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Review of marine alien isopods in Türkiye with two new records: of *Paracerceis sculpta* and *Paranthura japonica*

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Abstract

This study focuses on the alien isopod species recorded in the Turkish seas. To date, two alien species (*Paradella dianae*, *Sphaeroma walkeri*) have been reported in the country, accounting for almost 2.4% of the total number of isopod species occurring in the Turkish seas. The faunistic analysis of benthic samples collected from Dardanelles (Çanakkale) Straits and Izmir Bay revealed two new alien isopod species (*Paranthura japonica* and *Paracerceis sculpta*), on the Turkish coasts. Additionally, this is the first record of *P. japonica* in the Black Sea ecosystem. This study analyses and discusses the morphological, ecological and distributional characteristics of the species.

Keywords: Isopoda; *Paranthura japonica*; *Paracerceis sculpta*; alien; eastern Mediterranean Sea; Sea of Marmara.

Introduction

The eastern Mediterranean Sea is currently witnessing an unprecedented invasion by alien marine species, introduced mainly from the Red Sea via the Suez Canal, various oceans via ships (hull fouling or ballast water) and mariculture (Zenetos *et al.*, 2012; Galanidi *et al.,* 2023). Twenty-three isopod alien species occur in the Mediterranean Sea (Castelló *et al*., 2020), but only two of them have been reported in the surveys conducted so far on the Turkish coasts (*Paradella dianae* (Menzies, 1962), *Sphaeroma walkeri* Stebbing, 1905 (Bakır *et al.,* 2014), whereas a third one [*Paracerceis sculpta* (Holmes, 1904)] has been found only on boat hulls (Ulman *et al*., 2017).

The first record of *Paradella dianae* in the Mediterranean Sea was from Civitavecchia, Italy (Forniz & Maggiore, 1985). The species has a rather wide distribution throughout the Pacific and Atlantic Oceans, the coasts of Australia and Arabian Seas, and it has most likely been introduced into Mediterranean harbours by vessels as a fouling organism (Galil *et al.,* 2008; Kırkım *et al.,* 2017). It was first recorded on the Turkish coasts (Aegean and Levant) by Çınar *et al*. (2008) and Kırkım *et al*. (2015). Particularly, *P. dianae* was recorded from Izmir Bay in the Aegean Sea in 2004 with an abundance of 1,075 ind.m^{-2} (Çınar *et al*. 2008) and from the inner part of Izmir Bay with an abundance of 1,250 ind.m^{-2} (Doğan *et al.,* 2015). Subsequently, it was recorded from Fethiye Bay for the first time on the Levantine coast of Turkey in 2008 with a single specimen collected from 0–5 m depth and rocky substrate (Kırkım *et al.,* 2015). It has also been recorded in Mersin Bay with an abundance of 1,175 ind.m^{-2} (Çınar *et al.,* 2017).

Sphaeroma walkeri is a species native to the northern Indian Ocean, first described from Sri Lanka by Stebbing (1905). This species occurs worldwide: Atlantic Ocean, Indian Ocean, Red Sea and the Suez Canal. It has entered the Mediterranean Sea either through vessels or via the Suez Canal (Ramalhosa *el al*., 2017) from which it spreads. In Türkiye it occurs along the Aegean coasts (Kırkım, 1998; Kırkım *et al.,* 2006) as well as in the Levantine coasts (Kırkım *et al.,* 2017). Kırkım (1998) recorded two male and ten female *S. walkeri* specimens from Marmaris and Datça, marking the first record from the Aegean coast of Türkiye. The specimens were found under stones at depths between 0.1 and 0.5 m. Additionally, Kırkım *et al*. (2017) recorded four specimens from Fethiye Bay, representing the second record from the Levant coast of Türkiye. Furthermore, Ulman *et al*. (2017) reported this species from Heraklion, Greece, providing the first country record for Greece.

