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Research Article

# Extended distribution of *Phtisica marina* Slabber, 1769 (Crustacea: Amphipoda): first observation of alien Caprellid in the coastal waters of Indian subcontinent

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## Abstract

*Phtisica marina,* originally described by Slabber, 1769 from Netherlands, is one of the most abundant caprellid amphipod species reported from numerous regions around the globe and is primarily associated with fouling communities in harbours. This study chronicles the further spreading out of *P. marina* into the Indian coastal waters. During a regular coastal survey in Gulf of Kachchh (Northwest coast of India), an established population of *P. marina* was observed in the subtidal regions of Vadinar and Sikka during April 2017. The caprellid could be a possible alien species in Indian waters as the species met the criteria for exotic taxa. The most possible introductory vectors and pathways are discussed in this study. As this species can survive in the stressed environments of low hydrodynamics and it has opportunistic behaviour, further studies are necessary to reveal its potential impact on local communities.

**Key words:** benthic, amphipod, Gulf of Kachchh, invasive species, shipping

## Introduction

Biodiversity is not a static aspect that can be described once and for all, but is constantly varying, influenced by natural and anthropic processes (Devin et al. 2005). According to community assembly theory, the dynamic nature of community structure is due to a continuous process of sequential invasions and extinctions (Fargione et al. 2003). Introduction of new species in to local environments is an integral part of community development (Connell and Slatyer 1977; Karatayev et al. 2009) and it is essential for development of community structure and composition. However, the increased establishment of non-native species during the last decades has become a great threat to natural ecosystems and the services they provide (Ambrogi 2000; Ruiz et al. 2000; Karatayev et al. 2009). Globally, biological invasions are one of the major threats to biodiversity and functioning of marine ecosystems, especially when the introductions result from human activities such as aquaculture, shipping, and creation of artificial canals (Chapman and Carlton 1991; Marchini and Cardeccia 2017). Fouling of commercial vessels, ballast water and aquaculture are generally considered as major vectors responsible for introduction of species across oceans (Gaonkar et al. 2010; Guerra-García et al. 2011). Harbours and ports are recognized as most suitable habitats for settlement of potential invasive species in the local environments (Floerl and Inglis 2003; Guerra-García et al. 2011).

Numerous studies on invasive potential of marine animals confirm that crustaceans are successful bio invaders (Engelkes and Mills 2011; Ros et al. 2014). Caprellid amphipods are small marine epibionts that are mostly abundant in many littoral habitats of coastal waters, where they form an important trophic link between primary producers and higher trophic levels (Woods 2009). Caprellid amphipods have been proposed as an alternative food source in aquaculture (Baeza-Rojano et al. 2010). The limited dispersal capabilities due to the lack of larval stages, suggest that the cosmopolitan distribution of Caprellid amphipods are associated with their fouling nature on floating objects (natural or artificial flotsam) and commercial or recreational vessels (Thiel et al. 2003). Despite the fact that they are potential bioindicators of marine pollution and environmental stress (Guerra-García and García-Gómez 2001), there is still a lack of information on the diversity and distributional patterns of Indian Caprellidae (Guerra-García et al. 2010). From the contributions made by Giles (1888); Mayer (1890, 1904); Sundara Raj (1927); Sivaprakasam (1969, 1970, 1977); Swarupa and Radhakrishna (1983); Takeuchi and Lowry (2007) and Guerra-García et al. (2010), only 11 valid species of Caprellids are so far known from Indian waters (refer Guerra-García et al. 2010 for detailed information). Undoubtedly, the poorly studied Indian coastal waters are expected to host many new Caprellid records and species.

