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Rapid Communication

New invasive copepod species from the Levantine Sea, north-eastern Mediterranean: *Oithona davisae* (Ferrari and Orsi, 1984) (Cyclopoida: Oithonidae)

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Abstract

İskenderun Bay is a hotspot for bioinvasions in the Mediterranean Sea, where alien species are frequently introduced, easily settle, and therefore, can often be encountered. The small-sized invasive copepod *Oithona davisae* (Ferrari and Orsi, 1984) has rapidly spread in several ecosystems worldwide, including the Black Sea, Wadden Sea, Marmara Sea, Adriatic Sea, and Aegean Sea, becoming an integral part of the pelagic communities there. Here, we report *O. davisae* in İskenderun Bay, in the north-eastern part of the Mediterranean Sea, and provide information on its spatiotemporal variation and assess its potential impact on the seasonal abundance and biomass of the mesozooplankton community, at present and in the near future. Zooplankton abundance and biomass were at their lowest levels in winter (1066 ± 313 ind. m^{-3}, 1.9 ± 0.8 mg m^{-3}) and highest in spring (7738 ± 1583 ind. m^{-3}, 18.5 ± 5.8 mg m^{-3}). However, the relative abundance of oithonid copepods was highest during the winter (35.7 ± 10%). The proportion of copepodites in the oithonid assemblage was high in spring (72.5 ± 9.3%), summer (72.7 ± 13.3%) and winter (68.5 ± 3.6%) but the relative abundance of male oithonids remained low across all seasons. *Oithona davisae* was observed only in the autumn, in abundances of 8.4 to 12.6 ind. m^{-3}. These low abundances could be attributed to the new arrival of this species and the relatively large mesh size used in this study (200 µm). Nevertheless, the successful introduction and assimilation into other mesozooplankton communities elsewhere, rapid adaptability and wide tolerance to environmental conditions of *O. davisae,* suggest that this species may become a dominant part of the zooplankton community across the Levantine Basin in the very near future.

Key words: alien, Copepoda, İskenderun Bay, mesozooplankton, opportunistic traits, shipping

Introduction

Zooplanktonic organisms hold great importance in pelagic ecosystems by maintaining the cycles of matter and energy between lower trophic levels and upper predators in the food web (Lenz 2000). Among zooplankters, the small-bodied oithonid copepods are of particular significance. They link protozoan and metazoan food webs as the prey of fish larvae while predating on small flagellates and ciliates (Nakamura and Turner 1997). *Oithona davisae* is a small-sized (female: 0.48–0.62 µm; male: 0.47–0.54 µm, Razouls et al. 2005–2021) neritic oithonid that generally prefers coastal and estuarine habitats. This species displays marked adaptability and can easily settle shortly after being introduced to a novel ecosystem, becoming an integral and dominant part of the recipient community (Altukhov et al. 2014; Doğan and İşinibilir 2016; Zagami et al. 2018; Terbıyık Kurt and Beşiktepe 2019). *Oithona davisae* can tolerate a wide range of environmental parameters (Zagami et al. 2018), including temperature (−1.8 to 29 °C) and salinity (12 to 35 psu) (Ferrari and Orsi 1984; Uye and Sano 1998; Temnykh and Nishida 2012; Mihneva and Stefanova 2013; Cornils and Wend-Heckman 2015; Doğan and İşinibilir 2016; İşinibilir et al. 2016a; Zagami et al. 2018; Terbıyık Kurt and Beşiktepe 2019). Nonetheless, it seems that this species generally thrives in warmer conditions (Zagami et al. 2018). *Oithona davisae* was first noticed in the inshore waters of San Francisco Bay (Sacramento-San Joaquin Estuary) in 1963 (Ferrari and Orsi 1984; Cordell et al. 2008), but was not identified as a new species until 1984 (Ferrari and Orsi 1984). This species, endemic to the Eastern Asian coast with a native range limited to the Japanese and Chinese seas (Nishida 1985; Razouls et al. 2005–2021), has increased its worldwide distribution utilizing various introduction vectors (e.g. ballast water, mariculture, and currents). *Oithona davisae* has established viable populations in several ecosystems, such as the Black Sea (Altukhov et al. 2014), Mediterranean Sea (Saiz et al. 2003), Bilbao estuary (Uriarte et al. 2015) and Wadden Sea (Cornils and Wend-Heckmann 2015). Along the coast of Turkey, *O. davisae* was first observed from the Sinop coast in 2009 (Üstün and Terbıyık Kurt 2016), then in 2014 from the Marmara Sea (Doğan and İşinibilir 2016), and finally, in 2015 from the Aegean Sea (Terbıyık Kurt and Beşiktepe 2019).

Due to its unique hydrological conditions, İskenderun Bay is one of the most invaded regions in the Mediterranean Sea and has experienced a high rate of bioinvasions (Çevik et al. 2006). Human-induced stressors, such as thermal discharge, shipping, coastal development and industrial activities, affect the ecosystem of the bay (Doygun and Alphan 2006). In addition to the plethora of alien Indo-Pacific species of fish, cnidarians, molluscs, and polychaetes, which are frequently observed in the eastern Mediterranean (Çınar 2009; Bilecenoğlu 2010; Özcan et al. 2010; Bakır et al. 2012; Çevik et al. 2006), established populations of alien zooplanktonic species such as *Ferrosagitta galerita* (Terbıyık et al. 2007), *Pleopis schmackeri* (Terbıyık Kurt and Polat 2017) and *Dioithona oculata* (Terbıyık Kurt 2018) have been reported in İskenderun Bay. While the goals of our original project were to characterize the mesozooplankton community in İskenderun Bay, we report here the first record of *O. davisae* as part of the mesozooplankton community in the Levantine Basin.

