Turkish Journal of Zoology

http://journals.tubitak.gov.tr/zoology/

Research Article

Turk J Zool
(2015) 39: 378-387

doi:10.3906/zoo-1311-14

Zooplankton abundance, biomass, and size structure in the coastal waters of the northeastern Mediterranean Sea

Tuba TERBIYIK KURT*, **Sevim POLAT**
Department of Marine Sciences, Faculty of Fisheries, Çukurova University, Adana, Turkey

Received: 06.11.2013 • **Accepted:** 10.06.2014 • **Published Online:** 04.05.2015 • **Printed:** 29.05.2015

Abstract: Zooplankton was studied seasonally between 2009 and 2011 in İskenderun Bay in order to determine temporal variations in abundance, biomass, and size structure and their relationships with environmental factors. Zooplankton sampling was performed vertically using a WP-2 net (200-µm). A total of 30 zooplankton taxonomic groups were identified. Cladocera was the dominant group, and together with Copepoda and Appendicularia constituted approximately 90% of zooplankton. In respect to abundance and biomass values, 2 peaks were observed in 2009, the first in spring and the second in autumn. However, a second peak was observed in summer in both 2010 and 2011, due to increases in cladoceran abundance. During all seasons and years of the study period, small-sized organisms (200–500 µm) constituted the majority of the zooplankton. Zooplankton abundance was influenced by environmental factors. The relationship between the abundance of zooplankton groups and environmental parameters varied according to the groups. In conclusion, clear seasonal variation and slight differences among years were observed in terms of the examined properties of the zooplankton groups. Abiotic environmental variables and availability of food were considered to particularly affect this variability.

Key words: Zooplankton, abundance, biomass, size structure, İskenderun Bay

1. Introduction

The coastal marine environment has great ecological and economic importance. It is highly sensitive and variable because of the variations in terrestrial input and open seawaters. In particular, estuaries and bays support various communities and are directly or indirectly affected by human activities (Cummins et al., 2004) and physical, chemical, and biological processes. Zooplanktonic organisms are one of the most important components of aquatic ecosystems; they convert plant protein into animal protein and contribute to matter and energy cycles. In addition to their important role in the food chain, these organisms are rapidly affected by variations in environmental factors and therefore provide information about the status of the ecosystem. Zooplankton composition in coastal areas can vary under specific hydrographic conditions, and these organisms reflect sharp changes in environmental factors such as temperature, salinity, light, density, and water circulation (Sherman, 1967).

İskenderun Bay is located on the southeastern coast of Turkey. The bay is surrounded by many industrial facilities, and agricultural activities are carried out in the areas adjacent to the bay (Aksu et al., 2013). Approximately 500,000 people live around the bay, and, as the bay is a touristic spot, this number increases during summer. Moreover, fishery activities are intensively carried out in the bay. It has been observed that the bay is influenced by human activities (Terbiyik Kurt and Polat, 2013).

The aim of this study was to increase our knowledge about the seasonal distribution of zooplankton abundance, group, and size composition and the impact of certain environmental parameters on zooplankton distribution in İskenderun Bay. This study will contribute to a better understanding of the coastal zooplankton ecology and provide basic information for long-term future studies in İskenderun Bay.

There have been several studies on the distribution of zooplankton groups, abundance, and biomass in the coastal waters of the western Mediterranean Sea (Calbet et al., 2001; Jamet et al., 2001; Fernandez de Puelles et al., 2003; Jamet et al., 2005; Rossi and Jamet, 2009) and eastern Mediterranean Sea (Mazzocchi and Ribera d'Alcala, 1995; Siokou-Frangou, 1996; Mozetic et al., 1998; Siokou-Frangou et al., 1998; Ramfos et al., 2006; Vidjak et al., 2007; Kamburska and Fonda-Umani, 2009; Mazzocchi et al., 2011). However, there is limited information on the zooplankton community of the southern coast of Turkey.

* Correspondence: tterbiyik@cu.edu.tr

The majority of the zooplankton in İskenderun Bay are of Atlanto-Mediterranean origin (Lakkis and Toklu-Aliçli, 2007). Terbiyik Kurt and Polat (2013) reported that the mesozooplankton abundance in this bay was related to the availability of food; however, species composition was dependent on abiotic variables such as temperature and salinity. Zooplankton abundance, composition, and size groups were investigated in Mersin Bay, and small-sized zooplankton groups were reported to be dominant (Zenginer Yılmaz and Besiktepe, 2010). Furthermore, Dönmez et al. (2006) studied the zooplankton composition in Akkuyu Bay and found Copepoda to be the dominant group. These studies were generally conducted for a 1-year period and were therefore inadequate to determine variations in different years. Thus, for the first time, in this study, we investigated the interannual abundance, biomass variations, and size structure of zooplankton in İskenderun Bay.

2. Materials and methods

2.1. Study area

İskenderun Bay is located at the easternmost part of the Mediterranean Sea on the southern coast of Turkey (Figure 1). The bay is 65 km in length and 35 km in width, with an area of 2247 km^2 and an average depth of 70 m. The entrance of the bay is the deepest section and is approximately 100 m in depth (Avşar, 1999). The bay is influenced by currents and wind movements because of its connection to the open sea via a large entrance (İyiduvar, 1986). The Ceyhan River is the largest river discharging water into İskenderun Bay, with a mean flow rate of 180 m^3/s. İskenderun Bay is one of the busiest coastal areas of Turkey in terms of industrialization. In addition to the settlement areas along the bay with an increasing population in summer, there are several industrial facilities around the bay, including petroleum filling plants, fertilizer factories, Baku–Tbilisi–Ceyhan pipelines, thermal plants, iron and steel factories,

