A taxonomic revision helps to clarify differences between the Atlantic invasive *Ptilohyale littoralis* and the Mediterranean endemic *Parhyale plumicornis* (Crustacea, Amphipoda)

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Abstract

*Ptilohyale explorator* (formerly *Parhyale explorator*), described by Arresti (1989), can be considered to be a synonym of west-Atlantic *Ptilohyale littoralis* (Stimpson, 1853), based on morphological observations of paratypes and specimens recently collected in the type locality of *Ptilohyale explorator*. The first collections of *Ptilohyale littoralis*, from the eastern Atlantic were from the port of Rotterdam (The Netherlands) in 2009 and later in Wimereux, Opal Coast (France) in 2014; however, the synonymy of *Ptilohyale explorator* with *Ptilohyale littoralis* backdates to the first European record of *Ptilohyale littoralis* in 1985 at La Vigne, Bay of Arcachon (France). This indicates that *Ptilohyale littoralis* has been established along European Atlantic coast for many years.

An assessment of the nominal valid species belonging to the genus *Ptilohyale* was carried out and a comparison between the Atlantic *Ptilohyale littoralis* and the very similar Mediterranean hyalid species, *Parhyale plumicornis*, is presented based on morphological features and distribution. Due to the invasive ability of *Ptilohyale littoralis*, a comparison between the two species is necessary.

Keywords

Atlantic, Hyalidae, Invasive species, Mediterranean Sea, *Parhyale plumicornis*, *Ptilohyale littoralis*
Introduction

Ptilohyale explorator (formerly Parhyale explorator) was described by Arresti (1989) from La Vigne, Bay of Arcachon, France. He collected eleven male and three female specimens in the intertidal zone, on the sand of a semi-enclosed beach under stones, in July 22, 1985; following Barnard’s (Barnard 1979: 120) “Key to the Species of Parhyale and Parallorchestes”, he established that the specimens sampled showed a feature that was not included in the key, i.e., the presence of long tufts of plumose setae in antenna II starting at the 5\textsuperscript{th} peduncular segment. However, as Barnard’s taxonomic key (Barnard 1979) had omitted some hyalid species already described at that time, Arresti did not take into consideration some preceding descriptions (listed in Table 1) that could fit with his collected specimens.

As a consequence, Arresti described a new hyalid species under the name Parhyale explorator, and deposited eight males and two females in the laboratory of the University of the Basque Country (Spain; holotype; allotype; six males and one female paratypes), one male paratype in the Carcinology Laboratory of Natural History Museum of Paris (France), and one male and one female paratypes in the Laboratory of Dr. S. Ruffo in the Museum of Natural History of Verona (Italy).

In 2008, Ptilohyale explorator (Arresti 1989) was reported as a new alien species within the Mediterranean Sea (Bakir et al. 2008), but later acknowledged to be a misidentification (Bakir et al. 2013), who re-identified the samples as Parhyale plumicornis (Heller, 1886), an endemic Mediterranean species (Iaciofano and Lo Brutto 2017). Regrettably, the case of this erroneous identification caused a cascade-effect on successive papers and documents that reported a further non-indigenous species (NIS) within Mediterranean (Bakir et al. 2010, Christodoulou et al. 2013, Faasse 2014, Zenetos 2010, Zenetos et al. 2010), although this was not the case.

Ptilohyale explorator is currently considered a valid species even if some authors have already highlighted the need of further investigations, in light of its high similarity with Ptilohyale littoralis (Faasse 2014, Spilmont et al. 2016, Marchini and Cardeccia 2017).

To clarify the position of Ptilohyale explorator, here considered species inquirenda, the paratypes deposited at the Natural History Museum of Verona and at the Natural History Museum of Paris were examined, together with some topotypic specimens collected in the type locality of the species, Bay of Arcachon, France. Descriptions and illustrations of current species belonging to the genus Ptilohyale were also consulted, and it was observed that some of them were not ascribable to this genus.