Materials and methods

Study area

İskenderun Bay, characterized by its rectangular shape, is located in the north-eastern corner of the eastern Mediterranean and was formed by

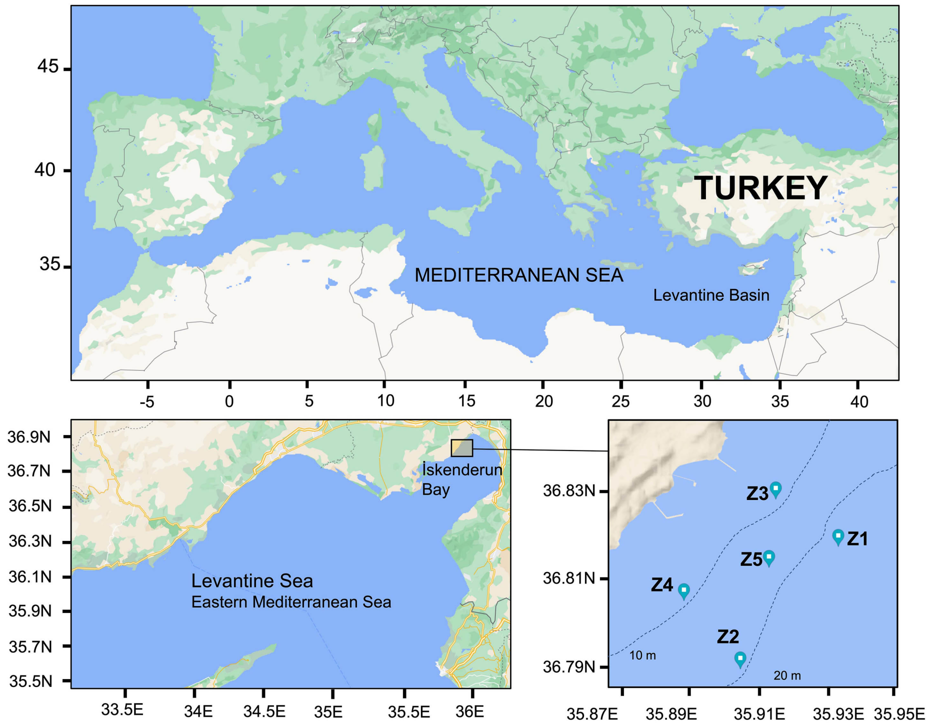

Figure 1. The sampling stations in the study area of İskenderun Bay, along the coast of Turkey.

recessing into Anatolia. The bay is ~ 65 km long, 35 km wide and has an area of 2275 km^2. The average depth of the bay is 70 m, and it is one of the areas with the largest continental shelf (after the Nile Delta) in the eastern Mediterranean Sea (Avşar 1999). The Yumurtalık district and the thermal power plant, Botaş oil filling facilities, BTC pipeline and the Toros fertilizer factory are located on the north-western shores of İskenderun Bay. On the south-eastern shores are the districts of İskenderun and Dörtyol, the iron and steel factory and İskenderun port. There are also summer cottages and camping areas on these shores, so the human population residing around the bay increases exponentially in the summer months. For these reasons, the anthropogenic impacts in İskenderun Bay are assumed to be high. However, eutrophication has not been observed due to the dynamic nature of water flow into and out of the bay (Yılmaz et al. 1992).

Sampling and laboratory studies

Sampling was carried out seasonally in the second week of April, July, October, and December 2018 at five stations in İskenderun Bay during the daytime (Figure 1). The stations were located close to the shore and the deepest depth was 15 m. Samples were collected vertically with a WP-2 zooplankton net (200 μm mesh) and fixed with a 4% formaldehyde seawater solution. In the laboratory, sub-samples were taken from the zooplankton samples with a Folsom splitter. Counting and identification were performed with an Olympus SZX16 stereomicroscope and Leica microscope. Copepod abundance was calculated as number of individuals per species per cubic meter. The filtered water volume was determined based on the vertical cylinder volume, calculated using the diameter of the mouth opening of the net and the hauling depth. Temnykh and Nishida (2012) identification keys were used to identify *O. davisae*.

Environmental variables (e.g. temperature, salinity) were measured with a YSI 6600 at the surface, and 5 m, 10 m and 15 m depth. Seawater samples were taken by Niskin bottles at corresponding depths to determine chlorophyll-*a* concentrations, phytoplankton and protozooplankton abundances. For chlorophyll-*a* analysis, two litres of seawater were filtered through Whatman GF/F glass fibre filters, extracted with 90% acetone solution, and measured using the spectrophotometric method according to Strickland and Parsons (1972). To count the protozooplankton, 10 litres of seawater were collected from the surface then filtered through 18-µm mesh, fixed with Lugol solution (2.5%), and then 2% formaldehyde fixation several hours after. For phytoplankton identification and counting, two-liters seawater samples were fixed with a Lugol solution (2.5%). In the laboratory, the samples were placed in a settling chamber for 48 hours. The cells were counted by the Utermohl method using a CK 40 Olympus inverted microscope for each plankton group (Utermöhl 1958; Venrick 1978).

Data analysis

A two-way ANOVA tested the significance of season and site and their interaction on zooplankton abundance and biomass data, which were normally distributed. Posthoc Tukey's HSD pairwise tests tested for significant differences in abundance and biomass between seasons. R Statistics version 4.0.2 was used for the statistical analysis.

Results

Diagnosis of Oithona davisae *Ferrari and Orsi, 1984*

The total length of *O. davisae* (n = 5) ranged from 500 to 550 µm (Figure 2A). *Oithona davisae* had a curved, sharply pointed rostrum, and dorsal hair rows were absent on urosome (Figure 2B). The formula of the exopod spine on the swimming legs was 1, 1, 3 in P1–P3 (Figure 2C, D, E) and 1, 1, 2 (Figure 2F) in P4. A long distal spine was present in the first inner lobe of the maxillule, and individuals had one seta on the endopod (Figure 2G). There were four setae on the endopod of mandible (Figure 2H).

Environmental variables

Mean water column temperatures varied between 18.50 °C and 29.33 °C throughout the year (Figure 3), with similar temperature values in spring and winter (respectively, 18.77 ± 0.33 °C and 18.87 ± 0.26 °C). Salinity fluctuated irregularly during the sampling seasons (from 37.11 to 41.43 psu). Salinity was not measured in winter. Maximum salinity values were observed in summer (41.43 psu) and lowest values in autumn (Figure 3).

