Pseudodiaptomidae G.O. Sars., 1902

Giacomo Zagami, Vincenzo Bonanzinga, and Marco Pansera

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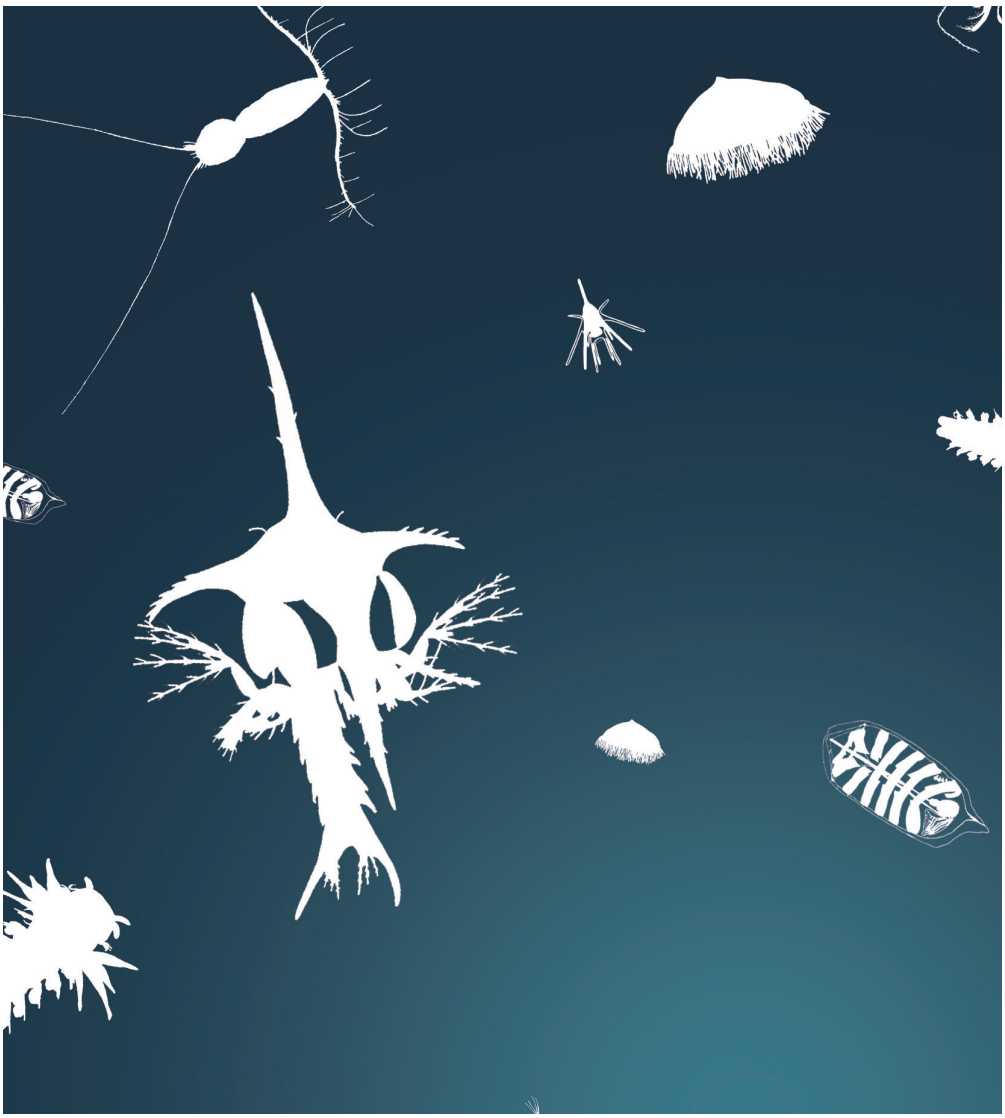

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Contents

Copepoda

Order: **Calanoida G.O. Sars, 1903**

Family: **Pseudodiaptomidae G.O. Sars, 1902**

Authors: Giacomo Zagami, Vincenzo Bonanzinga, and Marco Pansera

1 Summary

The family Pseudodiaptomidae G.O. Sars, 1902 includes three genera: *Calanipeda* Kritschagin, 1873, *Pseudodiaptomus* Herrick, 1884, and *Archidiaptomus* Madhupratap and Haridas, 1978. The genera *Calanipeda* and *Archidiaptomus* are both monotypic, consisting of *Calanipeda aquaedulcis* and *Archidiaptomus arroorus* respectively, whereas the genus *Pseudodiaptomus* includes 78 valid species (Walter and Boxshall, 2023). *Pseudodiaptomus* is divided up into seven species groups, and eight species subgroups can be distinguished based on the key to species groups and subgroups reported (Walter, 1986a; Walter *et al*., 2006; Srinui *et al*., 2013).

Calanipeda aquaedulcis is a freshwater euryhaline species and usually occurs in rivers, lakes, and estuaries around the Mediterranean Sea, Black Sea, and Caspian Sea regions as well as Spanish, and Portuguese waters (Razouls *et al*., 2005–2023). *Archidiaptomus arroorus* is found in brackish coastal waters of India (Madhupratap and Haridas, 1978). *Pseudodiaptomus* species are spread over a broad latitudinal range worldwide and are typically found in tropical and temperate shallow coastal and estuarine waters (Walter, 1989). They usually occur in a range of salinity, from hypersaline, marine to freshwaters (Walter, 1986a).

To date, in both the ICES area and the Black Sea, among Pseudodiaptomidae species, *Pseudodiaptomus marinus* Sato, 1913 and *C. aquaedulcis* occur, whereas in the Mediterranean Sea these two species occur in addition to *Pseudodiaptomus salinus* Giesbrecht, 1896, *Pseudodiaptomus trihamatus* Wright S., 1937, *Pseudodiaptomus australiensis* Walter, 1987, and *Pseudodiaptomus arabicus* Walter, 1998. (Razouls *et al*., 2005–2023). A key modified from Boxshall and Halsey (2004) for the identification of the three genera included in the family Pseudodiaptomidae, a key for the identification of the five species included in the genus *Pseudodiaptomus*, and the morphological features of *C. aquaedulcis* are presented.

The aim of this leaflet is to help with the morphological identification of the species of Pseudodiaptomidae present in the ICES area as well as in the adjacent Ponto-Mediterranean region and to provide their geographic distribution. This is a new leaflet and shows an unedited stereomicroscope image of a *P. marinus* egg-carrying female (Figure 1).

