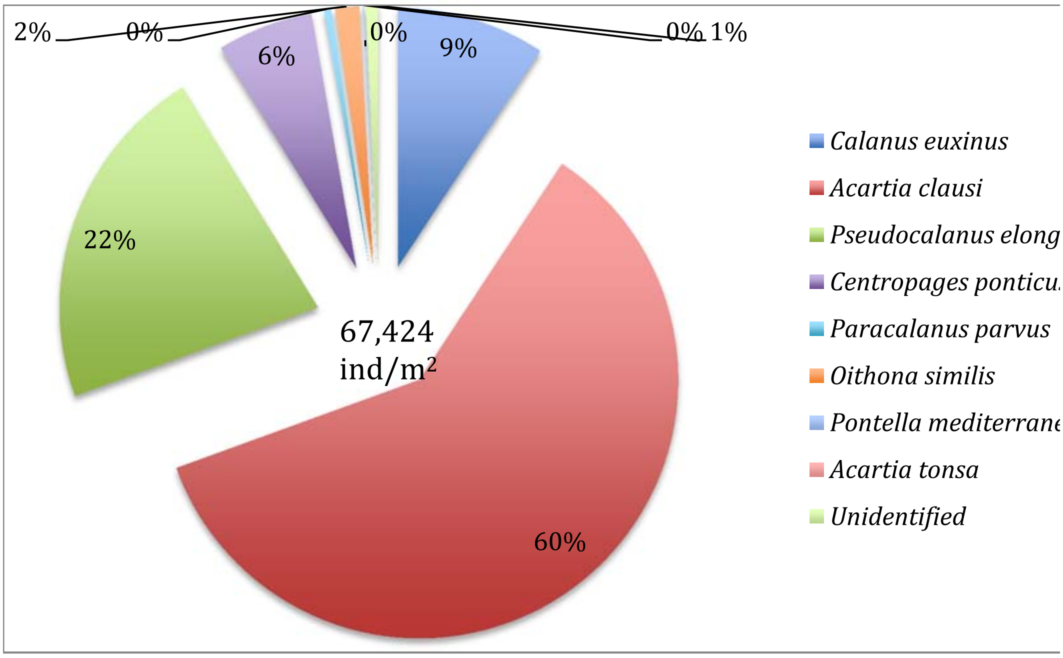
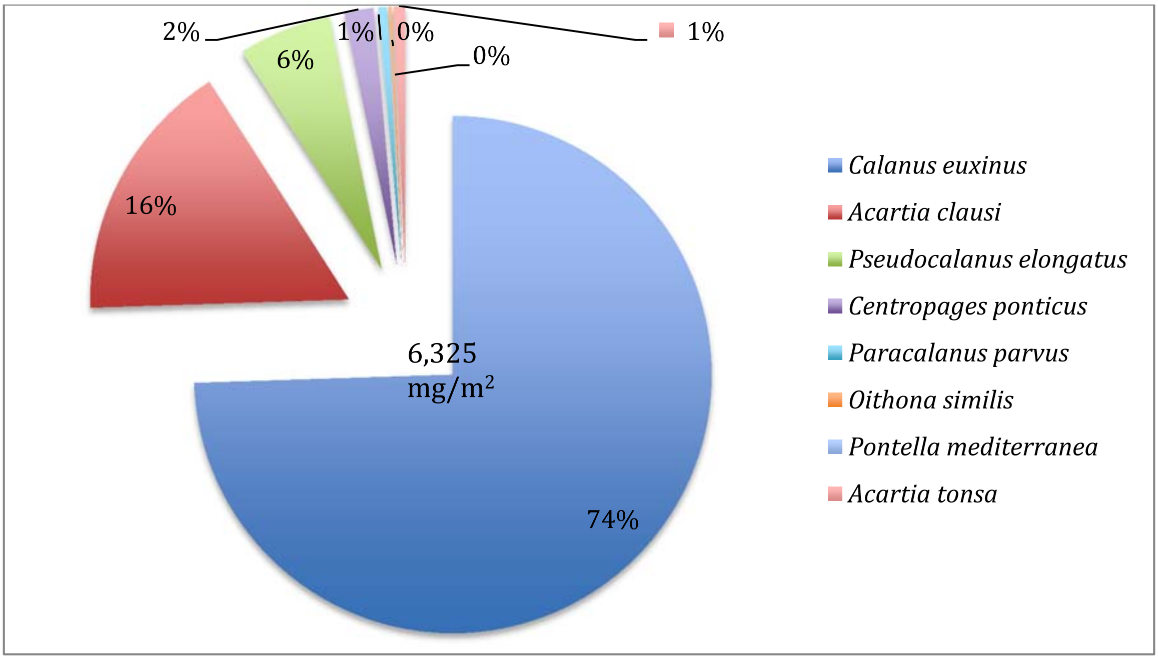


Figure 37 Percent abundance (ind/m^2) contributions of the copepod species in the southern Black Sea in July 2013. The copepod species were: *Calanus euxinus*, *Acartia clausi*, *Acartia tonsa*, *Pseudocalanus elangatus*, *Paracalanus parvus*, *Centropages ponticus*, *Oithona similis*, *Pontella mediterranea*. A. Southern Black Sea B. Western stations C. Middle stations D. Eastern stations

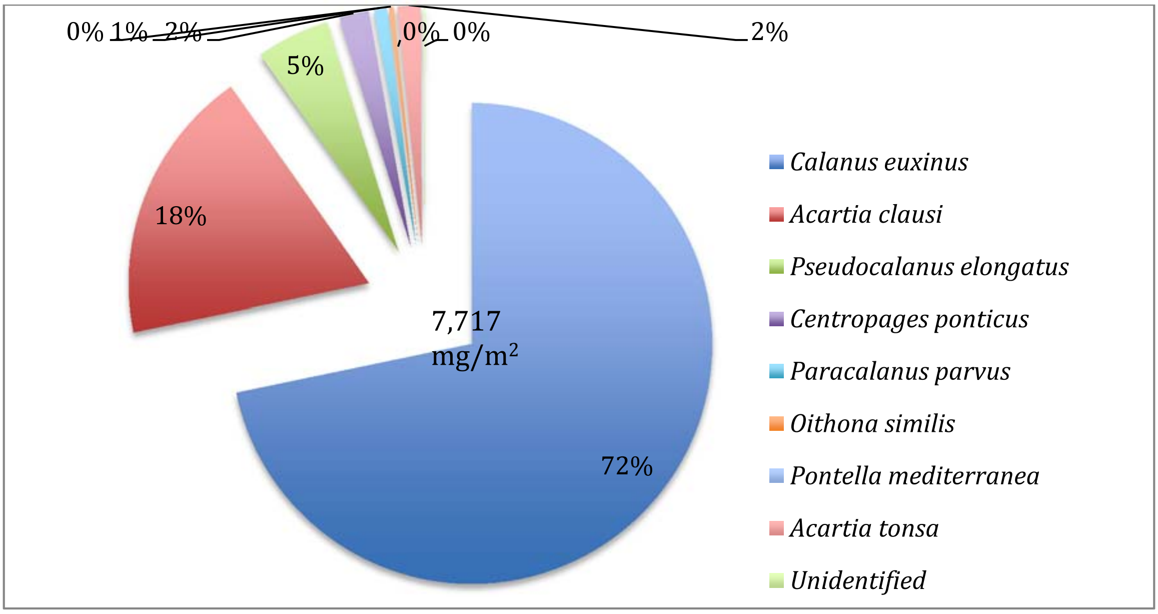
As a result, *A. clausi* was the most abundant in the both regions of the southern Black Sea. While its abundance value was highest in the western area, the percent abundance in the middle part is higher than other regions due to the low number of individuals of all other species in this region. The percent of *P. elongatus* was highest in the eastern (22%), similar in the other 2 regions (Figure 37).

In terms of biomass *C. euxinus* was the species that constituted the bulk of the copepod biomass at both regions. It constituted more than half of the total copepod biomass, and in the eastern part it was 81% (Figure 38).

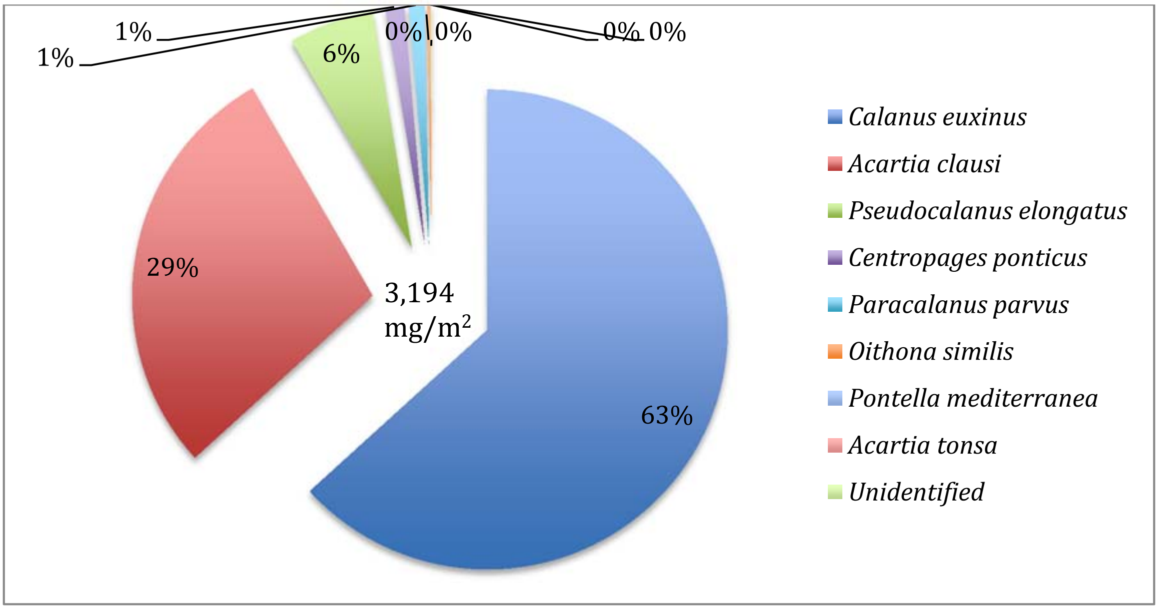
A


2%
6%
1%
0%
0%
1%
16%
6,325
mg/m²
74%
Calanus euxinus
Acartia clausi
Pseudocalanus elongatus
Centropages ponticus
Paracalanus parvus
Oithona similis
Pontella mediterranea
Acartia tonsa

B


0%
1%
2%
5%
0%
0%
2%
18%
7,717
mg/m²
72%
Calanus euxinus
Acartia clausi
Pseudocalanus elongatus
Centropages ponticus
Paracalanus parvus
Oithona similis
Pontella mediterranea
Acartia tonsa
Unidentified

C



D

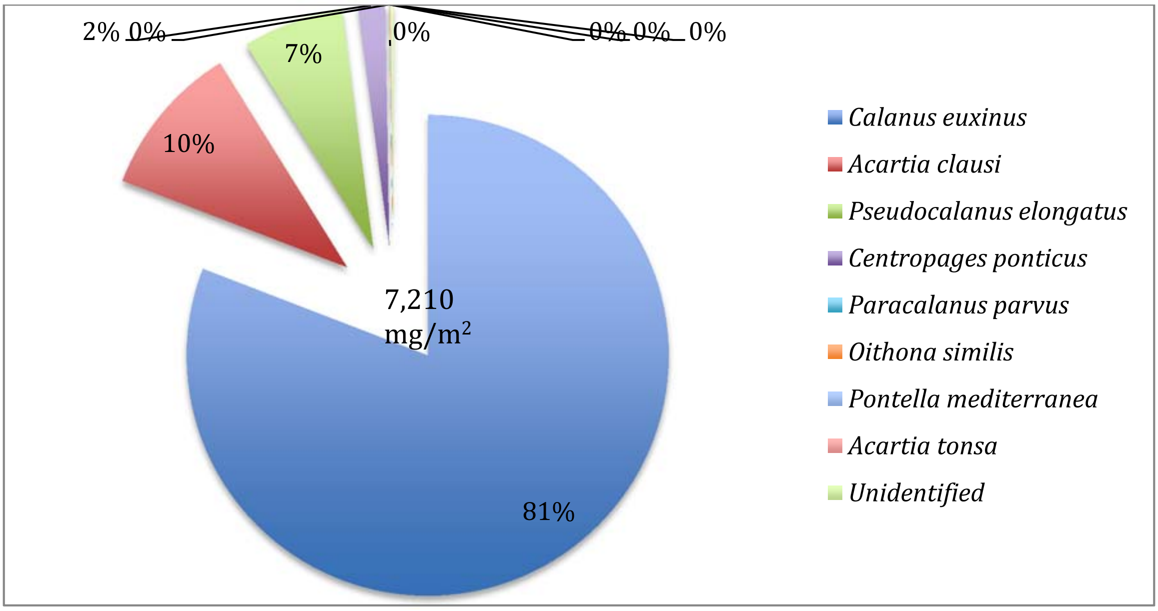
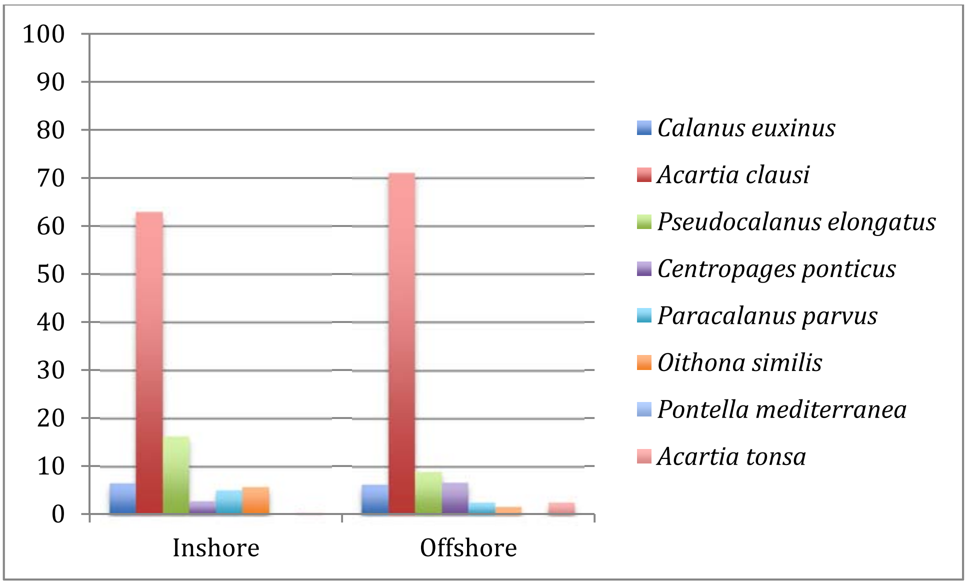


Figure 38 Percent biomass (mg/m^2) contributions of the copepod species that were identified in the southern Black Sea in July 2013. The copepod species were: *Calanus euxinus*, *Acartia clausi*, *Acartia tonsa*, *Pseudocalanus elangatus*, *Paracalanus parvus*, *Centropages ponticus*,

Oithona similis, *Pontella mediterranea*. A. Southern Black Sea B. Western stations C. Middle stations D. Eastern stations

The comparison of the abundance values of copepod species for inshore and offshore waters showed that in terms of abundance *Acartia* species, *C. ponticus* showed a preference for the offshore waters, while *P. parvus*, *O. similis* found to be more abundant at the inshore waters (Figure 39). However, *C. euxinus* was also one of the species preferring the offshore waters, whereas *P. elongatus* did not show any preference (Table 10).

A



B

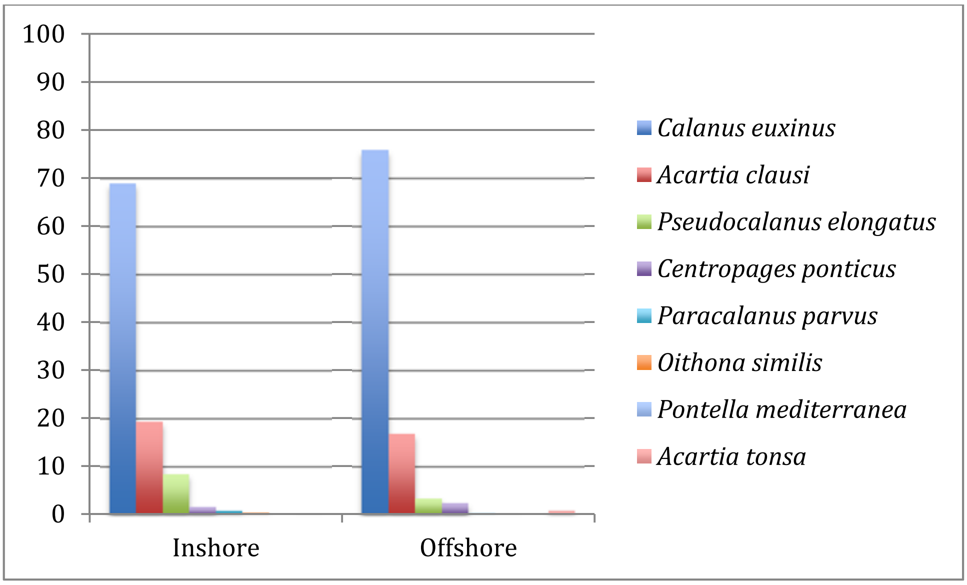


Figure 39 The spatial inshore - offshore distributions in the relative abundance of copepod species identified in the southern Black Sea in July 2013: *Calanus euxinus*, *Acartia clausi*, *Acartia tonsa*, *Pseudocalanus elangatus*, *Paracalanus parvus*, *Centropages ponticus*, *Oithona similis*, *Pontella mediterranea*. A. Abundance (ind/m^2) B. Biomass (mg/m^2)

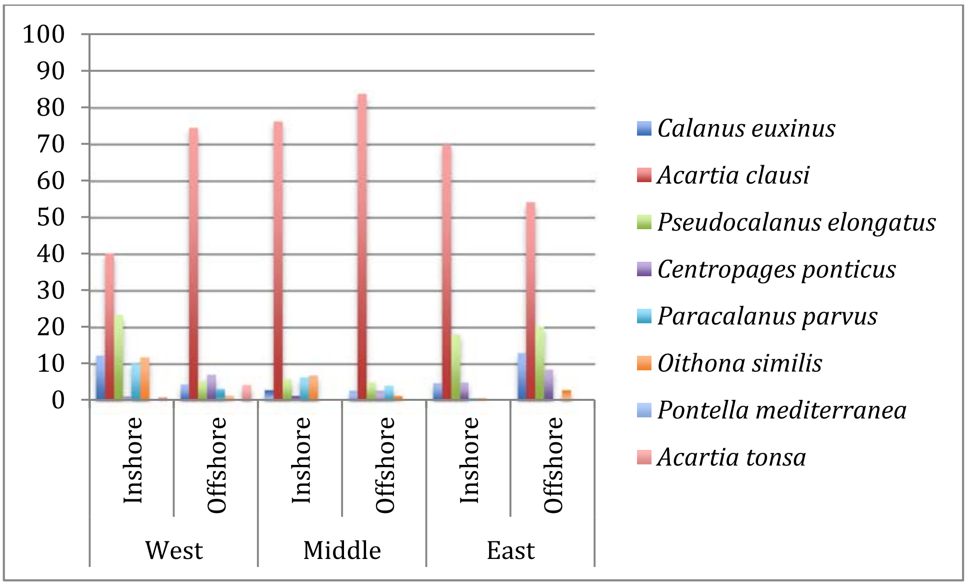


Figure 40 The spatial distributions in the relative abundance (ind/m^2) of copepod species identified in the southern Black Sea in July 2013: *Calanus euxinus*, *Acartia clausi*, *Acartia*

tonsa, *Pseudocalanus elangatus*, *Paracalanus parvus*, *Centropages ponticus*, *Oithona similis*, *Pontella mediterranea* for inshore and offshore waters of the 3 different regions of the southern Black Sea in July 2013

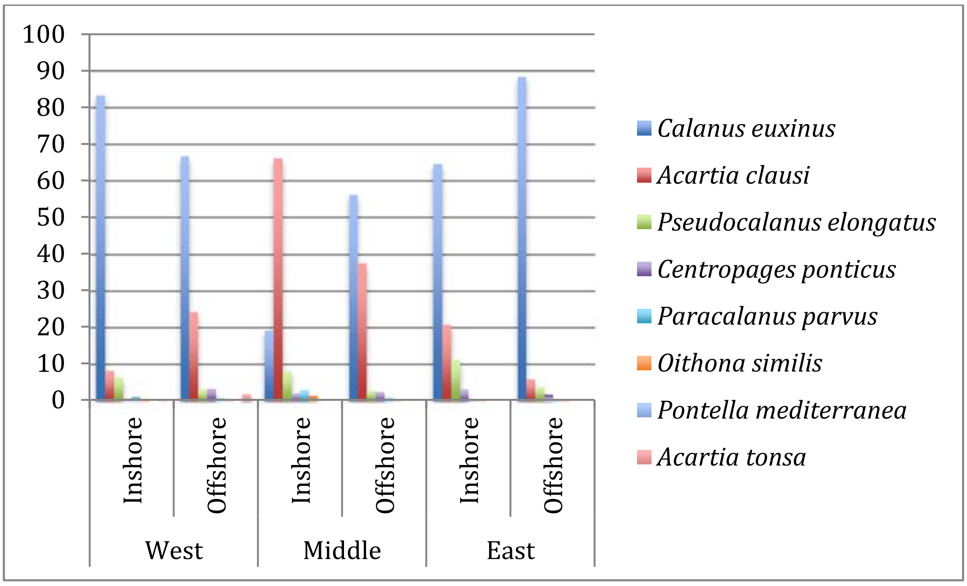


Figure 41 The spatial distributions in the relative biomass (ind/m^2) of copepod species identified in the southern Black Sea in July 2013: *Calanus euxinus*, *Acartia clausi*, *Acartia tonsa*, *Pseudocalanus elangatus*, *Paracalanus parvus*, *Centropages ponticus*, *Oithona similis*, *Pontella mediterranea* for inshore and offshore waters of the 3 different regions of the southern Black Sea in July 2013

3.3.1.1.1 *Calanus euxinus*

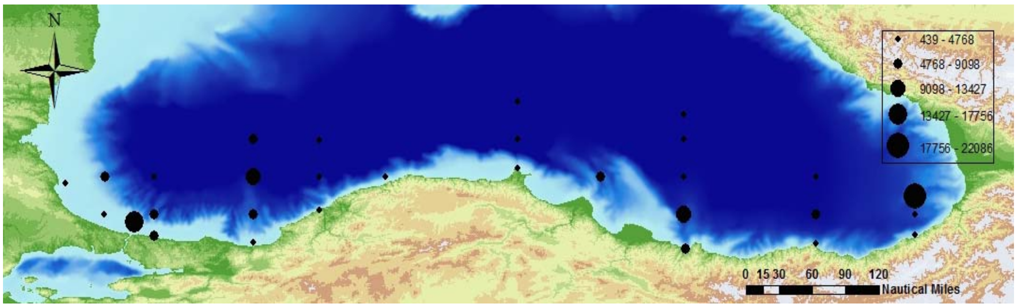
Spatial abundance and biomass distributions

The mean abundance value for *C. euxinus* was 5,260 ind/m^2. Spatial distribution of *C. euxinus* showed different preference in the southern Black Sea. Highest abundance was observed in western region 6,548 ind/m^2 that was almost similar with the abundance value that belongs to eastern side of the southern Black Sea. The lowest abundance value was belonging to the middle part. Abundance of *C. euxinus* displayed preference of some regions, for example in the western region the nearest station to the Bosphorus (14,556 ind/m^2) and in the eastern regions station in the Batumi Gyre (22,086 ind/m^2). Also some stations like offshore waters of the Zonguldak and nearest 2 stations to the Ordu showed high abundance values of this species. However, in the middle part of the southern Black Sea both inshore and offshore waters showed lowest abundance values for *C. euxinus*.

These results were also same for the biomass distribution of *C. euxinus*. The biomass values for offshore stations were always much higher than those from inshore stations. Mean biomass value for southern Black Sea was 4,700 mg/m^2. Like abundance, biomass values were almost same in west and east regions; however, highest mean biomass was observed in the east. Biomass values for the station, that in Batumi Gyre was 24,415 mg/m^2 and near the Bosphorus was 12,267 mg/m^2 (Figure 42).

The only difference was in the stations next to the Bosphorous, while the abundance values were almost same in the inshore and offshore stations, biomass value was lower in the inshore station. This indicates higher number of adult individual in the offshore station and higher number of copepodite stages in the inshore water. On the other hand, abundance value of *C. euxinus* was higher in the offshore waters of the Trabzon region, while biomass is almost equal in the offshore and inshore water, which means higher number of copepodite stages in the offshore waters in this region (Figure 45).

A



B

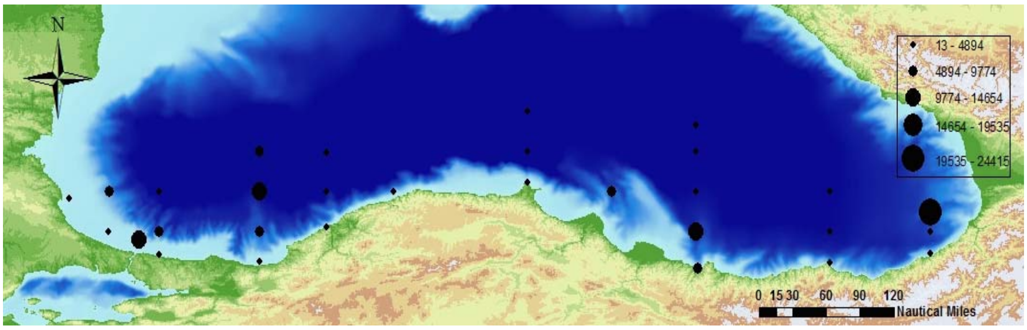


Figure 42 The spatial abundance and biomass distribution of *Calanus euxinus* in the southern Black Sea in July 2013 A. Abundance (ind/m^2), B. Biomass (mg/m^2)

Size-frequency distribution of *Calanus euxinus*

In July 2013, the number of copepodite stages and adult individuals of *C. euxinus* showed that adult individuals (2,278 ind/m^2 female and 1,604 ind/m^2 male) were highly dominating the population (Figure 43 and Figure 44).

The percentage of the adult individuals was more than half of the C. euxinus population, while c1, c2 and c3, c4, c5 abundances were similar to each other.

The spatial distribution of copepodite stages was shown in 2 groups. Most of the smallest individuals displayed high numbers in the inshore waters, while the number of adult individuals was mostly higher in the offshore waters. The comparison of 3 different areas showed difference, in the western region of the southern Black Sea showed higher number of copepodite stages of *C. euxinus* (in some stations more than).

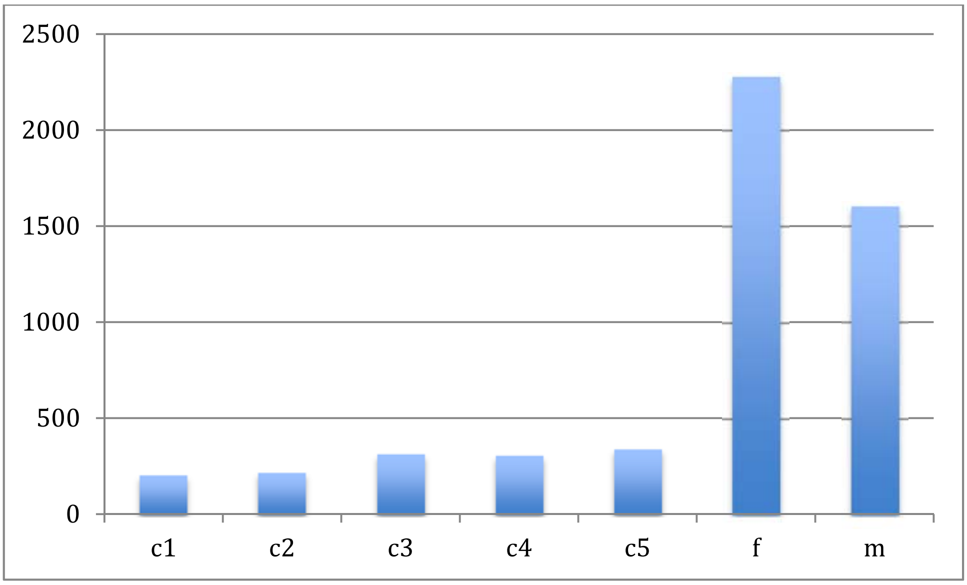


Figure 43 Stage frequency distribution of *Calanus euxinus* off southern Black Sea in July 2013.

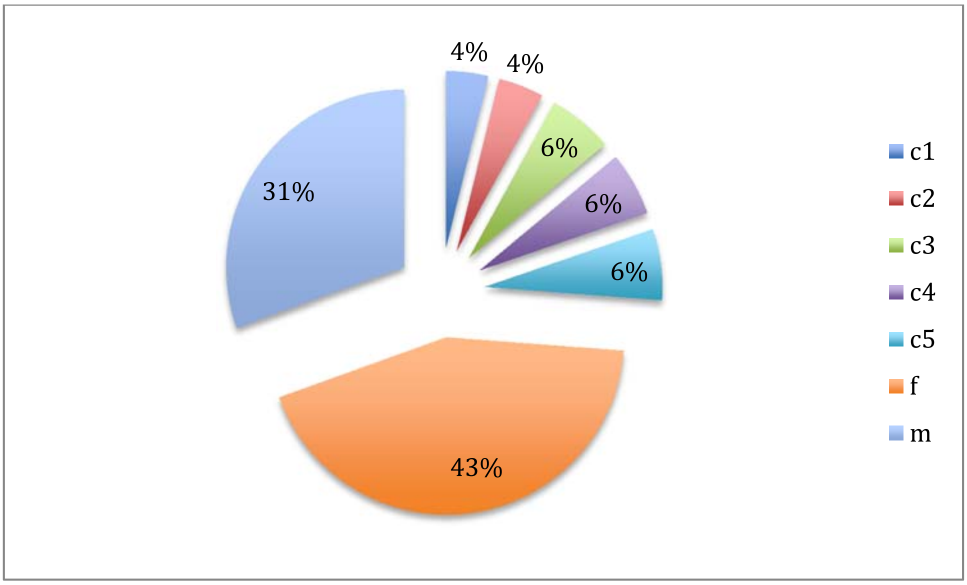


Figure 44 Percent composition of stage-frequency distribution of *Calanus euxinus* off southern Black Sea in July 2013.

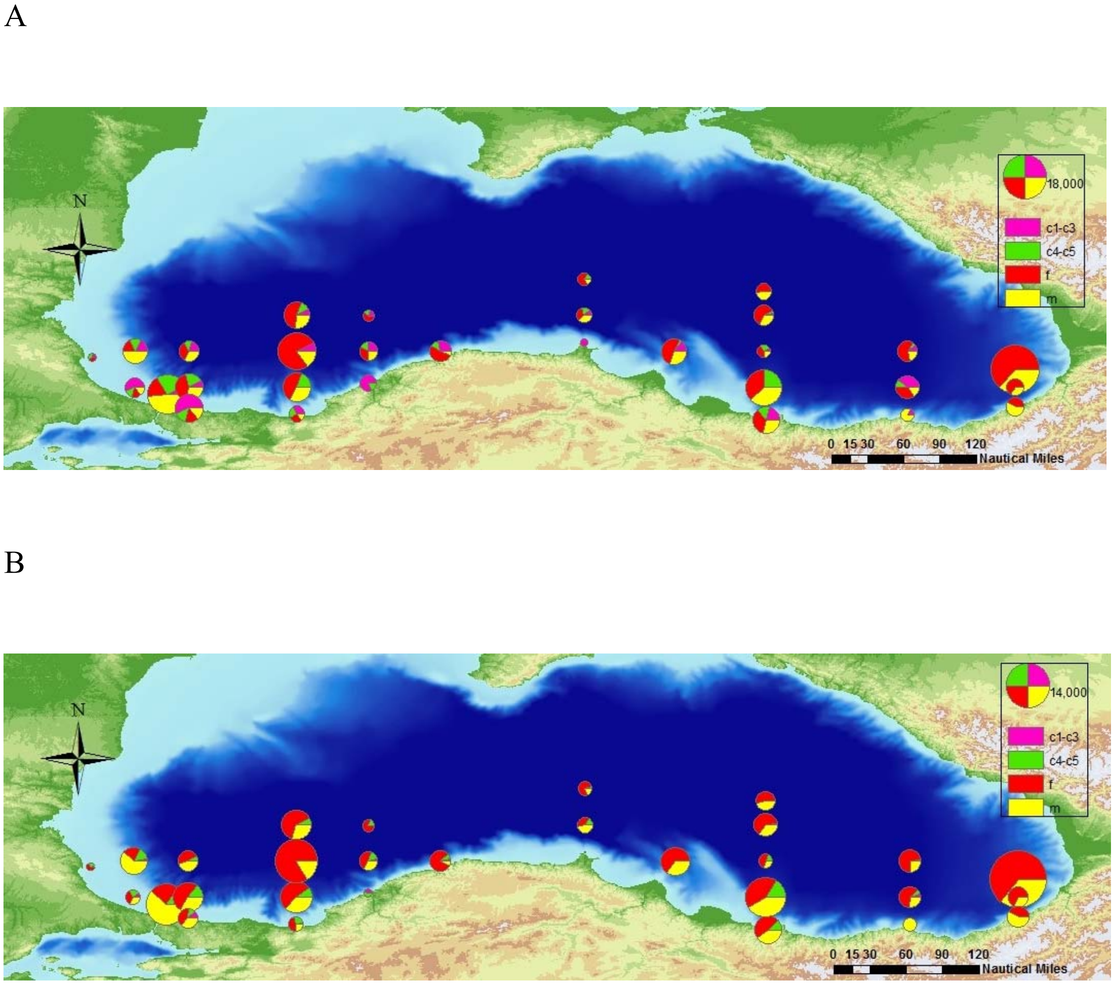


Figure 45 The spatial stage frequency distribution of *Calanus euxinus*. Pink color represents individuals of c1, c2 and c3 stages, green color represents c4 and c5 stages, red color for females and yellow for male idividuals. A. Abundance (ind/m^2), B. Biomass (mg/m^2).

3.3.1.1.2 *Acartia* species

Spatial abundance and biomass distributions

Two *Acartia* species, namely *A. clausi* and *A. tonsa* were found to be abundant in the southern Black Sea. Unfortunately, it is almost impossible to distinguish between two species while they are in their juvenile or naupliar stages. The two species can only be distinguishable in their fifth copepodite stages and adult forms. Here, all the c1, c2 and c3 copepodite stages of *Acartia* species represented as *Acartia clausi*.

Mean abundance value for *A. clausi* was 49,673 ind/m^2. The distribution of *A. clausi* showed highest abundance values in the western region of the southern Black Sea. Mean value decreased from west to east. Two stations with high abundance values (143,560 ind/m^2 and 137,537 ind/m^2) of *A. clausi* were in the inshore and offshore waters near İstanbul and one of them was in the offshore water of Zonguldak (220,862 ind/m^2). The lowest abundance was in the eastern region, which was almost 2 times less than the west.

1,037 mg/m^2 was the mean biomass value of *A. clausi* in the southern Black Sea. In terms of biomass, highest values (1,427 mg/m^2) were also observed in the western region in the southern Black Sea (Figure 46). 4,665 ind/m^2 was the highest biomass value in the offshore waters of the Zonguldak, followed by 3,200 ind/m^2 near to the Bosphorus and 2,787 ind/m^2 in the offshore waters of the İstanbul.

Both the *A. clausi* abundance and biomass were higher in the station that near to the Bosphorus than the station in the offshore waters of the İstanbul. This indicates, higher number of bigger individuals is in front of the Bosphorus.

The distribution of abundance and biomass values for *A. tonsa* was only observed in the 6 stations in the western region of the southern Black Sea (Figure 47). 1,514 ind/m^2 was the mean abundance value, while it was 44 mg/m^2 in terms of biomass. Highest numbers were also observed for both abundance and biomass values, in 3-mentioned station for *A. clausi*. 17,066 ind/m^2 and 501mg/m^2 were the highest values for abundance and biomass, which were observed in the station that near to the Bosphorus.

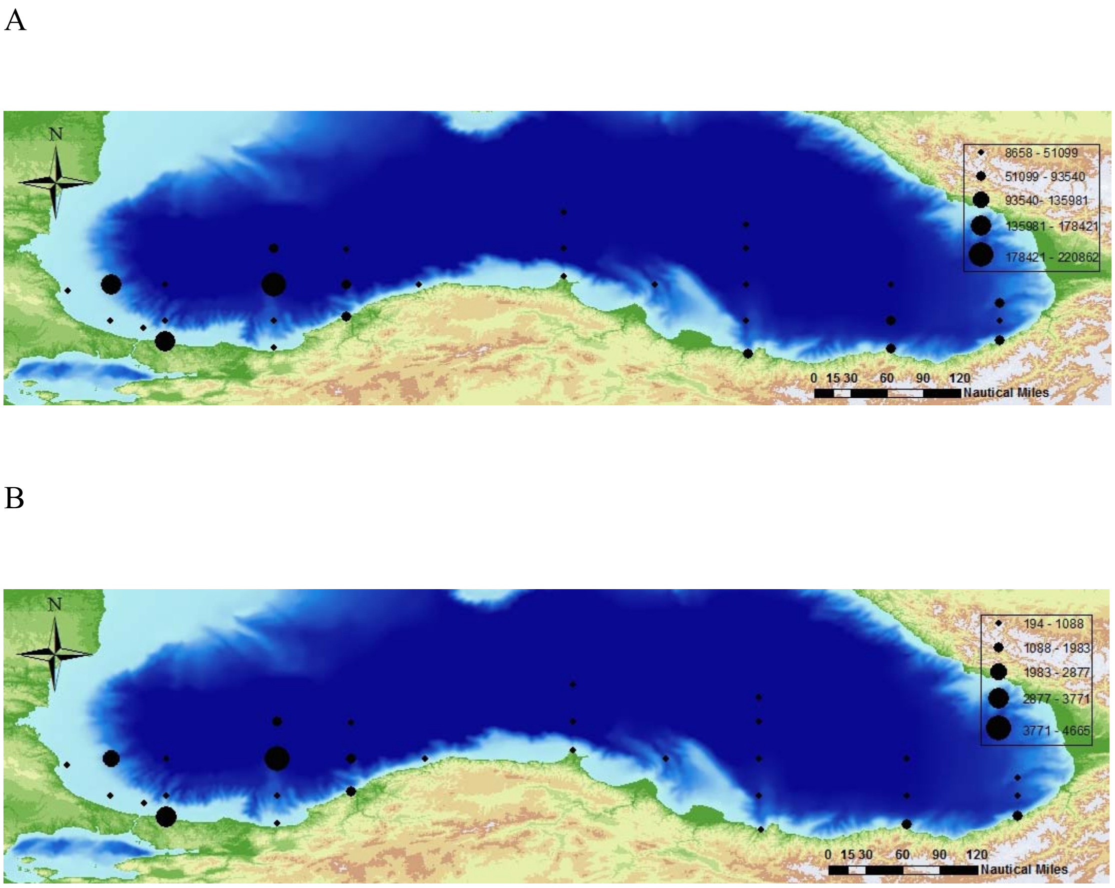
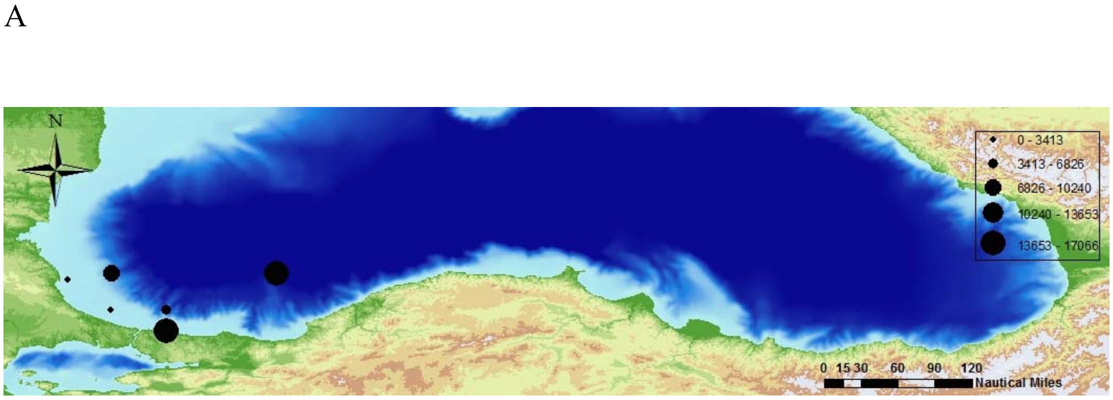


Figure 46 The spatial abundance and biomass distribution of *Acartia clausi*. A. Abundance (ind/m^2), B. Biomass (mg/m^2)



B

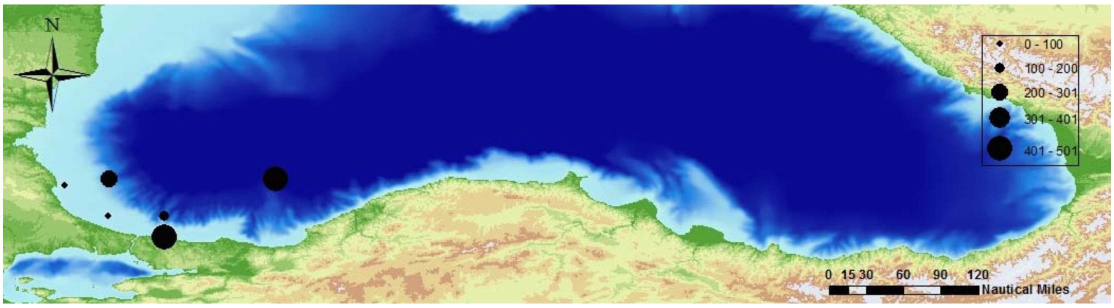


Figure 47 The spatial abundance and biomass distribution of *Acartia tonsa* . A. Abundance (ind/m^2), B. Biomass (mg/m^2)

Size-frequency distribution of *Acartia clausi* and *Acartia tonsa*

Stage-frequency distribution showed high values of female individuals and c5 and c4 stages. The lowest abundance value of copepodite stages was belonging to c1 stage (33 ind/m^2), c2 stage (107 ind/m^2) and c3 stage (2,154 ind/m^2). Number of females was higher than male individuals (Figure 48).

Figure 49 shows adult stages of the *A. clausi* constituting the 43% of the entire population and followed by c5 stage 32%.

The spatial distribution of copepodite stages of *A. clausi* was shown in 2 groups (c1-c3 and c4-c5). In terms of abundance c4 and c5 stages were dominant and half of the all individuals almost in the all stations. Number of adult individuals displayed higher numbers in the inshore waters in 3 mentioned regions. Smallest size group seemed to be more dominant in the eastern region of the southern Black Sea (Figure 50). In terms of biomass c4 and c5 stages of *A. clausi* were the most dominant in both inshore and offshore stations for entire southern Black Sea, except the station near the Bosphorus.

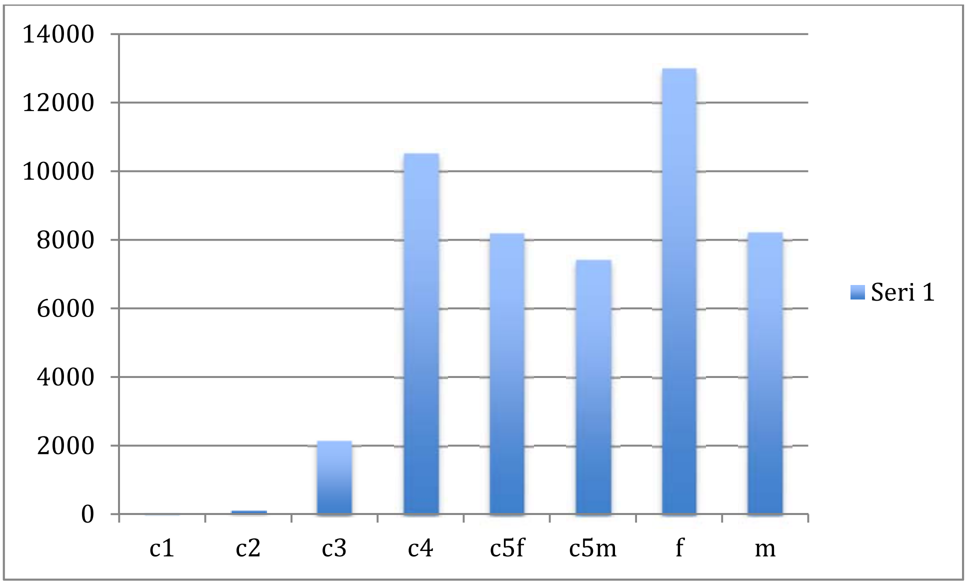


Figure 48 Stage frequency distribution of *Acartia clausi* off southern Black Sea in July 2013.

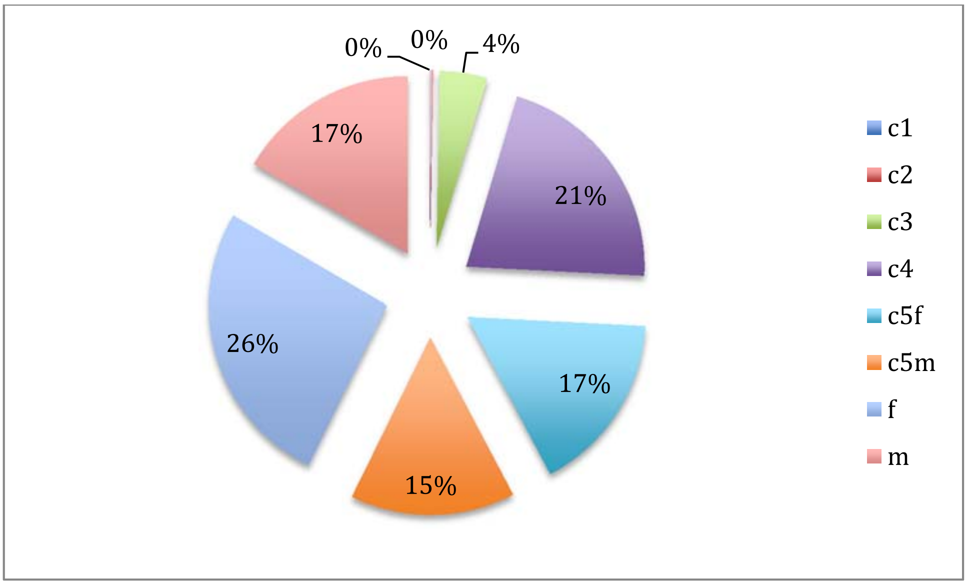
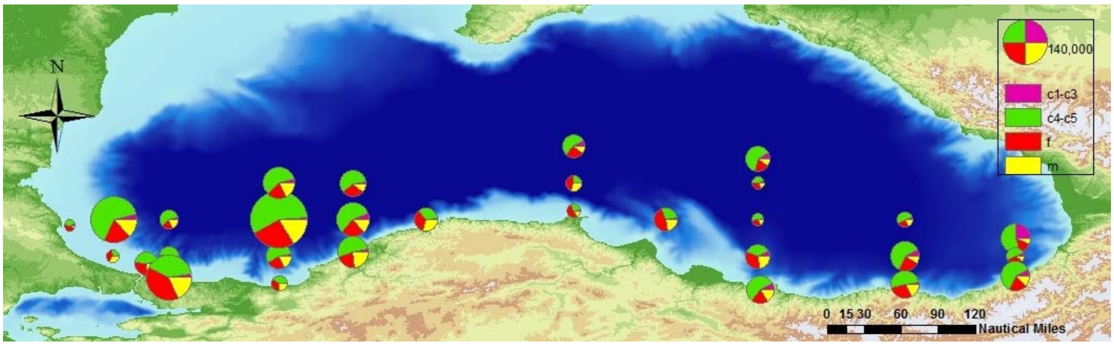


Figure 49 Percent composition of stage-frequency distribution of *Acartia clausi* off southern Black Sea in July 2013.

A



B

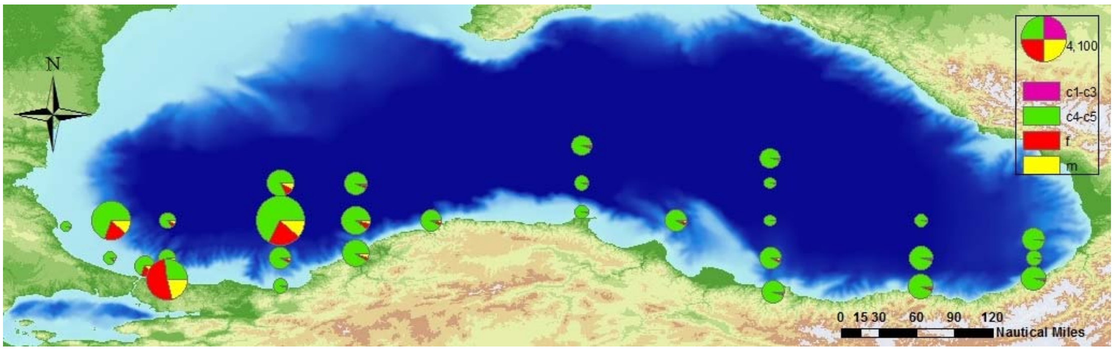


Figure 50 The spatial stage frequency distribution of *Acartia clausi*. Pink color represents individuals of c1, c2 and c3 stages, green color represents c4 and c5 stages, red color for females and yellow for male idividuals.A. Abundance (ind/m^2), B. Biomass (mg/m^2)

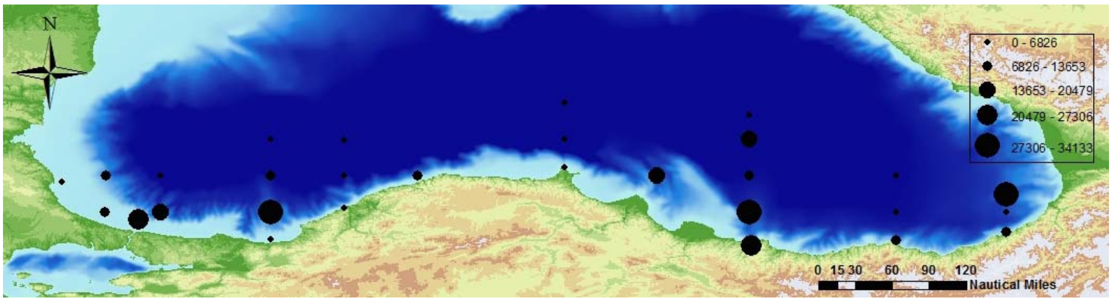
3.3.1.1.3 *Pseudocalanus elongatus*

Spatial abundance and biomass distributions

Mean abundance value of *P. elongatus* was 10,556 ind/m^2 in the southern Black Sea in July 2013. Spatial distribution of *P. elongatus* in terms of abundance, showed differences compared to the *C. euxinus* and *Acartia* species. In 3 regions highest abundance (13,775 ind/m^2) was observed in the eastern region of the southern Black Sea and lowest was in the middle part (5,365 ind/m^2). Especially stations in Batumi Gyre (34,133 ind/m^2) and in offshore waters of Ordu region (27,607 ind/m^2) in the east showed high values of individuals. In the west offshore stations of the Zonguldak (29,113 ind/m^2) and the stations near the Bosphorus showed also high values (Figure 51).

In terms of biomass, highest value (488 mg/m^2) was observed in the eastern region of the southern Black Sea, while the lowest was recorded in the middle part (182 mg/m^2). The mean value was 367 mg/m^2 in terms of abundance for the southern Black Sea.