Paracerceis sculpta is a species native to the northeastern Pacific, first described from San Clemente Island by Holmes (1904). It has been introduced to many localities in the world and its distribution is steadily spreading. It was recorded from the Mediterranean for the first time from the Lake of Tunis by Rezig (1978). This species was reported in Türkiye in 2015 from the hulls of a fishing boat in the Fethiye Bay by Ulman *et al.* (2017) and again in 2017 by Martínez-Laiz *et al.* (2019). However, these findings are only indications of the transport vector and do not qualify as alien species in Türkiye (Marchini *et al.*, 2015).

The genus *Paranthura* in the family *Paranthuridae*, is very rich in terms of the number of species. Frutos *et al*. (2011) reported 64 species in this genus. Currently, this number has increased to 67 (Frutos *et al*., 2011; Jarquín–Martinez & García–Madrigal, 2021), with the addition of *Paranthura santiparrai* Frutos, Sorbe & Junoy, 2011, *Paranthura amorensis* Jarquín–Martínez & García–Madrigal, 2021 and *Paranthura tientai* Jarquín–Martínez & García–Madrigal, 2021. Among these species, *Paranthura nigropunctata* (Lucas, 1846) and *Paranthura costana* Bate & Westwood, 1866 are native species from the European waters and Mediterranean Sea. Recently, a new *Paranthura* species identified as *Paranthura japonica* Richardson, 1909, was detected from the French Atlantic coast (Frutos *et al.,* 2011) and subsequently from the Mediterranean.

The first description of *Paranthura japonica* was based on a single female specimen sampled off the coast of Hokkaido Island, Japan (Richardson, 1909). The native geographic range of this species encompasses northwest Pacific Ocean (Lavesque *et al*., 2013). About 80 years after the first description, the species was recorded in the east of San Francisco Bay and then in southern California, well outside its native range. In these regions, it has been regarded as an alien species introduced by human activities (Cohen & Carlton 1995). In the Mediterranean region, Marchini *et al*. (2014) reported the species from La Spezia (Italy, Ligurian Sea), Olbia (Sardinia, Italy, Tyrrhenian Sea) and Lagoon of Venice (Italy, Adriatic Sea). In subsequent years, an explosion of new records of *P. japonica* was reported by various researchers across the Mediterranean region, especially from commercial ports and marinas (Lorenti *et al*., 2016; Tiralongo & Mancini, 2016; Langeneck & Tempesti, 2017; Ulman *et al*., 2017; Bonifazi *et al*., 2018; Gambi *et al*., 2019; Fortič & Mavrič, 2020). In addition to the wide distribution of the species in the Western and Central Mediterranean, it was reported at the port of Heraklion (Greece), Eastern Mediterranean in 2012 by Tempesti *et al*. (2016). This record is the easternmost record of the species in the Mediterranean Sea.

In this study, we update the list of alien isopods in Türkiye, documenting the first occurrence of *Paranthura japonica* Richardson, 1909, new to the Turkish marine fauna, and confirming the first record of *Paracerceis sculpta* in Türkiye. The paper also provides a biogeographic overview of alien isopods records in Türkiye from secondary data.

Materials and Methods

Study area

The Strait of Çanakkale, also known as the Dardanelles, is a crucial component of the Turkish Strait System, which includes the Sea of Marmara and Strait of İstanbul (Başar, 2010). These 62 km-long marine channels connect the Aegean Sea and the Marmara Sea. The average depth of the Çanakkale Strait is 55 m, with the deepest point reaching more than 100 m, and its width ranges from 1.2 to 7 km (Yaltırak *et al.,* 2000). The Çanakkale Strait constitutes a two–layer system. The water of the Mediterranean Sea, which is characterised by high salinity (around 38.9 PSU), enters the Sea of Marmara in the lower layer (Beşiktepe *et al.,* 1993), whereas, the water of the Black Sea, with a salinity of around 25–29 PSU, enters the North Aegean Sea as the upper layer (Androulidakis *et al.,* 2012). The Turkish Straits experience remarkably dense maritime traffic, due to the presence of merchant vessels, coastal vessels, fishing vessels and local maritime activities (Başar, 2010).