*Phtisica marina* Slabber, 1769 is an epibenthic crustacean commonly found attached to green and brown algae, sea grasses, sponges, hydroids, bryozoans, echinoderms (McCain 1968) and sandy and muddy bottoms (Díaz et al. 2005; Winfield et al. 2006; Paz-Ríos and Ardisson 2013) with a reported depth range of shallow waters to 1470 m (Winfield et al. 2006; LeCroy et al. 2009). This species can tolerate stressed areas of low hydrodynamics, high rates of sedimentation, organic matter (Conradi et al. 1997; Guerra-García and García-Gómez 2001), perturbation associated with trawling activities and is considered as an "opportunistic" species (González et al. 2008). Predatory mode of feeding was reported along with the capability of switching to filter feeding mechanism (Guerra-García et al. 2002). It is an abundant species in different benthic communities of Atlantic and Pacific oceans and in the Mediterranean Sea (McCain 1968; Krapp-Schickel 1993; Guerra-García et al. 2014). Being cosmopolitan in nature (Bellan-Santini and Ruffo 1998), *P. marina* has been reported from fouling communities including floating plastic debris and aquaculture facilities (Katsanevakis and Crocetta 2014; Fernandez-Gonzalez and Sanchez-Jerez

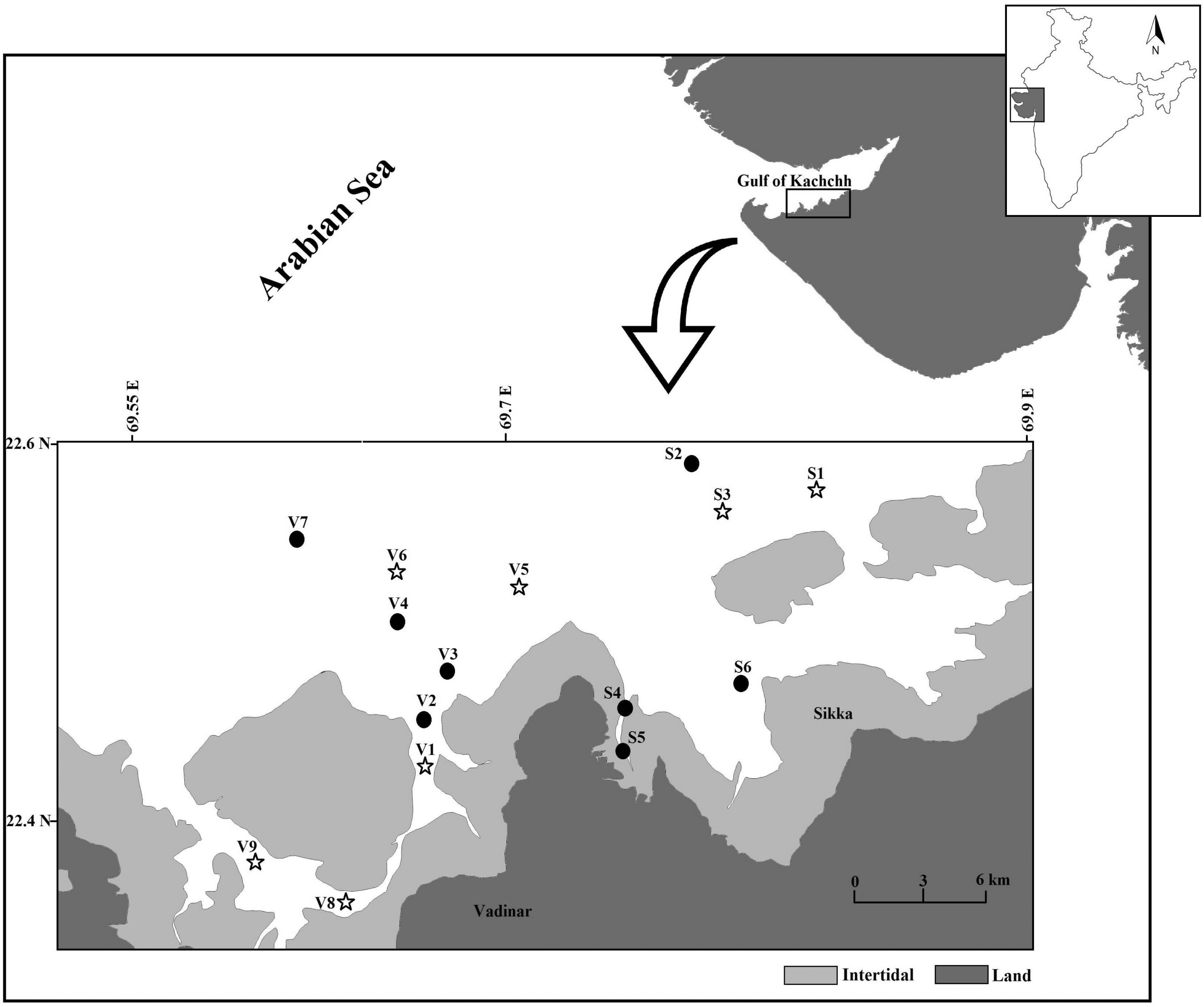


**Figure 1.** Map showing the study area. Star symbol indicates stations with presence of *Phtisica marina*.

2017; Leclerc and Viard 2018). The species is reported to have been introduced in to the waters of South Africa (Griffiths 1973), Japan (Arimoto 1980), California (Fairey et al. 2002), Mexico (LeCroy et al. 2009), Carribean Sea (Miloslavich et al. 2010) and Brasil (Lacerda et al. 2011) previously. Here, we provide knowledge on the further extended distribution of the caprellid *P. marina* in the waters of Indian subcontinent (twelfth recorded Caprellid species so far), a bio geographic area from where it was hitherto unknown, and its possible introduction pathways.

## Materials and methods

### *Study site*

The present study was conducted in the Gulf of Kachchh (GoK) (Figure 1), as a part of a regular coastal monitoring programme of the Gulf. The GoK is an indentation on the northwest coast of India oriented in the east-west direction, occupying a total area of about 7350 km$^2$. This is the first Marine National Park and Sanctuary (MNPS) established in an area of 457.92 km$^2$