2 Introduction

Pseudodiaptomidae are circumglobally found in tropical and temperate, marine, brackish, and freshwaters. Their abundances are generally low in coastal waters but can be particularly high in environments rich of particulate organic matter such as lagoons, estuaries, and rivers (Pansera *et al*., 2014; Lazareva, 2018; Barroeta *et al*., 2022). This transitional environment adaptation is also favoured by their resistance to a wide variability of temperature, salinity, and low oxygen concentrations (Svetlichny *et al*., 2019; Uttieri *et al*., 2020 [Table 1]). Morphologically, Pseudodiaptomidae show intermediate adaptations to benthic and pelagic ecosystems: the large exopod spines, typical of benthopelagic copepods, are coupled with long antennules and an elongated body shape, typical traits

of pelagic species. Such morphological ambivalence allows many species of Pseudodiaptomidae to have alternating epibenthic and pelagic phases (Sabia *et al*., 2015), an epibenthic detritivorous phase during daylight and a pelagic herbivorous phase at night (Bradford-Grieve, 2002), exploiting both detritivorous and herbivorous feeding habits (Uye and Kasahara, 1983; Svetlichny *et al*., 2012).

Historical background

The family Pseudodiaptomidae includes three genera *Calanipeda*, Kritchagin, 1873, *Pseudodiaptomus* Herrick, 1884, and *Archidiaptomus* Madhupratap and Haridas, 1978. Pseudodiaptomidae was included in the superfamily Diaptomoidea (as Centropagoidea) by Andronov (1974) and Park (1986). The genera *Calanipeda* and *Archidiaptomus* both include only one species, *Calanipeda aquaedulcis* Kritchagin, 1873 and *Archidiaptomus arroorus* Madhupratap and Haridas, 1978, respectively; the genus *Pseudodiaptomus* includes 78 valid species (Walter and Boxshall, 2023). Andronov (1974) observed that the family Mazellinidae Rose, 1957 was synonymous with Pseudodiaptomidae. The genera *Schmackeria* Poppe and Richard, 1890, *Weismannella* Dahl, 1894, and *Mazellina* Rose, 1957 were incorporated as synonyms of *Pseudodiaptomus* (Walter 1986a, 1989). *Popella guernei* Richard, 1888 and *Siatella durbini* Labbé, 1927 are synonyms of *Calanipeda aquaedulcis* (Boxshall and Halsey, 2004).

Species identification

Species identification of Pseudodiaptomidae is based on the morphology of the adult; nauplii and copepodids are identified at genus level, since for most of the species the postembryonic development is not known. The developmental stages are divided into six naupliar stages (NI to NVI), five copepodid stages (CI to CV), and the adult stage. Each stage is separated by molt, but no moulting occurs after reaching the adult phase (Boxshall, 1992). In the *Pseudodiaptomus* genus, the postembryonic development has been described for the following nine species: *P. euryhalinus* (Johnson, 1948), *P. aurivilli* (Ummerkutty, 1964), *P. ardjuna* (Alvarez and Kewalramani, 1970), *P. coronatus* (Grice, 1969), *P. marinus* (Uye and Onbé, 1975), *P. richardi* (Cicchino, 1975), *P. acutus* (Björnberg,1972), *P. hessei* (Jerling and Wooldridge, 1989), and *P. annandalei* (Golez *et al*., 2004). The adults present a marked sexual dimorphism, which starts from the fourth copepodid stage (Jerling and Wooldridge, 1989). As the fifth legs of *Pseudodiaptomus* females are more uniform in structure than the fifth legs of males, species identification is mostly based on morphological distinctions of the male fifth legs, primarily with respect to possession of either a left and or right endopod and complexity of the endopod (Walter, 1986a). All Pseudodiaptomidae species are egg-carrying; the ovigerous females can carry either paired egg-sacs, as for all females of the Lobus species group of the *Pseudodiaptomus* genus (Golez *et al*., 2004; Srinui *et al*., 2013), or only a single egg-sac, as for the other *Pseudodiaptomus* Indo-Pacific groups (Walter, 1986a, 2006) and the *Calanipeda* genus. The egg-sacs, attached to the genital somite, can contain approximately eight to 20 eggs per clutch in *P. annandalei* (Golez *et al*., 2004) and from 20 to 60 in *C. aquaedulcis* (Dussart, 1967; Lazareva, 2018).

Pseudodiaptomidae in the ICES area and Ponto-Mediterranean region range in size from 0.94–1.37 mm in males and from 1.18–1.80 mm in females (Table 2). Adults are efficiently sampled by mesozooplankton nets with a mesh size of 200 μm, while nauplii and copepodites are under-sampled (Pansera *et al*., 2014).

The aim of this leaflet is to help the morphological identification of the six species of Pseudodiaptomidae present in the ICES area as well as in the adjacent Ponto-Mediterranean region and to provide their geographic distribution. The geographic distribution of species reported here is based on the World Register of Marine Species, WoRMS (Walter and Boxshall, 2023; Razouls *et al*., 2005–2023).

3 Distribution

The family Pseudodiaptomidae is widely distributed throughout the ICES area and Ponto-Mediterranean region, with five species belonging to the *Pseudodiaptomus* genus (*Pseudodiaptomus marinus*, *P. australiensis*, *P. salinus*, *P, arabicus,* and *P. trihamatus*) and one to the *Calanipeda* genus (*Calanipeda aquaedulcis*). To date, *Pseudodiaptomus marinus* and *C. aquaedulcis* are the only representatives of Pseudodiaptomidae occurring in the ICES area (Razouls *et al*., 2005–2023). In addition, four other species of the *Pseudodiaptomus* have occasionally been recorded in the Mediterranean Sea: *Pseudodiaptomus salinus* Giesbrecht, 1896 (Halim, 1969); *Pseudodiaptomus trihamatus* Wright S., 1937 (Eltohami *et al*., 2017); *Pseudodiaptomus australiensis* Walter, 1987; and *Pseudodiaptomus arabicus* Walter, 1998 (Ounissi *et al*., 2016). These four species have remained confined to few areas of their first observation sites (Walter and Boxshall, 2023).