The bay of Izmir, which is exposed to various pollution discharges, intense marine traffic and increasing human population, has been considered one of the most–polluted areas of the Mediterranean Sea over the last two decades (Doğan *et al.,* 2005). The bay is divided into three sub–regions (inner, middle and outer regions) based on faunistic and hydrographic factors (Kocataş, 1980). The inner region is located in the most populated region of Izmir City, close to the industrial and domestic discharge points, and is subjected to dense sedimentation due to weak circulation. The middle region is a transitional area between polluted and unpolluted zones and is defined as a semi–polluted area. The outer bay, which covers the large portion of the bay, is characterised by sensitive species and is therefore regarded as relatively unpolluted (Çınar *et al.,* 2012).

Material examined and taxonomic identification

The specimens of *Paranthura japonica* were collected from four stations in Çanakkale (Dardanelles) Strait on 11 November 2022 between the depths of 8 and 21 m (Fig. 1). The biotope structures of the stations consisted of sand, mud and mollusc shells in various proportions. Benthic samples were collected using a Van Veen grab with a sampling area of 0.1 m^2. In the field, the collected material was sieved through a 0.5 mm mesh. The retained material on the mesh screen was placed in a plastic jar before it was fixed with 4% formalin solution diluted with sea water for transport to the Ege University Benthology Laboratory.

Specimens of *Paracerceis sculpta* were collected at ten stations comprising six on soft and four on hard substrate (Fig. 1) in the inner region of the Izmir Bay (Aegean Sea) between April 2022 and April 2023. The coordinates, depths and sediment characteristics of the stations in the Izmir Bay are shown in Table 1. At the

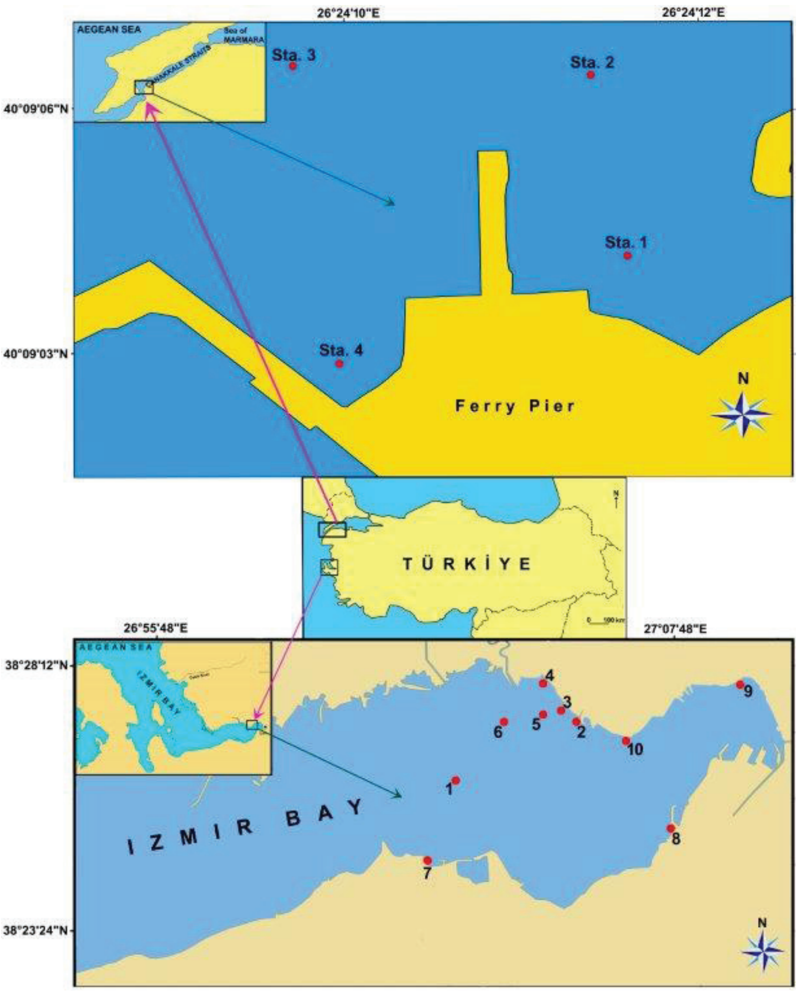

Fig. 1: Map of the study area showing sampling sites.