Materials and methods

The paratypes of Parhyale explorator (voucher number 330/P) deposited in Sandro Ruffo’s collection of the Museum of Natural History of Verona, Verona (Italy) and the Ptilohyale explorator paratype (voucher number MNHN-Am3957) deposited at
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Table 1. List of Parhyale and Ptilohyale species excluded by Barnard’s taxonomy key (Barnard 1979: 120) and by Arresti (1989), here named according to Lowry (2010) and Lowry et al. (2010).

| Species                          | Former Name                  |
|---------------------------------|------------------------------|
| Ptilohyale littoralis (Stimpson, 1853) | formerly Allorchestes littoralis |
| Ptilohyale plumulosus (Stimpson, 1857) | formerly Allorchestes plumulosus |
| Ptilohyale crassicornis (Haswell, 1879) | formerly Allorchestes crassicornis |
| Parhyale inyacka KH Barnard, 1916 |                              |
| Ptilohyale barnardi (Chevreux, 1926) | nomen dubium – formerly Hyale barnardi |
| Ptilohyale ptilocerus (Derzhavin, 1937) | formerly Allorchestes ptilocerus |
| Ptilohyale tristanensis (Macnae, 1953) | nomen dubium – formerly Allorchestes tristanensis |
| Ptilohyale iole (JL Barnard, 1970) | formerly Hyale iole |
| Ptilohyale barbicornis (Hiwatari & Kajihara, 1981) | formerly Hyale barbicornis |

the crustaceans collection of the Natural History Museum of Paris (MNHN), Paris (France) were examined under a stereo-microscope, and photos were produced.

Additionally, a total of 126 specimens of Ptilohyale sp. (84 females and 42 males) was collected in the intertidal zone associated with mussel beds (Mytilus edulis), from Bay of Arcachon, France (the type locality of Ptilohyale explorator), 43°34’N, 1°14’W (DDM), in October 2015, and fixed in 95% ethanol. Their body lengths, from tip of rostrum to apex of telson, were measured using ImageJ software after placement on graph-paper and photography (FINEPIX S1800, FUJIFILM); pencil drawings were scanned and ‘inked’ using the software Adobe Illustrator CS5. The specimens were identified as Ptilohyale littoralis and deposited at the Museum of Zoology of the University of Palermo (MZPA), Palermo (Italy), Voucher Number MZPA-AMPH-0024.

Descriptions of the 12 world species of the genus Ptilohyale, according to the World Amphipoda Database (Horton et al. 2017), were consulted and the diagnostic characters delimiting Ptilohyale Bousfield & Hendrycks, 2002 were verified: (1) heavily plumose (finely brush-setose) antenna II starting at the 5th peduncular article (both sexes); (2) lack of a guiding robust seta on the medial face of the propodus of gnathopod I (male); (3) variously developed carpal lobe of gnathopod II (male); (4) distomedial robust seta on the peduncle of uropod I; (5) inner ramus of uropod III more or less fused to the peduncle. The subsequent generic status for each of these species was then revised.

Results

The paratypes of Ptilohyale explorator preserved in the Museum of Natural History of Verona were entire and in good condition for observations (Fig. 1), while the paratype stored in the Carcinology Laboratory of Natural History Museum of Paris had deteriorated and some body parts were lost (i.e., heads).

Comparison with the description of Ptilohyale explorator (Arresti 1989: 103–111) and the paratypes stored at the museums of Verona and Paris showed some incongru-
Table 2. Diagnostic character states observed in the *Ptilohyale explorator* (*species inquirenda*) paratypes stored at the Museum of Natural History of Verona (Italy) and the Natural History Museum of Paris (France), and in the *Ptilohyale littoralis* sampled in the Bay of Arcachon (France); compared with Arresti's description of *Ptilohyale explorator* and Bousfield and Hendricks's *Ptilohyale littoralis* description. The table shows the incongruences (*) between the description of *Ptilohyale exploratory* by Arresti and the deposited paratypes.

| Characters | Samples of *Ptilohyale littoralis* (this paper) | Bousfield and Hendricks's description of *Ptilohyale littoralis* | Paratypes of *Ptilohyale explorator* (deposited by Arresti at Museum of Verona) | Paratype of *Ptilohyale explorator* (deposited by Arresti at Museum of Paris) | Arresti's description of *Ptilohyale explorator* |
|------------|---------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|---------------------------------|
| Antenna II, flagellar articles ventrally setose * | 4–9 | NA | 8 | NA | 10–11 |
| Coxal plate I | subquadrate | subquadrate | subquadrate | NA | subquadrate |
| Gnathopod I, basis distinct anterodistal lobe | absent | absent | absent | NA | absent |
| Peraeopod VII basis* | without strong depression on posterior margin | without strong depression on posterior margin | without strong depression on posterior margin | without strong depression on posterior margin | with strong depression on posterior margin |
| Uropod I rami spines* | 3–4 outer; 1–2 inner | 2–3 outer | 3 outer; 2 inner | NA | 6 outer; 2 inner |
| Uropod II rami | subequal | subequal | subequal | subequal | subequal |
| Uropod III apical spines* | 5–9 | 5–6 | 5–6 | NA | 8–10 |

NA, not available
ences (Table 2). The most significant difference was the absence of a strong depression on the basipodite of peraeopod VII in all paratypes, conversely to what was indicated in the description. Other diagnostic characters described by Arresti (1989) were also unlike the paratypes, including the number of plumose articles on antenna II, and the arrangement of setae on uropods I and III (see Table 2 for details).