(22°15′ to 23°40′N and 68°20′ to 70°40′E) during 1980 to 1982 under the provisions of the Wildlife (Protection) Act, 1972 of India. A chain of 42 islands, many with rich coral reefs and mangroves, provides a uniquely productive habitat for heterogeneous group of flora and fauna. Climate is hot and humid and temperature reaches up to 44.8 °C during summer. The coastal waters are thermally well mixed, vertically as well as laterally. Tides in the Gulf are mixed, predominantly of semidiurnal type with a large diurnal inequality. Tidal ranges vary from 3.06 m to 5.89 m with an average of 4 m. The GoK is an area of negative water balance; more water evaporates from its water body than is recharged through rainfall and river runoff. The maximum surface currents are moderate (0.7–1.2 m/s) but increases considerably (2–2.5 m/s) in the central portion of Gulf. The calm and deep waters of its southern shores, makes the GoK an ideal commercial cargo transit channel.

Two industrialized (Vadinar and Sikka) zones of MNPS were selected to study the benthic communities. The Vadinar and Sikka belt comprises of oil terminals, refineries, crude oil tank farms, several single point moorings (SPM), jetties, extensive pipeline network for unloading crude oil and exporting petroleum products. India's largest petroleum refinery is located at Sikka.

### *Field sampling and analyses*

A total of 15 subtidal stations covering an area of more than 200 km$^2$ were sampled (Figure 1) in the two study zones for macrobenthos during April 2017. At each station, four sediment samples were collected using a van-Veen grab (0.04 m$^2$) and sieved through 0.5 mm mesh. The retained materials were preserved in 5% buffered formalin solution containing Rose Bengal stain. During processing the macrobenthic samples in the laboratory, a distinctive caprellid was observed and identified as *Phtisica marina* Slabber, 1769. Identification of *P. marina* was based on the morphological descriptions provided by Díaz et al. 2005; Guerra-García et al. 2010 and Paz-Ríos et al. 2014. All *P. marina* individuals were extracted from the samples and counted for number of male and female individuals. Males and females were primarily classified on the presence or absence of oostegite (Figures 2 and 3). Photographs of each specimen were taken with Olympus BX-53 microscope. This species was designated as non-indigenous based on the criteria given by Chapman (1988) and Chapman and Carlton (1991). In addition, bottom water samples were collected in duplicate at each station using Niskin sampler for analyzing temperature (°C) and salinity. An extensive search of published materials in peer-reviewed journals, reports and the internet sources was conducted for global distribution of *Phtisica marina*.