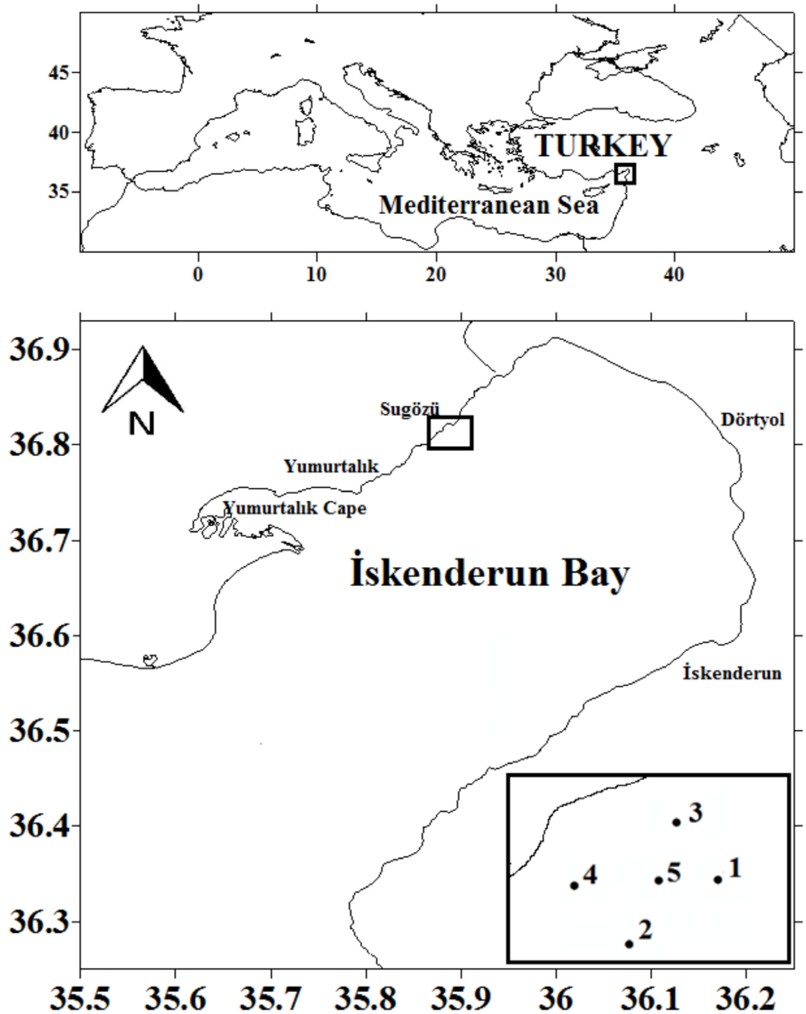

Figure 1. Sampling stations in the study area.

and the İskenderun Port. Considering all these hydrological and manmade factors, the bay is significantly affected by human activities, as well as land input. Therefore, it can be said that this bay has a dynamic structure.

2.2. Sampling and laboratory studies

Investigations were conducted seasonally during the period between 2009 and 2011 in the coastal waters of Yumurtalık, located in İskenderun Bay. Zooplankton samples were vertically collected from 5 stations at depths varying from 5 to 15 m by using a 200-µm mesh WP-2 type zooplankton net (Figure 1). Zooplankton sampling was performed twice at each station. One sample in each set was fixed in 4% buffered formaldehyde for group identification and abundance counts. Identification of zooplankton groups was done according to Johnson and Allen (2005) and Zhong (1988). The other sample was used for biomass measurement. These 2 samples were filtered through 1000-µm and 500-µm filters and divided into size groups (200–500 µm, 500–1000 µm, >1000 µm). The samples for abundance and species identification were divided into subsamples according to individual numbers using a Folsom splitter. These subsamples were used for group identification and were counted using a Bogorov counting chamber. Samples of each size group for each biomass measurement were first filtered through Whatman GF/C filters. These filters were then dried in an incubator at 60 °C for 24 h and stored in a desiccator for approximately 1 h. The filters used in these procedures were weighed using a sensitive scale, and biomass values were estimated by subtracting the initial weight of the filter from the final weight. Abundance was calculated as individuals/m^3 (ind/m^3), while biomass was calculated as mg/m^3. The volume of filtered water was calculated using net diameter and haul depth.

Environmental parameters such as temperature and salinity were measured at the surface and at depths of 5, 10, and 15 m using a YSI 6000 CTD probe. Water samples were collected using Niskin bottles, and these samples were used for phytoplankton count (Semina, 1978) and chlorophyll *a* (Chl *a*) analysis (Parsons et al., 1984). Average values of all measured environmental parameters were used.

2.3. Data analysis

Analysis of variance was used to test for variance between seasons, years, and stations in terms of the abundance and biomass values of zooplankton. A square-root transformation was used because of the nonparametric distribution of the zooplankton abundance values. The Spearman correlation test was used to determine the statistical significance of the relationship between the environmental parameters (phytoplankton abundance, Chl *a*, temperature, and salinity) and zooplankton biomass and abundance. All statistical analyses were done with SPSS 20.0. The abundance of the cladoceran group in the present study was obtained from Terbiyik Kurt and Polat (2014).

3. Results

3.1. Environmental variables

Seawater temperature measured between 2009 and 2011 ranged from 17.55 to 29.23 °C. The highest and lowest temperature values were observed in summer 2011 and spring 2009, respectively. Seawater temperature values showed a significant variation among seasons, while the variation among stations was found to be similar (Figure 2). Salinity values fluctuated between 36.96 and 41.12 psu at the sampling stations. The lowest salinity was observed at Station 4 in spring 2009, while the highest salinity was at Station 5 in winter 2010. Salinity values also showed fluctuations among years. Phytoplankton abundance and Chl *a* values were found to reach their highest levels during the spring of each year. It was observed that phytoplankton abundance significantly increased in 2011 (Figure 3).

3.2. Zooplankton abundance and biomass

Annual mean abundance of zooplankton increased in the last 2 years of the study period. Despite this increase in abundance, the annual mean zooplankton biomass values were almost the same in all years (Figure 4). Two zooplankton abundance and biomass peaks were observed in each year. The first peak was observed during spring in each year, while the second peak was observed during autumn in 2009 and during summer in 2010 and 2011 (Figure 5).