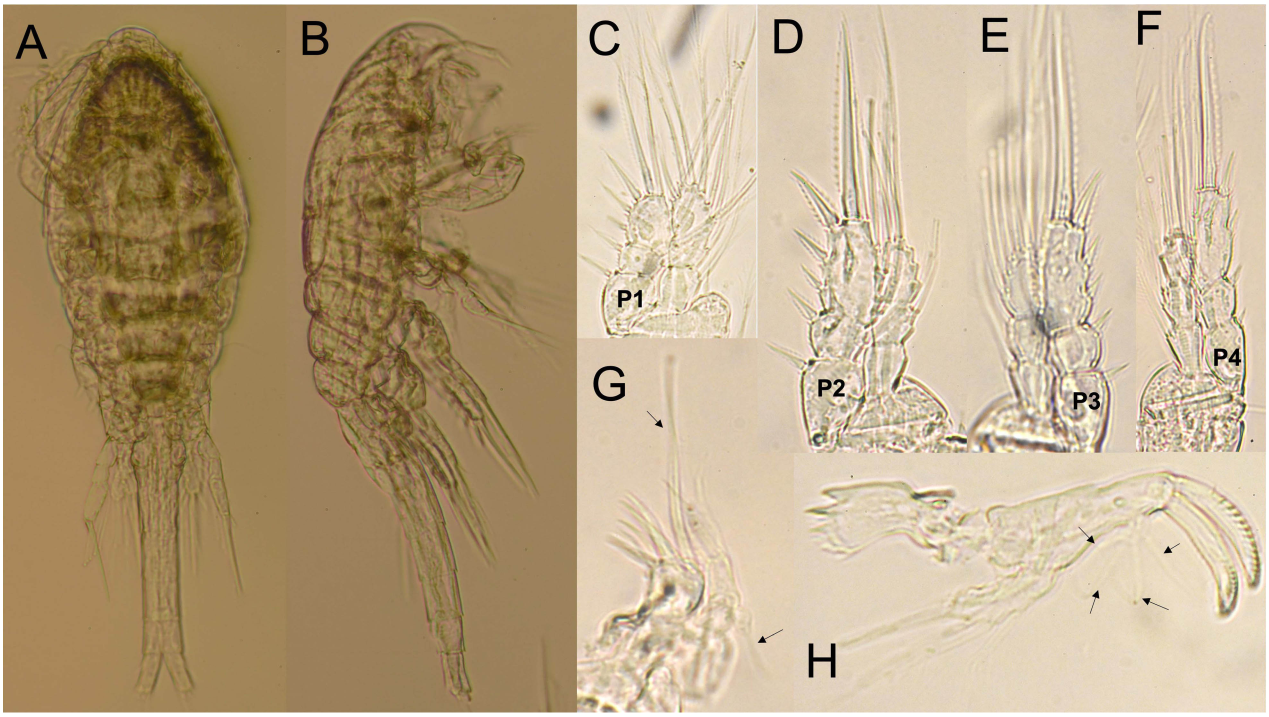

Figure 2. Diagnostic characters of *Oithona davisae* collected in autumn 2018 from İskenderun Bay. (A) Dorsal view of the body (B) Lateral view of the body (C) P1, (D) P2, (E) P3, (F) P4, (G) maxillule (H) mandible. Photomicrographs by Nikon D7200 (Tuba Terbıyık Kurt).

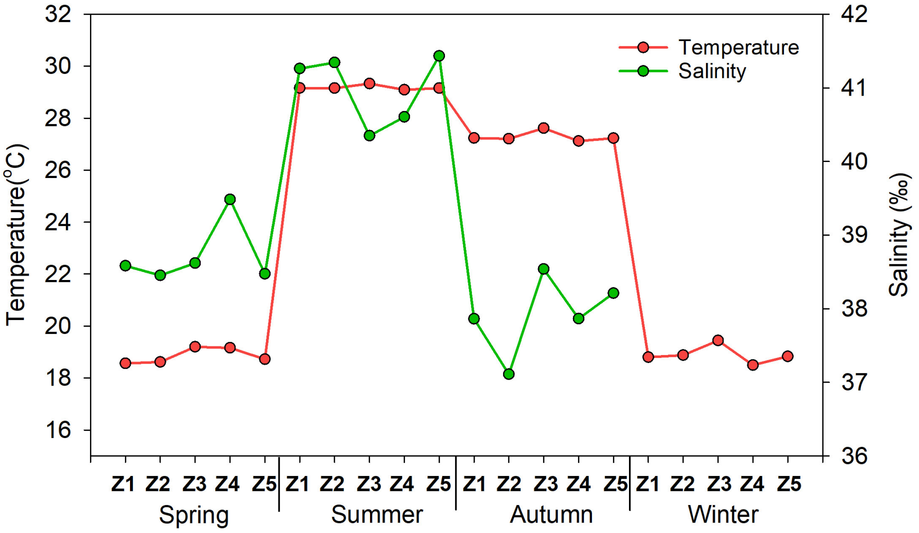

Figure 3. Seasonal changes of temperature and salinity at sampling stations in İskenderun Bay during 2018.

Biotic variables are described here only for autumn 2018, when *O. davisae* was observed. Depth-integrated chlorophyll-*a* values fluctuated from 0.49 to 0.68 μg L^{-1} in the study area (Figure 4). Phytoplankton concentrations varied between 0.7×10^3 (Z1) and 0.59×10^3 cell L^{-1} (Z2). The contribution of dinoflagellates was, at most, 36% (Z2) to the phytoplankton community (Figure 4). Protozooplankton abundance was very low and varied from 16 (Z1, Z5) to 90 ind. L^{-1} (Z4) at the surface (Figure 4).

