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Food composition and distribution of Gelatinous Macrozooplankton in the Southern Black Sea

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Food composition and distribution of gelatinous macrozooplankton (*Aurelia aurita* and *Mnemiopsis leidyi*) were determined during this study. Dominant main food of *A. aurita* and *M. leidyi* were found Copepoda (41.7% and 31.6%) and Bivalvia (16.3% and 27.6%) according to numerical occurrence. While the numerical and frequency rates of fish eggs and larvae in the *A. aurita* food composition were 0.8% and 1.5%, respectively. These values were determined as 0.9% and 1% for *M. leidyi*. Zooplankton was found as feeding preferences of *A. aurita* and *M. leidyi* in terms of food composition. Seasonal differences have been observed in biomass and abundance of species. Highest abundance and biomass were 16.67 n.m^{-2} and 124.17g.m^{-2} for *A. aurita,* 51 n.m^{-2} and 82.5 g.m^{-2} for *M. leidyi,* and 2.5 n.m^{-2} and 17.29 g.m^{-2} for *B. ovata*. *M. leidyi* showed correlation with temperature ($p<0.05$).

[**Keywords:**Black Sea, Sinop, Gelatinous Macrozooplankton, Food composition, Distribution]

Introduction

Coastal marine ecosystems is stressed due to global warming, eutrophication, pollution, the effects of excessive fishing, entrance of alien species[1]. Invasion of marine habitats by gelatinous macrozooplankton is a serious problem around the world. Invading *Mnemiopsis leidyi*rapidly reached a high biomass in the Black Sea, Azov, Caspian and Baltic Sea is the clearest indication of this problem[2,3,4,5]. Black Sea is unprotected against strong effects pollution and invading species and its' ecosystem experienced remarkable changes since 1960. These changes were firstly manifested with high nutrient load carried by major rivers in the Northwest[1,6,7,]. In 1980's the development of fishing fleet and equipment in the Black Sea and excessive and unconscious fishing resulted in dramatic decline of catch of pelagic fish[8]. In the early 1980's *Aurelia aurita* and in the late 1980's invader *M. leidyi* reached a high abundance in ecosystem. These organisms have negatively affected the zooplankton community and pelagic fishing in the Black Sea ecosystem[3,4,5,9,8,10]. Also, Black Sea fisheries activity is affected by the bloom of *A. aurita*[11]. *Beroe ovata* was first identified at the Black Sea in 1997[12]. It has restricted to development of *M. leidyi* in the Black Sea. *B. ovata* significantly contributed to recover of the Black Sea[2,13]. Zooplankton are main foods of small pelagic fishes and gelatinous zooplankton. They are important for food chain due to competition for nutrient between two groups[3,13,14]. Reproduction and abundance of gelatinous macrozooplankton are nearly relate to nutrient amounts in the environment[15,16,17]. Determine of gelatinous macrozooplankton food content depending on the temporal and different ecosystem are certainly important.

Present study consists the food composition of *A. aurita* and *M. leidyi*was defined and also seasonal distribution of *A. aurita*, *M. leidyi* and *B. ovata*were determined in Sinop coast of the southern Black Sea. This study is aimed to monitoring nutritional and the temporal distribution changes of the gelatinous macrozooplankton.

Materials and Methods

Distribution of abundance and biomass of gelatinous zooplankton were detected in the Southern Black Sea (Sinop coast) in the period from January 2008 to December 2008. The sampling was carried out during cruises aboard the R/V "Arastirma I" of Sinop University Fisheries Faculty. Sampling was made monthly or twice a month in three sampling stations (depend on weather conditions) during daytime by plankton nets (210 µm mesh size and 0.5 m diameter). Maximum depths of stations are 25 m for A, 50 m for B and 65 m for C (Fig 1). Each station was sampled vertically from the bottom to surface and tows were made with two replications.