The zooplankton biomass value was found to be highest in 2009 in autumn, while in other years, the highest biomass value was observed during spring. Zooplankton abundance values were higher during spring in each year. However, the lowest zooplankton biomass and abundance were found during winter in each year. Mean seasonal zooplankton biomass and abundance values were in ranges of 3.2–18 mg/m^3 and 1089–3848.5 ind/m^3 in 2009, 3.4–23.3 mg/m^3 and 1064.2–9858.2 ind/m^3 in 2010, and 3–15.2 mg/m^3 and 1387.9–10,892.7 ind/m^3 in 2011 (Figure 5) The differences among years and seasons was statistically

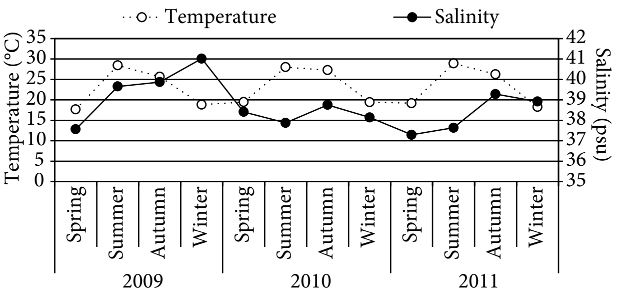

Figure 2. Temperature and salinity values in the seasons for 3 years.

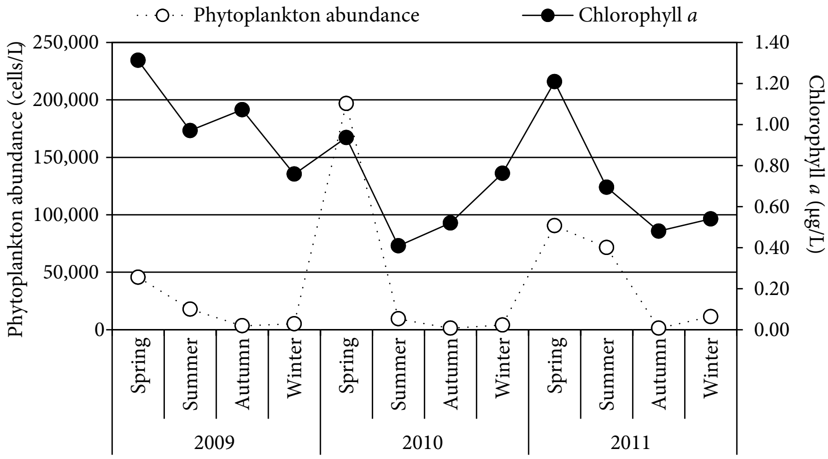

Figure 3. Phytoplankton abundance and chlorophyll-*a* values during the seasons over 3 years.

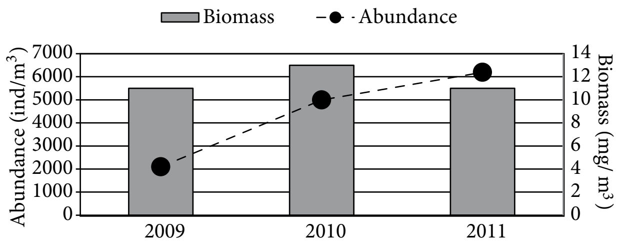

Figure 4. Annual mean values of zooplankton biomass and abundance.

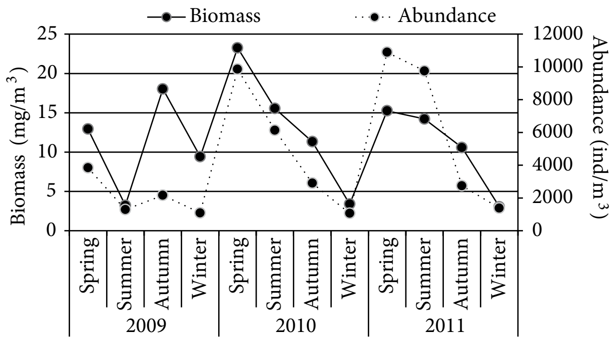

Figure 5. Seasonal variations of zooplankton abundance and biomass in the sampling period.

significant in terms of abundance ($P < 0.01$). In addition, there was a statistically significant difference only among seasons in terms of zooplankton biomass ($P < 0.01$).

The zooplankton specimens belonging to the 200–500-µm size group were found to have the highest abundance and biomass values in all years and seasons among all the size groups. As the size of organisms increased, their contribution to the total zooplankton abundance and biomass values decreased (Figure 6).

3.3. Zooplankton group composition

A total of 30 zooplankton groups were found in the study area during the sampling period. Twenty-seven zooplankton taxonomic groups were identified in 2009. However, 24 zooplankton taxonomic groups were identified in 2010 and 2011 (Table 1). Seasonal variations of abundant zooplankton groups are presented in Figure 7.

Although Cladocera was found to be dominant in all zooplanktonic groups during the spring and summer of 2010 and 2011, Copepoda was dominant in the rest of the sampling periods.

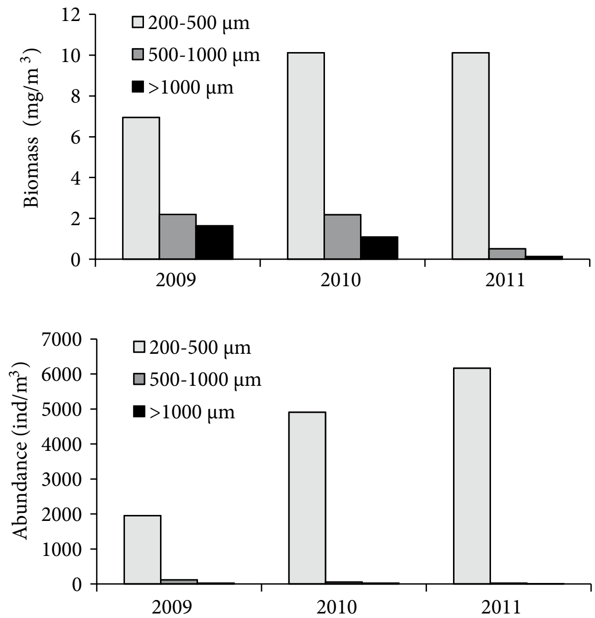

Figure 6. Annual mean values of zooplankton size groups.

