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RESEARCH PAPER

Study on Quality and Abundance of Zooplankton in Surface Offshore Waters of Southern Part of Caspian Sea

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Abstract

In this study diversity and abundance of zooplankton in south Caspian Sea offshore waters were investigated. During the first season of oceanographic cruise in winter 2014 at southern part of Caspian Sea, 8 stations at offshore waters of south Caspian Sea were selected. Totally, 4 Holopelankton and 6 meroplankton were identified. Among the identified zooplanktonic groups, Copepods were the main zooplanktonic group that constituted about 53% of total abundance and 65% of total biomass. They were dominant in all stations. Predominant species of copepods was *Acartia tonsa*. Its abundance was between (106±42 ind.m^{-3}) and (1545±181 ind.m^{-3}). After *A. tonsa*, lamellibranch larvae had the highest abundance in all stations (18%) and fish larvae was at second place in terms of biomass (27%). Results showed after invasion of *M. leidyi*, composition and abundance of zooplankton in south Caspian Sea waters greatly changed.

Introduction

Caspian Sea is the biggest land-locked saltwater lake in the world with a catchment area of 3.5 million km^2 (Mamaev, 2002). It is located between 36° N and 62°N.The basin of Caspian Sea is divided into three distinct physical regions: Northern, Middle, and Southern Caspian. The northern Caspian that only include the Caspian shelf is very shallow and accounts less than 1% of the total water volume. The middle Caspian accounts 33% of the total water volume. The southern Caspian is the deepest with oceanic depths of over 1000 m and accounts 66% of the total water volume. (Kosarev and Yablonskaya, 1994; Aladin and Plotnikov, 2004). Environmental conditions in the Caspian Sea has significantly changed under the impact of human activities and has been significantly altered during the past 30 years, apart from natural changes attributable largely to sea level variability (Rodionov, 1994). Anthropogenic pollution is a significant threat on the biodiversity of the Caspian Sea (Salmanov, 1999; Aladin and Plotnikov, 2004). Impacts on the ecosystem notably are from domestic pollutants including various detergents, industrial pollutants especially the heavy metals and agricultural pollutants, in particular nutrients owing to over fertilization and pesticides. The faunal composition of Caspian Sea has changed totally during last decades because of its water level fluctuations, human manipulation and the entry of an alien invasive species of a Ctenophore jellyfish. During 80s *Mnemiopsis leidyi* (originated from the north Atlantic waters) was transferred to the Black Sea, Azof, Marmara and east Mediterranean Seas and then to Caspian Sea (Shiganova, 1993; Dumont, 1995; Shiganova *et al*., 2001; Fuentes *et al*., 2010). Zooplankton are recognized among the best indicators to be particularly useful to investigate and document environmental changes (Sipkay *et al*., 2009). Major zooplankton taxa have short life cycle and the community structure is able to reflect real-time scenario as it is less enforced by the stability of individuals from previous years (Richardson, 2008). Zooplankton community structure serves as a critical trophic link between the lower and higher trophic levels. They represent a highly diverse and complex plankton group, participating in water circulation and energy having strong metabolic activity. Through the direct ingestion of phytoplankton, zooplankton influence population and species dynamics; through excretion and secretion, they contribute to the decomposition and circulation of organic matter in aquatic ecosystems and stimulate algae growth. Zooplanktons are the prey for fish and other aquatic animals, they play an important role in aquatic ecosystems (Guangjun, 2013). There are no documents on diversity and abundance of zooplanktons in south Caspian Sea's offshore waters. Most of the studies focus on investigating the composition and abundance of zooplankton in near shore waters. Most of the studies on zooplankton in south Caspian Sea water were carried out by Iranian Fisheries Research Organization (IFRO). Several studies have been undertaken regarding the zooplankton communities and their structures alongside Iranian coasts in the southern parts of the Caspian Sea in recent years such as: (Rowshantabari, 2000; Laloei *et al*., 2004; Hashemian *et al*., 2006; Hosseini *et al*., 2011; bagheri *et al.,* 2013; Rowshantabari et al, 2014; Pourang *et al.,* 2016 and *etc…*). No study has been done on the community of zooplankton in the offshore water of south Caspian Sea. Furthermore, regarding to the effects of alien species invasion (*M. leidyi*) in Caspian Sea, studying the structure and biomass of zooplankton in the offshore water of south Caspian Sea has high importance.

