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A historical data on the seasonal density variation of phytoplankton, zooplankton and *Mnemiopsis leidyi* in the South Caspian Sea

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ABSTRACT

The seasonal variation of phytoplankton, zooplankton (holoplankton) and ctenophore (*Mnemiopsis leidyi*) were investigated at eight transects from east to west in the South Caspian Sea. In spring (May), the most abundance of zooplankton was observed in the east area, where the temperature was over 19 °C, phytoplankton and *M. leidyi* were lower than 10×10^6 cells m^{-3} and 10 to 20 ind. m^{-3} respectively. In summer (August), the zooplankton and phytoplankton population increased by over 7000 ind. m^{-3} and over 50×10^6 cells m^{-3} in the east area respectively. When temperature was higher than 24 °C, *M. leidyi* increased in warm season (August) and also in November. Zooplankton and phytoplankton were elevated in winter and reached the maximum amount, while *M. leidyi* decreased sharply. In this study, we observed alterations in phytoplankton, zooplankton and *M. leidyi* in the South Caspian Sea from west to east along with the effects of temperature and seasonal variations on their distribution.

Keywords: Phytoplankton, Zooplankton, *Mnemiopsis leidyi*, Temperature, Caspian Sea.
Article type: Research Article.

INTRODUCTION

The Caspian Sea is the largest enclosed water body in the world (Dumont 1998). The surveys on the planktonic populations in the southern part of the sea were started in 1994 (Pourgholam *et al*. 1994) and 1996 (Hosseini *et al.* 2011). Plankton is important in the marine food web as an important indicator for ecosystem. Alterations in plankton communities can affect higher food web levels, such us fish. The phytoplankton of the Caspian Sea were studied by various authors in different years (Laloei 2001; Tahami *et al.* 2012). Ganjian *et al*. (2010) studied phytoplankton in summer 1994 to winter 2007, reporting that phytoplankton population increased in 2001 and 2002 and also water transparency was lower than that reported by previous studies. The diatoms were dominant in 1999-1997, however after introducing *Mnemiopsis leidyi* to Caspian Sea, dinoflagellates were higher than other groups (Bagheri *et al.* 2010). The study of zooplankton composition in Iranian coastal waters showed that three species of copepods, *Acartia tonsa, Eurytemora grimmi* and *E. minor* were dominant in the Caspian Sea before introducing *M. leidyi* (Rowshan Tabari *et al.* 2001). In 2000-2001 and 2005 *Eurytemora* was not observed (Rowshan Tabari *et al.* 2003, 2007), while *A. tonsa* was dominant species (Rowshan Tabari 2013). Copepods, specifically *A. tonsa*, are the most dominant zooplankton in the mesohaline section of Chesapeake (Kemp *et al*. 2005). Invasive species including *A. tonsa* and *Calanipeda aquedulcis* played a prominent role in the zooplankton of all studied areas of the sea (Krupa 2016). Rowshan Tabari *et al*. (2007) reported abundance and distribution of zooplankton in the South Caspian Sea in winter 2005, and compared the results with previous studies. In recent years, the zooplankton population decreased after introducing *M. leidyi* to the Caspian Sea (Rowshan Tabari *et al*.

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2003, 2013; Roohi *et al*. 2008; Bagheri *et al.* 2013). The decreased zooplankton was observed in the Azov, Black, Mediterranean and Caspian Seas (Shiganova, *et al*. 2001). High abundance of *M. leidyi* populations is of great concern because of leading to alterations in food web structure and function (Tiselius & Moller 2017). The aim of this study was to determine the effect of temperature on the density of phytoplankton, zooplankton and *M. leidyi* in the different area and seasons. These alterations are important in the food chain and exhibit the basis of life and feeding in the South Caspian Sea.

MATERIALS AND METHODS

Sampling and analysis of samples

Alongside the Iranian coastline, eight transects were sampled during four sequential seasons including spring (May) summer (August), autumn (November) and winter (March) in 2008. There were 8 transects and five vertical stations (5 m, 10 m, 20 m, 50 m and 100 m in depth) were selected on each transects (Fig. 1).