Table 1. Abundance of the zooplankton groups (ind/m^3) identified in the sampling area between spring 2009 and winter 2011.

Main groups	2009				2010				2011			
	Spring	July	Autumn	Winter	Spring	July	Autumn	Winter	Spring	July	Autumn	Winter
Acantharia	0	0	0	0	0	0	0	0	0	1.68	0	0
Amphipoda	4.6	0.16	0	0	0.92	1.26	0.06	0	0	0	0	0
Appendicularia	260.68	6	3.34	30.66	393.8	20.84	40.76	14.16	625.4	40.78	210	30.82
Ascidiacea	0	0.74	0.08	0	0	0.06	0.08	0.48	0	4.4	0	0
Bivalvia	17.62	10	17.02	33.5	6.96	11.08	205.22	128.36	9.42	44.84	180.32	85.8
Bryozoa	1.26	0	0	0	0	0	0	0	0	1.56	0.88	0
Chaetognatha	67.46	0.76	86.24	36.78	160.8	26.86	158.4	60.2	128.96	22.32	116.4	74.88
Cladocera	451.18	293.64	7.88	31.74	6969.4	4831.4	42.4	9.84	8413.6	6787.6	455.3	11.1
Cirripedia	51.7	0.32	2.66	3.62	202.8	1.58	0.62	10.2	70.68	0	3.12	2.06
Copepoda	2669	759.4	1916.2	845.6	1637.4	1129.4	2218.2	755	1178.6	2132.6	978.6	1027.6
Crustacea, egg	5.6	0.84	0.42	1.24	3.84	2.52	0	0	0.62	1.56	0	2.4
Ctenophora	0	0	0	0.3	0	0	0	0	0	0	8.38	0
Decapoda	13.04	25.92	61.8	8.64	101.56	26.92	46.94	28.28	38.16	85.92	111.62	14.9
Doliolida	1.52	0.44	36.1	17.26	47.14	11.2	85.76	1.26	80.46	3.36	447	22.92
Echinodermata	57.06	164.76	9.9	3.4	102.3	21.94	7.26	1	24.72	223.68	58.3	1.78
Enteropneusta	0	0	0	0	2.52	0	0	0	0	0	0	0
Foraminifera	11.72	0.8	1.54	28	11.34	5.9	23.56	8.84	5.22	11.2	6.28	48.32
Gastropoda	24.84	15.48	5.92	5.06	145.32	24.62	62.66	10.14	184.8	180.72	37.98	9.32
Hydrozoa	26.32	0.28	2.5	10.9	33.58	0.12	3.14	3.62	29.58	1.98	2.8	4.58
Ichthyoplankton	2.72	5.3	3.9	1.12	14.58	5.72	0.84	1.36	15.26	21.64	2.84	0.16
Isopoda	0	0	1.78	0.42	1.26	0.06	0	0	0	0	0	0
Nemertea	9.12	0	0	0	0	0.16	0	0	0	0	0	0
Ostracoda	0	0	0	4.44	0	0	0.06	0	0	0	0	0.44
Phoronida	2.16	0	0	0	0	0	0	0	0	0	0	0
Platyhelminthes	14.22	0	0.08	0	0	0	0	0	0	0	0	0
Polychaeta	75.12	7.14	1.7	12.84	11.76	7.32	5.02	9	33	29.22	12.18	9.48
Pteropoda	57.34	1.42	0	4.98	2.64	1.88	1.66	4.1	22	0.1	50.26	2.54
Radiolaria	0	0	0	0	0	0	0	0.84	0	0	0	1.66
Stomatopoda	0	0.18	0.54	0.06	0.26	2.86	0.16	0	0.88	1.3	0.06	0
Salpida	2.12	0	0	0.58	0	0	0	0	0.84	0.06	0	0
Siphonophora	18.6	0.76	0.5	7.48	3.92	1.24	2.72	15.24	30.68	0.36	0.06	10.32
Other	3.6	0.68	5.12	0.48	4.28	0	3.18	2.82	0	1.76	1.5	0.42