The genus *Pseudodiaptomus* originated in the Indo-Malayan region of the Indo-Pacific basin (Walter, 1986a). *Pseudodiaptomus* species are spread globally over a broad latitudinal range, in tropical and temperate regions (Walter, 1989). They occur in a range of salinity regimes – from full marine to freshwater – are sometimes dominant within the mesoplankton community of shallow coastal waters and such transitional environments as coastal lagoons and estuaries (Walter, 1986a), and are characterized by day-night vertical migration (Walter, 1986b). Some of the *Pseudodiaptomus* species are considered highly invasive, such as *Pseudodiaptomus forbesi* Poppe and Richard, 1890 (Orsi and Walter, 1991), *Pseudodiaptomus inopinus* Burckhardt, 1913 (Cordell *et al*., 2007; Bollens *et al*., 2012), while *P. marinus* has been considered a widespread but rare non-indigenous species (NIS) (Colautti and Mac Isaac, 2004*).* The spreading of some *Pseudodiaptomus* species out of their native region, recorded over the last decades, is mostly due to human activities such as ship ballast water and aquaculture (Madhupratap and Haridas, 1986; Fleminger and Kramer, 1988; Gubanova *et al*., 2020; Uttieri *et al*., 2020) and later, in the Mediterranean, probably via secondary introduction, driven by coastal water circulation and intra-coastal ship traffic. No resting eggs have been reported for the Pseudodiaptomidae family (Grindley, 1984), making the dispersal of the species through transoceanic currents unlikely. Recently, *P. marinus* has been recorded in the ballast water from ships docked in Italian and Slovenian ports (Cabrini *et al*., 2019).

Over the last decade, *Pseudodiaptomus marinus* has been increasingly expanding its distribution in the ICES area and Ponto-Mediterranean region (Figure 2) within a wide range of temperatures and salinities (Table 1). Among congeners, *P. marinus* is the most widespread, occupying ten global zoogeographical areas (Suzuki *et al*., 2013; Sabia *et al*., 2015; Ohtsuka et al., 2018; Uttieri *et al*., 2020; Barroeta *et al*., 2022). The species ranks as one of the most widespread NIS in Europe (Tsiamis *et al*., 2019). The known eurythermicity and euryhalinity of *P. marinus* (Suzuky *et al*., 2013; Sabia *et al*., 2015; Svetlichny *et al*., 2019), and the low respiration rate (Ikeda *et al*., 2001) could provide an additional competitive advantage in its spreading and settlement in European waters. The occurrence of *P. marinus* along the Italian coast of the northern Adriatic Sea was reported as the first record of this species in European waters (de Olazabal and Tirelli, 2011). Since 2007, *P. marinus* has been reported in European waters (southern North Sea, English Channel, eastern Atlantic coasts, Mediterranean Sea, and Black Sea, (Figure 2) with an increasing number of records (Sabia *et al*., 2015; Uttieri *et al*., 2020 and references therein). The first records of *P. marinus* along European Atlantic coasts were in Calais harbour and off Gravelines (France) in 2010 (Brilinsky *et al*., 2012) and in the Gironde estuary (France) (Richirt *et al*., 2019), followed by further records in 2010 in the Bilbao estuary (Spain) (Albaina *et al*., 2016; Uriarte *et al*., 2016) and in 2016 in the Guadalquivir estuary (Spain) (Reyes-Martinez and Gonzalez-Gordillo, 2019). Moreover, the species was recorded for the first time in 2011 in the Mondego (Portugal) and Urdaibai (Spain) estuaries (Uttieri *et al*., 2020; Barroeta *et al*., 2022). *P. marinus* then spread northwards, being recorded in the southern North Sea and North Sea coastal waters of Denmark, Germany, and the Netherlands (Jha *et al*., 2013; Deschutter *et al*., 2018; Günter *et al*., 2018; Wootton *et al*., 2018) and in the coastal waters off Plymouth, England (Uttieri *et al*., 2020). In the central Mediterranean Sea, *P. marinus* was recorded in numerous coastal and lagoon sites of the Ionian, Tyrrhenian, and Adriatic seas (Sabia *et al*., 2015 and references therein). In the eastern Mediterranean Sea, *P. marinus* was recorded in the

Köprüçay estuary (Turkey) (Erdoğan and Ertan, 2014). Recently, *P. marinus* was also recorded in Sevastopol Bay (Black Sea) (Garbazey *et al*., 2016; Gubanova *et al*., 2020) and the Levantine Sea (Haim *et al*., 2022).

Pseudodiaptomus salinus Giesbrecht, 1896 prefers a more marine habitat, though given the euryhaline nature of its genus, it can be found in reduced saline conditions (Walter, 1998). It has not been recorded in the ICES area. This species has been listed in the Mediterranean Sea by Halim (1969) and recently as NIS by Streftaris *et al*. (2005). Giesbrecht (1896) described *P. salinus* from the Red Sea based on only two females; the males were not known until described by Thompson and Scott (1903) from material collected near the type locality in the Red Sea and Suez Canal (Walter, 1998).

Pseudodiaptomus australiensis Walter, 1987 and *Pseudodiaptomus arabicus* Walter, 1998 have not been reported in the ICES area, and in the Mediterranean Sea have only been reported for Annaba Bay, Algeria (Ounissi *et al*., 2016). These species were sampled during the year 2010, and the occurrence of copepodid V stage of *P. australiensis* suggests that this species survives and truly reproduces in Annaba Bay but without developing an abundant population (*Ounissi et al., 2016*). *P. australiensis* and *P. arabicus* are native to the Indo-Pacific Ocean and Arabian Sea, respectively.

Pseudodiaptomus trihamatus Wright, 1937 was first recorded in the Philippines; it was later reported from Brazil and considered as an NIS (Medeiros *et al*., 1991; Medeiros *et al*., 2006). It has not been reported in the ICES area, and in the Mediterranean Sea it has only been recorded for the Nile estuary and Barge canal, Egypt (Eltohami, *et al*., 2017). The presence of *P. trihamatus* in this area, which was not recorded before in the Mediterranean Sea, may be caused by ship ballast water in the Damietta harbour (Eltohami *et al*., 2017). It was only recorded in the Nile River estuary and Barge canal during the year 2014, in narrow salinity intervals (23–31) (Eltohami *et al*., 2017). Native to the Indo-Pacific coast, the species occurred in the Nile estuary and Barge canal with copepodite stages as well as adult females, indicating its reproductive success in this new environment (Eltohami *et al*., 2017).

The genus *Calanipeda* is monotypic in having only one species (Boxshall and Halsey, 2004). *Calanipeda aquaedulcis* belongs to the Mediterranean complex of hydrobionts occurring in lakes, rivers, and coastal estuaries spreading from the southern part of European Russia to Portugal (Marquez *et al*., 2008; Brugnano *et al*., 2011; Lazareva, 2018; Barroeta *et al*., 2022; Razouls *et al*., 2005–2023). *Calanipeda aquaedulcis* is widespread in fresh and brackish waters throughout the year in water temperature ranging from −1 to 30°C and salinity from 0 to 15 (Lazareva, 2018). Females reach 1.6 mm long in brackish habitats and carry up to 25–60 eggs in an egg sac (Dussart, 1967; Lazareva, 2018). The species has been reported to be expanding its geographic distribution into new colonized environments and is considered as an invasive NIS introduced by different vectors such as ship ballast water and aquaculture activities (Lazareva, 2018).