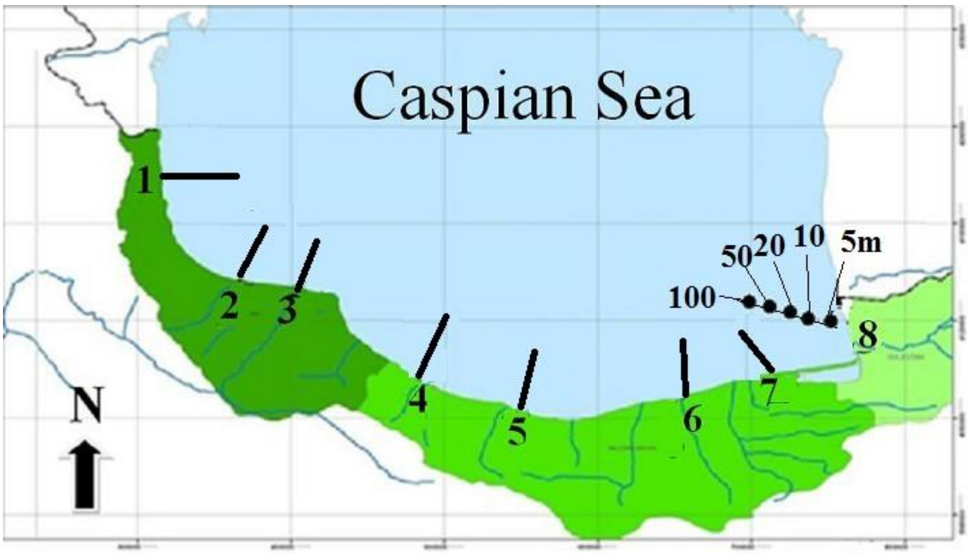

Fig. 1. The map of South Caspian Sea and location of sampling stations.

Samples were collected by a zooplankton net (0.36 m in mouth diameter and 100 μm mesh) by vertical hauling at each depth. Specimens were preserved in a 4 % formaldehyde and then studied in a Bogarov tray containing 0.5 mL of each sample (Harris *et al*. 2000). An invert microscope was used for identification and abundance was calculated per cubic meter (m^3). Phytoplankton samples were collected using a Ruttner water sampler. The samples were kept in 500-mL bottles and preserved in 4.0% buffered formaldehyde, then left for at least 10 days and the sample volume was reduced to 250 mL by siphoning. The subsamples were further reduced to 30.0 mL using a centrifuge (5 min at 3000 rpm; HettichD7200; Germany). For the enumeration of the phytoplankton, Sedgewick- Rafter counting slide was used and the samples were counted using a phase-contrast microscope (cover slip: 24 × 24 mm; magnifications: 10×, 20× and 40×; Vollenweider 1974; Newell & Newell 1977; Sournia 1978). Comb jelly (*M. leidyi*) was collected with METU net having a mouth opening of 0.2 m^2 (mesh size of 500 μm) as same as the Juday net from the same depths (Kideys *et al*. 2001). The body length of each individual with lobes was measured on board, then based on the length-groups, the density of *M. leidyi* (per m^3) was calculated. The data was tested using One-Way ANOVA and prior to analysis, transformed to log (x+1).

RESULTS AND DISCUSSION

Temperature

The temperature was less than 8 °C in March to over 28 °C in August. Its values varied between 8.80 (in January) to 28.6 °C (in August) in 2003 (Bagheri *et al*. 2014a). However, in the most areas in spring, it was 15-19 °C, followed by increasing in summer, which was >24 °C. In addition, in the most areas it was between 15 and 17°C in autumn and between 8 to 12°C in winter (Fig. 2). Water temperature plays an important role in seasonal alterations of phytoplankton and zooplankton (Kasimov 2004). Total zooplankton shows significant positive relationship with water temperature (Shil *et al*. 2013). Haberman & Haldna (2017) reported that when water temperature rises by one degree in spring, the abundance of zooplankton increases by 27%.

