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RESEARCH PAPER

First Report of the Occurrence of *Oithona Davisae* Ferrari F.D.&Orsi, 1984 (Copepoda: Oithonidae) in the Southern Black Sea, Turkey

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Abstract

We report the first occurrence of *Oithona davisae* Ferrari F.D.&Orsi, 1984 in the Sinop coast, Turkey. Data on the abundance and biomass of this species, and the proportion of adult and copepodite stages in the total copepods were investigated. The zooplankton samples were collected monthly by vertical hauls with plankton net of 112 µm mesh size from January to December 2009. However, *O. davisae* was observed for the first time in September, and continued to be observed for the remainder of the sampling period. The highest abundance and biomass of this species were recorded in November 2009 (1485.35 ind.m^{-3} and 2.9 mg.m^{-3}, respectively), which was 39.89% in the abundance and 14.35% of the biomass of the total copepods in November. In conclusion, the non-indigenous copepod species, *O. davisae*, has adapted to the ecological conditions of the Sinop coast.

Keywords: Non-indigenous, Sinop, abundance, biomass.

Türkiye'nin Güney Karadeniz'inde *Oithona davisae* Ferrari F.D.&Orsi, 1984 (Copepoda: Oithonidae) Bulunuşunun İlk Kaydı

Özet

Mevcut çalışmada, Oithona davisae Ferrari F.D.&Orsi, 1984 türünün Sinop, Türkiye kıyısındaki ilk bulunurluğu kaydedilmiştir. Türün bolluk ve biyokütle verisi ve toplam kopepod içerisindeki ergin birey ve kopepodit evrelerinin oranı incelenmiştir. Zooplankton örnekleri Ocak-Aralık 2009'da vertikal çekim yöntemiyle aylık olarak 112 µm ağ göz açıklığındaki plankton kepçesi ile toplanmıştır. Bu tür örnekleme periyodu boyunca ilk kez Eylül ayında belirlenmiş ve takip eden diğer aylarda da varlığı tespit edilmiştir. En yüksek bolluk ve biyokütle değeri Kasım 2009'da (1485,35 birey.m-3, 2,9 mg.m-3) kaydedilmiştir. Kasım ayında toplam kopepod bolluğuna katkısı %39,89 ve biyokütleye katkısı ise %14,35 idi. Sonuç olarak, elde edilen veriler yerli olmayan kopepod O. davisae Sinop kıyısının ekolojik koşullarına adapte olduğunu göstermektedir.

Anahtar Kelimeler: yerli olmayan, Sinop, bolluk, biyokütle.

Introduction

The Black Sea is a unique hydrological feature with poor diversity in terms of zooplankton fauna (Altukhov *et al.*, 2014). Many zooplankton species have been encountered around the Black Sea region of the Bosphorus area (Kovalev *et al.*, 1976; Selifonova *et al.*, 2008) as a result of water flow throughout the Turkish Straits system or from the ballast water of ships. However, few organisms can survive in the conditions of the Black Sea (Gubanova *et al.*, 2014) due to the low salinity and large variations in temperature. The ecological conditions of the Black Sea have changed substantially in the last 50 years and the introduction of new species has led to changes in the ecosystem. In particular, the introduction of *Mnemiopsis leidyi* A. Agassiz, 1865 in the 1980s led to a decrease in zooplankton density and change copepod diversity due to the heavy predation impact of this ctenophore (Bat *et al.*, 2007a). Some copepod species, such as *Oithona nana* Giesbrecht,1893, *Paracartia latisetosa* (Krichagin, 1873),and *Acartia* (*Acartiura*) *margalefi* Alcaraz, 1976, completely disappeared from the Black Sea ecosystem during this destructive period (Gubanova *et al.*, 2002). After the large-scale collapse of the Black Sea ecosystem, the devastating effects of *M. leidyi* were attenuated following the introduction of

Beroe ovata Bruguière, 1789, which is a voracious predator of *M. leidyi* (Kideys, 2002; Boxshall, 2007). Subsequently, the species lost from the Black Sea ecosystem have been replaced by other species that share a similar ecological niche. Therefore, the absence of *O. nana* together with the decrease of *M. leidyi* provided the opportunity for *O. davisae* to successfully invade the Black Sea. Individuals of this species not only could survive in Black Sea conditions, but also had established populations (Gubanova *et al.*, 2014).