4 Morphological characteristics

Genera *Pseudodiaptomus* Herrick, 1884, and *Archidiaptomus* Madhupratap and Haridas, 1978

The bodies of species within Pseudodiaptomidae are divided into prosome and slender urosome. Prosome are primitively six-segmented, comprising cephalosome and five free pedigerous somites: the first pedigerous somite is sometimes partly or fully incorporated into the cephalothorax; the fourth and fifth pedigerous somites are generally partly or completely fused. The posterolateral angle of the prosome is rounded. The urosome is generally four-segmented in females, with three free abdominal somites. The genital aperture is located on the ventral surface of the genital double-somite. Eggs are contained in single or paired sacs according to species. The urosome is five-segmented in males, comprising the genital somite and four free abdominal somites. A single genital aperture is located ventrolaterally on the left side of the genital somite. The caudal rami elongate bears up to six setae. The rostrum is with paired rostral filaments. The nauplius eye is present. The female antennule comprises from 20 to 25 antennomeres; the male right antennule geniculate is on the right side. Legs

one to four are biramous, with three-articulated rami. Female fifth legs are biramous with endopods one-articuled in *Archidiaptomus* and uniramous in other genera. Male fifth legs are asymmetrical, biramous, uniramous due to loss of the endopod in some species; comprising coxa and basis; right leg with three-articulated exopod, endopod one-articulated, sometimes absent.

Swimming legs one to four are biramous, with three-articulated rami. The inner seta on basis of leg one is absent. The spine and seta formula is typically as follows (sometimes reduced):

	coxa	basis	expodal articles	endopodal articles
leg 1	0-1	0-0	I-1; 0-1; II,I,3	0-1; 0-1; 1,2,3
leg 2	0-1	0-0	I-1; I-1; II,I,5	0-1; 0-2; 2,2,4
leg 3	0-1	0-0	I-1; I-1; II,I,5	0-1; 0-2; 2,2,4
leg 4	0-1	1-0	I-1; I-1; II,I,5	0-1; 0-2; 2,2,3

The spines (Roman numerals) and setae (Arabic numerals) are numbered from proximal to distal article on each branch of the limb, and from lateral to medial position on each article, as indicated in the above explanatory scheme.

Genus *Calanipeda* Kritschagin, 1873

C. aquaedulcis Kritschagin, 1873

Female features (Figures 3a and b)
The fifth legs are uniramous symmetrical, comprising coxa, basis, and a three-articulated exopod. The basis is naked; Re1 is with one distolateral spine; Re2 is with two short inner spines and one elongate spiniform distal process extending at one-third the length of Re3; Re3 is typically curved and hook-like, armed with one strong inner spine.

Male features (Figure 3c)
The fifth legs are asymmetrical, biramous; the coxa and basis are separate. The right leg has a three-articulated exopod and one-articulated endopod. The basis has one medial seta and one inner seta; Re1 is with one posterolateral spine; Re2 and Re3 are with two and one inner seta, respectively. The endopod has two setae. The left leg has two-articulated exopods and one-articulated endopod. The basis has one medial seta; Re1 is with a distolateral elongate spiniform process extending to the distal edge of Re2; Re2 is elongate, three times longer than Re1, with one small outer process and two small unequal distal processes.

5 Taxonomic key

Three Pseudodiaptomidae genera can be distinguished based on the revised key to genera reported by Boxshall and Halsey (2004).

Pseudodiaptomidae genera

1. Female fifth leg biramous with strong endopod; male right antennule with four antennomeres distal to geniculation ………………………………………………………….. ***Archidiaptomus aroorus***
   Female fifth leg uniramous, endopod absent; male right antennule with at most three antennomeres distal to geniculation ……………………………………………………………………... **2**
2. Female antennule 25-articulated; male and female antennary exopod six-articulated ……………………………………………………………………………………***Calanipeda aquaedulcis***
   Female antennule 20 to 23-articulated; male and female antennary exopod four-articulated ………………………………………………………………………………………......***Pseudodiaptomus***

Key to ***Pseudodiaptomus* species from the ICES area and Ponto-Mediterranean region**

Genus *Pseudodiaptomus* Herrick, 1884

This key is based solely on the male fifth legs (Figures 3 and 4), which provide the most reliable morphological characters used for species identification, because female fifth legs are typically symmetrical and of limited value to separate species of the genus *Pseudodiaptomus* (Walter, 2006).

1. Left P5 Ri absent (Figure 4a) ……..…...…..***P. trihamatus***
Left P5 Ri present ……..…..……. **2**

2. Right P5 Re1 with distolateral spine bifurcated at mid-length and outer ramus longer than the inner ramus; right Ri with outer ramus bearing three acute processes (Figures 5b and c) ……
……***P. marinus***
Right P5 Re1 with distolateral spine bifurcated at three quarter-length and outer ramus shorter than inner ramus……..... …….**3**

3. Right P5 Ri with outer ramus bearing four tooth-like processes (Figure 4b)**…….*P. australiensis***
Right P5 Re1 with distolateral spine not bifurcated, produced into elongate spiniform process extending to distal edge Re2; Right P5 Re2 with Se equal in length to Re3 …….....……**4**

4. Right P5 Ri with outer ramus with few distal spinules (Figure 4c) ……. ***P. salinus***
Right P5 Re1 with spiniform process short, one-third the length of Re2; Right P5 Re2 with pinnate Se, one-half the length of Re3 …….....**5**

5. Right P5 Ri with many distal and inner spinules (Figure 4d) ……..……***P. arabicus***

Genus *Calanipeda* Kritschagin, 1873

C. aquaedulcis is the only species of the genus.

6 Tables

Table 1. Salinity and temperature ranges of the locations in the ICES area and Ponto-Mediterranean region where *Pseudodiaptomus* species were reported, recorded by the different authors.

