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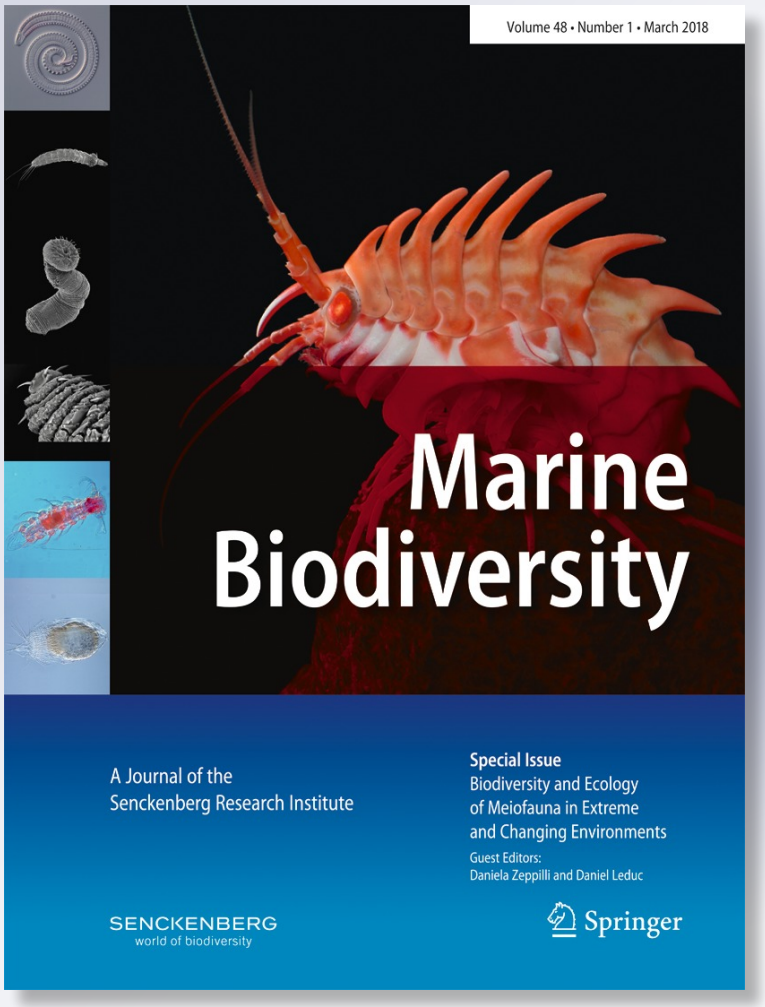

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ORIGINAL PAPER

Faunistic assessment of the marine Harpacticoida (Crustacea: Copepoda) fauna of Turkey with remarks on harpacticoid diversity in the eastern Mediterranean Sea

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Abstract In this study, phytal and intersititial harpacticoids inhabiting the marine coasts of the Turkish Aegean Sea and northern Cyprus were determined at 12 sampling stations. As a result, 24 species belonging to 20 genera distributed within 11 families were identified. Among the taxa identified, the family Cletopsyllidae, the genera *Isocletopsyllus*, *Sunaristes* and *Typhlamphiascus* and the species *Longipedia scotti*, *L. helgolandica*, *Sunaristes paguri*, *Dactylopusia glacialis*, *Orthopsyllus* cf. *sarsi*, *Isocletopsyllus tertius*, *Paramphiascella bulbifer*, *Sarsamphiascus tenuiremis*, *Robertgurneya remanei* and *Typhlamphiascus confusus* are recorded for the first time from the Turkish seas. On the other hand, the following species are reported for the first time from the Mediterranean Sea; *Longipedia helgolandica*, *Dactylopusia glacialis*, *Orthopsyllus* cf. *sarsi* and *Robertgurneya remanei*. In addition, *Paramphiascella* bulbifer and *Sarsamphiascus tenuiremis* are also reported for the first time from the eastern Mediterranean Sea. Moreover, the examination of the published papers on marine harpacticoids has revealed that there is no data on marine harpacticoids from the Cyprus seas, and; therefore, all species identified in this study (*Orthopsyllus* cf. *sarsi*, *Dactylopusia glacialis*, *Laophonte plana*, *Isocletopsyllus tertius* and *Sunaristes paguri*) are a first record for the marine harpacticoid fauna of Cyprus.