Oithona davisae is indigenous to Japan and the China Seas (Razouls *et al.*, 2005-2015) and is found in some eutrophic areas, such as Tokyo Bay (Uchima and Hirano, 1988; Uchima and Murano, 1988; Uye, 1994; Itoh *et al.*, 2011), Ariake Bay (Hirota, 1990), and Fukuyama Bay (Uye and Sano, 1995). This species is also invasive in coastal waters off the west coast of the United States (Ferrari and Orsi, 1984), southern Chile (Hirakawa, 1988), and the Spanish Mediterranean (Saiz *et al.*, 2003). It was demonstrated that the species which was identified as *Oithona brevicornis* in the Black Sea in 2001 (Zagorodnyaya, 2002), was actually *O. davisae* after re-examination of zooplankton samples of 2008 and 2011 (Temnykh and Nishida, 2012). As a result, although *O. brevicornis* (Zagorodnyaya, 2002; Altukhov and Gubanova, 2006; Gubanova and Altukhov, 2007; Selifonova, 2009; Altukhov, 2010; Timofte and Tabarcea, 2012) and *O. davisae* (Temnykh and Nishida, 2012; Mihneva and Stefanova, 2013; Altukhov *et al.*, 2014; Svetlevich and Hubareva, 2014; Shiganova *et al.*, 2015) are two different names for the same species in Black Sea, *O. davisae* is accepted as the correct name.

Here, we reported the occurrence of the non-indigenous copepod, *Oithona davisae*, for the first time in a coastal area of Sinop (southern Black Sea, Turkey) and provided new data on the abundance and biomass of this species during the period from September to December 2009.

Materials and Methods

Study Area

Sinop is located in the Boztepe Peninsula, which stretches toward the northern coastline of the southern Black Sea (Figure 1). The coastal zone of Sinop is shallow and has a maximum depth of 50-55 m. Sinop, with its 175 km coastline, is an important region owing to its natural harbor, offering anchorage and protection from northern and eastern winds (Anonymous, 2011). Its many *Zostera* grass beds are protected from the action of heavy waves, and this region supports benthic, demersal, and pelagic organisms, among others (Aysel *et al.*, 2004; Dural *et al.*, 2006). Sinop is at the conjunction of east- and west-flowing currents, and is therefore near an unusually rich marine biological environment (Oguz *et al*., 1993), enhanced by the city’s low population and underdeveloped industry, which produces little pollution.

Sampling and Laboratory Studies

Zooplankton samples were collected monthly from one station (indicated in Figure 1) located in the coastal zone of Sinop in the southern Black Sea (42°00'21"N, 35°09'32"E; depth of 50 m) in 2009. The temperature and salinity of the sea water were measured using an YSI 6600 brand CTD probe after each zooplankton sampling. The zooplankton samples were collected vertically from the bottom to the surface using plankton net (mesh size 112 µm, mouth diameter 50 cm). After collection, a zooplankton sample was immediately fixed in 4% formalin-sea water solution. In the laboratory, two subsamples were taken from a container of known volume using a stempel pipette (1 mL). The identification and counting of adult and copepodite stages of *O. davisae* were carried out using these subsamples under a microscope on a zooplankton counting chamber. Naupliar stages of this species were not included in this study due to the unsuitable mesh size of our zooplankton net (Uye and Sano, 1995). The abundance and biomass of *O. davisae* were calculated as individual (ind.) m^{-3} and $mg.m^{-3}$, respectively. Biomass were calculated based on wet individual weights (Petipa, 1957) and biomass values of *O. davisae* were calculated using the individual weight of *Oithona nana* due to their having a body of similar length and shape. The results are given as mean ± standard deviation. The main references used for the identification of *O. davisae* were Ferrari and Orsi (1984), Temnykh and Nishida (2012), and Razouls *et al*. (2005–2015).