A



B

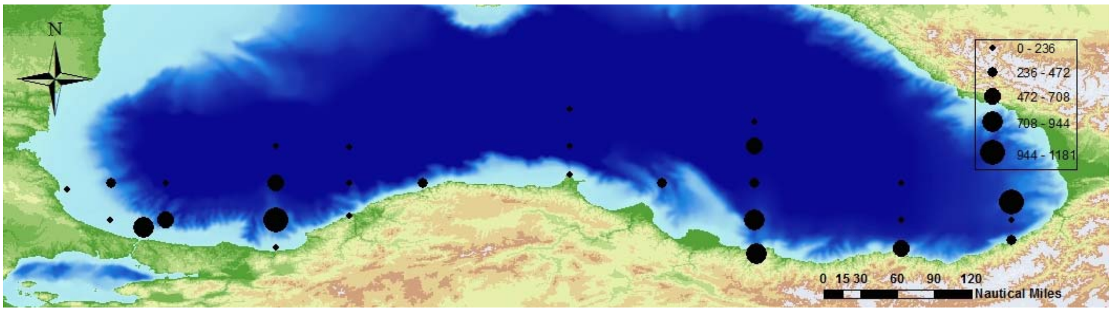


Figure 51 The spatial abundance and biomass distribution of *Acartia clausi*. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

Size-frequency distribution of *Pseudocalanus elongatus*

The highest number of individuals was belonging to the females, 3,275 ind/m^2, which constituting the 31% of the total population. Females were followed by c5 stage (3,147 ind/m^2), c4 stage (1,807 ind/m^2) and c3 stage (1,175 ind/m^2). The lowest numbers were recorded as c1 stage and males (Figure 52).

Size-frequency distribution showed that adult individuals were 40%, while copepodite stages were making up the 60% of the entire population (Figure 53).

In terms of abundance, spatial stage-frequency distribution showed that, copepodite stages were almost more than half in the offshore stations in both regions and number of adult individuals was higher in the inshore waters (Figure 54). Number of individuals of copepodite stages and adults was higher in the eastern region and followed by western and middle parts of the southern Black Sea.

In terms of biomass, females and c4-c5 stages were the most abundant groups in the entire southern Black Sea.

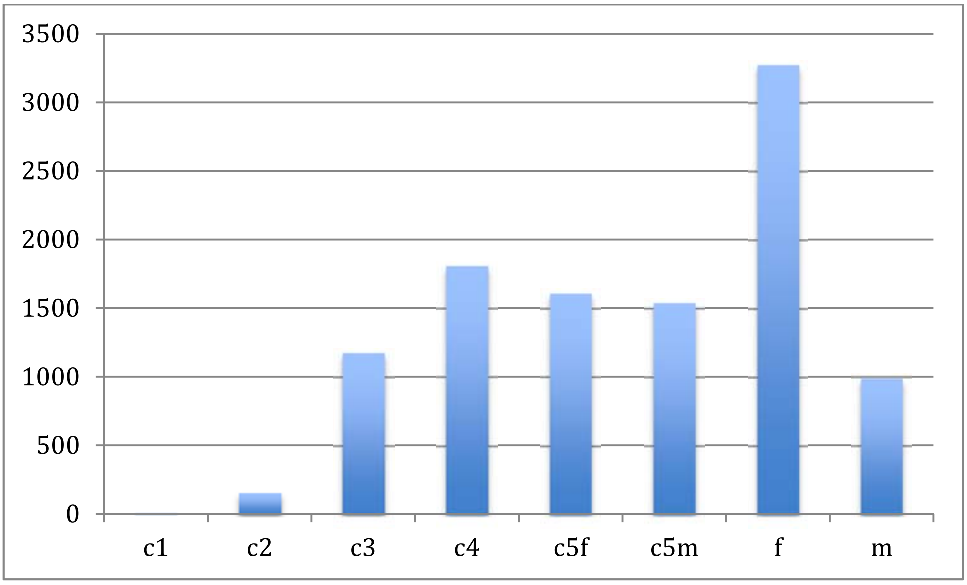


Figure 52 Stage frequency distribution of *Pseudocalanus elongatus* off southern Black Sea in July 2013.

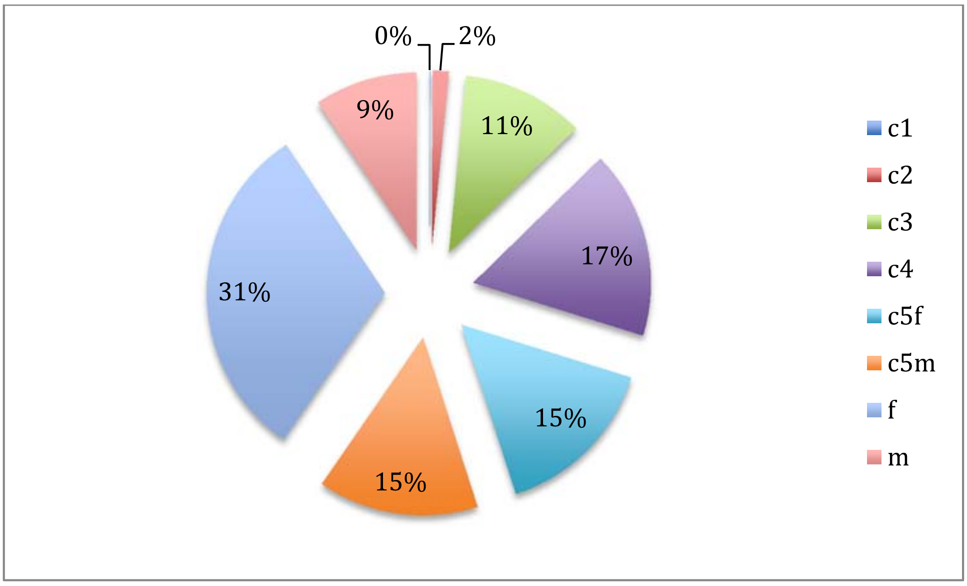
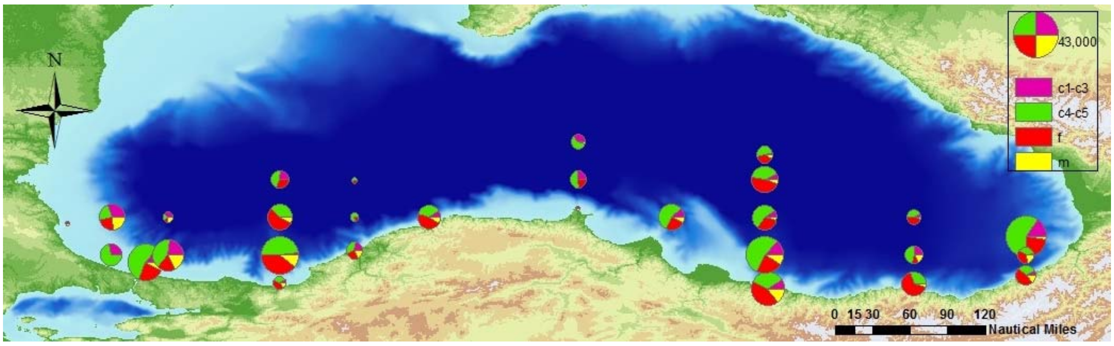


Figure 53 Percent composition of stage-frequency distribution of *Pseudocalanus elongatus* off southern Black Sea in July 2013.

A



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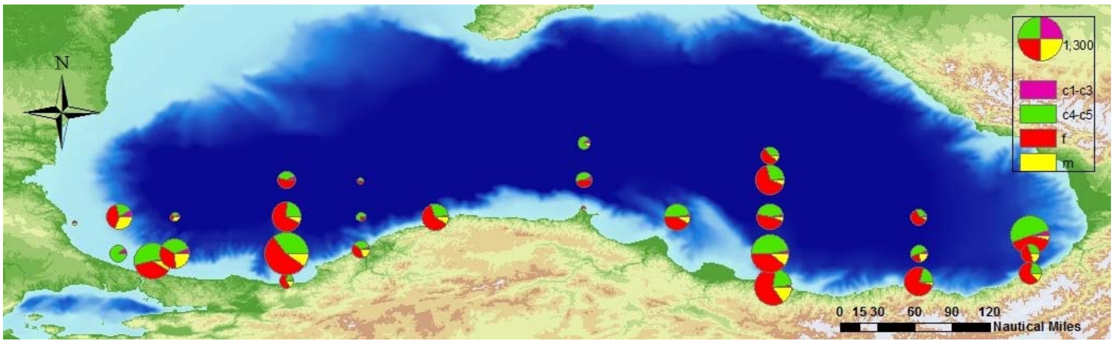


Figure 54 The spatial stage frequency distribution of *Pseudocalanus elongatus*. Pink color represents individuals of c1, c2 and c3 stages, green color represents c4 and c5 stages, red color for females and yellow for male idividuals. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

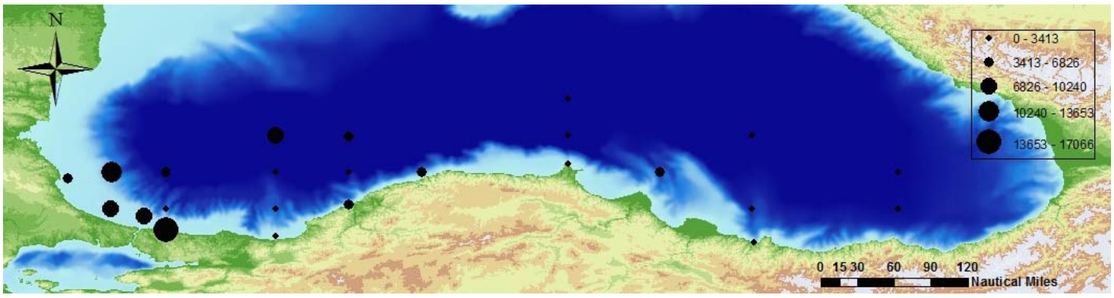
3.3.1.1.4 *Paracalanus parvus*

Spatial abundance and biomass distributions

Distribution of *P. parvus* in the southern Black Sea showed a preference of western region (Figure 55). While the mean abundance value was 3,093 ind/m^2 for *P. parvus* in the southern Black Sea, number of individuals decreased from west to the east, and did not observed in the most east stations (i.e. in the Batumi Gyre). The mean abundance value in the western region was 5,909 ind/m^2 and followed by middle part with 3,090 ind/m^2. The lowest abundance (280 ind/m^2) was in the eastern region. Highest values were displayed in the most western stations.

34 mg/m^2 was the mean biomass value for this species in July 2013. In terms of biomass, the highest biomass was observed in the western Black Sea (67 mg/m^2) and followed by middle part (34 mg/m^2). Lowest biomass value for *P. parvus* was in the eastern region with only 3 mg/m^2 in July 2013.

A



B

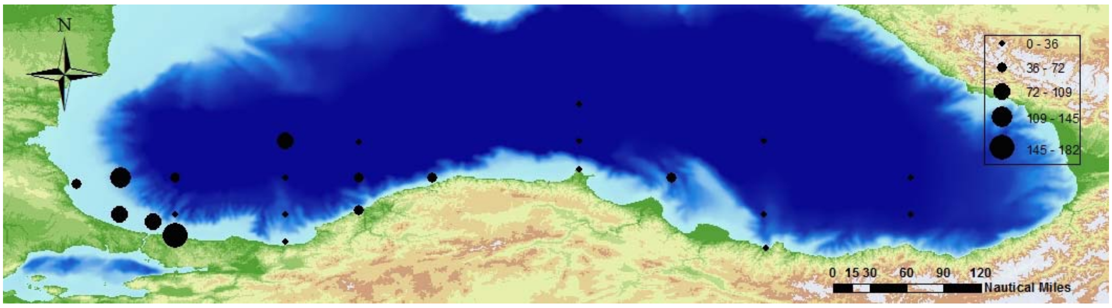


Figure 55 The spatial abundance and biomass distribution of *Paracalanus parvus*. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

Size-frequency distribution of *Paracalanus parvus*

The most abundant individuals of *P. parvus* in the southern Black Sea were females (1,420 ind/m^2), which constitute 46% of the total population (Figure 57). Adult individuals were 66% and c5 stage of *P. parvus* was 30%. Number of younger stages of this species displayed low percentage (only 4 %) due to the mesh size.

The spatial stage frequency distribution of *P. parvus* showed that high numbers of adult individuals displayed a preference of inshore waters (3,102 ind/m^2) than offshore waters (2,538 ind/m^2) in both west and middle parts of the southern Black Sea. In terms of biomass, high values were also shown in the inshore waters (Figure 56).

The comparison of the abundance values of copepodite stages in the west and middle parts of the Black Sea showed that, mean value of number of copepodite stages were more than ten times in the western region (Figure 58), while number of adult individuals were two times higher than middle region.

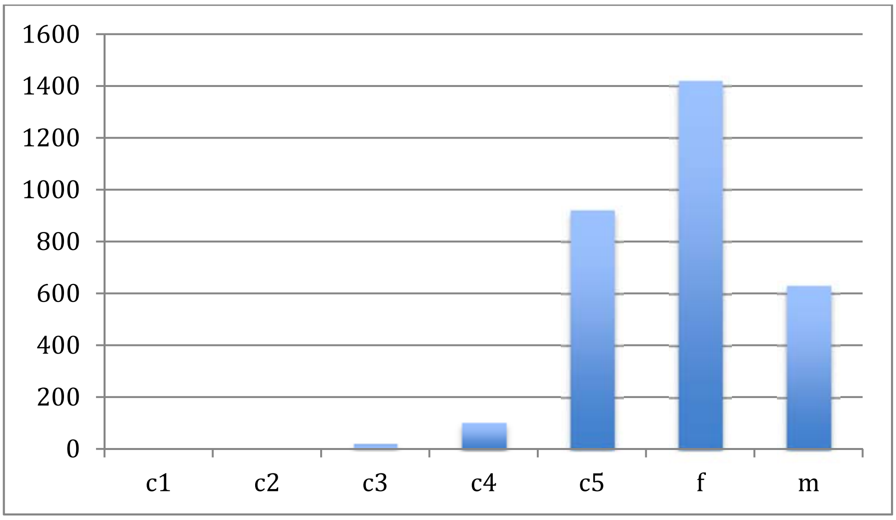


Figure 56 Stage frequency distribution of *Paracalanus parvus* off southern Black Sea in July 2013.

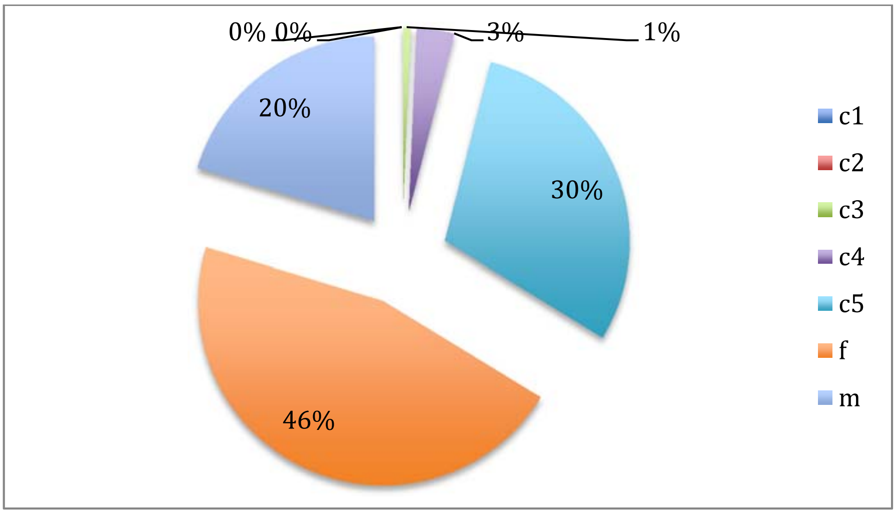
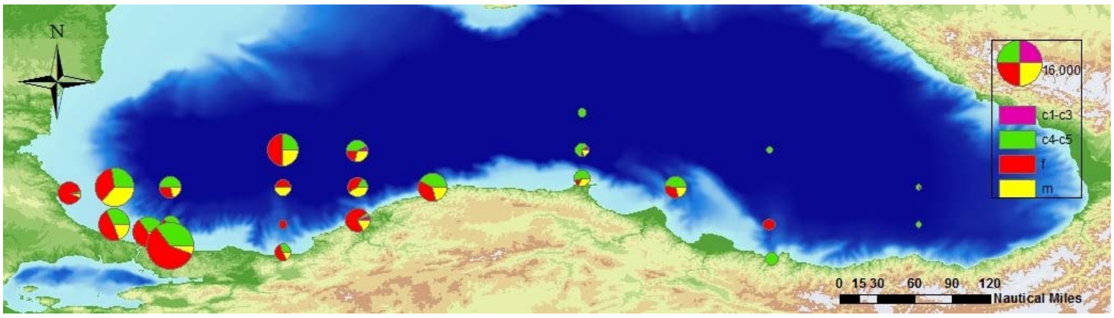


Figure 57 Percent composition of stage-frequency distribution of *Paracalanus parvus* off southern Black Sea in July 2013.

A



B

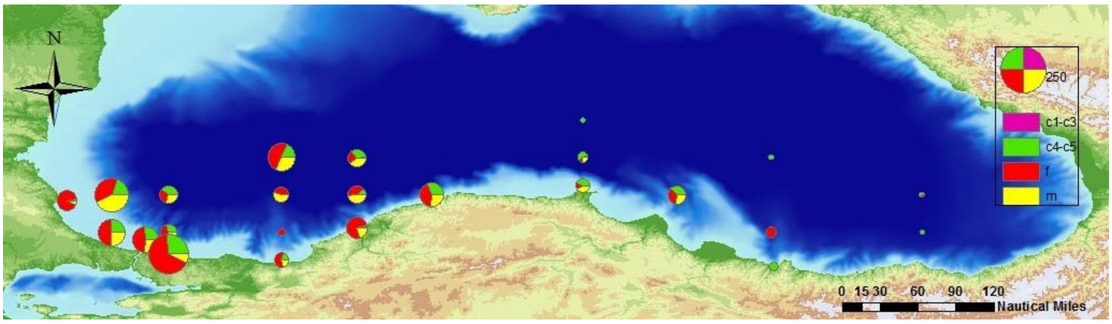


Figure 58 The spatial stage frequency distribution of *Paracalnus parvus*. Pink color represents individuals of c1, c2 and c3 stages, green color represents c4 and c5 stages, red color for females and yellow for male idividuals. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

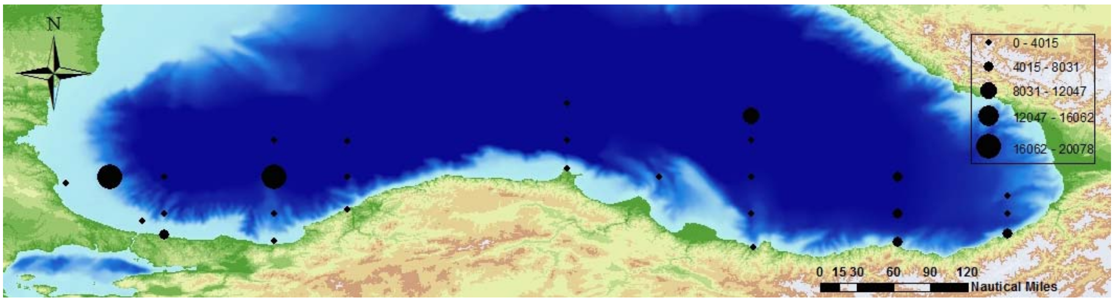
3.3.1.1.5 *Centropages ponticus*

Spatial abundance and biomass distributions

All stages of *C. ponticus* were found in the entire stations of southern Black Sea in July 2013. Mean number of individuals was 3,342 ind/m^2. The comparison of abundance values was different in 3-mentioned region. The highest number was in the western region 4,769 ind/m^2. In the western region, number of individuals was higher in the offshore waters, and the highest value was 20,078 ind/m^2 in the offshore waters of the Zonguldak region. The lowest number (1,059 ind/m^2) was observed in the middle part of the Black Sea, and *C. ponticus* did not showed preference of inshore or offshore waters. In the eastern region, the highest numbers (9,411 ind/m^2) of *C. ponticus* were observed in the offshore waters of the Ordu region.

Mean biomass value of *C. ponticus* was 115 mg/m^2 in the southern Black Sea in July 2013. This value was similar in west and east regions, while the lowest biomass was observed in the middle part. In terms of biomass, highest values was observed in the 555 mg/m^2 in the offshore waters of the Zonguldak and 511 mg/m^2 in the offshore waters of the İstanbul. Biomass values of *C. ponticus* were also higher in the station, which was in front of the Bosphorus than other stations in the western region. Lowest mean biomass value (40 mg/m^2) was also in the middle part of the southern Black Sea. Inshore station of most eastern stations, biomass value (271 mg/m^2) was higher compared to the offshore stations, which were in Batumi Gyre (Figure 59).

A



B

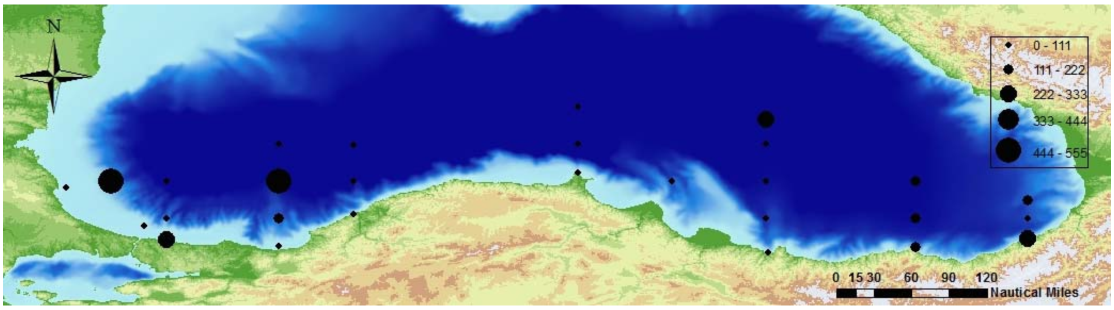


Figure 59 The spatial abundance and biomass distribution of *Centropages ponticus*. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

Size-frequency distribution of *Centropages ponticus*

Number of adult individuals of *C. ponticus* was 1,418 ind/m^2 (shown in Figure 60) of the total population, which constitutes 41% of the total population. Highest number of copepodite stages was belong to the c5 stage 1,048 (ind/m^2) and constitutes the 31%. All other stages were only making up the 28% of the entire population (Figure 61).

Spatial stage-frequency distribution of *C. ponticus* showed, preference of inshore waters for adult individuals and preference of offshore waters for copepodite stages in the southern Black Sea. The highest values for inshore (1,718 ind/m^2) and offshore waters (6,581 ind/m^2) were observed in the eastern region (Figure 62).

Mean abundance values of both copepodite and adult stages of *C. ponticus* were highest in the eastern region, and lowest in the middle part of the southern Black Sea.

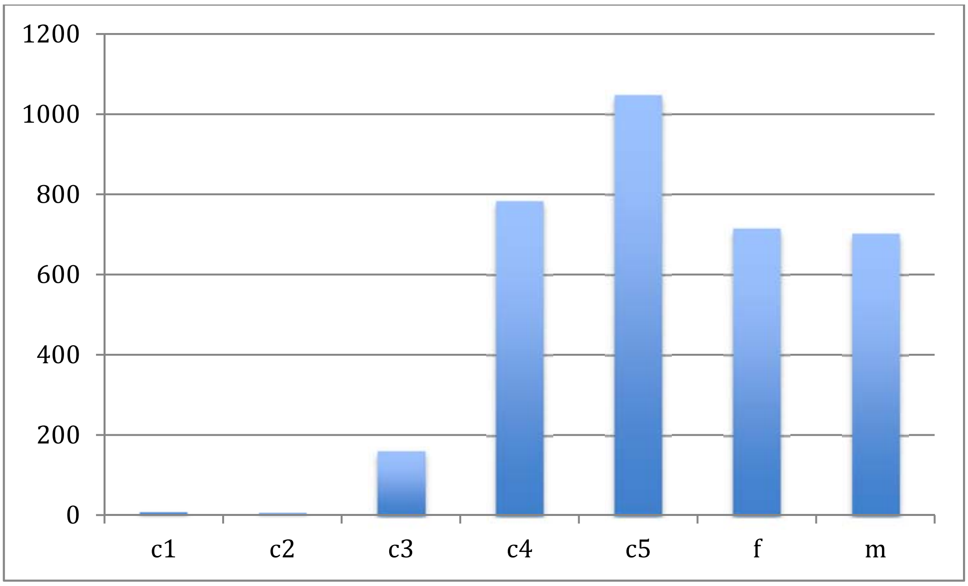


Figure 60 Stage frequency distribution of *Centropages ponticus* off southern Black Sea in July 2013.

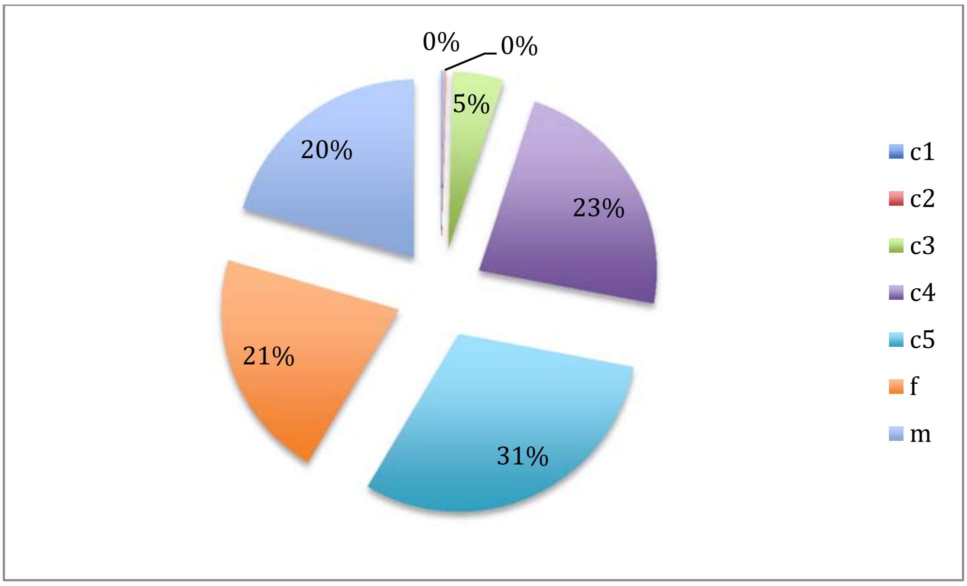
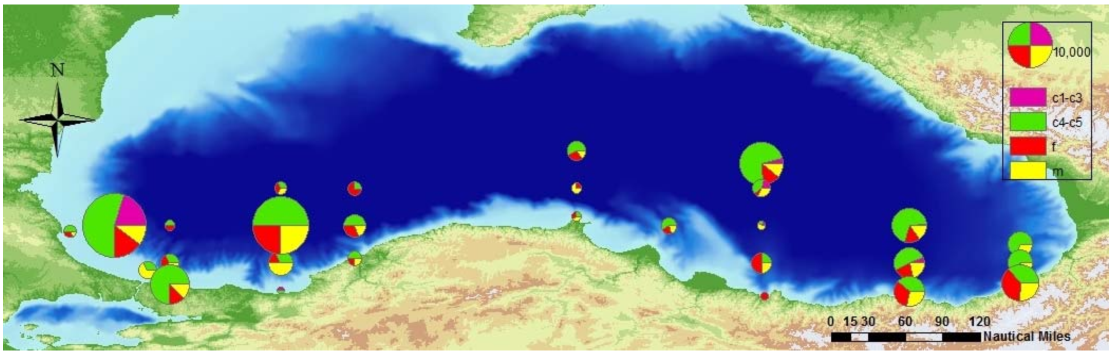


Figure 61 Percent composition of stage-frequency distribution of *Centropages ponticus* off southern Black Sea in July 2013.

A



B

Figure 62 The spatial stage frequency distribution of *Centropages ponticus*. Pink color represents individuals of c1, c2 and c3 stages, green color represents c4 and c5 stages, red color for females and yellow for male idividuals.A. Abundance (ind/m^2), B. Biomass (mg/m^2)

3.3.1.1.6 *Oithona similis*

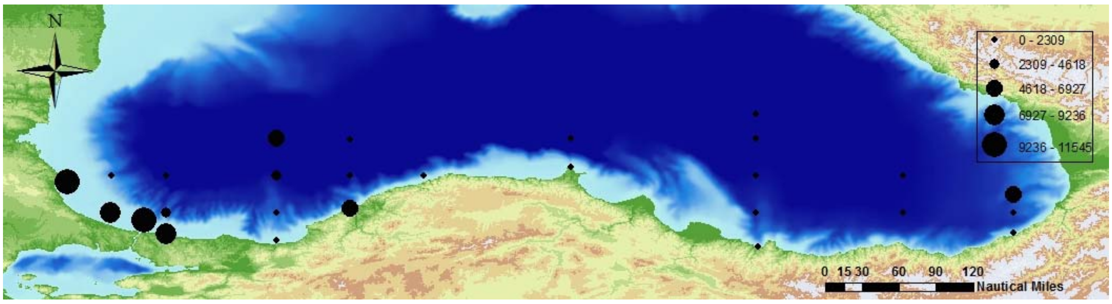
Spatial abundance and biomass distributions

Abundance value of *O. similis* in the southern Black Sea was 2,554 ind/m^2. Number of individuals of *O. similis* was decreased from west to east in the southern Black Sea in July 2013. Abundance of this species was 4,917 ind/m^2 in the western region and 1,506 ind/m^2 in the middle while, it was 953 ind/m^2 in the eastern region. The spatial distribution of *O. similis* displayed preference of inshore waters in the western regions of the southern Black Sea. 11,545 ind/m^2 were the highest abundance value in the inshore water of the İstanbul region. For the eastern part, high value (5,019 ind/m^2) was only observed in the station, which was in Batumi Gyre. For both regions only offshore station with high abundance and biomass value was in the Zonguldak region (Figure 63).

13 mg/m^2 was the mean biomass value for *O. similis* in July 2013. In terms of biomass, mean value decreased from west to east. In west biomass value (24 mg/m^2)

was 3 times greater than middle part and 6 times greater than eastern part of the southern Black Sea. Highest biomass value was 57 mg/m^2 for the station that was inshore waters of İstanbul region.

A



B

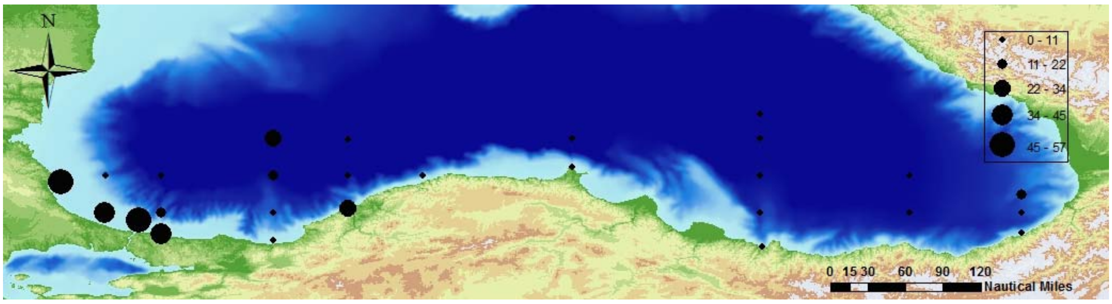


Figure 63 The spatial abundance and biomass distribution of *Oithona similis*. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

Size-frequency distribution of *Oithona similis*

Individuals of *O. similis* were identified in 3 groups, namely; c5, female and other. Other was bigger than c5 stage but they were not female. Younger stages were not observed due to the mesh size of WP-2 net that used in this study. Most dominant group was females (1,659 ind/m^2). Females were followed by c5 stage of *O. similis* (816 ind/m^2) (Figure 64).

According to Figure 65 adult stages constituted 65% of the total population, while c5 stage was 32% and other was only 3%.

The spatial stage-frequency distribution of *O. similis* displayed high numbers of adult individuals in the inshore waters of the southern Black Sea, while c5 stage of this species were more dominant in the offshore waters. High number of c5 stage (22 mg/m^2), was also observed in the station that in the Batumi Gyre (Figure 66).

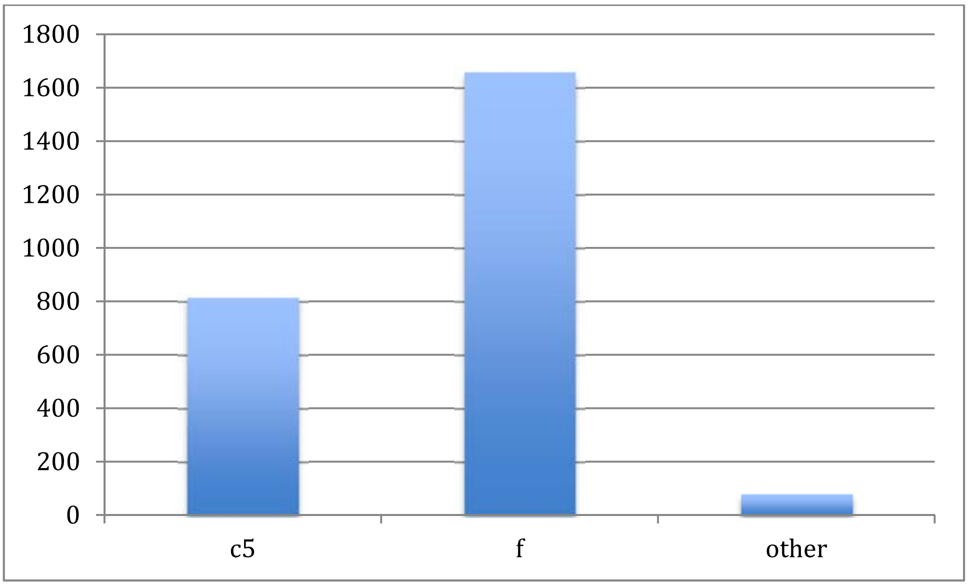


Figure 64 Stage frequency distribution of *Oithona similis* off southern Black Sea in July 2013.

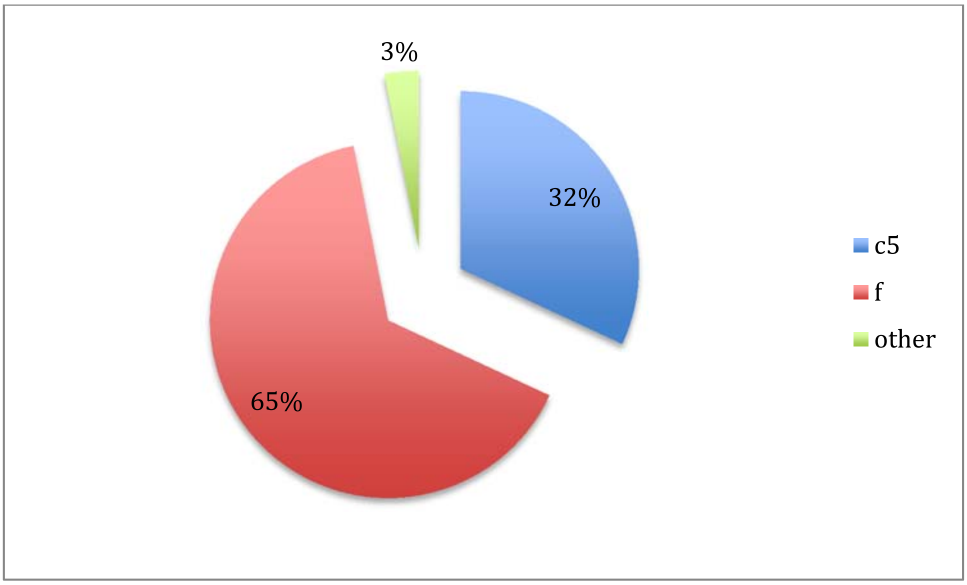
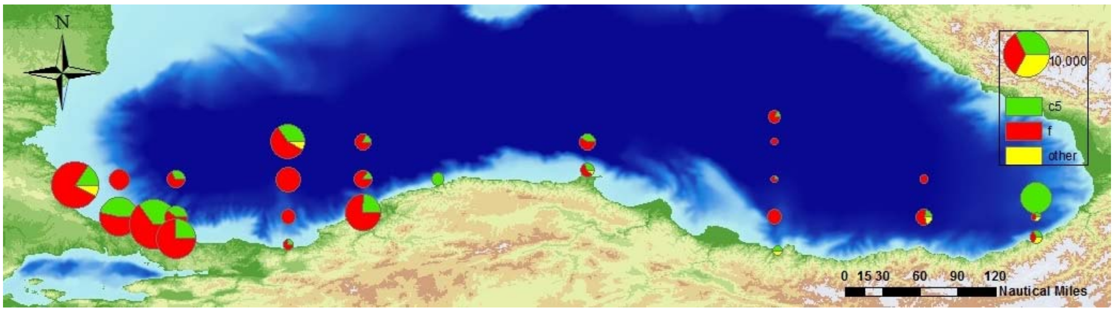


Figure 65 Percent composition of stage-frequency distribution of *Oithona similis* off southern Black Sea in July 2013.

A



B

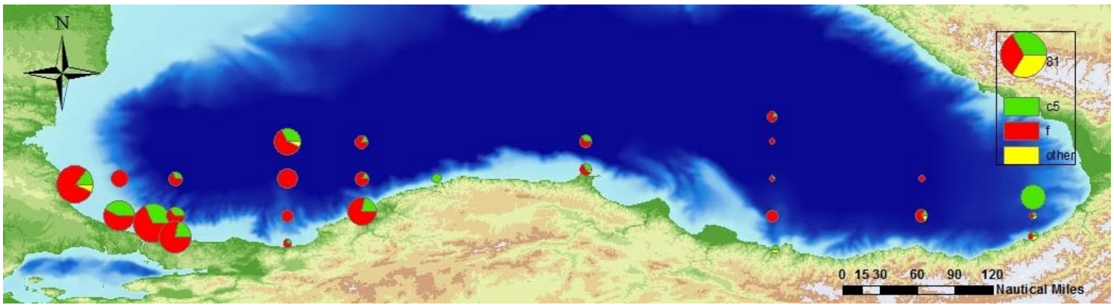


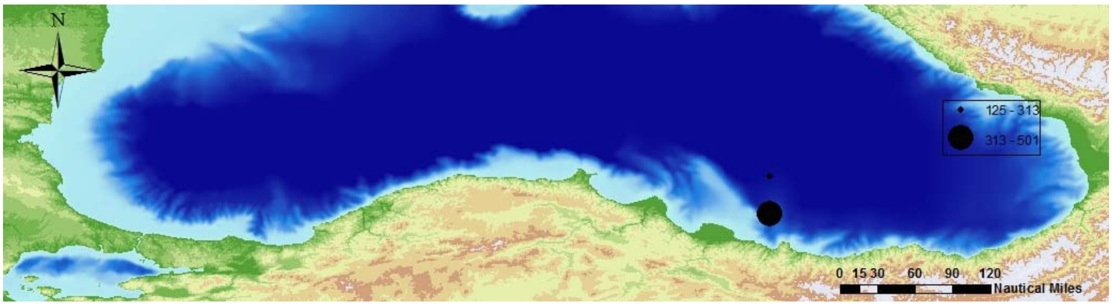
Figure 66 The spatial stage frequency distribution of *Oithona similis*. Green color represents c5 stages, red color for females and yellow for male idividuals.A. Abundance (ind/m^2), B. Biomass (mg/m^2)

3.3.1.1.7 *Pontella mediterranea*

Spatial abundance and biomass distributions

Individuals of *P. mediterranea* were only found in two stations (Figure 67) in the eastern part (Ordu) of the southern Black Sea. These individuals were naupliar stages of P. mediterranea. This species is a neustonic species and due to the vertical sampling this species abundance value was only 21 ind/m^2 and biomass value was 0.05 mg/m^2.

A



B

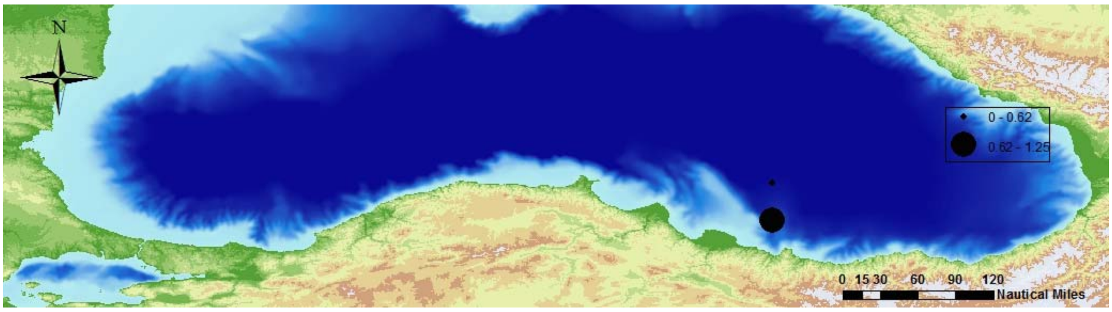


Figure 67 The spatial abundance and biomass distribution of *Pontella mediterranea*. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

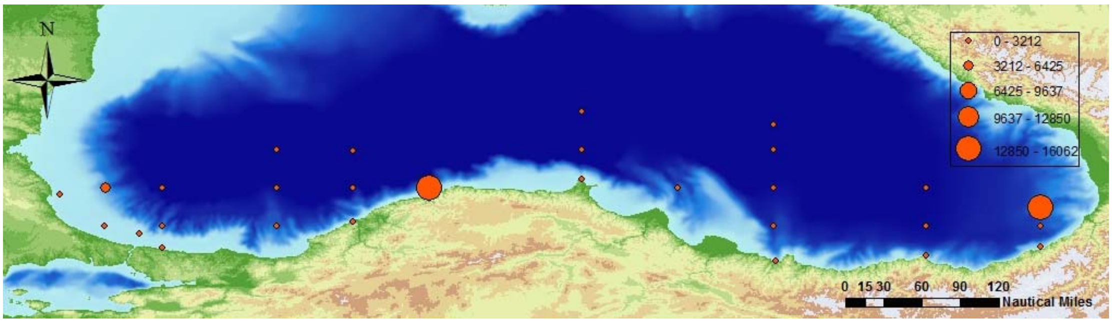
3.3.1.1.8 Egg and nauplii of copepoda

Copepod egg

Spatial abundance and biomass distribution

In terms of abundance and biomass, spatial distribution of eggs of copepod was displayed high values in 2 stations. One of station with highest abundance and biomass value was in the eastern region (16,063 ind/m^2 and 15 mg/m^2), which was in Batumi Gyre and the other one was in the middle part of the Black Sea (15,561 ind/m^2 and 14 mg/m^2), which was in Kastamonu region. Mean abundance and biomass values of copepod egg were 1,740 ind/m^2 and 2 mg/m^2 in the southern Black Sea. The comparison of the mean abundance and biomass values in the 3 regions showed that number of copepod eggs were highest in the middle region and followed by east, while it is lowest in the western part (Figure 68).

A



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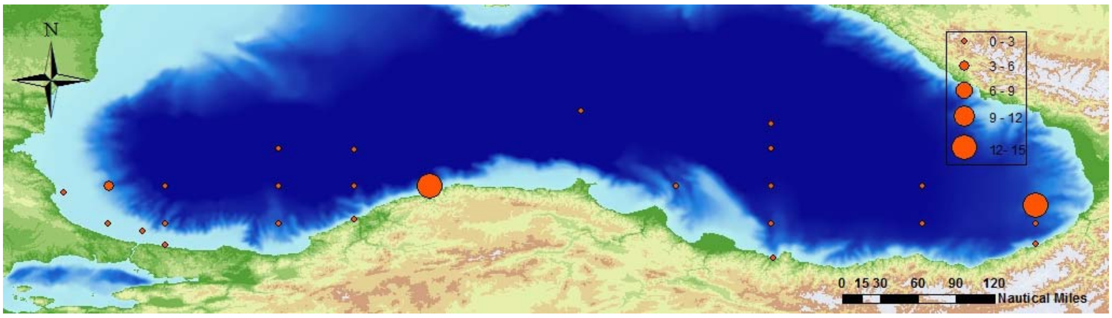


Figure 68 The spatial distribution of copepod egg in the southern Black Sea in July 2013. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

Copepod nauplii

Spatial abundance and biomass distribution

Nauplii stages of copepods displayed different spatial abundance and biomass distribution compared to the eggs of copepods. High values of abundance and biomass were also observed in two stations. The highest abundance and biomass values were observed in the station, which was the offshore station near the Batumi Gyre (13,051 ind/m^2 and 43 mg/m^2) in the east and followed by one of the most western station (8,031 ind/m^2 and 27 mg/m^2) in the southern Black Sea. Mean abundance and biomass values of nauplii of copepods were 1,765 ind/m^2 and 6 mg/m^2 in the southern Black Sea in July 2013 (Figure 69). The comparison of mean abundance and biomass values in the 3 regions of the southern Black Sea showed these values were highest in the eastern region and followed by the west, while the lowest values were in the middle part.

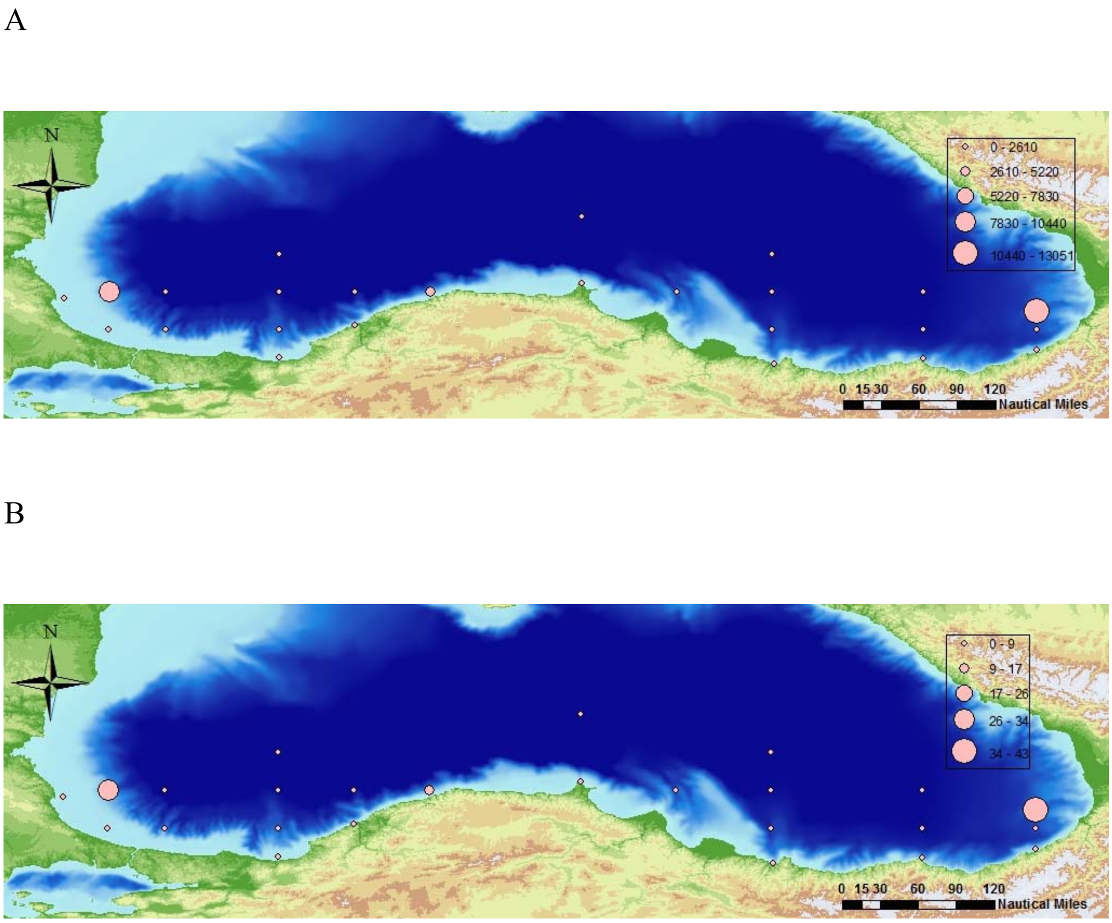


Figure 69 The spatial distribution of copepod naupli in the southern Black Sea in July 2013. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

3.3.1.2 Cladocera

Spatial abundance and biomass distribution

The mean abundance value for cladocerans was 8,257 ind/m^2 in the southern Black Sea. Mean abundance value for each region decreased from west to the east region. Maximum and min abundance value were highest in the western region (Table 11), while they were lowest in the eastern region. The maximum values were almost occurred in the inshore waters of the southern Black Sea in July 2013. 63,247 ind/m^2 was the maximum abundance value for a station, which were near the Bosphorus (Figure 70).

In terms of biomass, highest mean value (173 mg/m^2) was also in the western Black Sea. Mean biomass value was also decreased from west to the east (Figure 71), while minimum and maximum values were lowest in the middle part of the southern Black Sea (Table 11).

Table 11 Min, Max and Mean abundance (ind/m^2) and biomass (mg/m^2) values of cladocerans in the southern Black Sea in general and in 3 different regions

	Black Sea	**West**	**Middle**	**East**
Min Abundance (ind/m2)	263	4,016	263	502
Max Abundance (ind/m2)	63,247	63,247	17,318	19,075
Mean Abundance (ind/m2)	8,257	12,531	7,782	4,328
Min Biomass (mg/m2)	3	19	3	5
Max Biomass (mg/m2)	1,342	1,342	456	534
Mean Biomass (mg/m2)	173	251	190	81

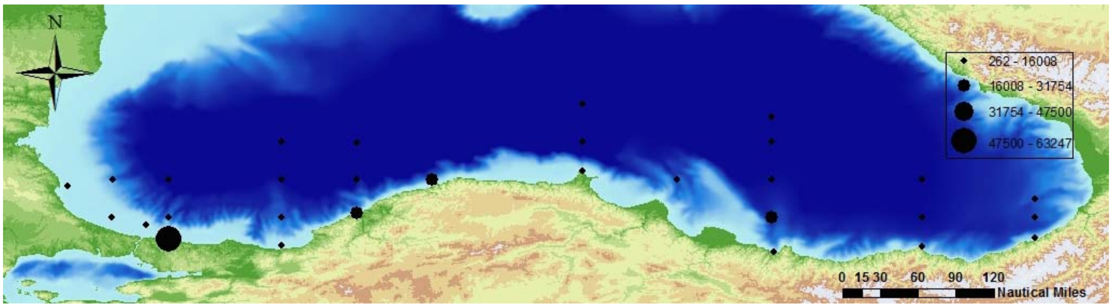


Figure 70 Spatial abundance (ind/m^2) contributions of the Cladocera species in the southern Black Sea in July 2013.

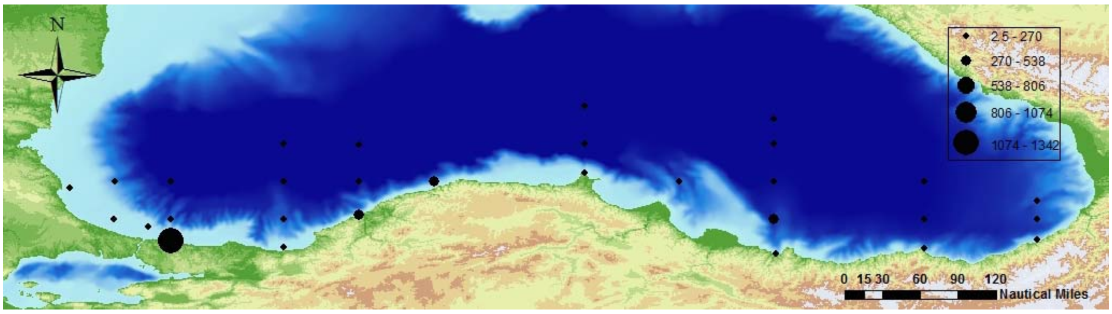


Figure 71 Spatial biomass (mg/m^2) contributions of the Cladocera species in the southern Black Sea in July 2013.