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Introduction

Taxonomic studies on biodiversity are necessary key tools for improving knowledge on biodiversity in order to make an effective judgment for sustainable use of natural sources and conservation of biodiversity (Ojaveer et al. 2014). Such taxonomic information is also critical to detect, handle and control the invasive species (Granjou et al. 2014).

The Harpacticoida is one of ten orders of the subclass Copepoda (Martin and Davis 2001) and contains over 6000 species in 645 genera and 59 families (Ahyong et al. 2011). They are essentially found in salt water, but over 945 species are also found solely in freshwater. The harpacticoids living in marine environments are found as free-living benthic organisms, although a few are found in plankton. They are usually the second most abundant meiofaunal taxon after nematodes in marine sediments; they are often dominant in marine algae but can be found in any kind of habitats and ecological regimes (Coull 1977; Huys et al. 1996; Giere 2009; Mascart et al. 2013).

Turkey has a vast coastline and comprises almost all type of biotopes. Unfortunately, there was no study until Noodt (1955) who carried out the first faunistic study on Turkish marine harpacticoids and reported 52 meiobenthic and phytal species and subspecies from littoral and subtidal zones in the Sea of Marmara. Forty-four years later, the second taxonomic study was published by Gündüz (1989) who recorded only *Mesochra aestuarii* from Bafra Balıkgölü, a coastal lagoon near the Black Sea. It was not until 2004 when a series of noteworthy taxonomic and faunistic papers began to be published.

The beginning of such taxonomic papers was to describe three new species from the intersititial habitats from the mediolittoral habitats of the Turkish Black Sea coasts (Karaytuğ and Huys 2004, Huys et al. 2005; Karaytuğ and Sak 2005). Later, Karaytug and Sak (2006) examined the phytal and intersititial harpacticoids inhabiting the coasts which were situated within the border of Balıkesir province and revealed 37 species and one subspecies. Sak et al. (2008a, b, c) added four species to Turkish fauna by describing two new species and by reporting two new records from the intersititial habitats in the mediolittoral zone of the sandy beaches. Pulat et al. (2009) reported six species belonging to Thalestridae and Laophontidae (Copepoda, Harpacticoida) associated with macroalgae *Cystoseira crinita* and *Haliptilon virgatum* in rocky biotopes of the mediolittoral zone in the Gümüldür coast (Aegean Sea). Alper et al. (2010) investigated harpacticoid copepods inhabiting interstitial and phytal habitats in the mediolittoral zone of sandy beaches of the Datça–Bozburun Specially Protected Area. Examination of the samples revealed that four families, 15 genera and 34 species that had not previously been reported from Turkish waters. Yalım et al. (2011) investigated the community structure of Beymelek Lagoon and determined four harpacticoid species in brackish water. Kaymak et al. (2012) investigated the laophontid copepods inhabiting interstitial and phytal habitats in the mediolittoral zone of sandy beaches of the Black Sea Coast by sampling 66 different localities, and eight species/subspecies were determined. Sönmez et al. (2012) investigated ectinosomatid species inhabiting interstitial habitats (a total of 89 localities) of the Mediterranean coast of Turkey and revealed four new records of ectinosomatids out of nine species. Two years later, Sönmez et al. (2014) attempted to reveal phytal and interstitial miraciids inhabiting all the Turkish coasts. After the morphological examination of a vast amount of materials collected from a total of 265 stations along the beaches of Black Sea (66 stations), Aegean Sea (110 stations) and Mediterranean Sea (89 stations), 17 species and one subspecies belonging to 14 genera were determined. It was revealed also that eight of the identified species were new records for the Turkish marine waters. Kaymak and Karaytuğ (2014) redescribed both sexes of *Heterolaophonte uncinata* and *H. curvata* based on newly collected material from the Black Sea and Mediterranean coasts of Turkey. Alper et al. (2015) investigated the interstitial and phytal harpacticoid fauna of the mediolittoral zone of the Dilek Peninsula within the border of Aydın Province. As a result of the examination of harpacticoid copepods collected from seven different localities between 2012 and 2013, there were revealed 78 species and subspecies belonging to 48 genera in 18 families. On the other hand, four families, 15 genera and 34 species were reported from Turkish marine waters for the first time. Köroğlu et al. (2015) carried out a revisionary study on marine darcythompsoniids collected from the intertidal zone of Turkish coasts and discovered three species of *Leptocaris* new for Turkish fauna. Kuru and Karaytuğ (2015) described a new species *Parastenhelia* collected among the sand samples from intertidal zone of a sandy beach adjacent to rocky shore in Kızkalesi, Mersin. Sönmez et al. (Sönmez et al. 2015a, b, 2016) respectively contributed to the diversity of marine meiofauna of Turkey by describing three new species belonging to *Schizopera*, *Diarthrodella* and *Arenosetella* collected from the intertidal zone of Alata beach, Kurtpınarı beach and Kazanlı beach along the Mediterranean coast of Turkey. But in the meantime, some pelagic/planktonic harpacticoids (*Euterpina acutifrons*, *Oculosetella gracilis*, *Distioculus minor*, *Clytemnestra rostrata*, *Clytemnestra scutellata*, *Macrosetella gracilis*, *Microsetella rosea* and *Microsetella. norvegica*) were also encountered among the mesozooplankton communities during the ecological studies in Turkish waters (See Bakır et al., 2014 for the complete reference list).