Material and Methods

The study was carried out in offshore water of south Caspian Sea (Figure 1). One transects with 8 stations were selected (Table 1). The distance among sampling stations was 30 km. Sampling was conducted in winter season (April 2014). Samples were collected in both day and night [7 stations at day and in 1 station (S_5) at night].

Samples were collected by zooplankton net (100 µm mesh with a 0.36 m mouth diameter) by vertical hauling from10m depth. After collecting, specimens were preserved in a 4% formaldehyde seawater solution. In the laboratory samples were studied in a Bogarov tray contained 0.5 ml of each sample (Postel *et al.,* 2000). Biomass of zooplankton was estimated from the shape of each species (Petipa, 1957) and an invert microscope was used for identifying them. Zooplankton taxonomic classification was performed based on (Birshtein *et al.,* 1968; Kusmorskaya, 1964; Kuticova, 1970). Biomass and abundance data were calculated as per cubic meter. Zooplankton distribution type was determined based on formula below:

$$A = \frac{\text{var}}{ave}$$

Where *A* indicates distribution index, *Var* variance of identified zooplankton and *Ave* average of identified zooplankton abundance. If (*A*<*Ave*), distribution will be uniform and if (*A*>*Ave*), distribution will be spotty and if (*A*= *Ave*), it will be randomly.

During collection of samples on shipboard, physical and chemical parameters of sea water including temperature, salinity, pH and dissolved oxygen (DO) were measured by using multimeter portable devices

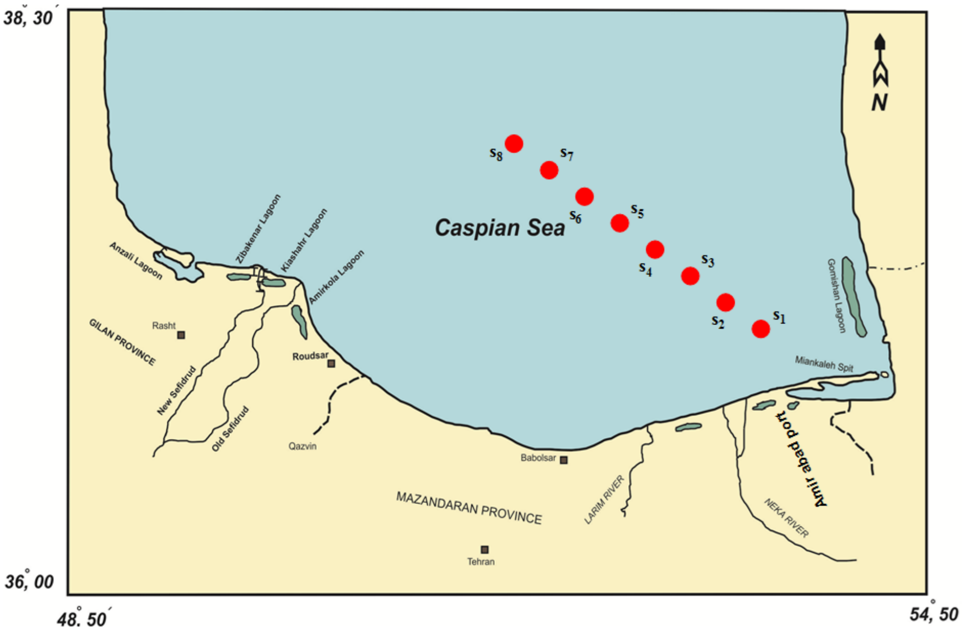


Figure 1. Map of sampling stations in the south Caspian Sea waters.

Table 1. Position of sampling stations in offshore waters of south Caspian Sea

Station	Position	Depth (m)
S_1	37N 02.671 53E 03.256	250
S_2	37N 16.866 52E 44.678	480
S_3	37N 31.005 52E 26.299	510
S_4	37N 44.441 52E 09.086	550
S_5	37N 58.549 51E 50.483	630
S_6	38N 09.947 51E 27.394	722
S_7	38N 20.452 51E 12.822	735
S_8	38N 20.033 51E 20.119	750

(Hach, HQ 40d). Water samples were filtered through membrane filter of 47 mm diameter and 0.45 µm pore size and kept frozen at -20°C for analysis of nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{3-}) and silicate ($H_3SiO_4^-$). Analyses were done according to the standard methodology (APHA, 1985).