Taxa	Reference	Site	Salinity range	Temperature range (°C)
P. marinus	De Olazabal and Tirelli (2011)	Rimini and Trieste, Italy	29.9–37.5	16.0–25.3
P. marinus	Delpy *et al.* (2012)	Berre Lagoon, France	23.0–35.0	3.4–28.2
P. marinus	Brylinski *et al.* (2012)	Gravelines and Calais harbour, France	33.1–34.2	5.5–19.0
P. marinus	Zagami and Brugnano (2013)	Lake Faro, Messina, Italy	34.9–37.3	10.0–28.4
P. marinus	Pansera *et al.* (2014)	Lake Faro, Messina, Italy	34.0–37.0	15.0–25.0
P. marinus	Sabia *et al.* (2015)	Gulf of Naples and Fusaro Lake, Italy	35.0–38.05	13.0–28.0
P. marinus	Reyes-Martínez and González-Gordillo (2019)	Guadalquivir estuary, Spain	17.4–27.8	20.8
P. marinus	Uttieri *et al.* (2020)	Mondego estuary, Portugal	11.3–34.8	11.8–27.0
P. marinus	Uttieri *et al.* (2020)	Bilbao and Urdaibay estuaries, Spain	28.8–34.5	11.9 - 22.7
P. marinus	Uttieri *et al.* (2020)	Sibenik Bay, Croazia	5.0–32.2	09.4–22.8
P. marinus	Gubanova *et al.* (2020)	Sevastopol Bay, Black Sea	17.0–18.0	6.2–26.2
P. marinus	Pansera *et al.* (2021)	Venice Lagoon, Italy	19.7–35.5	6.3–31.5
P. salinus	Halim (1969)	Port Said, Egypt	—	—
P. trihamatus	Eltohamy *et al.* (2017)	Nile estuary and Barge canal, Egypt	23.0–31.0	20.5–21.7
P. australiensis	Ounissi *et al.* (2016)	Annaba Bay, Algeria	35.1–36.8	18.7–21.4
P. arabicus	Ounissi *et al.* (2016)	Annaba Bay, Algeria	35.1–36.7	19.7–21.4

Table 2. Comparative table presenting the size ranges (mm) of adult females and males of each Pseudodiaptomidae species in the ICES area and Ponto-Mediterranean region and their ecological traits. Each species is linked with its corresponding Alphia ID, a unique numerical identifier given to each taxon listed in the World Register of Marine Species, WoRMS (http://www.marinespecies.org).

Taxa	Aphia ID	Total length (mm)		Habitat	Distribution
		Female	Male		
Pseudodiaptomus arabicus, Walter, 1998	361222	1.39–1.48	1.31–1.37	Coastal waters	Arabian Sea, Mediterranean Sea
Pseudodiaptomus australiensis, Walter, 1987	355133	1.20–1.80	1.04–1.06	Coastal waters	Indo-Pacific Ocean, Mediterranean Sea
Pseudodiaptomus marinus, Sato, 1913	360352	1.24–1.80	1.05–1.30	Coastal and estuarine waters	Cosmopolitan
Pseudodiaptomus salinus, Giesbrecht, 1896	232031	1.40–1.45	1.29–1.34	Coastal waters	Red Sea, Suez Canal, Mediterranean Sea
Pseudodiaptomus trihamatus, Wright, 1937	355193	1.18–1.28	0.94–1.00	Coastal and estuarine waters	Pacific Ocean, Mediterranean Sea
Calanipeda aquaedulcis Kritschagin, 1873	349522	1.30–1.60	1.00–1.1	Rivers and estuarine waters	Ponto-Mediterranean region

7 Figures

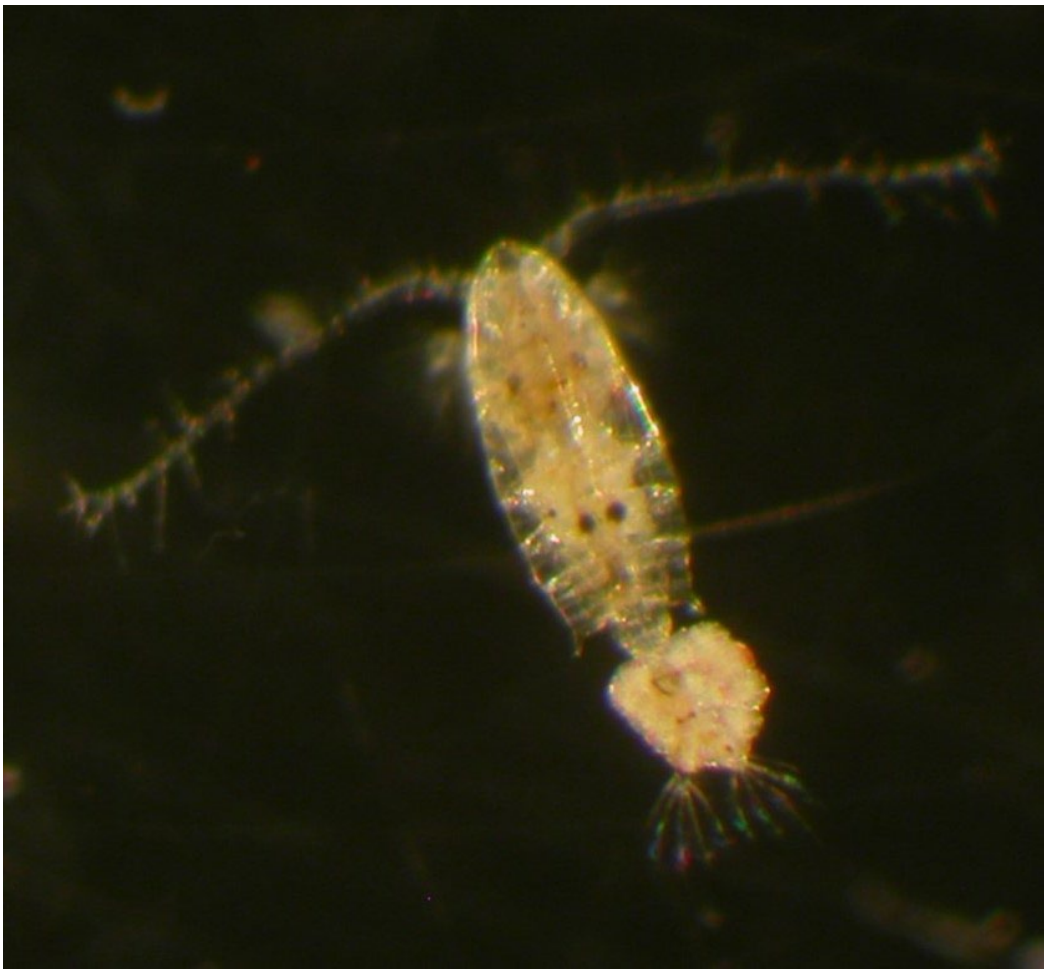

Figure 1. Stereomicroscope image of *Pseudodiaptomus marinus* egg-carrying female.