The results of the above given published data revealed that only 192 harpacticoid species have been reported from Turkish seas so far. Considering the diversity and the number of harpacticoid species and the presence of uninvestigated habitats of Turkish seas, it can be speculated that the number of harpacticoid species living in Turkish marine waters are far from being complete. On the other hand, nothing is known from Cyprus. The aim of this article is to contribute to marine harpacticoid fauna of Turkey and Cyprus as well as the diversity of the Mediterranean Sea.

Material and methods

Samples were collected qualitatively at 12 sampling stations at depths ranging from 0 to 92 m from the Turkish Aegean Sea and northern Cyprus Coasts between 1995 and 2002 (Fig. 1). The offshore samplings were carried out on board the R/V K.Piri Reis via bottom trawl, Van Veen grab and dredge studies, whereas coastal samplings were performed either by snorkelling and hand collection or Van Veen grab. A total of 24 sampling surveys were conducted (Table 1). Specimens were cleaned in lactic acid and dissected in lactophenol. Dissected parts were mounted on slides in lactophenol mounting medium. Broken glass fibres were added to prevent the animal and appendages from being compressed by the coverslip and to facilitate rotation and manipulation, allowing observation from all angles. All examinations have been made by using an Olympus BX-51 differential interference contrast microscope. Specimens were identified by using Lang (1948, 1965); Wells (2007) and relevant literature. All examined

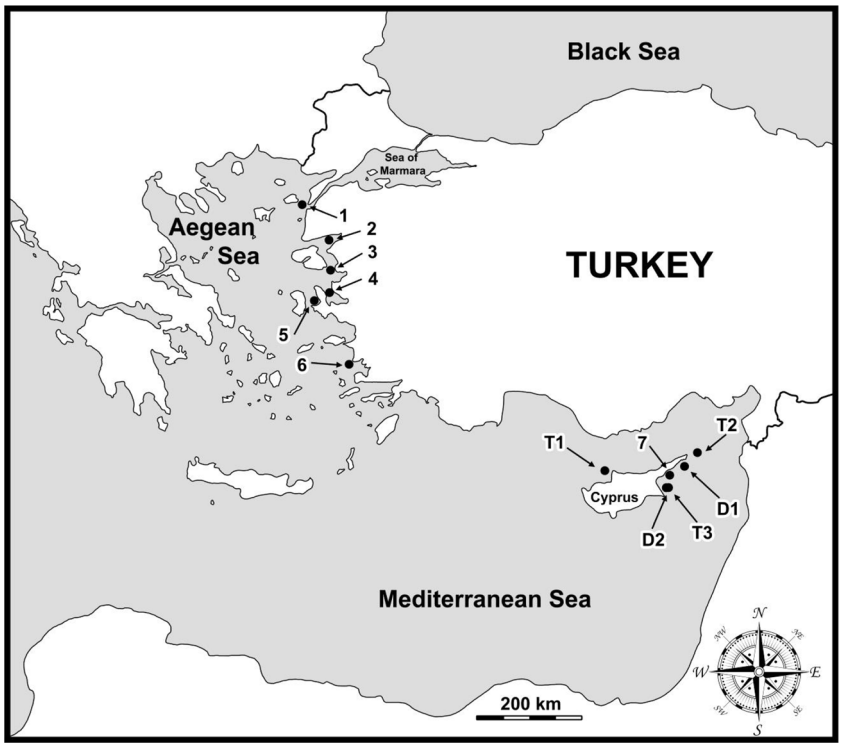

Fig. 1 Map showing the coastal sampling stations

specimens are deposited in the collection of biology department at Mersin University.