Group composition

The most dominant species of cladocerans were *Penilia avirostris*, forming up to 69% of the population in terms of abundance. *P. avirostris* were followed by *Pseudoevadne targestina* (17%), *Evadne spinifera* (9%) and *Pleopis polyphemoides* (5%) (Figure 73).

In terms of croup composition abundance and biomass values showed, P. *avirostris* were the most dominant cladoceran species in the entire southern Black Sea, and its abundance and biomass values were highest in the west, which decreased from west to east. *P. targestina* also displayed its highest abundance and biomass values in the west and decreased from west to east. *E. spinifera* displayed its highest abundance and biomass in the eastern region and followed by west. *E. spinifera* showed its lowest abundance and biomass values in the middle part. *P. polyphemoides* was more dominant in the western region and its abundance and biomass decreased from west to the east (Table 12).

Table 12 Abundance (ind/m^2) and biomass (mg/m^2) values of 4 cladocerans species; namely, *Penilia avirostris, Pseudovadne targestina, Evadne spinifera, Pleopis polyphemoides* in the southern Black Sea in general and in 3 different regions.

		Penilia avirostris	***Pseudoevadne targestina***	***Evadne spinifera***	***Pleopis polyphemoides***	**Total**
Abu	**W**	8,214	3,103	502	712	12,531
	M	6,558	518	322	384	7,782
	E	2,658	290	1,333	46	4,328
	BS	5,735	1,382	759	381	8,257
Bio	**W**	230	12	2	6	251
	M	184	2	1	3	190
	E	74	1	5	0	81
	BS	161	6	3	3	173

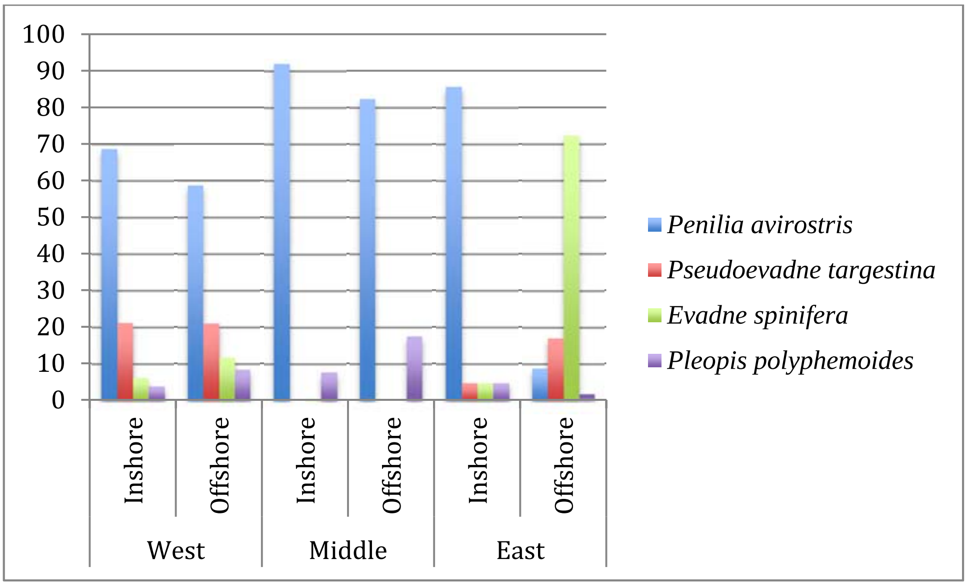
The composition of inshore and offshore waters in terms of both mean abundance and biomass values for cladoceran species showed preference of inshore waters for *P. avirostris* and *P. polyphemoides* and preference of offshore waters for *P. targestina* and *E. sinifera* species (Table 13).

Table 13 Abundance (ind/m^2) and biomass (mg/m^2) values of 4 cladocerans species namely, *Penilia avirostris, Pseudovadne targestina, Evadne spinifera, Pleopis polyphemoides* in inshore and offshore waters of the southern Black Sea in July 2013

	Abundance (ind/m^2)		**Biomass** (mg/m^2)	
	Inshore	**Offshore**	**Inshore**	**Offshore**
Penilia avirostris	5,835	2,114	163	59
Pseudoevadne targestina	558	760	2	3
Evadne spinifera	192	1,373	1	5
Pleopis polyphemoides	429	355	4	3

According to stations from selected transects as a representative of inshore and offshore waters, percent composition of these species displayed different results. *P. avirostris* was the only species that showed preference of inshore waters in 3 mentioned region off southern Black Sea, while P. *targestina, E. spinifera* showed preference of offshore waters. *Pleopis polyphemoides* was one of the inshore water species, while its abundance and biomass percent was higher in the offshore waters in the west and middle parts of the southern Black Sea in July 2013.

A



B

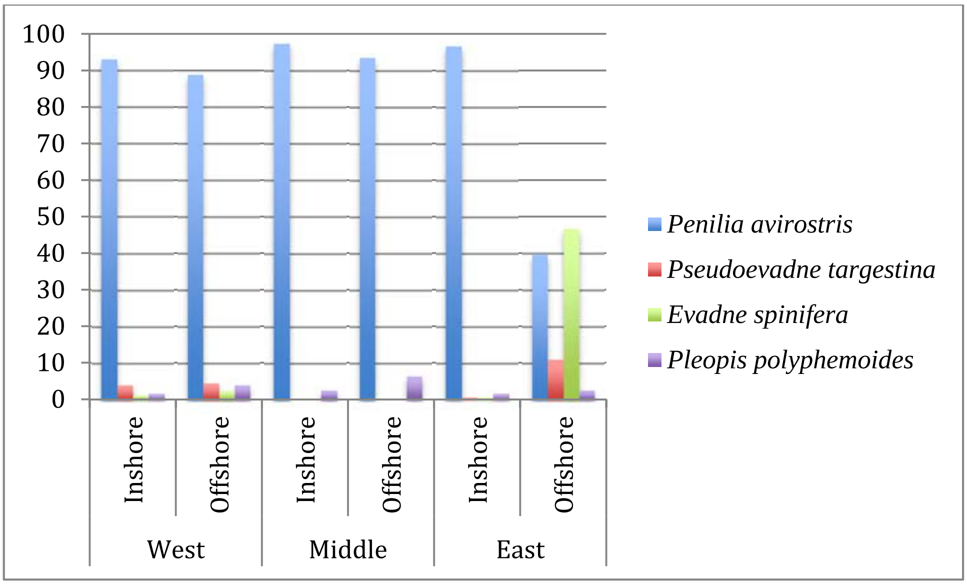


Figure 72 Spatial percent changes in the abundance and biomass of cladocerans off southern Black Sea in July 2013. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

Spatial percent changes of abundance and biomass values of cladoceran species showed detailed results. *P. avirostris* were more dominant in the inshore waters of 3 regions, *P. targestina* showed almost similar values for inshore and offshore waters in the west and middle parts of the Black Sea, while showed preference of offshore waters in the eastern region. *E. spinifera* and *P. polyphemoides* showed preference of offshore waters in both regions (Figure 72 and Figure 74).

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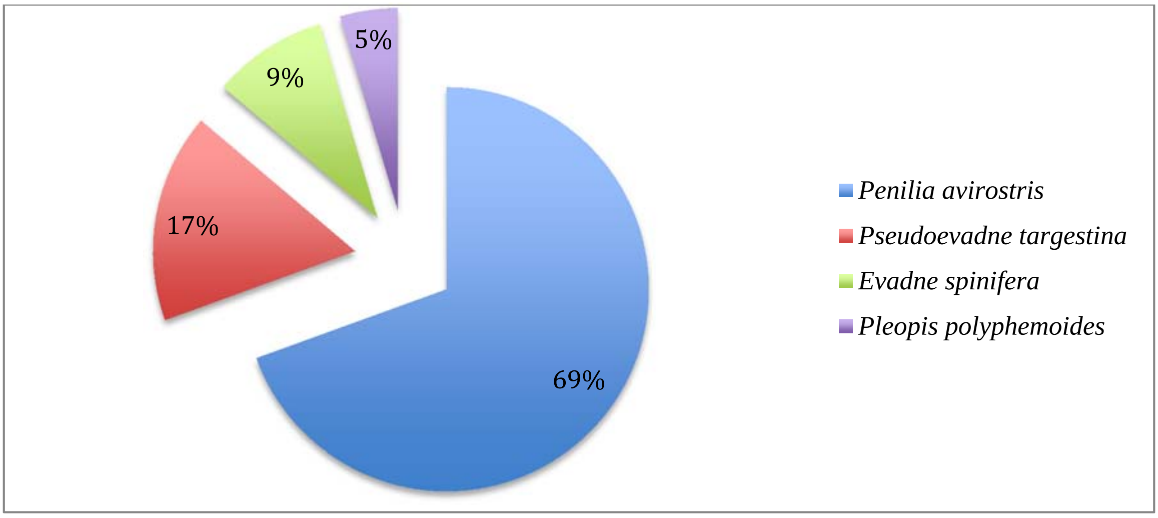
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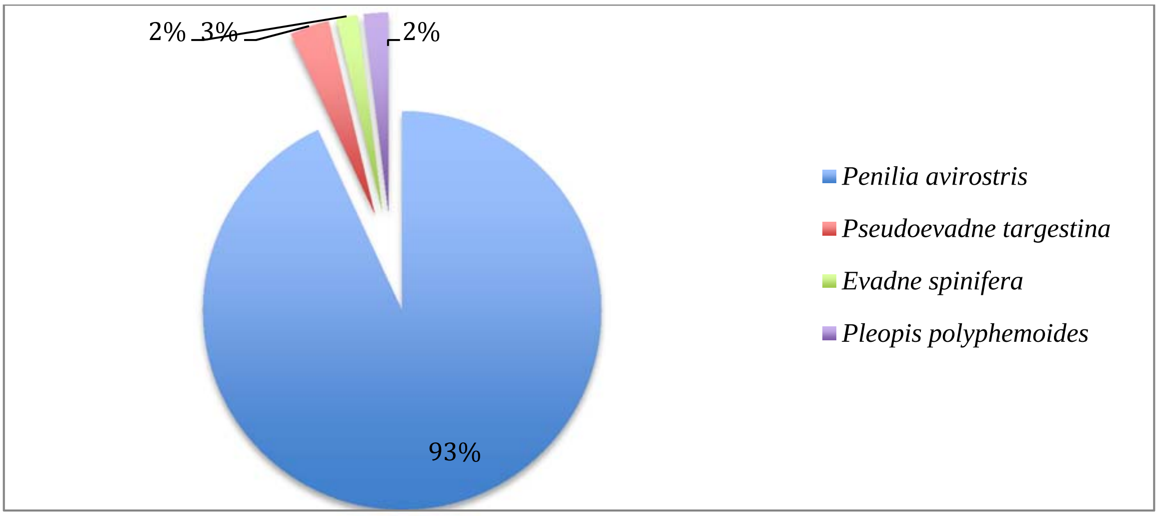
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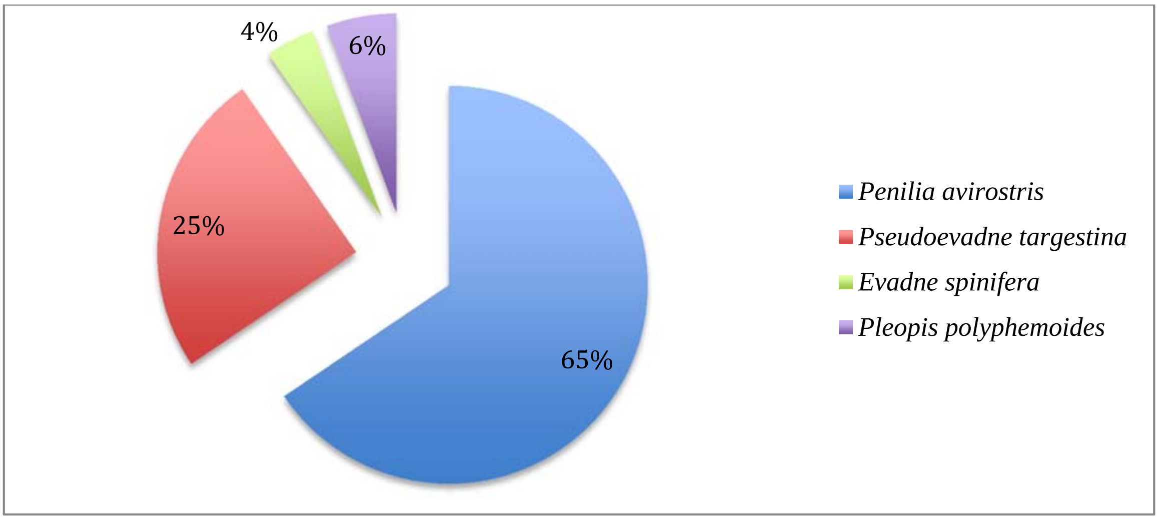
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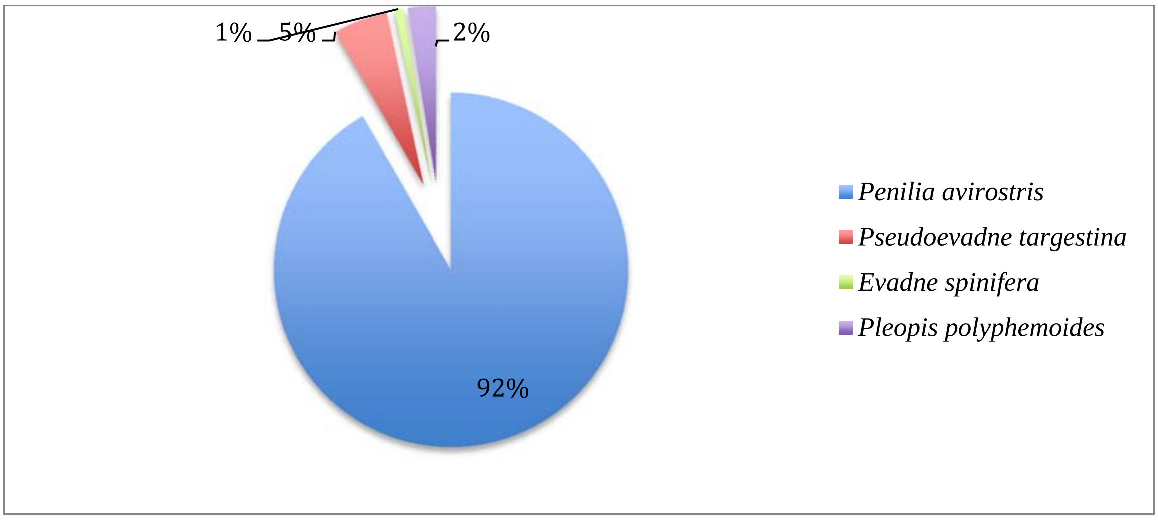
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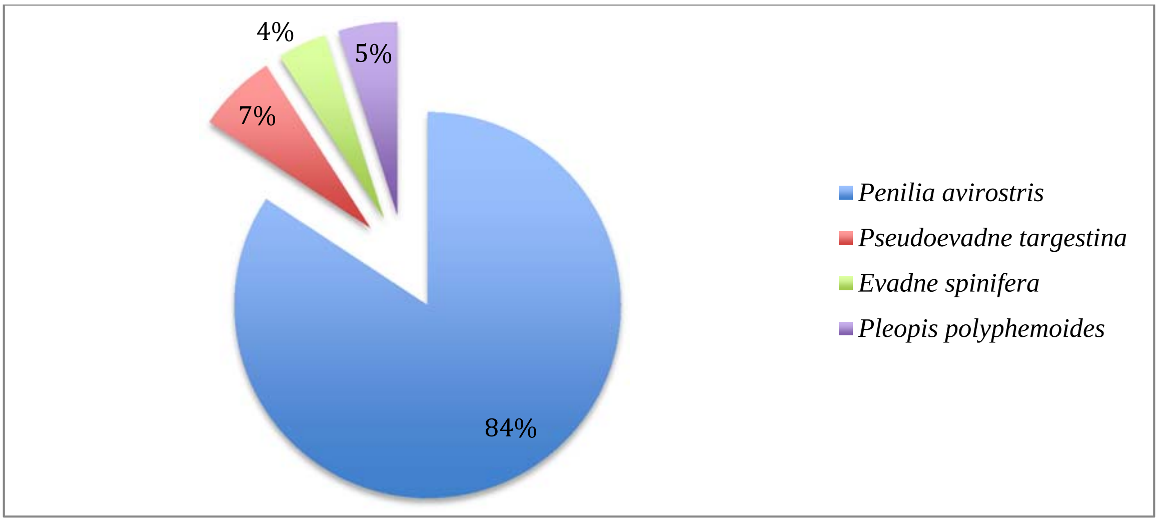
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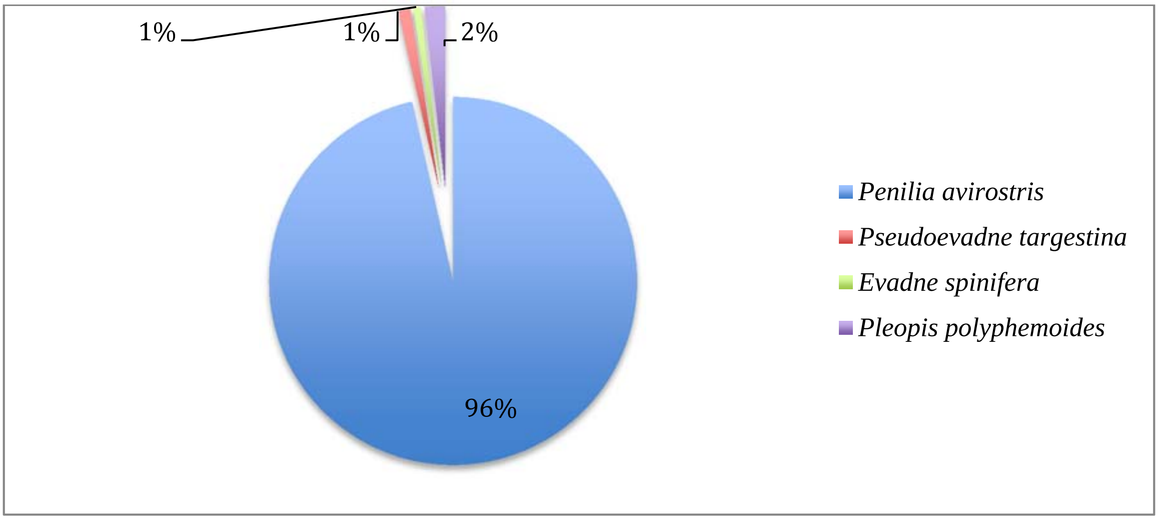
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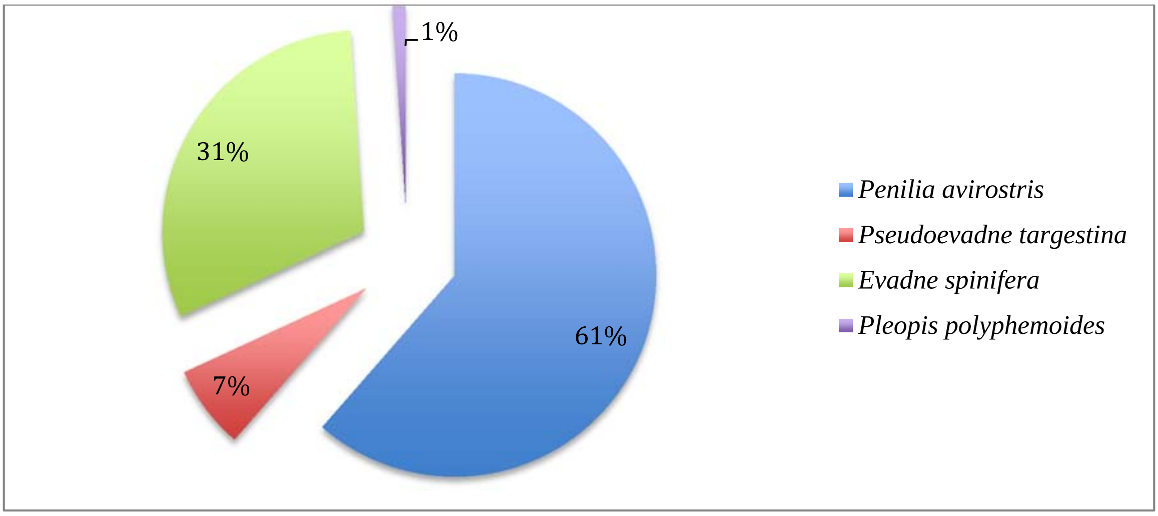
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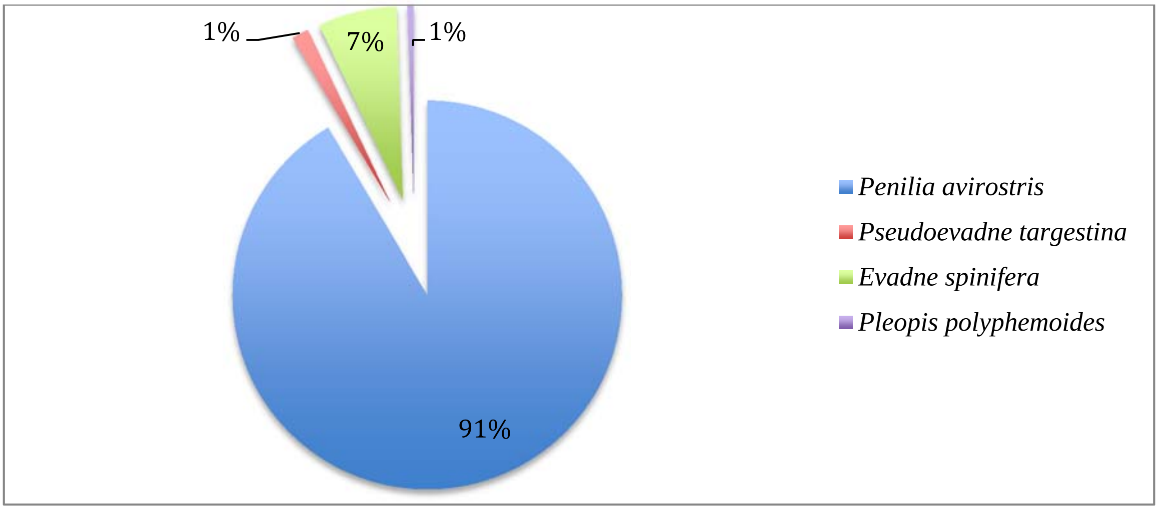
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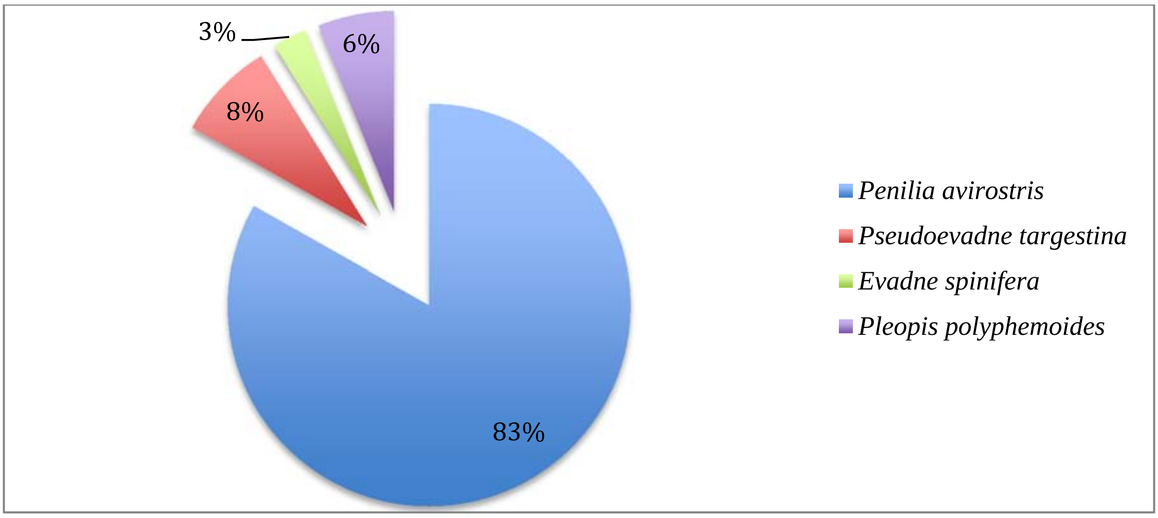
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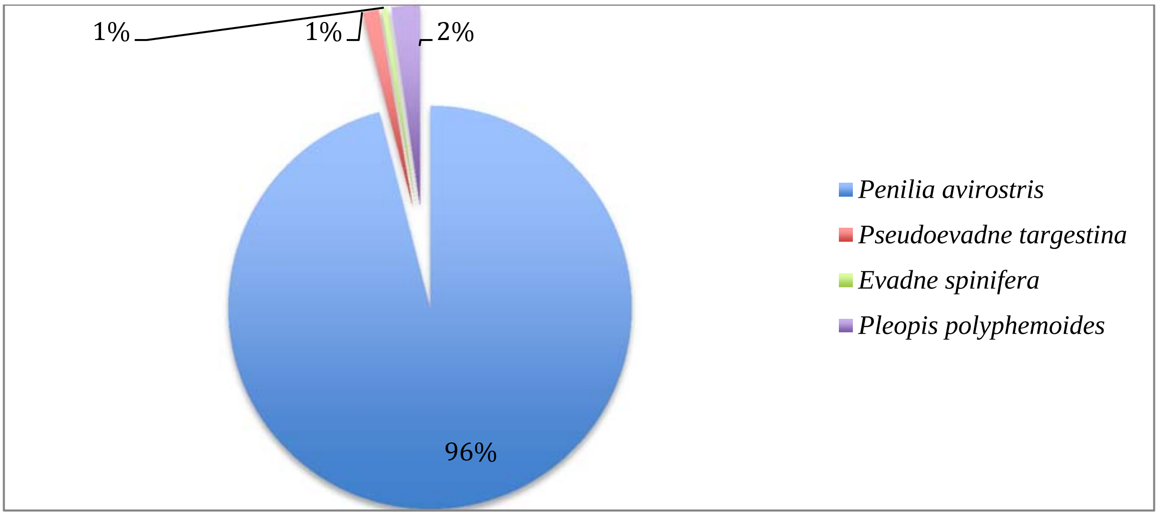
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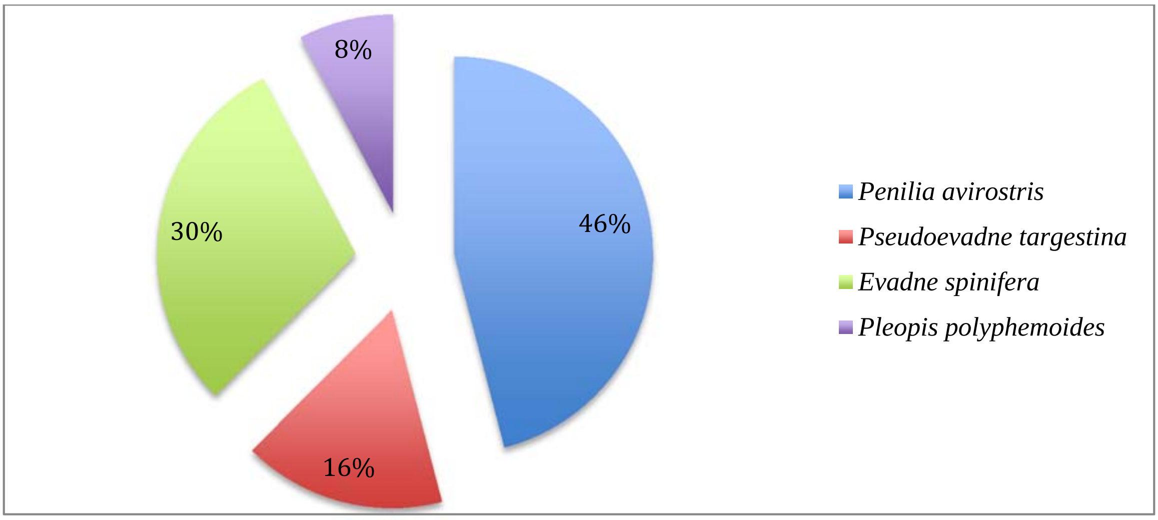

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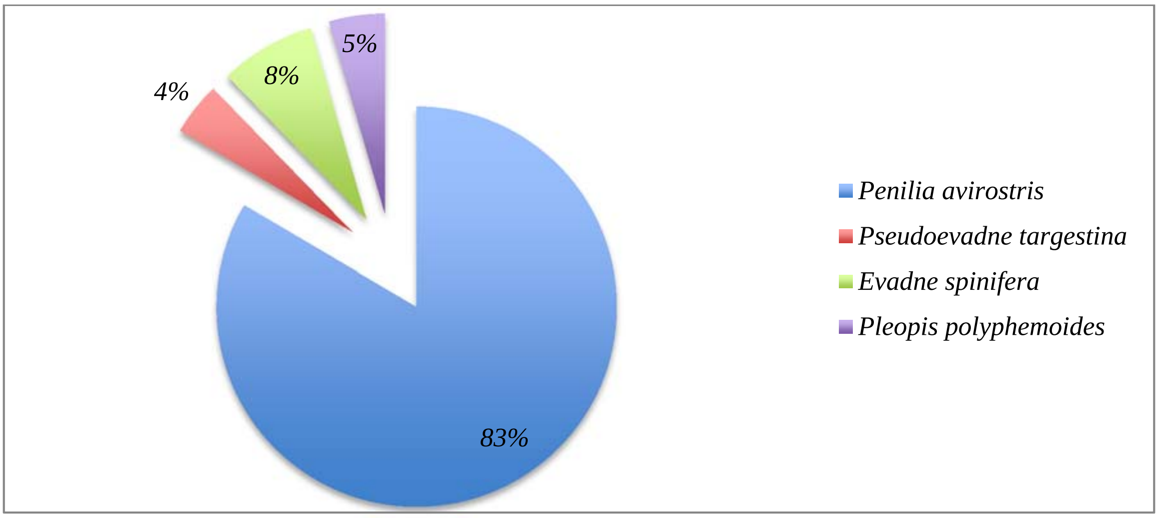

Figure 73 Percent composition of abundance (ind/m^2) and biomass (mg/m^2) of the four main species of cladocerans that were identified in the southern Black Sea in July 2013, namely: *Penilia avirostris*, *Pseudoevadne targestina*, *Evadne spinifera*, *Pleopis polyphemoides*. A. Abundance in the southern Black Sea in July 2013 B. Biomass in the southern Black Sea C. Abundance in the west D. Biomass in the west E. Abundance in the middle F. Biomass in the middle G. Abundance in the east H. Biomass in the east I. Abundance in inshore stations J. Biomass in inshore station K. Abundance in offshore station L. Biomass in offshore station

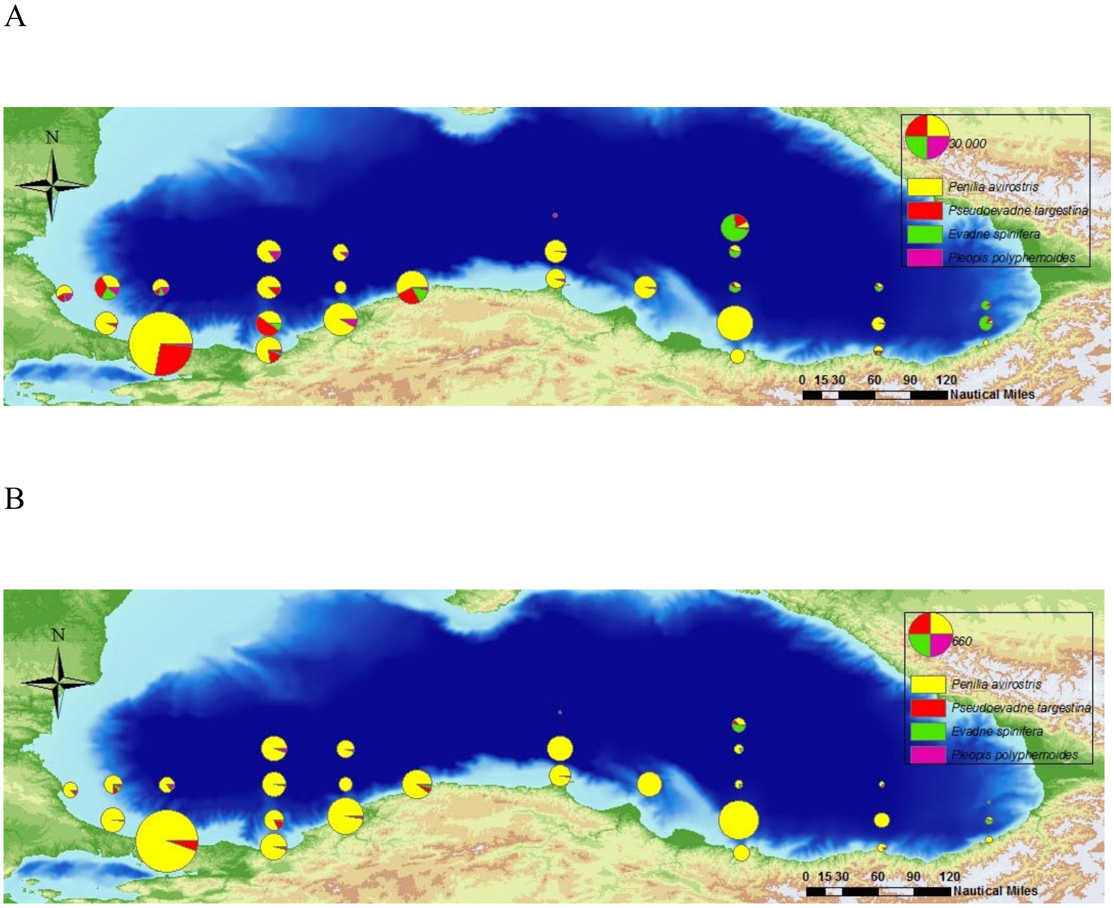

Figure 74 Spatial changes of abundance and biomass contributions of the four Cladocera species in the southern Black Sea in July 2013. Yellow color represents *P. avirostris*, red color *P. targestina*, green color for *E. spinifera* and pink for *P. polyhemoides* A. Abundance (ind/m^2), B. Biomass (mg/m^2)

3.3.1.2.1 *Penilia avirostris*

In terms of abundance, *P. avirostris* were consisting 93% of the total cladoceran species in the west (8,214 ind/m^2), and decreased to the 62% in the middle part (6,558 ind/m^2) and increased up to the 92% in the eastern region (2,658 ind/m^2). Number of individuals was decreased from west to the east (Figure 75); percent of this species was lower in the middle part than eastern part of the Black Sea, probably due to the higher abundance of other cladoceran species in the middle part. 45,167 ind/m^2 was the highest value, which belongs to a station near the Bosphorus. The total biomass value of *P. avirostris* was also decreased from west to the east, but the percent of this species were highest in the eastern region and followed by west and middle parts of the southern Black Sea. 1,264 ind/m^2 was the highest biomass value from of a station that was in the western region. In terms of biomass, the mean value was 161 mg/m^2 for southern Black Sea.

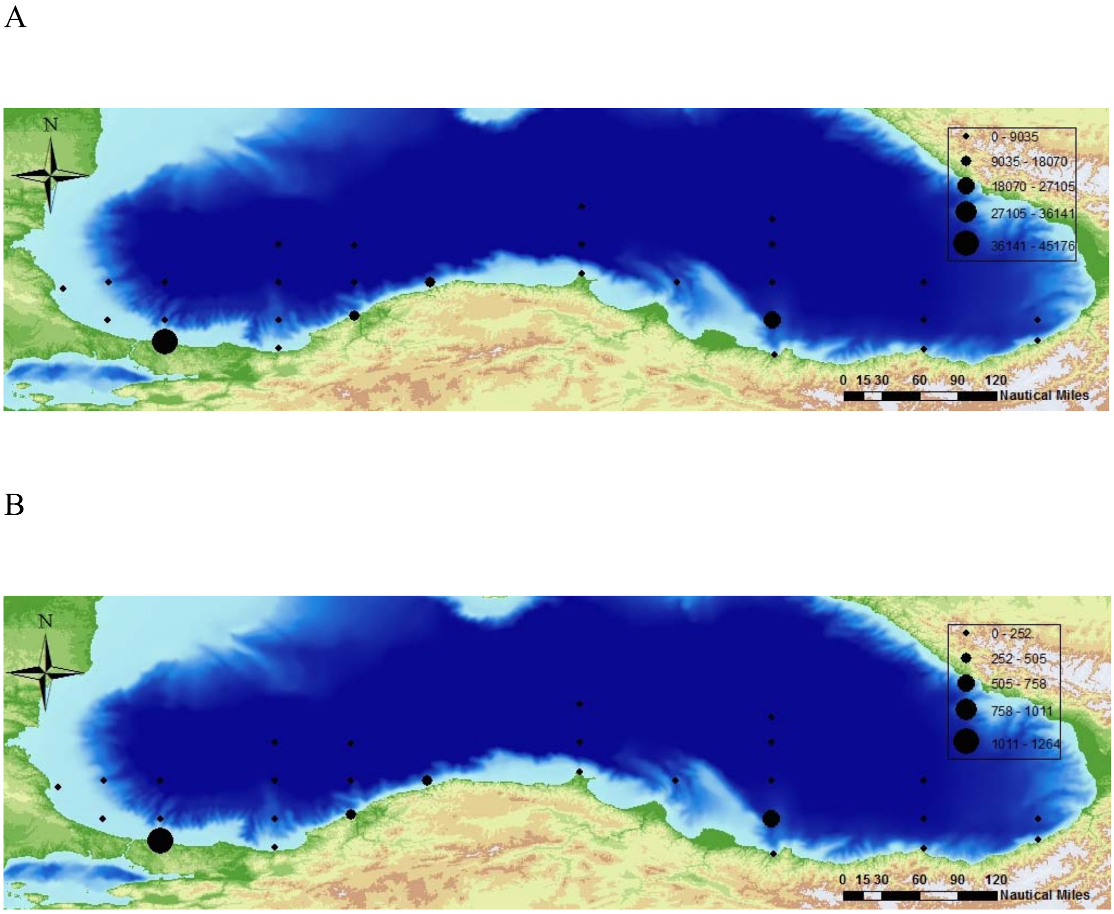

Figure 75 Spatial changes in the abundance and biomass of *Penilia avirostris*. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

3.3.1.2.2 *Pseudoevadne targestina*

Highest abundance and biomass values (3,103 ind/m^2 and 12 mg/m^2) for *P. targestina* were shown in the west. *P. targestina* showed low abundance and biomass values in the middle and east regions in the southern Black Sea (Figure 76). The station near the Bosphorus showed the highest number of individual (17,066 ind/m^2). Both abundance and biomass values decreased from west to the east. Biomass of *P.*

targestina was 12 mg/m^2 in the west, 2 mg/m^2 in the middle and 1 mg/m^2 in the east region of the southern Black Sea.

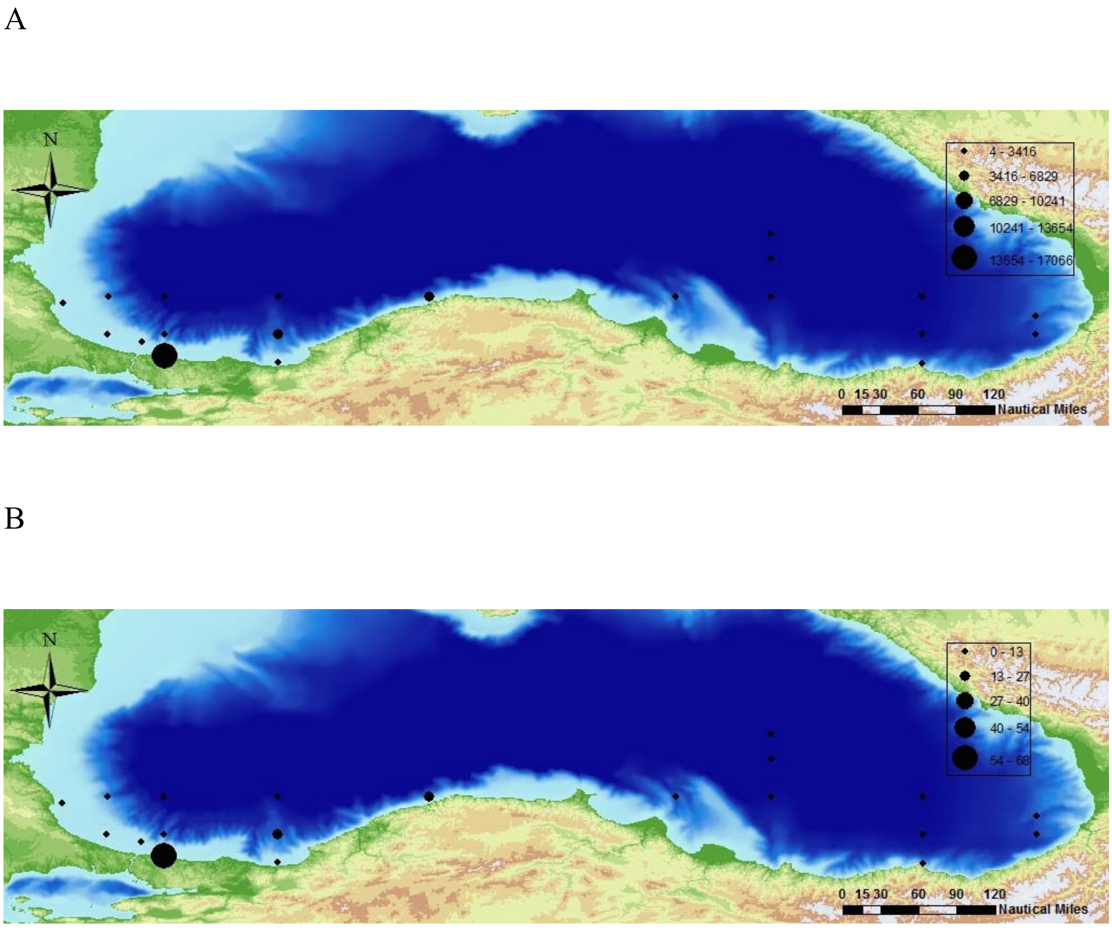

Figure 76 Spatial changes in the abundance and biomass of *Pseudoevadne targestina*. A. Abundance (ind/ m^2), B. Biomass (mg/m^2)

3.3.1.2.3 *Evadne spinifera*

Mean abundance and biomass values were 759 ind/m^2 and 3 mg/m^2 for the southern Black Sea in July 2013. Lowest abundance and biomass values for *E. spinifera* were seen in the middle part of the Black Sea. Spatial distribution of *E. spinifera* displayed preference of eastern region for both abundance (1,333 ind/m^2) and biomass (5 mg/m^2), especially offshore waters of the Ordu region (8,156 ind/m^2 and 32 mg/m^2) showed high values (Figure 77).

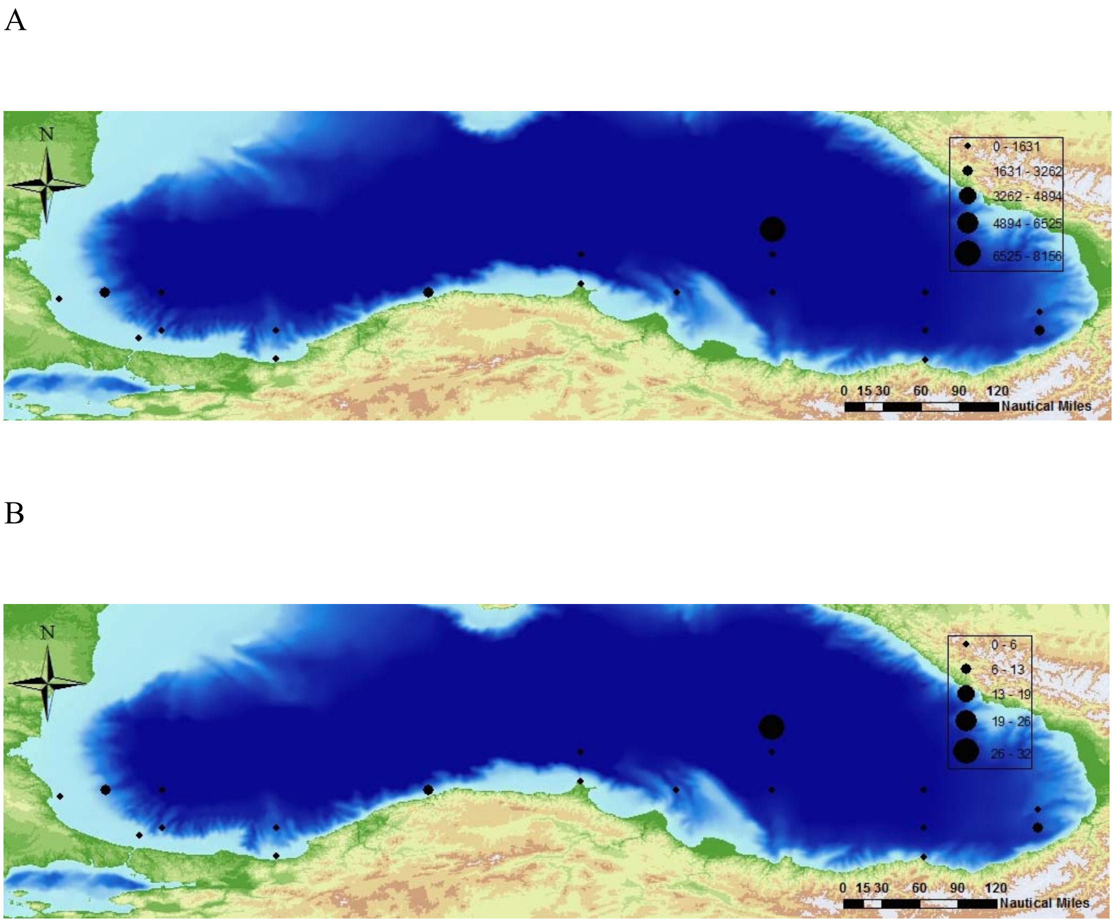

Figure 77 Spatial changes in the abundance and biomass of *Evadne spinifera*. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

3.3.1.2.4 *Pleopis polyphemoides*

Mean abundance value was 381 ind/m^2 and mean abundance was 3 mg/m^2 in the southern Black Sea in July 2013. Individuals of *P. polyphemoides* were found to be most dominant (712 ind/m^2 and 6 mg/m^2) in the southwestern Black Sea. This species did not show preference of inshore or offshore waters (Figure 78). Lowest abundance and biomass values were observed in the east.

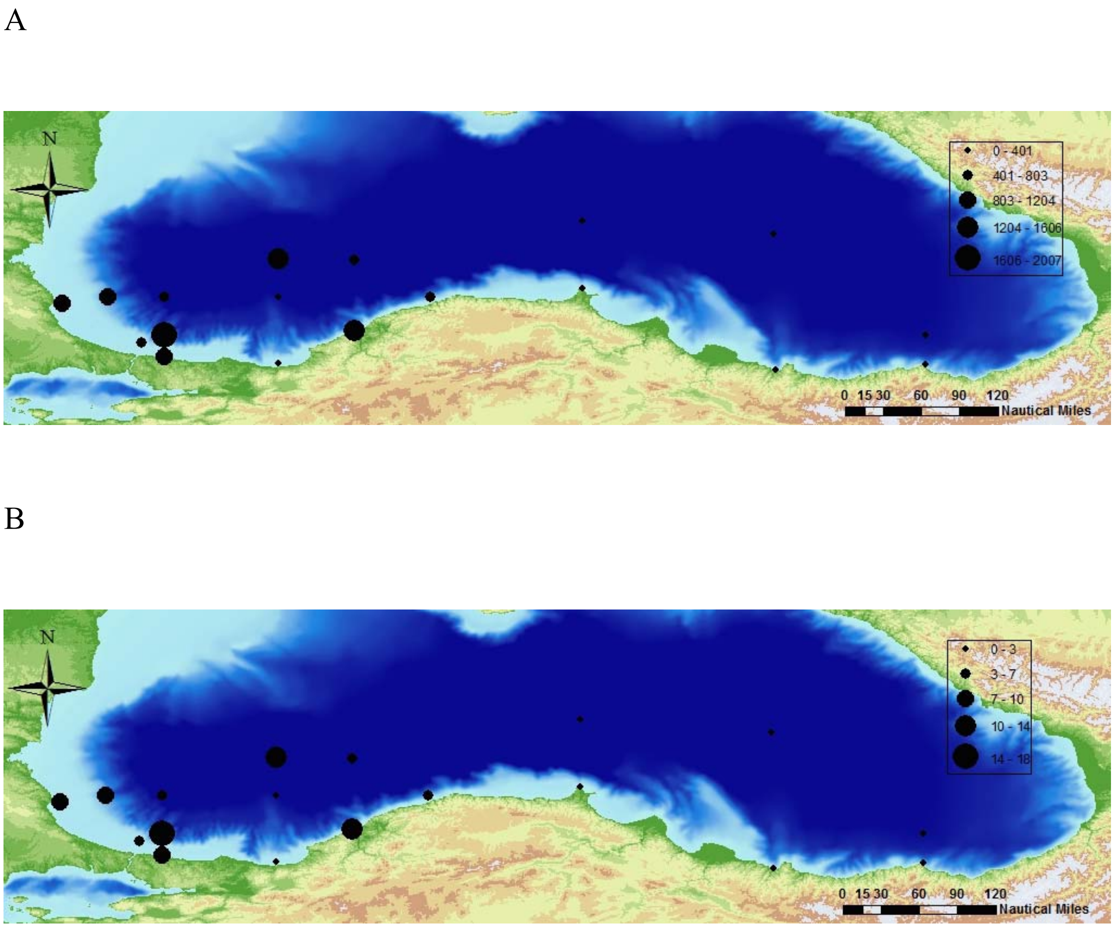

Figure 78 Spatial changes in the abundance and biomass of *Pleopis polyphemoides*. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

3.3.1.3 Meroplankton

Spatial abundance and biomass distribution

The meroplankton data collected in the July 2013 consisted of the groups Bivalvia, Cirripedia, Decapoda, Gastropoda, Ichthtyoplankton and Polychaeta. Abundance and biomass plots for meroplankton species in the southern Black Sea showed a preference of inshore waters, which reached its highest values in the western region.

On the other hand, meroplankton individuals were observed in all sampling stations.

4,769 were the mean abundance value for meroplankton in July 2013. The maximum abundance value was 7,41 ind/m^2 for the western region, followed by 4,633 ind/m^2 in the middle part (Figure 79). The lowest value (2,296 ind/m^2) occurred in the eastern region of the southern Black Sea. The highest value (23,082 ind/m^2) was observed in the inshore waters of Zonguldak.

Table 14 Mena abundance values (ind/m^2) of 7 meroplankton groups in the southern Black Sea and in 3 mentioned regions of it

Meroplankton groups	West	Middle	East	BS
Cirripedia	2,396	526	429	1,176
Bivalvia	1,730	2,477	666	1,539
Gastropoda	1,873	897	141	978
Polychaeta	57	114	143	104
Decapoda	405	214	46	222
Fish Egg	687	284	516	517
Fish Larvae	193	121	355	233

In terms of biomass, mean value was 98 mg/m^2, the maximum value was 182 mg/m^2 in the western Black Sea, which is followed by 74 mg/m^2 in the middle and lowest in the eastern region (30 mg/m^2). The highest biomass value for a station was recorded near the Bosphorus (Figure 80).