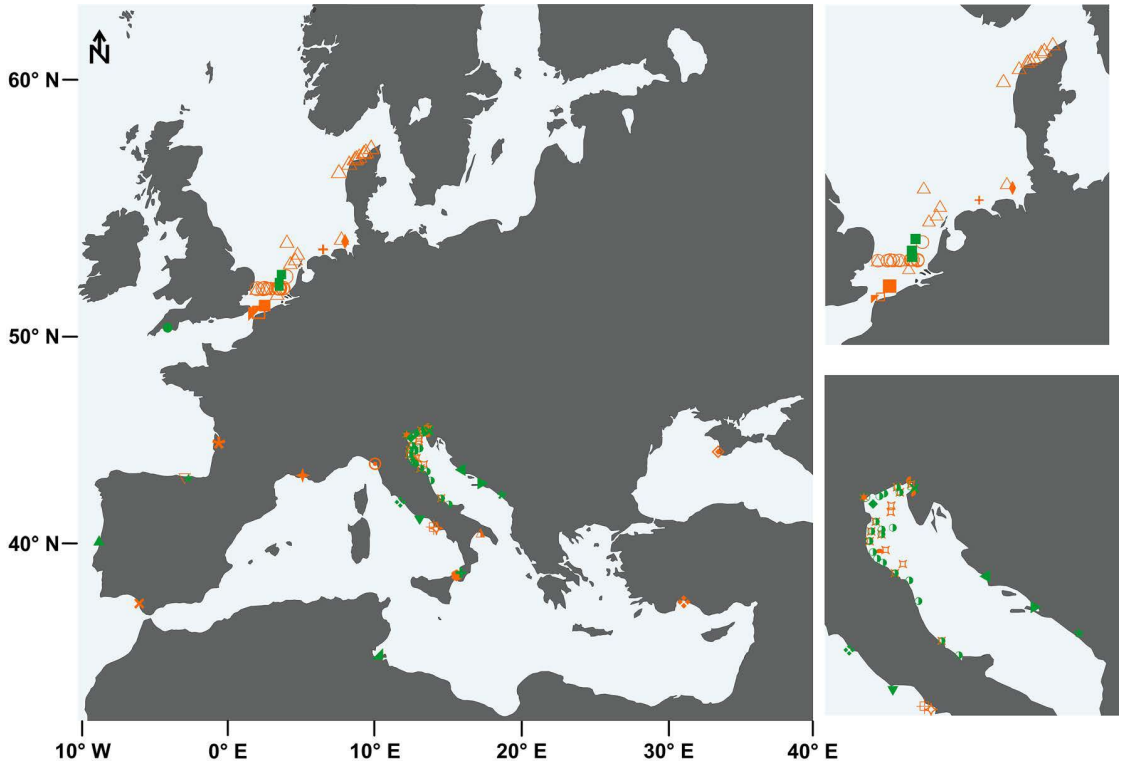

Figure 2. Distribution of the Asian alien copepod *Pseudodiaptomus marinus* in European waters, from Uttieri *et al.*, 2020. Orange symbols for literature data (labelled as LD in the text): △: southeastern North Sea (CPR survey; Wootton *et al.*, 2018); ♦: southern North Sea (Günther *et al.*, 2018); ✚: southern North Sea (German EEZ; Jha *et al.*, 2013); ○: southern North Sea (CPR Survey; Jha *et al.*, 2013); ■: southern North Sea (Belgian waters; Deschutter *et al.*, 2018); □: Gravelines (Brylinski *et al.*, 2012); ◤: Calais (Brylinski *et al.*, 2012); ★: Gironde Estuary (Brylinski *et al.*, 2012; Richirt *et al.*, 2019); ▽: Estuary of Bilbao (Albaina *et al.*, 2016; Uriarte *et al.*, 2016); ✕: Guadalquivir Estuary (Reyes-Martínez and González -Gordillo, 2019); ✦: Berre Lagoon (Delpy *et al.*, 2012); ⊙: Marina di Carrara (Sabia *et al.*, 2015); ⌖: Lake Fusaro (Sabia *et al.*, 2015); ◊: Gulf of Naples (multiple sites; Sabia *et al.*, 2015); ⬢: Lake Faro and Lake Ganzirri (Zagami and Brugnano 2013; Pansera *et al.*, 2014; Sabia *et al.*, 2015); ▲: Mar Piccolo of Taranto (Karuza *et al.*, 2016); ◇: Adriatic Sea (Sept. 2014 surveys, multiple sites; Stefanni *et al.*, 2018); ⬭: Rimini (de Olazabal and Tirelli 2011); ✶: Port of Venice (Vidjak *et al.*, 2019); ◖: Monfalcone (de Olazabal and Tirelli 2011) and Port of Trieste (Vidjak *et al.*, 2019); ◗: Port of Koper (Lučić *et al.*, 2015); ❖: Köprüçay (Erdoğan and Ertan 2014); ◈: Sevastopol Bay (Garbazey *et al.*, 2016). Green symbols for WGEUROBUS original data (labelled as ED in the text) presented in this study: ■: southern North Sea (CPR surveys); ●: Plymouth Sound; ★: Estuary of Urdaibai; ▲: Mondego Estuary; ❖: Civitavecchia harbour; ▼: San Felice Circeo; ✚: Gioia Tauro and Strait of Messina; ◑: Adriatic Sea (2011–2014 surveys; multiple sites); ○: Venice Lagoon (multiple sites); ◆: Gulf of Venice; □: Gulf of Trieste (LTER-C1); ✕: Gulf of Trieste (multiple sites); ◀: Šibenik Bay; ▶: Neretva River; ✱: Boka Kotorska; ◢: Gulf of Gabès. Insets in the right panel provide a more detailed view of the North Sea (upper panel) and Adriatic Sea (lower panel) basins. Coastline data: NOAA National Geophysical Data Center, coastline extracted: WLC (World Coast Line), date retrieved: 08 January, 2013, http://www.ngdc.noaa.gov/mgg/shorelines/shorelines.html.