Results

The following 24 species/within 18 families were identified:

Order: HARPACTICOIDA Sars, 1903

Suborder: OLIGOARTHRA Lang, 1944

Family: LONGIPEDIIDAE Boeck, 1865

Longipedia minor T. and A. Scott, 1893

Material examined: (St.4e) 5♀♀; (St.4e2) 3♀♀; (St.2) 2♀♀.

Distribution in Turkey: Aegean Sea (Bakır et al. 2014).

Longipedia scotti Sars, 1903

Material examined: (St.4f) 7♀♀; (St.4f1) 7♀♀; (St.4e) 19♀♀, 1♂, 3 copepodid V♀♀; (St.4e2) 2♀♀; (St.4e3) 2♀♀; (St.4a) 2♀♀; (St.4d) 2♀♀.

Distribution in Turkey: New record.

Longipedia helgolandica Klie, 1949

Material examined: (St.2) 2♀♀.

Distribution in Turkey: New record.

Family: CANUELLIDAE Lang, 1944

Sunaristes paguri Hesse, 1867

Material examined: (St.D2) 1♀.

Distribution in Turkey: New record.

Canuella furcigera Sars, 1903

Material examined: (St.4e) 1♀; (St.4e2) 1♀.

Distribution in Turkey: Eastern Mediterranean Sea (Bakır et al. 2014).

Canuella perplexa T. and A. Scott, 1893

Material examined: (St.2) 2♀♀.

Distribution in Turkey: Marmara Sea, Mediterranean Sea (Bakır et al. 2014).

Family: DACTYLOPUSIIDAE Sars, 1905

Dactylopusia glacialis Sars, 1905

Material examined: (St.T2) 1♀; (St.T1) 1♀.

Distribution in Turkey: New record.

Family: LAOPHONTIDAE T. Scott, 1905

Laophonte cornuta Philippi, 1840

Material examined: (St.4b) 5♀♀, 1♂.

Distribution in Turkey: Aegean Sea (Alper et al. 2015).

Laophonte plana Fiers, 1986

Material examined: (St.T1) 1♀.

Distribution in Turkey: Aegean Sea (Alper et al. 2015).

Heterolaophonte uncinata (Czerniavski, 1868)

Material examined: (St.4 g) 1♀.

Distribution in Turkey: Black Sea, Mediterranean Sea (Bakır et al. 2014).

Paralaophonte quaterspinata (Brian, 1917)

Material examined: (St.4b) 1♀.

Distribution in Turkey: Mediterranean Sea (Bakır et al. 2014; Alper et al. 2015).

Family: ORTHOPSYLLIDAE Huys, 1990

Orthopsyllus cf. *sarsi* Klie, 1941

Material examined: (St.T2) 1♂, 1♀ Cop V; (St.D1) 1♂: (St.7) 2♂♂.