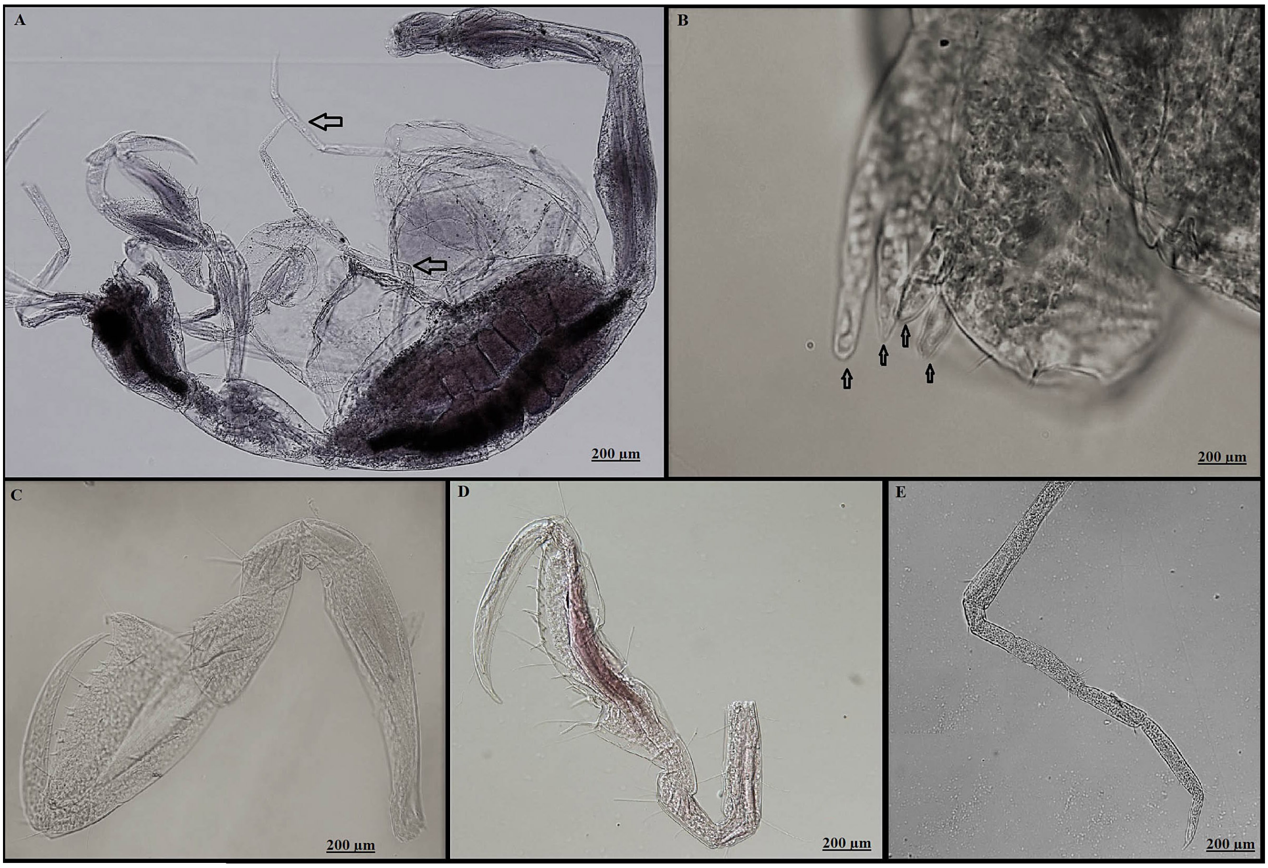

**Figure 2.** A) Lateral view of *Phtisica marina* (female). Arrows indicate pereopods 3 and 4, B) Abdomen with 2 pairs of two articulated appendages indicated by arrows (ventral view), C) Pereopod 1 (Gnathopod 1), D) Pereopod 2 (Gnathopod 2) and E) Pereopod 4. Photomicrographs by T. Srinivas.