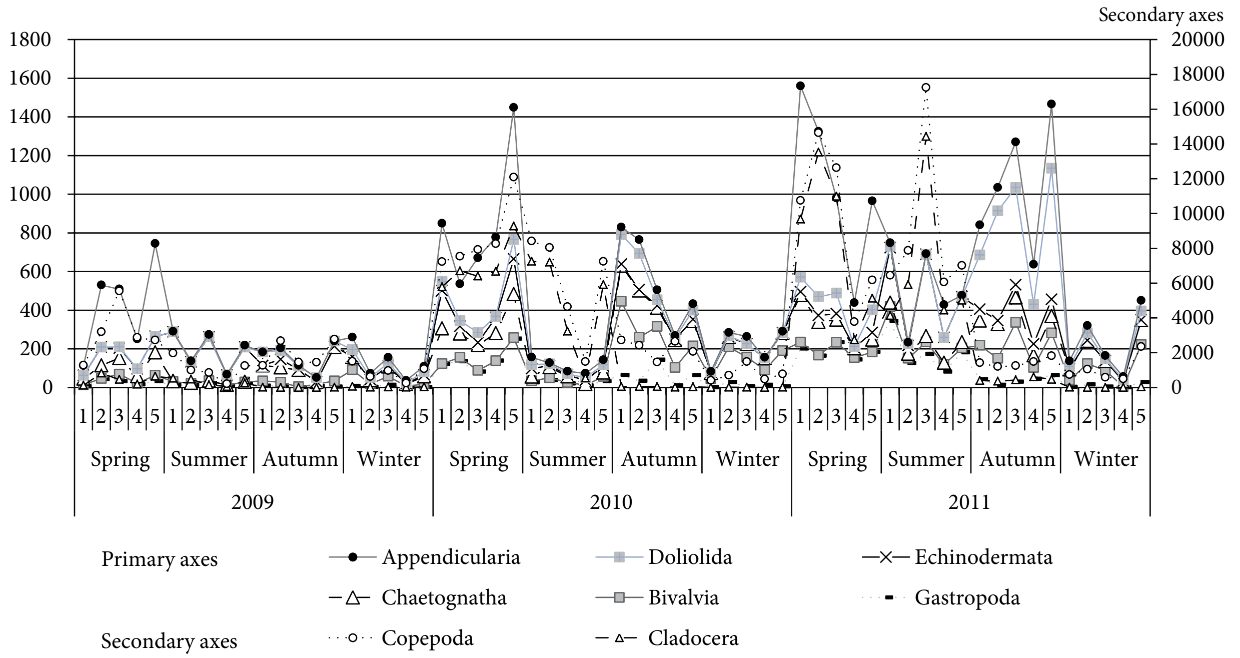

Figure 7. Seasonal abundance distribution of dominant zooplankton groups (ind/m³).

During the study period, Copepoda, Cladocera, and Appendicularia were found to be the most abundant zooplankton groups during spring. In addition to these groups, the other groups that significantly contributed to the zooplankton abundance were as follows: Cirripedia and Chaetognatha in all years, Pteropoda and Polychaeta in 2009, Echinodermata in 2009 and 2010, Decapoda in 2010, Gastropoda in 2010 and 2011, and Doliolida in 2011. Cladocera and Copepoda were dominant during all summers of the 3-year period. The groups that constituted the majority of the zooplankton abundance were Gastropoda, Decapoda, Echinodermata, and Appendicularia in all years; Bivalvia in 2009 and 2011; and Chaetognatha in 2010. During autumn in all years, Copepoda was found to be the dominant zooplankton group and Bivalvia, Decapoda, Chaetognatha, and Doliolida formed the bulk of the zooplankton population. Additionally, Gastropoda in 2010 and Cladocera and Appendicularia in 2010 and 2011 contributed to the zooplankton abundance. During winter, Copepoda was the dominant group during the entire study period. Bivalvia, Chaetognatha, and Appendicularia also significantly contributed to the zooplankton abundance during all sampling periods. Moreover, Foraminifera and Doliolida in 2009 and 2011, Cladocera in 2009, and Siphonophora and Decapoda in 2010 were significantly abundant.

It was found that total zooplankton abundance values were negatively correlated with salinity and positively correlated with phytoplankton abundance ($P < 0.01$). On the other hand, biomass values were not correlated with environmental parameters. The correlation of zooplankton groups with environmental parameters showed variations (Table 2). Cladocera, Copepoda, and Appendicularia were found to be the most abundant groups, with a 90% contribution to zooplankton abundance. Environmental factors affecting these groups also affected the total zooplankton abundance. Cladocera ($P < 0.01$), Copepoda ($P < 0.05$), and Appendicularia ($P < 0.01$) showed a negative correlation with salinity. Furthermore, Cladocera and Appendicularia were found to be positively correlated with phytoplankton abundance ($P < 0.01$). Among these groups, Cladocera was found to be positively correlated with temperature ($P < 0.05$), while Appendicularia was found to be negatively correlated with temperature ($P < 0.01$).

4. Discussion

The present 3-year study provided findings on the seasonal variation of zooplankton abundance, biomass, and size structure in İskenderun Bay, about which there was limited information. Although a 3-year study is inadequate to explain the annual variations in zooplankton, it demonstrates the variations in the effect of environmental factors on zooplankton during those 3 years. Since the study area is close to the coast, seasonal variations in terrestrial inputs (from agricultural activities and domestic wastes) and precipitation affect this region. Because of the relatively significant variations in environmental factors in coastal areas, determining the effect of these factors on marine organisms can provide more distinctive results.

Table 2. Correlation between zooplankton groups and environmental variables: total biomass (T. bio.), total abundance (T. abun.), temperature (Temp.), salinity (Sal.), phytoplankton abundance (Phyto.), and chlorophyll a (Chl *a*).

	T. bio. (mg/m^3)	T. abun. (ind/m^3)	Temp. (°C)	Sal. (psu)	Phyto. (cells/L)	Chl *a* (µg/L)
Total abundance	0.665**	1.000	0.193	−0.587**	0.544**	0.095
Total biomass	1.000	0.665**	0.121	−0.178	0.242	0.127
Foraminifera	−0.089	−0.030	−0.306*	0.060	−0.071	−0.241
Hydrozoa	0.168	0.283*	−0.502**	−0.275*	0.428**	0.395**
Siphonophora	−0.046	0.047	−0.638**	−0.310*	0.335**	0.330**
Gastropoda	0.407**	0.812**	0.273*	−0.561**	0.483**	0.071
Pteropoda	−0.009	0.121	−0.404**	−0.150	0.009	0.100
Bivalvia	−0.250	−0.180	0.098	0.178	−0.557**	−0.457**
Polychaeta	0.079	0.394**	−0.203	−0.474**	0.467**	0.266*
Cladocera	0.474**	0.839**	0.290*	−0.555**	0.642**	0.081
Copepoda	0.532**	0.646**	0.098	−0.278*	0.185	0.184
Cirripedia	0.221	0.236	−0.602**	−0.356**	0.452**	0.455**
Decapoda	0.397**	0.503**	0.431**	−0.022	0.019	−0.049
Chaetognatha	0.359**	0.397**	−0.293*	−0.072	−0.082	−0.006
Echinodermata	0.227	0.514**	0.433**	−0.218	0.424**	0.157
Doliolida	0.366**	0.254	−0.058	0.255*	−0.260*	−0.268*
Appendicularia	0.252	0.512**	−0.405**	−0.374**	0.337**	0.151
Ichthyoplankton	0.455**	0.703**	0.385**	−0.439**	0.600**	0.275*

*Correlation was significant at 0.05 level. **Correlation was significant at 0.01 level.