Table 1 Sampling localities

St.	Location	Coordinates	Date	Depth	Type of Substrate
1	Çanakkale (Anıt)	40°02′78″N-26°10′22″E	03/07/1995	1 m	*Posidonia oceanica*
2	Altınoluk (Edremit Bay)	39°33′03″N-26°53′35″E	06/07/1995	0-1 m	Rock
3	Dikili	39°04′14″N-26°51′27″E	07/07/1995	0-1 m	Rock
4	İzmir Bay				
4a	Foça	38°40′78″N-26°43′18″E	04/06/2002	60 m	Sand
4b	French Holiday Village	38°42′6″N-26°43′59″E	03/03/1994	0.5 m	*Cystoseira* sp.
4c	Karaburun	38°31′50″N-26°36′59″E	09/05/1996	0-1 m	Rock
4d	Mordoğan	38°31′45″N-26°37′51″E	04/06/2002	34 m	Sand
4e	Engeceli Harbour	38°28′13″N-26°36′09″E	14/06/2001	20 m	Sandy mud
4e1	Engeceli Harbour	38°28′21″N-26°35′75″E	15/10/2001	15 m	*Posidonia oceanica*
4e2	Engeceli Harbour	38°27′75″N-26°35′76″E	08/05/2002	20 m	Sandy mud
4e3	Engeceli Harbour	38°27′86″N-26°35′88″E	08/02/2002	20 m	*Posidonia oceanica*
4f	Balıklıova	38°27′52″N-26°13′99″E	09/11/2001	8 m	*Posidonia oceanica*
4f1	Balıklıova	38°26′31″N-26°36′27″E	25/12/2002	20 m	Sandy mud
4 g	Urla	38°22′32″N-26°47′28″E	14/06/1995	0-1 m	*Cladocera cespitosa*
4 g1	Urla	38°21′35″N-26°48′13″E	18/03/1994	1 m	*Padina pavonica*
4 h	Alsancak Harbour	38°25′31″N-27°07′54″E	04/06/2002	10 m	Mud
5	Ildırı	38°23′29″N-26°27′22″E	10/09/1995	0.5 m	*Padina pavonica*
6	Didim	37°23′48″N-27°24′13″E	23/07/1995	0-1 m	Rock
7	Famagusta Bay (northern Cyprus)	35°18′27″N-33°59′41″E	18/07/1998	4 m	*Posidonia oceanica*
Bottom trawl					
T1	Northern Cyprus	35°19′2″N-32°54′6″E; 35°17′7″N-32°54′4″E	13/05/1997	28-45 m	*Posidonia oceanica*
T2	Northern Cyprus	35°40′9″N-34°35′4″E; 35°40′6″N-34°35′3″E	16/05/1997	27-45 m	*Posidonia oceanica*
T3	Northern Cyprus	35°12′0″N-33°55′6″E; 35°13′3″N-33°55′1″E	18/05/1997	37-38 m	Muddy sand with *Caulerpa racemosa* and *Udotea petiolata*
Dredge					
D1	Northern Cyprus	35°34′8″N 34°25′9″E	15/05/1997	35 m	*Posidonia oceanica*
D2	Northern Cyprus	35°08′7″N-33°57′6″E	20/05/1997	92 m	Hard substrata with *Sargassum vulgare*

Distribution in Turkey: New record.

Family: CLETOPSYLLIDAE Huys and Lee, 1999

Isocletopsyllus tertius (Por, 1964)

Material examined: (St.T3), 1♂; (St.4f); 6♀♀; 5♂♂; (St.4 h) 1♀.

Distribution in Turkey: New Record

Family: ECTINOSOMATIDAE Sars, 1903

Microsetella norvegica (Boeck, 1865)

Material examined: (St.4e), 1♀.

Distribution in Turkey: Mediterranean Sea, Marmara Sea, Aegean Sea (Bakır et al. 2014).

Family: HARPACTICIDAE Dana, 1846

Harpacticus littoralis Sars, 1910

Material examined: (St.4c), 1♀; (St.4 g1); 7♀♀; 6♂♂.

Distribution in Turkey: Mediterranean Sea (Bakır et al. 2014), Aegean Sea (Alper et al. 2015).

Harpacticus obscurus T. Scott, 1895

Material examined: (St.5), 1♀, 1 Cop V♀.

Distribution in Turkey: Aegean Sea (Alper et al. 2015).

Family: MIRACIIDAE Dana, 1846

Paramphiascella bulbifer Guille and Soyer, 1966

Material examined: (St.4e) 1♀.

Distribution in Turkey: New record.

Haloschizopera marmarae Noodt, 1955

Material examined: (St.4e) 2♀♀.

Distribution in Turkey: Marmara Sea, Mediterranean Sea (Bakır et al., 2014).

Sarsamphiascus tenuiremis (Brady, 1880)

Material examined: (St.4e) 1♀

Distribution in Turkey: New record.

Robertgurneya remanei Klie, 1950

Material examined: (St.4e2) 1♀.

Distribution in Turkey: New record.