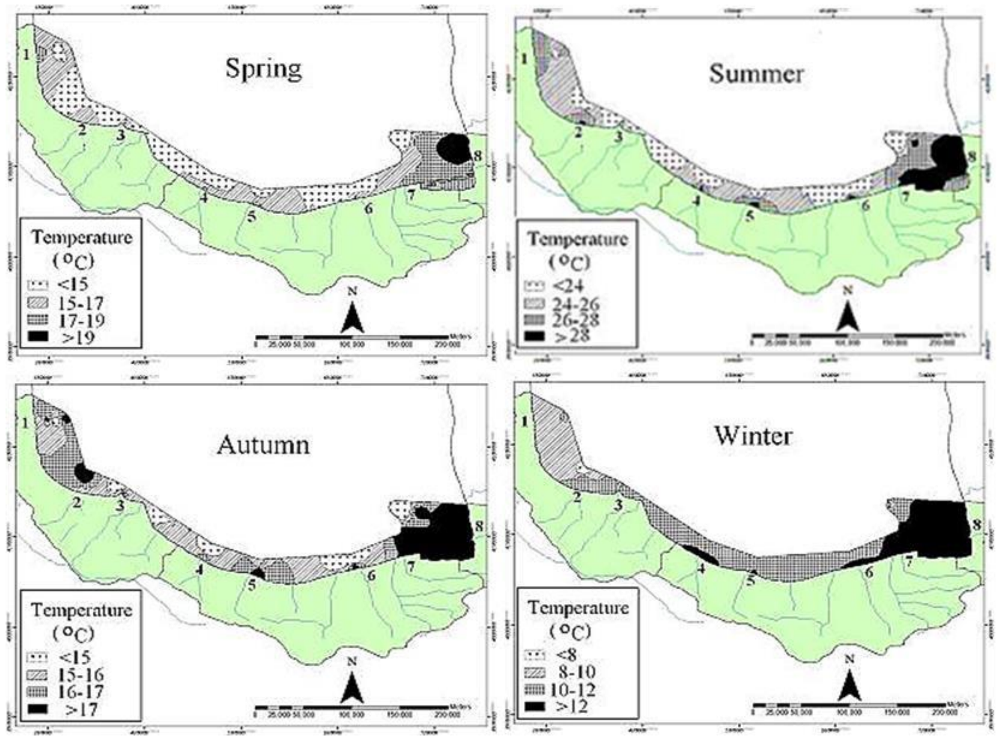

Fig. 2. The seasonal temperature (°C) fluctuations in the South Caspian Sea.

Phytoplankton

The lowest abundance of phytoplankton was observed in spring (May) which was lower than 10×10^6 cells m^{-3}. Phytoplankton increased in transects 8 in the east area during August. There was a small area with high phytoplankton over 150×10^6 cells m^{-3} in summer. Their abundance increased in autumn and reached to maximum value in winter (Fig. 3).

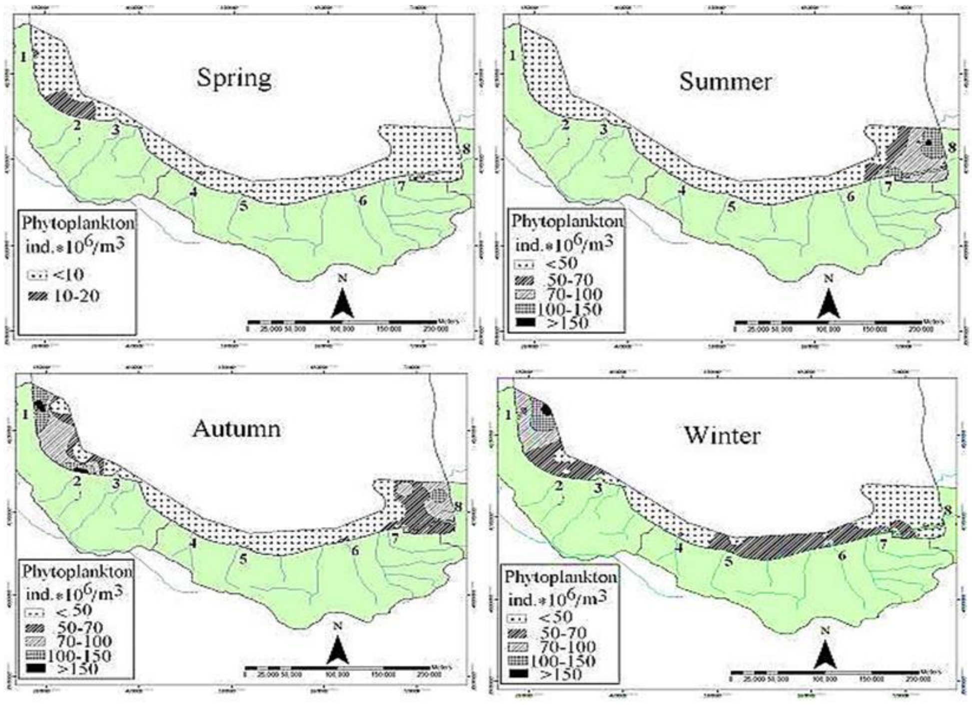

Fig. 3. The abundance of phytoplankton (× 10^6 cells m^{-3}) in the South Caspian Sea.