Zooplankton peak time and frequency showed variations in some Mediterranean coastal areas. It has been reported that 2 peaks (during spring and autumn) were observed in Niel Bay (Jamet et al., 2001) and İskenderun Bay (Terbiyik Kurt and Polat, 2013). On the other hand, spring and summer peaks occurred in Naples Bay (Mazzocchi and Ribera d'Alcala, 1995), Saronikos Bay (Siokou-Frangou, 1996), the southern coasts of Marseille (Gaudy and Champalbert, 1998), and Trieste Bay (Mozetic et al., 1998). However, 3 peaks (spring, autumn, and summer) were observed in a year in a small bay of Toulon (Jamet et al., 2001), the coastal waters of the Balearic Sea (Fernandez de Puelles et al., 2003), and Mersin Bay (Zenginer Yılmaz and Besiktepe, 2010). On the other hand, in certain areas, such as the Blanes coastal areas (Calbet et al., 2001), the presence of many zooplankton peaks were reported. In the present study, the zooplankton peaks varied during the study period, and summer peaks in the last 2 years were caused by the excessive increase in cladoceran abundance during summer. Salinity values decreased in the last 2 years compared to those in 2009. This salinity decrease was thought to be caused by increased input from Kızlar Creek, located in the north of the study area, and was most probably caused by the increase in cladoceran abundance. Additionally, a negative correlation between cladoceran abundance and salinity supports this idea.

There are a few studies on the distribution of zooplankton size groups. Some studies reported that small-sized groups were dominant in the zooplankton population (Champalbert, 1996; Zenginer Yılmaz and Besiktepe, 2010). Similarly, in our study, small-sized groups were found to be dominant in the zooplankton population with a significant difference. The eastern Mediterranean Sea has particularly high oligotrophic properties (Azov, 1991); pico- and nanosized phytoplankton are also dominant in this basin (Yacobi et al., 1995; Ignatiades et al., 2002). The predation of planktivorous fish in the coastal areas might have given rise to the increase in the number of small-sized zooplankton (Brooks and Dodson, 1965).

Zooplankton abundance measured in the study area was consistent with findings reported in Trieste Bay (Mozetic et al., 1998) and the Neretva Canal (Vidjak et al., 2007) in the Mediterranean Sea. However, zooplankton abundance in the present study was found to be higher than in certain coastal areas such as Maliakos Bay (Christou et al., 1995), the Balearic Sea (Fernandez de Puelles et al., 1998), Gökçeada coastal waters in the North Aegean Sea (Tarkan, 2000), the North Adriatic Sea (Guglielmo et al., 2002), Lebanese coasts (Lakkis, 2007), and Naples Bay (Ribera d'Alcala et al., 2004; Mazzocchi et al., 2011). Additionally, compared to areas such as Blanes Bay (Calbet et al., 2001) and the Vranjak Basin (Vidjak et al., 2006), zooplankton abundance was found to be lower in the present study. Various coastal areas of the Mediterranean Sea have different hydrographic properties. Population density in the coastal areas, variations in terrestrial inputs due to rainfall or other factors, and the number of industrial establishments in coastal areas have a substantial impact on the abundance and diversity of zooplanktonic organisms. These factors affect the amount of inorganic nutrients and many other physicochemical properties of the water column, which in turn can affect the primary producers and thereby zooplankton distribution and abundance.

Total zooplankton abundance was found to be correlated only with salinity and phytoplankton abundance. The insignificant correlation of zooplankton abundance with Chl *a* probably resulted from the feeding of zooplankton on heterotrophic bacteria and small autotrophs. In the present study, autotroph biomass had less impact on the seasonal cycle of zooplankton, which was similar to observations in other Mediterranean coastal areas (Mazzocchi and Ribera d'Alcala, 1995; Siokou-Frangou, 1996; Calbet et al., 2001; Fernandez de Puelles et al., 2003). On the contrary, Terbiyik Kurt and Polat (2013) reported that Chl *a* and phytoplankton abundance were positively correlated with zooplankton biomass and that there was no correlation with zooplankton abundance. In our study, it was found that temperature was correlated insignificantly with total zooplankton abundance, similar to Chl *a*. Similarly, Calbet et al. (2001) reported that there was no correlation between temperature and total zooplankton abundance. Temperature is known to affect the seasonal distribution of zooplankton in some Mediterranean coastal waters (Siokou-Frangou, 1996; Fernandez de Puelles et al., 2003; Vidjak et al., 2007). Terbiyik Kurt and Polat (2013) carried out a study in the same region and reported that abiotic factors, particularly temperature, affected the zooplankton community structure. Similarly, in the present study, although abiotic factors had less impact on the total zooplankton abundance and biomass, seasonal dynamics of zooplankton groups were significantly affected by abiotic environmental factors. The degree of effect of these factors varies according to the zooplankton groups. Although there was a low correlation between temperature and total zooplankton abundance and biomass, the seasonality of zooplankton was significantly determined by temperature. Certain groups such as Echinodermata, Gastropoda, Hydrozoa, Ichthyoplankton, Siphonophora, Appendicularia, Cirripedia, Chaetognatha, Cladocera, and Doliolida showed a significant seasonal cycle, and their abundance increased from 2009 to 2011. All groups, excluding Doliolida, were found to be negatively or positively correlated with temperature. On the other hand, some groups such as Bivalvia, Foraminifera, Polychaeta, Pteropoda, Copepoda, and Decapoda showed fluctuations. An unstable change in Copepoda, which is the dominant group, is thought to be caused by the dominance of different species in different seasons. Although salinity was found to be positively correlated with Doliolida, in the majority of other negatively correlated groups, zooplankton abundance increased in the last 2 years of the study period when salinity was low. This suggests that salinity was responsible for the variation in the study area. A similar negative correlation was reported by Fernandez de Puelles et al. (2003). Similar to many other regions of the Mediterranean Sea, Cladocera, Copepoda, and Appendicularia (Mazzocchi and Ribera d'Alcala, 1995; Siokou-Frangou, 1996; Calbet et al., 2001; Vidjak et al., 2007; Mazzocchi et al., 2011; Terbiyik Kurt and Polat, 2013) constituted the majority of the zooplankton population in our study area (approximately >90%). The factors affecting these groups also influenced the total zooplankton abundance. In this study, Copepoda was found to be inversely correlated with salinity. A similar negative correlation was also reported by Fernandez de Puelles et al. (2003) for the Balearic Sea and Vidjak et al. (2007) for the Adriatic Sea. It was reported that, in the Mediterranean coastal regions, cladoceran abundance was positively correlated with temperature but inversely correlated with salinity (Fernandez de Puelles et al., 2003; Vidjak et al., 2007). In addition to temperature, phytoplankton abundance also positively affected the increase in cladoceran abundance. It was reported that Appendicularia showed a positive correlation with temperature in some Mediterranean coastal regions (Calbet et al., 2001; Vidjak et al., 2007); it was particularly abundant during the warm periods of the year (Terbiyik Kurt and Polat, 2013). However, it showed a negative correlation with temperature in our study; Mazzocchi and Ribera d'Alcala (1995) reported that the abundance of this group was higher in winter. In another study carried out in our study area 1 year before our sampling period, Appendicularia was observed to be more abundant in summer, and cladoceran abundance was found to be quite low during this period (Terbiyik Kurt and Polat, 2013). A significant increase in Cladocera during this study period, particularly in 2010 and 2011, suggests that since appendicularians and cladocerans feed on organisms of similar size groups, the proliferation of appendicularians was prevented by the increasing cladoceran population due to competition for food.