Statistical Analysis

Statistical analyses were carried out by using SPSS software (SPSS ver. 16) and PAST program (ver. 2.09b). One-way analysis of variance (ANOVA) was used to test the differences among the abundance of zooplanktons in different stations. Tukey's test ($P<0.05$) was used to assess the significant differences among the stations. The relationship between abundance of zooplanktons and physico-chemical parameters in different stations was estimated by using a Pearson's rank correlation coefficient and Principal components analysis (PCA) ($P<0.05$). According to environmental conditions similarity among stations was calculated using the Bray-Curtis coefficient after transforming data by the log X.

Results

Physico-chemical parameters of sea water are shown in (Figure 2). The range of salinity was from (12.52 g. Kg^{-1}) at station 1 to (12.87 g. Kg^{-1}) at station 3. Maximum temperature was (13.80^{0}C) at station 4 and minimum was (11.70^{0}C) at station 3. Station 7 had the highest value of pH (8.67) and the lowest was found at station 4 (8.60). DO values were found maximum and minimum (10.54 and 9.97 mg. L^{-1}) at stations 7 and 4, respectively. Figure 3 shows nutrients concentration in all stations. Nitrite concentration only measured at station 1 (2.13 µg. L^{-1}) and it was not detectable in the other stations. The highest concentration of nitrate was found at station 3 (42.05 µg. L^{-1}) and the lowest was at station 1 (4.28 µg. L^{-1}). Also, the range of silicate concentration was between 12 µg. L^{-1} at station 1 and 156 µg. L^{-1} at station 4. In all stations, concentration of phosphate was not detectable. Based on the cluster analysis, all stations were divided in two main groups; group A contained the station with the lowest concentrations of all abiotic parameters measured. On the other hand, group B contained two subgroups: B_1 contained three stations with high concentration of silicate. B_2 contained four stations with medium concentration of silicate (Figure 4). Both axes from the Principal Components Analysis (PCA) explained 66% of the total variance. In component 1, most positive correlation was found among salinity, silicate and nitrate, being negatively correlated to the nitrite. In component 2, most positive correlation was found between DO and pH (Figure 5), having negative correlation with temperature. Dispersal of stations may be explained by nitrate and silicate concentrations. In this study a total number 4 Holoplankton and 6 meroplankton were identified, including: *Acartia tonsa* and Nauplius of *A. tonsa*; Copepoda – *Asplanchna priodonta*; Rotifera – *Podon polyphemoides*; Cladocera - Larvae of *Nereis diversicolor*; Nereididae - Cypris, nauplius and cirrus stages of *Balanus improvises*; Cirripedia - Lamellibranch larvae;bivalvia and Fish larvae.

Table 2 shows the average abundance of the identified zooplanktons in each of the 8 stations. As shown, *Acartia tonsa* has the highest abundance at station 5 (1545±181 ind.m^{-3}) followed by Nauplis of *A. tonsa* (1168±232 ind.m-3) at the same station. The lowest abundance belongs to Cypris of *Balanus improvisus* (64±22 ind.m^{-3}) at station 4. Among all

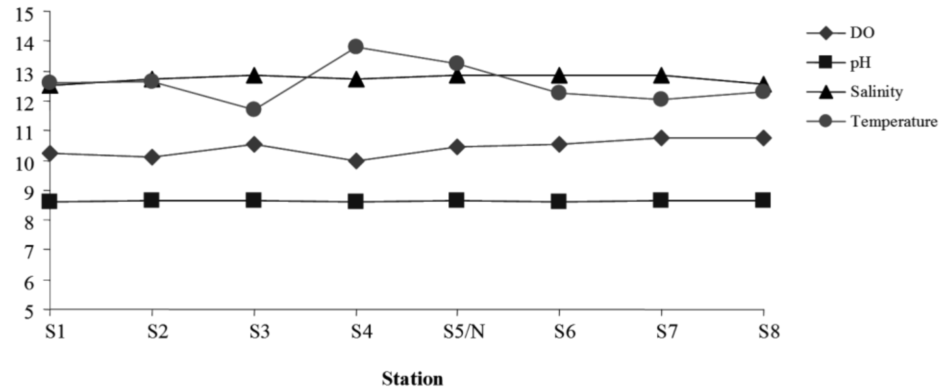


Figure 2. Physico-chemical parameters measured in all stations.