Results

Hydrography of Study Area

Temperature and salinity values at 10 m depth were used for the characterizing the temporal changes in sampling area. This depth was chosen owing to the susceptibility to rapid changes in these parameters at this depth caused by wind, solar heating, or rain. During the sampling period, the sea water temperature fluctuated from 8.49°C to 23.96°C. The minimum temperature values were recorded in February and March, whereas the maximum values were in July and August. Sea water salinity varied slightly over the year and ranged between 17.46‰ to 18.02‰. The lowest salinity values were observed in July and March, whereas the highest value was measured in December. (Figure 2).

Morphology of *O. Davisae*

Measurements were taken from 32 female specimens. The total length of *O. davisae* female

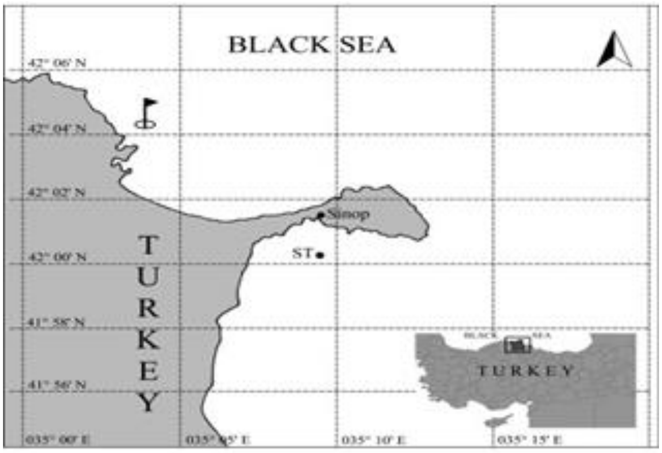

Figure 1. Location of the sampling station.

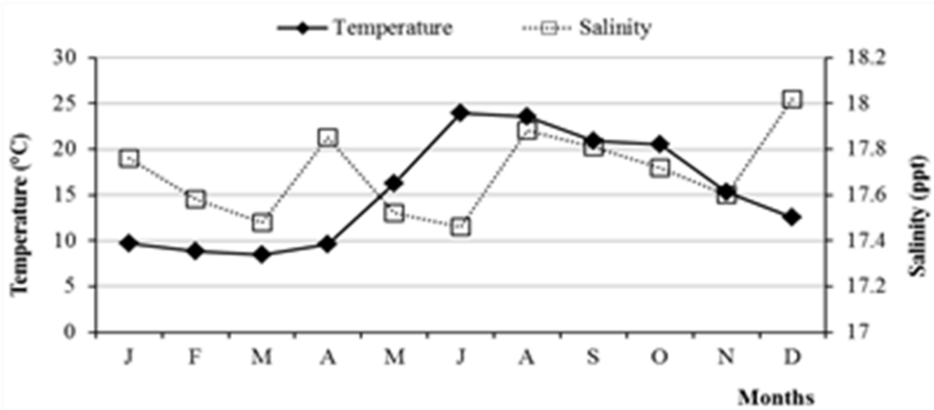

Figure 2. The monthly change in sea water temperature (°C) and salinity (‰) at 10 m depth throughout 2009 in Sinop coastal area.

ranged from 0.48 to 0.54 mm (mean length 0.51 ± 0.02 mm). The length ratio of the prosome/urosome in the dorsal view measured between 1.17 and 1.50 (mean of 32 specimens was 1.32 ± 1.38 mm) (Figure 3a). Antennule length ranged from 0.23 to 0.26 mm (mean of eight specimens was 0.24 ± 0.014 mm). The distal single seta of the first inner lobe were long, approximately 2.5 times the length of the single seta on the maxillule (Figure 3b). The proportional lengths of the first-to-fifth urosomal segments and caudal rami were 12.72:31.63:15.00:12.93:10.76:10.52 (mean value of 10 specimens). The caudal ramus measured 2.42 ± 0.15 times longer than it was wide (mean value of 10 specimens) (Figure 3d).