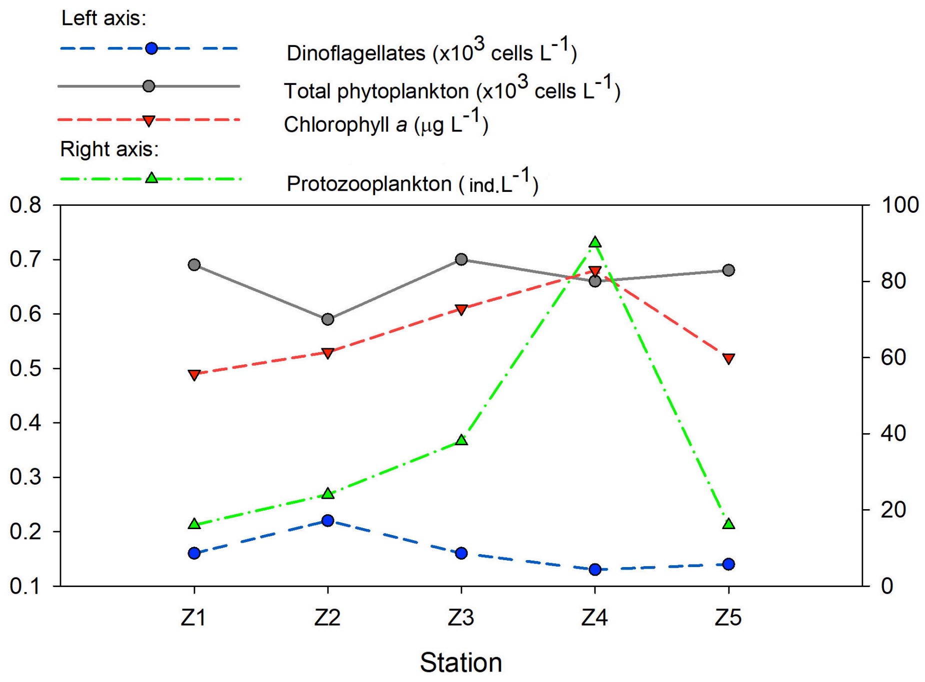

Figure 4. The abundance and distribution of some biotic elements (Total phytoplankton, dinoflagellate, Protozooplankton and chlorophyll-*a*) at sampling stations of İskenderun Bay in autumn 2018.

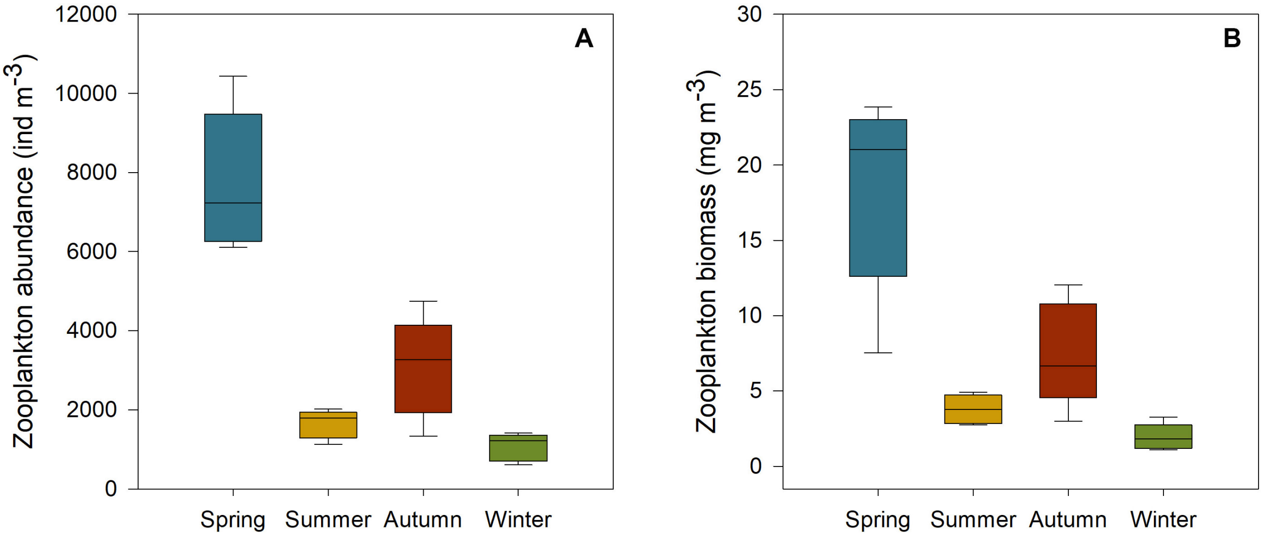

Figure 5. Box-plot diagram of seasonal zooplankton abundance (A) and biomass (B) in İskenderun Bay 2018.

Seasonal distribution

Total zooplankton abundance and biomass were significantly different across seasons (two-way ANOVA, $p < 0.01$), but neither site nor the interaction of site and season affected total zooplankton abundance and biomass ($p > 0.1$ and $p > 0.05$, respectively). The abundance and biomass in spring were significantly higher than all other seasons (Tukey's HSD, $p < 0.05$). The lowest zooplankton abundance and biomass values were observed in winter (1066 ± 313 ind. m^{-3}, 1.9 ± 0.8 mg m^{-3}, respectively), and the highest values were observed in spring (7738 ± 1583 ind. m^{-3}, 18.5 ± 5.8 mg m^{-3}) (Figure 5). The relative ratio of copepods in the mesozooplankton

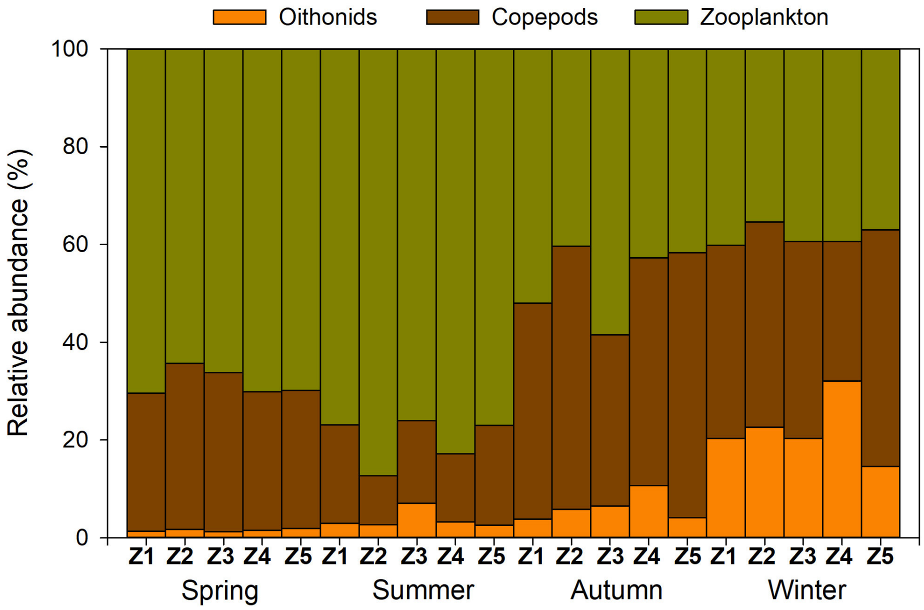

Figure 6. Proportional distribution of oithonids and Copepoda in zooplankton at sampling stations in İskenderun Bay across the four seasons of 2018.