Following the detailed description updated by Faasse (2014) and the recent Hyalidae taxonomic key presented by Bousfield and Hendrycks (2002), the paratypes of Ruffo’s collection and all 126 specimens sampled at the Bay of Arcachon (France), were identified as specimens of *Ptilohyale littoralis*. *Ptilohyale explorator* (formerly *Parhyale*) (Arresti, 1989) can be considered synonym of *Ptilohyale littoralis* (Stimpson, 1853).

**Systematics**

**Suborder SENTICAUDATA** Lowry & Myers, 2013  
**Infraorder TALITRIDA** Rafinesque, 1815  
**Superfamily TALITROIDEA** Rafinesque, 1815  
**Family HYALIDAE** Bulycheva, 1957  
**Subfamily HYALINAE** Bulycheva, 1957  
**Genus Ptilohyale** Bousfield & Hendrycks, 2002

*Ptilohyale littoralis* (Stimpson, 1853)

Figures 2–3

*Allorchestes littoralis* Stimpson, 1853: 49, t 3, fig. 36; Smith 1873: 556; Stebbing 1906: 595; Miner 1950: 462, pl. 148.  
*Hyale littoralis* (Stimpson, 1853) Holmes 1905: 472, pl. 3, fig. 2; Barnard and Karaman 1991: 369.  
*Hyale prevosti* (part) Della Valle, 1893: 519.  
*Hyale plumulosa* (Stimpson, 1853) Bousfield 1973: 155, pl. XLIV.2; Pollock 1998: 241, fig. 15.120.  
*Plumulohyale plumulosa* (Stimpson, 1853) Bousfield 2001: 104.  
*Ptilohyale littoralis* (Stimpson, 1853) Bousfield and Hendrycks 2002: 103; Faasse 2014: 1.  
*Parhyale explorator* Arresti, 1989: 101–115.  
*Ptilohyale explorator* (Arresti, 1989) Bousfield and Hendrycks 2002: 98–99.

**Type.** Neotype deposited in Canadian Museum of Nature Collection; voucher number CMNC 2002-0071 (Bousfield and Hendrycks 2002).

**Type locality.** Grand Manan Island (Canada), northern eastern Atlantic coast.

**Material examined.** One hundred and twenty-six specimens were collected at the Bay of Arcachon France (43°34’N, 1°14’W), 13October 2015; intertidally, 0 m, on the heavy substrate of the semi-closed beach (MZPA-AMPH-0024).
Description. Male. 11.4 mm length specimen. Antenna II ventral margins of the 5th peduncular article and first 4–9 flagellar articles (other one or two articles with sparse plumose setae) densely covered with plumose setae (brush setae). Palp of maxilla I with median constriction. Coxal plate I sub-quadrate with distinctive cups; Gnathopod I, basis lacking distinct anterodistal lobe (hydrodynamic lobe). Gnathopod II, carpus lobe present in juvenile male and absent on adult male. Coxal plate V posterior lobe smaller than anterior lobe; Peraeopod V, basis rounded. Peraeopod VII slender, basis rounded. Uropod I, peduncle with one distomedial robust seta; rami subequal with 3–4 robust setae on outer ramous and 1–2 robust setae on inner ramus. Uropod II, rami sub-equal in length. Uropod III, outer ramus with 5–9 apical robust setae. Telson acute. Female. Description based on a 10.6 mm length specimen. Gnathopod I, basis with anterodistal lobe.