The total length in the dorsal view ranged from 0.44 to 0.50 mm (mean of 27 specimens was 0.47 ± 0.02 mm) in males. The length ratio of the prosome/urosome fluctuated between 1.50 and 1.88 (mean of 30 specimens was 1.64 ± 0.1 mm) (Figure 4a). The length of antennule varied from 0.17 to 0.21 mm (mean of 9 specimens was 0.19 ± 0.015 mm). The caudal ramus was 2.18 ± 0.26 times longer than it was wide (mean value of 10 specimens). The proportional lengths of the first-to-sixth urosomal segments and caudal rami were 8.06:33.33:14.72:12.64:10.42:9.17:12.08 (mean value of 10 specimens) (Figure 4d).

Abundance and Biomass Distribution of *O. Davisae*

Zooplankton samples were collected during all of 2009. However, *O. davisae* was the first observed in September 2009 and became common in subsequent sampling months. The abundance and biomass of *O. davisae* were 56.05 ind.m^{-3} and 0.15 mg.m^{-3}, respectively in September; these measures increased during other sampling periods, reaching the highest levels in November (1485.35 ind.m^{-3}, 2.9 mg.m^{-3}) (Figure 6).

O. davisae comprised 15.9% of the total copepod abundance between September and December, with the highest proportion (39.9%) being recorded in November. According to biomass, the average contribution of *O. davisae* to the copepod total over four months was 5.3%, with the highest proportion (14.4%) being measured in November (Figure 5).

Copepodite stages and adults of *O. davisae* were observed from September to December. The

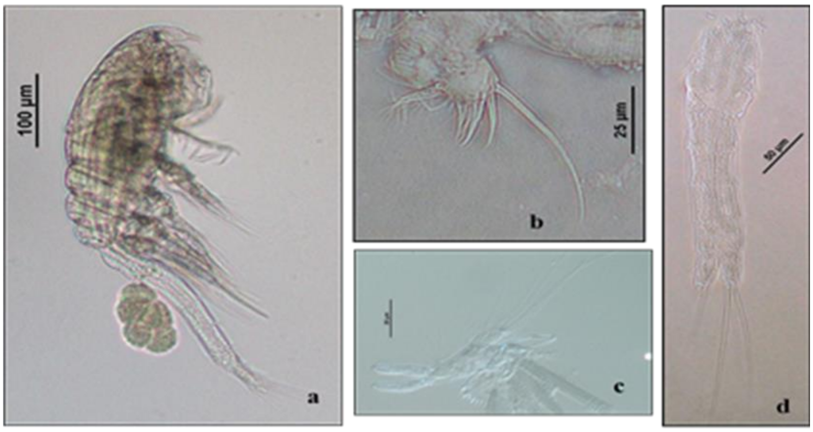

Figure 3. Lateral view (a); maxillule (b); mandible (c); urosome (d) in female.

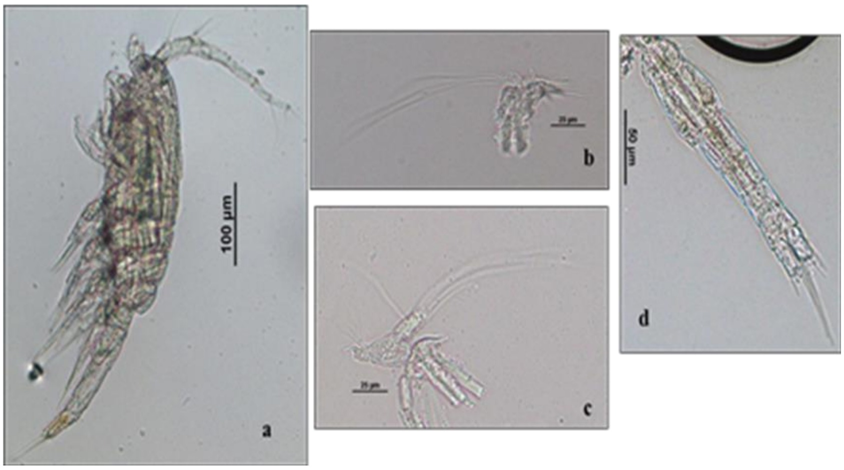

Figure 4. Lateral view (a); maxillule (b); mandible (c); urosome (d) in male.