Typhlamphiascus confusus (T. Scott, 1902)

Material examined: (St.4f1). 1♀, 1♂; (St.4e) 3♂♂; (St.4e1) 1♀; (St.4e2) 2♀♀, 1♂.

Distribution in Turkey: New record.

Amphiascopsis cinctus (Claus, 1866)

Material examined: (St.4f) 1♀; (St.4f1) 2♀♀; (St.4 g) 3♀♀.

Distribution in Turkey: Marmara Sea, Mediterranean Sea (Bakır et al. 2014).

Family: LOUROINIIDAE Monard, 1927

Lourinia armata (Claus, 1866)

Material examined: (St.2) 1♀; (St.1) 1♂.

Distribution in Turkey: Mediterranean Sea (Bakır et al. 2014), Aegean Sea (Alper et al. 2015).

Family: THALESTRIDAE Sars, 1905

Phyllothalestris mysis (Claus, 1863)

Material examined: (St.5) 1♀; (St.3) 2♀♀; (St.4c) 5♀♀, 1♂.

Distribution in Turkey: Mediterranean Sea (Bakır et al. 2014).

Eudactylopus robustus (Claus, 1863)

Material examined: (St.6) 1♀

Distribution in Turkey: Aegean Sea (Alper et al., 2015).

Discussion

The report of the three species among the taxa identified in this study is interesting to note. The first species is *Orthopsyllus sarsi* which initially was described from Skjerstad Fjord in northern Norway under the name of *O. linearis* by Sars (1909), but later Klie (1941) arrived at the conclusion that *O. linearis* determined by Sars (1909) in fact belonged to a new species and renamed it as *O. sarsi*. The present material can best be identified as *O. sarsi* but some significant differences are observed between the type description and the present specimens. Apart from one male, all other specimens had three setae on the second endopod of P2 of the right ramus. Otherwise all other specimens carry two setae on the second endopod of P2. The taxonomic history of the genus *Orthopsyllus* has been rather complicated (Vervoort 1964; Lang 1965; Boer 1971; Huys 1990) and many authors created subspecies within the type species rather than establishing species due to the incomplete previous description of type species, *O. linearis* (Claus, 1866). It is difficult to decide about the specific status of present male specimens due to incomplete descriptions of other congeners. Therefore, we tentatively regard the present specimens as *Orthopsyllus* cf. *sarsi*. The genus *Orthopsyllus* requires urgent revision, especially the so-called *O. linearis* complex.

The second species, *Sunaristes paguri*, was originally described by Hesse (1867) from the French coast. It was later reported from Norway, Sweden, Germany, Scotland, England, Ireland, Ceylon, New Guinea (Lang 1948) the Mediterranean Sea and the Black Sea (Huys et al. 1996; Apostolov and Marinov 1988). It is generally found in shells occupied by the common hermit crab (Sars 1903); in a maximum depth of 30 meters a single female was collected from a depth of 92 m on hard substratum by dredge. This is the deepest habitat in which *S. paguri* has been collected so far.

The third species, *Isocletopsyllus tertius*, is interesting in terms of biogeography. The characteristics of the present materials match well with the original description. This is the second record of *Isocletopsyllus tertius* since its original description from Israel (Por 1964).

On the basis of published data, only 192 harpacticoid species have been reported from Turkish seas so far (Bakır et al. 2014; Kaymak and Karaytuğ 2014; Alper et al. 2015; Köroğlu et al. 2015; Kuru and Karaytuğ 2015; Sönmez et al. 2015a,b; Sönmez et al. 2016). As a result of this study, 24 species belonging to 20 genera distributed within 11 families were identified. The family Cletopsyllidae, the genera *Isocletopsyllus*, *Sunaristes* and *Typhlamphiascus* and ten species (*Longipedia scotti*, *L. helgolandica*, *Sunaristes paguri*, *Dactylopusia glacialis*, *Orthopsyllus* cf. *sarsi*, *Isocletopsyllus tertius*, *Paramphiascella bulbifer*, *Sarsamphiascus tenuiremis*, *Robertgurneya remanei* and *Typhlamphiascus confusus*) were recorded for the first time from the Turkish seas. With the present study, the number of published harpacticoid species has reached 202.

