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Introduction of a new Indo-Pacific marine cladoceran to the Mediterranean Sea

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Abstract

Pleopis schmackeri, a podonid cladoceran not previously recorded in the Mediterranean Sea, was found in the İskenderun Bay for the first time. The samples were collected seasonally during 2012–2015 in the coastal area of İskenderun Bay using a WP-2 zooplankton net (200 µm). Six cladoceran species were found in total, and *Penilia avirostris, Pseudevadne tergestina* and *Evadne spinifera* constituted the bulk of the population, while the contribution of *P. schmackeri* was very low. Although only a single individual was observed in July 2012, the abundance and frequency of *P. schmackeri* increased in the following years, reaching 25.10 ind.m^{-3} in 2015. Thus, *P. schmackeri* could be considered as established in İskenderun Bay; however, it seems that it did not affect the distribution of other cladoceran species in the area up to now. *P. schmackeri* could have entered in İskenderun Bay either as a Lessepsian migrant or by ballast waters of commercial ships.

Keywords: *Pleopis schmackeri*, cladocerans, first record, alien, İskenderun Bay, Mediterranean.

Introduction

The Mediterranean Sea is one of the world's hotspots for marine bio-invasion (Rilov & Galil, 2009). Approximately 821 alien species are currently recognised from the Mediterranean Sea; however, 613 of these species were established (Zenetos *et al.*, 2017). Many factors facilitate the entry of such alien organisms into the Mediterranean, including interoceanic canals, biofouling, transport from other countries in ballast water, mariculture, the bait and pet trade and market discards (Ruiz *et al.*, 1997). In particular, the Suez Canal is considered a major gateway for the entry of alien species (Galil, 2000); fully half of alien species have been introduced through the Suez Canal since 1869 (Galil *et al.*, 2014).

Marine cladocerans are significant components of the coastal-area zooplankton assemblages in tropical and temperate regions during the warm periods (Atienza *et al.*, 2007). Out of about 600 cladoceran species, only eight truly inhabit the marine environment (Tang *et al.* 1995; Onbé, 1999). Among them, *Penilia avirostris* (Dana, 1849), *Pseudevadne tergestina* (Claus, 1877), *Evadne spinifera* (P.E. Müller, 1867), *Evadne nordmanni* (Lovén, 1836), *Pleopis polyphemoides* (Leuckart, 1859), *Podon leuckartii* (G.O. Sars, 1862) and *Podon intermedius* (Lilljeborg, 1853) were recorded in the Mediterranean Sea (Moraitou-Apostolopoulou & Kiortsis, 1973; Gaudy, 1985; Sampaio de Souza *et al.*, 2011). Except for *P. leuckartii*, a species more common in cold waters (Onbé, 1999), all Mediterranean species are found along the Turkish Mediterranean coast (Toklu & Sarıhan, 2003; Aker & Özel, 2006; Terbıyık Kurt & Polat, 2013, 2014). The population dynamics of the cladocerans in the Bay are characterized by the sharp seasonal variation, with habitual increases in spring and summer and low abundances in the remaining period (Terbıyık Kurt & Polat, 2014; Terbıyık Kurt & Zenginer Yılmaz, 2016). In this study, we refer to the first record of the marine cladoceran *Pleopis schmackeri* in İskenderun Bay (Eastern Mediterranean Sea) and its abundance in comparison with the other cladocerans, and we discuss possible pathways of penetration of this species in the study area.

Material and Methods

The study area

İskenderun Bay is located on the southern Mediterranean coast of Turkey; it is approximately 65 km long and 35 km wide, with a maximum depth of 100 m. The general circulation in the Bay is affected by the prevailing currents and cyclonic gyres of the open sea (Yilmaz *et al.,* 1992). The study area is located in the interior part of İskenderun Bay, which is affected by the subtropical climatic conditions that prevail in the Eastern Mediterranean. In addition, annual average seawater temperature has increased about 2ºC in İskenderun Bay since 1970 (Turan *et al.*, 2016) and warmer conditions prevailed in winters after 2009 (Mavruk *et al.*, 2017).