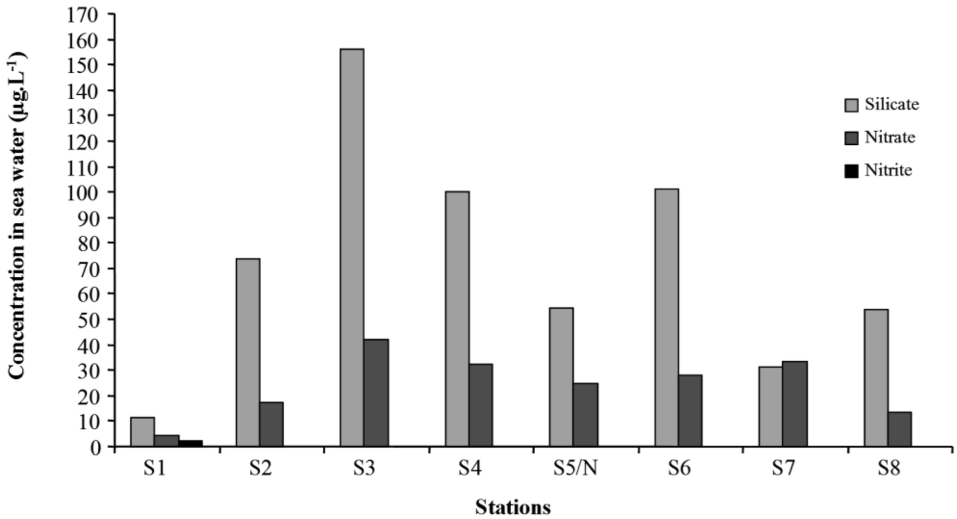


Figure 3. Nutrients concentration measured in all stations.

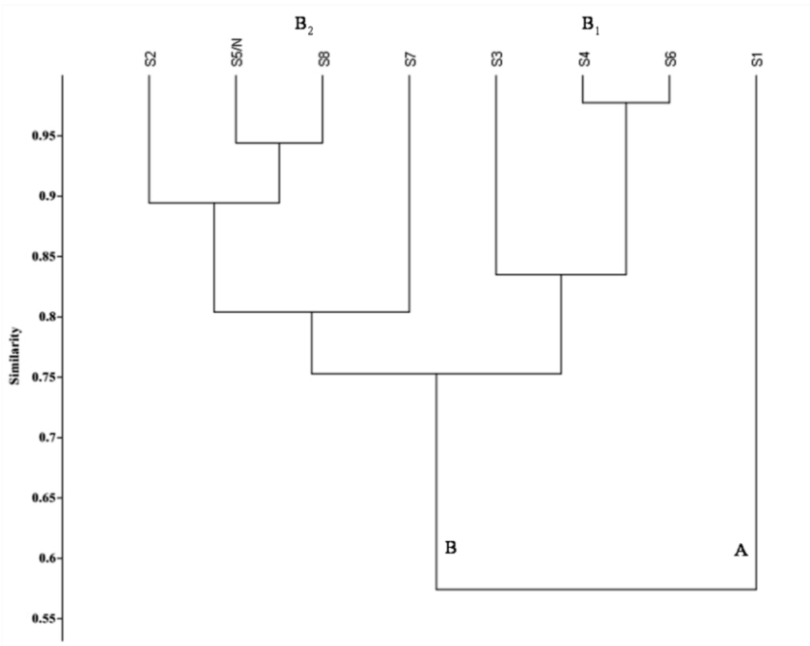


Figure 4. Similarity among stations base on the environmental parameters.