Increased population of phytoplankton in autumn was due to *Thalassionema nitzschioides*, while in winter to *Pseudo-nitzschia seriata* bloom (14.05×10^6 cells m^{-3}). In winter, although water temperatures decreased, this species constituted 30% of the phytoplankton density, while in other seasons was less than 1 % of the total (Golaghaei *et al.* 2012). Pautova *et al*. (2009) had reported that a winter bloom of *Cerataulina pelagica* was observed for the first time in the central part of the Caspian Sea in February 2008 (up to 10^6 cells L^{-1}) at 11.4 °C, and the *C. pelagica* bloom was accompanied by *P. seriata* bloom as well with an up to 10^6 cells L^{-1}. This species has been reported among phytoplankton species since 2008, while was not observed in the West Caspian Sea in previous studies (Bagheri & Fallahi 2014).

Zooplankton (Holoplankton)

In spring, the highest abundance of zooplankton was in transect 8 (over 7000 ind. m^{-3}), where temperature was higher than 19°C, while the lowest abundance was found around the station 4 (Fig. 4). The abundance of zooplankton was high in the east, where the abundance of phytoplankton was high as well and temperature was higher than 29°C in the summer. In the autumn, zooplankton density in the eastern area was observed to be between 1000 and 3000 ind. m^{-3}, where the water temperature was higher than 17 ° C. A small part in the west in the Astara areas exhibited a density of over 7,000 ind. m^{-3} with a temperature of between 15 and 16 °C. In winter, zooplankton increased and reached maximum value, especially in the west area. The highest zooplankton and phytoplankton densities were observed in the autumn and winter in the west, while in the summer in the east; their distributions were similar. The population of zooplankton was due to *Asplanchna priodonta* in the winter. This species increased sharply in coastal areas (5 m in depth) by decreased temperature, containing 40% of the abundance of zooplankton (Rowshan Tabari *et al.* 2012a). The abundance of zooplankton in the spring and summer in the Middle Caspian was reported to be 3800 ± 700 ind. m^{-3} and 3600 ± 700 ind. m^{-3}, respectively, which was lower than in the North (Krupa 2019). The number of microalgae, predominantly consumed by planktonic invertebrates, was also higher in the North ($373.9\text{-}415.9 \times 10^6$ cells m^{-3}) than in the Middle ($28.0\text{-}47.9 \times 10^6$ cells m^{-3}; Krupa *et al.* 2012).

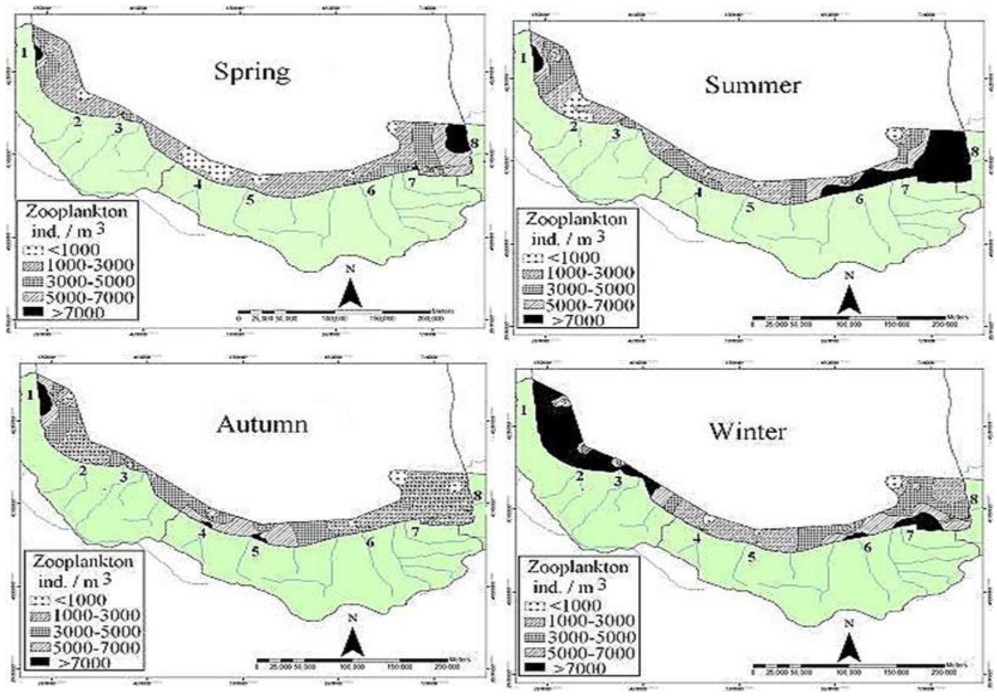

Fig. 4. The abundance of zooplankton (ind. m^{-3}) in the South Caspian Sea.