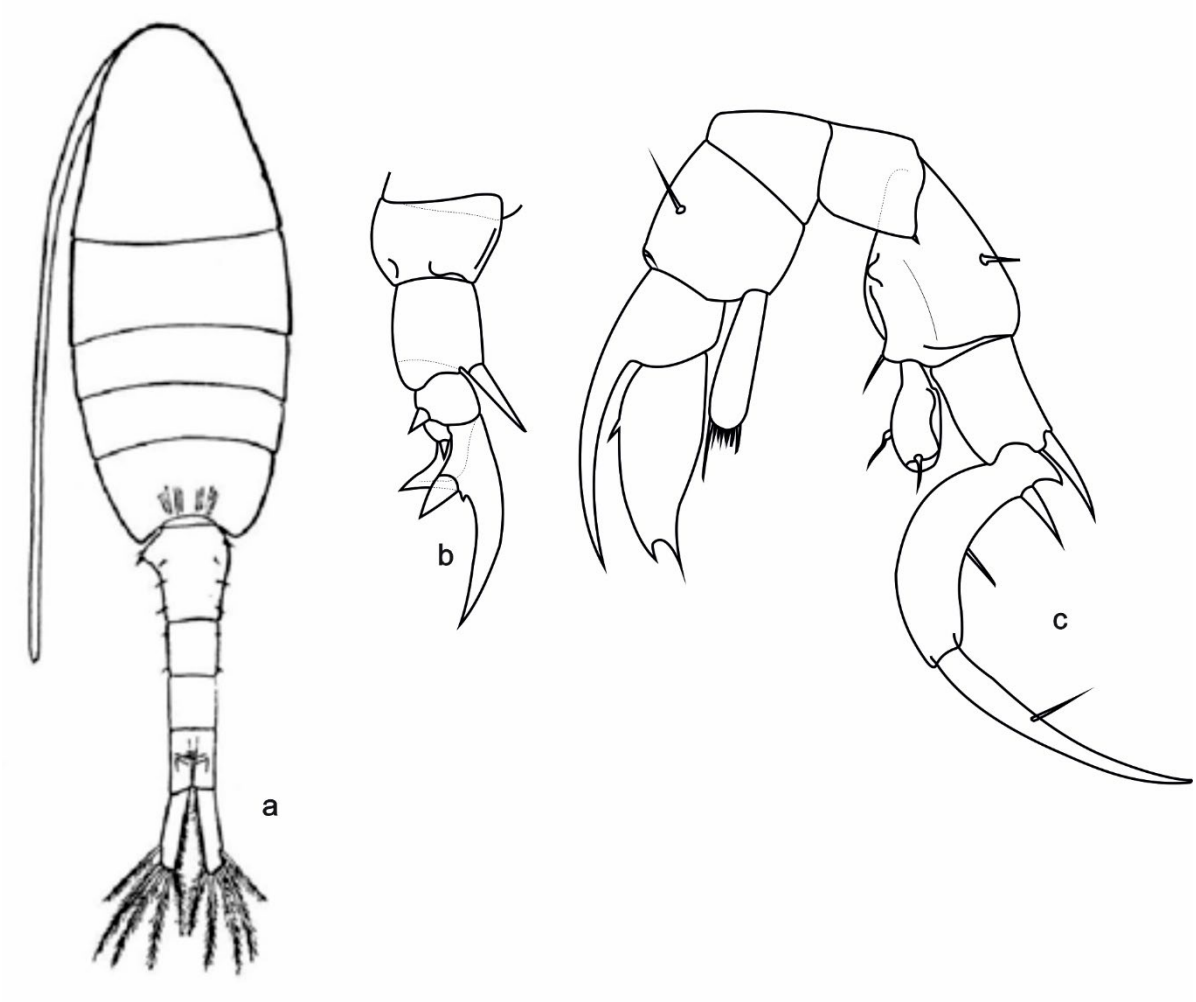

Figure 3. ***Calanipeda aquaedulcis,*** **redrawn from Dussart, 1967. (a) Female dorsal view; (b) female fifth leg posterior view; (c) male, fifth leg posterior view.**

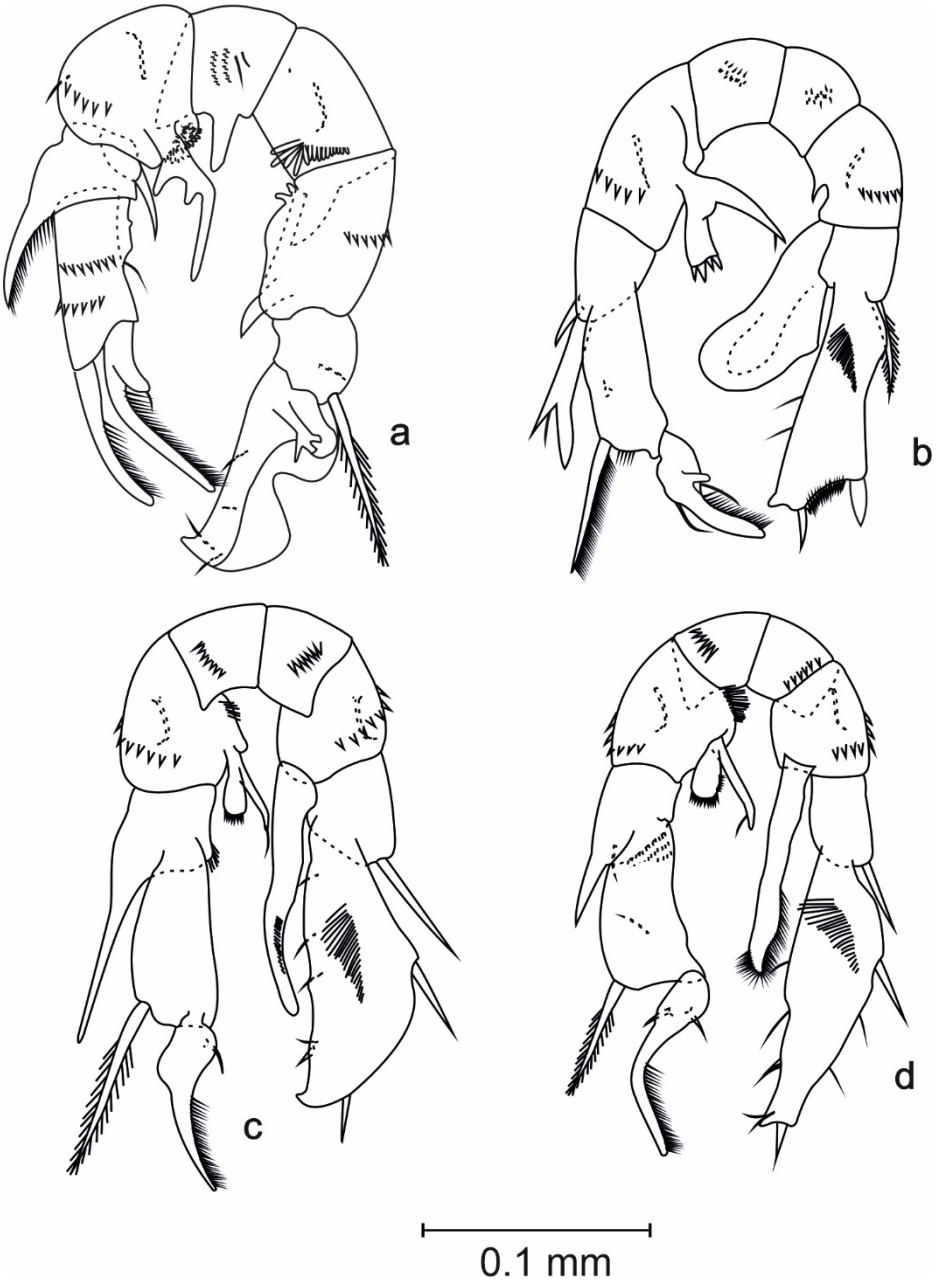

Figure 4. *Pseudodiaptomus* **male fifth leg anterior view. Redrawn from Walter, 1984, 1987, 1998. (a)** ***trihamatus*****; (b)** ***australiensis*****; (c)** ***salinus*****; (d)** ***arabicus*****.**