Sampling and examination

Zooplankton sampling was carried out in April, July, October and December from April 2012 to December 2015. Vertical hauls were performed from near bottom to surface at five stations located along the coast of Yumurtalık (Iskenderun Bay) (Table 1) using a WP-2 net

Table 1. Coordinates of the sampling stations.

Stations	*Latitude*	*Longitude*
1	35.93267333 E	36.81907683 N
2	35.90415583 E	36.790854 N
2	35.9144805 E	36.82999083 N
4	35.88773383 E	36.8065875 N
5	35.91251417 E	36.81425733 N

with a 200-µm mesh. The depth of the sampling layer varied from 5–15 m according to the station. Zooplankton samples were immediately preserved in a 4% formaldehyde–seawater solution after collection. In laboratory, the entire samples were analysed for detecting the presence of *P. schmackeri* and other rare cladoceran species, while the abundance of other cladocerans was counted in aliquots varying 1 to 1/32 of the total sample; aliquots were taken with the use of a Folsom splitter and counts were performed in subsamples. Species identification was performed using an Olympus SZX16 stereomicroscope and Leica microscope, under magnifications of 115 and 200. Photos were taken with a digital camera. The identification of cladoceran species was performed according to Onbe (1999) and Petryashev *et al.* (2004). The abundances were calculated as number of individuals per m^3. Salinity and temperature were measured simultaneously to zooplankton sampling, with YSI 6600 CTD probe at the surface of the sampling stations.

Results

Mean temperature over stations fluctuated between 17.31 and 29.31°C with clear seasonal cycle: high values in summer-autumn and low values in winter-spring. Salinity varied from 36.99 to 39.06 and presented irregular fluctuations depending on the freshwater input from the small river in the study area (Fig. 1).

The collected specimens of *P. schmackeri* had an easily distinguished small hemispherical body shape (Fig. 2), very shallow cervical groove and a slender caudal furca sharply pointed with spinules (Fig. 3); they had four setae on the exopods of thoracic limbs 1–3 (Fig. 4). The measured body length of these specimens varied between 250 and 410 µm (351 ± 40 µm, N=14). All specimens were parthenogenetic females and the number of carried embryos ranged from one to eight (approximate mean: five embryos).

A single specimen *of P. schmackeri* was found in summer (July) 2012 (0.78 ind. m^{-3}) at station 4 (Fig. 5). In 2013, this species was observed at stations 2 (0.26 ind. m^{-3}) and 4 (0.78 ind. m^{-3}) in summer (July). The abundance of the species increased in July 2014 at station 4, and it was also observed at stations 1 and 2. In July 2015 up to 25.1 ind. m^{-3} were found at stations 3 and 4, while it was also found at stations 1, 2 and 5 with lower abundance. Overall, its mean abundance *over* stations increased from 0.15 ind. m^{-3} in 2012 to 12.26 ind. m^{-3} in 2015; similarly its contribution to total cladocerans was amplified from 2012 (>0.01%) to 2015 (0.7%). During the period of *P. schmackeri* presence in Iskenderun Bay, temperature ranged between 26.39 and 29.00 °C, and salinity between 37.13 and 37.93.

Cladocerans contributed to the mean annual zooplankton abundance of the bay between 14.1% and 18%. Their abundance values peaked in summer (2012, 2014 and 2015) and in spring (2013) (Fig. 6). In total, six cladoceran species were observed in the investigated area during the study period. *P. avirostris* was observed in all seasons, and it was more abundant in spring and summer (Fig. 6); its contribution to total cladoceran abundance during summer (period of *P. schmackeri* presence) varied between 86.4% (2013) and 98% (2015) (mean values over stations).