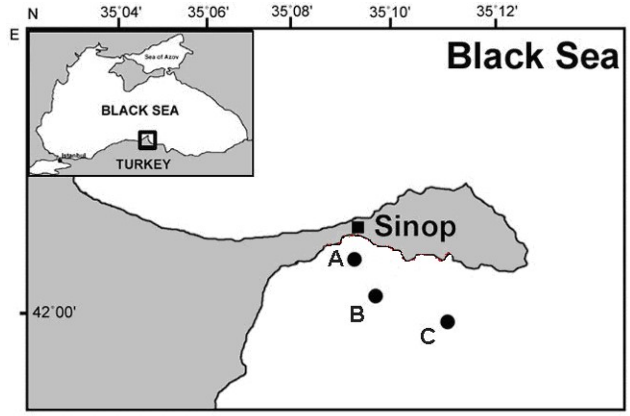

Fig. 1 —Sampling stations at Sinop coast in the Southern Black Sea (A: 42° 01' 15" N- 35° 09' 00"E, B: 42° 00' 21" N- 35° 09' 32"E, C: 41° 59' 27" N- 35° 10' 12"E)

Gelatinous macrozooplankton were separated from the other mesozooplankton using a 2 mm mesh sieve. Samples were immediately examined aboard the ship. Wet weights (WW) were determined for each individual by displacement volume using a finelydivided cylinder.

Abundance and biomass was calculated as n (individual).m^{-2} and g (wet weight).m^{-2}, respectively[18].

Physical parameters which are temperature and salinity were obtained by YSI 6600 Sounder during the survey. The relationships between abundance and biomass of gelatinous species and physical parameters were analysed with Pearson Correlation.Kruskal-Wallis (ANOVA) non-parametric variance analysis (MINITAB 15.0 package program)was used to determine for differences

Undamaged *A. aurita* and *M. leidyi* obtained from the plankton samplings are used in the determination of their food composition. Gelatinous species were transferred to plastic bottles of 180- 200 ml containing sea water filtered from a 100 µm plankton mesh. In each plastic bottle one individual was stored, and the samples were preserved by formaldehyde buffered by borax in a manner as their concentration will be 5% [19,20].

While examining the food composition of gelatinous organisms, the stomach, body cavities and the solution in which it exists were examined together. Group and species identification of the samples were realized at the laboratory under the NIKON SMZ-2T model microscope. In the qualitative and quantitative determination of nutrients in food composition, numerical occurrence (NO%) and frequency occurrence (FO%) methods were used[21, 22].

*FO= (Fi/Ft)*100*

FO: frequency occurrence;

Fi: number of gelatinous individual in which the food item i

Ft: total number of gelatinous individual

*NO =(Ni/Nt)*100*

NO: numerical occurrence

Ni:the number of food item i

Nt: the total number of food item

Results and Discussion

In the present study, the food composition of 236 *A. aurita* and 205 *M. leidyi* specimens were examined. The main common food consumed by *A. aurita* were Copepoda+copepoda nauplii(41.7%) and Bivalvia (16.3%), according to the NO%. Copepoda+copepoda nauplii presented the highest FO% (36.4%) following by the Bivalvia (15.2%). NO and FO rates of fish egg and larvae within the food composition of *A. aurita* were 0.8% and 1.5%, respectively (Table 1). *A. aurita* individuals having empty stomach consisted the 40.3% of all the individuals sampled. It was observed that the individuals sampled in winter encountered more nutritional difficulty. High NO and FO in the food composition were determined 7.7% and 5.4% for *Penilia avirostris*, 6.6% and 6.3% for *Oikopleura dioica* (Table 1). When examined NO and FO of food groups Copepoda and Mollusca was found predominant (Fig 2).

The highest NO in the food composition of *M. leidyi* were Copepoda+copepoda nauplii (31.6%) andBivalvia (27.6%). Its high FO were found Bivalvia (15.9%) groups followed by the Copepoda (42.7%). The more preferred species from Cladocera were *Evadne* spp. and *P.avirostris*.The NO and FO of fish eggs and larvae were determined as 0.9% and 1.2%, respectively. (Table 1). Percentage NO and FO of food groups was given in Fig 3. Following to Copepoda, Mollusca(29.6%) was second dominant group as NO%. In frequency occurrence, Cladocera and Mollusca wereconsumed by *M. leidyi*with equal percentage (19.5%).

During the sampling, the lowest temperature was obtained in January at 7.8 °C and highest value obtained in July at 25.73 °C. Temperature values increased from surface water in the spring to the summer months, and then decrease.A remarkable thermocline layer was determined in July. The average salinity was found as 17.78 ‰ (Fig 4).