There are limited studies on İskenderun Bay (Toklu, 2006; Lakkis and Toklu, 2007); only Terbiyik Kurt and Polat (2013) reported the quantitative values of zooplankton and determined their relationships with environmental parameters. Although the zooplankton biomass values in that study were approximately 2 times higher than those in the present study, the abundance values were found to be similar to the 2009 values of the present study. This difference might have resulted from the increase in the abundance of large-sized organisms. The abundance of Labidocera and Calanopia particularly increased in autumn (Terbiyik Kurt and Polat, 2013). Similarly, despite some exceptions, the seasonal cycle of zooplanktonic groups identified in the present study is similar to those reported by previous studies (Toklu, 2006; Lakkis and Toklu, 2007; Terbiyik Kurt and Polat, 2013).

In conclusion, İskenderun Bay is similar to other Mediterranean coastal regions in terms of the investigated characteristics. Many zooplanktonic groups have a seasonal cycle, and this seasonality occurs according to temperature changes. On the other hand, in this 3-year study, it was found that salinity affected the variation in abundance among the years.

References

Aksu M, Başaran A, Egemen Ö (2013). Effects of Baku-Tbilisi-Ceyhan crude oil pipeline on the water quality in Yumurtalık Coast of the Iskenderun Bay. Ege J Fish Aqua Sci 30: 7–13.

Avşar D (1999). Physico-chemical characteristics of the eastern Mediterranean in relation to distribution of the new Scyphomedusae (*Rhopilema nomadica*). Turk J Zool 23: 605–616 (in Turkish with English abstract).

Azov Y (1991). Eastern Mediterranean—a marine desert? Mar Pollut Bull 23: 225–232.

Brooks JL, Dodson SI (1965). Predation, body size, and composition of plankton. Science 150: 28–35.

Calbet A, Garrido S, Saiz E, Alcaraz M, Duarte CM (2001). Annual zooplankton succession in coastal NW Mediterranean waters: the importance of the smaller size fractions. J Plankton Res 23: 319–331.

Champalbert G (1996). Characteristics of zooplankton standing stock and communities in the western Mediterranean Sea: relations to hydrology. Sci Mar 60: 97–113.

Christou ED, Pagou K, Christianidis S, Papathanassiou E (1995). Temporal and spatial variability of plankton communities in a shallow embayment of the eastern Mediterranean. In: Eleftheriou A, Ansell AD, Smith CJ, editors. Proceedings of the 28th European Marine Biological Symposium; 23–28 September 1993; Crete, Greece. International Symposium Series, Biology and Ecology of Shallow Coastal Waters. Fredensborg, Denmark: Olsen and Olsen, pp. 3–10.

Cummins SP, Roberts DE, Ajani P, Underwood AJ (2004). Comparisons of assemblages of phytoplankton between open and seagrass habitats in a shallow coastal lagoon. Mar Freshwater Res 55: 447–456.

Dönmez A, Toklu-Alıçlı B, Sarıhan E (2006). The seasonal changes of zooplankton in Akkuyu Bay (Mersin). İstanbul University Journal of Fisheries & Aquatic Sciences 20: 1–7.

Fernandez de Puelles ML, Gras D, Hernandez-Leon S (2003). Annual cycle of zooplankton, biomass, abundance and species composition in the neritic area of the Balearic Sea, Western Mediterranean. PSZN Mar Ecol 24: 123–139.

Fernandez de Puelles ML, Jansa J, Morillas A, Amengual B, Vicente L (1998). Spatial and seasonal variability of the zooplankton in the Balearic Sea (Mediterranean). Rapp Comm Int Mer Medit 35: 430–431.

Gaudy R, Champalbert G (1998). Space and time variations in zooplankton distribution south of Marseilles. Oceanol Acta 21: 793–802.

Guglielmo L, Sidoti O, Granata A, Zagami G(2002). Distribution, biomass and ecology of meso-zooplankton in the northern Adriatic Sea. Chem Ecol 18: 107–115.

Jamet JL, Boge G, Richard S, Geneys C, Jamet D (2001). The zooplankton community in bays of Toulon area (northwest Mediterranean Sea, France). Hydrobiologia 457: 155–165.