Table 1. Physico-chemical characteristics of the stations at which *Paranthura japonica* (from Çanakkale Straits) and *Paracerceis sculpta* (from Izmir Bay*)* were sampled. S: salinity, T: temperature (°C), O_2: oxygen (mg.L^{-1}).

	Sta.1	Sta.2	Sta.3	Sta. 4	1	2	3	4	5	6	7	8	9	10
S	27.74	27.76	27.77	27.74	32.8	33.2	30.0	32.4	31.9	32.4	37.2	37.2	38.1	38.0
T°*C*	15.68	15.25	15.72	15.75	17.1	18.2	17.0	17.6	17.2	17.3	14.8	14.9	28.6	22.9
pH	8.11	8.12	8.09	8.11	8.10	8.21	7.84	8.36	8.14	8.32	8.21	8.04	8.31	8.40
O_2	9.31	8.64	8.99	9.05	9.71	7.32	6.54	8.65	6.94	7.45	8.84	7.91	6.10	6.30

soft substrate stations (Station 1 to 6) in the Izmir Bay, three replicates were taken at each station by a van Veen Grab sampling an area of 0.1 m^2. At each hard substrate station (Station 7 to 10), three replicates were taken at the depth of 0.2 m by scraping an area of 400 cm^2 using a spatula. At Station 7 located in İnciraltı, mussel samples were taken from the rock. At Station 8 located in Pasaport Harbour, mussel samples were taken from a submerged rope. At Station 9 located in Alsancak Harbour, mussel samples were taken from a submerged concrete block. At Station 10 located near the sailing Club in Karşıyaka, mussel samples were collected from a submerged concrete block. The benthic material in each replicate was sieved through 0.5 mm sieve, before the material retained on the sieve was placed in separate jars containing a 4% seawater formaldehyde solution.

In the laboratory, the collected benthic material was rinsed with tap water onto a 0.5 mm mesh size, before crustacean specimens were sorted under a stereomicroscope (Olympus SZ51) and preserved in small bottles containing 70% ethanol solution. The preserved crustacean specimens were identified and counted under a stereomicroscope (Olympus SZX7). We identified *P. japonica* specimens primarily using the original description by

Richardson (1909), following the distinctive taxonomic features outlined in Lavesque *et al*. (2013), Marchini *et al*. (2014) and Lorenti *et al*. (2016). Specimens of *P. sculpta* were identified following guidelines in Menzies (1962), Fryganiotis & Chintiroglou (2014), Marchini *et al*. (2018), Ramalhosa *et al.* (2017) and El Kamcha *et al*. (2021). Taxonomic slides were prepared and observed under an optical (light) microscope (Olympus BX51). Photographs of entire and dissected specimens were taken with an Olympus digital camera mounted on stereo– and light microscopes (Olympus SZX7).

Faunistic analysis of benthic samples collected from various depths and biotopes along the Çanakkale Strait and Izmir Bay revealed a total of two alien isopod species, accounting for 443 individuals. Among these, *Paranthura japonica* was found at the Dardanelles Straits, whereas *P. sculpta* was found at Izmir Bay (Fig. 2). The morphological, ecological and distributional features of these species are discussed under the Results section.

Bakır *et al*. (2014) and Ulman *et al.* (2017) were used for the distribution of alien isopods along the coasts of Türkiye.