Distribution. Northern, western, and eastern Atlantic coasts; north eastern Pacific coast.
Remarks. The genus *Ptilohyale* includes 12 species: *P. barbicornis* (Hiwatari & Kajihara, 1981); *P. barnardi* (Chevreux, 1925); *P. bisaieta* (Kim & Kim, 1991); *P. brevicrus* (Eun et al., 2014); *P. crassicornis* (Haswell, 1879); *P. eburnea* (Krapp-Schickel, 1974); *P. explorator* (Arresti, 1989); *P. iole* (Barnard, 1970); *P. littoralis* (Stimpson, 1853); *P. plumulosus* (Stimpson, 1857); *P. ptilocerus* (Derzhavin, 1937); *P. tristanensis* (Macnae, 1953) (Bousfield and Hendrycks 2002, Eun et al. 2014, Lowry 2010). Of these, the descriptions of three of the species showed characters not ascribable to *Ptilohyale sensu* Bousfield & Hendrycks (2002). *Ptilohyale barnardi* (formerly *Hyale barnardi*) has brush-setae in antenna II that start at the 4th peduncular article (see Chevreux 1925, Fig. 4A); *P. tristanensis* (formerly *Allorchestes tristanensis*) (see Macnae 1953, Fig. 4B) and *P. eburnea* (see Krapp-Schickel 1974, Fig. 4C), do not have brush-setae in antenna II. The absence of some diagnostic character states makes us consider *Ptilohyale barnardi, P. tristanensis, and P. eburnea as nomina dubia*, and we encourage further investigations.
Discussion

*Ptilohyale* (formerly *Parhyale*) *explorator* was described by Arresti (1989) using the dichotomous key to “*Parhyale* and *Parallorchestes*” of Barnard (1979: 120); he observed that the specimens collected were not ascribable to any of the species listed therein, due to the presence of dense elongate tufts of plumose setae ventrally on the peduncular article 5 of the antenna II and peduncle of uropod I with distomedial robust seta. These characters (and others listed in Table 3) prompted Arresti to describe a new species, and to revise Barnard’s key; however, both authors had excluded some hyalid species that could be identified with Arresti’s specimens (Table 1).

The following character states are considered diagnostic of *Ptilohyale explorator*: the arrangement of setae on the uropods and the presence of a strong depression on the posterior margin of the basis of peraeopod VII (Table 2). Here, it has been verified that these characters described in Arresti (1989) did not match with the paratypes (Fig. 5). The setae arrangement on uropod III and the posterior margin of basis of peraeopod VII of the paratypes, on the contrary, matched with specimens recently sampled from the *explorator* type locality and were identified as *Ptilohyale littoralis*. In fact, following the dichotomous key to Hyalidae of Bousfield and Hendrycks (2002), the detailed description of Faasse (2014), the paratypes in Ruffo’s collection, and the present specimens collected in Bay of Arcachon can all be identified as *Ptilohyale littoralis* (Stimpson, 1853). For these reasons, *Ptilohyale explorator* (Arresti, 1989) is proposed as a synonym of *Ptilohyale littoralis* (Stimpson, 1853), which, on base of the Principle of Priority, article 23 of the ICZN Code (Ride Chairman et al. 1999), becomes the valid name of this taxon.

Bousfield (1973) synonymised *Ptilohyale littoralis* with *Ptilohyale plumulosus*, a species distributed along the Pacific coast of North America. This synonymy was subsequently rejected (Bousfield and Hendrycks 2002), thus limiting the distribution of *Ptilohyale littoralis* to the western Atlantic coast of North America (Bousfield and Hendrycks 2002).

Recently, *Ptilohyale littoralis* was declared as a recent alien species spreading along the eastern Atlantic coast since 2009 (Faasse 2014, Spilmont et al. 2016, Marchini and Cardeccia 2017), but this study has shown that the species inhabited the Atlanto-European coast at least since 1985.

Moreover, *Ptilohyale littoralis* was recently recorded along the eastern Pacific coast of North America (Campbell River, Vancouver, Choi et al. 2016; and Puget Sound, Washington State, Heerhartz et al. 2016), suggesting an extension of the species’ range.

The genus *Ptilohyale* has been diagnosed with plumose setae on ventral margins of antenna II that start at the 5th peduncular segment and distomedial robust seta on peduncle of uropod I. Behaviourally, it is described as saltatory and occurring in brackish and estuarine waters (Bousfield and Hendrycks 2002).