Monthly distribution of gelatinous macrozooplankton was examined vertical plankton tows. In August, sampling could be made only at Station A due to the malfunction on board.Gelatinous species composition

Table 1 — Pooledfood items in the food composition of *A. aurita* and *M. leidyi* (NO as %: numerical occurrence, FO as %: frequency occurrence)

Food Items	*A. aurita*		*M. leidyi*	
	NO	FO	NO	FO
Appendicularia				
Oikopleura dioica	6.6	6.3	2.9	3.6
Fish egg-larvae	0.8	1.5	0.9	1.2
Barnacle nauplii–larvae	4.0	4.5	0.9	2.6
Chaetognatha				
Sagitta setosa	1.8	1.8	0.2	0.6
Cirripedia nauplii	0.2	0.3	0.2	0.6
Cirripedia	0.8	1.2	0.0	0.0
Cladocera	0.2	0.3	0.0	0.0
Peniliaavirostris	7.7	5.4	6.8	7.9
Pleopis polyphemoides	2.3	2.4	6.4	4.8
Evadne spp.	2.8	3.6	12.7	6.7
Copepod nauplii	12.0	8.1	5.5	6.7
Copepoda	29.7	28.3	26.1	36.0
Decapod larvae	2.0	3.0	1.3	2.4
Dinophyta				
Noctilucascintillans	1.7	1.8	0.0	0.0
Mollusca				
Bivalvia larvae	16.3	15.2	27.6	15.9
Gastropoda larvae	4.9	7.7	2.0	3.7
Isopoda	1.0	1.4	0.2	1.2
Ostracoda	1.2	2.2	0.2	0.6
Polychaetae larvae	2.0	2.0	0.4	1.2
Zoo. egg	0.6	0.6	0.0	0.0
Unidentified food items	1.4	2.4	5.7	4.3
Total number food item	650		456	
Max. prey/ ind.	94		50	
Number ind. without food item	95		86	
Total no ind. examined	236		205	

varied monthly. *A. aurita*abundance growth was observed in spring. Its highest abundance and biomass were determined 16.67n.m^{-2} in March and 124.17g.m^{-2} in April. *M. leidyi* abundance was increased summer. Maximum value was 51 n.m^{-2} in August;however, maximum biomass was determined 82.5 g.m^{-2} in January. *B. ovata* was found only three months namely October, November and December. Maximum abundance and biomass were 2.5 n.m^{-2} in December and 17.29 g.m^{-2} in September (Fig 5 A, B). The all species exhibited clearly seasonality in study. *M. leidyi* decreased with emerge of *B. ovata* in autumn. *A. aurita* was found low amount when *M. leidyi* increased, however there was no correlation between species (p>0.05).

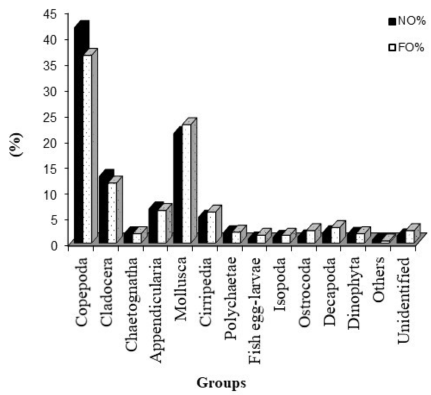

Fig. 2 — Frequency occurrence (FO, %) and numerical occurrence (NO, %) of food groups in food composition of *A. aurita*

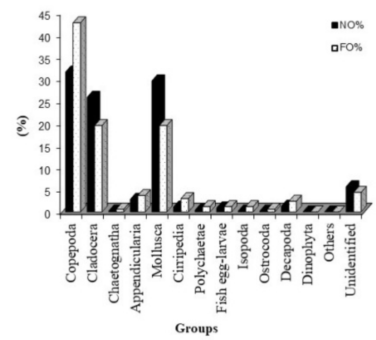

Fig. 3 — Frequency occurrence (FO, %) and numerical occurrence (NO, %) of food groups in food composition of *M. leidyi*

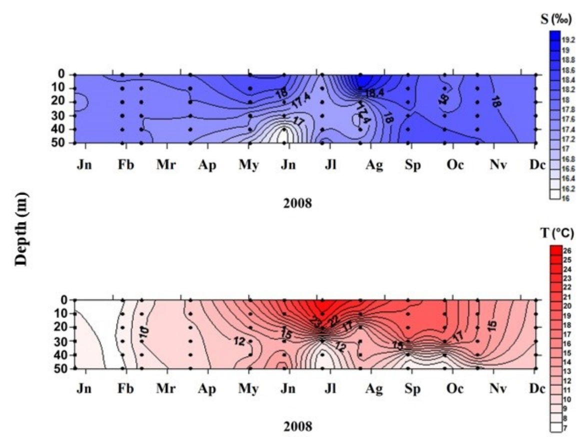

Fig 4 — Salinity (‰) and Temperature (°C) parameters in Sinop coast of the Southern Black Sea in 2008