Mnemiopsis leidyi

The density of *M. leidyi* increased in the summer and peaked in the autumn, declining sharply in the winter. In the spring, in more areas was lower than10 ind. m^{-3}. In the summer, most of the western and central areas were observed to be over 150 ind. m^{-3}, and almost the entire South Caspian basin displayed a density of higher than 150 ind. m^{-3}. In winter, by decreased temperature, the density of *M. leidyi* dropped in all areas, so that, in the most areas it was lower than 10 ind. m^{-3} (Fig. 5). There were significant differences between phytoplankton, zooplankton and *M. leidyi* in different seasons ($p < 0.05$). In the spring, temperature was less than 17 °C in the most areas. Phytoplankton were lower than 10×10^6 ind. m^{-3} in most areas the basin, and an increasing was observed in the west (station 2Anzali). The zooplankton and *M. leidyi* increasing from west to east. The temperature is one of the important factors affecting zooplankton (McLaren 1963). In the summer, water temperature was higher than 26 °C and the highest was recorded in the east. The highest densities of phytoplankton and zooplankton were recorded in the east, and the temperature in these regions was higher than 26 °C, hence, by warming the temperature and upraising the zooplankton population, the amount of *M. leidyi* also increased. In the autumn, *M. leidyi* density reached its peak, while zooplanktons decreased during this time, reflecting that they were fed by *M. leidyi* (Rowshan Tabari *et al*. 2012b). However, on the other hand, phytoplankton density increased until winter. The water temperature decreased and in the most areas were between 15 and 17 °C.

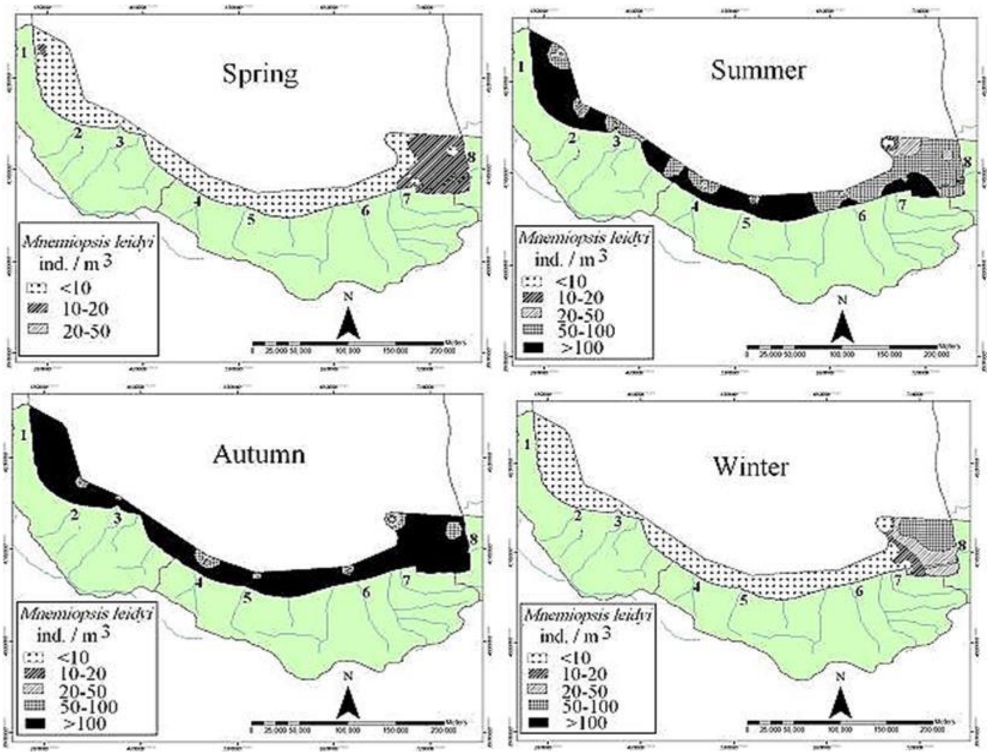

Fig. 5. The abundance of *Mnemiopsis leidyi* (ind. m^{-3}) in the South Caspian Sea.