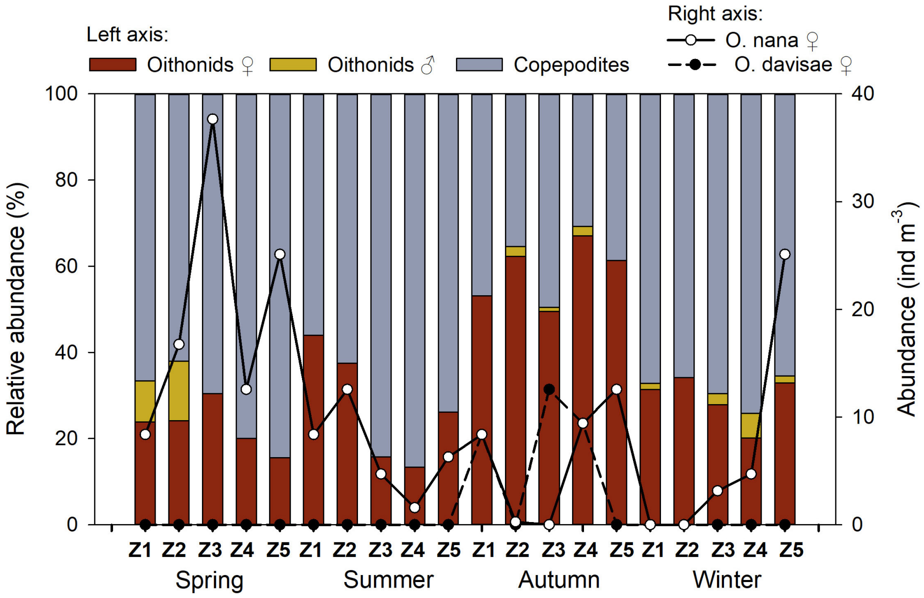

Figure 7. Seasonal distribution of *Oithona davisae* and *O. nana* abundance, and ratio of oithonid females, males and copepodites at sampling stations in İskenderun Bay in 2018.

was low in spring and summer (32 ± 2.5%, 20 ± 4.4%) and highest in the winter (61.7 ± 1.8%) (Figure 6). Similarly, the relative abundance of oithonids (the group to which *O. davisae* belongs) in the copepod community was low in spring (3.6% to 6.4%). The contribution ratio of oithonids to the Copepoda community was the highest in the winter and ranged from 23.3% to 52.9% in this season, depending on the site (Figure 6). The proportion of copepodites among oithonids was high, reaching 87% (Z4) in July. In autumn, the proportion of oithonid copepodites remained comparatively low and fluctuated between 30.8% and 49.5%. The proportion of oithonid males was very low and did not exceed 4.7% on average (Figure 7). Our first observations of *O. davisae* in the study area were in autumn (October). The abundance of this species was relatively low as compared to other *Oithona* species and varied from 8.4 to 12.6 ind. m^{-3}, with the highest densities observed at the station closest to the coast. *Oithona nana*, which is a similar species of a similar size, was observed in all seasons. Its average abundance was highest in spring (20 ind. m^{-3}), and ~ 6 ind. m^{-3} were found in the other seasons.

Discussion

This study presents the first observation of *O. davisae* in the Levantine coastal waters of Turkey. Previously, the species had been commonly and abundantly observed in coastal areas of Turkey in the Black Sea (Üstün and Terbıyık Kurt 2016), Marmara Sea (Doğan and İşinibilir 2016) and Aegean Sea (Terbıyık Kurt and Beşiktepe 2019). In the Mediterranean Sea, the spread of the species has been restricted and only reported from Barcelona harbour (Saiz et al. 2003), Lake Faro (Zagami et al. 2018), Lake Ganziri (Zagami et al. 2018) and the port of Venice (Vidjak et al. 2019). Therefore, it appears that *O. davisae* has expanded its distribution eastwards towards the Turkish seas and the Levantine Basin in the Eastern Mediterranean Sea.

The Mediterranean Sea is a hotspot for marine bioinvasions. The opening of the Suez Canal in 1869 connected two different biogeographic provinces, becoming a major pathway in the passage of alien species from the Red Sea to the Mediterranean Sea in a process termed the Lessepsian migration (Por 1978). In addition to passage via the Canal, species are introduced into the Mediterranean Sea by other pathways, including shipping, aquaculture and aquarium trade (Ruiz et al. 1997; Galil and Zenetos 2002; Zenetos et al. 2010). Of these, shipping has been assumed by many researchers to be the most important vector transporting *O. davisae* to novel environments (Uriarte et al. 2015; Altukhov et al. 2014; Cornils and Wendhackman 2016; Üstün and Terbıyık Kurt 2016; Terbıyık Kurt and Beşiktepe 2019). A local zooplankton distribution monitoring program, conducted since 2004 in the study area (Terbıyık Kurt and Polat 2013, 2014, 2015, 2017; Terbıyık Kurt 2018, 2019), has not observed *O. davisae* nor has the species been reported along the coasts of other countries in the Levantine Sea prior to 2019. It is likely that *O. davisae* has been transported to İskenderun Bay through ballast waters. Indeed, İskenderun Bay plays an important role in maritime transport, and it is the second-most important marine transportation and trading centre that serves the Middle East in the Mediterranean region of Turkey (Doygun and Alphan 2006).