Table 15 Biomass values (mg/m^2) of 5 meroplankton groups in the southern Black Sea and in 3 mentioned regions of it

Meroplankton groups	West	Middle	East	BS
Cirripedia	98	22	18	48
Bivalvia	9	12	3	8
Gastropoda	20	10	2	11

Polychaeta	1	2	2	1
Decapoda	54	29	6	30

Both abundance and biomass values of meroplankton were observed to be decreasing from western the eastern region in the southern Black Sea (Table 14 and Table 15).

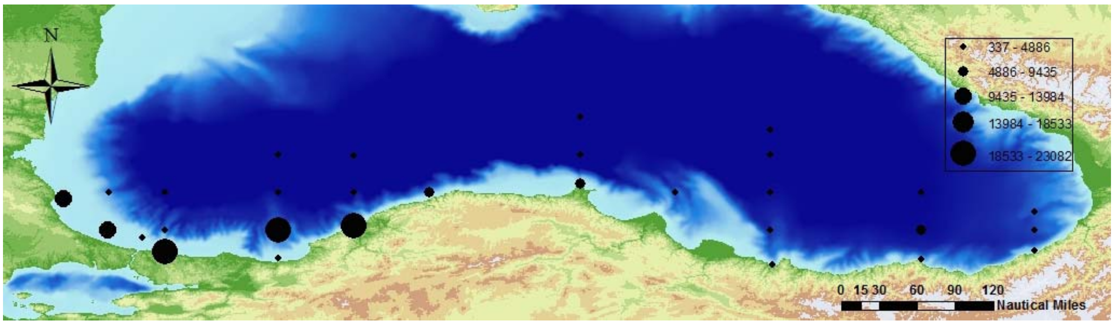

Figure 79 Spatial abundance (ind/m^2) contributions of the main meroplankton species in the southern Black Sea in July 2013.

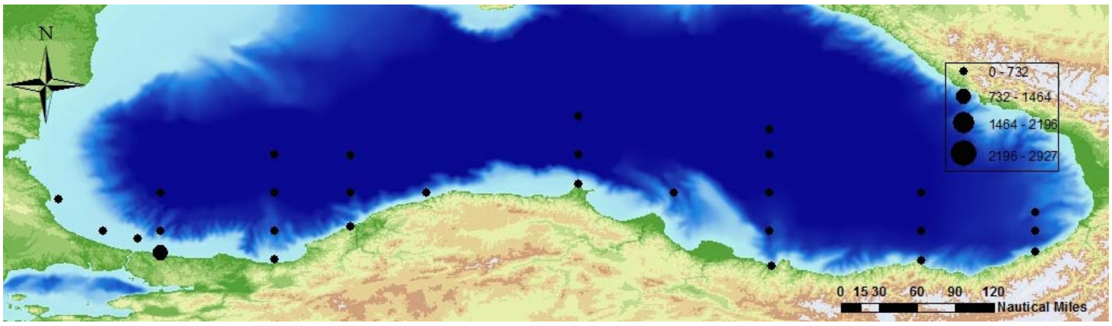

Figure 80 Spatial biomass (mg/m^2) contributions of the main meroplankton species in the southern Black Sea in July 2013.

Group composition

Among the meroplankton groups that were identified in the southern Black Sea, group Bivalvia had dominance over the other groups, forming up to 32% of the overall sum in terms of abundance and up to 8% in terms of biomass. Abundance values of Bivalvia was almost same in the western and middle parts of the Black Sea, while it is lower more than half in the eastern region (shown in Figure 81).

The second most abundant group of meroplankton was Cirripedia, which constitutes the 25% of the total meroplanton in terms of abundance and 49% of the total meroplankton in terms of biomass. Number of Cirripedia was similar in the middle and east parts of the southern Black Sea, while this number was almost 25 times higher in the western region. Cirripedia followed by Gastropoda that constitutes 20% of the overall sum in terms of abundance and, forming up only 11% of the total biomass. Number of Gastropoda was highest in the western region and lowest in the eastern region.

Ichthyoplankton was examined in two groups namely fish egg and fish larvae. Fish egg constituted 11% of the total abundance and number of eggs was higher in the western region and lowest in the middle region, while percentage of egg was 9% in the west and 23% in the east.

In terms of larvae of fish, this group was making up the 5% of the total meroplankton and highest value was in the eastern region and lowest in the middle part of the southern Black Sea. Percentage of fish larvae was similar 3% in the west and middle parts of the Black Sea and 15% in the eastern region.

Decapoda constituted 5% of the total meroplankton, while it was making up the 30% of the total biomass of meroplankton. Total abundance value was maximum in the western region and decreased from west to east.

Polychaeta was only 2% in terms of abundance and 2% in terms of biomass. In contrast to the all other meroplankton species, polychaeta was increased from west to the east. Percentage of polychaeta was 1% in the west, 2% in the middle part of the southern Black Sea, while it was 6% in the eastern region.

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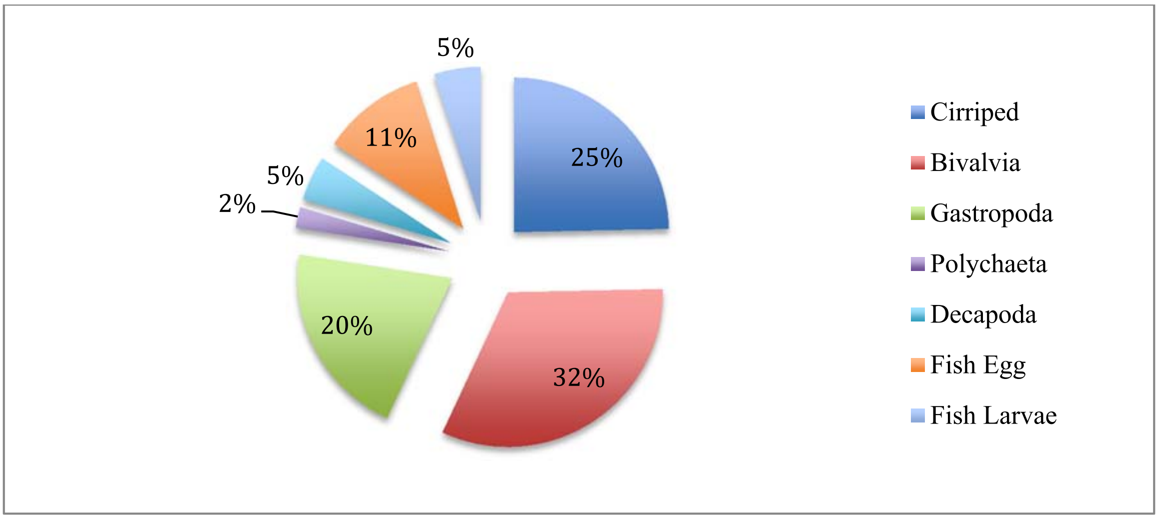
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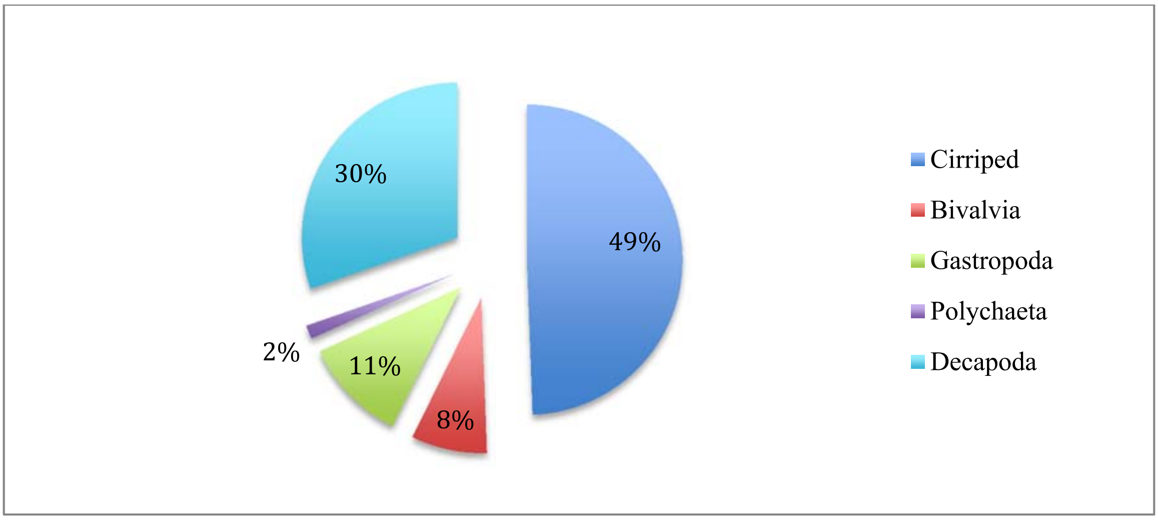
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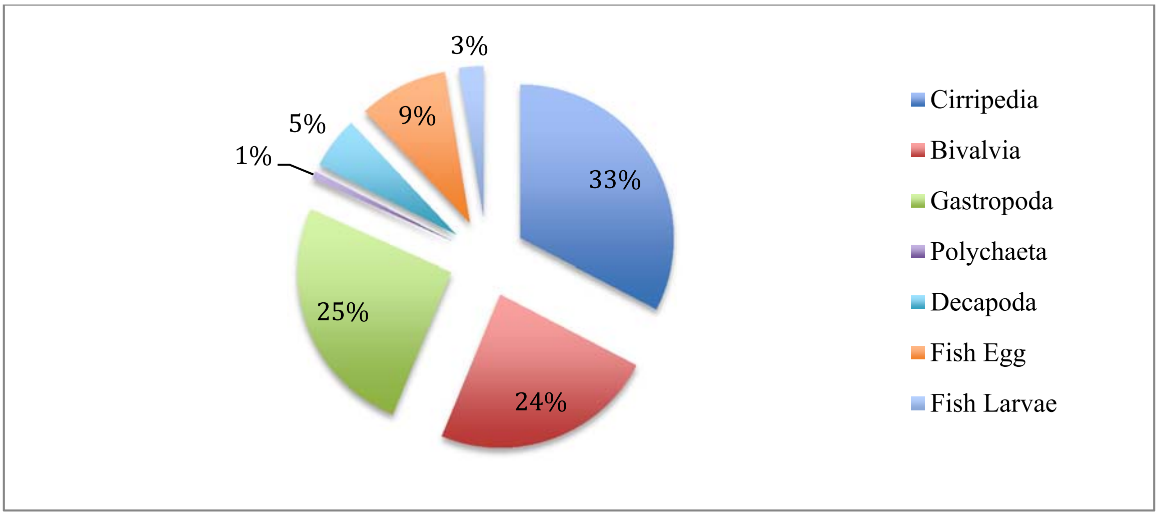
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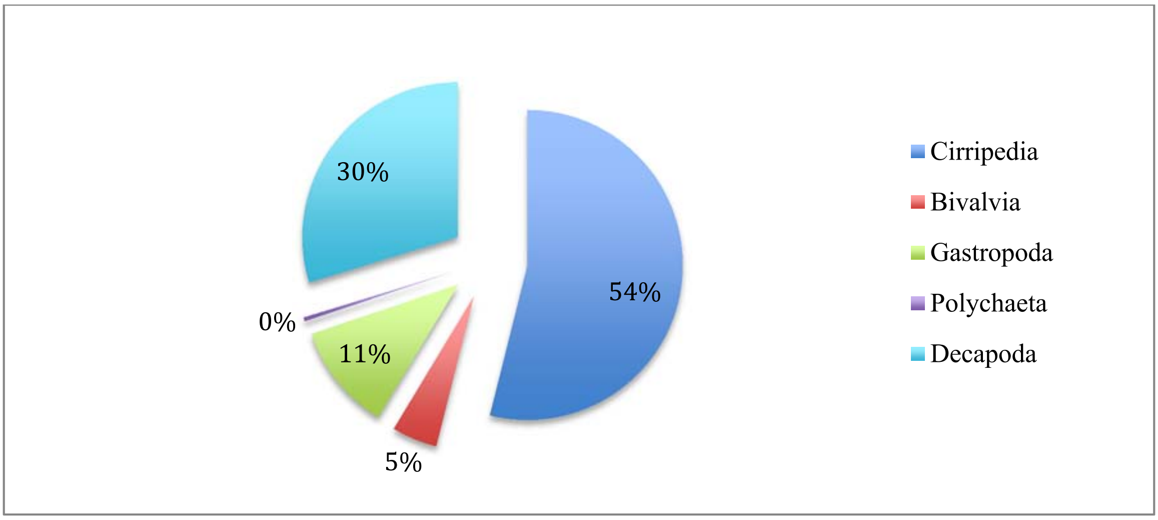
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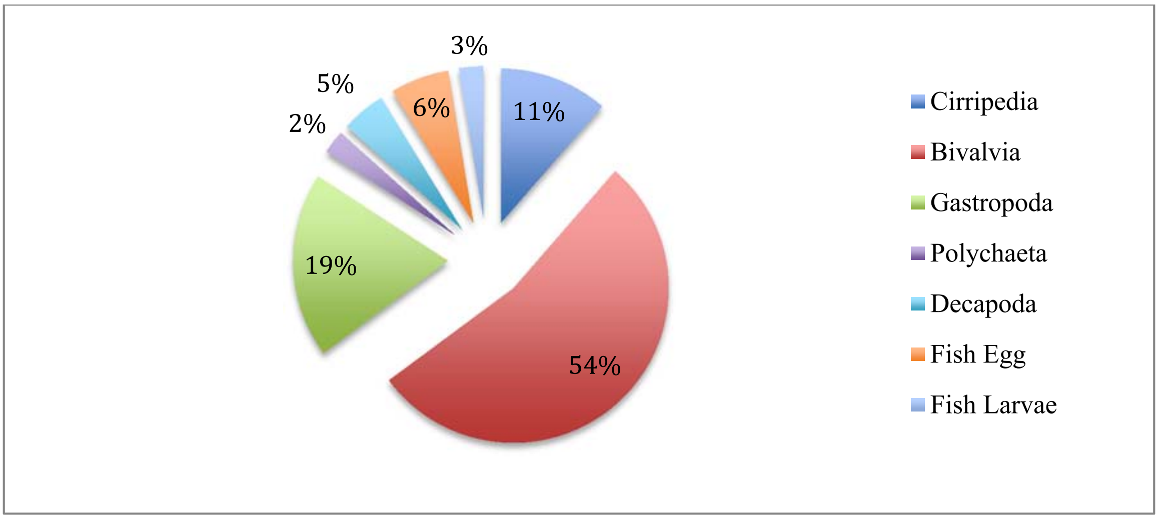
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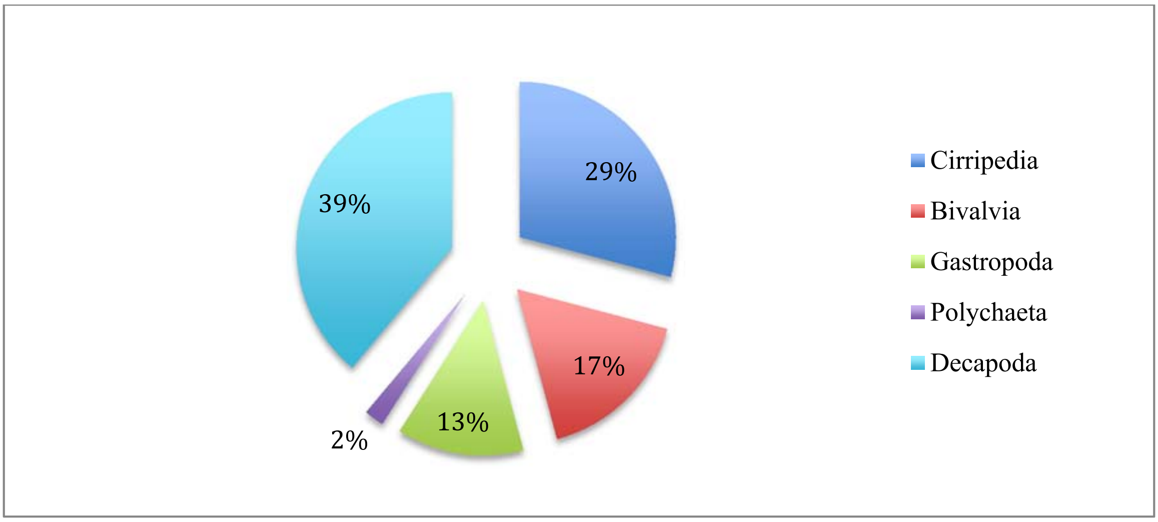
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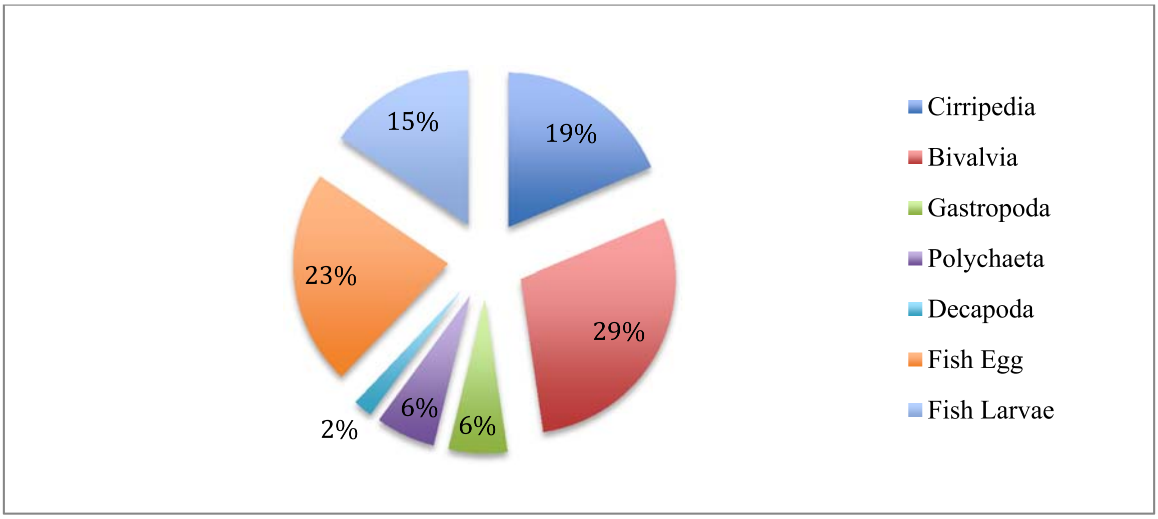
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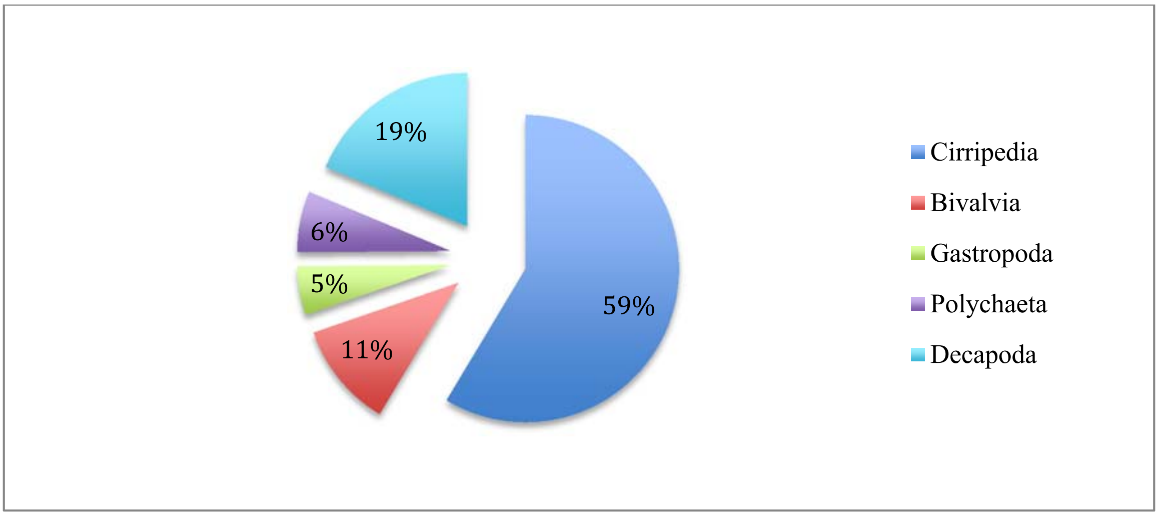
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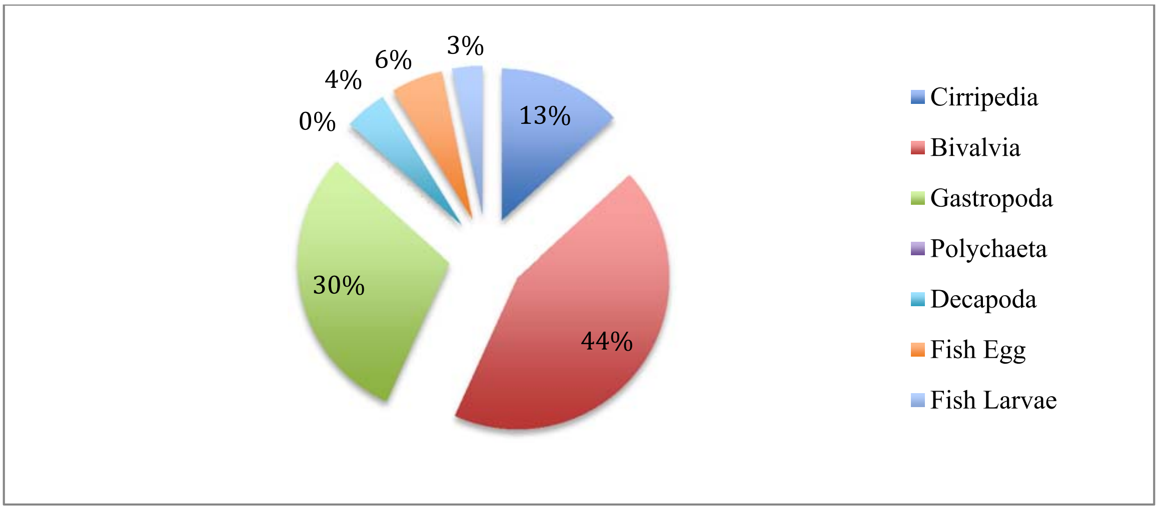
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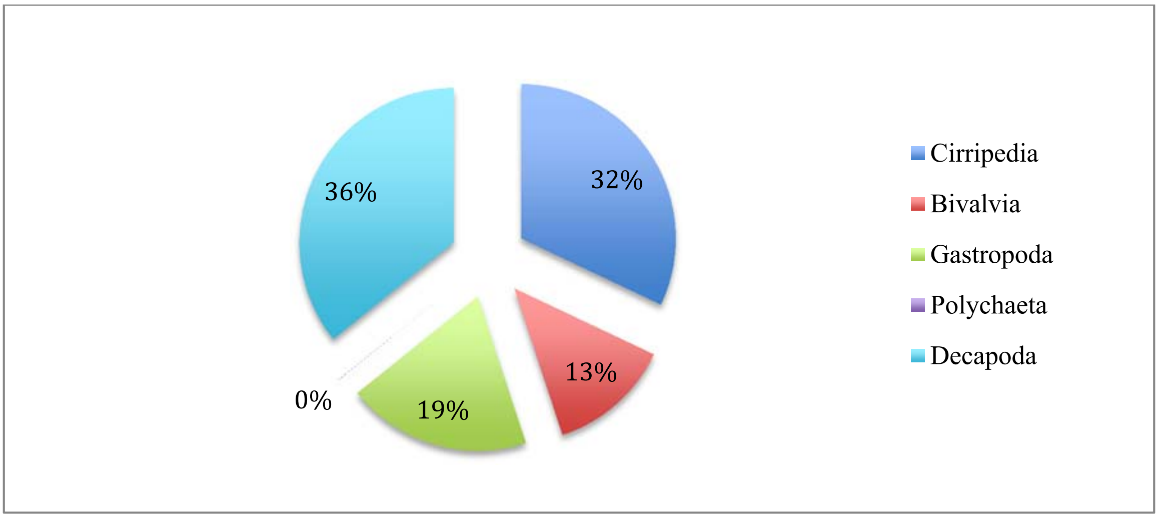
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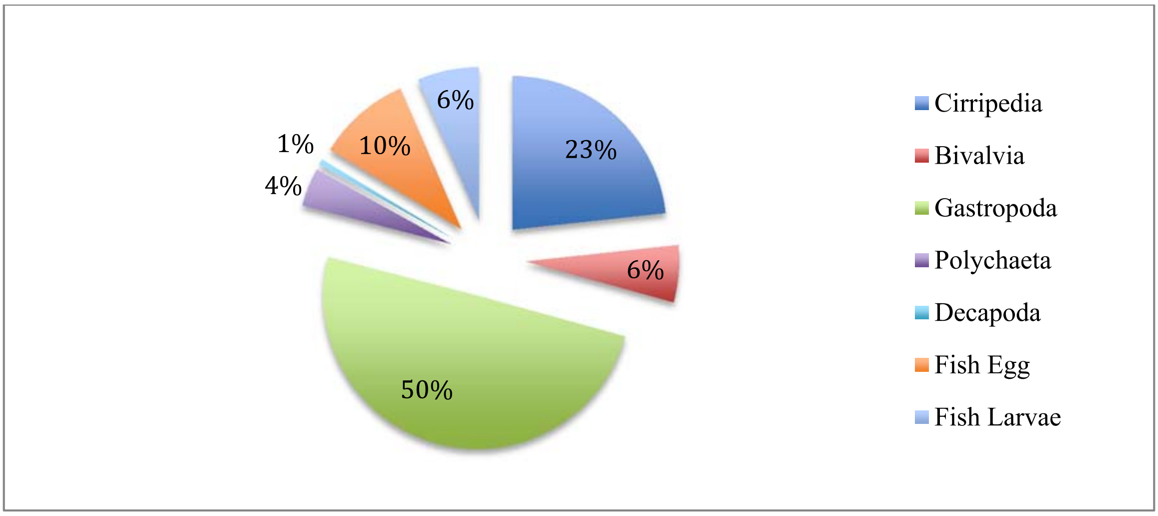

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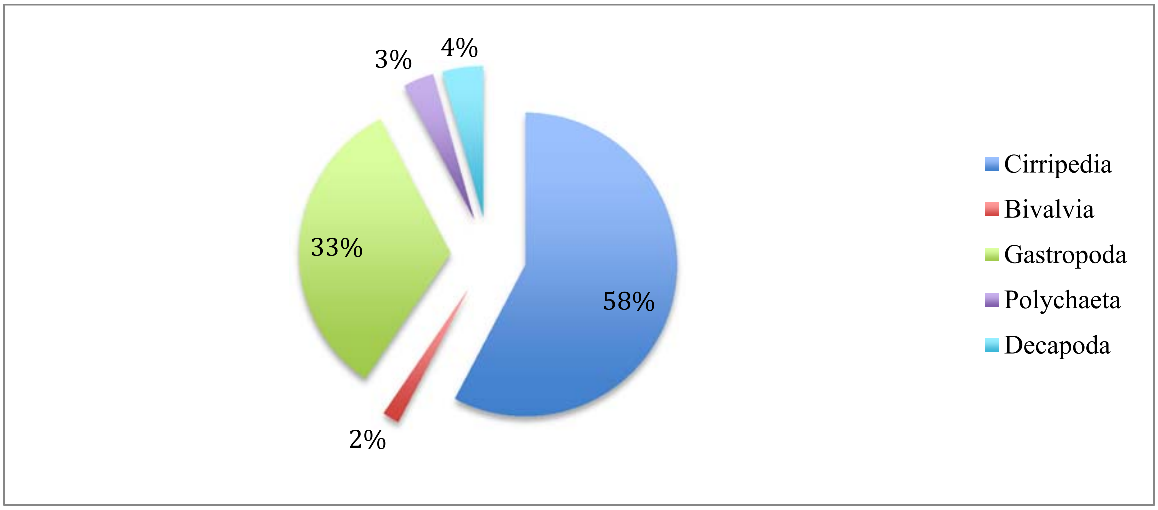
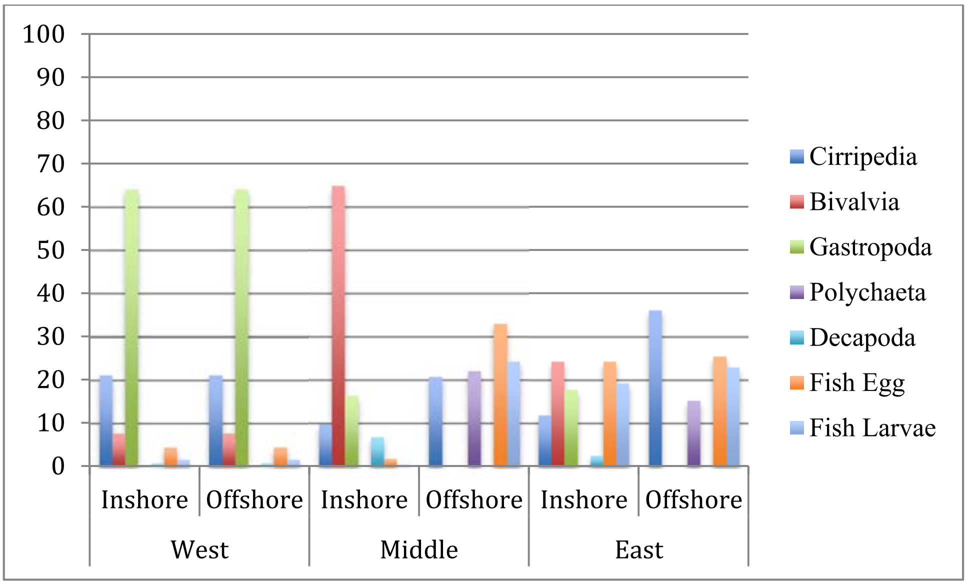


Figure 81 Percent composition of the main meroplankton grops in terms of abundance (ind/m^2) and biomass (mg/m^2). A. Abundance in the southern Black Sea in July 2013 B. Biomass in the southern Black Sea C. Abundance in the west D. Biomass in the west E. Abundance in the middle F. Biomass in the middle G. Abundance in the east H. Biomass in the east I. Abundance in inshore stations J. Biomass in inshore station K. Abundance in offshore station L. Biomass in offshore station

A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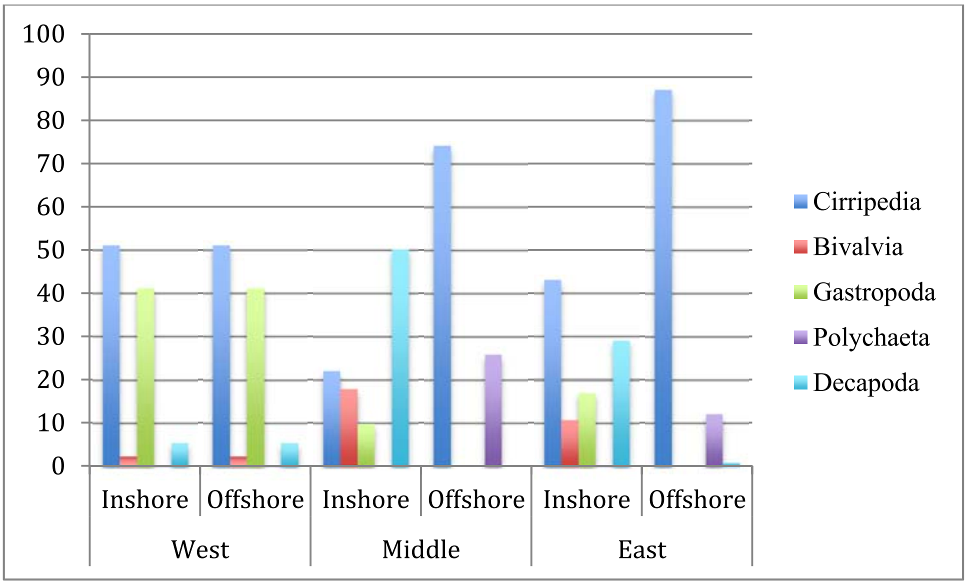
Decapoda
Fish Egg
Fish Larvae

B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Cirripedia
Bivalvia
Gastropoda
Polychaeta
Decapoda

Figure 82 Spatial percent changes in abundance and biomass of meroplankton in the inshore and offshore waters of 3 mentionesd regions of the southern Black Sea in July 2013. A. Abundance B. Biomass

The comparison of percent values for 3 regions showed that, in terms of abundance fish egg, fish larvae, cirripedia and polychaeta were the species had a preference of offshore waters while, bivalvia, gastropoda and decapoda were the species that had a preference of inshore waters (Figure 82), however these results were obtained for selected transects.

3.3.1.3.1 Bivalvia

Spatial abundance distribution of Bivalvia showed preference of inshore waters in the southern Black Sea (Figure 83). Abundance and bomass of Bivalvia decreased from west to east. Highest abundance and biomass were 2,477 ind/m^2 and 12 mg/m^2 in the west. The comparison of regions revealed that eastern region displayed the lowest abundance and biomass values (666 ind/m^2 and 3 mg/m^2) for Bivalvia in July 2013. The highest values were observed in the Sakarya and Zonguldak regions.

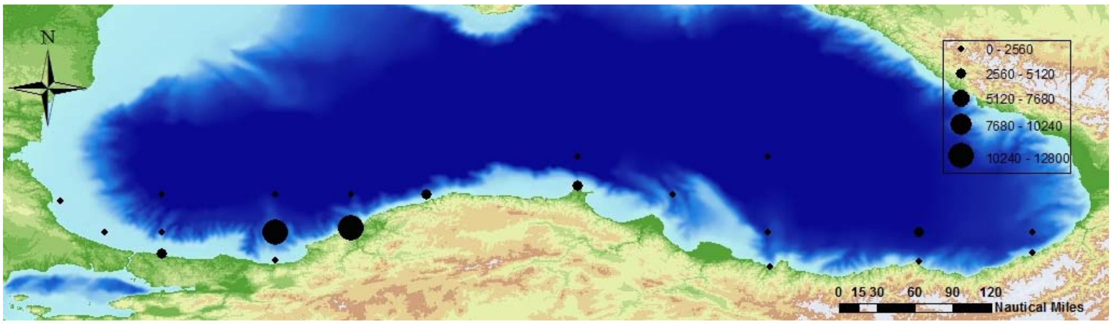


Figure 83 Spatial abundance (ind/m^2) contributions of Bivalvia in the southern Black Sea in July 2013.

3.3.1.3.2 Cirripedia

Cirripedia that was identified in the southern Black Sea displayed mass dominance in the western region. Total abundance value of Cirripedia in the west (2,396 ind/m^2) was almost being about 5 times greater than the other regions. In terms of abundance and biomass higher values were observed in the inshore waters (Figure 84) of the southern Black Sea.

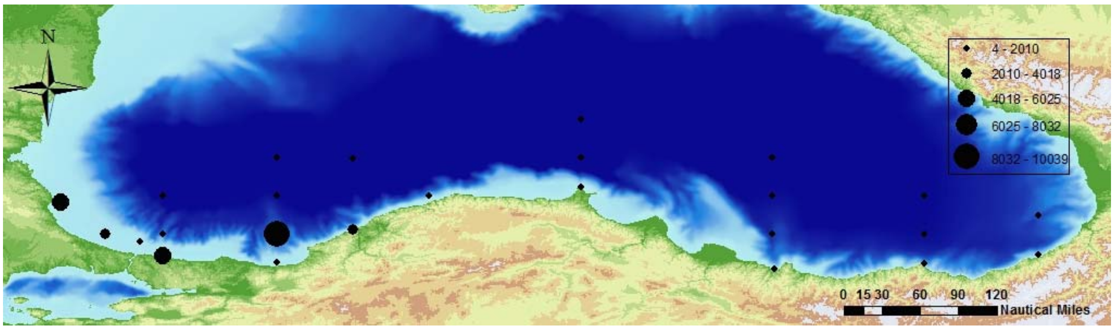


Figure 84 Spatial abundance (ind/m^2) contributions of Cirripedia in the southern Black Sea in July 2013.

3.3.1.3.3 Decapoda

Mean abundance value was 222 ind/m^2 and mean biomass value was 30 mg/m^2. Decapoda that was identified in the southern Black Sea displayed mass dominance in the western region. Mean abundance and biomass values (405 ind/m^2 and 54 mg/m^2) were almost 2 times greater than middle part and 9 times greater than eastern region. Especially, the station just near to the Bosphorus (4,454 ind/m^2) showed the highest abundance values (Figure 85). Individuals of Decapoda showed high preference of inshore waters.

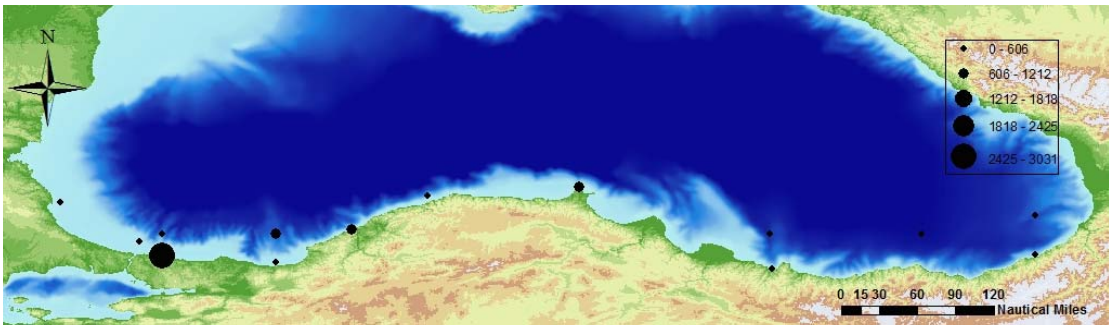


Figure 85 Spatial abundance (ind/m^2) contributions of Decapoda in the southern Black Sea in July 2013.

3.3.1.3.4 Gastropoda

Gastropods clearly preferred the inshore stations. 1,873 ind/m^2 and 20 mg/m^2 were found to be in the western region of the southern Black Sea, which was almost 2 times greater than middle part and more than 13 times greater than eastern region (Figure 86). 3 inshore stations showed high values in terms of abundance. Western side of the Bosphorus (8,533 ind/m^2), eastern side of the Bosphorus (5,019 ind/m^2) and stations near Bartın (3,764 ind/m^2) showed high values. The mean abundance and biomass values of Gastropods were 978 ind/m^2 and 11 mg/m^2 in the southern Black Sea in July 2013.

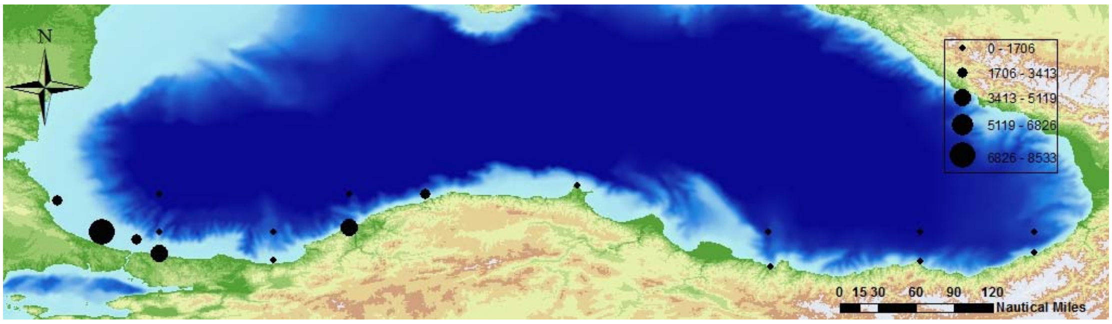


Figure 86 Spatial abundance (ind/m^2) contributions of Gastropoda in the southern Black Sea in July 2013.

3.3.1.3.5 Polychaeta

The Polychaeta displayed rather offshore distribution in the entire southern Black Sea. According to Figure 87, its abundance was also higher in the eastern region (143 ind/m^2) and decreased from east to the west. Abundance in the middle (114 ind/m^2) was 2 times greater than west region. Mean biomass value of polychaeta individuals in southern Black Sea was 1 mg/m^2.

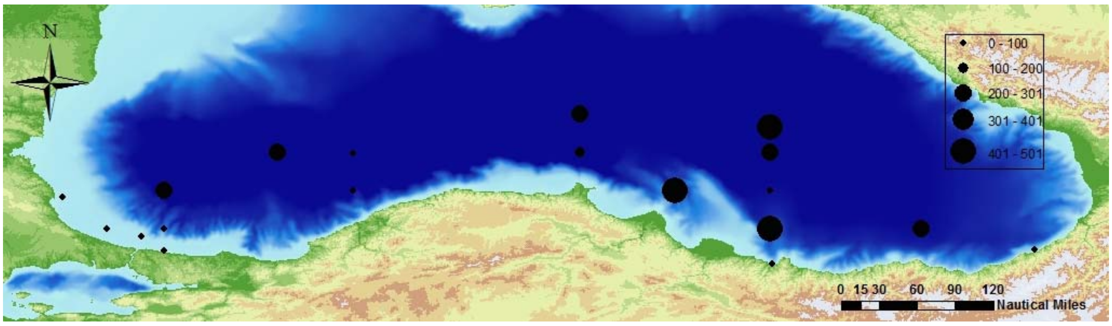


Figure 87 Spatial abundance (ind/m^2) contributions of Polychaeta in the southern Black Sea in July 2013.

3.3.1.3.6 Fish Egg

The mean abundance value of fish egg was 517 ind/m^2 in the southern Black Sea in July 2013. Spatial abundance distribution of fish eggs displayed the highest values in the western region. 1052 ind/m^2 was the highest value for a station, which was near to the Bosphorus. The highest mean abundance value was 687 ind/m^2 in the west and followed by eastern region 516 ind/m^2. The lowest abundance value of fish egg was in middle part 284 ind/m^2. The second figure (which excludes the station with highest value) that shows distribution on eggs of fish displayed high values in the most west stations and inshore waters of the eastern stations (Figure 88).

Fish eggs were analyzed in 3 different groups namely alive anchovy egg, dead anchovy egg and other eggs. 96% of the total abundance of fish eggs was anchovy, while the other eggs were only constitutes 4%. Within the anchovy group, 80% was dean and only 20% was alive.

The comparison of abundance values of fish egg in 3 mentioned region showed that 81% of the anchovy egg was dead in the western region and this ratio was 86% in the middle part, while it is 80% in the eastern region.

The mean abundance of alive eggs of anchovy was highest in the east and the mean abundance of dead eggs was highest in the west.

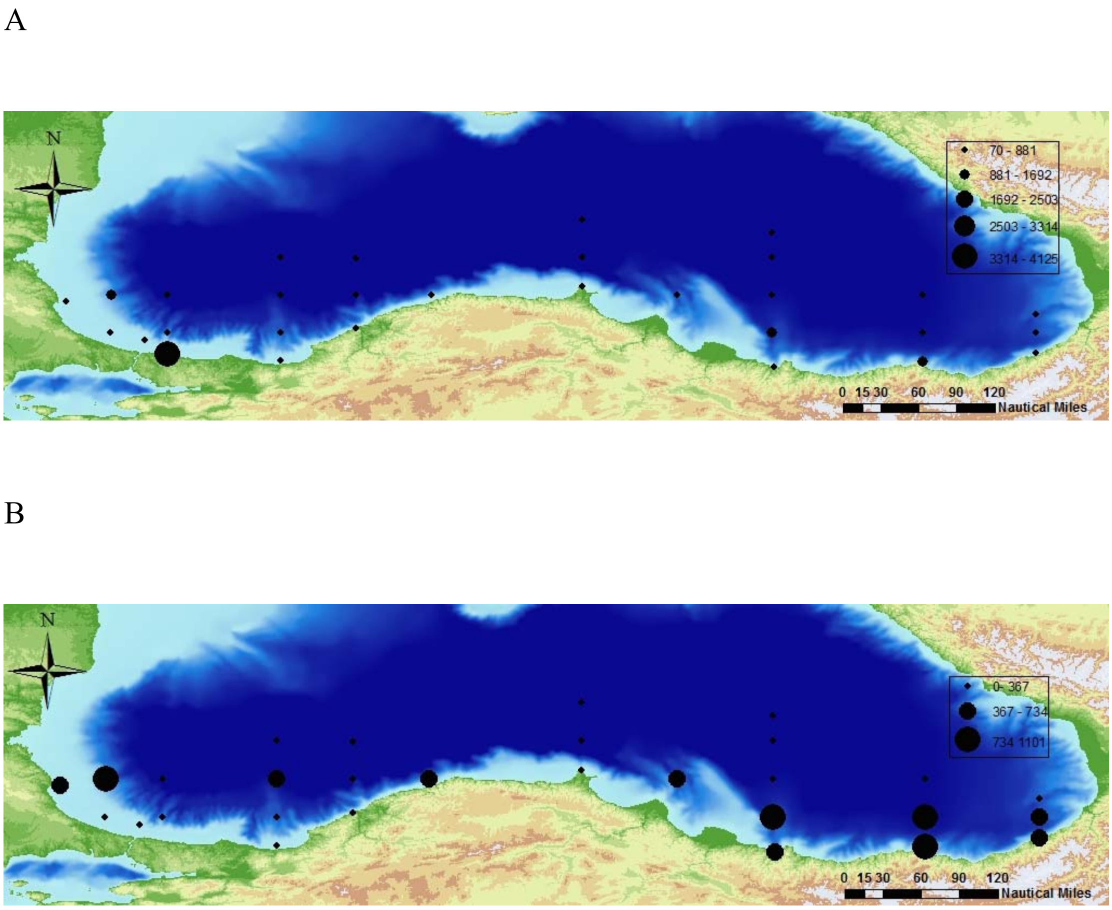


Figure 88 The spatial abundance (ind/m^2) distribution of fish egg in the southern Black Sea in July 2013.

3.3.1.3.7 Fish Larvae

The mean abundance value of fish larvae was 233 ind/m^2 in the southern Black Sea in July 2013. The spatial abundance distribution of fish larvae displayed high abundance values (355 ind/m^2) in the eastern region, which was almost 2 times greater than west and 3 times greater than the middle parts of the southern Black Sea. The highest value for a station was 212 ind/m^2 in the eastern region (Figure 89).

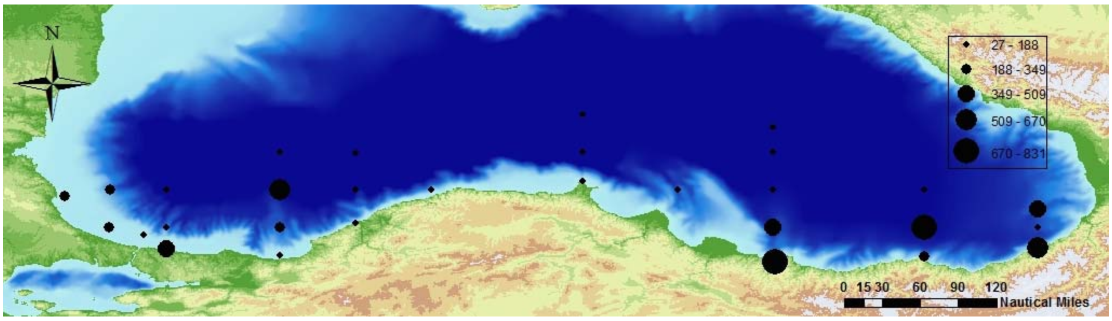


Figure 89 The spatial abundance (ind/m^2) distribution of fish larvae in the southern Black Sea in July 2013.

3.3.1.4 *Parasagitta setosa*

Spatial abundance and biomass distribution

Spatial abundance distribution of *Parasagitta setosa* displayed high values (average of 5,972 ind/m^2) in the eastern region of the southern Black Sea and followed by western region. Highest values were observed in the most eastern stations and off shore wasters of the western regions and the station near the Bosphorus. The highest value for a station was 16,654 ind/m^2, which was near the Trabzon region. Both inshore and offshore waters of the middle part of the southern Black Sea displayed the lowest value in terms of abundance Table 16).

In terms of biomass, the highest values (5,955 mg/m^2) were observed in the western regions, while the highest abundance values were observed in the eastern region of the southern Black Sea. This indicates low numbers of bigger individuals in the eastern regions. The lowest biomass value was observed in the middle part (1,282 mg/m^2), which was lower more than 5 times compared to the western region (Table 17). This ratio was not that much in terms of abundance that indicates smaller individuals of *P. setosa* constitutes bigger part of the total population compared to the other regions. Spatial distribution of *P. sagitta* displayed high values especially in two stations. The first one was in the offshore waters of Istanbul (24,568 mg/m^2) and the second one was in the Batumi Gyre (25.371 mg/m^2) (Figure 90).

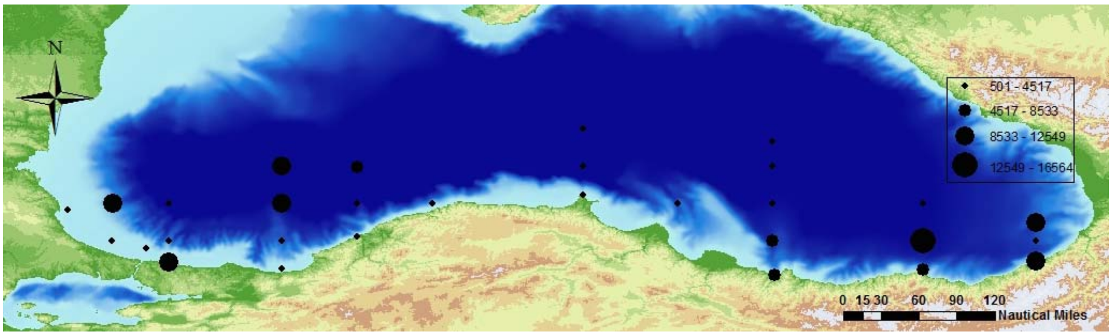
Table 16 Abundance values (ind/m^2) of *Parasagitta setosa* in the southern Black Sea in general and in 3 regions particularly

	West	**Middle**	**East**	**BS**
0.5-5.0	3,788	2,149	5,122	3,840
5.0-10.0	445	275	245	326
10.0-15.0	23	16	188	82
15.0-20.0	468	125	416	358
Total	4,723	2,565	5,972	4,605

Table 17 Biomass values (mg/m^2) of *Parasagitta setosa* in the southern Black Sea in general and in 3 regions particularly

	West	**Middle**	**East**	**BS**
0.5-5.0	146	60	188	139
5.0-10.0	157	134	83	124
10.0-15.0	110	75	639	294
15.0-20.0	5,543	1,013	4,003	3,770
Total	5,955	1,282	4,913	4,327

A



B

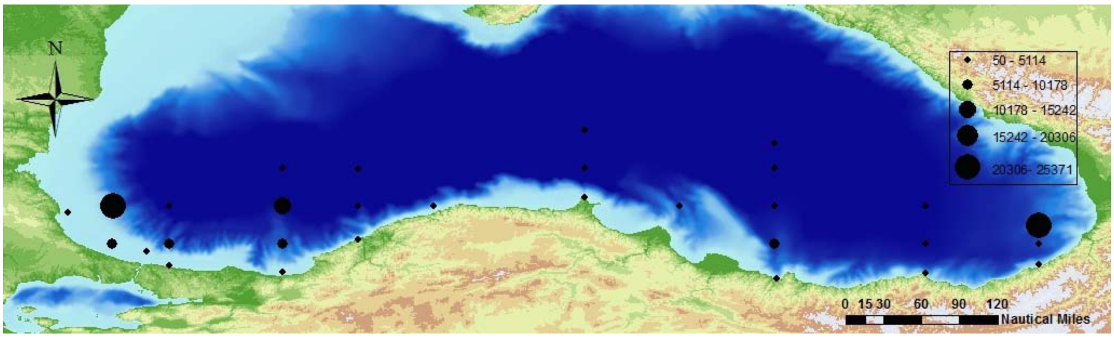


Figure 90 The spatial distribution of *Parasagitta setosa* off southern Black Sea in July 2013. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

Size-frequency distribution of *Parasagitta setosa*

Highest number of individuals was belonging to the smallest size groups, 1,533 ind/m^2 (1.0-2.0 mm) and 1.006 ind/m^2 (2.0-3.0 mm) (Figure 91). Size frequency distribution of *P. setosa* was examined in 4 size groups, 0.5-5.0, 5.0-10.0, 10.0-15.0 and 15.0-20.0 mm. The smallest size group (0.5-5.0 mm) was the most dominant group (3,840 ind/m^2) that constitutes 83% of the total population. According to Figure 92, the second size group (5.0-10.0 mm) constituted 7%, while the third size group (10.0-15.0 mm) constituted only 2% of the entire population. The biggest size group (15.0-20.0) constituted the 8% (358 ind/m^2).