Seasonal distribution of *A. aurita* was not correlated with temperature and salinity (p>0.05). *M. leidyi* showed correlation with temperature (p<0.05) but not with salinity (p>0.05). No significant correlation was found between *B. ovata* and surface temperature and

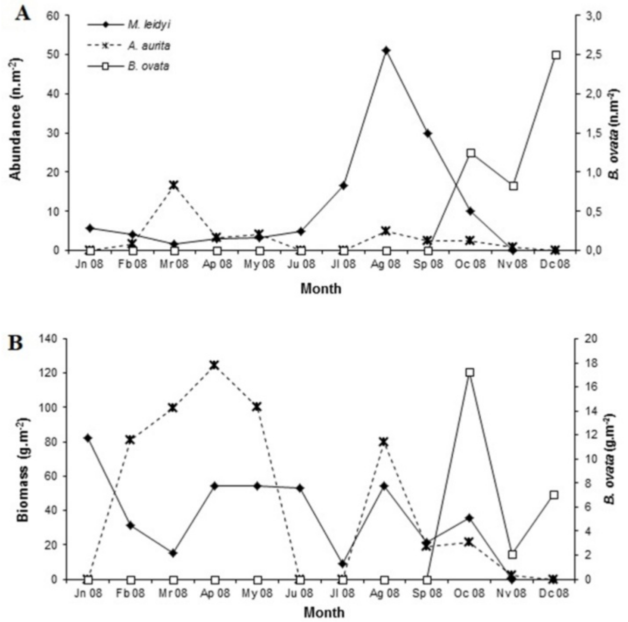

Fig. 5 — Gelatinous macrozooplankton species vertical abundance (A) and biomass (B) at Sinop coast of the Southern Black Sea in 2008.

salinity. The biomass and abundance of gelatinous specieswere not significantly different between stations ($p>0.05$).

Discussion

In food composition of *A. aurita* was observed a mucus structure within gastric pocket and solution which surrounds the nutritional organisms. Nutritional diversity was observed more at gastric pockets and oral arms. In this study, food item was not determined in the food composition of 40.3% of *A. aurita*and 41.9% of *M. leidyi*. It is being considered that the individual which had completed digestion before or which encounter nutritional difficulty causes this result. Food composition of *A. aurita*was mainly consisted of Copepoda and Bivalvia. Cladocera followed these groups. In study realized at the Turkish, Bulgarian and Romanian Economic Zone of the Black Sea during 1991-1995, had specified that the food composition of *A. aurita* consisted of Copepoda (42%), Mollusca (35%), Cladocera (4%), fish eggs-larvae and others (16%)[20]. The most food item within the food content of *A. aurita* was found as 225 in total as being 220 Bivalvia larvae and 5 Copepoda in March-April 1995. In this research, the most nutrient in the food composition was found as 94, of which 72 was Bivalvia, and 17 was Copepoda and Copepoda nauplii. Smaller *A. aurita* individuals prefer mostly Bivalvia and small Copepoda species was determined in the present study. Rotifer and Copepoda nauplii species were preferred mostly by *Aurelia* ephyra form at the Gulf of Narragansett[23]. It is considered that the concentration of zooplankton groups in the environment is one of the causing different nutrient preferring.

A. aurita is a significant competitor against the nutrition of planktonic fish species at the Black Sea. The primary nutrients of *A. aurita* consist of small planktonic Crustacea larvae of benthic invertebrates and Appendicularia[24]. Similar results had been obtained in European seas[25,26]. In this study, NO% of Appendicularia was 6.6%, Cirripedia 4.9% and Decapoda 2% in the nutritional composition of *A. aurita*. In Gulf of Tokyo, its nutritional contents was found a broad taxonomic range of prey, and Copepod *Oithona davisae* was determined predominant[27]. Copepoda species (*Paracalanus parvus*, *Oithona nana*) and Copepodites were observed predominantly in the food composition of *A. aurita* by Malej et al.[28]. They found larvae of Gastropoda, Bivalvia and Cirripedia 17%, nauplii 8%, Appendicularia 2% and other nutritional pieces and Cladocera about 1%.