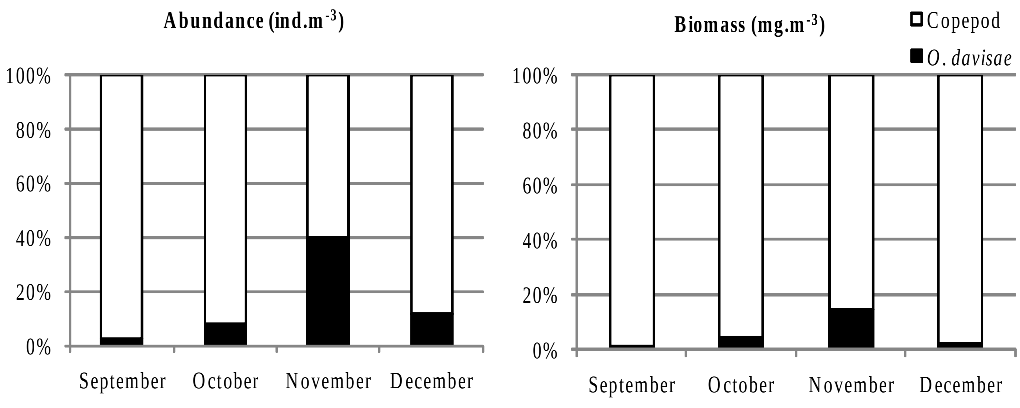

Figure 5. Contribution (%) of *Oithona davisae* to the total copepod abundance and biomass in the sea of Sinop in four months.

proportion of individuals in the copepodite stages increased gradually over these four months. The C5-C4 stages were more abundant in the *O. davisae* population and followed the C3-C2-C1 stages in terms of abundance. However, the contribution of the adult population to the total biomass was greater than the C3-C2-C1 stages in September and October (Figure 6).

Discussion

O davisae (first identified as *O. brevicornis*) was first recorded in Sevastopol Bay in December 2001 and their abundance changed from 8.3 to18 ind.m^{-3} in this month (Zagorodnyaya, 2002). This species appeared again four years later in October 2005 (2 adult females) in Sevastopol Bay (northern Black Sea). Within one month of this discovery, *O. davisae* began to appear in the samples regularly. The maximum abundance was 2311 ind.m^{-3} (mean: 492 ind.m^{-3}) in October-December 2005, 620 ind.m^{-3} (mean: 134 ind.m^{-3}) in January-March 2006, and was not discovered in April-May 2006 in net catches (Altukhov and Gubanova, 2006). This species was seen again in plankton in late August 2006 and its peak abundance (42667 ind.m^{-3}) was recorded at the end of October 2006 in Sevastopol Bay. The contribution of this species to the total copepod abundance was 70% (reaching a maximum of 96-97%) between September and the end of 2006 (Gubanova and Altukhov, 2007). The abundance of *O. davisae*, which was highly variable from 2001 to 2006, increased gradually in 2007-2009 and was always detected in plankton samples during this time. Peak abundance was reached to the mouth of Sevastopol Bay in late October 2007 (46200 ind.m^{-3}), to the center of the bay in early December 2008 (91650 ind.m^{-3}) and mid-June 2009 (71167 ind. m^{-3}). From 2006 to 2009, the annual average abundance of *O. davisae* increased from 1749 to 5543 ind.m^{-3} in the mouth of Sevastopol Bay and from 4347 to 22284 ind.m^{-3} in the center of bay. During the period of maximum density of *O. davisae*, its contribution to total copepod abundance increased to 96.42% (mouth of bay) and 98.72% (center of bay). Moreover, between 2006 and 2009, the population of this species increased along the shores of Sevastopol, and its contribution to the total abundance of Copepoda reached 99% (Altukhov *et al*., 2014).