Jamet JL, Jean N, Boge G, Richard S, Jamet D (2005). Plankton succession and assemblage structure in two neighbouring littoral ecosystems in the north-west Mediterranean Sea. Mar Freshwater Res 56: 69–83.

Johnson WS, Allen DM (2005). Zooplankton of the Atlantic and Gulf coasts: a guide to their identification and ecology. Baltimore, MD, USA: Johns Hopkins University Press.

Ignatiades L, Psarra S, Zervakis V, Pagou K, Souvermezoglou E, Assimakopoulou G, Gotsis-Skretas O (2002). Phytoplankton size-based dynamics in the Aegean Sea (Eastern Mediterranean). J Marine Syst 36: 11–28.

İyiduvar O (1986). Hydrographic characteristics of İskenderun Bay. MSc, Middle East Technical University, Erdemli, Turkey.

Kamburska L, Fonda-Umani S (2009). From seasonal to decadal interannual variability of mesozooplankton biomass in the Northern Adriatic Sea (Gulf of Trieste). J Marine Syst 78: 490–504.

Lakkis S (2007). Dataset and database biodiversity of plankton community in Lebanese seawater (Levantine Basin, East Mediterranean). In: Vanden Berghe E, Appeltans W, Costello MJ, Pissierssens P, editors. Proceedings of Ocean Biodiversity Informatics: International Conference on Marine Biodiversity Data Management; 29 November–1 December 2004; Hamburg, Germany. Oostende, Belgium: VLIZ Special Publication 37, pp. 99–112.

Lakkis S, Toklu-Aliçli B (2007). Contribution to the study of zooplankton community in Iskenderun Bay (north-eastern Mediterranean). Rapp Comm Int Mer Medit 38: 527.

Mazzocchi MG, Licandro P, Dubroco L, Di Capua J, Saggiomo V (2011). Zooplankton associations in a Mediterranean long-term time-series. J Plankton Res 33: 1163–1181.

Mazzocchi MG, Ribera d'Alcala M (1995). Recurrent patterns in zooplankton structure and succession in a variable coastal environment. ICES J Mar Sci 52: 679–691.

Mozetic P, Fonda-Umani S, Cataletto B, Malej A (1998). Seasonal and inter-annual plankton variability in the Gulf of Trieste (northern Adriatic). J Mar Sci 55: 711–722.

Parsons TR, Maita Y, Lalli CM (1984). A Manual of Chemical and Biological Methods for Seawater Analysis. Oxford, UK: Pergamon Press.

Ramfos A, Isari S, Somarakis S, Georgopoulos D, Koutsikopoulos C, Fragopoulu N (2006). Mesozooplankton community structure in offshore and coastal waters of the Ionian Sea (eastern Mediterranean) during mixed and stratified conditions. Mar Biol 150: 29–44.

Ribera d'Alcala M, Conversano F, Corato F, Licandro P, Mangoni O, Marino D, Mazzocchi MG, Modigh M, Montresor M, Nardella M et al. (2004). Seasonal patterns in plankton communities in a pluriannual time series at a coastal Mediterranean site (Gulf of Naples): an attempt to discern recurrences and trends. Sci Mar 68: 65–83.

Rossi N, Jamet JL (2009). Structure and succession of plankton communities in two Mediterranean neighbouring coastal ecosystems (Toulon bays, France). In: Martorino L, Puopolo K, editors. New Oceanography Developments. New York, NY, USA: Nova Science Publishers, pp. 269–282.

Semina HJ (1978). Treatment of an aliquot sample. In: Sournia A, editor. Phytoplankton Manual. Paris: UNESCO Press, p. 181.

Sherman K (1967). Coastal Zooplankton. Am Biol Teach 29: 460–464.

Siokou-Frangou I (1996). Zooplankton annual cycle in a Mediterranean coastal area. J Plankton Res 18: 203–223.

Siokou-Frangou I, Papathanassiou E, Lepretre A, Frontier S (1998) Zooplankton assemblages and influence of environmental parameters on them in a Mediterranean coastal area. J Plankton Res 20: 847–870.

Tarkan AN (2000). Abundance and distribution of zooplankton in coastal area of Gökçeada Island (Northern Aegean Sea). Turkish J Marine Sciences 6: 201–214.

Terbiyik Kurt T, Polat S (2013). Seasonal distribution of coastal mesozooplankton community in relation to the environmental factors in İskenderun Bay (north-east Levantine, Mediterranean Sea). J Mar Biol Assoc UK 93: 1163–1174.

Terbiyik Kurt T, Polat S (2014). Characterization of seasonal and inter-annual changes in the abundance of species of marine Cladocera on the Turkish coast of the northeastern Levantine Basin. Crustaceana 87: 769–783.

Toklu B (2006). Seasonal changes and distribution of zooplankton in the İskenderun Bay (Yumurtalık-Kokar Cape). PhD, Çukurova University, Adana, Turkey.

Vidjak O, Bojanic N, Kuspilic G, Gladan ZN, Ticina V (2007). Zooplankton community and hydrographical properties of the Neretva Channel (eastern Adriatic Sea). Helgol Mar Res 61: 267–282.

Vidjak O, Bojanic N, Kuspilic G, Marasovic I, Gladan ZN, Brautovic I (2006). Annual variability and trophic relations of the mesozooplankton community in the eutrophicated coastal area (Vranjic Basin, eastern Adriatic Sea). J Mar Biol Assoc UK 86: 19–26.

Yacobi YZ, Zohary T, Kress N, Hecht A, Robarts RD, Waiser M, Wood AM, Li WKW (1995). Chlorophyll distribution throughout the southeastern Mediterranean in relation to the physical structure of the water mass. J Marine Syst 6: 179–190.

Zenginer Yılmaz A, Besiktepe S (2010). Annual variations in biochemical composition of size fractionated particulate matter and zooplankton abundance and biomass in Mersin Bay, NE Mediterranean Sea. J Marine Syst 81: 260–271.

Zhong Z (1988). Marine Planktonology. Beijing, China: China Ocean Press.