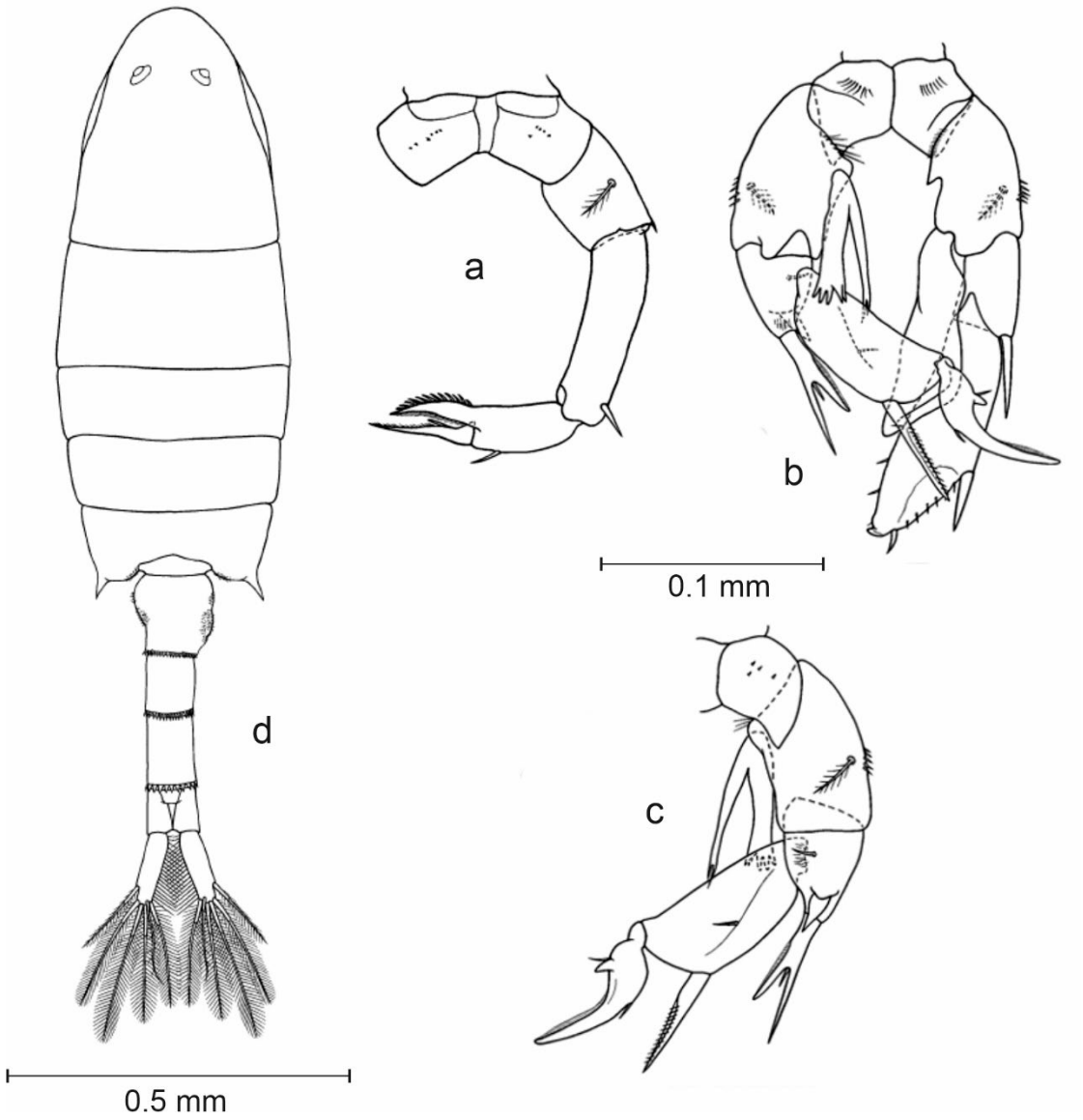

Figure 5. *Pseudodiaptomus marinus,* **redrawn from Gubanova *et al.*, 2020. (a) Female, right fifth leg and left coxa, posterior view; (b) male, fifth leg anterior view; (c) male, right fifth leg posterior view; (d) female dorsal view.**

8 Links to further information

WoRMS http://www.marinespecies.org

Molecular information

To date, there are 75 nucleotide sequences (Schoch *et al*., 2020) for *P. marinus*, nine for *C. aquaedulcis*, and none for *P. arabicus*, *P. australiensis*, *P. salinus*, or *P. trihamatus*, deposited in GenBank. Despite the numerous records of *P. marinus* in different global regions, the reports of molecular identification of this species are limited, relative to ribosomal genes 18S rRNA, and ITS 1, ITS2 rDNA (Abad *et al*., 2016; Sabia *et al*., 2017; Gubanova *et al*., 2020) and the cyt *b* mtDNA and COI mtDNA (Albaina *et al*., 2016; Ohtsuka *et al*., 2018; Stefanni *et al*., 2018; Gubanova *et al*., 2020). A new COI minibarcode primer (124 bp) was used in the identification of *P. marinus* in the North Sea (Günther *et al*., 2018). According to Uttieri *et al*. (2020), these results are not truly comparable nor can a more extensive analysis be performed because of the different markers used.

NCBI nucleotide database: Pseudodiaptomidae (crustaceans). Available at:

- *Pseudodiaptomus marinus* https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?mode=Info&id=207990
- *Calanipeda aquaedulcis* https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?mode=Info&id=1245925

9 Terminology and abbreviations

NI–NVI	First–sixth naupliar stage
CI-CV	First–fifth copepodid stage
P5	Fifth leg
Re1	First exopod article
Re2	Second exopod article
Ri	Endopod
Re3	Third exopod article
Se	Outer seta

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