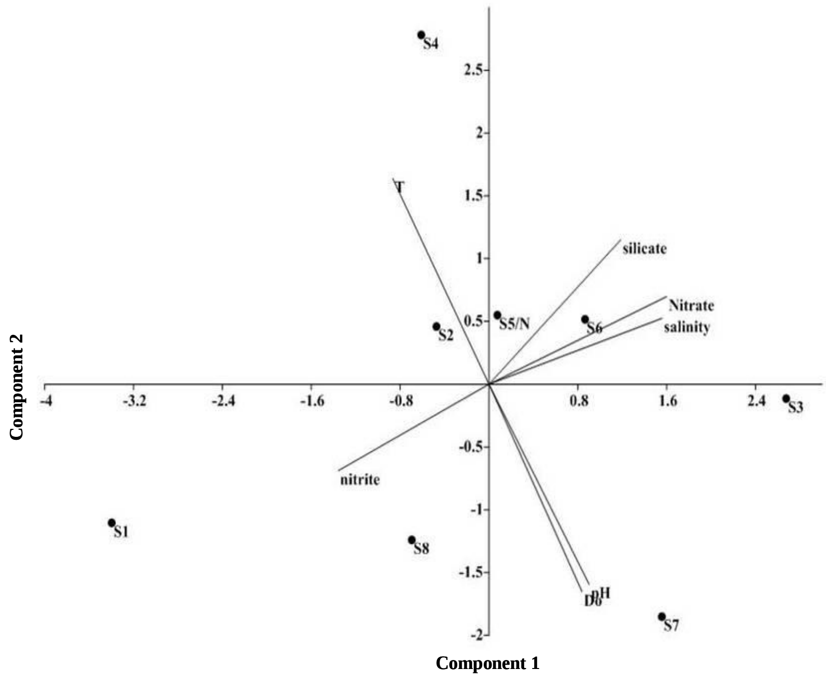


Figure 5. Principal Components Analysis of environmental parameters in all stations.

Table 2. Average of abundance (±SD) of identified zooplanktons in each of the 8 stations

	S_1	S_2	S_3	S_4	$S_{5/N}$	S_6	S_7	S_8
Acartia tonsa	830±87	448±114	382±85	255±43	1545±181	321±59	189±127	106±42
Nauplius of *A. tonsa*	566±85	531±94	262±33	120±44	1168±232	207±91	160±43	99±44
Nauplius of *Balanus improvisus*	113±28	153±54	0	85±57	307±54	104±43	0	78±44
Asplanchna priodonta	500±156	0	0	0	495±142	0	0	0
Nereis diversicolor	141±57	0	0	0	0	0	0	0
Podon polyphemoides	0	0	0	0	165±74	151±71	123±43	71±33
Lamellibrach larvae	293±43	708±93	248±33	219±74	318±71	368±113	198±57	0
Cypris of *B. improvisus*	160±91	189±74	99±44	64±22	260±90	160±59	0	0
Fish larvae	0	106±35	0	0	0	0	0	0
Cirrus Stage of *B. improvisus*	0	0	0	0	0	95±43	0	85±21

stations, $S_{5/N}$ has the highest abundance of total zooplanktons (426±524 ind.m^{-3}) and S_8 has the lowest abundance of total zooplanktons (43±48 ind.m^{-3}).

According to the one-way ANOVA and Post Hoc Tukey's test, significant differences were observed (P<0.05) in the abundance of zooplanktons among the stations. Also, there was significant correlation between abundance of some of the zooplanktons and environmental parameters. Nauplius of *B. improvisus* had significant correlation with temperature (P<0.01). Cirrus stage of *B. improvisus* showed significant correlation with DO (P<0.05). Significant correlation was also found between *A. priodonta* and silicate (P<0.05). *Nereis diversicolor* had significant correlation with silicate, nitrate (P<0.05) and nitrite, salinity (P<0.01). *P. polyphemoides* significantly correlated to DO (P<0.01) and salinity (P<0.05). Fish larvae and Lamellibranch larvae showed significant correlation with DO P<0.05 and P<0.01, respectively, (Table 3).