The physico-chemical water characteristics of the stations in Izmir Bay and Dardanelles Strait are shown in Table 1. In the sampling area, the water quality variables (temperature, salinity, pH and oxygen solubility) of the stations were measured *in situ* by means of a YSI 650 MDS multiparameter display system.

Results

Table 2 summarises the distribution of isopods along the Turkish coasts as based on literature and data collected in this study. Stations at the Dardanelles Straits exhibited temperature ranging from 15 to16°C, pH around 8 and salinity around 27.8 PSU. Additionally, the concentration of dissolved oxygen ranged from 8.64 mg/l to 9.31 mg/l (Table 1).

In the inner region of Izmir Bay salinity ranged between 30.0 and 38.1 PSU, pH between 7.84 and 8.40 and temperature between 17.0°C and 28.6°C. The concentration of dissolved oxygen ranged from 6.10 to 9.71 mg/l (Table 1).

The population density of *Paracerceis sculpta* (Fig. 2) varied among stations and seasons in Izmir Bay, peaking in spring (Table 2). The population density ranged from 10 ind.m^{-2} (Station 6) to 840 ind.m^{-2} (Station 3) in spring 2023 and 850 ind.m^{-2} (Station 7) in spring 2022; 3,375 ind.m^{-2} (Station 10) in summer 2022; 10 ind.m^{-2} (Station 2) to 800 ind.m^{-2} (Station 8) in autumn 2022; 475 ind.m^{-2} (Station 9) in winter 2022.

In this study, 8, 26, 70 and 1 individuals of *Paranthura japonica* were detected in the samples from Station 1, Station 2, Station 3 and Station 4, respectively (Table 2). The characteristics that emerged from the examination of a total of 105 individuals are as follows: this particular species can be easily distinguished by the fusion of pleonites 1–5 along the mid–dorsal region, whereas they are distinct at the lateral sites (Fig. 3).

Careful examinations revealed several other defining features of these specimens. The most obvious of these features is that the pleonites are fused in dorsal view, but they are separate when viewed from the side. Apart from this, the specimens have elongated body with large compound eyes composed of less than 17 ommatidia. The patches of dark pigmentations occur throughout the entire body and the anterolateral angles of cephalon exceed rostral projection (Fig. 4; Fig. 5A–H).

Fig. 2: Dorsal view of male and female individuals of *Paracerceis sculpta* (Scale bar: 1 mm).

Table 2. List of sampling sites, with collection date, geographic coordinates, depths (m), number of species, source of information and additional ecological/geographic data.