O. davisae was reported in northeastern Black Sea (Novorossiysk Bay) for the first time in 2003. Its maximum abundances in this area were 1620 and 1060 ind.m^{-3} in the autumn of 2005 and 2006, respectively. In both years, its abundance increased until the end of autumn. This species was not observed in samples during February-May. Several specimens of *O. davisae* were found in September 2005, and its abundance increased to 5500 ind.m^{-3} in November 2009 in Gelendzhik Bay. In Port Tuapse, its abundance was 840 ind.m^{-3} in October 2005, 1060 ind.m^{-3} in September 2006, and 3000 ind.m^{-3} in November 2009. *O. davisae* was not found in 2004-2007 in Anapa Bay, but in December 2009, the abundance of this species was less than 900 ind.m^{-3} (Selifonova, 2009; Selifonova, 2011).

O. davisae was discovered in the western Black Sea (Bulgarian coasts) in September 2009 and abundance values varied between 128 and 4492 ind.m^{-3} in 2009, 19-43818 ind.m^{-3} in 2010, and 17-5918 ind.m^{-3} in 2011. The average value was reported as being 1194 ind.m^{-3} in 2009, 4824 ind.m^{-3} in 2010, and 854 ind.m^{-3} in 2011. This species was observed in September and November in 2009. The following year, *O. davisae* was found from July to December 2010, with surface temperatures ranging from 24.5ºC in July to 12.8ºC in December. In 2011, the species was present from April to October with surface temperatures ranging from 14.9 to 16.4ºC. In 2012, the species was found in March at temperatures of 7.3ºC with abundance ranging between 12-61 ind.m^{-3}

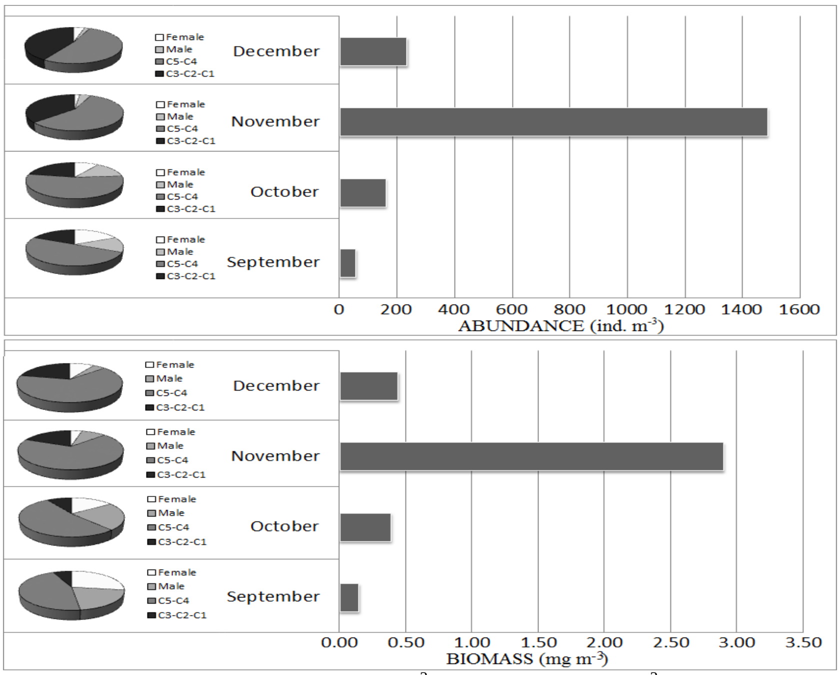

Figure 6. The monthly change of total abundance (ind.m^{-3}) and biomass (mg.m^{-3}) of *Oithona davisae*, and monthly percent abundance and biomass contribution of copepodite and adult individuals of *Oithona davisae* of Sinop coast during September to December 2009.

with an average value of 15 ind.m^{-3} (Mihneva and Stefanova, 2013). The average abundances of *O. davisae* were 315 ind.m^{-3} in August 2010 (maximum 1375 ind.m^{-3}) and 111 ind.m^{-3} in September 2010 (maximum 510 ind.m^{-3}) in the northwestern Black Sea (Romanian coasts) (Timofte and Tabarcea, 2012).