Acartia tonsa has the highest total abundance (509±472 ind.m^{-3}) of all zooplanktons, followed by Nauplius of *A. tonsa* (389±362 ind.m^{-3}) and Lamellibranch larvae (294±200 ind.m^{-3}). Fish larvae have the lowest total abundance (13±37 ind.m^{-3}). Abundance percentages of zooplanktonic groupd are shown in Figure 6. So, Copepoda has the highest percentage of abundance (53%) followed by Lamellibranch larvae and Cirripedia (18 and 15%, respectively). The lowest percentages belong to Polychaeta (Nereididae) and fish larvae (1%). Distribution types of zooplanktons are shown in (**Table** 4). Half of zooplanktons had uniform and other had spotty distribution in stations.

Acartia tonsa has the highest amount of biomass (80 $mg.m^{-3}$) followed by fish larvae (37 $mg.m^{-3}$). The lowest amount of biomass belong to Nauplius of *B. improvises* and *N. diversicolor* (0.41 and 0.44 $mg.m^{-3}$ respectively). The highest percentage of biomass among all zooplanktonic groups belongs to Copepoda (63%) and followed by fish larvae (27%). Also, Polychaeta (*N. diversicolor*) has the lowest percentage of biomass among all groups (0.3%) (Figure 7).

Discussion

In this study the abundance, biomass and species composition of zooplankton in the southern part of Caspian Sea were investigated. The last station (S_8) was very close to border of south and middle Caspian. Based on our results, abundance of zooplankton significantly correlated with the physico-chemical parameters of water, except in case of pH. While, these correlations were not found for copepods, and they did not show significant correlation with any of measured parameters. Parts of Our results obtained in this study are congruent with the observation made by Coman *et al.,* (2003) reporting the lack of correlation between water quality and zooplankton abundance observed. While, Lubzens *et al.,* (1993) found significant correlation between salinity, temperature, DO and the abundance of rotifers. In this study 7 species of zooplankton belong to 7 families were identified. These species either including both Holo and meroplanktons. For the Caspian Sea, studies regarding to the composition and diversity of the plankton where made (Rowshantabari *et al.,* 2003; Bagheri *et al.,* 2010; Bagheri *et al.,* 2013) reporting a maximum of 55 species including: 9 copepods, 6 rotifers, 5 protozoans and 29 cladocerans. Rowshantabari *et al.,* (2012) reported 14 species of zooplankton. Later Rowshantabari *et al.,* (2014) reported 22 species of zooplankton in the southern of Caspian Sea, including 4 copepods, 9 rotifers, 2 protozoans and 7 cladocerans, both studies made at the south of the Caspian Sea. Comparing this study results with the previous antecedents, the

Table 3. Relationship among zooplankton abundance and environmental parameters

	Silicate	Nitrate	Nitrite	DO	Salinity	Temperature	pH
Acartia tonsa	-0.266	-0.148	-0.193	-0.149	0.068	0.374	-0.119
Nauplius of *A. tonsa*	-0.242	-0.214	0.193	-0.165	0.062	0.317	-0.048
Nauplius of *Balanus improvisus*	-0.215	-0.172	0.061	-0.256	-0.032	0.546**	-0.268
Cypris of *B. improvisus*	0.020	0.022	0.115	-0.344	0.127	0.263	-0.157
Cirrus stage of *B. improvisus*	0.082	-0.120	-0.162	0.432*	-0.129	-0.258	-0.289
Asplanchna priodonta	-0.504*	-0.301	0.525	-0.128	-0.282	0.321	-0.115
Nereis diversicolor	-0.463*	-0.415*	0.939**	-0.234	-0.622**	0.028	-0.065
Podon polyphemoides	-0.156	0.094	-0.248	0.551**	0.417*	-0.074	0.144
Fish larvae	0.020	-0.165	-0.108	-0.418*	-0.068	0.033	-0.006
Lamellibranch larvae	0.096	0.009	0.015	0.516**	0.187	0.089	-0.101