Longipedia helgolandica, *Dactylopusia glacialis*, *Orthopsyllus* cf. *sarsi*, *Robertgurneya remanei* are reported for the first time from the Mediterranean Sea. *L. helgolandica* is known from the eastern Atlantic seaboard and South-West Africa (Wells 1980), European waters (Veit-Köhler et al. 2010), Costa Rica and Barbados (Suárez-Morales et al. 2006). *Dactylopusia glacialis* was originally described from Norwegian arctic region (Sars 1909) and later recorded from Scoresby Sund of the Greenland Sea, the Californian coast (Lang 1965), North West Atlantic (Brunel et. al. 1998), south-western Iceland (Steinarsdóttir et al. 2003) and European waters (Huys 2001). The descriptions of *Dactylopusia glacialis* in the literature are not up to date, and the species requires urgent redescription based on the type material as well as material from a wide range of areas. It is highly possible that this species represent a species complex. The type locality of *Orthopsyllus sarsi* is Skjerstadfjord of Norway (Klie 1941) and later it has been reported only from the North Atlantic coast (Costa Vasca) of Barcelona so far (Aguirrezabalaga et al. 1984). The taxonomy of this family is very uncertain and still awaits serious revision. *Robertgurneya remanei* was described only from the type locality Helgoland (Klie 1950) and Sweden (Willems et al. 2009). On the other hand, although *Paramphiascella* bulbifer was reported from Marseille (Bodin 1968) and *Sarsamphiascus tenuiremis* are reported from the northwest Mediterranean (Mascart et al. 2013), these two species are also reported for the first time from the eastern Mediterranean Sea.

The examination of the published papers on marine harpacticoids has revealed no data about the marine harpacticoids of Cyprus Seas although few freshwater harpacticoids were reported (Fiers 2013). Thus, the following species are reported for the first time by this study on the marine harpacticoids of Cyprus; *Orthopsyllus* cf. *sarsi*, *Dactylopusia glacialis*, *Laophonte plana*, *Isocletopsyllus tertius* and *Sunaristes paguri*.

The harpacticoids living in marine environments are usually the second most abundant meiofaunal taxon after nematodes in marine sediments, and they are often the dominant in marine algae but they can be found in any kind of habitats and ecological regimes (Coull 1977; Huys et al. 1996; Giere 2009; Mascart et al. 2013). Meiobenthic and phytal habitats have usually been studied in faunistic/taxonomic studies and in terms of species numbers, Ectinosomatidae is usually the dominant family in meiofauna (Rose and Seifreid 2006) while Miraciidae is the dominant family in phytal habitats followed by Laophontidae (Sarmento et al. 2012; Alper et al. 2015). Investigation of the species diversity in the Mediterranean Sea based on published papers also indicates that Ectinosomatidae is the dominant family in meiofauna while Miraciidae is the dominant family in phytal habitats. Unfortunately, studies on the ecology and taxonomy on the harpacticoid fauna of the Mediterranean is far from being complete causing difficulty to make reliable comparisons and comments about the structure of species complexes on different types of sediments/macrophytes, etc. The only comprehensive study including ecological and taxonomical data in the Mediterranean is still that of Por (1964) who only studied the Levantine basin in the Mediterranean. So far about 400 harpacticoid species have been reported from the Mediterranean basin (Por 1964 and the references therein; Coll et al. 2010 and the references therein; Sönmez et al. 2014; Alper et al. 2015). It is not an aim here to prepare a complete check list of the Mediterranean harpacticoids; therefore, several recent papers (in which many new species were described) are not cited.

Environmental complexity and ecological factors determine the harpacticoid diversity. Usually, areas covered by different species of algae have much diverse harpacticoid fauna (Hicks 1985). However, little is known about how the distribution of these animals varies between particular microhabitats in their host plants. Abundance and species richness in phytal habitats can be affected by plant surface area, epiphyte biomass, food availability and plant age as well as other physicochemical parameters (Hicks 1980). In meiobenthos, the sediment grain size, organic content of the sand and competition as well as the physicochemical variables determines the species richness and diversity (Coull 1988). Unfortunately, most of the harpacticoid specimens obtained in this study were the subset of the material collected from epibenthic and phytal habitats, so the harpacticoid materials do not reflect the true diversity of the harpacticoids in the samples, and it would not be reliable to make comments on the structure of species complexes on different types of sediments/macrophytes and correlation of species richness with depth.

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