In general, younger individuals were dominating the population.

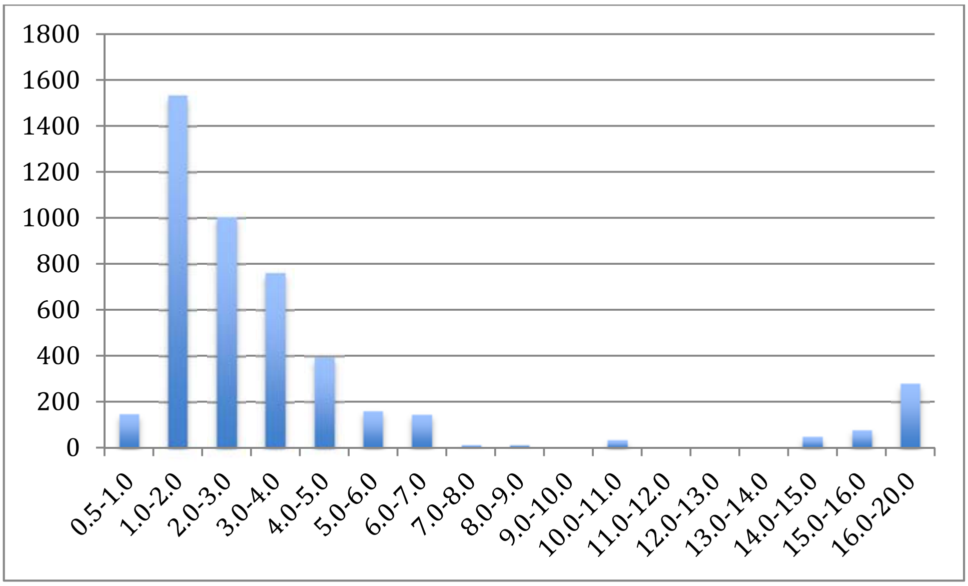


Figure 91 Size-frequency distribution of *Parasagitta setosa* in the southern Black Sea in July 2013. Values represented in mm versus ind/m^2

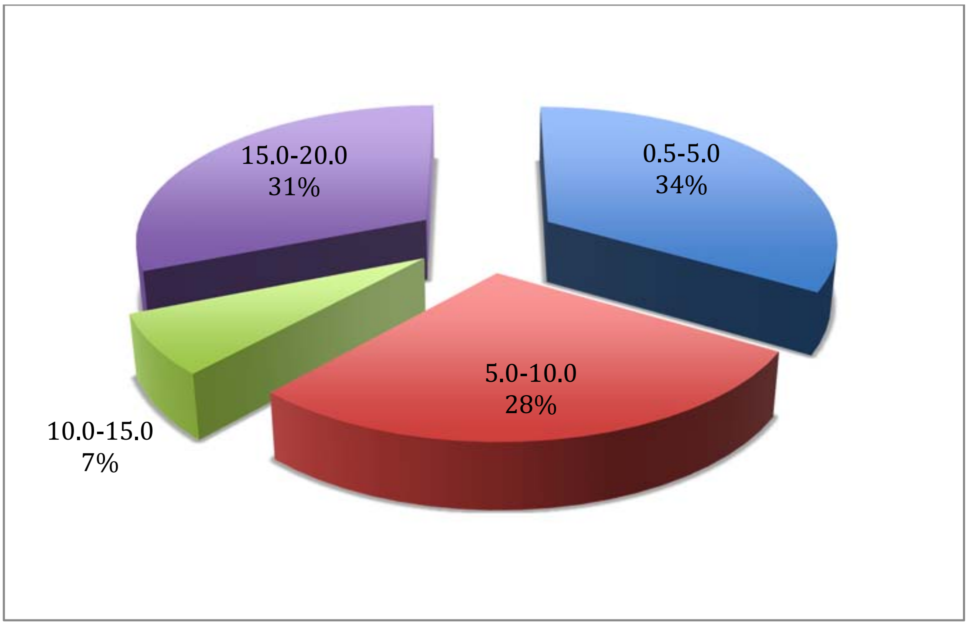


Figure 92 Percent composition of length-frequency distribution (mm versus ind/m^2) of *Parasagitta setosa*

The spatial stage frequency distribution of *Parasagitta setosa*

The spatial size frequency distribution of *P. setosa* showed that smallest size group of this species were more dominant (5,122 ind/m^2) in the eastern region, while the second smallest size group was more dominant in the western region and abundance of this group was almost similar in the middle and east parts of the southern Black Sea (Figure 93). The biggest size group of *P. setosa* was most dominant in the western region (468 ind/m^2). In terms of abundance of these size groups, lowest values were observed in the middle part of the southern Black Sea. In terms of biomass, mean value for the southern Black Sea was 5,955 mg/m^2, followed by eastern region and middle. For all size groups biomass were highest in the west and lowest in the middle, except second size group (5.0-10.0).

A

B

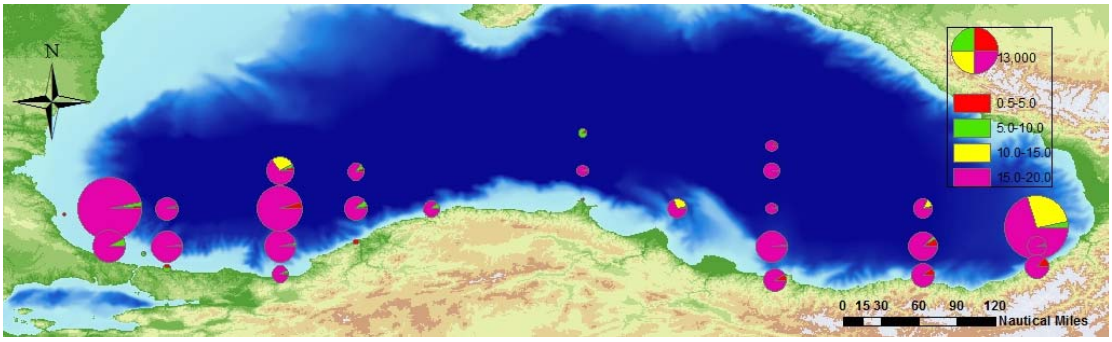


Figure 93 The spatial stage frequency distribution of *Parasagitta setosa* Red color represents 0.5-5.0 mm, green represents 5.0-10.0 mm, yellow color for 10.0-15.0 mm and pink color represents 15.0-20.0 mm sized individuals A. Abundance (ind/m^2), B. Biomass (mg/m^2)

3.3.1.5 *Oikopleura dioica*

Spatial abundance and biomass distribution

Mean abundance value of *O. dioica* was 1,809 ind/m^2 in the southern Black Sea in July 2013. Spatial abundance distribution of *O. dioica* displayed a preference of western region (Figure 94). Abundance value in the western region (2,738 ind/m^2) was 3 times greater than the east (913 ind/m^2) and almost 2 times greater than the middle part (1,766 ind/m^2) of the southern Black Sea. *O. dioica* was found mainly in the inshore waters of the western region. The highest abundance value was 6,023 ind/m^2 for the stations, which were near the Bosphorus and Zonguldak. Lowest values were observed in the offshore waters of both middle and east parts of the southern Black Sea Table 18).

In terms of biomass, higher values were decreased from west to the east, while number of individuals was highest in the west and lowest in the middle. This indicates, existence of bigger size class in the middle compared to the other regions. Mean biomass value of *O. dioica* was 21 mg/m^2. The highest value was 33 mg/m^2 in the west in terms of biomass and followed by 20 mg/m^2 in the middle part (Table 19), while the lowest biomass value was 9 mg/m^2 in the eastern region. Biomass values of offshore stations in Sakarya and Zonguldak were also higher compared to the other offshore stations.

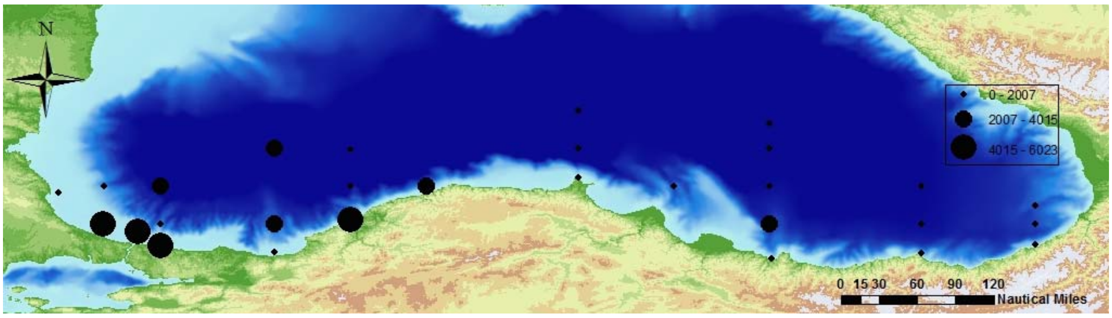
Table 18 Abundance values (ind/m^2) of *Oikopleura dioica* in the southern Black Sea in general and in 3 regions particularly

	West	Middle	East	BS
0.5-1.0	970	792	456	734
1.0-2.0	1,643	864	434	992
2.0-3.0	125	110	23	84
Total	2,738	1,766	913	1,809

Table 19 Biomass values (mg/m^2) of *Oikopleura dioica* in the southern Black Sea in general and in 3 regions particularly

	West	Middle	East	BS
0.5-1.0	3	3	1	2
1.0-2.0	23	12	6	14
2.0-3.0	7	6	1	4
Total	33	20	9	21

A



B

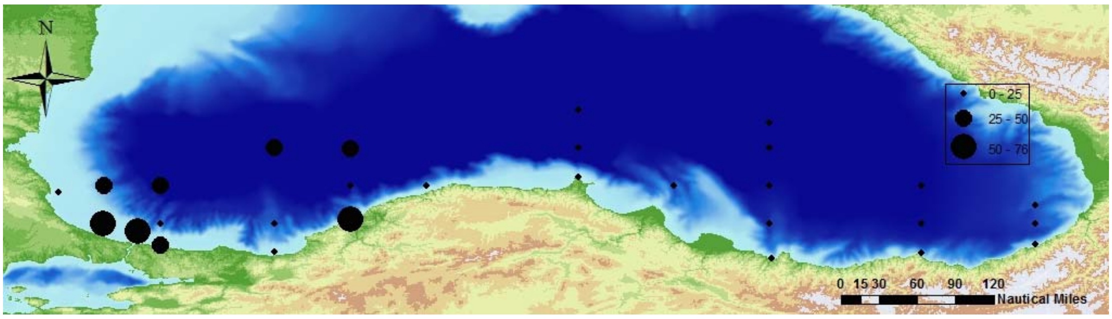


Figure 94 The spatial distribution of *Oikopleura dioica* off southern Black Sea in July 2013. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

Size-frequency distribution of *Oikopleura dioica*

Size groups of *O. dioica* were examined in 3 groups, namely 0.5-1.0, 1.0-2.0 and 2.0-3.0. Size frequency distribution of *O. dioica* showed high values of 1.0-2.0 size group 992 ind/m^2 and followed by the smallest size group 734 ind/m^2 (Figure 95). The lowest abundance was belonging to the biggest size group (2.0-3.0) that was 84 ind/m^2. This group constituted only 5% of the total population, while the smallest size group constituted 40% and the second group was 55% of the entire population (Figure 96).

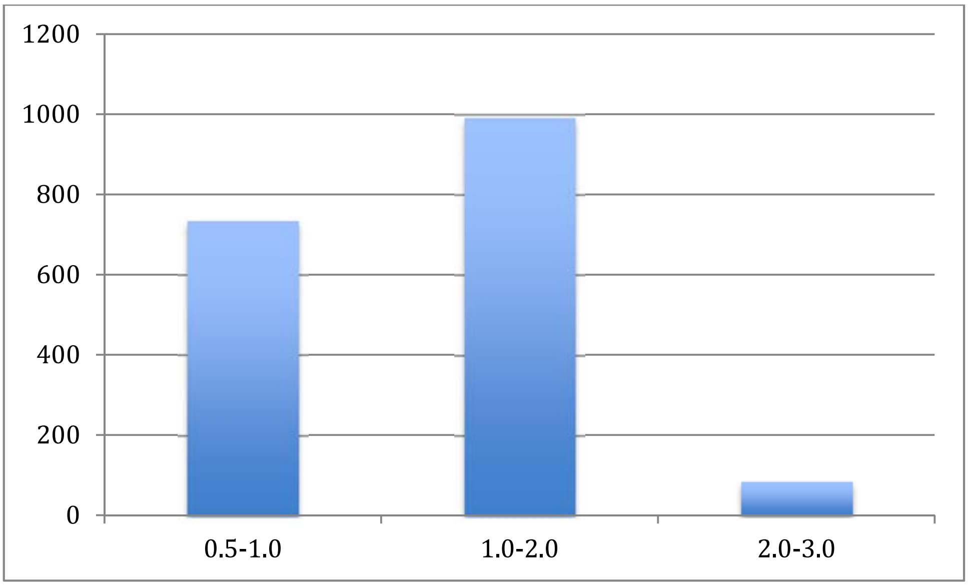


Figure 95 Size-frequency distribution of *Oikopleura dioica* in the southern Black Sea in July 2013

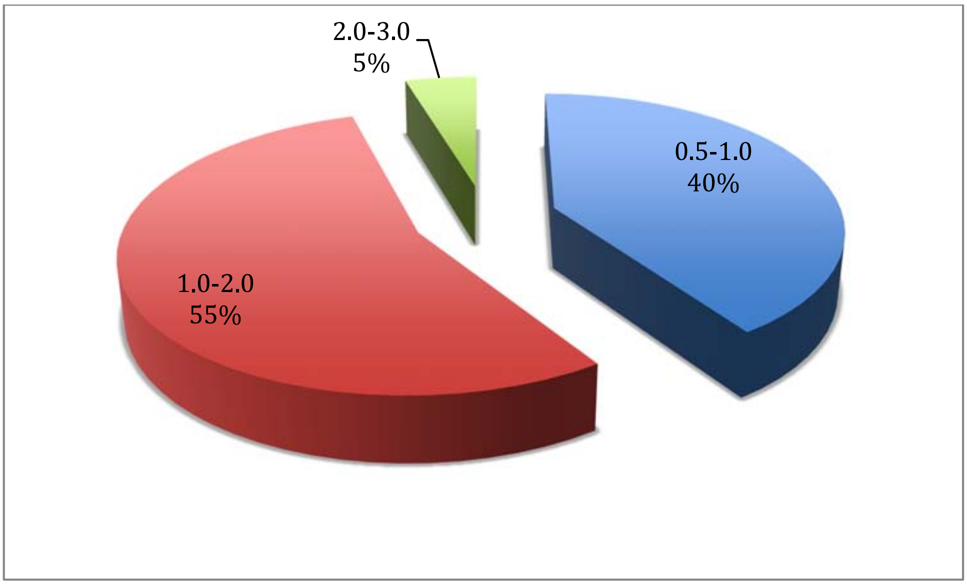


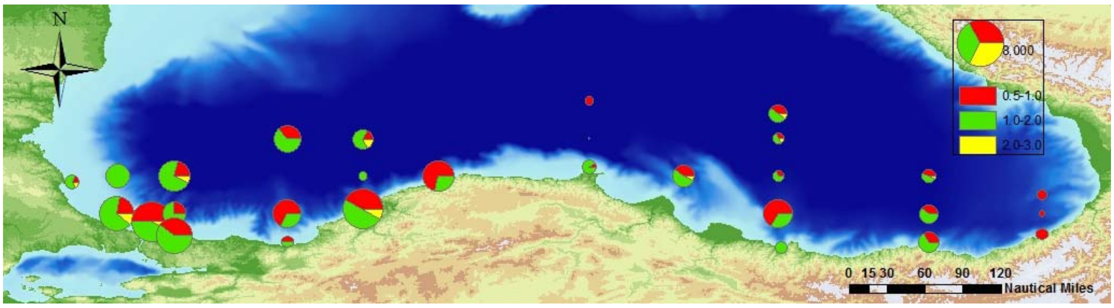
Figure 96 Percent composition of length-frequency distribution (mm versus ind/m^2) of *Oikopleura dioica*

The spatial stage frequency distribution of *Oikopleura dioica*

The spatial stage frequency distribution of *O. dioica* showed highest value (970 ind/m^2) of smallest size group was more dominant in the western region and the number of individuals belonging to this size group, were decreasing from west to the eastern region of the southern Black Sea (Figure 97). This result is also same for the most dominant second size group and the smallest size groups. Their abundance values were decreasing from west to the east.

Number of smaller individuals was decreased from inshore to offshore waters in the western region.

A



B

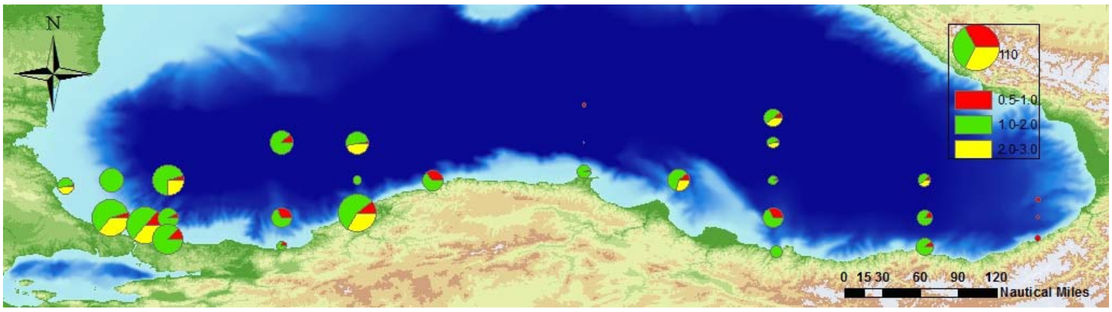


Figure 97 The spatial stage frequency distribution of *Oikopleura dioica* Red color represents 0.5-1.0 mm, green represents 1.0-2.0 mm and yellow color represents 2.0-3.0 mm sized individuals A. Abundance (ind/m^2), B. Biomass (mg/m^2)

3.3.2 *Noctiluca scintillans*

Spatial abundance and biomass distribution

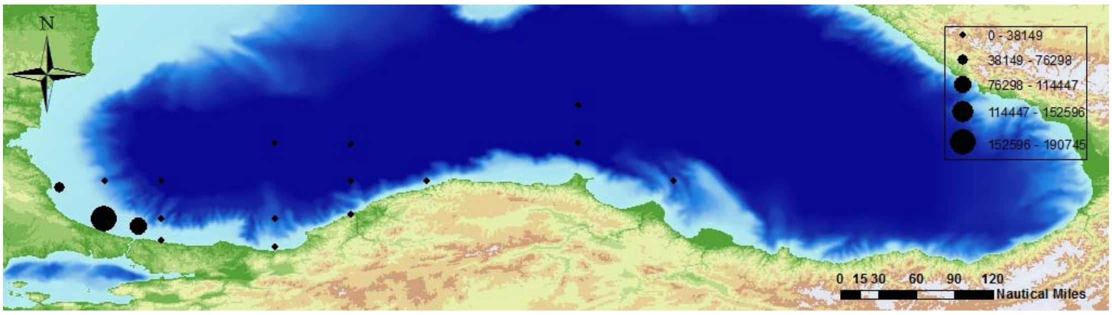
In terms of abundance, the mean value of *N. scintillans* was 16,799 ind/m^2 and 1,478 mg/m^2 in terms of biomass. *N. scintillans* was not observed in the eastern region of the southern Black Sea both in inshore and offshore waters. The comparison of west and middle parts showed that, abundance and biomass values of *N. scintillans* was 5 times greater in the west that the middle in terms of mean abundance and mean biomass value (Figure 98).

The highest abundance (190,745 ind/m^2) and biomass (16,785 mg/m^2) values were observed (Table 20) in the station that was near to the Bosphorus region.

Table 20 Abundance (ind/m^2) and biomass (mg/m^2) values of *Noctiluca scintillans* in the southern Black Sea in general and 3 different regions in particularly

	West	**Middle**	**East**	**BS**
Abundance (ind/m^2)	39,495	8,690	0	16,799
Biomass (mg/m^2)	3,476	765	0	1,478

A



B

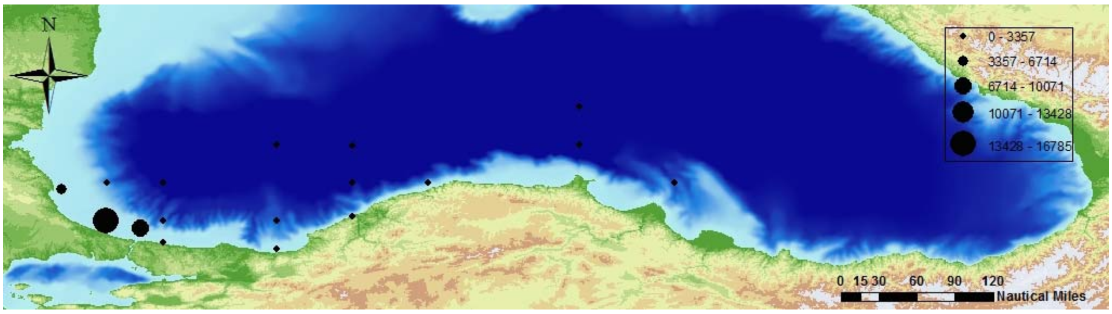


Figure 98 Spatial distribution of *Noctiluca scintillas* in terms of abundance and biomass in the southern Black Sea in July 2013. A. Abundance (ind/m^2), B. Biomass (mg/m^2)

3.3.3 Gelatinous Zooplankton

Spatial abundance and biomass distribution

A total of 4,763 macrogelatinous individuals (belonging to species *Aurelia aurita, Beroe ovata, Mnemiopsis leidyi* and *Pleurobrachia pileus*) were sampled and measured. Only 7 individuals of *Beroe ovata* were observed during the cruise in July 2013. The mean abundance value was higher in the east part of the southern Black Sea that is almost 2 times greater than other regions. The mean abundance value for the Black Sea was 414 ind/m^2. The station, which displayed the highest abundance value, was in the Batumi Gyre (Figure 99). In terms of biomass, the total biomass value was in the western region that was also 2 times greater than other regions, while the lowest biomass value was observed in the western region of the southern Black Sea. In terms of mean biomass value middle part of the Black Sea showed the highest value and middle part was followed by eastern region of the Black Sea (Table 21). The mean abundance value for the southern Black Sea was 500 mg/m^2. These values showed number of small gelatinous individuals displayed high preference of eastern region, while the bigger individuals displayed preference of middle region of the southern Black Sea in July 2013.

For the commonest three macrogelatinous zooplankton species found here, the most abundant groups in the size-frequency diagrams were the smallest size classes indicating mid-summer to be a highly reproductive period for these species.

Table 21 Abundance and biomass values of gelatinous zooplankton in the southern Black Sea in general and in 3 different regions in particularly

	West	**Middle**	**East**	**BS**
Abundance (ind/m^2)	363	343	595	414
Biomass (g/m^2)	461	573	512	500

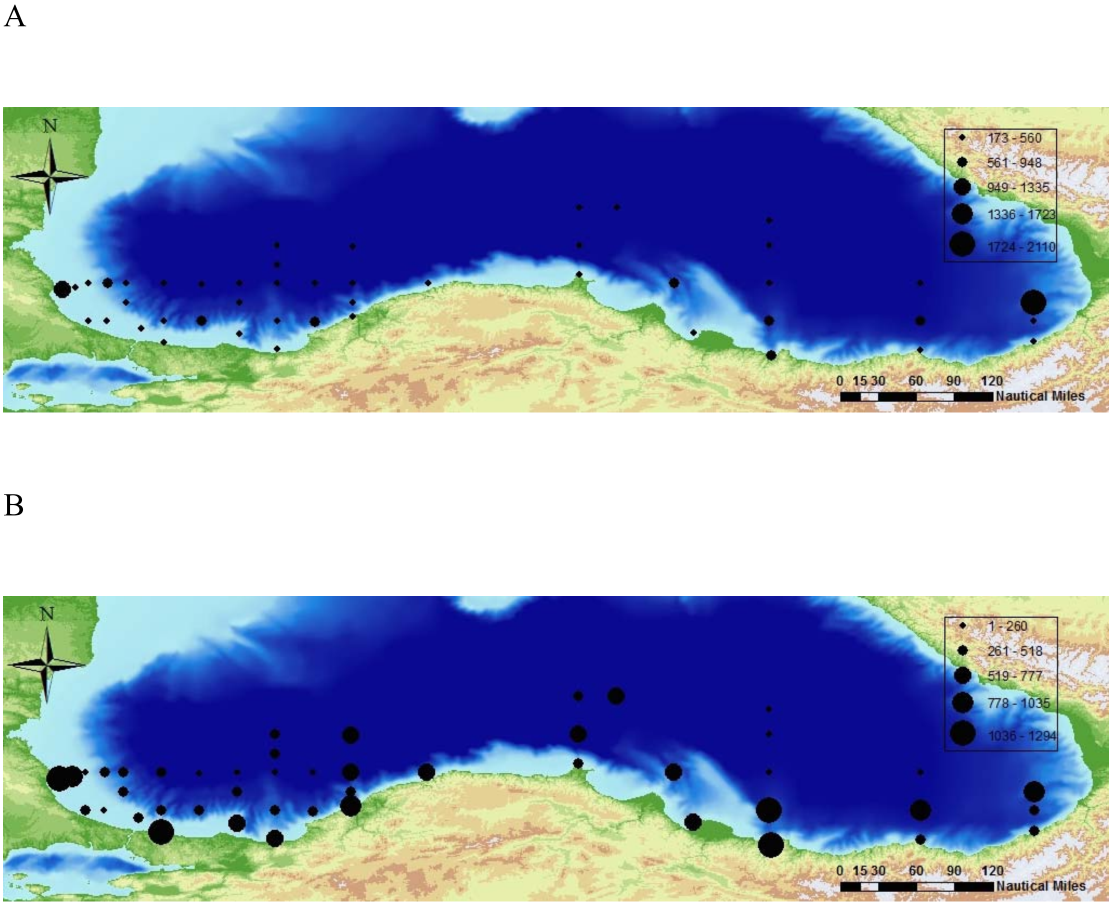


Figure 99 Distribution of gelatinous zooplankton at 46 stations from the southern Black Sea in July 2013. A. Abundance (ind/m^2), B. Biomass (g/m^2)

Group composition

In terms of abundance the highest value was belonging to *P. pileus* and followed by *M. leidyi, A. aurita* and *B. ovata* in the southern Black Sea in July 2013. Abundance of *P. pileus* was higher in the west and lowest in the east. *M. leidyi*'s abundance values was decreased from west to the east while the mean value was highest in the middle part and lowest in the western part of the southern Black Sea. The third most abundant species was *A. aurita* and its total abundance value was highest in the west and lowest in the middle part, while the mean biomass was highest in the east and almost similar in the west and middle parts of the southern Black Sea (Table 22 and Table 24).

In terms of biomass, *M. leidyi* was the most dominant species in the southern Black Sea. *M. leidyi* was followed by *A. aurita* and *P. pileus*. Biomass value of *M. leidyi* was more dominant in the western region and decreased from west to the east. Biomass value in the west was 2 times greater than the eastern region. The second most dominant species was *A. aurita* was also displayed the highest value in the west and followed by middle part of the southern Black Sea. The lowest biomass value of *A. aurita* was observed in the eastern region, while the highest mean biomass value was in this region. *P. pileus* displayed its highest abundance value in the western region. Abundance of *P. pileus* in the west was 2 times greater than the middle and 3 times greater than the eastern part, while the mean biomass value was highest in the middle part of the southern Black Sea. The lowest biomass and abundance value was belonging to *B. ovata*. These individuals were found only in the western region (Table 23 and Table 24).

In terms of abundance *P. pileus* was dominating (especially in offshore stations) from west to the east and in terms of biomass *M. leidyi* was dominant. Highest biomass values were in the western Black Sea, probably due to Danube River effect.

Table 22 Abundance values (ind/m^2) for 4 gelatinous zooplankton species namely, *Aurelia aurita, Beroe ovata, Mnemiopsis leidyi, Pleurobrachia pileus* in the southern Black Sea in general and in 3 different regions in particularly

		Aurelia aurita	*Beroe ovata*	*Mnemiopsis leidyi*	*Pleurobrachia pileus*
W	Total	350	27	1,835	6,495
	Mean	15	1	76	271
	Max	54	24	192	800
	Min	0	0	0	27
M	Total	150	0	1,508	2,119
	Mean	14	0	137	193
	Max	35	0	308	454
	Min	0	0	58	46
E	Total	227	0	1,192	5,122
	Mean	21	0	108	466
	Max	58	0	319	1,964
	Min	0	0	0	208
BS	Total	727	27	4,534	13,736
	Mean	16	0,6	99	299
	Max	58	24	319	1,964
	Min	0	0	0	27

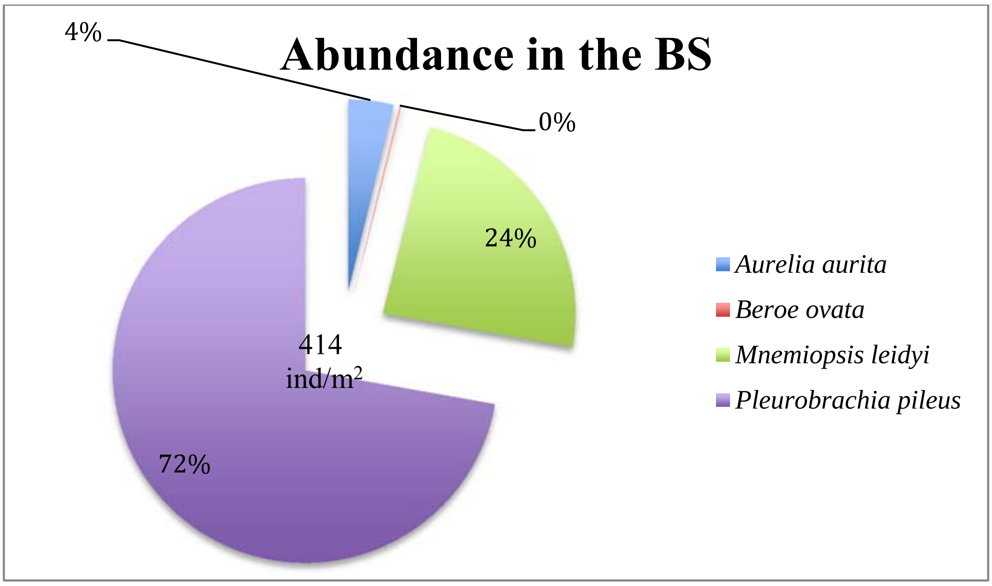
Table 23 Biomass values (mg/m^2) for 4 gelatinous zooplankton species namely, *Aurelia aurita, Beroe ovata, Mnemiopsis leidyi, Pleurobrachia pileus* in the southern Black Sea in general and in 3 different regions in particularly

		Aurelia aurita	*Beroe ovata*	*Mnemiopsis leidyi*	*Pleurobrachia pileus*
W	Total	4,064	0,2	5,996	1,007
	Mean	169	0.008	250	42
	Max	741	0.16	703	276
	Min	0	0	0	0.06
M	Total	1,696	0	4,107	501
	Mean	154	0	373	46
	Max	391	0	793	166
	Min	0	0	113	0.1
E	Total	2,539	0	2,754	342
	Mean	231	0	250	31
	Max	633	0	713	111
	Min	0	0	0	0.62
BS	Total	8,300	0.2	12,857	1,851
	Mean	180	0.004	280	40
	Max	741	0.16	793	276
	Min	0	0	0	0.1

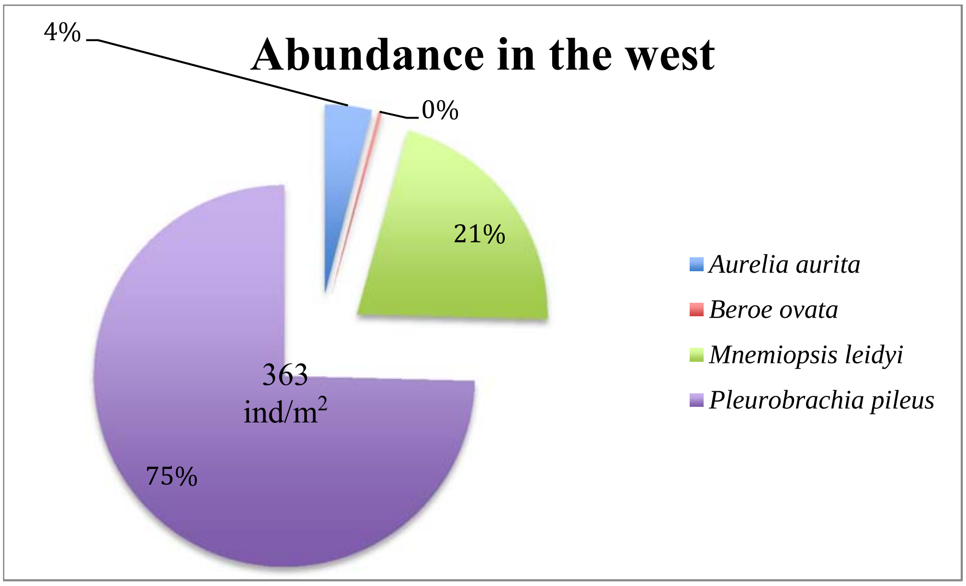
Table 24 Maximum and mean abundance (ind/m^2) and biomass (g/m^2) values of 3 gelatinous zooplankton species, namely; *Aurelia aurita, Mnemiopsis leidyi, Pleurobrachia pileus* in southern Black Sea in general

	Max abundance (ind/m^2)	**Mean abundance** (ind/m^2)	**Max biomass** (g/m^2)	**Mean biomass** (g/m^2)
Aurelia aurita	58	16	741	180
Pleurobrachia pileus	1964	299	276	40
Mnemiopsis leidyi	319	99	793	280

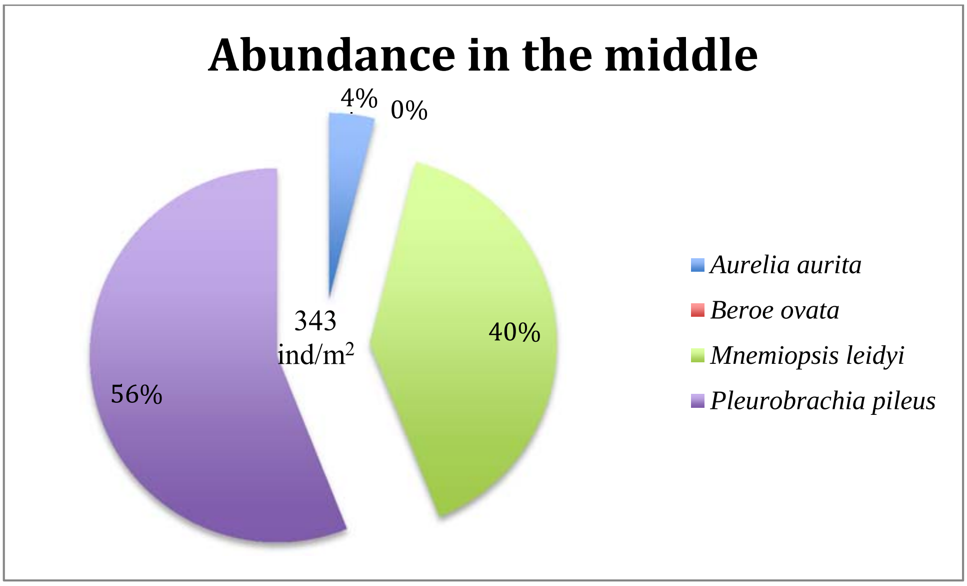
A



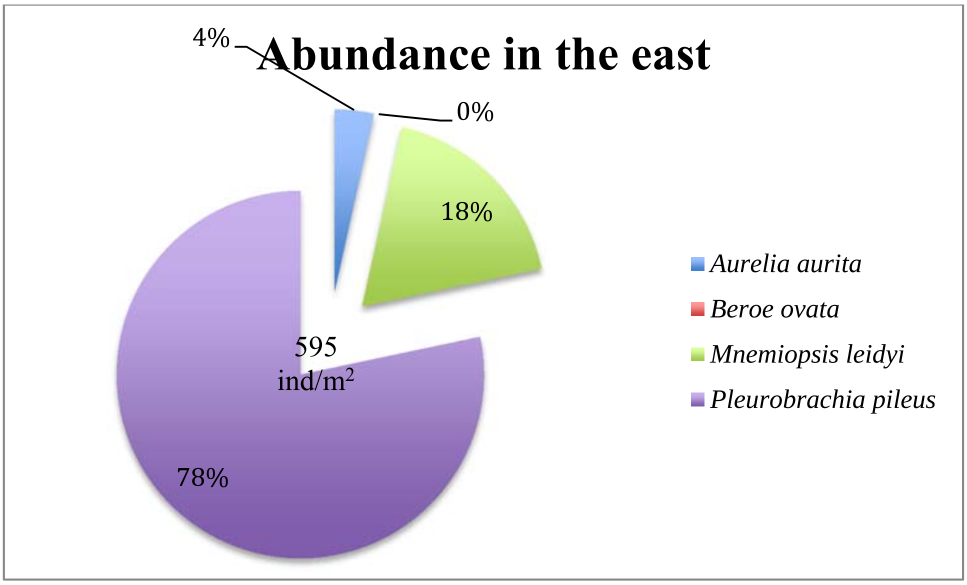
B


Abundance in the west
4%
0%
21%
363 ind/m²
75%
Aurelia aurita
Beroe ovata
Mnemiopsis leidyi
Pleurobrachia pileus

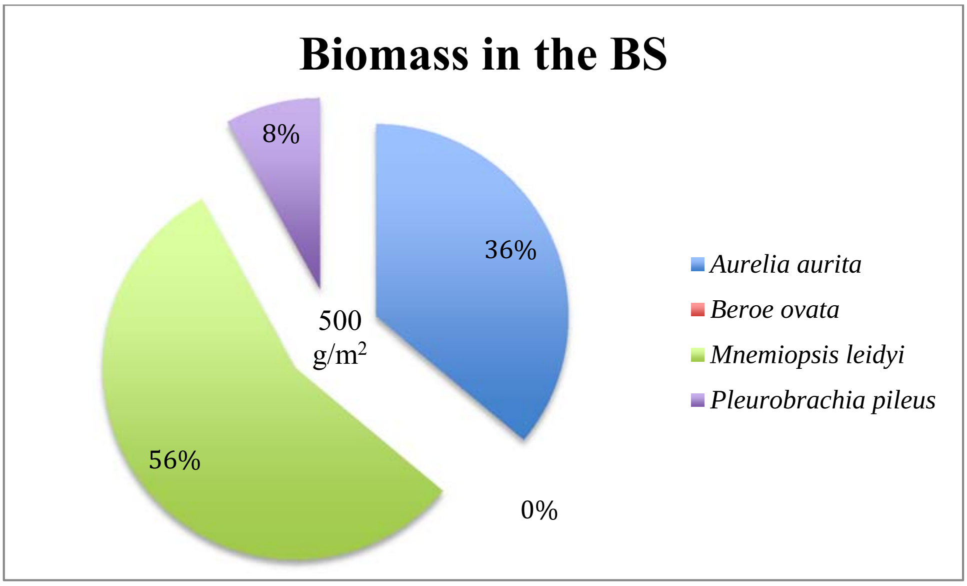
C


Abundance in the middle
4%
0%
343 ind/m²
40%
56%
Aurelia aurita
Beroe ovata
Mnemiopsis leidyi
Pleurobrachia pileus

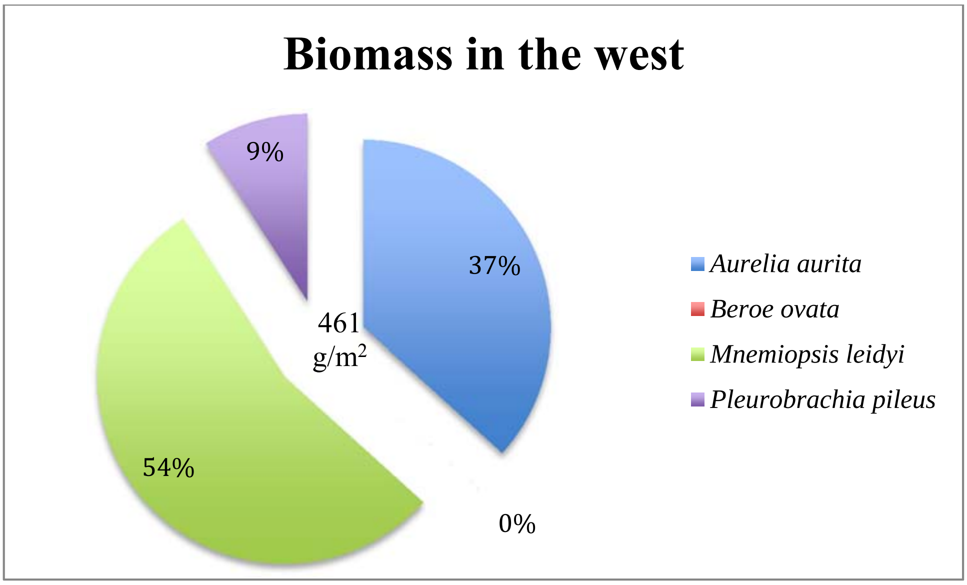
D


Abundance in the east
4%
0%
18%
595
ind/m²
78%
Aurelia aurita
Beroe ovata
Mnemiopsis leidyi
Pleurobrachia pileus

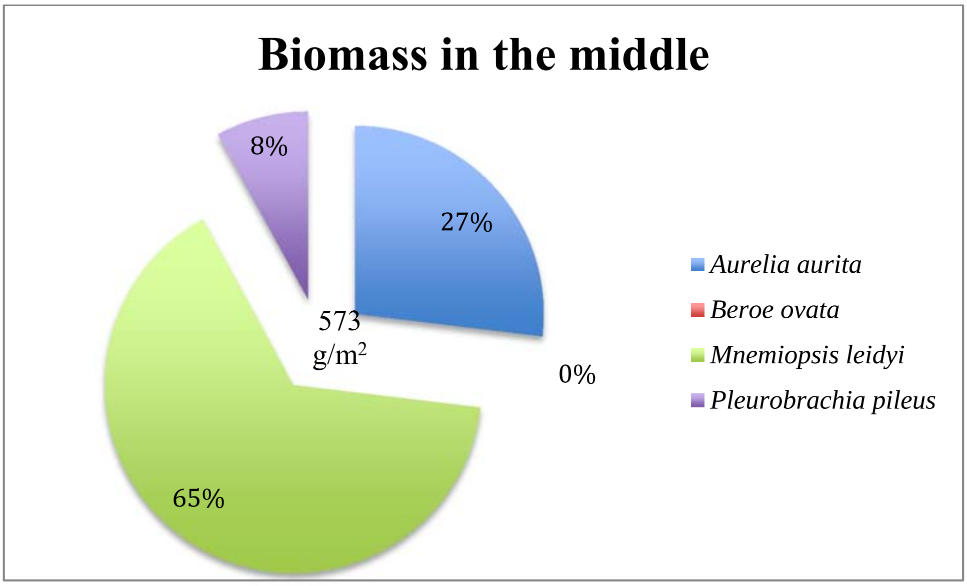
E


Biomass in the BS
8%
36%
500
g/m²
56%
0%
Aurelia aurita
Beroe ovata
Mnemiopsis leidyi
Pleurobrachia pileus

F


Biomass in the west
9%
37%
461 g/m2
54%
0%
Aurelia aurita
Beroe ovata
Mnemiopsis leidyi
Pleurobrachia pileus

G


Biomass in the middle
8%
27%
573 g/m2
0%
65%
Aurelia aurita
Beroe ovata
Mnemiopsis leidyi
Pleurobrachia pileus

H

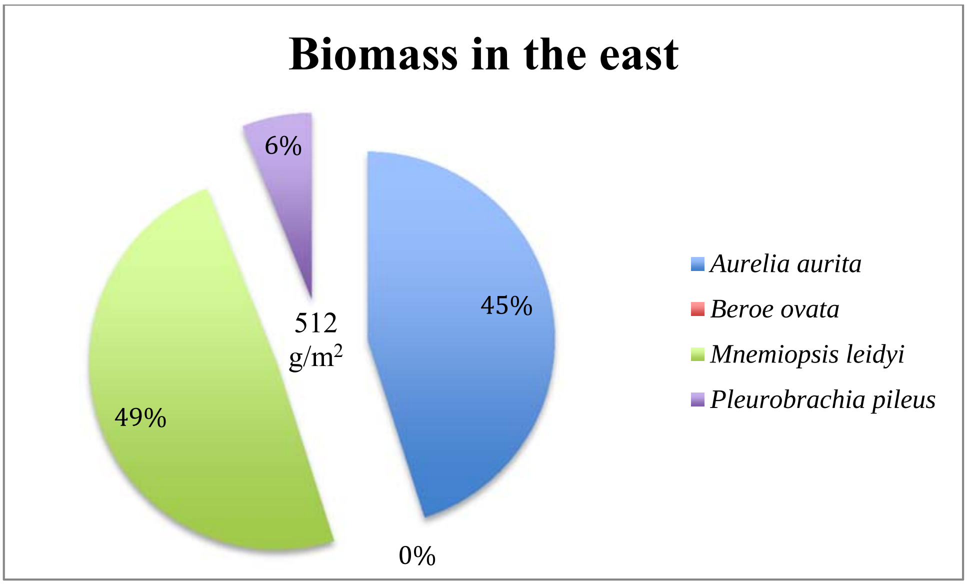


Figure 100 Percent composition of gelatinous zooplankton species namely; *Aurelia aurita, Beroe ovata, Mnemiopsis leidyi* and *Pleurobrachia pileus* in terms of abundance and biomass. A. Abundance in the southern Black Sea B. Abundance in the west C. Abundance in the middle D. Abundance in the east E. Biomass in the southern Black Sea F. Biomass in the west G. Biomass in the middle H. Biomass in the east

In terms of biomass, the comparison of percent composition of gelatinous species in the Black Sea showed domination of *M. leidyi* in the southern Black Sea and 3 mentioned part of it, especially in the middle part (Figure 100). However, in terms of abundance *P. pileus* was the most abundant species in the southern Black Sea and 3 mentioned parts of it, especially in the east.

3.3.3.1 *Aurelia aurita*

Spatial abundance and biomass distribution

The mean abundance value of *A. aurita* was 16 ind/m^2 in the southern Black Sea. The comparison of mean abundance values of *A. aurita* displayed its highest value in the eastern part 21 ind/m^2, and followed by the western region (15 ind/m^2). The lowest mean abundance value was in the middle part of the southern Black Sea. The maximum abundance value for a station was 58 ind/m^2 that was observed in the east.

In terms of biomass, the mean biomass value was 180 g/m^2 in the southern Black Sea in July 2013. The comparison of the mean abundance value of *A. aurita* in 3 regions displayed the similar distribution with mean abundance. The highest mean biomass value was observed in the eastern region that was 231 g/m^2 and followed by west, which was 169 g/m^2. The lowest mean biomass value was displayed in the middle part of the southern Black Sea. The maximum biomass for a station was 741 ind/m^2.

In general concentration of *A. aurita* was high in the west and anticyclonic eddies in the east (Figure 101).

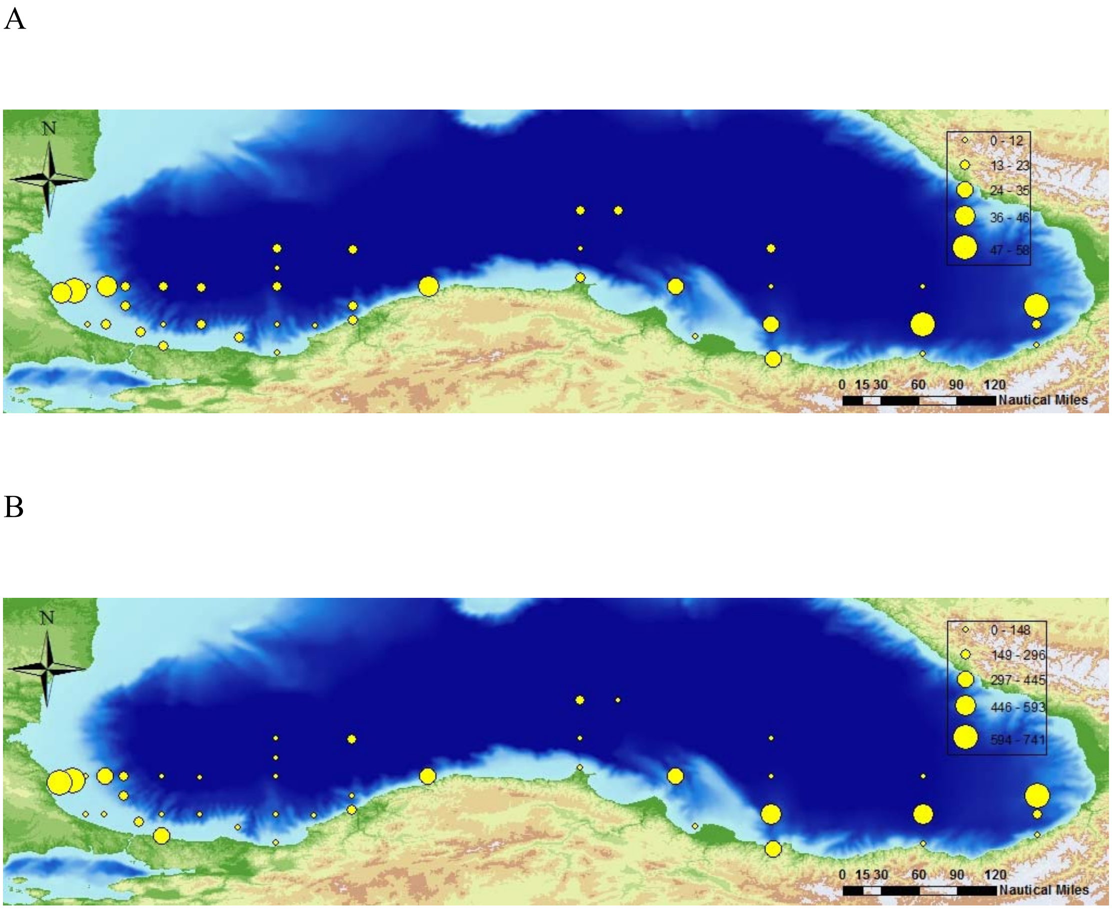


Figure 101 The spatial distribution of *Aurelia aurita* in the southern Black Sea in July 2013. A. Abundance (ind/m^2), B. Biomass (g/m^2)

Size-frequency distribution of *A. aurita*

The maximum length for *A. aurita* was 15 cm. Size-frequency distribution of this species showed highest number for 5 cm size class and size classes of 1 cm and 3 cm were also showed high values (Figure 102). Number of individuals, which was bigger than 5 cm decreased, as they get bigger.