*Ptilohyale* is distributed along both the Atlantic and Pacific coasts (Bousfield and Hendrycks 2002, Eun et al. 2014, Faasse 2014, Haswell 1879, Heerhartz et al. 2016, Hiwatari and Kajihara 1981, Hutchings et al. 2013, Kim and Kim 1987,
Table 3. Characters used by Arresti (1989) for diagnosing Parhyale explorator (subsequently synonymised Ptilohyale explorator) from the other species of the genus Parhyale.

| Parhyale explorator | Parhyale eburnea Krapp-Schickel, 1974 |
|---------------------|-------------------------------------|
| Uropod I with robust seta on peduncle; Rami of uropods I and II with strong dorsal setae. | Uropod I without robust seta on peduncle; Rami of uropods I and II without strong dorsal setae. |

Parhyale explorator

| Parhyale explorator | Parhyale plumicornis (Heller, 1866) |
|---------------------|-------------------------------------|
| Uropod III with only apical seta; Inner ramous of uropod III poorly defined and fused to the peduncle; Carpus of gnathopod II male with stout process. | Uropod III with apical and dorsal setae; Inner ramous of uropod III well defined and not fused to the peduncle; Carpus of gnathopod II male with evident process. |

Parhyale explorator

| Parhyale explorator | Parhyale aquilina (Costa, 1857) |
|---------------------|----------------------------------|
| Uropod I with robust seta on peduncle. | Uropod I without robust seta on peduncle; |

| Parhyale explorator | Parhyale ? zibellina (Derzhavin, 1937) |
|---------------------|--------------------------------------|
| Uropod III with only apical seta; Propodus of peraeopod VII without setae on posterior margin. | Uropod III with apical and dorsal setae; Propodus of peraeopod VII with setae on posterior margin. |

Parhyale explorator

| Parhyale explorator | Parhyale ? iwasai (Shoemaker, 1956) |
|---------------------|-------------------------------------|
| Inner ramous of uropod III poorly defined and fused to the peduncle; Rami of uropods I and II with strong dorsal setae. | Inner ramous of uropod III well defined and not fused to the peduncle; Rami of uropods I and II without strong dorsal setae. |

Parhyale explorator

| Parhyale explorator | Parhyale bawaisiensis (Dana, 1853) |
|---------------------|-------------------------------------|
| Inner ramous of uropod III poorly defined and fused to the peduncle; Propodus of peraeopod VII without setae on posterior margin. | Inner ramous of uropod III well defined and not fused to the peduncle; Propodus of peraeopod VII with setae on posterior margin. |

Parhyale explorator

| Parhyale explorator | Parhyale penicillata Shoemaker, 1956 |
|---------------------|-------------------------------------|
| Inner ramous of uropod III poorly defined and fused to the peduncle; Rami of uropods I and II with strong dorsal setae. | Inner ramous of uropod III well defined and not fused to the peduncle; Rami of uropods I and II without strong dorsal setae. |

Parhyale explorator

| Parhyale explorator | Parhyale fascigera Stebbing, 1897 |
|---------------------|-------------------------------------|
| Inner ramous of uropod III poorly defined and fused to the peduncle; Propodus of peraeopod VII without setae on posterior margin. | Inner ramous of uropod III well defined and not fused to the peduncle; Rami of uropods I and II without strong dorsal setae. |

Parhyale explorator

| Parhyale explorator | Parhyale of Bulycheva |
|---------------------|----------------------|
| Inner ramous of uropod III poorly defined and fused to the peduncle; Basipodite of peraeopod VII with rounded posteroventral lobe. | Inner ramous of uropod III well defined and not fused to the peduncle; Basipodite of peraeopod VII without rounded posteroventral lobe. |

Parhyale explorator

| Parhyale explorator | Parhyale basrensis Salman, 1986 |
|---------------------|----------------------------------|
| Inner ramous of uropod III poorly defined and fused to the peduncle; Uropod I with robust seta on peduncle; Propodus of peraeopod VII without setae on posterior margin. | Inner ramous of uropod III well defined and not fused to the peduncle; Uropod I without robust seta on peduncle; Propodus of peraeopod VII with setae on posterior margin. |

Parhyale explorator

| Parhyale explorator | Parhyale multispinosa Stock, 1987 |
|---------------------|----------------------------------|
| Inner ramous of uropod III poorly defined and fused to the peduncle; Propodus of peraeopod VII without setae on posterior margin. | Inner ramous of uropod III well defined and not fused to the peduncle; Propodus of peraeopod VII with setae on posterior margin. |

1991, Macnae 1953, McDermott 1998, Peart 2004, Spilmont et al. 2016, Tsoi and Chu 2005, Tunnell and Withers 2009, Turbeville and Caplins 2010). The genus still includes 12 species in some documents (e.g., Bousfield and Hendrycks 2002, Eun et al. 2014, Horton et al. 2017, Lowry 2010) instead of the eight nominal valid species (Table 4).
**Table 4.** List of *Ptilohyale* species exhibiting diagnostic generic characters, and their distribution.