Oithonids are an important contributor to zooplankton communities in İskenderun Bay (Terbıyık Kurt and Polat 2013). According to published records, six species belonging to the family Oithonidae (*Oithona plumifera, O. nana, O. similis, O. tenuis, O. setigera* and *D. oculata*) are found in İskenderun Bay (Toklu and Sarıhan 2003; Terbıyık Kurt and Polat 2013;

Toklu-Alıçlı and Sarıhan 2016; Terbıyık Kurt 2018). Previous sampling in 2012 at our study sites found that *O. plumifera* was the dominant species during the summer and autumn (Terbıyık Kurt and Polat 2013). However, the abundance of the small oithonid *O. nana*, which is similar in size to *O. davisae*, was relatively low and peaked in the spring. The relative abundance of male oithonids was low. However, previous studies also found higher abundances of oithonid copepodites in autumn and winter in İskenderun Bay (Terbıyık Kurt and Polat 2013), as was also observed in the present study.

The abundance of *O. davisae* seems low at present in İskenderun Bay, similar to the reported abundances from the Venice Lagoon (Adriatic Sea) (Vidjak et al. 2019). In addition, the net mesh size (200 μm), which is regularly used for sampling, is too large to efficiently collect this small-sized species. Therefore, these abundances are likely an underestimation. Alternatively, low population numbers could be indicative of a newly arrived population of *O. davisae* to this region. Although the reported abundances were low, *O. davisae* has a high tolerance to variable temperatures (Svetlichny et al. 2021), and the conditions in İskenderun Bay are ideal for it to settle and thrive. In Sevastopol Bay (Black Sea), the highest abundance of *O. davisae* was observed from September to November, when the water temperature was 15–23 °C, and abundances dropped sharply at temperatures below 8 °C (Svetlichny et al. 2016). Only adult females were observed between 8 and 17.5 °C (from the end of February to the middle of May), and male individuals were observed when the temperature reached 22 °C (at the end of May). At 17.5 °C, copepodites started to appear in the community (Svetlichny et al. 2016). In Fukuyama harbour (inland Sea of Japan), the highest abundance of *O. davisae* was observed during the summer, when the water temperature was relatively high (20–28 °C in June, July and September) (Uye and Sano 1995). In the coastal waters of İskenderun Bay, the water temperature shows a clear seasonal cycle that fluctuates between 15.6 and 29.6 °C (Terbıyık Kurt and Polat 2013, 2014, 2015, 2017; Terbıyık Kurt 2018), but in the present study, the temperature did not fall below 18 °C. Further work directly monitoring *O. davisae* in İskenderun Bay is needed to understand the seasonal cycling of this species in the non-native waters and to uncover if it has already based an established population.

In addition to having the correct thermal regime, the regions in which high abundances of *O. davisae* have been reported are generally productive areas (İşinibilir et al. 2016b; Üstün and Terbıyık Kurt 2016; Zagami et al. 2018; Terbıyık Kurt and Beşiktepe 2019). In Lakes Faro and Ganziri, the highest abundance of *O. davisae* was observed during late spring and early summer, which is when the density of small-sized flagellates is the highest (Zagami et al. 2018). Although Iskenderun Bay has 2–4 times higher chlorophyll-*a* concentrations compared to surrounding regions, it is generally considered oligotrophic (Yılmaz et al. 1992). In the study sites, chlorophyll-*a* concentrations and the abundance of dinoflagellates and protozooplankton (mainly ciliates), which could serve as food to *O. davisae*, were at low levels in autumn (which is the only season in which we found *O. davisae*). These low satiating food concentrations are sufficient for feeding and egg production in the adult females of *O. davisae* (Almeda et al. 2010; Zamora-Terol and Saiz 2013), suggesting an adaptation to oligotrophic environments in which *O. davisae* can survive, reproduce and outcompete native species. This may explain the ecological success of this species where food is a limiting factor for other copepods (Almeda et al. 2010), enabling its invasiveness as it settles easily in novel environments and becomes dominant in a short period of time (Zagami et al. 2018; Altukhov et al. 2014; Doğan and İşinibilir 2016; Terbıyık Kurt and Beşiktepe 2019).

Although no harmful effects have been documented in ecosystems where *O. davisae* has settled, its presence in the community could signal an ecosystem change (Ivanova et al. 2017). Therefore, to determine the status and impact of *O. davisae* in the northeast Levantine Basin, this species should be monitored using suitable sampling nets with a smaller mesh size (< 200 µm). This will provide reliable estimations of its population structure and standing stocks in the productive areas of İskenderun Bay, such as the coast of Toros fertilizer factory, the mouth of the Ceyhan River and the lagoon systems.

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Authors' contribution

TTK: sample design and methodology, investigation and data collection, data analysis and interpretation, writing – review and editing; SP: investigation and data collection, data analysis and interpretation; TGH: data interpretation, writing – review and editing.

References

Almeda R, Augustin CB, Alcaraz M, Calbet A, Saiz E (2010) Feeding rates and gross growth efficiencies of larval developmental stages of *Oithona davisae* (Copepoda, Cyclopoida). *Journal of Experimental Marine Biology and Ecology* 387: 24–35, https://doi.org/10.1016/j.jembe.2010.03.002

Altukhov DA, Gubanova AD, Mukhanov VS (2014) New invasive copepod *Oithona davisae* Ferrari and Orsi, 1984: Seasonal dynamics in Sevastopol Bay and expansion along the Black Sea coasts. *Marine Ecology* 35: 28–34, https://doi.org/10.1111/maec.12168

Avşar D (1999) Physico-chemical characteristics of the eastern Mediterranean in relation to distribution of the new Scyphomedusae (*Rhopilema nomadica*). *Turkish Jounal of Zoology* 23: 605–616

Bakır BB, Öztürk B, Doğan A, Önen M (2012) Mollusc fauna of İskenderun Bay with a checklist of the region. *Turkish Journal of Fisheries and Aquatic Sciences* 12: 171–184, https://doi.org/10.4194/1303-2712-v12_1_20

Bilecenoğlu M (2010) Alien marine fishes of Turkey - an updated review. In: Golani D, Appelbaum-Golani B (eds), Fish invasions of the Mediterranean Sea: change and renewal. Pensoft Publishers, Sofia-Moscow, Russia, pp 189–217

Cordell JR, Bollens S, Draheim R, Systma M (2008) Asian copepods on the move: recent invasions in the Columbia - Snake River System, USA. *ICES Journal of Marine Science* 65: 753–758, https://doi.org/10.1093/icesjms/fsm195