**Correlation is Significant at the 0.01 level ($P<0.01$)
* Correlation is Significant at the 0.05 level ($P<0.05$)

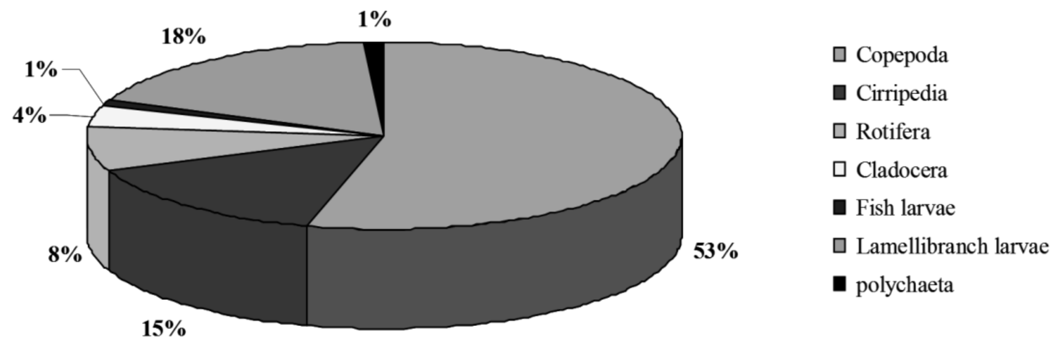
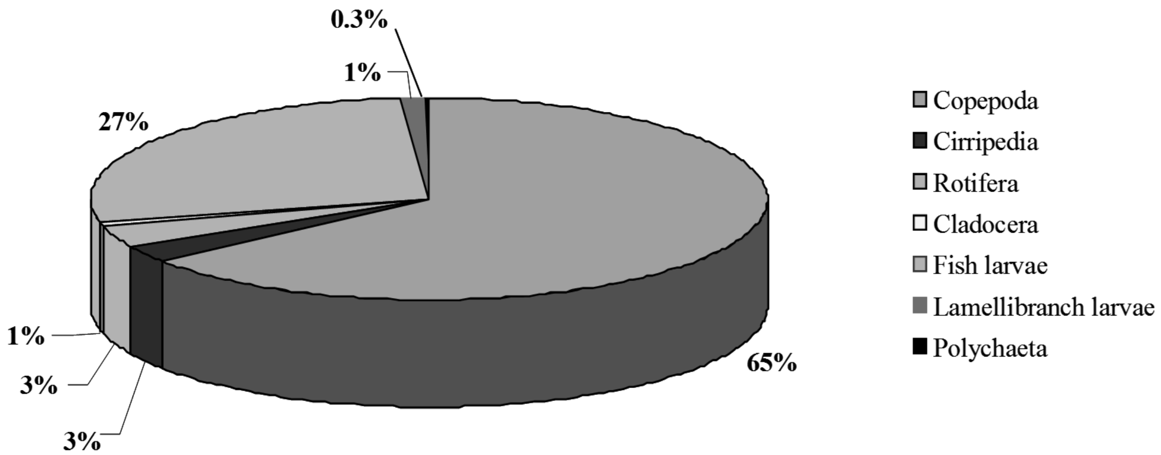


Figure 6. Percentage of abundance of zooplanktonic groups in all stations.

Table 4. Type of Distribution of identified zooplanktons in all stations

Zooplanktons	Mean abundance	Distribution index	Type of distribution
Acartia tonsa	510±459	414	Uniform
Nauplius of *A. tonsa*	389±356	325	Uniform
Nauplius of *Balanus improvisus*	105±99	94	Uniform
Asplanchna priodonta	124±229	422	Spotty
Nereis diversicolor	18±51	142	Spotty
Podon polyphemoides	64±78	95	Spotty
Lamellibranch larvae	294±200	136	Uniform
Cypris of *B. improvisus*	116±101	87	Uniform
Fish larvae	13±37	136	Spotty
Cirrus of *B. improvisus*	22±43	82	Spotty