Species	Date	Location	Latitude N	Longitude E	Depth range (m)	Ecological or/and geographical data	Number of specimens	Source of info
P. japonica	11.11.2022	Dardanelles Strait	40.151233° N	26.402642° E	8 m	Muddy sand	8	This study
P. japonica	11.11.2022	Dardanelles Strait	40.152061° N	26.402575° E	21 m	Muddy sand with mollusc shells	26	This study
P. japonica	11.11.2022	Dardanelles Strait	40.152150° N	26.401439° E	18 m	Sand with mollusc shells	70	This study
P. japonica	11.11.2022	Dardanelles Strait	40.150881° N	26.401711° E	10 m	Muddy sand	1	This study
P. sculpta	13.04.2023	Izmir Bay	38.434167° N	27.044444° E	8 m	Sandy mud with shell fragments	170	This study
P. sculpta	29.09.2022	Izmir Bay	38.452989° N	27.091822° E	2 m	Sandy mud with mollusc shells	10	This study
P. sculpta	28.04.2023	Izmir Bay	38.456086° N	27.086222° E	1 m	Mud with mollusc shells	840	This study
P. sculpta	28.04.2023	Izmir Bay	38.465364° N	27.078669° E	1 m	Mud with mollusc shells	50	This study
P. sculpta	28.04.2023	Izmir Bay	38.454969° N	27.079589° E	1 m	Sandy mud with mollusc shells	100	This study
P. sculpta	28.04.2023	Izmir Bay	38.453103° N	27.064947° E	3 m	Sandy mud with mollusc shells	10	This study
P. sculpta	14.04.2022	Izmir Bay	38.406239° N	27.069394° E	0,2 m	*Mytilus gallorovincialis* bed	850	This study
P. sculpta	23.10.2022	Izmir Bay	38.446144° N	27.167011° E	0,2 m	*Mytilus gallorovincialis* bed	800	This study
P. sculpta	22.01.2022	Izmir Bay	38.465989° N	27.152933° E	0,2 m	*Mytilus gallorovincialis* bed	475	This study
P. sculpta	28.07.2022	Izmir Bay	38.448986° N	27.109242° E	0,2 m	*Mytilus gallorovincialis* bed	3375	This study
P. dianae	January 2004	İzmir Bay	38.411° N	27.036° E	0–2 m	submerged concrete block	1075	Çınar *et al.*, 2008
P. dianae	July 2008	Fethiye Bay	36.715°N	28.989°E	0–5 m	rocky bottom	1	Kırkım *et al.*, 2015
P. dianae	November 2014	Izmir Bay	38.046° N 38.425° N 38.449° N	27.044° E 27.132° E 27.109° E	mediolittoral zone	*Mytilus galloprovincialis* facies	227	Doğan *et al.*, 2015
P. dianae	2005	Mersin Bay	36.782° N	34.614° E	mediolittoral zone	*Brachidontes pharaonis* beds	1175	Çınar *et al.*, 2017
P. dianae	September 2015	Fethiye Bay	36.623° N	29.101° E	no data	no data	-	Ulman *et al.*, 2017
S. walkeri	July 1995	Datça	36.721°N	27.689°E	0,5–1 m	Supra–medio algae and under rocks	12	Kırkım *et al.*, 2006
S. walkeri	July 1995	Marmaris/ Turunç	36.771°N	28.251°E	0–0,5 m	Supra medio algae and under rock	9	Kırkım *et al.*, 2006
S. walkeri	June– Sept. 2008	Fethiye Bay	36.636°N	29.099° E	0–5 m	rocky	2	Kırkım *et al.*, 2017
S. walkeri	June– Sept. 2008	Fethiye Bay	36.748°N	28. 93° E	5–30 m	rocky and sand	2	Kırkım *et al.*, 2017
S. walkeri	September 2015	Fethiye Bay	36.623° N	29.101° E	no data	no data		Ulman *et al.*, 2017

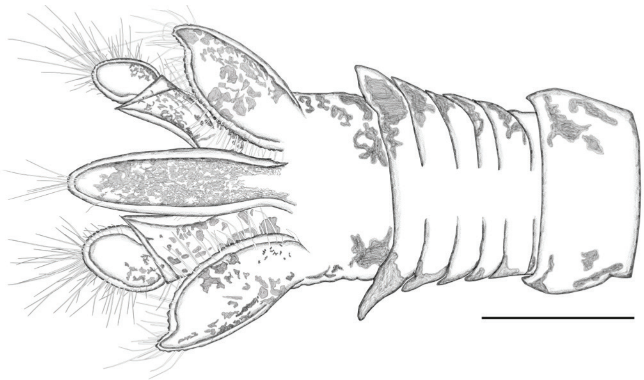

Fig. 3: Pleon, telson and uropods of *Paranthura japonica* (Scale bar: 0,5 mm).

Fig. 4: Side view of *Paranthura japonica* from the Dardanelles Strait (Scale bar: 1 mm).