**Figure 3.** A) Lateral view of *Phtisica marina* (male) Arrows indicate pereopods 3 and 4, B) Pereopod 2 (Gnathopod 2), C) Pereopod 3 and D) Pereopod 4. Arrows indicate spines in the pereopods. Photomicrographs by T. Srinivas.

## Results and discussion

*Phtisica marina* was encountered in 7 out of 15 sampled stations from GoK (Figure 1). The bottom water temperatures ranged from 27.0 °C (Station V7) to 29.5 °C (Station V2) and salinity was from 37.9 (Station V5 and V6) to 38.7 (Stations V8 and S5) (Supplementary material Table S1). In addition to the caprellid populations previously known from Indian waters, here we add information on the newly reported species *Phtisica marina*. This species was not included in the latest checklist of Indian caprellids (Guerra-García et al. 2010). Generally, occurrences of caprellids from Indian waters are rare considering that most of the previous studies did not record these amphipods. The exact reason for the absence or low abundance of caprellids from Indian waters is still unknown (Guerra-García et al. 2010). In the current study too, the abundances of *Phtisica marina* along with other caprellid species was very low with the highest abundance being observed at station S3 (44 ind $m^{-2}$) and lowest at stations V1 and V8 (6 ind $m^{-2}$).

*Phtisica marina* can be easily distinguished from native Indian caprellid species by the presence of fully articulated pereopods 3 and 4 (Figures 2A and 3A; see Guerra-García et al. 2010 for more information on morphological descriptions on Indian caprellids). Other important morphological characters include an abdomen with 2 pairs of biarticulated appendages (Figure 2B). Males can be distinguished by an extra pair of pyriform appendages and 3 or 4 spines on the propodus palm of pereopods 3 and 4 (Figures 3C and D) (refer to McCain 1968; Ortiz et al. 2002; Díaz et al. 2005; Paz-Ríos et al. 2014 for better textural and graphical details). *Phtisica marina* has a complicated taxonomy which shows wide morphological differences. McCain (1968) has described *Phtisica marina* from Western North Atlantic as a smooth bodied organism without any spines on its pereopod 3 and 4. In contrast, Arimoto (1980) reported prominent spines on pereonites 3 and 4 in adult females of this species. Ortiz et al. (2002) and Díaz et al. (2005) illustrated *Phtisica marina* with three spines on pereopods 3 and 4. The specimen reported in this study closely resembled the description of Paz-Ríos et al. (2014), who reported four spines on the propodus palm of pereopod 3 and 4. Owing to almost similar characteristics, *Phtisica marina* can be easily misidentified as another species *Hemiproto wigleyi* McCain, 1968 which also belongs to the same sub family Phtisicinae, usually a native to South-eastern Florida, Gulf of Mexico and Caribbean Sea (McCain 1968; Díaz et al. 2005; Ortiz et al. 2006; Winfield et al. 2006; Ortiz and Lalana 2010). *Hemiproto wigleyi* is also characterized by the presence of fully developed pereopods 3 and 4, but differs from *Phtisica marina* in the number of abdominal appendages; the males have two pairs of uni-articulated abdominal appendages and the females have a single pair (Díaz et al. 2005; Paz-Ríos et al. 2014).