We observed that nutritional contents of *M. leidyi*were available at stomach, oral lobs, and within solution. Kremer[29]reported that when the nutritional concentration was high, the *M. leidyi* could not digest all the organisms it catches and that it discharges by wrapping with mucus or kept within the gastric fluid. NO% of Copepoda and Bivalvia consisted the main nutritional groups of *M. leidyi*. Bivalvia had predominant food item in the gelatinoussampled in the late summer and early autumn. In small *M. leidyi* individuals, Copepodites, Copepod nauplii, Cladocera species were observed more frequently. The Northern Black Seawas reported that the nutritional content of *M. leidyi* consisted of Bivalvia, Copepoda, Cladocera eggs. As the zooplankton abundance increases, a decrease in the amount of *M. leidyi* with empty stomach was recorded[30].In another study, while Tintinidae and Cypris were found more in the gastrovascular cavity of small individuals, *Sagitta* sp. and fish eggs and larvae could not be identified[31]. In the study between 1991 and 1995, food in gastrovascular cavity of *M. leidyi* was composed of Copepoda (50%), Mollusca (40%), fish eggs and larvae (1%) and Cladocera (1%)[32]. In our study, the most nutrients in the individual food composition was determined as 50 items. This number was found as 94 by Mutlu[32] and as 111 by Zaika and Revkov[30].

The high energy food groups are preferred to the nutrition by *M. leidyi*[33]. It is found that Copepoda with high enegy[33] most preferred food group by it. In addition energy values of food groups and size of ctenophore; digestion rates, movement speeds and their abilities to escape of preys were effective in *M. leidyi* food preference[34].

In this study, phytoplankton species except *Noctiluca scintillans* was not encountered in the food composition of *M. leidyi*. Individuals of *M. leidyi* put in the same environment with algae did not consume it, and a decrease of 51-8.2% occurred in their weights[35]. Some researchers have pointed out that phytoplankton can be found only in *M. leidyi* nutritional contents by clinging to other organisms[36].

Fish eggs and larvae in the food composition was foundin the gelatinous species approximately as 1%. Eggs larva and larva was belong to anchovy (*Engraulis encrasicolus*) and sprat (*Sprattus sprattus*). Eggs were determined in the individuals sampled in August, and larvae were determined in the individuals sampled in October. In the Black sea,spawning period of anchovy and sprat was from late spring to middle autumn[37]. We suggested that gelatinous macrozooplankton are feed on eggs and larvae if theseare in the ambient seawater.In another study, itwas found in food composition as 3% in *A. aurita*[32] and as 1% for *M. leidyi*[30]. These differ egg and larval ratios in the food content may be due to difference amount of in ambient of seawateror sampling periods.

Food composition studies on *M. leidyi and A. aurita* in Turkish coasts showed that gelatinous macrozooplankton graze on zooplankton and ichthyoplankton[20,32,38,39,40]. However, *M. leidyi* is capable of excessive feeding, have higher digestive rate and can feed insatiable on mesozooplankton. Even if its gastrovascular atrium is full, it continues to take food and vomits that are not large digested in large quantities together with the mucus[31,41]. Adult individual of *M. leidyi* consumes food 40-70% of their body weight daily, moreover small individuals and larvae need more[42]. Because of all these reasons, high abundance of *M. leidyi*is causing serious significant pressure on zooplankton and fish eggs-larvae in the Black Sea.

Down-welling and up-welling flows occurring in the Black Sea are effective in the vertical distribution of gelatinous macrozooplankton[18,43]. The gelatinous accumulate at these upwelling areas with high productivity area, and show a highly development[44]. While it is providing an efficient feeding area for planktivorous fish such as anchovy and sprat, high catch yield is obtained from this area[45]. Present sampling area is within the cyclonic and anti-cyclonic eddy triangle at the Black Sea, and it is under the influence of current systems[46]. In this area, pelagic fishery is performed intensely[10].Based on personal observation in the present study, the abundance of gelatinous was more at coastal areas. Additionally, weather conditions and wave movements were determinant in the amounts and regional dispersion of gelatinous organisms in the coastal. The distribution of gelatinous macrozooplankton showed regional differences by current system, temperature and salinity at the Black Sea[5,47,48]. In the study performed at previous years at the coasts of Sinop, it was reported that the abundance and biomass of gelatinous macrozooplankton reached maximum values when the water temperature was 23.53°C in July 2003. Whereas, it was recorded low in July 2004, when the water temperature was 9.65 °C[49,50].