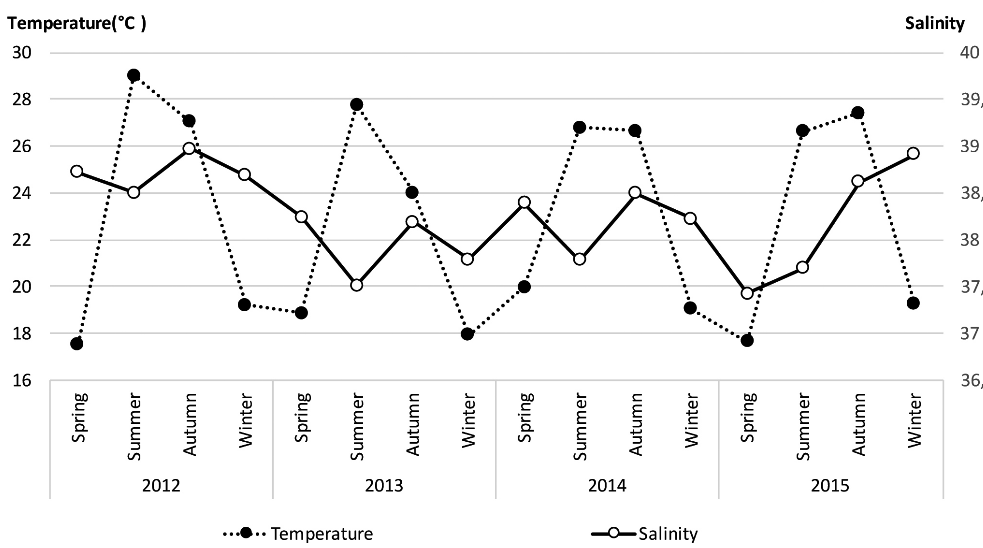

Fig. 1: Seasonal variations of the sea surface temperature and salinity values in the study area (mean values over stations).

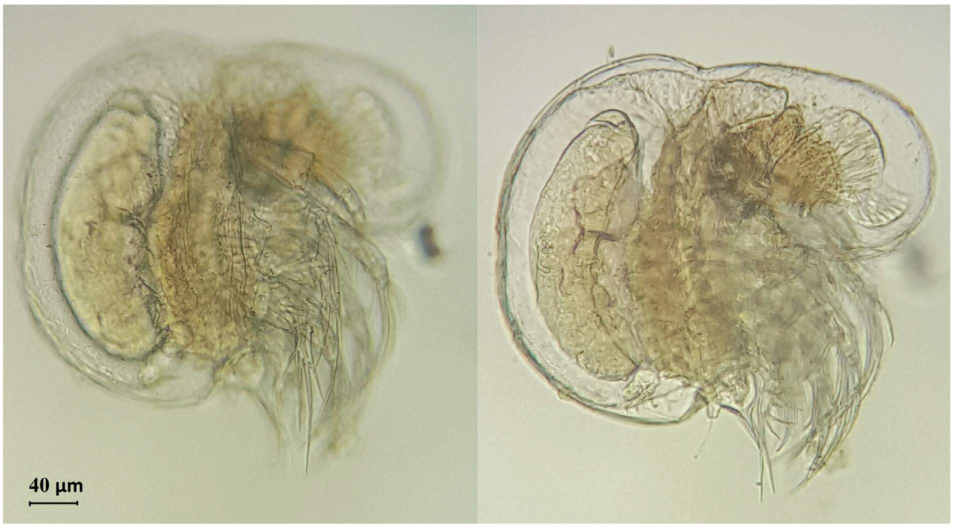

Fig. 2: Body appearance of *Pleopis schmackeri* (original caption).