Figure 7. Percentage of biomass of each zooplanktonic group in all stations



richness here obtained are less. It seems that the diversity of zooplanktons have decreased after invasion of *M. leidyi* according to the previous suggestion made by Rowshantabari *et al.,* (2007); Roohi *et al.,* (2010) and Hosseini *et al.,* (2011) mentioning that zooplankton diversity had decreased considerably after the invasion of *M. leidyi* into the Caspian Sea from late 80s. *M. leidyi* is an active predator of zooplankton and fish larvae to an extent that could deplete zooplankton biomass if their populations increase abnormally (Mayer, 1912; Herman *et al.,* 1968; Rowshantabari *et al.,* 2007). Invasive species also have an effect on the appearance or disappearance of some zooplankton species (Shiganova *et al.,* 2001). So, presence of some species had greatly been affected by the biomass and abundance fluctuations of this invasive Ctenophore (Shiganova *et al.,* 2001). As mentioned in results, *A. tonsa* had the highest abundance and biomass in winter. Rowshantabari (2000) had stated that, in 1996, *A. tonsa* was dominant in summer and autumn but *Eurytemora grimmi* and *E. minor* that have not seen in our study were dominant in copepod population in spring and winter. Since 1982, *A. tonsa* has been transferred to Caspian Sea (Kurashova and Abdullaeva, 1984) and since then its population has grown sharply after 1985. Today, *A. tonsa* is the major and dominant zooplankton in the Caspian Sea (Rowshantabari *et al.,* 2012). Before entrance of *A. tonsa* in the south Caspian Sea, *Calanipeda aquae-dulcis* was dominant (Yelizarenko, 1992). This species lives at the surface layers and its abundance was 1329 ind.m^{-3} in winter 1996 (Rowshantabari, 2000). After introduction of *M. leidyi*, their population disappeared in south Caspian Sea. In this study, copepods constituted the dominant population of zooplankton with 53% of total zooplankton abundance. However, in other studies (Omori & Ikeda, 1984; Mauchline, 1998; Rowshantabari, 2000) they constituted about 88% in spring, 99% in summer and autumn and 31% in winter of the whole zooplankton population. *A. tonsa*, the dominant species of copepods, dominated other species and reached at its maximum value in summer. Within rotifers, only *A. priodonta* was seen. It constituted about 8% of whole zooplankton population. *A. priodonta* is a cosmopolitan rotifer and is one of the biggest planktonic predators and it feeds on Cyanobacteria, diatoms, dinoflagellates and protozoans and both as grazer and predator (Pociecha & Wilk-Woźniak 2008). Also, it feeds on other rotifers, such as *Keratella* and cladocerans (Kappes *et al.,* 2000). Among cladocera, only *P. polyphemoides* was found. Also, in a study on Impact of a new invasive ctenophore (*M. leidyi*) on the zooplankton community of Southern Caspian Sea made by Roohi *et al.,* (2008) only the cladocera *P. polyphemoides* was found. In 1996 the maximum number of species among the zooplankton belonged to cladocera, but the representation of this group decreased drastically to only one species, following *M. leidyi* invasion. *P. polyphemoides* exist in surface layers (Manolova, 1964). Rowshantabari *et al.,* (2014) found the highest density of *P. polyphemoides* in spring with a decrease in summer and autumn (1 ind.m^{-3}) and again increased towards the winter. Within cirripedia three larval stage of *B. improvisus* were found. Among them, cypris stage had the highest abundance. Two larval stages (nauplius and cypris) had reported before (Bagheri *et al.,* 2013) but, cirrus stage had not been reported previously in the southern part of Caspian Sea.

Conclusions

The Caspian Sea is an enclosed water body that plays an important geopolitical role in the central Asia region. The Caspian Sea is under intense pressure from environmental threats such as changes in sea water level, allowed excessive fishing, risk striker marine, infested industries and agriculture as well as developing the urban of most of the Caspian countries (Karrari et al. 2012; Jamalomidi, 2013). Additionally, a novel type of anthropogenic impact that became widespread across the world in recent years, started to affect the Caspian Sea, viz. invasions by undesirable alien species of animals and plants (Shiganova *et al.,* 2004). *Mnemiopsis leidyi* is a highly fecund comb jelly feeding extensively on zooplankton (Kideys *et al.,* 2008). The impact of the introduced ctenophore *M. leidyi* (Ivanov et al., 2000) has been tremendous on the Caspian ecosystem causing sharp decreases in zooplankton levels, pelagic fish stocks and other higher components of the ecosystem (Shiganova *et al.,* 2001; Kideys, 2002). It seems that after invasion of *M. leidyi*, composition and abundance of zooplankton in south Caspian Sea waters greatly changed. Some of the species have been vanished from ecosystem and some others have been dominant. Generally, invasive ctenophore deeply affected on planktonic community and ultimately on total food chain of Caspian Sea. Due to the high importance of zooplankton in the food chain, studying the abundance and diversity of them in southern part of Caspian Sea is useful for better management of fish stocks and other aspects of the sea.

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