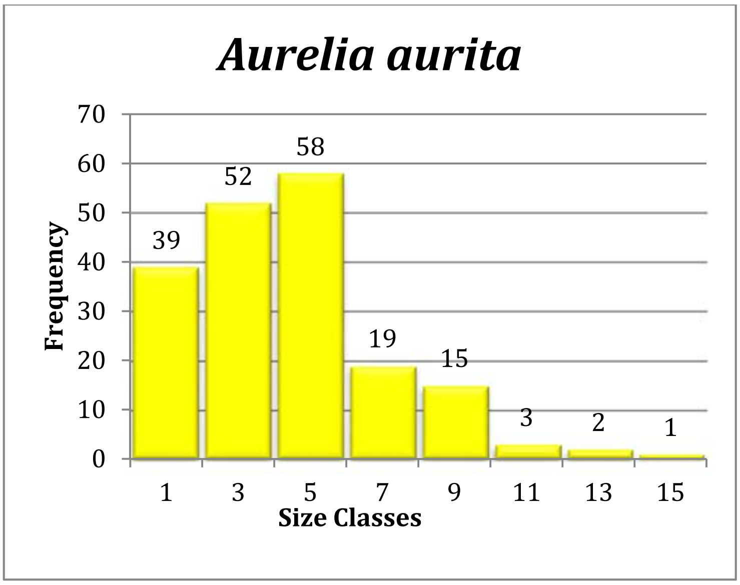


Figure 102 Size-frequency distribution of *Aurelia aurita* in the southern Black Sea in July 2013

3.3.3.2 *Mnemiopsis leidyi*

Spatial abundance and biomass distribution

The mean abundance value of *M. leidyi* was 99 ind/m^2 in the southern Black Sea. The comparison of mean abundance values of *M. leidyi* displayed different distribution compared to the other gelatinous zooplankton species, its highest value was in the middle part 137 ind/m^2, and followed by the eastern region (108 ind/m^2). The lowest mean abundance value was in the western part of the southern Black Sea. The maximum abundance value for a station was 319 ind/m^2 that was observed in the east.

In terms of biomass, the mean biomass value was 280 g/m^2 in the southern Black Sea in July 2013. The comparison of the mean biomass value of *M. leidyi* in 3 regions displayed the similar distribution with in the western and eastern regions (250 g/m^2). The highest mean biomass value was observed in the middle part that was 373 g/m^2. The maximum biomass for a station was 793 g/m^2, which was observed in the middle part of the southern Black Sea (Figure 103).

In general the biomass of *Mnemiopsis leidyi* was greater at inshore stations. Biomass was high in the western Black Sea, but the abundance of small individuals concentrated more in the eastern Black Sea, which seems like more reproduction in this area.

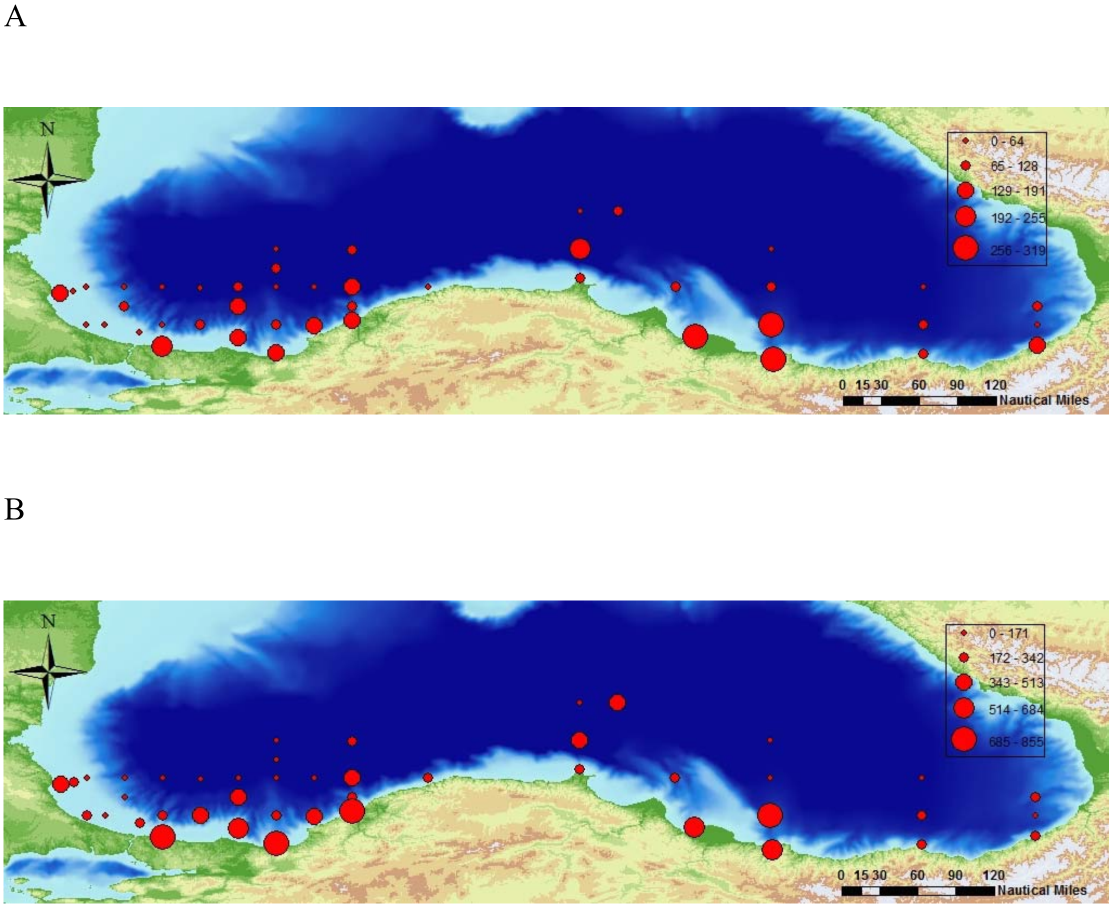


Figure 103 The spatial distribution of *Mnemiopsis leidyi* in the southern Black Sea in July 2013. A. Abundance (ind/m^2), B. Biomass (g/m^2)

Size-frequency distribution of *M. leidyi*

The maximum volume of an individual of *M. leidyi* was 40 ml. The smallest size class of *M. leidyi* was %90 of the sample, which indicates July, is high reproduction time (Figure 103).

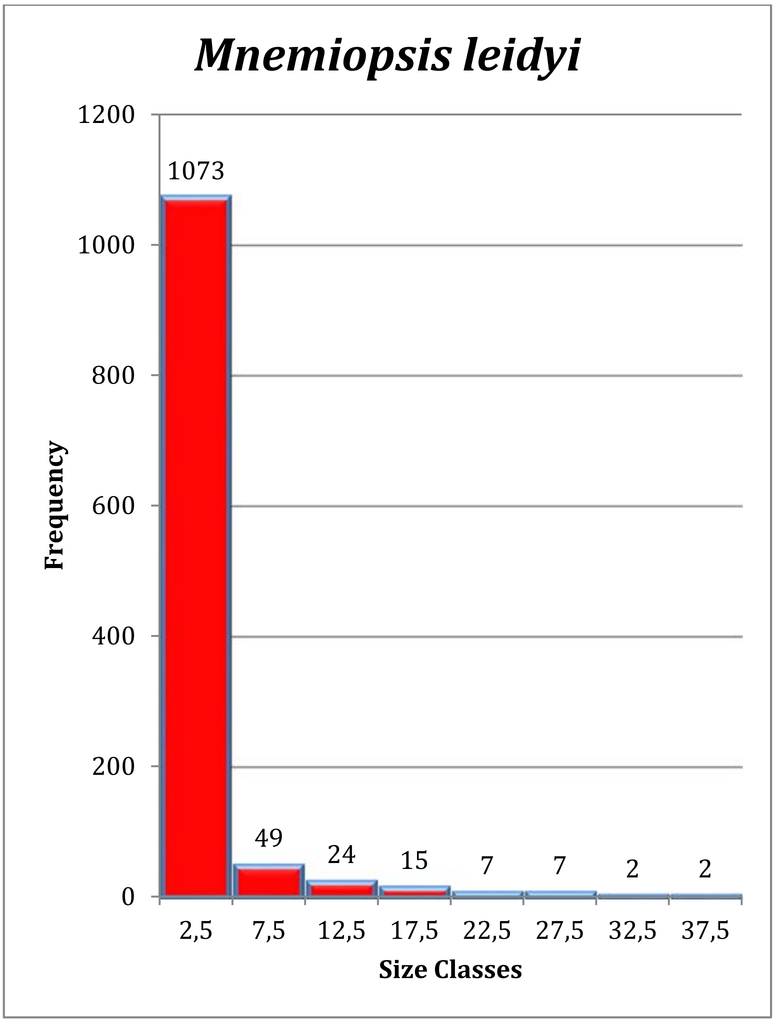


Figure 104 Size-frequency distribution of *Mnemiopsis leidyi* in the southern Black Sea in July 2013

3.3.3.3 *Pleurobrachia pileus*

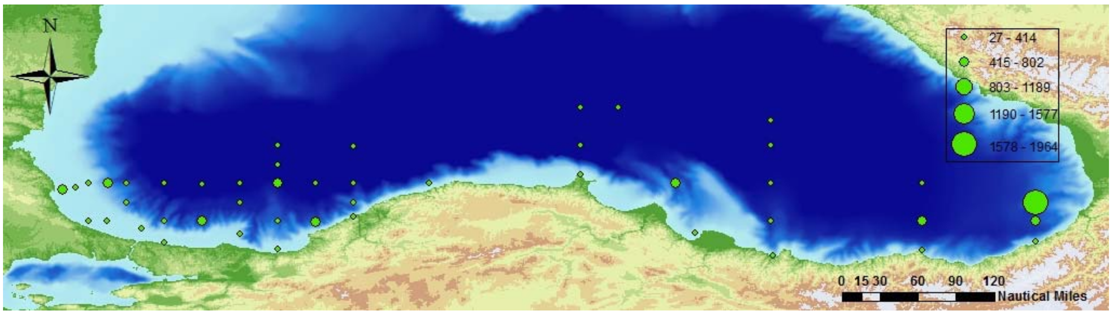
Spatial abundance and biomass distribution

The mean abundance value of *P. pileus* was 299 ind/m^2 in the southern Black Sea. The comparison of mean abundance values of *P. pileus* displayed its highest value in the eastern part 466 ind/m^2, which was almost 2 times greater than the other parts. The lowest mean abundance value was in the middle part of the southern Black Sea. The maximum abundance value for a station was 1,964 ind/m^2 that was observed in the east.

In terms of biomass, the mean value was 40 g/m^2 in the southern Black Sea in July 2013. Even the lowest abundance value was recorded; the highest mean biomass value was observed in the middle part, which indicates bigger individuals of *P. pileus* were there. Middle part followed by west and the lowest mean biomass value for this species was observed in the east, while the highest mean abundance value was recorded in this area (Figure 105). The maximum mean biomass value for a station was 276 g/m^2 that was observed in the west.

The *P. pileus* biomass was greater at deep-water stations in both regions, especially in the west and middle parts of the southern Black Sea.

A



B

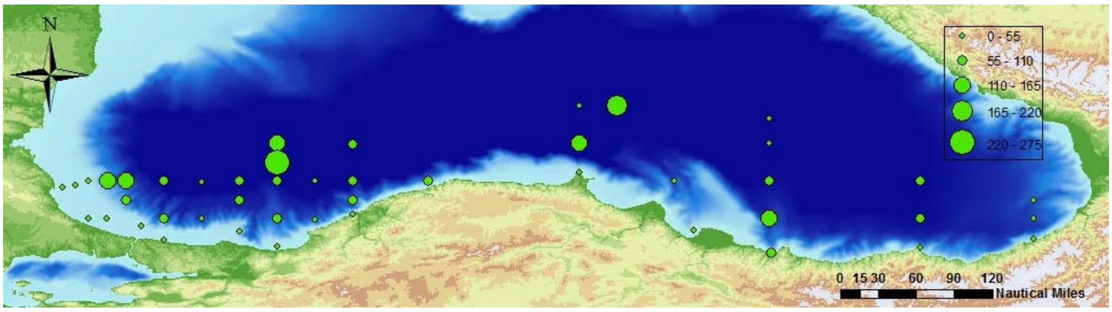


Figure 105 The spatial distribution of *Pleurobrachia pileus* in the southern Black Sea in July 2013. A. Abundance (ind/m^2), B. Biomass (g/m^2)

Size-frequency distribution of *P. pileus*

The maximum length for *P. pileus* was 2 cm. Size-frequency distribution of this species showed highest number for 0.55 mm size class and number of individuals decreased, as they get bigger (Figure 106).

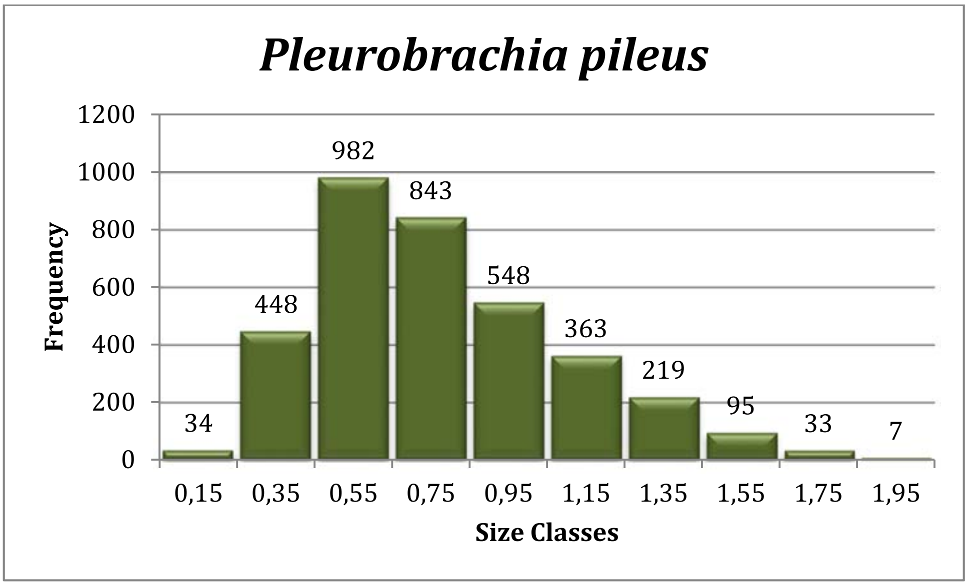


Figure 106 Size-frequency distribution of *Pleurobrachia pileus* in the southern Black Sea in July 2013

3.4 DNA barcoding of zooplankton in the southern Black Sea

Zooplankton samples that were collected with WP-2 net were photographed under microscope (shown in Appendix C). Taxonomically identified fish (that were collected from Şile) and zooplankton (samples that were collected from 7 stations shown in Figure 5) species shown in Table 25 and the sequences of the potential zooplankton are shown in Appendix A.

19 fish species and 1 star fish morphologically identified and 1 species of Appendicularia, 1 species of Chaetognatha, larvaes of Bivalvia, Brachyura, Bryozoa, Cirripedia, Ctenophora, Decapoda, Gastopoda, Hydromedusae, Isopoda, Polychaeta and eggs and larvaes of Teleostei were identified. Besides, 4 cladoceran species, 6 copepod species and 5 species of gelatinous zooplankton were identified.

Table 25 Fish and zooplankton species analyzed in barcoding study. Species positively identified in barcoding is shown in bold red.

Fish species	Zooplankton species	
Sarda sarda	*Oikopleura dioica*	Isopoda
Spicara flexuosa	Bivalvia	*Noctiluca scintillans*
Scorpaena sp.	**Brachyura Megalopa Larvae**	Ostracoda
Helicolenus dactylopterus	Bryozoa Cyphonautes Larvae	Polychaeta
Engraulis encrasicolus	***Parasagitta setosa***	***Engraulis encrasicolus* egg and larvae**
Merlangius merlangus euxinus	**Cirripedia Larvae**	Teleostei Egg
Alosa pontica	***Pseudoevadne tergestina***	Teleostei Larvae
Mullus barbatus	***Penilia avirostris***	*Aurelia aurita*
Gobius niger	*Podon sp.*	*Beroe ovata*
Gaidropsarus	***Evadne spinifera***	*Mnemiopsis leidyi*

mediterraneus		
Chelidonichthys lucerna	***Calanus euxinus***	*Pleurobrachia pileus*
Psetta maxima	***Acartia* sp.**	*Rhizostoma pulmo*
Serranus hepatus	*Centropages ponticus*	
Squalus sp.	***Paracalanus parvus***	
Raja sp.	*Oithona similis*	
Platichthys flesus	Ctenophora (cydipid)	
Trachinus draco	Decapod Larvae	
Neogobius melanostomus	***Pseudocalanus elongatus***	
Gobius sp.	**Gastropoda**	
Asterias rubens	Hydromedusae	

List of morphological and molecular results for each station is given in Appendix B. According to Table 25; 9 species of fish, 5 species of copepoda, 3 species of cladocera, 1 species of brachyura, chaetognatha, gastropoda and cirripedia identified in barcoding study.

3.5 Statistical analysis

Multivariate analyses (two-dimensional non-metric Multi-Dimensional Scaling - MDS) have shown formations of distinct zooplankton assemblages along the southern Black Sea coast. Figure 107 displays two-dimensional non-metric MDS plots of zooplankton assemblages forming four distinct clusters at an arbitrary similarity level (based on Bray-Curtis similarity) of 70% (shown in Figure 108)

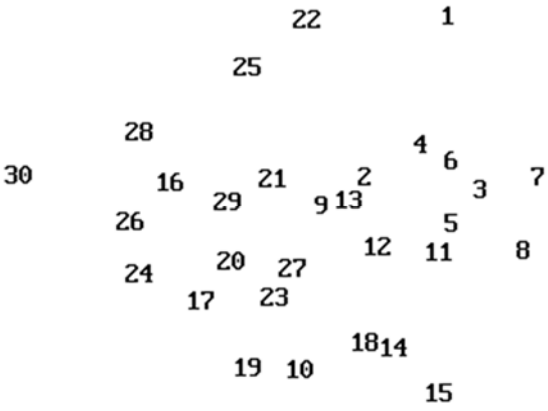


Figure 107 Two-dimensional non-metric MDS plots of zooplankton

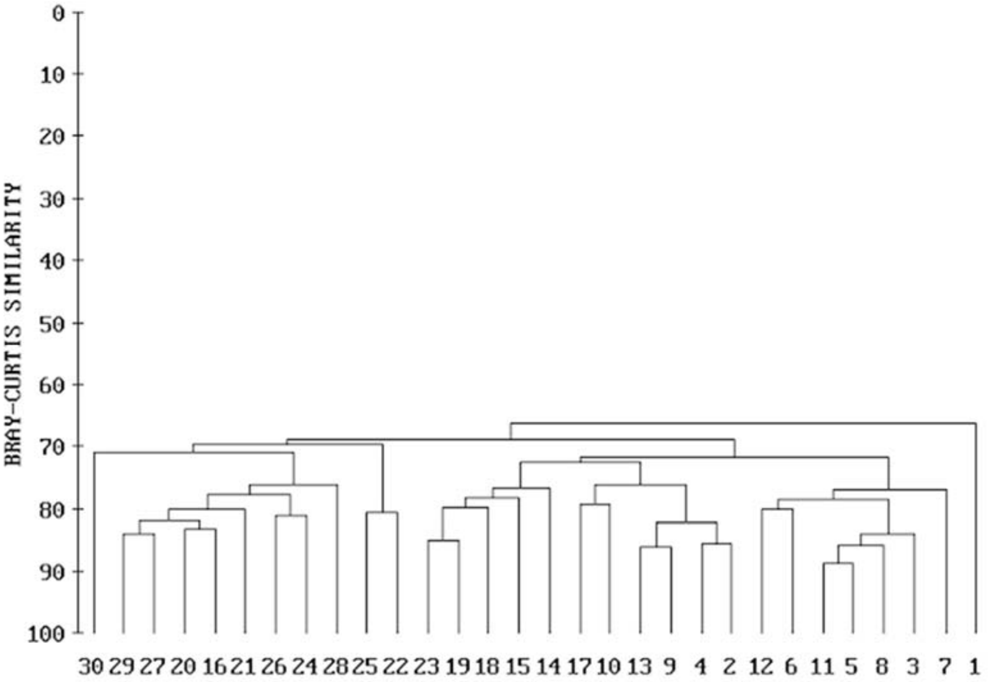


Figure 108 Bray- Curtis similarity for 30 stations in the southern Black Sea in July 2013

The largest group represents mainly the eastern Black sea stations except the only station located on the Batumi anticyclone. The second largest group contains mainly the stations in the west.

Figure 109 Four different groups of stations, which displayed similarity more than 75% (colored with white, brown, pink and red) according to Bray-Curtis similarity

For the first group that constituted by nine stations in the western part of the southern Black Sea, represent by brown color (Figure 109). The second group, constituted (shown in white color) by 2 stations, was also in the western but located in the offshore waters. Third group was constituted by 18 stations, which represent as purple in the figure. These stations were spread from the most eastern part to the western part of the southern Black Sea. Finally, the last group was the most different group compared to other three groups, and only represent by one station in the offshore waters of most eastern part of the southern Black Sea. This station was near the Batumi anticyclonic eddy and shown in red color.

4. DISCUSSION

Kovalev *et al*. (2003) and Kopuz *et al*. (2012) stated that phytoplankton seasonality and population structure affect seasonal peaks of zooplankton. Many studies describe the relationship withbetween the ratio of dinoflagellates and changes in nutrient balance and the temperature regime of the seawater (Feyzioglu and Seyhan, 2007; BSC, 2008; Bat *et al*., 2011). According to earlier studies, there are two periods for the increase of primary production (early spring and autumn). Recently however, additional summer blooms have been reported in the coastal and open waters (Hay *et al*., 1990; Sur *et al*., 1996; Yilmaz *et al*., 1998). For a spring bloom to occur, the main reasons are river input for inshore waters and establishment of a seasonal thermocline for offshore waters (Yunev *et al*., 2007; McQuatters-Gollop *et al*., 2008; Yilmaz *et al*., 2008). The major nutrient source for an autumn bloom occurs in the deeper layers due to breaking up of the thermocline (Vinogradov *et al*., 1999). In the Black Sea, additional summer/early autumn blooms are mainly formed based on coccolithophores with the strong thermocline and depletion of nutrients (Hay *et al*., 1990; Vedernikov and Demidov, 1997; Yilmaz *et al*., 1998). It is worth noting that the sampling period (July) of the present study is during the most stagnant period in the Black Sea and hence the least oscillation is expected in the zooplankton composition and amount. For phytoplankton, even for the same periods, populations in different parts of the southern Black Sea showed differences in their community structure (Uysal and Sur, 1995; Feyzioglu and Guneroglu, 2011). For zooplankton, although the study in the 1950's reported no difference in zooplankton community structure in the southern Black Sea (Einarsson and Gürtürk, 1959), more recent studies showed substantial differences, similar to the results obtained here (Yıldız and Feyzioğlu, 2014; Kideys *et al*., 1994; Üstün, 2010).

In the present study, even though the methodology is appropriate for zooplankton sampling and the sampling stations covered the whole Turkish EEZ, the number of species found (19 identified at species level and another 13 species identified at a genus or group level, totaling 32) is much lower than the total number of species reported for the Black Sea, possibly due to the fact that sampling was carried out only in one month/season. Koval (1984) reported about 150 zooplanktonic species for the Black Sea, including numerous brackish-water and freshwater organisms, which are restricted to the northwestern region and other coastal areas. Üstün (2010) identified 33 taxonomic groups in her study in June 2006, October 2006 and May 2007 for the entire southern Black Sea. Yıldız (2010) identified 19 zooplankton species in the southeastern Black Sea. Yıldız and Feyzioğlu (2014) also identified a total of 15 zooplankton species in their monthly sampling in the southeastern Black Sea 7 of which belonged to the copepod group.

Mediterraneanization is one of the issues that affect the number of species and this was also addressed in this study. Kovalev *et al.* (1998c) listed 60 copepod species originating from the Mediterranean Sea, which were mostly found only off the Bosphorus region. İşinibilir *et al*. (2011) found 8 Mediterranean copepod species near the Bosphorus in addition to the typical Black Sea copepods. Güner (1994) identified five copepod species in the southern Black Sea namely *Acartia clausi, Calanus euxinus, Centropages ponticus, Paracalus parvus, Pseudocalanus elongatus* and Beşiktepe (1998) listed 5 replacing *Oithona similis* with *C. ponticus*. In addition to these species Ünal (2002) observed *Acartia tonsa* and *Pontella mediterranea*. The latest list of copepoda was compiled by Gubanova (2014), which consisted of 11 native and established copepod species (Table 26).

Table 26 List of native and established copepod species of the Black Sea (Gubanova, 2014)

Species Name	**Comments**
Acartia clausi Giesbrecht, 1889	Common in neritic areas and offshore all year round
Acartia tonsa Dana, 1849	Alien species. Established in early 1970s. Common in neritic areas and bays in warm season
Anomalocera patersoni Templeton, 1837	Rare
Calanus euxinus Hulsemann, 1991	Common offshore in all seasons; in neritic areas in cold season
Centropages ponticus Karavaev, 1894	Common in neritic areas in warm season
Labidocera brunescens Czerniavsky, 1868	Rare

Oithona davisae Ferrari F.D. & Orsi, 1984	Alien species. Established in 2005–2006. Common in neritic areas all year round
Oithona similis Claus, 1866	Common offshore in all seasons; in neritic areas in cold season
Paracalanus parvus Claus, 1863	Common in neritic areas and offshore all year round
Pontella mediterranea Claus, 1863	Rare
Pseudocalanus elongatus Boeck, 1865	Common offshore in all seasons; in neritic areas in cold season

Koval (1984) and Lakkis *et al.* (1999) reported five species of cladocera namely; *Evadne nordmani, E. spinifera, Pseudoevadne tergestina, Podon polyphemoides, Penilia avirostris* and 3 species of Pontellidae copepods namely; *Pontella mediterranea, Anomalocera patersoni, Labidocera brunescens*. However, Yıldız and Feyzioğlu (2014) identified only 7 copepod and 2 Cladoceran species. The Cladoceran species *E. nordmani, E. spinifera,* and *Pleopis polyphemoides* were not observed in the latter study.

In this study, a total of 19 zooplankton species were identified at species level however, 13 groups could not be identified at species level in July 2013 (shown in Table 27). Some species occurred only in certain locations. It is known that the number of species is higher in the western region of the southern Black Sea because of the lower Bosphorus current continuously carrying the Mediterranean species to the Black Sea. However, in this study only individuals of Ostracoda and Cumacea were sampled solely from the west (in addition to *Acartia tonsa* and *Beroe ovata*). On the contrary, some species were sampled only in the eastern region (such as *Pontella mediterranea*) and interestingly *Noctiluca scintillans* that was expected to be observed in all regions but was not seen in the east.

Eight common and one rare copepod species were observed in this study. One of the common copepod species (*Oithona davisae*) was not seen in the present study. *Oithona davisae* is one of the smallest copepod species in the Black Sea and hence may not have been caught by the relatively large mesh size (200 micron) of the net used in this study. Other rare copepod species *Anomalocera patersoni* and *Labidocera brunescens* were not observed in this study.

In this study, four cladoceran species were observed in samples during July 2013, namely, *Evadne spinifera, Penilia avirostris, Pleopis polyphemoides* and *Pseudoevadne targestina*. Üstün (2010) reported none of these species except *P. polyphemoides*, identified in the samples that were collected from the entire southern Black Sea in June 2006. Four macrogelatinous organisms; namely *Aurelia aurita, Beroe ovata, Mnemiopsis leidyi* and *Pleurobrachia pileus* occurred in the samples and *Rhizostoma pulmo* specimens were seen during sampling from the research vessel but did not appear in the samples from the WP-2 net due to the visibly low abundance.

Table 27 Existence of identified zooplankton groups and species in 3 different regions of the southern Black Sea in July 2013

Group	Species	West	Middle	East
Appendicularia	*Oikopleura dioica*	x	x	x
Bivalvia		x	x	x
Brachyura	Larvae	x	x	x
Cirripedia	Larvae	x	x	x
Chaetognatha	*Parasagitta setosa*	x	x	x
Copepoda	*Acartia clausi*	x	x	x
	Acartia tonsa	x		
	Calanus euxinus	x	x	x
	Centropages ponticus	x	x	x
	Oithona similis	x	x	x
	Paracalanus parvus	x	x	x
	Pseudocalanus elongatus	x	x	x
	Pontella mediterranea			x
Cladocera	*Evadne spinifera*	x	x	x
	Penilia avirostris	x	x	x
	Pleopis polyphemoides	x	x	x
	Pseudoevadne targestina	x	x	x
Ctenophora	Larvae	x	x	x
Cumacea		x		
Decapoda		x	x	x

Gastropoda		x	x	x
Gelatinous	*Aurelia aurita*	x	x	x
	Beroe ovata	x		
	Mnemiopsis leidyi	x	x	x
	Pleurobrachia pileus	x	x	x
Ichthyoplankton	Fish egg	x	x	x
	Fish larvae	x	x	x
Isopoda		x	x	x
Nematoda		x		x
	Noctiluca scintillans	x	x	
Ostracoda		x		
Polychaeta		x	X	x

According to the historical data of 1957-1982 (Kovalev *et al*. 2001) copepods constituted 60-80% of total zooplankton abundance, followed by cladocerans, appendicularians, and gelatinous zooplankton among the major groups. Greze (1989) also observed that the contribution of other groups to zooplankton abundance was not significant.

In this study copepoda was the most abundant group in July 2013 followed by *Noctiluca*, Cladocera, Meroplankton, Chaetognatha and Appendicularia. The comparison of group composition (in terms of percentage) of zooplankton between June 2006 (Üstün 2010) and July 2013 is shown in Figure 110 for the entire southern Black Sea. According to this figure, percentages of Appendicularia, Chaetognatha, Copepoda, and Cladocera displayed highest values in 2013 however, lower percentagevalues were seen for *Noctiluca* and meroplankton. Üstün (2010) stated that the most abundant copepod species in June 2010 were *P. elogatus, A. clausi* (a eutrophic species) and *O. similis*. However, in 2013, *A. clausi* was the most dominant copepod species for the central region of the southern Black Sea, followed by *P. elongatus,* and *C. euxinus*. In June 2006 *Noctiluca* comprised almost 50% of the overall zooplankton abundance (Üstün, 2010), but only 14% in July 2013. *Oithona nana* (a species sensitive to pollution) was also identified in the southern Black Sea, in 2006, but was not identified in this study. Individuals of *A. tonsa, P. mediterranea,* *Evadne spinifera, P. avirostris, P. targestina,* Cumacea and Isopoda were encountered in the present study in July 2013, whilst none of these organisms were observed in June 2006 (Üstün, 2010).

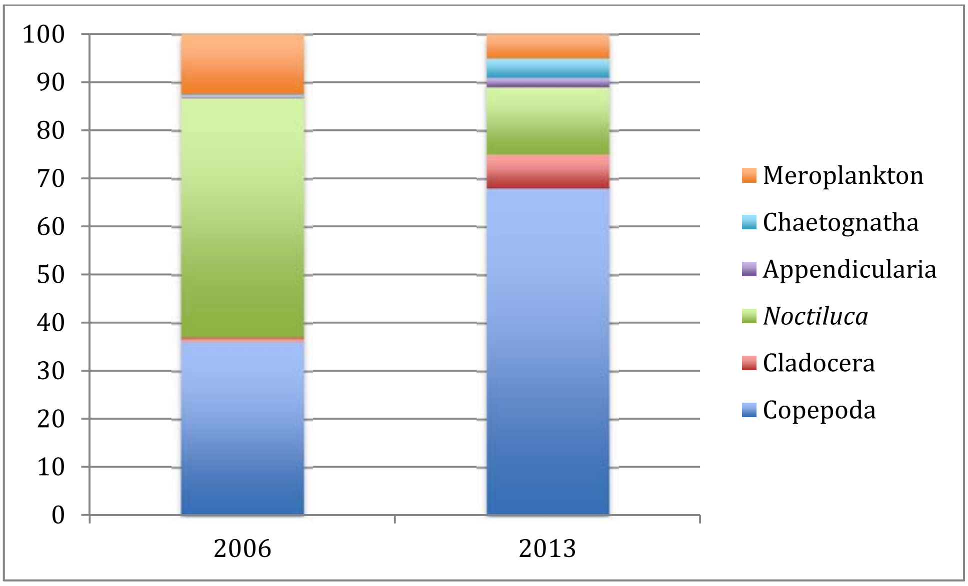


Figure 110 Comparison of percentages of zooplankton groups that observed between 2006 (Üstün, 2010) and 2013 (present study)

(Kovalev *et al*., 1998a) reported that the copepods *Acartia clausi, Oithona similis* and *Paracalanus parvus*, all species of Cladocera, *Oikopleura dioica*, and larval Polychaeta and Gastropoda had decreased, particularly in the upper layer and coastal areas and that *Pontella mediterranea* (a neustonic species) had completely disappeared since the summer of 1989. In this study, however, the latter species was observed in the samples.

According to Tarkan *et al*. (2005) the total abundance of two Mediterranean originated species, *Penilia avirostris* and *Acartia clausi,* was the highest in zooplankton in the western Black Sea. For this area, the annual mean percentages of the dominant groups were as follows; Copepoda - 42.25%, Cladocera - 17.5%, Appedicularia - 3.8%. In July 2013, the percentage compositions of these groups were found to be as follows; Copepoda - 61%, Cladocera - 7% and Appendicularia - 2%. In this study *A. clausi* constituted 64% of the total copepod population.

Copepoda was also the most dominant group in the central region in 2002, 2003, 2004 and 2006 constituting more than 50% of zooplankton abundance (Üstün, 2005; 2010). In July 2013 this group formed 69% of the entire community. *A. tonsa* was encountered in the central region of the southern Black Sea in 2002 and 2004 by Üstün (2010), however, this species was not observed in the same region in July 2013.

For the eastern region, Yıldız and Feyzioğlu (2014) stated absence of *Acartia tonsa* and *Pontella mediterranea*, which were encountered in previous studies (in the central region of the southern Black Sea) (Ünal, 2002; Üstün, 2005). In this study *P. mediterranea* was identified in the east, however, *A. tonsa* was encountered only in the western area of the southern Black Sea. According to Yıldız and Feyzioğlu (2014), due to the lower species biodiversity of the eastern zoneof the southern Black Sea compared to the western region, they identified only two species of cladocerans. In this study, all cladoceran species with the exception of *Evadne nordmanni* were identified in the eastern area of the southern Black Sea. A comparison of the percentage of mesozooplankton in the eastern zone of the southern Black Sea was done with previous studies. In 2008, 52% of the total sample was composed of Cladocerans and 32% was *Noctiluca*, followed by copepods with 12% (Özdemir, Ak 2012). They also observed a decreasing trend in the distribution of *Noctiluca* in July, which continued in August. Özdemir (2013) stated the most dominant species was *Noctiluca* (30%), which was not encountered between 2012 and 2013 in the eastern region of the southern Black Sea and the most dominant groups were copepoda (56%) and cladocera (11%). In 2013, the percentage values of copepods and cladocerans were 82% and 5 %, respectively, whilst no *Noctiluca* was encountered. The total absence of *Noctiluca* in the eastern Black Sea in July 2013 could be explained by the high temperatures observed (25- 26 °C). In July 2008, the temperature was slightly lower than 2013, which could be one of the explanations for differences in the abundance of *Noctiluca* (a detailed discussion on *Noctiluca* distribution is presented below).

Within the five main groups of zooplankton, namely, chaetognatha, cladocera, copepoda, meroplankton and *Noctiluca*, only chaetognatha and copepoda displayed preference for offshore waters. It is important to note that inshore and offshore stations were chosen not by their distance to shore or the total depth of the station but their position on the transect. Therefore this can not be stated to as the perfect method to claim the preference of inshore or offshore waters for chaetognatha. However their abundance and biomass values were higher in the chosen offshore stations, where cladocerans, meroplankton and *Noctiluca* abundance and biomass values were low.

Acartia clausi, Acartia tonsa, Calanus euxinus and *Centropages ponticus* were the copepod species with higher abundance and biomass values in offshore waters of the southern Black Sea compared to *Oithona similis, Paracalanus parvus* and *Pseudocalanus elongatus*, which preferred inshore stations. Among cladocerans, *P. avirostris* showed the highest abundance and biomass values for inshore waters followed by *P. polyphemoides*.

In the present study mesozooplankton distribution showed remarkable differences within the sampling area (i.e. the southern Black Sea). One reason for this is the relatively longer sampling period (18 days) to cover the western, centraland eastern Black Sea waters as well as both inshore and offshore areas where a total of 46 stations were visited. For a better coverage, different water dynamics (such as upwelling and downwelling regions), proximity to rivers, Bosphorus effect etc. were taken into account in deciding the location of stations as these parameters all have a substantial impact on zooplankton communities.

Evaluation of the long-term zooplankton abundance and biomass distribution for any specific area requires many others conditions to be met; in particular similarity of sampling period and methodology. Zooplankton studies in Turkish waters of the Black Sea intensified after 1980. Hence the “long-term” comparison could only be made for the last 2-3 decades. Secondly even though the number of zooplankton studies have increased throughout the years, only a few of these could be compared with this study due to the large sampling area.

Long-term changes in the zooplankton biomass (fodder zooplankton in particular) were studied by various researchers, such as Konsulov and Kamburska, 1997; Niermann and Greve, 1997; Niermann *et al*., 1998; Shiganova, 1997,1998; Shiganova *et al*., 1998; Kovalev *et al*., 1998c,d. Even the fodder zooplankton has been found to fluctuate through the years, a reverse trend was observed between the shallow western and deep eastern regions of the Black Sea. After an increasing trend in fodder zooplankton between the 1960's and 1970's, a decreasing trend occurred until the 1990s. On the contrary, the biomass of fodder zooplankton increased from the 1960's to the 1990's except in the 1970's in the deep eastern region. The phytoplankton biomass increased substantially from the 1960s in the deep eastern region indicates this region became more productive, which also affected the zooplankton biomass (Kıdeys *et al*., 2000).

One of the first studies of zooplankton in the southern Black Sea that aimed to evaluate the differences between the west and the east as well as inshore and offshore waters was carried out in 1955-1956 (Einarsson and Gürtürk, 1959). At this starting point the result did not display a significant difference between mentioned areas of the southern Black Sea with almost homogeneous plankton distribution.

However, the present study found that different areas of the southern Black Sea displayed different characteristics. Whilst in the 1950's distributionwas correlated with the physical characteristics of the Black Sea, it is assumed that our results are possibly due to changing climate and anthropogenic impacts on the southern Black Sea. For example, increasing riverinput is one of the major parameters to affect primary production thereby modifying the zooplankton abundance and composition. Comparison of inshore and offshore waters shows the preferences of different groups and is important to understand the dynamics between one another.

In July 2013 the abundance of zooplankton (including *Noctiluca*, gelatinous zooplankton and fodder zooplankton) was 117,258 ind/m^2 and biomass was 539,885 mg/m^2 for the southern Black Sea. In terms of abundance, comparison of the western, central and eastern regions demonstrated that the western area displayed the highest value (175,495 ind/m^2), which was almost twice the value of other regions. The eastern region showed the lowest abundance. However, the central are recorded the highest biomass (586,976 mg/m^2), followed by eastern zone. The lowest biomass of zooplankton was observed in the west.

Holoplankton, which constituted the majority of the zooplankton in the present study, displayed its highest abundances in the western region. The high Chl-a values (as an indication of high primary production) observed in the satellite data (shown in Figure 8) correspond well with the high zooplankton values found in the present study. Meroplankton also showed high values in the western zone of the southern Black Sea. A substantial amount of meroplankton is constituted by the early stages of benthic species of which abundance is in turn related to the expansion of suitable substrates. Therefore the wider shelf may support a higher abundance of meroplankton. On the other hand, expansion of the rocky shelf area may determine the abundance of groups such as bivalves, barnacles, gastropods and decapods. In this study, the early stages of bivalvia were found to be high in the central southern Black Sea where the hard bottom shelf area is larger than those of either the eastern or western Black Sea (Figure 83). Abundance and biomass values of meroplankton were also higher in inshore waters of the central southern Black Sea in July 1999 (Ünal, 2002), which is in concordance with this study.

In terms of fodder zooplankton as the most important component among the zooplankton groups, the average abundance was 100,013 ind/m^2 in the southern Black Sea (in July 2013). The west showed a near two-fold abundance (135,611 ind/m^2) compared to the other regions. The lowest value was recorded in the central region, however this was quite similar with values for the east. In terms of biomass, the average value was 11,614 mg/m^2. Even though the abundance value of fodder zooplankton was two-fold lower in the eastern region compared to the west, the biomass value (13,834 ind/m^2) was almost similar with the western area (14,290 ind/m^2) of the southern Black Sea in July 2013. One of the most important areas in the east was the Batumi anticyclonic eddy in terms of fodder zooplankton biomass. However, the average biomass was highest in the west and lowest in the central region (three fold lower than the west). In conclusion, the highest abundance and biomass values of fodder zooplankton were observed in the west.

Since biomass provides more information about higher trophic levels, however, considering the biomass of fodder zooplankton for the entire southern Black Sea is more substantial. Even though the difference in abundance of fodder zooplankton is significant between the western and eastern regions, the biomass values were almost similar.

Üstün (2010) reported abundance and biomass for the entire southern Black Sea for summer 2006. According to her results, the abundance and biomass of fodder zooplankton were higher in the western region of the southern Black Sea. Sorokin (1983) reported constant high values of zooplankton in the southeastern anticyclonic region; boundaries of western and eastern eddies and in the coastal region between Ereğli and Istanbul.

All of the available data from 1954-1995 shown in Figure 111 depict the distribution of summer fodder zooplankton biomass and the relation between the patchiness of these organisms and the meso-scale circulation structure. A higher biomass of summer fodder zooplankton was observed in the coastal anticyclonic eddies and the highest values were in the easternmost region of the southern Black Sea (Oğuz *et al.*, 2008). Considering highest values were found in the western Black Sea compared to the central and eastern regions, the results obtained here are not in good agreement with those found in Figure 111 for the reasons explained below.

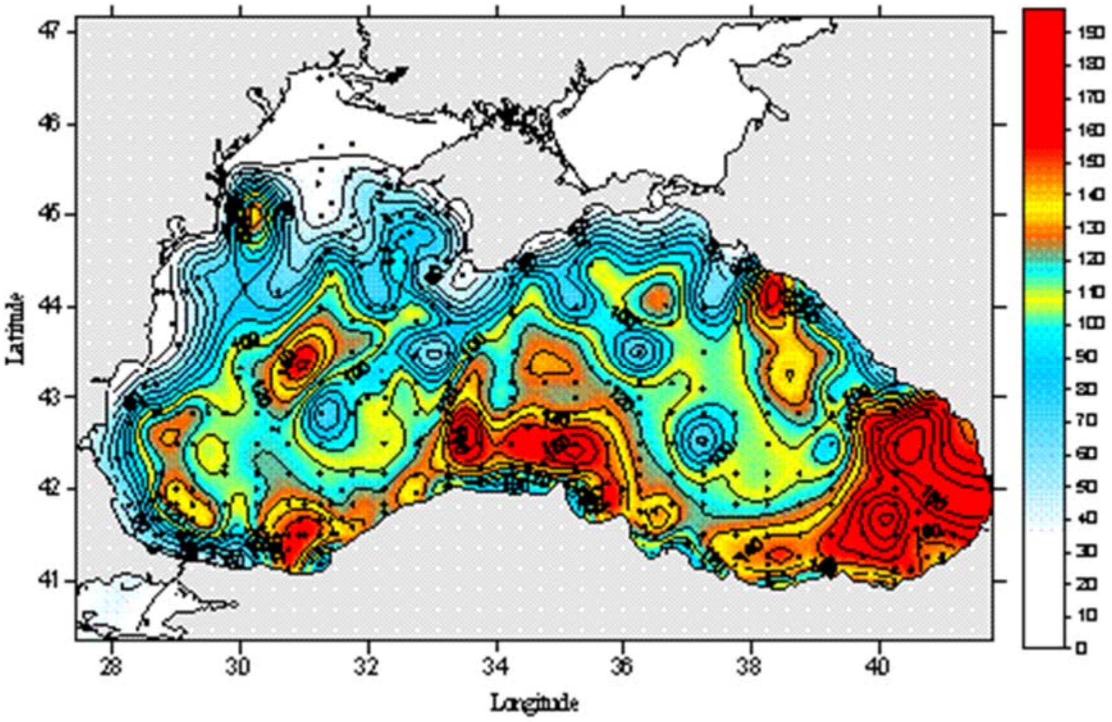


Figure 111 Distribution of summer edible zooplankton biomass (mg/m^3) during 1954-1995 in the Black Sea (after Temnykh, 2006)

Differences between the fodder zooplankton abundance and biomass for the three regions of the southern Black Sea could be answered by the following questions;

1) What are the reasons for the highest abundance and biomass of fodder zooplankton in the west?
2) Why were both the lowest abundance and biomass observed in the central region?
3) What are the reasons for similar biomasses between the western and eastern regions of the southern Black Sea, whilst the abundance values for the east were almost half those of the west?

First of all, as stated by previous studies (as presented earlier), due to the high riverine input in the western region by rivers such as the Danube and Dniester, the nutrient content is higher compared to the other areas of the southern Black Sea. For this reason, higher primary production and higher zooplankton abundance were observed in the western area. High Chl-a values are also shown in Figure 8. The lowest abundance in the central region could also show the relationship between Chl-a values and fodder zooplankton. Another reason for high abundance in the west due to the high Chl- a values could be the heavy presence of *Noctiluca* (compared to other parts of the southern Black Sea). The organisms carried from the Sea of Marmara via the Bosphorus (İşinibilir *et al*., 2011) and increasing water dynamics are also among the reasons of high abundance of fodder zooplankton; dead or alive. However, Tarkan *et al.* (2005) stated the abundance and biomass of zooplankton is higher for the Black Sea water compared to the Mediterranean water that flows underneath. Zenkevitch (1963) also observed high plankton abundance and biomass in the western region of the Black Sea as a result of shallower topography and river inputs in the west.

Secondly, the lowest abundance and biomass values of fodder zooplankton in the central compared to other regions of the southern Black Sea could be explained by reasons such as low Chl-a values affecting primary production, which was also shown in Figure 8. In this study, in the central region where the highest biomass of gelatinous organisms was observed, copepod, fish eggs, fish larvae and chaetognatha displayed their lowest biomass values compared to the other areas of the southern Black Sea. Lower fodder zooplankton biomass such as that of *Calanus euxinus* in the central region could also be related with the higher presence of gelatinous zooplankton, most notably the high biomasses of *Mnemiopsis leidyi* and *Pleurobrachia pileus*. These findings reveal the impact and relationship between gelatinous organisms and fodder zooplankton in the southern Black Sea.

One of the most important species due to its impact on fodder zooplankton is *Mnemiopsis leidyi*, which occurred with its highest abundance and biomass value in the central region of the southern Black Sea in this study. The *Mnemiopsis leidyi* population was estimated to consume 2.8-20.5 mg fodder zooplankton per m^2 daily (Anninsky, *et al*., 2013). Major reproduction for *M. leidyi* begins in summer, depending on the atmospheric temperature. According to Mutlu (1999), young individuals were more abundant primarily in summer and secondarily in winter. Smallest size group of *M. leidyi* constituted 90% of the samples in this study, indicating the reproductive season for this species. Since the main diet of *M. leidyi* is composed of *Acartia clausi* and *Calanus euxinus* (Tsikhon-Lukashina *et al*., 19991; Vinogradov and Shushkina, 1992), high numbers of small individuals and the highest biomass of *M. leidyi* in the central region could also be the reason for the low abundance and biomass of these two copepods. According to Finenko *et al.* (2013), the main food items (of *M. leidyi*,) belonging to the groups of mesozooplankton are *Acartia clausi*, *A. tonsa*, *Calanus euxinus*, *Penilia avirostris* and *Pleopis polyphemoides* and among the meroplankton groups bivalves, gastropods and cirripeds.

It is well known that *P. pileus* mainly (about 90% according to Grece (1972)) feeds upon copepods, cladocera, mollusca, fish eggs and larvae. Vinogradov *et al.*(1986) and Mutlu & Bingel (1999) stated that *P. pileus* preys upon *C. euxinus* (39%), *Pseudocalanus elongatus* (30%) and *Acartia clausi* (28%). Similar to *M. leidyi* and *P. pileus*, the stomach contents of *Aurelia aurita* were mostly dominated by copepoda (42%) especially *Acartia clausi* (31%), mollusca (35%) ichthyoplankton (3%) (Mutlu, 2001). Shushkina and Musayeva (1983) reported the impact of *Aurelia aurita* on fish eggs and larvae as a predator and a competitor for food with the planktivorous fish.

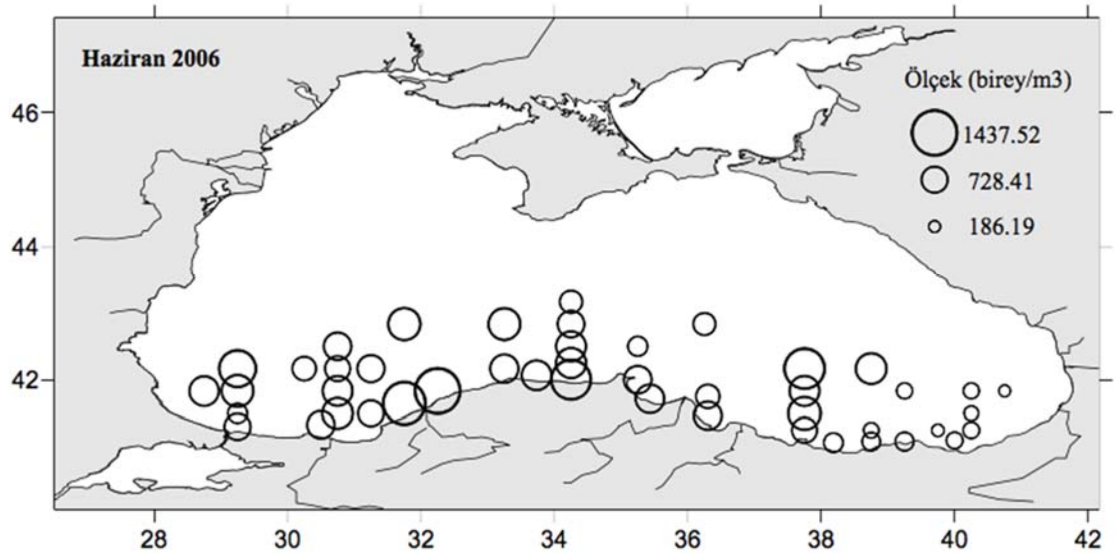
Lower Chl-a values in the east compared to the western area of the southern Black could be one of the explanations for the lower abundance and biomass values of fodder zooplankton in the east , which are also shown in Figure 8. Ağirbaş *et al.* (2014) obtained the lowest amounts of nutrients in the offshore waters of the eastern region (Trabzon) of the southern Black Sea during their bi-monthly sampling period from March 2010 to December 2010. He stated in July when the mixed layer depth was shallower than that of the eutrophic layer, the highest concentrations of nutrients (>1 µg L^{-1}) were measured, however this value was lower than for other areas of the southern Black Sea (Ağırbaş *et al*., 2014).