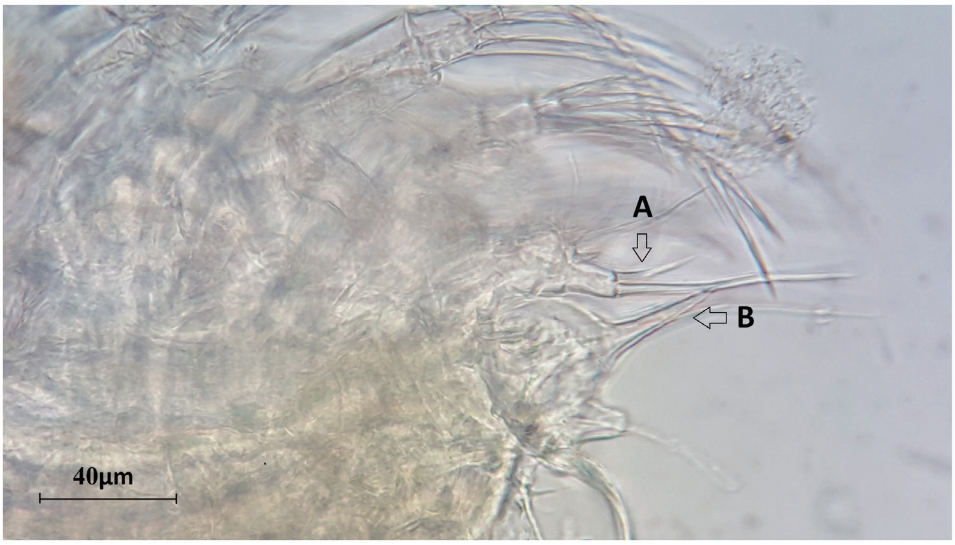

Fig. 3: A: Exopod of 4th thoracic limbs, B: caudal furca (original caption).

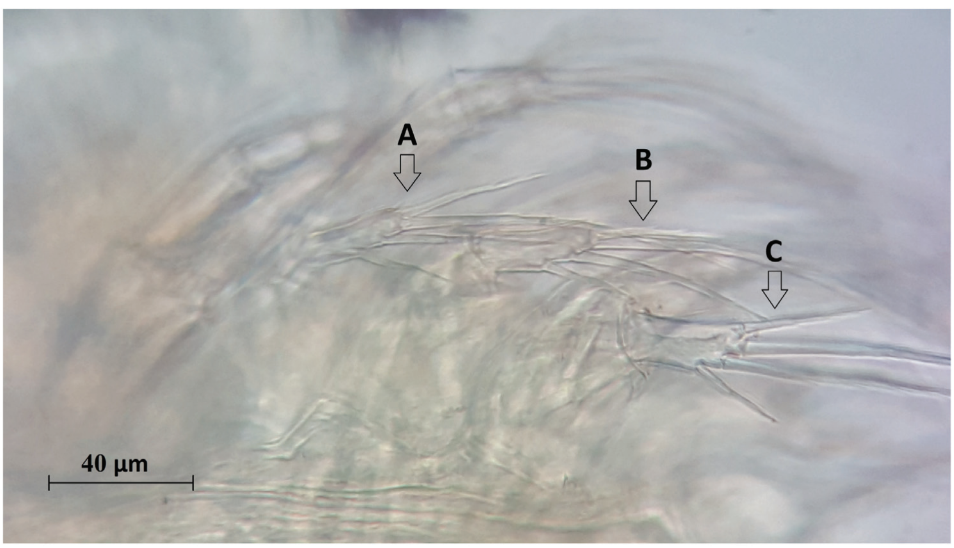

Fig. 4: Thoracic limbs of *Pleopis schmackeri*, A: exopod of 1st thoracic limbs, B: exopod of 2nd thoracic limbs, C: exopod of 3rd thoracic limbs (Original captions).

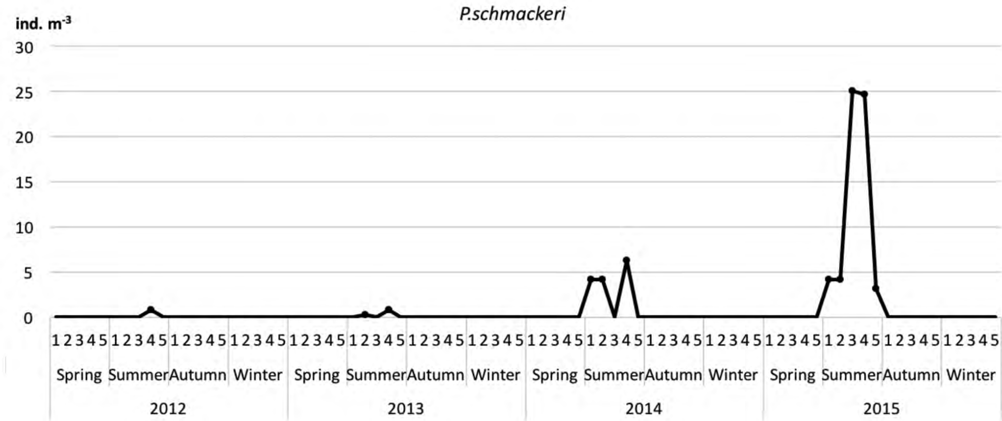

Fig. 5: Variability of *P. schmackeri* abundance at the sampling stations.