In the spring, when the water temperature was 15.1 °C, the phytoplankton, zooplankton and *M. leidyi* densities were 6.6×10^6 cells m^{-3}, 1864 ind. m^{-3}, and 4 ind. m^{-3} respectively (Fig. 6). In the summer, temperature was 20.3 °C. Hence, phytoplankton, zooplankton and *M. leidyi* increased 3.1, 1.8 and 21.9 times higher than in the spring respectively. In the autumn, the temperature dropped to 15.8 °C, hence *M. leidyi* continued to grow and feed on zooplankton, possibly leading to reduction in their population. As zooplankton declined, phytoplankton upraised. In the autumn and especially in winter, *P. seriata*, as a cold-water phytoplankton species, upraised sharply. *Asplanchna priodonta* (a zooplankton) increased in winter and also *M. leidyi* decreased and reached 6 ind. m^{-3} in this season. In winter, the temperature caused natural control of the *M. leidyi*, because there were high abundances of phytoplankton and zooplankton. However, *M. leidyi* population was reduced (Roohi *et al*. 2010 Farabi *et al.* 2012; Rowshan Tabari *et al.* 2012a; Rostamian *et al*. 2011). Similar alterations were also observed in the Black, Azov, Marmara, and Mediterranean seas (Studenikia *et al*. 1991; Shiganova 1993; Shiganova *et al*. 2001). Daily rate and clearance in *M. leidyi* increased by elevating in its body length and also temperature, due to reducing in zooplankton population in the warm seasons (Rowshan Tabari *et al*. 2012b). In this study, the abundances of phytoplankton, zooplankton and *M. leidyi* in the South Caspian Sea, as well as the effects of *M. leidyi* on the of zooplankton and phytoplankton populations were assessed (Fig. 6).

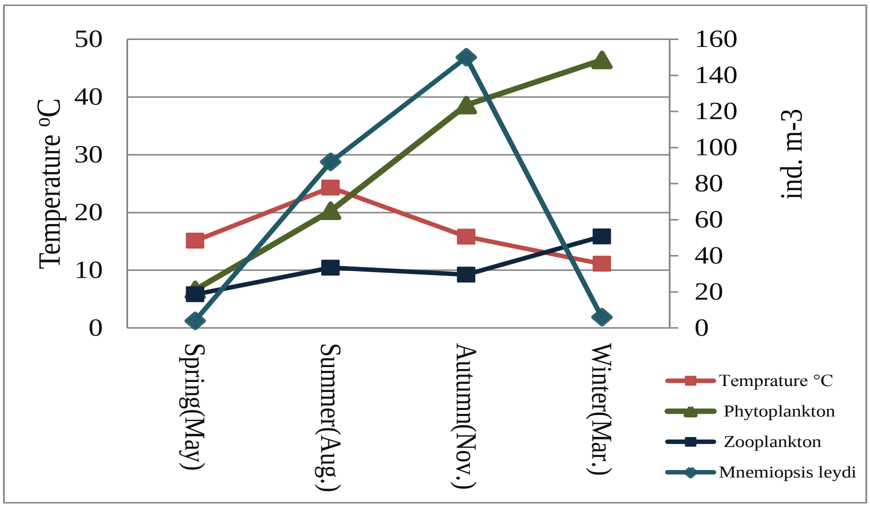

Fig. 6. The abundance of phytoplankton (× 10^6 cells m^{-3}), zooplankton (× 1000 ind. m^{-3}), *M. leidyi* (ind. m^{-3}) and water temperature (°C) in the South Caspian Sea.

CONCLUSION

Temperature is an important factor in the biological activity of plankton in the Caspian Sea and has played an important role in seasonal alterations of phytoplankton and zooplankton populations. Phytoplankton is the food source of zooplankton and other organisms. Such that, zooplankton feeds on phytoplankton and *Mnemiopsis leidyi* on zooplankton. *M. leidyi* was introduced in the Caspian Sea, from Black Sea by ballast water of ships in1980s (Vinogradov, 1992). Zooplankton was their main food, so by elevating *M. leidyi* density, zooplankton population decreased, while phytoplankton population upraised. Zooplankton and phytoplankton populations were elevated in winter by dropped temperature. In addition, *Asplanchna priodonta* (zooplankton) increased and *Pseudomizetesia seriata* (phytoplankton) exhibited bloom in South Caspian Sea during the winter.

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