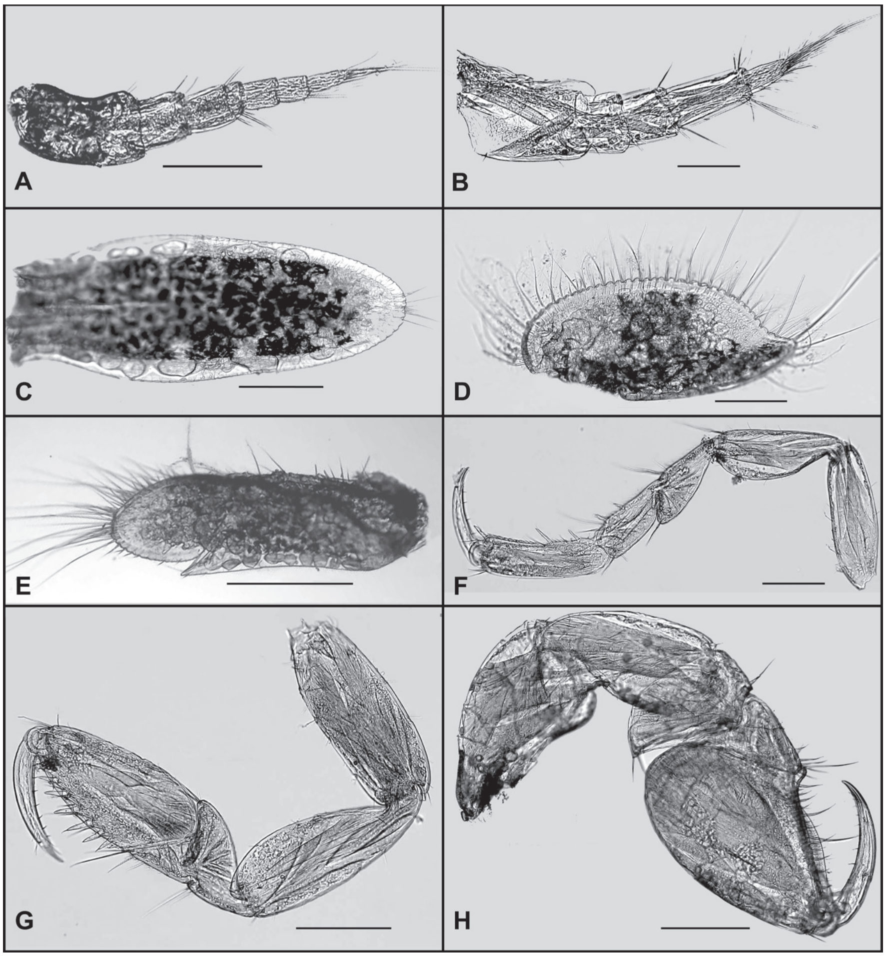

Fig. 5: Body parts of *Paranthura japonica* (A, first antenna; B, second antenna; C, telson; D, uropodal exopod; E, uropodal endopod; F, fourth pereiopod; G, second pereiopod; H, first pereiopod. Scale bar: 80 µm).

Discussion

According to Bakır *et al*. (2014), approximately 82 isopod species occur on the Turkish coasts, 37 isopod species occur in the Sea of Marmara and the Aegean Sea harbours 69 isopod species. This study increases the known number of isopod species in Türkiye from 82 to 84 species, by adding *Paranthura japonica* and *Paracerceis sculpta* to the list and increasing it from 82 to 84 species. Consequently, *P. japonica* is added to the list of the Turkish Straits System, thus increasing the number of species from 37 to 38. *Paracerceis sculpta* is added to the number of isopod species occurring in the Turkish Aegean Sea, thus increasing it from 69 to 70 species.