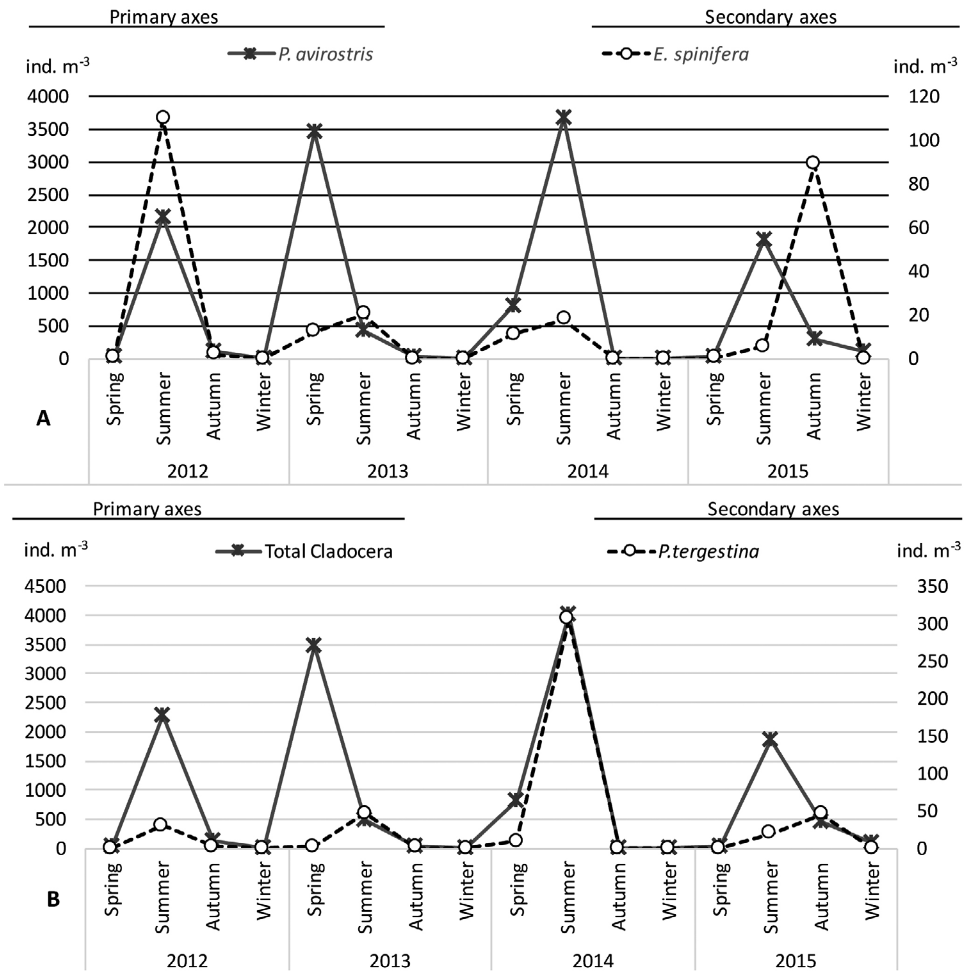

Fig. 6: Mean abundance values (over the stations) of *P. avirostris, E. spinifera, P. tergestina* and total cladocerans.

Table 2. Descriptive statistics of abundance of cladoceran species (ind. m^{-3})

	Evadne spinifera	*Penilia avi-rostris*	*Podon polyphemoides*	*Pleopis schmackeri*	*Podon inter-medius*	*Pseudevadne tergestina*	Total Cladocera
Mean	16,71	808,94	0,04	0,97	0,86	28,89	856,41
Std. Dev.	40,11	1421,34	0,35	4,03	2,54	99,01	1494,09

P. tergestina and *E. spinifera* were only not found in winter (Fig. 6); during summer, the relative abundance of the former species ranged between 1.1 % (2015) and 9.4 % (2013), while that of the latter varied between 0.3% (2015) and 4.8% (2012). *Podon intermedius and Pleopis polyphemoides* were observed rarely and only in spring (Table 2); the former species was observed in all year, while the latter was found only in 2014.