Even if the differences between the abundances of fodder zooplankton in the western and eastern areas are quite large, the biomasses of fodder zooplankton are similar to each other. This indicates the existence of larger individuals in the eastern region of the southern Black Sea. Erkan and Gücü (2000) and Özdemir and Ak

(2012) indicated a domination of small organisms in the southeastern Black Sea, such as *Noctiluca, Oithona similis* and early stages of *Pseudocalanus elongatus*. These observations contrast with those of the present study. In the east, *P. elongatus* displayed higher ratios of adult individuals, along with the absence of *Noctiluca* and lowest abundance of *O. similis* and *P. parvus* (as 2 of the smallest sized copepoda) compared to other areas of the southern Black Sea. Moreover, a higher number of individuals of *Calanus euxinus* individuals were observed in this area. As mentioned before, the cell weight of *Noctiluca* is relatively less compared to copepods and other fodder zooplankton. Kovalev *et al*. (1998) and Shiganova *et al*. (1998) stated an increasing trend of *Noctiluca* in the southern Black Sea. However, the species was not encountered in the eastern region of the southern Black Sea in this study. Among the fodder zooplankton groups, copepoda was almost always the most abundant group. For example, copepods are shown to constitute 80% of the total fodder zooplankton in terms of abundance and 54% in terms of biomass (Üstün, 2005, 2010; Tarkan *et al.*, 2005, Özdemir, 2014). Percentages of copepods varied for the three different areas in the southern Black Sea.

Copepoda was more dominant in the west in terms of both abundance and biomass (Figure 36). Even the abundance values were similar in the central and eastern regions; the biomass value of the eastern zone was close to that of the western zone, which indicates that larger individuals were present in the east compared to the central area of the southern Black Sea as mentioned earlier.

A



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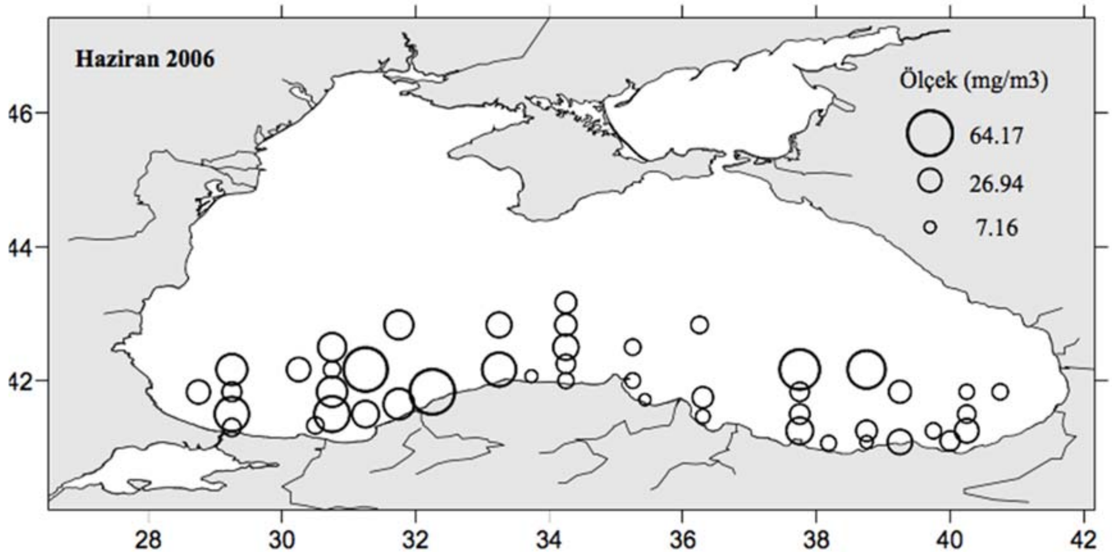

Figure 112 Abundance (ind/m^2) and biomass (mg/m^2) distribution of copepoda in June 2006 in the southern Black Sea (Üstün, 2010)

Figure 112 shows that the abundance and biomass distributions of copepods in the central region were also the lowest, whilst abundance was higher in the west (Üstün, 2010). This result is similar to the present study in terms of biomass, with relatively lower values compared to the west.

Acartia clausi, Acatia tonsa, Oithona similis (also observed by Üstün (2010)) and *Paracalanus parvus* showed a decreasing trend from west to east in terms of abundance and biomass in this study. Üstün (2010) also stated the decreasing trend from west to east for *O. similis* in June 2006. *Centropages ponticus* and *Calanus euxinus* also showed their highest abundances in the west; however the highest biomass of *Calanus euxinus* was in the east, like *Pseudocalanus elongatus* that displayed its highest abundance and biomass in the southeastern Black Sea. Contrary to this, for June 2006, *C. ponticus* displayed its highest abundance and biomass in the eastern region and *P. elongatus* displayed its highest abundance in the western region of the southern Black Sea (Üstün, 2010). It is clear that high biomass values of copepods in the east (compared to displaying near two-fold lower abundances than in the western region) could be explained by high *Calanus euxinus* (the largest copepod species in the Black Sea) biomass in this area. The lowest abundance and biomass of copepods were observed in the central region.

Chaetognatha is the most important species of fodder zooplankton in terms of biomass, which is also more important in offshore waters. High abundance values of *P. setosa* were observed in offshore waters of the western region and offshore waters of the easternmost stations in July 2013. Adult individuals showed higher distribution density in offshore waters, while the number of eggs and juveniles were higher in inshore waters in the central region of the southern Black Sea (Ünal, 2002).

Distribution of *P. setosa* in the Black Sea was previously studied by Zenkevith (1963), Vinogradov *et al.* (1990), (1992), Niermann & Greve (1997), Feyzioğlu *et al.*, (1998), Beşiktepe & Ünsal (2000) and Öztürk (2002). The spatial distribution of *P. setosa* was shown to be related with high salinity and deep water (Niermann *et al.*, 1998; Beşiktepe and Ünsal, 2000). Nierman *et al.* (1997) observed a high abundance of this species in the coastal currents and low abundance in the shore and center of the Black Sea. The highest abundance for *P. setosa* was observed during the summer months, when the highest number of small sized individuals of *P. setosa* occurred, which indicates the breeding season of this species as the summer months for the southern Black Sea (Beşiktepe and Ünsal, 2000; Öztürk, 2002; Ünal, 2002; Yıldız 2010 and Özdemir 2013). According to Niermann *et al.* (1998), in the Black Sea, the number of adult individuals of *P. setosa* increases in July whilst in late July/August this number decreases rapidly having been replaced by juveniles. As Beşiktepe (1998) and Nierrman *et al.* (1999) the period for dominance of juveniles occurs prior to July whilst adult individuals are more abundant in the colder periods. Oresland (1986) claimed the death of *P. setosa* after breeding. Greze (1979) also defined the breeding time of *P. setosa* as starting by the end of July. Arashkevich *et al.* (2013) also stated a high abundance of large-sized *P. setosa* and correlated the high biomass values to their life cycle stages. These reasons may explain the high numbers of small/young individuals and low numbers of large/adult individuals in the southern Black Sea in July 2013.

In this study size-frequency distribution (shown in Figures 91 and 92) is also compatible with earlier studies. Small individuals (0.5-5.0 mm) of *P. setosa* constituted 34% of the entire population. The abundances were higher in the east, while the biomasses were higher in the west due to the higher percentage (8%) of larger size groups(15.0-20.0 mm).

Öztürk (2002) reported the abundance of *P. setosa* for July 2000 as 4.451 ind/m^2 in the eastern region of the southern Black Sea. 5.972 ind/m^2 was the average abundance value of *P. setosa* in the east for this study. According to the historical data (1957-1982) chaetognatha accounted for 9-13 % of total zooplankton in the Black Sea (Kovalev *et al.*, 2001). Özdemir and Ak (2012) presented the percentage of *P. setosa* as only 1% of total zooplankton whilst it was 4% in 2013 (this study).

A high abundance of *Parasagitta setosa* is a sign of high copepod abundance as Feigenbaum (1991), Froneman and Pakhomov (1998) and Oreslan (1987) stated since copepods (mainly *Calanus euxinus* (Utkina, 1988)) are considered to be the most important prey species of *Parasagitta setosa*. As a result of increasing abundance of copepods in summer/early autumn, this is followed by the breeding and growth of *Parasagitta setosa* (Besiktepe and Unsal, 2000) as mentioned before.

The relation between copepoda and *P. setosa* can also be seen in Figures 36 and 90. In this study, the low abundance (only 20%) of *C. euxinus* (<c5) and high numbers of small sized *P. setosa* could be the explanation of the prey-predator relationship between the two species. In this study the abundance and biomass distribution of small and large size classes of *P. setosa* displayed its lowest values in the central region in both inshore and offshore waters in July 2013. As mentioned above, lowest copepod abundance and biomass values in the central region due to the effect of gelatinous zooplankton could be the main explanation of lowest abundance and biomass distribution of *P. setosa* in the central area compared to others.

According to Quevedo *et al*. (1999) *Noctiluca* affects zooplankton abundance and community structure mainly by reducingtheir egg/larva numbers. Elbrachter and Qi (1998) also stated their impact on zooplankton through competition for food resources. The high growth rate of *Noctiluca* (Buskey, 1995; Nakamura, 1998) proves an important advantage to this species over other herbivorous zooplankters even though the *Noctiluca*'s clearance rate is lower (Nakamura, 1998) than that of the same sized zooplankton (Hansen *et al*., 1997).

Because of its fast growth, and several reproduction cycles per season, *Noctiluca* appeared as a successful r-strategist with its opportunistic behavior. Moreover, *Noctiluca* differed from other r-strategists by its high competitive ability, year round occurrence, and large size (Yılmaz *et al*., 2005).

Ünal (2002) reported the peak value of *Noctiluca* in July, also mentioning it to be the dominant mesozooplankton species in the central regionof the southern Black Sea. Many studies (Ünal, 2002; Üstün *et al*. 2007; Özdemir, 2013; Feyzioğlu, 1996; Özdemir and Ak, 2012) in the southern Black Sea mentioned a decrease in fodder zooplankton when *Noctiluca* starts to increase. On the contrary, this statement was not true for this study. Fodder zooplankton displayed its highest abundance and biomass distributions in the west, where *Noctiluca* also occurred in high quantities. Indeed, it was very interesting that this indicator species was not observed at all in the east of the southern Black Sea in July 2013. Üstün (2005) determined the abundance as 73,800 ind/m^2 and biomass as 8,687 mg/m^2 for the inshore waters of the central area of the southern Black Sea. Decreased abundance and biomass values of *Noctiluca* in the southeastern Black Sea were also indicated by Feyzioğlu (1996), Özdemir and Ak (2012), and Özdemir (2013). Even though many previous studies mentioned the low abundance of *Noctiluca* in the east (Fevzioğlu, 1996; Erkan and Gücü 2000; Fevzioğlu and Sivri, 2003; Yıldız, 2010; Özdemir and Ak, 2012; Özdemir, 2013 and Deniz and Gönülol, 2014), none of these mentioned a total absence of *Noctiluca* in July in the eastern zone of the southern Black Sea

One of the reasons for the absence of *Noctiluca* in the east could be related to its temperature tolerance. In this study, the water temperature in the west was lower than 26°C, increasing in the central and eastern Black Sea (Figure 10). According to Uhlig and Sahling (1995) the upper temperature tolerance limit of *Noctiluca* is around 26 ° C. Özdemir (2013) pointed out the negative relationship between *Noctiluca* existence and temperature between March 2012-February 2013. The decrease in *Noctiluca* could be a sign of increased water temperature for July compared to previous years.

Noctiluca scintillans dominated mesozooplankton in the Black Se in October 1996 and July 1997; it did not show a clear vertical movement but occuring only in surface layers (< 60 m) (Erkan *et al*., 2000).

In this study, Spearman Rank Correlation is used to understand the relation between temperature (at 5 m depth), salinity (at 5 m depth) and abundance of Noctiluca. The Spearman Rank Correlation for temperature and abundance and Noctiluca displayed significant negative correlation (-0.386) between two of them. Even it was also displayed negative correlation (-0,32) for salinity and abundance of Noctiluca, this was not significant.

The absence of *Noctiluca* most probably had an effect on the high summer Chl-a values observed from the satellite which in turn had a positive impact on fodder zooplankton. In this study, not only copepod adults but also egg numbers displayed low abundances in the west where *Noctiluca* was abundant (shown in Figures 68 and 98). It is reported that copepod eggs (Mironov, 1954) or fish eggs (Enomoto, 1956) are also amongst the food items for *Noctiluca scintillans*. Üstün (2010) reported a decrease in copepod egg and nauplii numbers between July and September due to an increase in the abundance of *Noctiluca*.

Gelatinous zooplankton have been studied by Mutlu *et al*. (1994), Petran and Moldoveanu (1997), Shiganova (1997,1998), Anninsky *et al*. (1998), Konsulov and Kamburska (1998), Shiganova *et al*. (1998), Shulman *et al*. (1998), Kideys and Romanova (2001); Mutlu (2001), Kideys *et al*. (2005) and Bat *et al*. (2009) in the southern Black Sea.

Four species of gelatinous zooplankton were sampled in July 2013. The average biomass of gelatinous zooplankton was highest in the eastern region with 595 ind/m^2 (Table 21). Individuals of *Aurelia aurita* and *Pleurobrachia pileus* displayed their highest abundance in the east, while *Mnemiopsis leidyi* was most abundant in the central region of the southern Black Sea. *B. ovata* was only observed at two stations in the west. According to Mutlu *et al.* (1994) the abundance of *M. leidyi* increased from the summer of 1991 to the summers of 1992 and 1993 and these abundances were much higher in the eastern than the western zones of the Black Sea, similar to respective results of this study. In terms of biomass, highest values were observed in the central region. *Aurelia aurita* displayed its highest biomass value in the east and *M. leidyi* and *P. pileus* showed their highest biomasses in the central area.

Among these three species, the number of individuals larger than 5 cm in umbrella diameter was lower in the *A. aurita* population. Mutlu, (2001) also stated larger individuals were more abundant in July 1992, and the largest individual was 21,4 cm umbrella diameter, while it was only 15 cm in July 2013 probably due to the difference in the sampling method (mouth area of the net). The smallest size group of *M. leidyi* constituted 90%, indicating intense reproduction for this species. Even the maximum length was measured as 2 cm in July 2013, the most dominant size group was 0.55 mm and the number of individuals decreased as the size increased.

Shiganova *et al*. (2001) stated that the reproduction of *M. leidyi* in the inshore waters becomes intense in July and requires temperatures around 24°C. Spatial distribution of *M. leidyi* in the southern Black Sea in July 2013 also showed a preference for inshore waters (see Figure 103) as stated by Grishin *et al*. (2007).

Abundance and biomass of *Mnemiopsis leidyi* was associated with surface circulation (Mutlu, 1999), water temperature and salinity (Zhong, 1998). The reason for high abundance and biomass in the anticyclonic eddies was assumed to be due to accumulation in the core of the eddies by the downwelling water masses (Mutlu and Bingel, 1999). Upwelling waters in cyclonic gyres also force the individuals to move toward the perimeter and aggregate at the eddies whilst interactions between the eddies create a complex-patchy distribution ending up with high biomasses on the outskirts of the cyclonic gyres (Mutlu, 1999). Because of the various circulation characteristics in the southern Black Sea in the three areas, abundance and biomass of these species are different from each other.

Shiganova *et al*. (2001) also stated that *Mnemipsis leidyi* spatially overlaps with *Aurelia aurita* due to its greatest abundance in inshore waters even though it occurs throughout the sea. In July 1992 the abundance and biomass of *Aurelia aurita* showed no difference between the western and eastern regions, while a significant difference was observed between the inshore and offshore waters of the southern Black Sea and its main biomass was found between the anticyclonic eddies due to the dominance of *M. leidyi* in the core of the anticyclonic eddies. As for *M. leidyi, A. aurita* was more abundant in the eutrophic inshore waters.

A. aurita abundance was positively correlated with *M. leidyi* due to food competition and inhabiting the same layer, while *M. leidyi* was more closely correlated with *P. pileus*. There was no correlation between *A. aurita* and *P. pileus* abundances probably due to their inhabiting different layers of the water column. *Aurelia aurita* is found above the thermocline, whilst *P. pileus* occupies deeper water (Shushkina and Musayeva, 1983; Vinogradov *et al*., 1985; Vinogradov *et al*., 1989; Shushkina and Vinogradov, 1991 a,b; Mutlu and Bingel, 1999; Mutlu, 2001).

Comparisons of abundance and biomass of gelatinous species for the entire southern Black Sea between 1992 (Mutlu and Bingel, 1999; Mutlu, 1999, 2001), 1996 (Kideys and Romanova, 2001) and 2013 (this study) are shown in Table 28.

Table 28 Abundance (ind/m^2) and biomass (mg/m^2) values of 3 gelatinous species namely; *A. aurita* (yellow colored*), P. pileus* (green colored) and *M. leidyi* (red colored) for the entire southern Black Sea between 1992, 1996 and 2013

Aurelia aurita	**July 1992**	**July 1996**	**July 2013**
Max. abundance (ind/m^2)	29		58
Mean abundance (ind/m^2)	4	8	15
Max. biomass (g/m^2)	3,224		741
Mean biomass (g/m^2)	201	186	173
Pleurobrachia pileus			
Max. abundance (ind/m^2)	1,638		1,961
Mean abundance (ind/m^2)	523	196	293
Max. biomass (g/m^2)	871		275
Mean biomass (g/m^2)	244	111	40
Mnemiopsis leidyi			
Max. abundance (ind/m^2)	569		319
Mean abundance (ind/m^2)	54	67	99
Max. biomass (g/m^2)	1,924		855
Mean biomass (g/m^2)	226	221	280

The average abundance and biomass of *M. leidyi* are higher in July 2013. However, for *P. pileus* the mean abundance is lower than in 1992 (maximum values were almost the same for this species in 1992-2013) and higher than 1996. In terms of biomass, the mean value for 2013 is lower than in previous years. Even the average abundance value of *A. aurita* is higher compared to 1992 and 1996; the biomass is lower in the southern Black Sea.

Investigations in the Black Sea have shown that *Beroe ovata* feeds almost exclusively on *Mnemiopsis leidyi* and is very effective in controlling its levels (Finenko *et al*. 2000, 2001, 2003, Kideys *et al*. 2000 and Shiganova *et al*. 2001a). Low abundance and biomass of *B. ovata* in the southern Black Sea is probably the result of a lower abundance of *M. leidyi* before July.

Gelatinous organisms have a strong impact on ichthyoplankton as previously stated by many studies (Kideys, 2002; Zaitsev 1992, Kovalev *et al*., 1998; Anninsky *et al*., 2005; Gordina *et al*., 2005; Kideys *et al*., 2005; Finenko *et al*., 2006; Satılmış *et al*., 2006 and many others). However, because of the sampling method, it is not very appropriate to discuss interactions between gelatinous zooplankton and ichthyoplankton in this study. Yet the abundance of ichthyoplankton was observed to be high in the western region of the southern Black Sea, mainly because of the high number of individuals in front of the Bosphorus, whilst it was lowest in the central region and increased again in the inshore waters of the eastern region.

As in many other ecosystems, it is important to monitor certain species, which play a key role towards understanding the changes in the Black Sea (such as *Mnemiopsis leidyi, Noctiluca scintillans* or *Oithona similis*). In this study results for some of these organisms did reveal differences compared to the previous studies.

In this study, indicator species displayed unexpected occurrences. It is known that *Noctiluca scintillans* caused blooms in the entire southern Black Sea (Kofoid and Swezy 1921, Feyzioğlu and Sivri, 2003), from the westernmost point to the easternmost part.. Even though sampling covered almost the entire southern Black Sea in this study, the presence of *Noctiluca* was limited to the west and offshore waters of the central region. The number of individuals surprisingly started to decrease from the west to the centre and completely disappeared in the eastern zone. The highest abundance (190,745 ind/m^2) and biomass (16,785 mg/m^2) were observed in the station that was near the Bosphorus region.

As one of the most famous semi-enclosed basins, monitoring indicator species of eutrophication is important for the Black Sea marine ecosystem (which was considered as oligotrophic by Sorokin (1983) in the 1940's). Among the cladoceran species *Pleopis polyphemoides* is considered as a eutrophic species, found to be abundant in the Black Sea in this study. *P. polyphemoides* also displayed a decreasing trend like *Noctiluca* from the west to the east and almost disappeared in the most eastern stations. Another indicator species for eutrophication is *A. clausi*. Comparing the three specified regions of the southern Black Sea showed a decrease in numbers of individuals from west to east. Individuals belonging to *Pontellidae* are copepod species highly sensitive to pollution of the Black Sea. These findings revealed a lower number of eutrophic species particularly in the eastern region.

One of the most important results of this study was the establishment of the first DNA zooplankton database to be generated for the Black Sea. Indeed, there are no DNA barcoding studies for the Black Sea. However, there are a limited number of genetic studies for specific species or groups. Ünal (2006) studied the phylogeography of two species of *Calanus* (copepoda) and found genetic similarities between them as a consequence of ancestral polymorphism. Popa *et al*. (2014) studied the population genetics of *Platynereis dumerilii* (Polychaeta, Nereididae) in the western region of the Black Sea. Shigavona *et al*. (2015) studied the genetics of a non-native copepod species (*Oithona davisae*) in the western and northeastern regions of the Black Sea. Bayha *et al*. (2015) studied the worldwide phylogeography of the invasive ctenophore *Mnemipsis leidyi*.

The DNA barcoding was successful for many zooplankton species in this study. Morphological and molecular identification was successful amongst the copepod species *C. euxinus, P. elongatusi A. clausi, A. tonsa*; the cladoceran species *P. avirostris* and species belonging to Brachyura, Cirripedia and Gastropoda. Some species however did not present good results. Species such as *C. ponticus, P. parvus* and *O. dioica*, which were expected to present successful results, could not be identified. According to Katz *et al*. (2009), unexpected zooplankton species could be the result of sequence-based identification. Also some of the sequence results belonged to the zooplankton species due to contamination. The main conclusion from the results of this study is that, barcoding alone may not be sufficient for species identification for the entire zooplankton community and morphological identification is irreplaceable (seen in Appendix B). However, this method has much potential to be developed further by collecting more samples of more species, so that this will be used by people who may not be specialized in zooplankton identification.

5. SUMMARY AND CONCLUSIONS

Basically, the most important conclusion is that the spatial distribution and composition of zooplankton in the southern Black Sea is successfully described in detail. Other important conclutions can be listed as follows:

- Spatial distribution and compostion of Black Sea zooplankton were examined in 3 different parts of the southern Black Sea namely; west, middle and east. Differences in species composition of inshore and offshore waters of there areas were also examined.

- A total of 19 zooplankton species were identified at species level however, 13 groups could not identified at species level in July 2013. Some species occurred only in certain locations.

- Zooplankton of the Black Sea was made up three main groups: fodder zooplankton, gelatinous organisms and *Noctiluca scintillans*.

- The total zooplankton was showed its highest abundance in the western part of the southern Black Sea, while the total biomass was highest in the middle part due to high biomass values of gelatinous organisms.

- Abundance and biomass values of these 3 groups of zooplankton did reveal a difference between the 3 mentioned parts of the southern Black Sea. These differences could be explained by temperature, circulation system of the Black Sea, primary production, population struction of phytoplankton, competition among zooplankton groups and predator-prey relationships.

- Absence of *Noctiluca scintillans* in the southern Black could also explained with changing physical charactesistics.

- DNA barcoding study for the Black Sea zooplankton was made for the first time in the southern Black Sea. Gene library for marine planktonic organisms achieved for certain species.

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APPENDICES

APPENDIX A: SEQUENCES OF THE POTENTIAL ZOOPLANKTON IN BLACK SEA

Table A.1 COI sequences of the potential zooplankton organisms in Black Sea

Organism	**COI sequence**
Oithona similis	AGATATTGGAACTCTATATCTTTTAACTGGAGTTTGGGCAGGAATAATTGGAACTAGGATAAGTGTTATTATCCGAATTCAACTTTCGTACCCTACTGGTTTTTTGTGTAATGAGCAGCTTTATAATGTAATGGTTACAGCCCATGCTTTTATTATAATTTTTTTTATAGTAATACCGATCTTAATCGGTTGTTTTGGAAATTGGCTAGTTCCTTTAATAATTGGATCTCCAGATATAGCTTTTCCCCGACTCAACAATATGAGCTATTGACTACTAGTCCCTGCTTTGTTCTTACTACTAGTAGGCTCTATAGTAGAATCTGGAGCTGGTACAGGTTGGACAGTGTATCCCCCTCTTAGGTCATACATTTTTCATGGAGGCGCTTCTGTGGATTTTACAATTTTCAGGCTGCATTTAGCAGGAGTTTCTTCTCTCCTAGGCGCCGTGAACTTTATTAGAACAGTATTAAATCTTCGTGCATTAGGCATGCTAATAGACCGGATACCTTTATTCCCTTGAGCTGTGTTTATTACAGCTATTCTTTTACTGCTATCACTTCCCGTGTTAGCTGGGGCAATTACGATATTGCTAACAGACCGAAATTTAAACACTTCATTTTACGATCCCATAGGGGGAGGGGATCCTGTCTTGTACCAACACTTATTTTGATTT
Paracalanus parvus	AAGATATTGGAACACTATATTTACTAGCAGGGGCCTGATCTGGTATGATTGGCACAGGATTAAGAATGATTATTCGTTTAGAATTGGGGCAATCGGGTTCTTTAATTGGCGACGATCAAATTTATAATGTAGTTGTAACAGCCCATGCGTTTATCATAATTTTTTTTATGGTTATACCTATTTTAATTGGAGGGTTTGGAAATTGACTGGTTCCATTAATACTTGGAGCAGCTGATATAGCGTTCCCTCGAATAAATAATATAAGATTTTGATTTTTAATTCCAGCTTTAATTATATTATTATCTAGTTCTCTCGTAGAAAGAGGAGCAGGAACAGGCTGAACTGTATATCCTCCTCTATCTAGGAATATTGCTCACGCAGGAAGTTCAGTAGATTTTGCTATTTTTTCATTGCATTTAGCAGGAGTAAGTTCAATTTTAGGTGCGGTTAATTTTATTAGAACATTAGGAAATTTACGAGTGTTTGGAATATTATTAGACCGAATACCTTTATTTGCATGGGCGGTATTAATTACAGCAGTTTTACTATTATTATCTCTACCTGTCTTAGCTGGGGCTATTACTATATTATTAACAGATCGAAATTTAAATACAACTTTTTATGATGTTGGGGGTGGTGGGGATCCTATTTTATATCAGCATCTATTTTGATTCTTTGGACATCCTGAAGTCTATATTTTAATTTTACCTGGGTTTGGATTAATTTCTCATATTGTAGCTCAAGAAAGAGGAAAAAAAGAAACCTTTGGAGTTTTAGGTATAGTCTATGCTATATTACAGCTTGG

	T
Pseudocalanus elongatus	TTAATAGCTGGGGCATGGGCAGGAATAATTGGTACAGGGTTGAGAATGATTATTCGAATAGAGCTAGGTCAGGCCGGGTCCTTAATCGGGGATGACCAGATTTATAATGTTGTTGTCACAGCACACGCTTTTATCATAATTTTTTTATAGTTATACCAATTTTAATTGGAGGGTTTGGTAATTGGTTAGTCCCTCTTATATTAGGGGCAGCAGATATAGCTTTCCCACGTATAAATAACATGAGTTTTTGATTTTTAATACCTGCCCTAATTATACTTCTCTCAAGTTCTCTAGTTGAAAGAGGCGCAGGCACAGGGTGGACTGTTTACCCTCCGTTATCGAGGAATATCGCACACGCAGGAGGGTCTGTAGACTTTGCTATTTTCTCTCTTCATTTAGCGGGGGTAAGATCTATCTTAGGTGCGGTAAATTTTATTAGTACTTTAGGTAATTTACGAGTATTTGGCATACTTTTAGATCAGATACCATTATTTGCGTGGTCTGTATTAGTAACGGCTATTCTTTTACTACTGTCCTTACCCGTCTTAGCTGGAGCTATTACTATATTATTAACAGATCGAAATTTAAATACTTCTTTTTATGAT
Acartia tonsa	ACTTTATATTTATTAGCAGGTATATGATCAGGAATAGTGGGAACAGGATTAAGAATAATTATCCGAATAGAATTAGGACAAGCTGGAAGGCTAATTGGAGATGATCAAATTTATAACGTAGTGGTTACAGCTCATGCTTTTATTATAATTTTTTTTATGGTTATACCTATTTTAATTGGAGGATTTGGTAATTGATTAGTTCCTTTAATATTAGGAGCTGCAGACATAGCATTTCCTCGAATAAATAATATAAGATTTTGACTTCTATTACCAGCTTTAATTATATTATTATCTAGGTCGCTAGTAGAAAGAGGTGCAGGTACAGGATGAACCGTTTATCCCCCTTTATCAAGCAATATTGCCCATGCTGGCGCATCAGTAGATTTTGCTATTTTCTCGCTTCACCTTGCAGGTGCAAGTTCAATTTTAGGAGCAGTAAATTTTATTTCAACAATTGGTAATTTACGATCTTTTGGAATAGTTCTTGATTTAATACCTTTGTTTGCGTGAGCAGTATTAATTACTGCGGTTTTACTATTATTATCTTTGCCTGTTTTAGCAGGTGCAATTACAATATTGTTAACCGACCGAAATTTAAATTCTTCTTTTTATGATGCAAGTGGAGGAGGAGATCCAATTCTT
Acartia clausi	ATTCGAATAGAGCTAGGCCAAGCCGGTAAACTAATTGGGGATGATCAAATTTATAATGTAGTGGTAACAGCTCATGCATTTATTATAATTTTCTTTATAGTAATGCCGATTCTAATTGGTGGTTTTGGTAATTGGTTAATTCCTTTAATATTAGGTGCTGCTGATATAGCTTTTCCTCGAATGAATAATATAAGATTTTGACTACTTTTACCTGCCTTAGTAATACTTTTATCAAGCTCTTTAGTAGAGAGAGGGGCGGGGACGGGATGAACAGTTTACCCTCCTTTGTCGAGTAATATTGCTCATGCAGGAGCTTCTGTCGATTTTGCTATTTTCTCCCTTCACCTAGCAGGTGCTAGATCGATTTTAGGCGCAGTTAACTTTATTTCAACGATTGGTAATTTACGATCTTTTGGGATAGTAGCTGATCTAATGCCTTTATTCAGGTGGGCAGTAATTATTACAGCGGTGTTGTTATTATTATCTTTGCCTGTTTTAGCAGGAGCTATTACTATGCTTTTAACAGATCGAAACCTTAATTCTTCATTTTATGATG

	CAGGAGGGGGAGGAGACCCAATTTTATATCAGCATTTATTTTGATTTTTCGGACATCCTGAAGTTTATATTCTTATCCTTCCTGGGTTTGGGCTAATTTCTCATATTGTCTCCCAAGAGAGAGGAAAGAGAGAGACATTTGGGATGCTTGGAATAGTTTATGCAATAATATCTATTGGATTACTAGGTTTTGTAGTATGAGCACACCACATGTTTACTGTAGGAATAGATGCAGACACTCGAGCATATTTTACATCTGCTACAATAGTAATTGCAGTTCCAACGGGTATTAAAGTGTTCAGGTGATTAGGAACACTTCATGGGGTGCGTTTAATTTTTTCTCCTTCAATATTATGATCTTTAGGTTTTATTTTTTTATTTACAGTGGGG
Calanus euxinus	ACATTATATTTATTGGCCGGTGCGTACTCAGGAATAATCGGTACGGGACTCAGTATAATTATTCGTCTAGAATTAGGTCAAGCTGGGTCTTTAATTGGAGATGATCAAGTATATAACGTTGTAGTAACTGCACACGCATTTATTATAATTTTTTTTATAGTTATGCCTATTTTAATTGGAGGATTTGGAAACTGATTGGTCCCTTTAATATTGGGTGCAGCAGATATGGCATTTCCTCGTATAAATAATATAAGATTCTGGTTCTTAATGCCAGCTTTAATTATACTTTTGTCAAGATCTCTGGTTGAAAGGGGCGCAGGTACTGGGTGAACCGTGTACCCCCCCTATCCAGAAATGTAGCCCATGCTGGAGCTTCTGTCGACTTTGCTATTTTTTCGTTACATTTAGCTGGGGTGAGATCTATTTTAGGGGCTGTAAATTTTATTAGAACCCTTGGCAATCTTCGAGTGTTTGGTATATTGCTTGATCGAATGCCTCTTTTTGCCTGGGCTGTTCTAATTACTGCGGTCTTACTTCTTTTATCTCTCCCTGTTTTGGCCGGGGCAATTACAATACTACTTACAGACCGAAACCTAAATACGACATTTTATGATGTAGGGGGCGGGGGAGACCCTATTTTATATCAGCACCTATTT
Penilia avirostris	ATGGTAGGTACTGCTTTAAGAATGCTAATCCGAGCTGAACTAGGACAATGTGGAAGAGTAATTGGTGATGAGCAGATTTACAACGTTGTAGTAACAGCTCATGCCTTTGTTATGATTTTCTTTATGGTCATACCAATTTTAATTGGGGGGTTTGGGAACTGATTGGTTCCTTTAATGCTCGGGGCTCCTGATATGGCTTTTCCTCGTTTGAATAATTTAAGATTTTGGCTTCTGCCTCCTTCTTTAACATTGCTTTTAGTAGGGAGAGCTGTTGAAAGAGGTGCTGGTACAGGATGAACCGTTTATCCTCCTTTATCAAGAACAATCGCCCACGCGGGTGCTTCTGTAGATCTTARAATCTTCTCCTTGCATTTAGCGGGGATTTCATCAATCCTCGGAGCTGTAAACTTTATTACGACAATTGTAAATATACGATCTAAAGGAATAACTTTAGATCGTATTCCCCTCTTTGTGTGGGCTGTTGGAATTACTGCTTTATTACTCCTACTTAGACTTCCTGTACTTGCAGGAGCTATCACTATGCTTCTGACAGACCGAAATTTAAATACTTCTTTYTTTGATCCTGCGGGAGGGGGGGACCCTATTCTTTATCAACACTTGTTCTGATTTTTTGGCCATCCGGAAGTTTACATTTTGATCTTGCCTGGGTTTGGTATGATTTCTCATATTATTAGCCACGAAAGGGGAAAAAAAGAAGCATTCGGTACCCTGGGTATAATTTATGCTATAATAGCAATTGGTATTTTAGGATTC

Evadne spinifera	GGTATTTGAGCAGGGATAGTAGGAACTGCTTTGAGTATACTAATTCGAGCTGAATTAGGACAGGCAGGGAGCTTATTAGGAGATGATCAACTTTATAATGTTATCGTTACCGCTCATGCTTTTATTATGATTTTCTTCATGGTTATACCAATCATGATTGGGGGATTTGGGAACTGATTAGTTCCTCTTATGCTCGGGGCCCCAGATATGGCTTTTCCTCGTCTTAATAACCTCAGTTTTTGATTTTTACCTCCAGCACTTACTCTTCTTCTTGCCGGGGGAATGGTAGAAAACGGAGCAGGGACAGGGTGAACTGTCTACCCCCCTCTTTCTGCGGGGATTGCGCATGCAGGGGCTTCAGTAGACCTTAGTATTTTCGCTCTTCATCTTGCTGGGATCTCATCAATTTTAGGGGCTATTAACTTCATTACTACGATCGTGAATATACGATCTCAAGGAATGACGCTTGATCGAATTCCACTCTTCGTTTGATCAGTAGGGATCACTGCTCTTTTACTTCTTTTAAGCTTACCTGTTCTAGCAGGAGCTATTACTATGCTTCTAACGGACCGGAATCTAAACACATCGTTCTTCGATCCTGCAGGGGGAGGGGACCCGATTCTTTACCAACATCTATTC
Evadne nordmanni	GCTGAATTAGGACAGGCAGGGAGCTTATTAGGAGATGATCAACTTTATAATGTTATCGTTACCGCTCATGCTTTTATTATGATTTTCTTCATGGTTATACCAATCATGATTGGGGGATTTGGGAACTGATTAGTTCCTCTTATGCTCGGGGCTCCAGATATGGCTTTTCCTCGTCTTAATAACCTCAGTTTTTGGTTTTTACCTCCAGCACTTACTCTTCTTCTTGCCGGGGGAATGGTAGAAAACGGAGCAGGGACAGGATGAACTGTCTACCCCCCTCTTTCTGCGGGGATTGCGCATGCAGGGGCTTCAGTAGACCTTAGTATTTTCGCTCTTCATCTTGCTGGGATCTCATCAATCTTAGGGGCTATTAACTTCATTACTACAATCGTAAATATACGATCTCAAGGAATGACGCTTGATCGAATTCCACTCTTCGTTTGATCAGTAGGGATCACTGCTCTTTTACTTCTTTTAAGTTTACCTGTTCTAGCAGGAGCTATTACTATGCTTCTAACGGACCGGAATCTAAACACATCGTTCTTCGATCCTGCAGGGGGAGGGGATCCGATTCTTTACCAACATCTATTCTGATTTTTTGGT
Pleopis polyphemoides	TGAGCTGGAATAGTAGGAACAGCGTTAAGTATACTAATTCGAGCTGAGTTAGGACAGGCGGGAAGTCTAATTGGAGACGACCAACTGTACAACGTAATCGTTACAGCTCATGCTTTTGTAATAATTTTCTTCATGGTAATACCTATTATGATTGGAGGATTTGGGAATTGATTAGTTCCTTTAATATTAGGGGCACCTGATATGGCTTTCCCTCGACTTAATAACCTAAGTTTTTGATTCTTACCGCCCGCTTTAACTCTTCTTCTAGCTGGAGGAATAGTTGAAAATGGAGCCGGGACTGGGTGAACAGTTTACCCTCCTTTATCGGCGGGGATTGCCCATGCTGGTGCATCAGTCGACTTAAGAATTTTCTCTCTTCATTTGGCTGGGATCTCATCAATTTTAGGAGCTATTAACTTTATTACTACTATCGTTAATATACGATCTCAAGGAATGACACTTGATCGAATCCCACTATTTGTATGAGCAGTGGGAATTACAGCTCTTCTTTTACTTCTTAGTCTACCAGTATTAGCTGGTGCAATTACAATGCTTCTTACTGACCGTAATCTAAATACGTCATTCTTTGATCCAGCTGGGGGTGGAGACCCGATTCTTTACCAACATCTATTTTGATTTTTTGGTCAC

Pleurobrachia pileus	ATATGAAGGTGGTTGTTCTGAGTTTATCATAAAGATATCGCTGGTTTATATTTTTTTTTTTCCATCATTATGGGTTTTATCGGTTTTTTTACTCGTTGATAATGAGGTTATCTCTTTCTTGGAGTTACTCCTTTATTACTAACGGTGTAGTTTATTTACATTTTGTTACCTTACACGCAGTTTACATGATATTTTTTTTTGTTATGCCTTTTAGTATTGGAGGTTTATCAAATTTACTAATTCCTCTTTGTTTTAGCTTAGCAGATATGTGTTTACCCAGAATTAATAACCTTTCTTTTTGGATGTTATTTTTCTCTTTTGGTTTAACTGTAATTTCTTCCTCCGTTTATTTAGGAGCTAGTTCTGGTTGGACGTTATACCCACCTTACTCTTCTTACCCAGGTTCTTCATGATTATCAACTGATTTTATTATATTTTCCTTACATCTTGCAGGTGCTAGTTGAATTCTTTCTTGAATTAATTTTATAGTAACTATTTTTGTCTTACCTATAAATTATAATTTTTCTTTTTTCCAATATCCTTTGTTTATAGTTGCTCAGCTAACTGTAAGTTTCCTCTTACTGATCTCCTTGCCTGTTCTAGCAGCTGCCATAACTATGTTGCTTTTTGATCGTAATTTCTCTACTTATTTTTTTAGTAATGTTAATGGAGGTGACGCCCTTTTATATCAACATTTGTTTTGGTTCTTTGGACACCCTGAGGTTTATGTTNTAATACTTCCTGCTTTCGCAGTTATATGACACTTTTTATCCTTTTCCATTAATCGTGCTATACCCTTTTCCTATCCTGGGTTAAGTATTGCTATTATTGGTATTGGAGTTTTAGGTTGTGTTGTTTGGGCTCATCATATGTTTACTTCTGGTATGGATATAGATACTAGATTTTATTTTGCTTCTGCTACCTTAATTATAGCAGTACCCACCGGTATTAAAATCTTCTCTTGGTTATTTACTTTACTATCAGACTCCATAATTTATA
Mnemiopsis leidyi	ATTAGATGATTATTTTCTACTAATCACAAAGATATAGCTTCTCTATATTTTTTTTTTTCTATAATTATGGGTTTTTGTGCTTTTTTCTATTCTTTTGTCATGCGTTTAGCTTTAGTTTGACCTTTTGCTTTTATCGAATCTGGTATTATTTATTTATATTACGTCACTTTACATGCTGTTTACATGATTTTTTTTTTTGTTATGCCTTTTAGTATAGGTGGTTTATCAAATTTATTAATTCCATTATGTTTTCATTTGGCTGATATGTGTTTACCTCGTATTAATAATTTATCTTTCTGACTTTTATTTGCTTCTTTTATTATCTCTCTTTTATCCTCTTTTCACTACTATGGTCCAAGTTCAGGATGAACTTTATACCCTCCTTATTCTTCTTATCCTGCTAGTGCCTATTTATCAACTGATTTAATAATTTTCTCTTTACATTTAGCGGGTGCTAGTTCTATATTATCATCCATAAACTTTATAGTTACTGTATTTATTTTACCCATAAATACTTCGTTTTCATTTTTTCAATATCCTTTATTTATTGTCGCCCAAATTACTGTTTCTTTTCTTCTTTTAATATCATTACCTGTATTAGCTGCAGCTATTACTATGTTACTTTTTGATCGTAATTTTAATACTTCTTTTTTTTCAAATTATCTTGGTGGTGATGCTTTACTTTATCAACATTTATTTTGATTTTTTGGCCATCCAGAAGTTTATGTTTTAATATTACCAGCTTTTGCTATTATTTCTCATGTTTTGTCATTTTTAATTAACAGAAATGTACCTTTTTCCTATCCTGGCTTAAATATAGCTATAATTAGTATAGGTTTATTAGGTTGTTTAGTTTGAGCCCATCATATGTTTACTTCGGGTATGGATTTAGATACTCGTTTTTATTTTGCTTCAGCTACCTTAATC

	ATAGCTATTCCTACTGGTATTAAAATTTTTTCTTGAATTTTTACTATTCTTTCTGATACTTTTGTTTT
Aurelia aurita	TCAAGATGATTATTCTCAACTAACCACAAAGATATAGGAACACTATACTTAATATTTGGTGCTTTTTCCGCCATGGTGGGAACTGCCTTCAGTATGATTATAAGACTGGAACTATCAGGCCCAGGATCCATGTTGGGGGACGATCAACTATATAACGTTGTAGTGACCGCTCATGCTCTTATAATGATTTTCTTTTTCGTAATGCCCGTTTTGATAGGGGGATTTGGAAACTGGCTAGTTCCCCTATATATAGGAGCTCCAGATATGGCCTTTCCAAGGCTTAACAATATCAGTTTCTGATTATTACCTCCAGCTTTATTACTATTATTAGGGTCTTCCCTTATAGAACAAGGAGCAGGTACTGGTTGAACCATTTACCCTCCTTTAAGTTCAATACAAGCTCATTCTGGGGGTTCAGTAGATATGGCCATATTTAGTCTTCATTTAGCAGGAGCTTCCTCTATTATGGGTGCTATTAACTTTATTACCACTATTTTAAATATGAGAGCCCCTGGTATGACCATGGATAGAATACCTTTATTCGTATGATCTGTATTAGTTACTGCAATCTTATTATTGTTGTCCTTACCCGTATTAGCTGGGGCAATTACCATGTTGTTGACTGATAGAAATTTCAACACATCCTTCTTTGACCCTGCTGGAGGAGGAGATCCAATACTATTCCAACATTTATTTTGGTTTTTGGACACCCAGAAGTGTATATATTGATTCTACCCGGATTTGGAATTGTATCTCAGATAATACCAACATTTTCTTCTAAGAAACAAATATTTGGGTATCTAGGAATGGTCTATGCTATGATAGCTATAGGTATACTTGGATTTATAGTTTGGGCTCACCATATGTTTACAGTTGGTATGGACGTAGATACTAGAG
Engraulis encrasicolus	GCTGGAATAGTAGGCACGGCCTTAAGCTTGCTCATCCGAGCTGAACTAAGCCAACCAGGTGCCCTTCTTGGGGACGACCAGATCTACAATGTAATCGTTACGGCCCATGCCTTCGTAATGATTTTCTTTATAGTAATACCAATTATGATTGGAGGATTTGGAAACTGACTTATTCCTCTAATGATCGGAGCCCCCGACATGGCATTCCCACGAATGAACAACATGAGCTTCTGACTCCTTCCCCCCTCTTTCCTTCTGCTCCTAGCTTCTTCAGGAGTTGAGGCTGGAGCCGGAACCGGTTGAACAGTCTACCCTCCCCTTGCCGGCAACCTGGCCCACGCAGGGGCATCAGTTGACCTAACTATTTTCTCACTTCACTTAGCAGGGGTTTCCTCAATTCTTGGGGCAATTAACTTCATCACAACAATTATCAATATGAAACCTGCAGCTATTTCTCAGTATCAAACACCACTGTTTGTATGAGCTGTACTAATTACAGCTGTTCTTCTCCTACTTTCCCTTCCAGTCCTTGCCGCTGGTATTACAATGCTCCTTACAGACCGAAACCTAAATACAACCTTCTTCGACCCTGCAGGAGGGGGAGACCCAATCCTTTACCAACACCTA
Trachurus mediterraneus	TTTTATCAGATATTGGGTGCTTGAGCTGGAATAGTAGGAACCGCTTTAAGCCTGCTTATTCGGGCAGAACTAAGCCAACCTGGCGCCCTTCTAGGGGATGACCAAATTTACAACGTAATTGTTACGGCCCACGCTTTCGTAATAATTTTCTTTATAGTAATGCCAATTATGATTGGAGGCTTTGGAAACTGACTGATTCCGTTAATGATCGGGGCCCCTGATATAGCCTTCCCTCGAATGAATAACATGAG

	CTTCTGACTACTCCCTCCCTCCTTCCTTTTGCTTTTAGCCTCTTCAGGGGTTGAAGCCGGGGCCGGAACTGGTTGAACAGTCTATCCCCCACTGGCTGGGAACCTTGCCCACGCCGGAGCGTCCGTAGATTTAACCATCTTCTCCCTTCACCTAGCAGGGGTCTCGTCAATTCTAGGGGCTATTAATTTTATTACCACTATTATTAACATGAAACCTCCTGCAGTCTCAATATATCAAATCCCACTATTTGTTTGAGCTGTCTTAATTACAGCTGTCCTTCTTCTTCTCTCTCTTCCTGTCCTAGCTGCTGGCATTACAATACTTCTAACAGACCGAAATCTAAATACTGCTTTCTTTGATCCAGCAGGAGGGGGAGACCCAATTCTTTATCAACACCTATTC
Mullus barbatus	TCTTATATAGTCTTTGGTGCTTGGGCCGGTATAGTAGGAACTGCTCTAAGCCTTCTTATTCGTGCCGAACTCAGCCAGCCCGGTGCTCTCCTAGGAGATGACCAAATTTACAACGTAATCGTTACGGCCCATGCCTTTGTAATAATTTTCTTTATGGTAATACCAATTATGATTGGAGGGTTCGGCAACTGACTAATTCCATTAATGATTGGAGCCCCCGATATGGCTTTCCCCCGAATGAATAACATGAGCTTCTGGCTCCTTCCGCCCTCATTCCTTCTTCTACTAGCCTCTTCAGGCGTTGAAGCTGGTGCGGGCACCGGTTGGACAGTTTACCCCCCTTTAGCAGGCAACCTAGCACACGCTGGGGCCTCCGTTGACCTAACCATTTTCTCCCTTCATCTGGCAGGCATTTCTTCTATTCTTGGGGCTATTAACTTCATCACCACAATTATTAATATGAAACCCCCAGCAATTTCACAGTATCAGACCCCCCTGTTTGTGTGGGCCGTTCTCATTACAGCTGTTCTCCTCCTTCTGTCGCTCCCCGTTCTTGCTGCTGGCATCACAATACTTCTTACAGACCGAAACCTAAACACAACGTTCTTTGATCCCGCTGGCGGAGGGGACCCTATCCTCTATCAACACCTGTTC
Diplodus annularis	CCTTTATGTTGTATTTGGTGCTTGGGCCGGAATAGTAGGAACTGCCCTAAGCCTGCTCATTCGAGCTGAACTAAGCCAGCCTGGCGCTCTCCTTGGAGACGACCAGATTTATAATGTAATTGTTACAGCACATGCATTTGTAATAATTTTCTTTATAGTAATACCAATCATGATTGGAGGCTTTGGAAACTGATTAATTCCCCTTATGATCGGTGCCCCCGATATAGCATTCCCCCGAATAAATAATATGAGCTTCTGATTACTCCCCCCATCGTTCCTTCTCCTGCTAGCTTCTTCCGGAGTTGAAGCTGGGGCTGGGACCGGGTGAACAGTTTACCCGCCTCTGGCAGGAAACCTTGCCCACGCAGGTGCATCAGTTGACTTAACCATTTTCTCCCTCCCCCTAGCCGGGATCTCATCTATTCTTGGTGCTATTAACTTCATCACCACAATTATTAACATGAAACCTCCCGCTATTTCGCAATATCAAACACCGCTATTTGTATGAGCTGTCCTAATTACTGCCGTATTACTTCTTCTATCTCTTCCAGTCCTTGCCGCAGGCATTACAATACTCCTCACAGATCGAAACCTAAACACCACTTTCTTCGACCCAGCAGGAGGGGGAGACCCAATTCTCTACCAACATCTATTT
Scolelepis squamata	GGAACCCTGTATTTCATACTTGGTATGTGATCAGGTCTCTTAGGGACATCTATAAGACTTCTTATTCGGGCCGAGTTAGGTCAACCTGGCTCCCTTCTTGGAAGGGACCAGCTATACAACACTATTGTAACTGCACATGCATTTTTAATA