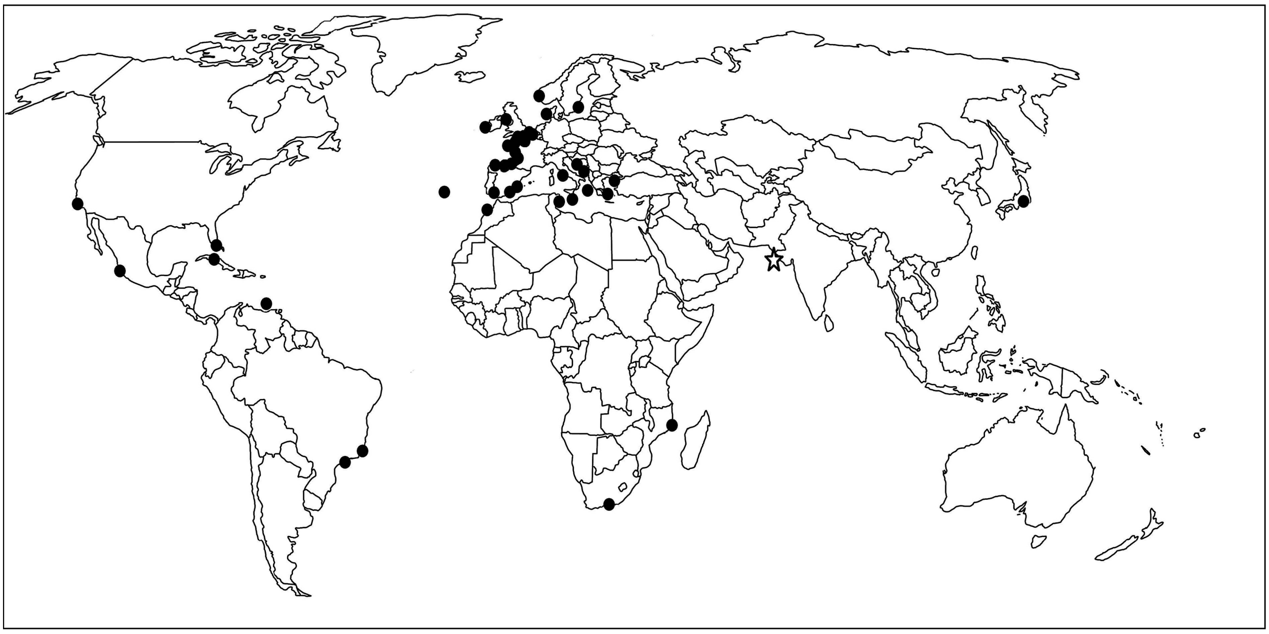

**Figure 4.** Distribution of *Phtisica marina*. Star symbol indicates current study. Reference on distribution have been taken from Griffiths 1973; Arimoto 1980; Hayward and Ryland 1990; Mees 1994; Dauvin 1999; Bellan-Santini and Costello 2001; Cattrijsse and Vincx 2001; Massin et al. 2002; Bachelet et al. 2003; Christie et al. 2003; González et al. 2008; Felder and Camp 2009; Guerra-García et al. 2009; Borges et al. 2010; Koukouras 2010; Miloslavich et al. 2010; Aslan-Cihangir and Pancucci-Papadopoulou 2011; Beermann and Franke 2011; Guiry and Guiry 2011; Lacerda et al. 2011; Dyntaxa 2013; Zalmon et al. 2013; Guerra-García et al. 2014; Fernandez-Gonzalez and Sanchez-Jerez 2017.

Similar to other valid alien caprellid species (Marchini and Cardeccia 2017), the exotic species status of *Phtisica marina* in the coastal waters of Indian subcontinent can be assessed using the criteria of Chapman and Carlton (1991, 1994) and in accordance with Essl et al. (2018). The criteria stipulates (1) The appearance of species in local regions where it was not found previously; (2) post-introduction range expansion; (3) association with human dispersal mechanism(s); (4) association with or dependent on other known introduced species; (5) association with or restriction to new or artificial environment(s); (6) relatively discontinuous or restricted regional distribution; (7) disjunct geographic distribution; (8) inadequate life history adaptations for global dispersals; and (9) exotic evolutionary origin.