Discussion

This study is the first report of *P. schmackeri* in the coastal area of İskenderun Bay, Turkey, and is the first record of this species in the Mediterranean Sea. This species is clearly distinguished by the presence of fourth seta on exopods of thoracic limbs 1-3 (Egloff *et al*., 1997; Petryashev *et al.,* 2004), as opposed to the congeneric species *P. polyphemoides* which possesses only three setae on exopods of the respective limbs. *Pleopis schmackeri* was originally described in Hong Kong by Poppe (1889), and its distribution along the Asian coast extends from the south-eastern shores of the Indochina Peninsula to the eastern coastal waters of Korea, and to the southern regions of the Sea of Japan (Kim & Onbe, 1989). Almost a century later, *P. schmackeri* was found near the Rio Una do Prelado River on the Brazilian coast (Rocha, 1985). It became established in this region and spread from Guanabara Bay to Rio Grande do Sul (Resgalla & Montú, 1993; Marazzo, 2002; Domingos-Nunes & Resgalla, 2012; Monteiro-Ribas *et al*., 2012). Moreover, sporadic records are reported in Aqaba Bay (Red Sea), in Madagascar (Indian Ocean) (Onbe, 1999) and in Port Tawfiq at the southern entrance to the Suez Canal (Gurney, 1927).

Total body length and female fecundity of *P. schmackeri* measured in İskenderun Bay are within the ranges reported for the south Atlantic and Pacific coasts specimens. Namely, Marazzo (2002) reported a body length of 420 µm and five embryos in the Rio de Janeiro area. In other Brazilian areas, the range of the body length was 340–470 µm and 5–6 embryos were carried by the female specimens (Rocha, 1985). In the north-western Pacific Ocean, the body length of this species was measured as 452 µm (Kim & Onbe, 1989). Body length range of 0.34–0.50 mm was recorded by the above authors in the southern waters of Kyushu, Japan, with a gradual increase towards the northern waters of the Sea of Japan, where the size range was 0.49–0.65 mm. Fecundity values were 5.20 and 5.36 embryos in the southern waters of Kyushu and the Sea of Japan, respectively. However, lower values were measured in the waters of southern Honshu and the Korean Strait (2.35 and 3.90 embryos, respectively), which could be the result of a combined effect of environmental conditions such as temperature, salinity and food availability (Kim & Onbe, 1989).

Before the introduction of *P. schmackeri* into the İskenderun Bay, the seasonal pattern of cladoceran species in the study area was characterized by the presence of *P. intermedius* in early spring, and the increasing abundance of *Penilia avirostris*, *Evadne spinifera* and *Pseudevadne tergestina* as the conditions become warmer, while the contribution of *P. polyphemoides* is usually very low (Terbıyık Kurt & Polat 2013, 2014). In the present study, an almost similar seasonal pattern of cladoceran species was observed, and it seems that the presence of *P. schmackeri* in the bay did not affect yet the distribution or abundance of the other cladoceran species.

According to Kim & Onbe (1989) *P. schmackeri* prefers warm water with low salinity; in the north-western Pacific and in the south-western Atlantic, the species was recorded in a temperature range 21–27 °C and a salinity range 19–34 (Onbe, 1983; Rocha, 1985; Onbe & Ikeda, 1995; Marazzo, 2002; Domingos-Nunes & Resgalla, 2012; Monterio Ribas *et al*., 2012). In the present study, it was found in summer, when temperature and salinity are higher (26.4–29.1 °C and 37.39–37.96, respectively) than those mentioned by the above authors. *P. schmackeri* has been found in very low abundance in most areas where it has been recorded (Rocha, 1985; Marazzo, 2002; Kim &and Onbe, 1989; Domingos-Nunes & Resgalla, 2012). Namely, Rocha (1985) collected one hundred parthenogenetic female specimens near the mouth of Rio Una do Prelado, and the mean abundance was approximately 4 ind. m^{-3} along the Brazilian Coast (Marazzo, 2002). In Southern Kyushu, Southern Honshu, Korea Strait and the eastern coast of Korea, its abundance varied from 0.03 to 8.9 ind. m^{-3} (Kim & Onbe, 1989). Despite the low abundance, the species is common in the coastal waters of Brazil (Domingos-Nunes & Resgalla, 2012) and Japan Sea (Kim & Onbe, 1989). The abundance of *P. schmackeri* found in İskenderun Bay are within the range of the above-mentioned values.