	ATTTTCTTTCTAGTTATACCTACATTTATTGGTGGATTTGGGAATTGACTTCTCCCACTTATACTAGGTGCACCAGATATAGCATTCCCCCGTTTAAATAACATAAGATTCTGACTTCTTCCTCCTTCCTTAGCCCTTCTTCTTGCCTCCGCAGCAGTTGAAAAAGGCGTAGGAACAGGGTGAACTGTCTACCCTCCCCTCTCAAGAAACTTAGCTCACGCAGGTCCTTCTGTAGACCTTGCAATTTTCTCTCTACACCTTGCGGGGGTCTCCTCTATTCTTGGGGCTCTAAATTTTATTACCACTGTAGTCAATATGCGGTGAGATGGCCTTCGTCTAGAAAATATCTCACTCTTTGTTTGAGCCGTAACAATTACCGCAATTCTTTTATTACTCTCCCTTCCTGTCCTTGCGGGAGCGATTACCATACTTTTAACAGACCGTAATTTAAATACTTCTTTCTTTGATCCTGCGGGAGGGGGGGACCCTATTCTTTACCAGCATCTATTT
Alitta succinea	GTATATGATCAGGTCTTCTAGGAACCTCTATAAGACTCCTGATTCGAGCAGAACTTGGTCAACCTGGCGCCCTACTTGGAAGAGACCAGTTATATAATACAATCGTCACTGCTCACGCCTTCTTAATGATTTTCTTCCTCGTTATACCAGTTATAATCGGGGGATTTGGTAACTGATTGGTACCTTTAATATTAGGAGCCCCAGATATAGCTTTTCCTCGACTTAACAACATGAGTTTCTGATTATTACCTCCATCTCTAATTCTTTTACTATCCAGGGCTGCAGTAGAAAAAGGAGTTGGTACAGGATGAACTGTGTACCCTCCCCTTTCTAGTAATATTGCCCACGCCGGCCCATCAGTAGATTTAGCAATTTTCTCTCTCCACCTTGCAGGAGTTTCATCCATCATAGGAGCTCTTAACTTCATTACAACAGTTATTAATATACGATCTAAGGGATTACGCTTAGAACGAGTACCCCTATTCGTCTGATCTGTAGTGATTACCGCGG
Nephtys hombergii	CTTCTAGCAACCTCAATAAGACTTCTTATCCGGGCTGAATTAGGACAACCCGGTGCTTTATTAGGAAGAGATCAGCTTTATAATACAATTGTTACTGCTCACGCTTTCTTAATAATTTTCTTCTTAGTAATACCAGTAATAATCGGAGGGTTTGGAAACTGACTTGTTCCATTAATACTAGGAGCCCCTGATATAGCTTTCCCTCGTTTAAATAATATATCTTTCTGACTTCTTCCCCCTTCTTTAATTCTTCTTGTTATATCCGCAGCTGTAGAAAAAGGAGTCGGGACCGGTTGAACCGTTTACCCCCCTCTATCTAGAAACATTGCTCATGCCGGAGCAAGAGTTGACCTTGCTATTTTCTCTCTTCACTTAGCTGGAGCCTCTTCAATTTTAGGGGCCCTAAATTTCATTACTACAGTTATAAACATACGATGAAAAGGACTACGATTAGAACGTGTTCCTTTATTCGTATGAGCAGTTAAAATTACTGCTATTCTTCTACTTTTATCCCTTCCAGTTCTTGCGGGGGCAATTACAATACTTCTTACAGACCGAAACCTAAACACTTCTTTCTTCGACCCTGCAGGGGGAGGAGATCC
Pholoe synophthalmica	GGCACACTATATTTTATTTTTGGAACCTGATCTGGCTTATTAGGCACCTCCATAAGGATGCTTATTCGTGCTGAATTAGGACAACCCGGGTCTTTACTAGGAAGAGATCAGCTTTATAATACAATTGTGACAGCACATGCGTTTCTAATAATTTTTTTCTTAGTCATACCTATCTTAGTAGGAGGGTTCGGTAACTGACTTA

	TTCCCCTTATATTAGGAGCTCCTGATATAGCGTTCCCCCGTTTAAACAACATAAGATTCTGGTTATTGCCCCCCTCGCTAATTCTTTTATTAAGATCCAGTGCAGTTGAAAAAGGGGTTGGGACTGGATGAACAGTCTACCCCCCTCTAGCAGCAAACATTGCCCACGCTGGCCTTCAGTTGACCTAGCTATTTTTTCACTTCATATTGCAGGAGTTTCATCAATTCTAGGGGCATTAAACTTCATCACCACAGTCCTTAATATACGATATAAAGGACTACGATTAGAACGGGTACCTTTATTTGTTTGAGCTGCTAAAGTAACCGCCATTCTATTACTTCTGAGGCTCCCTGTATTAGCTGGTGCAATTACCATACTACTAACAGACCGTAATTTAAACACTGCTTTCTTTGACCCTGCGGGGGGAGGAGACCCAATTCTCTACCAACACTTATTT
Phyllodocidae	ACTTTATATATAATTTTTGGGATTTGATCTGGGCTTCTTGGAACTTCTATAAGAATGTTAATTCGTGCTGAGTTGGGGCAGCCCGGCTCTTTGTTAGGAAGGGATCAGCTTTATAATACAATTGTTACTGCACATGCTTTTTTAATAATTTTTTTTTTGGTTATGCCTGTTATAATTGGAGGGTTTGGAAATTGGTTAGTTCCTTTAATGCTTGGAGCTCCTGATATAGCTTTTCCTCGTTTAAATAATATAAGGTTTTGGTTACTTCCACCTTCTCTCATTATACTTTTAGGGTCTGCTGCAGTAGAGCAGGGTGCTGGTACTGGCTGAACAGTTTATCCTCCCTTATCTAGCAATGTTGCTCATTCAGGTCCTTCAGTTGATTTAGCTATTTTTTCTTTACACTTAGCAGGGGTGTCTTCTATTCTTGCTTCAATTAATTTTATTACCACAGCAATAAATATGCGTTCTAGAGGTCTACGATTAGAGCGGGTTCCTTTATTTGTCTGGTCAGTTGCTATTACTGCTCTGCTTCTTTTACTATCACTTCCTGTTCTAGCAGGTGCTATTACTATATTACTTACTGATCGTAATTTAAATACTTCTTTTTTTGACCCTGCTGGGGGTGGTGATCCTATTTTATATCAGCATCT
Mytilus galloprovincialis	TCTTTATCTATATAGGGGGGTCTGAGGAGGTTTGTTCGGGGCAAGGTTAAGTCTGATAATTCGGATACAGTTAGGGCATCCTGGAGTATTTTTAAAAAGTGACTGGTTTTATAATGTGGTTGTTACAACACATGCCTTAATAATAATTTTCTTTGCTGTAATACCGATCCTAATCGGAGCTTTTGGTAATTGGCTGATTCCTCTATTAGTAGGTGGTAAAGATATAATTTATCCGCGGATAAATAATTTGAGTTATTGGTTATCTCCTAATGCGCTATATTTACTTATATTATCTTTTAGAACGGATAAAGGGGTAGGTGCTGGATGGACTATTTACCCGCCATTGTCTGTATACCCTTATCATAGCGGGCCGAGGATAGATGTTCTTATTGTGTCCTTGCATTTAGCTGGGTTAAGTTCTTTGGTGGGTGCTATTAATTTTGCCAGTACCAACAAAAACATACCAGTTTTAGAGATAAAAGGAGAACGAGCTGAGCTTTATGTCCTATGGATTAGAGTTACTGCCGTATTGCTAATTATTTCTATTCCGGTTTTAGGAGGGGGTATCACAATAATTCTGTTTGATCGGAATTTTAACACAACATTTTTTGATCCAGCAGGAGGGGGTGACCCTGTCTTGTTTCAACATTTGTTC
Scapharca inaequivalvis	TCCGCGGTTAAATAATTTCAGTTACTGAATTTTACCAGGCGCTTTATTTATAGTAATAATATCTGCCTTAATCGAGGGGGGGGTGGGTACTGGCTGGACG

	TTATATCCTCCTTTATCAAGGTGAATTTTTCATAGAAGTCCAGCTTTAGATATAGTAATTCTTTCTCTTCACATTGCAGGATTTGGGTCAATAATAAGTTCTGTAAATTTTATAAGTACAATAATCACAAGTCGGTTTTTTGTTTTAATTCCTGAGCGGATACCTGTTTTTTGTTGGTCGATATTTGTAACGTCTTGGTTACTATTGTTCTCTCTGCCAGTGTTGGCTGGAGGGTTAACTATGTTATTAACGGATCGTCATGTAAATAGCTCTTTTTTTCGTCCTCAAGGTGGTGGGGATCCTTTATTATTTCAACATTTGTTTTGATTTTTTGGTCATCCGGAAGTTTATGTTCTAATTCTCCCCGGGTTCGGGTTAATTAGTCATACAATTATTAAGAGAGGCGGCAAGTTGCGAGTTTTTGGCCTCGCAGGAATGGTATATGCTATACAATCTATTGGAGTATTAGGATTCGTTGTGTGGGCTCACCATATATTTACAGTAGGAATAGACGTTGATAGTCGTGCCTATTTTACTGGAGCAACGATGGTAATTGCCATTCCTACAGGAATTAAAGTTTTCAGATGATTAGCAACTCTTCACGGAAGGGTGCTACTTCGGTATACACCTAGGTTTTGTTGAGTACTGGGGTTTTTATTTTTGTTTACTATAGGCGGCCTAACTGGTGTAATTCTATCACATGGTA
Hydrobia acuta	ATTTTATTTGGTATGTGGTCTGGGTTAGTAGGTACAGCACTAAGTTTGTTAATTCGTGCTGAACTAGGTCAGCCGGTGCGCTTTTGGGTGATGATCAGCTTTATAACGTAATTGTTACTGCTCATGCCTTTGTTATGATTTTTTTTCTTGTAATGCCTATAATAATTGGTGGCTTTGGAAATTGATTAGTGCCTTTAATACTTGGTGCTCCAGATATAGCTTTTCCTCGGCTTAATAACATAAGTTTCTGACTTTTACCTCCTGCTTTGCTATTATTACTTTCTTCGGCAGCTGTAGAGAGAGGAGCGGGGACAGGATGAACCGTGTATCCCCCATTATCTAGTAACATTGCTCACGCGGGGGGGTCTGTAGATTTAGCTATTTTTTCTCTCCACTTAGCGGGTGTTTCTTCTATTCTTGGGGCTGTAAATTTTATTACAACTATCATTAATATACGGTGACGAGGAATGCAGTTTGAGCGGCTTCCGTTGTTCGTATGATCTGTAAAAATTACTGCCATTCTATTATTACTATCTTTACCTGTCTTAGCTGGTGCTATTACTATGCTTTTAACGGATCGAAATTTTAATACTGCATTTTTCGACCCAGCAGGAGGTGGAGATCCTATTTTATAC
Retusa sp.	GACTTTATATATAATTTTTGGAATATGATGTGGTCTTGTAGGAAGAGGGTTAAGGTTACTAATTCGGTTCGAGCTAGGAAATGTTTCAGCTTTTTTAGAGGATGATCATTTTTACAATGTTATGGTCACAGCCCATGTGTTTGTAATAATTTTTTTTATAGTTATACCCTTAATAATTGGGGGGTTTGGGAATTGAATAGTTCCTTTATTAATTGGGGCTCCTGATATAAGGTTTCCTCGGATAAATAATATAAGATTTTGGCTTCTTCCTCCTTCTTTTATCTTATTATTAGTATCAAGAATAATTGAAGGAGGGGCAGGGACAGGATGAACTGTTTATCCTCCTCTATCAGGGCCGATTGCACACGGTTCTACATCTGTAGATTTAGTTATTTTTTCCCTACATCTTGCTGGAATATCATCAATTTTAGGGGCTATTAATTTTATTACTACTATCATTAATATACGTTCCCCAGGGATTACATTTGAACGTTTAAGTTTATTTGTTTGGTCAGTTTTTGTGACAACATTAAAGATGTTACTTTTATTACCTGAA

	ACGGCGTGAACTATTATACAACTTTTTACACATTGAAATTTAAATACTAGGTTTTTTGATCCAGCAGGAGGGGGGGACCCAATCTTATATCAACATTTATTT
Haminoea navicula	AATCATAAAGATATTGGAACACTATATATAATCTTTGGNATGTGATGTGGTCTAGTAGGTACGGGACTTAGTCTGCTAATTCGGTTCGAACTAGGAACAGCATCAGCTTTCCTTGGAGATGATCACTTTTATAATGTAATTGTTACGGCTCATGCCTTTGTAATAATTTTTTTTATAGTTATGCCTCTAATAATTGGAGGATTTGGAAATTGAATGGTTCCTCTGTTAATTGGGGCTCCTGACATGAGTTTTCCTCGAATGAATAATATAAGTTTTTGACTTTTACCACCTTCTTTCATTCTTTTACTAGTTTCTAGTATAGTCGAAGGAGGGGCCGGGACAGGGTGAACTGTATACCCCCCTCTCTCTGGACCTATCGCTCATGGGTCTTGTGCTGTGGACTTAGCTATTTTCTCACTTCACTTGGCGGGTATGTCATCTATTTTAGGTGCTATTAACTTCATTACGACGATTATTAACATACGGGCTCCTGGTATCACTTTTGAGCGACTAAGCCTATTTGTTTGATCAGTGTTCGTTACTGCCTTCTTACTTTTACTATCTCTTCCCGTCTTGGCTGGGGCTATTACTATGCTTTTAACTGATCGAAACTTTAATACGAGGTTCTTTGATCCGGCAGGAGGTGGTGACCCTATTCTCTACCAACACCTGTTTTGATTTTTTGGTCACCCTGAA
Tergipes tergipes	TACTTTGTACATATTTTTAGGTATGTGATGCGGCCTAGTTGGTACTGGGTTAAGTTTATTAATTCGGTTTGAATTAGGTACTGCTGGTGCTTTGCTAGGTGATGATCATCTTTACAATGTAATTGTAACTGCCCATGCTTTTGTTATAATTTTTTTCATGGTTATGCCTTTAATAATTGGGGGTTTTGGTAATTGGATAGTTCCTTTACTAATTGGTGCTCCTGATATAAGGTTCCCTCGAATAAATAACATAAGGTTTTGGTTGTTGCCCCCATCTTTCTTACTTTTACTTTCGAGAACTCTTATAGAAGGGGGTGCAGGTACTGGTTGGACAGTTTACCCTCCTCTTTCTGGTCCTATAGGTCATGGAGGATGTTCAGTAGACTTGGCTATTTTTTCTTTACACTTAGCAGGTATGTCTTCTCTGTTGGGGGCTATTAACTTTATTACTACTATTTTTAATATGCGATCTCCGGAGATAACGTGAGACCGGTTAAGGTTGTTTGTGTGGTCTGTTCTTGTAACTGCTTTTCTTTTGTTACTATCTCTTCCTGTTCTAGCTGGTGCTATTACTATGTTGCTTACAGATCGTAATTTTAACACTAGTTTTTTTGATCCTGCGGGGGGTGGTGACCCTATTCTTTACCAGCATTTATTCTGATTTTTCGGACATCCTGAAGTGTATATTTTAATTCTTCCTGGGTTTGGTATAATCTCTCATATTTTGAGAAACTTTTCTTCTAAGCCTGCTTTTGGGACTTTAGGGATGGTTTATGCTATAATTTCTATTGGGGTTCTTGGGTTTATTGTCTGAGCTCACCATATGTTCACTGTTGGAATGGATGTAGATACTCGGGCTTACTTTACTGCTGCTACTATAGTAATTGCTGTTCCTACTGGGATTAAAATTTTTAGGTGGTTGATAACTCTTTACGGTAAACGAGGTCCTATGACTGCTTCTATGTATTGAGTTCTTGGGTTTATTTTTCTTTTCACTTTAGGAGGGCTTACTGGTATTATTCTTTCTAATTCTTCTTTAGACATTGTCTTACATGATACTTATTATG

	TTGTTGCTCACTTTCATTATGTGTTGTCAATGGGTGCGGTATTTGCTATTTTTGGAGGCTTTGTTTATTGATTCCCTATGATAACTGGTGTAACCCTTCATGACCGGTGAGCTAAGGCTCAGTTTGTTTTAATGTTTAGGGCTGTAAACATCACTTTCTTTCCTCAACATTTTTTAGGGCTTTCTGGAATGCCTCGGCGTTATTCGGGCTACCCAGATGTTTTCTACAAGTGAAACCAGGTGTCTTCTTTTGGGTCTTTACTGTCAGTGTTTGCAGTGCTTATGTTTATTTTCTTACTTTGAGAAGCTTTACAGTCACAGCGTGGTGTTCTTTTTTCTCGGGCTCCTTCGCTTTCCCGGGAGTGGGTTGATGTTCTTCCTCTTGATTTTCATAGCAACACTGAGAGGTCTGTTTCTTGTATTTAATTAGAAGTTAAGAGTGTAGTATAAATTACATTTCAGTTACATTGAAAAGATCCTTACGATAGGCGCTCTTATTATTGGTTTAAATTATTTAATTTAGTTTGATTATTAAAAATTACAGTGATGGAATTAAATTTATATAAAAATTTTGGTTGATCTTACCTTTTGTATAATGGTTTTACTATAATAAAATTATTTTATTGTTCCCGAATTAAGAAGAGCTAACTATAGACTTCTCTTAGGATTATACGGCTTATGTGGAAATATGGGCTCTAGATTTATAGTTAGGGGTGAAATTCCTTCAATTTTTAGGGTATCTGGAAGCTGGGGAAAAGCATTTAGTGCTTAAAAGTGAGGTGTAAAGTGTTTAGATTTTACACATAGAGGATTATAATTTAAATTAGAGATTCTAGGGTTAAACTCCTTGATTATTTTTAAACTACAAATTAATTTTTTTTAAATCTCTTATCATACCCAGCATTTCTTTTTAACTTTTTAAAGAAGTTACAATGTAAAAATTAGTAATAATTGTTTTAAATAAGTTTATTAGTTTAATTACTATACTTTTTTATTTTTAAATAGTTTTAAGGAACTCGGCAAAAATAGACTTGGACTGTTTAACAAAAACATAGCCACTTGAATATATTTGGGTTTAACCTGCCCAATGTAACTAATATGAATGCCCGCGGTACCTTGCCCGTGCTAAGGTAGCGTAATCAGTTGGCTTTTAAATGGAGTCAGGTATGAATGGGATAACTGGGTCTAGCTGTCTCAGAAATATTTTTTTGAATTTACTGTTTAAGTGAAAAAGCTTAAATTTTATAAAGGGACGAGAAGACCCTTGGAATTTTTTTTAATTTAGGATTATTCCTGATGTTATTTTGTTGGGGCGACATAGAAATAGTTAAAACTTTCTTTATAACATGAGTCGGAATTTTCAGGAAAAGATAAATTACCCAAGGGATAACAGCATAATTCTATAAATGAGTTTGTGACCTCGATGTTGGACTAGGAAGCTGGCAGGTTAGCTGCTTGTCGTGCGAATTCTGTTCGAATTTTAACTCCT
Upogebia	TACATTATATTTTATATTTGGAGCATGAGCCGGAATAGTGGGAACTTCACTAAGATTGGTTATTCGAGCAGAATTAGGTCAACCTGGAAGATTAATTGGAGATGACCAAATTTATAATGTTGTTGTTACCGCCCACGCCTTCCTTATAATTTTTTTTATAGTTATACCTATTATAATCGGAGGTTTTGGAAATTGACTAGTACCCCTTATATTAGGAGCTCCTGATATAGCTTTTCCCCGTATAAATAATATAAGATTTTGACTTTTACCTCCATCATTAACACTACTTTTAATAAGAGGAATAGTAGAAAGAGGTGTTGGGACAGGATGAACAGTTTACCCTCCTTTATTAGCAGCCATTTCCCACGCAGGTGCTTCCGTTGATATGGGTATTTTTTCTCTTC

	ATTTAGCAGGTGTGTCATCAATTTTAGGAGCAGTAAATTTTATTACCACAGTTATTAATATACGATCTGTAGGGATAACTATGGATCGAATACCCCTATTTGTATGATCAGTATTTATTACTGCTATTTTATTACTTCTATCTCTACCAGTTTTAGCTGGAGCTATTACTATACTTTTAACAGATCAAAATTTAAATACCTCATTTTTTGACCCAGCTGGAGGAGGAGATCCTATTTTATACCAACATTTATTT
Xantho poressa	TGTTCTCTACCAACACTTATTTTGATTTTTTGGCCATCCAGAGGTTTATATTCTAATTCTTCCCGCCTTTGGTATAATCTCCCATATTGTAAGACAAGAATCAGGGAAAAAAGAATCTTTCGGTACATTAGGGATGATTTACGCTATGTTGGCTATTGGTGTTCTAGGATTCGTCGTATGAGCTCATCACATGTTTACAGTAGGTATGGATGTGGATACCCGGGCGTACTTTACTTCTGCTACTATAATTATTGCGGTCCCCACCGGTATTAAAATTTTCAGATGATTAAGAACCTTACACGGCACTCAAATTTCTTACAGACCTTCGTTACTTTGAGCATTAGGGTTTATCTTCCTCTTCACAGTTGGAGGTTTAACCGGGGTCGTACTAGCTAACTCTTCTATTGACATTATCCTTCATGATACATACTATGTCGTCGCTCATTTCCATTATGTACTGTCTATAGGAGCTGTATTTGGAATCTTCGCTGGAATTGCCCATTGATTCTCATTATTCACTGGCCTTTCCTTAAATCCTAAATGGTTAAAAATTCATTTCTTCGTCATGTTTGTTGGTGTTAATACAACCTTCTTTCCTCAGCATTTCCTAGGACTGAACGGTATACCTCGGCGTTACTCC
Rhithropanopeus harrisi	TACATTATATTTTATTTTTGGAGCATGAGCTGGTATAGTAGGAACCTCATTAAGTTTAATTATTCGAGCTGAACTAGGTCAACCTGGTACCCTCATTGGTAATGACCAAATTTACAATGTTGTAGTAACAGCTCACGCCTTTGTAATAATCTTTTTCATAGTTATACCCATTATAATTGGAGGATTTGGTAATTGACTAGTTCCATTAATATTAGGAGCCCCTGATATAGCATTTCCTCGTATAAATAATATAAGATTCTGACTTTTACCACCATCACTTACACTCCTCCTAATAAGAGGAATAGTAGAAAGAGGAGTTGGAACAGGATGAACTGTATATCCTCCTTTAGCTGCTGCTATTGCTCATGCAGGAGCCTCCGTTGATATAGGAATCTTCTCCTTACATTTAGCAGGTGTTTCTTCTATTTTAGGTGCCGTTAATTTTATAACAACCGTAATTAATATACGATCATTTGGTATAACTATAGACCAAATACCATTATTTGTTTGAGCAGTATTTATTACTGCTATTTTATTACTTTTATCTTTACCTGTATTAGCTGGAGCCATTACTATACTTTTAACTGATCGTAATTTAAATACCTCATTTTTCGATCCTGCTGGAGGAGGAGACCCTATTTTATACCAACATTTATTT
Crangon crangon	ATTTTAATCCTGCCTGCCTTTGGAATAATTTCTCATATTATTAGACAAGAAAGAGGTAAAAAAGAAGCCTTTGGTACCCTTGGTATAATTTATGCTATAATAGCAATTGGGGTTTTAGGTTTTGTAGTATGAGCACATCATATATTCACAGTAGGTATAGATGTGGACACACGAGCATACTTCACTTCAGCAACTATAATTATTGCTGTCCCTACAGGTATTAAAATTTTCAGATGACTAGGTACTCTTCAT

	GGTACTCAACTTTTTTATAGACCTTCATTAATATGAGCTCTTGGATTTGTTTTCCTTTTCACAGTTGGAGGTTTAACAGGAGTAGTTCTAGCTAATTCATCAATTGATATTCTCTTACATGATACATATTATGTAGTAGCACATTTCCATTATGTATTATCTATAGGGGCGGTGTTTGGTATTTTTGCAGGATTAATTCATTGATTCCCTTTATTTACAGGCCTATCATTAAATGATAAATTATTAAAAATTCATTTTATCACTATATTTGTAGGAGTAAATATTACTTTCTTCCCTC
Palaemon elegans	ATTTTATTTTCGGAGCTTGAGCAGGAATAGTAGGGACTTCTCTAAGACTTTTAATTCGAGCTGAATTAGGTCAACCTGGTAGGTTAATCGGAAATGACCAAATTTATAATGTTATTGTTACCGCCCACGCTTTCGTTATAATCTTTTTTATGGTTATGCCAATTATAATTGGCGGGTTTGGAAATTGACTGGTACCATTAATGCTAGGAGCCCCTGATATGGCTTTTCCACGAATAAATAATATAAGGTTTTGACTTTTACCCCCTTCCTTAACTCTCCTTCTTTCTAGAGGGATGGTTGAAAGGGGAGTGGGAACAGGATGAACTGTTTACCCTCCTCTAGCGAGAGGATTAGGACATGCTGGCGCTTCTGTAGATCTTGGTATTTTCTCCCTTCATTTAGCAGGAATCTCTTCCATCCTAGGAGCAGTTAACTTTATTACTACTGTAATCAATATACGAGCTCCAGGTATAACTATAGATCGAACTCCTCTTTTCGTGTGGGCTGTTTTTCTAACAGCTATTCTTCTTTTACTATCCTTACCAGTTTTAGCAGGGGCTATCACCATGCTCCTTACTGACCGTAATTTAAATACTTCATTCTTTGATCCTGCTGGAGGGGGTGACCC
Athanas nitescens	CGCTATATTTTATTTTCGGAGCCTGAGCCGGGATATTAGGCACATCCCTCAGACTATTAATTCGAGCGGAGCTAGGACAACCAGGAAGCCTTATTGGAAATGATCAAATTTATAATGTAATTGTTACCGCCCATGCCTTTATTATGATTTTTTTTATAGTCATACCTATTATAATTGGAGGCTTCGGTAATTGACTGATCCCACTTATATTAGGTGCCCCGGACATAGCCTTCCCCCGGATGAATAACATAAGGTTCTGGCTATTACCACCATCTCTCACGCTACTACTATCTAGAGGAATAGTAGAAAACGGGGTTGGAACAGGATGAACTGTATACCCTCCTCTGTCAACCAATATCGCACATGCAGGGGCCTCGGTGGACCTTGGTATTTTCTCTCTTCACCTGGCAGGAGTCTCTTCGATCCTAGGAGCTATTAACTTTATAACTACTGTTGCTAATATACAACCAGGTGGTGTAACTTTTGACCAACTATCTCTTTTCACCTGATCTGTCTTTCTCACAGCCATTTTACTCCTACTCTCCCTACCAGTCTTAGCGGGAGCAATTACAATACTTCTTACAGACCGAAACCTCAACACATCTTTCTTTGATCCTGCAGGAGGAGGAGACCCTATTCTCTACCAACACTTATT
Alpheus sp.	GAAGTTTATATTCTAATTCTACCAGCTTTCGGTATAATCTCCCACATTATTAACCAAGAGTCTGGTAAAAAAGAAGCATTTGGAACCCTAGGTATAATCTACGCCATAGCAGCAATTGGAATCCTAGGATTTGTAGTATGAGCCCACCACATATTTACAGTCGGCATGGACGTTGACACGCGGGCCTACTTCACATCAGCCACTATAATTATTGCAGTTCCCACTGGAATTAAAATTTTCAGGTGGCTGG

	GCACCCTCCATGGAACACAATTCACCTACAGACCGTCCCTCCTATGGGCCCTAGGGTTTGTATTCTTATTCACAATGGGAGGACTAACTGGCGTGGTCCTAGCTAACTCTTCTATCGATATCATCCTCCACGACACGTACTATGTCGTAGCACACTTCCACTACGTCTTATCAATAGGAGCAGTGTTTGGAATTTTCGCCGGAATCGCCCACTGGTTCCCCCTATTTACCGGCCTATCCCTCAACCCCCAGTGACTTAAAATACACTTCTTTACTATATTTATTGGGGTAAACATTACATTCTTCCCC
Diogenes pugilator	GGCTCTTCACTCAGGGTGCTAGTGCGCCTAGAGTTAGGTCAGCCAGGGGGCTTAATTGGAGACGATCAGATCTACAATGTAATTGTTACAGCTCACGCTTTCGTTATAATTTTCTTTATAGTTATACCTATTATAATTGGGGGGTTTGGAAATTGGCTGGTACCTTTAATGTTAGGTGCGCCAGATATGGCTTTCCCACGTATAAACAATATAAGGTTCTGGTTGTTACCTCCTTCTTTAACCCTTCTCCTAAGTAGTGGTTTAGTTGAGAGAGGGGTAGGGACAGGGTGAACTGTTTATCCTCCCTTAGCGTCTGGTATTGCTCATGCCGGGGCTAGGGTTGACCTGGGTATTTTTTCTTTACATTTAGCTGGGGCTTCTTCTATTCTAGGGGCTGTTAATTTTATCTCTACTGTGATTAATATACGCAGGCCTGGTATAACTTGGGATCGGCTGCCTTTGTTCGTGTGGTCTGTCTTTATTACAGCGGTGTTACTGCTATTGTCGCTTCCGGTCCTCGCCGGGGCTATTACTATACTTTTAACAGATCGGAATTTAAATACTACTTTTTTTGACCCAACTGGGGGAGGGGATCCGATCTTGTACCAGCATCTATTTTGATTCTTTGG
Pachygrapsus marmoratus	TGGTATAGTTGGAACCTCTTTAAGTTTAATCATTCGAGCAGAACTTAGACAACCAGGTAGTTTAATTGGTAATGATCAAATCTATAATGTTGTTGTTACAGCTCATGCTTTTGTTATAATCTTTTTTATAGTTATACCGATTATAATTGGTGGATTTGGAAACTGGCTTGTTCCTTTGATATTAGGAGCCCCAGATATAGCTTTTCCGCGAATAAATAATATAAGATTTTGACTTTTACCTCCCTCCTTATCTCTCTTACTTACAAGAAGAATAGTGGAAAGTGGTGTGGGCACCGGATGAACTGTCTACCCACCCCTCGCCGCCGCTATCGCTCATGCCGGAGCCTCAGTTGATTTAGGAATTTTTTCTCTTCACCTAGCGGGTGTTTCCTCAATCCTAGGAGCCGTTAATTTTATAACTACTGTTATCAACATACGCTCTTATGGTATGACAATAGACCAAATACCATTGTTTGTTTGAGCAGTCTTTATTACTGCTATCCTTCTCTTGCTTTCCTTACCTGTATTAGCAGGCGCTATTACTATATTATTAACTGACCGTAACTTAAATACTTCATTCTTTGATCCTGCTGGGGGGGGTGACCCTGTCCTCTACCAACATTTATTC
Macropodia	CACTTTATATTTTATTTTTGGAAGGTGATCAGGAATAGTAGGTACTGCCTTAAGAATGATTATCCGAACCGAACTTGGTCAACCAGGAACATTTATTGGAAATGACCAAATTTATAACGTTATTGTTACAGCCCACGCTTTTGTAATAATTTTTTTTATAGTAATACCAATTATGATTGGAGGATTTGGAAATTGATTAGTTCCTCTTATACTAGGAGCCCCTGATATGGCTTTCCCTCGAATAAATAATA

	TAAGATTTTGATTATTACCCCCAGCTTTAACCTTACTACTTATAAGAAGAATAGTAGAAAGAGGAGTAGGAACTGGTTGAACAGTTTATCCTCCTTTATCAAGATCTATTGCTCACGCAGGAGCTTCAGTTGACATAGGAATTTTCTCTCTTCATTTAGCTGGTGTTTCTTCAATTCTAGGAGCTATTAATTTTATTACTACAGTAATTAATATACGATCATACGGGATAAATTTAGATCAAATACCTTTATTTGTATGATCAGTATTTATTACTGCTATTTTACTTCTTTTATCACTTCCAGTTCTTGCAGGAGCAATTACAATATTACTTACAGACCGAAATTTAAATACTTCATTCTTCGATCCAAGAGGAGGAGGCGATCCTATTCTTTATCAACATTTATTC
Balanus	TTGGTTCTACTCTATCTTTTATTAGAGCCTTAGGATTTATTTATATTATTTGAGAAGCTATAGTATCACAACGACCTACAATTTTTAGTCCAAATTTATCTTCTAATTTAGAATGAGTTCATACTACTCCTCCTCACTATCATAGTTATGATGAACTTCCACAATTTACTATTCGATAATTCTATAAAATAAATATAGTAGATTTTTAATCTACCTAAAGTTTAATACTTAAGAATTTTAACCTTTTTAAGGTTACGATAGGTGAATCTGTAAGACCTCGAACAACCTTCCTAGTGGTATTCCTTTGTTACACTTATATCTCCGATGACCAGCCGGCCGGCTTTAGTATAATGGTCAAAGGAGCTATAGTTGTAACAAAGGGATACTGCTAAGAAGGTTGTACGAGGTTTTATAAGTTCACCCAGATTGTTACGATATTTATATATTTATTATATATCTATGTTTAACCTACAAGAAATAAACCTTTACTAAGGTCTTGTGGTCTGAAATGGCAGATTAGTGCTGTAGATTTAAGATCTACCCAAAAAGGTTTAAGTCCTTTTTTCAGAATTTAATGTCAACATGATCACAATTAAGTTTTCAAGATAGAGCTTCCCCATTAATAGAAGAATTAATTATATTCCACGACCACGCAATATTAGTTTTAACTTTAGTAACAACTTTAGTTGCTTATATTATTTTAACAATATTTAGAAATAAATTTGTAGACCGATTCCTTTTAGAAGGGCATTTAATTGAAGTAATTTGAACAG
Phoronis	AAAGATATTGGAACATTATATTTAATTTTCGGAGTGTGAACAGGATTAGTAGGAACTGGGCTAAGAGCTTTAATTCGATTAGAATTAGGTCAACCTGGGACTCTTTTAGGAGATGATCAATTGTATAATGTAATTGTTACAGCTCATGCTTTTGTTATAATTTTTTTTATAGTAATGCCTGTCATAATAGGGGGGTTTGGAAACTGGCTGGTTCCTTTAATAATTGGAGCTCCAGATATAGCTTTTCCACGACTAAATAATATAAGTTTTTGATTACTACCCCCTTCTCTTATACTCTTGTTAAGCTCTGCTGCAGTAGAGAGAGGAGTTGGAACTGGCTGAACAGTCTACCCTCCTTTAGCAGGAAATATTGCACATAGAGGAGGTTCTGTAGACTTAGCCATTTTTTCTTTACATCTAGCAGGAATTTCTTCTATTTTAGGTTCAATTAACTTTATTACGACAGTAATTAATATACGATGAGAGGGCTACCAATTAGAGCGTGTTCCGCTGTTTGTGTGGTCTGTCAAGTTTACTGCGATTTTACTTGTTTTATCTTTACCTGTACTGGCTGGGGCAATTACTATATTATTAACTGACCGGAACTTTAATACTTCTTTTTTTGACCCAGCAGGAGGGGGGGATCCAATTTT

	ATATCAGC
Verruca	TTGGTTCTACTCTATCTTTTATTAGAGCCTTAGGATTTATTTATATTATTTGAGAAGCTATAGTATCACAACGACCTACAATTTTTAGTCCAAATTTATCTTCTAATTTAGAATGAGTTCATACTACTCCTCCTCACTATCATAGTTATGATGAACTTCCACAATTTACTATTCGATAATTCTATAAAATAAATATAGTAGATTTTTAATCTACCTAAAGTTTAATACTTAAGAATTTTAACCTTTTTAAGGTTACGATAGGTGAATCTGTAAGACCTCGAACAACCTTCCTAGTGGTATTCCTTTGTTACACTTATATCTCCGATGACCAGCCGGCCGGCTTTAGTATAATGGTCAAAGGAGCTATAGTTGTAACAAAGGGATACTGCTAAGAAGGTTGTACGAGGTTTTATAAGTTCACCCAGATTGTTACGATATTTATATATTTATTATATATCTATGTTTAACCTACAAGAAATAAACCTTTACTAAGGTCTTGTGGTCTGAAATGGCAGATTAGTGCTGTAGATTTAAGATCTACCCAAAAAGGTTTAAGTCCTTTTTTCAGAATTTAATGTCAACATGATCACAATTAAGTTTTCAAGATAGAGCTTCCCCATTAATAGAAGAATTAATTATATTCCACGACCACGCAATATTAGTTTTAACTTTAGTAACAACTTTAGTTGCTTATATTATTTTAACAATATTTAGAAATAAATTTGTAGACCGATTCCTTTTAGAAGGGCATTTAATTGAAGTAATTTGAACAG
Botryllus schlosseri	TTGTATTTTATTTTTAGAATTTGGTCAAGATTTATTGGTACTGGAATAAGTGTCTTCATTCGTTTAGAATTGTCTCAAGTAGGTCAAGTGGTTAGAGATAGGCAATTGTATAATGTAATTGTAACTGCTCATGCTTTTGTGATGATTTTCTTTTTTGTTATACCTATGATAATTAGGAGGTTTGGTAATTGGTTATTACCTTTGATAGTGGGGAGTCCAGATATGGCTTTTCCTCGATTAAATAATATAAGTTTTTGATTGTTGCCCCCTGCTTTGTTTTTTCTTTTTAGAAGTTCTATAATTGAAAGTGGAGTTAGGACTGGGTGAACTGTTTATCCTCCCCTTTCTAGAAATCTAGCTCATTCTAGAGCTGCTTTGGATTGTGCTATTTTTTCTTTACATTTGGCTAGAGTGTCTAGTATTTTAAGATCTCTTAACTTTATGACTACTTTGTTTAATATAAAGGTAAAAGGTTGGGGACTCTTTTCTATATCTTTGTTTTGTTGAACTGTATTGGTCACTACTATTTTGTTATTACTATCTTTACCTGTTTTGGCAGCTGCTATTACTATGTTATTGTTTGATCGAAATTTTAATACTTCTTTTTTTGACCCG

APPENDIX B: LIST OF IDENTIFIED ZOOPLANKTON AND FISH SPECIES VIA BARCODING

Code Name	Morhphological findings	Molecular findings	Accession
B3	*Spicara flexuosa*	*Spicara flexuosa*	KP136713
bsex-071-CHS-3	*Parasagitta setosa*	*Parasagitta setosa*	KP136550
bsex-071-clapen-1	*Penilia avirostris*	*Penilia avirostris*	KP136551
bsex-071-clapen-2	*Penilia avirostris*	*Penilia avirostris*	KP136552
bsex-071-claspi-3	*Evadne spinifera*	*Evadne spinifera*	KP136553
bsex-071-cop-acl-1	*Acartia* sp.	*Acartia clausi*	KP136554
bsex-071-copcale-1	*Calanus euxinus*	*Calanus euxinus*	KP136555
bsex-071-coppse-5	*Pseudocalanus elongatus*	*Pseudocalanus elongatus*	KP136558
bsex-071-ENGRA-EQ-3	*Engraulis encrasicolus*	*Engraulis encrasicolus*	KP136560
bsex-071-ost-1	Cirripedia	*Amphibalanus improvisus*	KP136562
bsex-071-ost-2	Cirripedia	*Amphibalanus improvisus*	KP136563
bsex-071-ost-3	Cirripedia	*Amphibalanus improvisus*	KP136564
E1	*Engraulis encrasicolus*	*Engraulis encrasicolus*	KP136715
E4	*Engraulis encrasicolus*	*Engraulis encrasicolus*	KP136718
F1	*Merlangius merlangus euxinus*	*Merlangius merlangus*	KP136720
F2	*Merlangius merlangus euxinus*	*Merlangius merlangus*	KP136721
F3	*Merlangius merlangus euxinus*	*Merlangius merlangus*	KP136722
F4	*Merlangius merlangus euxinus*	*Merlangius merlangus*	KP136723
F5	*Merlangius merlangus euxinus*	*Merlangius merlangus*	KP136724
H1	*Mullus barbatus*	*Mullus barbatus*	KP136730
H2	*Mullus barbatus*	*Mullus barbatus*	KP136731
H4	*Mullus barbatus*	*Mullus barbatus*	KP136732
H5	*Mullus barbatus*	*Mullus barbatus*	KP136733
J1	*Gaidropsarus mediterraneus*	*Gaidropsarus mediterraneus*	KP136735
L1	*Psetta maxima*	*Psetta maxima*	KP136736

M1	*Serranus hepatus*	*Serranus hepatus*	KP136737
M2	*Serranus hepatus*	*Serranus hepatus*	KP136738
2B-3	bentic species	*Phyllophora* sp.	KP136544
2B-5	bentic species	*Cystoseira baccata*	KP136545
2B-8	bentic species	unidentified Polychaeta	KP136546
2B-11	bentic species	unidentified Polychaeta	KP136539
2B-17	bentic species	unidentified Sabellida	KP136540
2B-20	bentic species	unidentified Polychaeta	KP136541
2B-22	bentic species	unidentified Sabellida	KP136542
2B-23	bentic species	unidentified Bangiophyceae	KP136543
2C-1	bentic species	unidentified Rhodophyta	KP136547
bsex-072-BRAC-SP1-3	Brachyura sp1	unidentified Brachyura	KP136567
bsex-072-BRAC-SP2-1	Brachyura sp2	unidentified Brachyura	KP136568
bsex-072-CHS-1	*Parasagitta setosa*	*Parasagitta setosa*	KP136570
bsex-072-CHS-2	*Parasagitta setosa*	*Parasagitta setosa*	KP136571
bsex-072-CHS-3	*Parasagitta setosa*	*Parasagitta setosa*	KP136572
bsex-072-CLA-PEN-1	*Penilia avirostris*	*Penilia avirostris*	KP136573
bsex-072-CLA-PEN-2	*Penilia avirostris*	*Penilia avirostris*	KP136574
bsex-072-COP-ACL-1	*Acartia* sp.	*Acartia clausii*	KP136576
bsex-072-COP-ACL-2	*Acartia* sp.	*Acartia clausii*	KP136577
bsex-072-COP-ACL-3	*Acartia* sp.	*Acartia clausii*	KP136578
bsex-072-COP-CAL-1	*Calanus euxinus*	*Calanus euxinus*	KP136579
bsex-072-COP-CAL-3	*Calanus euxinus*	*Calanus euxinus*	KP136580
bsex-072-COP-PAR-1	*Paracalanus parvus*	*Paracalanus parvus*	KP136582
bsex-072-engra-EQ-1	*Engraulis encrasicolus* egg	*Engraulis encrasicolus*	KP136583

bsex-072-engra-L-2	*Engraulis encrasicolus* larvae	*Engraulis encrasicolus*	KP136584
bsex-072-OST-1	Cirripedia	*Amphibalanus improvisus*	KP136585
bsex-072-OST-2	Cirripedia	*Amphibalanus improvisus*	KP136586
bsex-072-OST-3	Cirripedia	*Amphibalanus improvisus*	KP136587
bsex-117-chs-1	*Parasagitta setosa*	*Parasagitta setosa*	KP136588
bsex-117-chs-2	*Parasagitta setosa*	*Parasagitta setosa*	KP136589
bsex-117-chs-3	*Parasagitta setosa*	*Parasagitta setosa*	KP136590
bsex-117-cla-ost-1	Cirripedia	*Amphibalanus improvisus*	KP136591
bsex-117-cla-ost-3	Cirripedia	*Amphibalanus improvisus*	KP136592
bsex-117-copaca-1	*Acartia* sp.	*Acartia clausii*	KP136593
bsex-117-copaca-2	*Acartia* sp.	*Acartia clausii*	KP136594
bsex-117-copaca-4	*Acartia* sp.	*Acartia clausii*	KP136595
bsex-117-copcal-2	*Calanus euxinus*	*Calanus euxinus*	KP136596
bsex-117-copcal-3	*Calanus euxinus*	*Calanus euxinus*	KP136597
bsex-117-cop-pse-1	*Pseudocalanus elongatus*	*Pseudocalanus elongatus*	KP136601
bsex-117-cop-pse-3	*Pseudocalanus elongatus*	*Pseudocalanus elongatus*	KP136602
BSEX-128-BIV-3	Bivalvia	unknown Bivalvia	KP136604
bsex-128-chs-1	*Parasagitta setosa*	*Parasagitta setosa*	KP136605
bsex-128-chs-2	*Parasagitta setosa*	*Parasagitta setosa*	KP136606
bsex-128-chs-3	*Parasagitta setosa*	*Parasagitta setosa*	KP136607
BSEX-128-CIRPL-1	Cirripedia Larvae	*Amphibalanus improvisus*	KP136608
BSEX-128-CIRPL-2	Cirripedia Larvae	*Amphibalanus improvisus*	KP136609
BSEX-128-CIRPL-3	Cirripedia Larvae	*Amphibalanus improvisus*	KP136610
BSEX-128-CLAPEN-1	*Penilia avirostris*	*Penilia avirostris*	KP136611
BSEX-128-CLAPEN-2	*Penilia avirostris*	*Penilia avirostris*	KP136612
BSEX-128-CLAPEN-3	*Penilia avirostris*	*Penilia avirostris*	KP136613
BSEX-128-COPACA-1	*Acartia* sp.	*Acartia clausii*	KP136616
BSEX-128-COPACA-2	*Acartia* sp.	*Acartia clausii*	KP136617
BSEX-128-COPACA-3	*Acartia* sp.	*Acartia clausii*	KP136618

BSEX-128-COPCAL-1	*Calanus euxinus*	*Calanus euxinus*	KP136619
BSEX-128-COPPSE-1	*Pseudocalanus elongatus*	*Pseudocalanus elongatus*	KP136623
BSEX-128-COPPSE-2	*Pseudocalanus elongatus*	*Pseudocalanus elongatus*	KP136624
bsex-128-engra-egg-1	*Engraulis encrasicolus*	*Engraulis encrasicolus*	KP136625
bsex-128-engra-L-3	*Engraulis encrasicolus*	*Engraulis encrasicolus*	KP136627
bsex-128-isop-1	Isopoda sp1	unidentified Malacostraca	KP136629
bsex-128-isop-2	Isopoda sp1	unidentified Malacostraca	KP136630
BSEX-128-ISOP-L-3	Isopoda	unidentified Arthropoda	KP136628
ctd-23k-brac-meg-L2-1	Brachyura Megalopa sp2	unidentified Brachyura	KP136634
ctd-23k-brac-meg-L2-2	Brachyura Megalopa sp2	unidentified Brachyura	KP136635
CTD-23K-BRAC-SP5-1	Brachyura sp5	*Eriphia verrucosa*	KP136637
ctd-23k-cepc-2	Cephalochordata	*Branchiostoma lanceolatum*	KP136638
ctd-23k-cepc-3	Cephalochordata	*Branchiostoma lanceolatum*	KP136639
CTD-23K-CIRPL-1	Cirripedia sp1	*Amphibalanus improvisus*	KP136640
CTD-23K-CIRPL-2	Cirripedia sp1	*Amphibalanus improvisus*	KP136641
CTD-23K-CIRPL-3	Cirripedia sp1	*Amphibalanus improvisus*	KP136642
CTD-23K-CIRPL-3-1	Cirripedia sp3	*Euraphia depressa*	KP136643
CTD-23K-CIRPL-3-2	Cirripedia sp3	unidentified euraphia sp.	KP136644
CTD-23K-CIRPL-L2-1	Cirripedia sp2	*Amphibalanus improvisus*	KP136645
CTD-23K-CLA-PEN-1	*Penilia avirostris*	*Penilia avirostris*	KP136646
CTD-23K-CLA-PEN-2	*Penilia avirostris*	*Penilia avirostris*	KP136647
CTD-23K-CLA-PEN-3	*Penilia avirostris*	*Penilia avirostris*	KP136648
CTD-23K-COPACA-	*Acartia* sp.	*Acartia clausii*	KP136652

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CTD-23K-COPACA-3	*Acartia* sp.	*Acartia tonsa*	KP136653
CTD-23K-GAS-SP1-1	Gastropoda_sp1	unidentified Gastropoda	KP136656
CTD-23K-GAS-SP1-2	Gastropoda_sp1	unidentified Gastropoda	KP136657
CTD-23K-GAS-SP1-3	Gastropoda_sp1	unidentified Gastropoda	KP136658
CTD-23K-GAS-SP2-1	Gastropoda_sp2	*Rapana venosa*	KP136659
CTD-23K-GAS-SP2-2	Gastropoda_sp2	*Rapana venosa*	KP136660
CTD-23K-GAS-SP2-3	Gastropoda_sp2	*Rapana venosa*	KP136661
ctd-23k-poly-sp2-1	Polychaeta	unidentified Polychaeta	KP136663
ctd-23k-poly-sp2-3	Polychaeta	unidentified Polychaeta	KP136664
ctd-23k-poly-sp3-1	Polychaeta	unidentified Polychaeta	KP136665
ctd-23k-poly-sp3-2	Polychaeta	unidentified Polychaeta	KP136666
ctd-23k-poly-sp3-3	Polychaeta	unidentified Polychaeta	KP136667
ctd-23k-TL-Mb-1	*Mullus barbatus*	*Mullus barbatus*	KP136668
ctd-23k-TL-Mb-2	*Mullus barbatus*	*Mullus barbatus*	KP136669
CTD-23K-TL-SP1-1	Teleostei sp1	unidentified Blenniidae	KP136670
CTD-23K-TL-SP1-2	Teleostei sp1	unidentified Blenniidae	KP136671
CTD-23K-TL-SP1-3	Teleostei sp1	unidentified Blenniidae	KP136672
MAREX-COPCAL-2	*Calanus euxinus*	*Calanus euxinus*	KP136673
MAREX-ENGRA-EGG-3	*Engraulis encrasicolus*	*Engraulis encrasicolus*	KP136675
MAREX-ENGRA-L-1	*Engraulis encrasicolus*	*Engraulis encrasicolus*	KP136676
MAREX-ENGRA-L-2	*Engraulis encrasicolus*	*Engraulis encrasicolus*	KP136677
MAREX-ENGRA-L-3	*Engraulis encrasicolus*	*Engraulis encrasicolus*	KP136678
sile_acik-brac-	Brachyura Megalopa sp1	unidentified Brachyura	KP136679

megL1-1			
sile_acik-brac-sp6-2	Brachyura sp6	*Eriphia verrucosa*	KP136680
sile_acik-brac-sp6-3	Brachyura sp6	*Eriphia verrucosa*	KP136681
sile_acik-brac-sp7-1	Brachyura sp7	unidentified Xanthidae	KP136682
sile_acik-brac-sp7-2	Brachyura sp7	unidentified Xanthidae	KP136683
sile_acik-brac-sp7-3	Brachyura sp7	unidentified Xanthidae	KP136684
sile_acik-chs-1	*Parasagitta setosa*	*Parasagitta setosa*	KP136688
sile_acik-chs-3	*Parasagitta setosa*	*Parasagitta setosa*	KP136689
sile_acik-cirpL-1	Cirripedia Larvae	*Amphibalanus improvisus*	KP136690
sile_acik-cirpL-2	Cirripedia Larvae	*Amphibalanus improvisus*	KP136691
sile_acik-cirp-L2-1	Cirripedia Larvae sp2	*Amphibalanus improvisus*	KP136692
sile_acik-cirp-L2-2	Cirripedia Larvae sp2	*Amphibalanus improvisus*	KP136693
sile_acik-cirp-L2-3	Cirripedia Larvae sp2	*Amphibalanus improvisus*	KP136694
sile_acik-cla-evate-3	*Evadne tergestina*	*Evadne targestina*	KP136695
sile_acik-cla-pen-1	*Penilia avirostris*	*Penilia avirostris*	KP136696
sile_acik-cla-pen-2	*Penilia avirostris*	*Penilia avirostris*	KP136697
sile_acik-cla-pen-3	*Penilia avirostris*	*Penilia avirostris*	KP136698
sile_acik-copaca-2	*Acartia* sp.	*Acartia clausii*	KP136699
sile_acik-engra-egg-1	*Engraulis encrasicolus*	*Engraulis encrasicolus*	KP136703
sile_acik-gas-sp1-1	Gastropoda_sp1	unidentified Gastropoda	KP136704
sile_acik-gas-sp1-2	Gastropoda_sp1	unidentified Gastropoda	KP136705
sile_acik-gas-sp1-3	Gastropoda_sp1	unidentified Gastropoda	KP136706
sile_acik-gas-sp2-1	Gastropoda_sp2	*Rapana venosa*	KP136707
sile_acik-gas-sp2-2	Gastropoda_sp2	*Rapana venosa*	KP136708
sile_acik-gas-sp2-3	Gastropoda_sp2	*Rapana venosa*	KP136709
sile_acik-gas-sp3-1	Gastropoda_sp3	unidentified Gastropoda	KP136710
MAREX-COPCAL-3	*Calanus euxinus*	*Calanus euxinus*	KP136674

APPENDIX C: PHOTOGRAPHS OF ZOOPLANKTON IDENTIFIED UNDER MICROSCOPE