The increasing of gelatinous macrozooplankton abundant had continued as from the late spring until early autumn 2008. *M. leidyi* showed a distribution as from the end of spring to middle of autumn. Highest value was determined in August 2008 in which temperature was 23.5°C. At the same region, its maximum values were obtained in summer months, and minimum values were determined in winter monthsbetween 2002-2004[49,50]. In 1999 had informed increasing in the abundance and biomass of *M. leidyi* from March until July[51]. At the Black Sea, the optimum temperature for *M. leidyi*to reproduce is over 20°C[52] and their annual biomass is being observed higher in summer and autumn[53]. Between the 1998 -2004 was determined that *M. leidyi* was higher at the Western Black Sea in which the surface water temperature was20-24°C compare to North Eastern Black sea[54].

In the current study, a decreasing for *A. aurita* was determined when the amount of *M. leidyi* reached high values. Similar results were obtained in 2002-2004, but between two species obtained in horizontal tows was determined negative correlation[37,50]. In 1980s, the total biomass of *A. aurita* in the whole sea area had reached 300-500 million tons[55]. By the reaching of *M. leidyi* to peak values, a decrease was recorded in the amount of *A. aurita*[42,56]. Studies and data analyses in the Black Sea showed that *A. aurita* and *M. leidyi*is competitionon same food group and *M. leidyi* is predominant in this competition[1,9].It was informed *M. leidyi* cannot survive in the long period in the shallow Kertinge Nor of Denmark where a large population of small *A. aurita* exist in ever year[57].

B. ovata was first seen in October, and its presence continued until the end of December 2008. With the appearance and increase of *B. ovata*, the abundance of *M. leidyi* decreased or not detected in sampling. We suppose *B. ovata* controls the level of *M. leidyi*. Researcher[58]reported similar result for Izmir Bay in 2001-2002. In October 2006 was reported *B. ovata* biomass reached 3.81 million tons[5]. In the same period, *M. leidyi* biomass declined, it was high value in June 2006. In between 2002-2004, *B. ovata* was observed by the coasts of Sinop as from September until the January. The average abundance and biomassof *M. leidyi* raised 86.25 n.m^{-2}, 350.6 g.m^{-2}in 2003 compared with 2002 and 2004.In the same period, abundance and biomass values of *B. ovata* were found low[37,50,59,60]. In the Northern Black Sea[3], *M. leidyi* abundance increased to 1000n.m^{-2} by the end of August. Then *B. ovata* abundance reached to 27n.m^{-2} and biomass 49.4n.m^{-2} in early September, *M. leidyi* abundance and biomass decreased as 233n.m^{-2} and 445g.m^{-2}. *B. ovata* completely destroyed the population of *M. leidyi* at the inner shelf of the North-western Black sea in 2005 and in the autumn of 2010[61].

A. aurita biomass increase was observed in spring and autumn with contribution of new individuals due to reproduction. In other studies realized at the Black Sea, maximum biomass values of *A. aurita* were determined similarly in the same periods[20,55,62,60]. In the North Atlantic,*A. aurita* reached higher abundance values in the mild years[63]. In coast of Marmara Sea[64], maximum biomass of *A. aurita* was found 5111 g.m^{-2} in April2015 and 13177.9 g.m^{-3} in March. In the current study, the highest *A. aurita* biomass (124.17 g.m^{-2}) was determined in April. In the previous research[59,62], the highest values were obtained in July 2002 as 225 g.m^{-2}; in March 2003 as 2130 g.m^{-2}; and in August 2004 as 268 g.m^{-2}. In present study *A. aurita*biomass did not show a high increase in summer months in the Black Sea, as it occurred in previous years[60,62]. However, *M. leidyi*abundance was determined almost every month in this year and its abundance increased maximum value in August 2008 after 2003. As a result, we can deduce that increase of *M. leidyi* affect development of *A. aurita* in the Black Sea.Our opinion is that competition in the interspecies, mesozooplankton composition in the ambient seawater and the climate change are probablylead to different population growth of gelatinous species and these factors affected distribution of gelatinous macrozooplankton different region.

Conclusions

Gelatinous macrozooplankton species showed different distribution as monthly and seasonality. It is determined that the temperature is a significant effect on *M. leidyi*. It was determined that the main food content of *A. aurita* and *M. leidyi* is zooplankton, and this species consume fish eggs and larvae. Gelatinous macrozooplankton have an important role in the Black Sea. Precautions to be taken should be investigated and well analyzed in order to prevent negative effects of gelatinous blooms in the Black Sea ecosystem. They should be constantly monitored with environmental factors such as eutrophication, climatic change might favour gelatinous species. There needs to be more fundamental research on gelatinous zooplankton ecology, their complex life cycles, and ecosystem roles.

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