In this study, we confirm the occurrence of the non-indigenous isopod *Paracerceis sculpta* (Holmes, 1904) in Türkiye, particularly along the Aegean Sea where it is well established. The species is commonly found in shallow soft bottoms and was frequently detected in polluted substrates in the Izmir Bay. This species was first recorded in the Turkish seas in 2015 only from the hulls of fishing boats (Ulman *et al*., 2017; Martinaiz-Laiz *et al.*, 2019) and was subsequently erroneously reported from the Levantine coast of Türkiye without specific locality, biotope and depth information (Çınar *et al*, 2021). Bilecenoğlu & Çınar (2021) reported that this species was found in the

Fethiye Bay together with *Sphaeroma walkeri* and *Paradeella dianae,* but again this was based on Ulman *et al*., 2017. In this study, specimens of this species were found on sandy muddy substrates with shell fragments and *Mytilus galloprovincialis* facies at depths between 0.2 and 8 m in the Izmir Bay. The highest population density of this species (3,375 individuals.m^{-2}) was recorded in the beds of *Mytilus galloprovincialis* at 0,2 m depth at Station 10.

Paranthura japonica is widely distributed in all oceans. Its introduction to the Mediterranean Sea, specifically the Italian coasts, was documented by Marchini *et al*. (2014) and Lorenti *et al*. (2016). Possible mechanisms for the transfer of *P. japonica* are hull fouling, ballast water and oyster transplants. The species occurs on various habitats, including fouling communities on docks, floats, boat hulls and aquaculture gear; mussel and oyster beds; burrows made by shipworms and gribbles (*Limnoria* spp.); seagrass and seaweed beds; salt marshes and muddy sands (Kang & Yun 1988; Wang *et al*. 2010; Lavesque *et al*. 2013; Marchini *et al*. 2014; Lorenti *et al*. 2016). *Paranthura japonica* specimens exhibit a high preference for artificial substrates, consistent with the tendency observed in other peracarid crustaceans (Aikins, & Kikuchi, 2001; Ros *et al.*, 2020) Scribano *et al*., 2021). Additionally, *P. japonica* has become one of the most common species found in Mediterranean marinas (Ulman *et al*., 2019). In this study, we report the first record of *P. japonica* in Türkiye from the Çanakkale Ferry Pier. This species was found in muddy sand with shell fragments and sandy substrates with mollusc shell between 8 and 21 m depths. Specimens were also found among fouling organisms on ship hulls (Ulman *et al.*, 2019). The highest population density (700 individuals.m^{-2}) of *P. japonica* was observed at 18 m at Station 3, whereas the lowest density of 10 individual.m^{-2} was found at Station 4 at 10 m.

The occurrence of *Paranthura japonica*, which does not have a free–swimming larval stage, in many seas of the world cannot be attributed to natural means of dispersal (Lavesque *et al.,* 2013). The main hypothesis for the global spread of *P. japonica* is that it spread through production and trade in various regions around the world (from Japan to the Americas and Atlantic coasts) and the subsequent spread to nearby areas as a fouling organism by commercial shipping and recreational marine traffic (Lavesque *et al.,* 2013; Marchini *et al.,* 2014; Tempesti *et al.,* 2016). Perhaps, the reason for not observing a wide distribution of *P. japonica* in the Central and eastern Mediterranean in the last 10 years is that the individuals of the species are small, local populations are not dense, or remain undetected for a long time due to misidentification (Lavesque *et al.,* 2013). The species prefers both natural and artificial hard substrates: mussel beds, oyster reefs (French records, Lavesque *et al.,* 2013), docks and wooden poles (Marchini *et al.,* 2014), and was not observed on soft bottoms. The relative shallowness of the Dardanelles, its heavy ship traffic and the presence of biotopes with molluscan makes it highly suitable for *P. japonica* to reach and settle in the sampling area.

Thus, finding suggests that *Paranthura japonica* reached the north of the Aegean Sea and formed at least one population in the Dardanelles. These findings are the first record of *P. japonica* in the Black Sea ecosystem and the fauna of Türkiye. It seems that this species is expanding its distribution area to the eastern Mediterranean coasts and will most likely be reported from various sites in Türkiye in future studies.

A continual monitoring of the isopod community in the area is important for detecting changes in species composition, monitoring the appearance of exotic species, evaluating the effects of invasive species on the native ones and determining extinction risks. As a result of this study, the number of alien isopod species occurring on the Turkish coasts has increased to 4.

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