Our first hypothesis on the origin of *P. schmackeri* in the Iskenderun Bay is that this species entered the eastern Mediterranean as a Lessepsian migrant from the Red Sea *via* the Suez Canal, and was then carried northwards by currents towards İskenderun Bay. The dominant counter-clockwise surface current in the eastern Levantine Sea reaches the Turkish coast (Hamad *et al*., 2006), and directly affects İskenderun Bay due to the wide mouth opening of the bay. This basin scale circulation plays an important role in the distribution of species entering through the Suez Canal and in their transport in different regions of Levantine Sea, including the Anatolian coastline (Occhipinti-Ambrogi & Galil, 2010). The cyclonic and anticyclonic eddies covering İskenderun Bay favour the expansion of the introduced surface water to inner areas of the bay (İyiduvar, 1986), facilitating the transport of zooplankton species to the inner parts of İskenderun Bay. An alternative hypothesis is that *P. schmackeri* could have entered in the region by ballast waters of commercial ships. Shipping is the second most important pathway of introduction of alien species after introduction by corridors such as the Suez Canal (Zenetos *et al*., 2012). İskenderun Bay is an important trade location, hosting one of the largest international ports in Turkey (Matyar & Dinçer, 2010).

The presence of this species may have been missed in previous studies due to its sparse distribution and small size. This could be due to the use of a 200-µm mesh net, which does not sample effectively individuals smaller than 450 µm (Hopcroft *et al.*, 2001). Their absence from previous studies often happens when studies do not aim at detecting allochthonous species, and the presence of such species is not noted by non-specialized taxonomists; consequently, specimens of alien species are accidentally referred to as similar congeneric native species or their juveniles (Torres *et al.*, 2012). It is unlikely that this species entered the Mediterranean Sea via the Strait of Gibraltar through natural expansion, because *P. schmackeri* is primarily distributed along the western coast of the Atlantic Ocean, and to the best of our knowledge has not yet been recorded along the eastern coast of this ocean close to the Gibraltar Strait. The presence of this species in the Red Sea, particularly in the Suez Canal (Gurney, 1927) and Indo-Pacific region (Kim & Onbe, 1989), supports the hypotheses that this species was carried in Iskenderun Bay via currents or by ships' ballast waters.

Red Sea species play an important role in the biodiversity of the eastern Mediterranean, particularly along the south-eastern coast. There has been a significant increase in Red Sea immigrant organisms since the Suez Canal was widened and dredged, along with the construction of the Aswan Dam in 1967 (Por, 1978; Kovalev, 2006). The natural ecological and hydrographical properties of the eastern Mediterranean seem to favour the settlement of such immigrant species (Çevik *et al.*, 2008). Alien species from the Indo-Pacific region primarily settled in İskenderun Bay along the Turkish coast (Çevik *et al.*, 2006) such as *Ferosagitta galerita* (Terbıyık *et al.*, 2007), *Electroma vexillum* (Çevik *et al.*, 2008), and *Trachurus indicus* (Dalyan & Eryılmaz, 2009). The climatic conditions in the inner part of the bay make this area more suitable for the establishment of species of Indo-Pacific origin. Moreover, the reported primary production values in the Bay are 2–4 times higher than those observed in the surrounding areas (Yılmaz *et al.*, 1992), and we may assume that this production could favour the settlement of alien zooplankton species in this region, by reducing the food competition between alien and local species. Indeed, Mavruk *et al.* (2016) observed that a significant positive correlation was clear between the variations of Lessepsian ichthyofaunal composition and chlorophyll-*a* concentration in the sampling area.

In conclusion, the consecutive observations of *P. schmackeri* indicate its successful acclimatisation and establishment in the coastal ecosystem of İskenderun Bay. We suggest that monitoring studies should be conducted to quantify the status of this species, with respect to its adaptation and population density, and to determine whether it has had a positive or negative effect on İskenderun Bay's biodiversity.

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