Cornils A, Wend-Heckmann B (2015) First report of the planktonic copepod *Oithona davisae* in the northern Wadden Sea (North Sea): Evidence for recent invasion? *Helgoland Marine Research* 69: 243–248, https://doi.org/10.1007/s10152-015-0426-7

Çevik C, Erkol IL, Toklu B (2006) A new record of an alien jellyfish from the Levantine coast of Turkey - *Cassiopea andromeda* (Forsskål, 1775) [Cnidaria: Scyphozoa: Rhizostomea]. *Aquatic Invasions* 1: 196–197, https://doi.org/10.3391/ai.2006.1.3.18

Çınar ME (2009) Alien polychaete species (Annelida: Polychaeta) on the southern coast of Turkey (Levantine Sea, eastern Mediterranean), with 13 new records for the Mediterranean Sea. *Journal of Natural History* 43: 2283–2328, https://doi.org/10.1080/00222930903094654

Doğan G, İşinibilir, M (2016) First report of a new invasive species *Oithona davisae* Ferrari and Orsi, 1984 (Copepoda: Cyclopoida) in the Sea of Marmara. *Turkish Journal of Fisheries and Aquatic Sciences* 16: 469–473, https://doi.org/10.4194/1303-2712-v16_2_27

Doygun H, Alphan H (2006) Monitoring urbanization of İskenderun, Turkey, and its negative implications. *Environmental Monitoring and Assessment* 114: 145–155, https://doi.org/10.1007/s10661-006-2524-0

Ferrari FD, Orsi J (1984) *Oithona davisae*, new species, and *Limnooithona sinensis* (Burckhardt, 1912) (Copepoda: Cyclopoida: Oithonidae) from the Sacramento-San Joaquin estuary, California. *Journal of Crustacean Biology* 4: 106–126, https://doi.org/10.2307/1547900

Galil BS, Zenetos A (2002) A sea change-exotics in the Eastern Mediterranean Sea. In: Leppäkoski E, Gollasch S, Olenin S (eds), Invasive Aquatic Species of Europe, Distribution, Impacts and Management. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp 325–336, https://doi.org/10.1007/978-94-015-9956-6_33

Ivanova P, Trayanova AT, Stefanova KB, Stefanova E, Raykov VS, Doncheva VG (2017) Population Status of Some Alien Species in Varna Bay, Bulgarian Black Sea Coast (2015-2016). *Acta Zoologica Bulgarica* Supplement 9: 73–82

İşinibilir M, Svetlich LS, Hubarev ES (2016a) Competitive advantage of the invasive copepod *Oithona davisae* over the indigenous copepod *Oithona nana* in the Marmara Sea and Golden Horn Estuary. *Marine and Freshwater Behaviour and Physiology* 49: 1–15, https://doi.org/10.1080/10236244.2016.1236528

İşinibilir M, Svetlich LS, Hubarev ES (2016b) Small oithonid copepods in the northeastern Marmara Sea. *Rapports Et procès-verbaux Des Réunions Commission Internationale Pour L'exploration Scientifique De La Mer Méditerranée* 41: 483

Lenz J (2000) Introduction. In: Harris R, Wiebe P, Lenz J, Skjoldal HR, Huntley M (eds), ICES Zooplankton Methodology Manual. Academic Press, London, United Kingdom, pp 1–32, https://doi.org/10.1016/B978-012327645-2/50002-5

Mihneva V, Stefanova K (2013) The non-native copepod *Oithona davisae* (Ferrari F.D. and Orsi, 1984) in the Western Black Sea: seasonal and annual abundance variability. *BioInvasions Records* 2: 119–124, https://doi.org/10.3391/bir.2013.2.2.04

Nakamura Y, Turner JT (1997) Predation and respiration by the small cyclopoid copepod *Oithona similis*: how important is feeding on ciliates and heterotrophic flagellates? *Journal Plankton Research* 19: 1275–1288, https://doi.org/10.1093/plankt/19.9.1275

Nishida S (1985) Taxonomy and distribution of the family Oithonidae (Copepoda, Calanoida) in the Pacific and Indian Oceans. *Bulletin of the Ocean Research Institute, University of Tokyo* 2: 1–167

Özcan T, Ergüden D, Turan C, Çevik C (2010) Distribution of alien nudibranch *Chromodoris annulata* Eliot, 1904 (Opisthobranch; Chromodorididae) in the Gulf of Iskenderun. Turkey. *Biharean Biologist* 4(1): 89–90

Por FD (1978) Lessepsian migration, The influx of Red Sea biota into the Mediterranean by way of the Suez Canal. Verlag, Berlin, Heidelberg, 228 pp, https://doi.org/10.1007/978-3-642-667282

Razouls C, de Bovée F, Kouwenberg J, Desreumaux N (2005-2021) Diversity and Geographic Distribution of Marine Planktonic Copepods. Sorbonne University, CNRS. http://copepodes.obs-banyuls.fr/en (accessed 8 June 2021)

Ruiz GM, Carlton JT, Grosholtz, ED, Hines AH (1997) Global invasions of marine and estuarine habitats by non-indigenous species: mechanisms, extent, and consequences. *American Zoology* 37: 621–632, https://doi.org/10.1093/icb/37.6.621

Saiz E, Calbet A, Broglio E (2003) Effects of small-scale turbulence on copepods: The case of *Oithona davisae*. *Limnology and Oceanography* 48: 1304–1311, https://doi.org/10.4319/lo.2003.48.3.1304

Strickland JDH, Parsons TR (1972) A Practical Handbook of Seawater Analysis. Ottawa, Canada, 310 pp

Svetlichny L, Hubareva E, Khanaychenko A, Gubanova A, Altukhov D, Beşiktepe Ş (2016) Adaptive strategy of Thermophilic *Oithona davisae* in the Cold Black Sea Environment. *Turkish Journal of Fisheries Aquatic Sciences* 16: 77–90, https://doi.org/10.4194/1303-2712-v16_9_09

Svetlichny L, Hubareva E, Uttieri M (2021) Ecophysiological and behavioural responses to salinity and temperature stress in cyclopoid copepod *Oithona davisae* with comments on gender differences. *Mediterranean Marine Science* 22: 80–101, https://doi.org/10.12681/mms.22496