There are no earlier records of this species in Indian waters (Guerra-García et al. 2010). On the global scale, *Phtisica marina* has a wide geographical distribution (Figure 4). It was first described from the Netherlands coast. Later it was reported from Northeastern Atlantic; Norway; British Isles; Azores; Canary Islands; Mediterranean Sea; Black Sea; West Africa; South Africa; Gulf of Mexico; St. John, Virgin Islands; Cubagus and Margarita Island, Venezuela; Cape lavela, Columbia; Rio de Janeiro, Brazil; Japanese waters, Sasebo; Korean waters; and California (References in Figure 4). *Phtisica marina* was the major constituent of the peracarid community structure of the Mediterranean Sea and Northeastern Atlantic Ocean (Aslan-Cihangir and Pancucci-Papadopoulou 2011; Guerra-García et al. 2009, 2014). Most of the global records of *Phtisica marina* are from areas with human activities (ports and aquaculture sites) indicating that human interference plays a fundamental role in global dispersal of *Phtisica marina*. *Phtisica marina* does not have a free-living planktonic larval stage; therefore it requires either natural or artificial vectors for long distance dispersal. *Phtisica marina* is frequently found associated with fouling communities of artificial substrates floating objects, buoys and ship hulls (Fernandez-Gonzalez and Sanchez-Jerez 2017).

Guerra-García et al. (2001) suggested that the water temperature and salinity were the two major limiting parameters in seasonal distribution of *Phtisica marina* from the estuarine zones of southwest Spain. These authors further stated that summer and autumn are the unfavorable periods as the temperature and salinity reaches at its high, thereby causing cessation in the reproduction of *Phtisica marina*. By virtue of its cosmopolitan nature, the distribution of *Phtisica marina* has expanded globally during the last few decades. Arimoto (1980) reported *Phtisica marina* as a newly introduced species in Japanese waters. Later, Fairey et al. (2002) detected the first appearance of this species in Californian waters and traced its origin from the Caribbean coast, though the exact vector of transport was unclear.

The presence of *Phtisica marina* in Indian waters is not surprising as it is reported to be a fouling species (Fernandez-Gonzalez and Sanchez-Jerez 2017), but it is difficult to postulate the actual vector of spreading in to Indian waters. Considering that the study areas are a shipping hub which handles large amount of traffic and the fouling ability of *Phtisica marina*, we conclude shipping as the potential transporter of this species. Although low abundances are reported in the current study, the presence of egg-bearing females, mature males and juveniles in more than 45% of sampled stations indicates the establishment of this species in the area. Thus, the positive scores of attributes 1, 3, 6, 7, 8 and 9, suggest that *Phtisica marina* is an alien species to the current study region. Since this study demonstrates the first observation of *Phtisica marina* due to the lack of previous studies on the biodiversity of invasive amphipod species from the study region, the attributes 2 and 4 cannot be taken into consideration to assess the invasive status of *Phtisica marina*. Criterion number 5 also could not be established through this study as samples were only collected from the subtidal zones.

Previous research has proven that the establishment of invasive species affect resident species, mainly species from the same ecological guild (Reichert and Beermann 2011). Being a dominant peracarid crustacean in most of benthic habitats of Mediterranean Sea and Atlantic Ocean (Guerra-García et al. 2014) and considering their opportunistic behaviour (González et al. 2008), it is expected that this species may affect the resident benthic communities. However, further studies are required to reveal the population dynamics, vector of transport and possible effects on native communities.

Furthermore, it can be hypothesised that this species may have been introduced from the other regions through the Suez Canal (on vessels from Mediterranean Sea). However, so far, this species has not been reported from Suez Canal and Red Sea but is largely found in high abundance in the Mediterranean mainly in harbours where this species is reported as a fouling organism. The introduction of *Phtisica marina* in India might be probably from this source.

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**Supplementary material**

The following supplementary material is available for this article:

**Table S1.** Records of *Phtisica marina* and environmental parameters surveyed in the present study.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2019/Supplements/BIR_2019_Srinivas_etal_Table_S1.xlsx