In the present study, *O. davisae* was initially observed in September 2009 (56 ind.m^{-3}), and was then observed at remarkable high densities until the end of the sampling period (December). The maximum abundance was observed in November (1485 ind.m^{-3}). The mean abundance value of *O. davisae* during the period from September to December was to be 484±671.5 ind.m^{-3} in Sinop in 2009. In this study, the abundance of *O. davisae* was generally lower than in other sampled areas (except northwestern region).

The studies described above demonstrated that this species acclimatized to the new environment after it was first recorded, and gradually both the frequency and its abundance among the Black Sea zooplankton increased. While *O. davisae* was initially observed in plankton in autumn, it was detected in the marine environment throughout the year in the following years. Maximum abundance was detected in August-December period.

Populations of *O. davisae* initially became established in coastal waters but later were detected in the off-shore waters of Black Sea. These findings demonstrate that the distribution of *O. davisae*, which is an epipelagic-neritic species, gradually expanded in the Black Sea year by year, as population abundance also increased. The non-indigenous species settling in the coastal zone have to adapt to wide variability in salinity (Lee *et al.*, 2003) and temperature (Altukhov *et al.*, 2014). The majority of holoplanktonic copepods are assumed to be osmoconformers (Mauchline, 1998). With their experimental study, Svetlichny and Hubareva (2014) demonstrated that the salinity tolerance of *O. davisae* was between 3 and 40‰. They also stated that the osmoregulatory abilities of *O. davisae* might facilitate their successful adaptation to the brackish Black Sea. The species was found at salinities between 22.8-32.3‰ in Japanese coastal water (Hirota, 1990; Uye and Sano, 1998; Itoh *et al.*, 2011) and at 12‰ salinity in San Francisco, California (Ferrari and Orsi, 1984). In the present study, *O. davisae* was found at salinities ranging from 7.6‰ (November)-18.02‰ (December).

O. davisae is regarded as the thermophilic species because its maximum population density occurs in warm seasons in natural system (T>20ºC; Uye and Sano, 1995; Nakane *et al.*, 2008). The presence of *O. davisae*, which is a eurythermic species, in plankton was observed between 8.2-23.2ºC in the northern Black Sea (Altukhov *et al.*, 2014) and between 7.3-24.5ºC in the western Black Sea (Mihneva and Stefanova, 2013). In the present study, the species was found at temperatures ranging from 20.95 (September) to 12.53ºC (December). In its original habitat (shore waters of southwestern Japan), *O. davisae* is found at temperatures between 8.9 and 28.2ºC (Uye and Sano, 1995). Its high tolerance to varying environmental conditions allows *O. davisae* to survive and reproduce in the Black Sea (Altukhov *et al.*, 2014).

The feeding strategy of *O. davisae* contributes to its widespread distribution in the ecosystem. *O. davisae* is microflegellat feeder (Uchima, 1988). Dinoflagellates and other micro-nanoplankton species have grown faster than diatoms in the Black Sea over the last 10 years (Nesterova *et al.*, 2008). Dinoflagellates are found at higher abundances in summer and autumn in Sinop (Bat *et al.*, 2007b). This ample food supply may enable *O. davisae* to reach high levels of abundance, especially in the autumn period.

In conclusion, *O. davisae* was discovered in the Sinop Bay for the first time. In consideration of the high tolerance to ecological variability and gradual increase in the range of this species in the Black Sea, it will become a permanent member of the zooplankton of this area. Natural succession in the zooplankton community may also be altered as a result of the high rate of spread of *O. davisae*, as has been observed in other areas of the Black Sea. We propose that monitoring studies are required to determine whether such changes affect the fish stocks or the jellyfish population, and to investigate the impacts this may have on the ecosystem.

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