Temnykh A, Nishida S (2012) New record of the planktonic copepod *Oithona davisae* Ferrari and Orsi in the Black Sea with notes on the identity of "*Oithona brevicornis*". *Aquatic Invasions* 7: 425–431, https://doi.org/10.3391/ai.2012.7.3.013

Terbıyık Kurt T (2018) Contribution and acclimatization of the swarming tropical copepod *Dioithona oculata* (Farran, 1913) in a Mediterranean coastal ecosystem. *Turkish Journal of Zoology* 42: 567–577, https://doi.org/10.3906/zoo-1802-42

Terbıyık Kurt T (2019) Yumurtalık kıyısal sularında (kuzey doğu Akdeniz) mesozooplankton stoklarının 2012-2017 yılları arasındaki zamansal değişimi. *Aquatic Research* 2: 1–15, https://doi.org/10.3153/AR19001

Terbıyık Kurt T, Beşiktepe Ş (2019) First distribution record of the invasive copepod *Oithona davisae* Ferrari and Orsi, 1984, in the coastal waters of the Aegean Sea. *Marine Ecology* 40: e12548, https://doi.org/10.1111/maec.12548

Terbıyık Kurt T, Polat S (2013) Seasonal distribution of coastal mesozooplankton community in relation to the environmental factors in Iskenderun Bay (north-east Levantine, Mediterranean Sea). *Journal of The Marine Biological Association of the United Kingdom* 93: 1163–1174, https://doi.org/10.1017/S0025315412001713

Terbıyık 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, https://doi.org/10.1163/15685403-00003325

Terbıyık Kurt T, Polat S (2015) Zooplankton abundance, biomass, and size structure in the coastal waters of the northeastern Mediterranean Sea. *Turkish Journal of Zoology* 39: 378–387, https://doi.org/10.3906/zoo-1311-14

Terbıyık Kurt T, Polat S (2017) Introduction of a new Indo-Pacific marine cladoceran to the Mediterranean Sea. *Mediterranean Marine Science* 18: 517–523, https://doi.org/10.12681/mms.13885

Terbıyık T, Çevik C, Toklu-Alicli B, Sarihan E (2007) First record of *Ferosagitta galerita* (Dallot, 1971) [Chaetognatha] in the Mediterranean Sea. *Journal of Plankton Research* 29: 721–726, https://doi.org/10.1093/plankt/fbm053

Toklu B, Sarıhan E (2003) The Copepoda and Cladocera (Crustacea) fauna along the Yumurtalık-Botaş coastline in İskenderun Bay. *Ege University Journal of Fisheries and Aquatic Sciences* 20: 63–68

Toklu-Alıçlı B, Sarıhan E (2016) Seasonal changes of zooplankton species and groups composition in İskenderun Bay (northeast Levantine, Mediterranean Sea). *Pakistan Journal of Zoology* 48: 1395–1405

Uriarte I, Villate F, Iriarte A (2015) Zooplankton recolonization of the inner estuary of Bilbao: influence of pollution abatement, climate and non-indigenous species. *Journal of Plankton Research* 38: 718–731, https://doi.org/10.1093/plankt/fbv060

Utermöhl H (1958) Methods of collecting plankton for various purposes are discussed. *SIL Communications 1953-1996* 9: 1–38, https://doi.org/10.1080/05384680.1958.11904091

Uye S, Sano K (1995) Seasonal reproductive biology of the small cyclopoid copepod *Oithona davisae* in a temperate eutrophic inlet. *Marine Ecology Progress Series* 118: 121–128, https://doi.org/10.3354/meps118121

Uye S, Sano K (1998) Seasonal variations in biomass, growth rate and production rate of the small cyclopoid copepod *Oithona davisae* in a temperate eutrophic inlet. *Marine Ecology Progress Series* 163: 37–44, https://doi.org/10.3354/meps163037

Üstün F, Terbıyık Kurt T (2016) First Report of the occurrence of *Oithona davisae* Ferrari FD & Orsi, 1984 (Copepoda: Oithonidae) in the Southern Black Sea, Turkey. *Turkish Journal of Fisheries Aquatic Sciences* 16: 413–420, https://doi.org/10.4194/1303-2712-v16_2_21

Venrick EL (1978) How many cells to count. In: Sournia A (ed), Phytoplankton Manual. UNESCO, Paris, France, pp 167–180

Vidjak O, Bojanić N, de Olazabal A, Benzi M, Brautović I, Camatti E, Marijana H, Lipej L (2019) Zooplankton in Adriatic port environments: Indigenous communities and non-indigenous species. *Marine Pollution Bulletin* 147: 133–149, https://doi.org/10.1016/j.marpolbul.2018.06.055

Yılmaz A, Baştürk O, Saydam C, Ediger D, Yılmaz K, Hatipoglu E (1992) Eutrophication in Iskenderun Bay, northeastern Mediterranean. In: Vollenweider RA, Marchetti R, Viviani R (eds), Marine Coastal Eutrophication, Elsevier, The Netherlands, pp 705–717, https://doi.org/10.1016/B978-0-444-89990-3.50062-6

Zagami G, Brugnano C, Granata A, Guglielmo L, Minutoli R, Aloise A (2018) Biogeographical distribution and ecology of the planktonic copepod *Oithona davisae*: Rapid invasion in Lakes Faro and Ganzirri (Central Mediterranean Sea). In: Uteri M (ed), Trends in Copepod Studies Distribution Biology and Ecology, Nova Science Publishers, Newyork, USA, pp 59–82

Zamora-Terol S, Saiz E (2013) Effects of food concentration on egg production and feeding rates of the cyclopoid copepod *Oithona davisae*. *Limnology and Oceanography* 58: 376–387, https://doi.org/10.4319/lo.2013.58.1.0376

Zenetos A, Gofas S, Verlaque M, Cinar ME, Garcia Raso JE, Bianchi CN, Morri C Azzurro E (2010) Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union' Marine Strategy Framework Directive (MSFD) Part I. Spatial distribution. *Mediterranean Marine Science* 11: 381–493, https://doi.org/10.12681/mms.87