| Ptilohyale species               | Distribution                                      | Reference                                                                 |
|----------------------------------|---------------------------------------------------|---------------------------------------------------------------------------|
| *Ptilohyale barbicornis* (Hiwatari and Kajihara, 1981) | Japan Sea, Korea and Japan                         | Hiwatari and Kajihara 1981, Eun et al. 2014                              |
| *Ptilohyale bisaeta* (Kim and Kim, 1991)              | Japan Sea, Korea                                  | Kim and Kim 1991                                                          |
| *Ptilohyale brevicrus* (Eun et al., 2014)             | Japan Sea, Korea                                  | Eun et al. 2014                                                           |
| *Ptilohyale crassicornis* (Haswell, 1879)*            | Tasman Sea, Australia; Yellows and Japan Seas, China and Korea | Haswell 1879, Hiwatari and Kajihara 1981, Kim and Kim 1987, Peart 2004, Tsoi and Chu 2005, Hutchings et al. 2013 |
| *Ptilohyale iole* (JL Barnard, 1970)                  | Pacific Ocean, Hawaii                             | Hiwatari and Kajihara 1981                                              |
| *Ptilohyale littoralis* (Stimpson, 1853)             | Atlantic Ocean, France, Netherlands, United States and Canada; Pacific Ocean, Canada | Bousfield and Hendrycks (2002), Choi et al. 2016, Faasse 2014, Spilmont et al. 2016, Heerhartz et al. 2016; this paper; |
| *Ptilohyale plumulosus* (Stimpson 1857)**            | Pacific Ocean, Alaska, Canada and United States   | McDermott 1998, Bousfield and Hendrycks 2002, Tunnell and Withers 2009, Turbeville and Caplins 2010, Heerhartz et al. 2016 |
| *Ptilohyale ptilocerus* (Derzhavin, 1937)            | Japan Sea, Russia                                 | Hiwatari and Kajihara 1981                                              |

* erroneously named *crassicorne* in Bousfield and Hendrycks (2002) instead of *crassicornis*

** erroneously named *plumulosa* in Bousfield and Hendrycks (2002) instead of *plumulosus*

**Figure 4.** Illustrations from the literature of: **A** *Ptilohyale barnardi* (Chevreux, 1925) **B** *Ptilohyale tristanensis* (Macnae, 1953) **C** *Ptilohyale eburnea* (Krapp-Schickel, 1974).
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The Atlantic *Ptilohyale littoralis* vs. the Mediterranean *Parhyale plumicornis*

Due the high connectivity between eastern Atlantic and Mediterranean area, which has already caused a high similarity in the Portuguese and Mediterranean amphipod fauna (Plicanti et al. 2016) it can be supposed that the Atlantic *Ptilohyale littoralis* may have spread into the Mediterranean, or vice versa, *Parhyale plumicornis* into the Atlantic Ocean.

*Parhyale plumicornis* belongs to the Mediterranean fauna and it is the most similar hyalid species to *Ptilohyale littoralis* due to the overlapping morphological and ecological characters such as the brush setae along ventral margin of antennae II (Bakir et al. 2013, Iaciofano and Lo Brutto 2017); and both their presences in the intertidal habitat in slow-drying sediments (Arresti 1989, Bousfield and Hendrycks 2002, Iaciofano and Lo Brutto 2017).

Some morphological character states are presented in Fig. 6 as a guide to the correct identifications: *Ptilohyale littoralis* (Fig. 6A) has brush setae on the ventral margin of antenna II that start at the 5th peduncular article (Fig. 6B) and distomedial robust setae on the peduncle of uropod I (Fig. 6C). In contrast, *Parhyale plumicornis* (Fig. 6E) has brush setae on the ventral margin of antenna II that start at the 4th peduncular article (Fig. 6F) and has a distolateral robust seta on the peduncle of uropod II (Fig. 6G).

These two species show a different and non-overlapping distributions: *Ptilohyale littoralis* was recorded along European Atlantic coast (Fig. 6D; Table 4), whereas *Parhyale plumicornis* was recorded along Mediterranean and Red Sea coasts (Fig. 6H; Iaciofano and Lo Brutto 2017 and reference therein). In light of the range extension of *Ptilohyale littoralis* already recorded over long distances, a clear representation of diagnostic character states is needed. *Ptilohyale littoralis* may be invading the Mediterranean Sea where it could probably be a competitor of the Mediterranean endemic *Parhyale plumicornis* as it occupies the same habitat.

**Figure 5.** Illustration of male paratype of *Parhyale explorator*, from Ruffo’s collection, uropods I (U1), II (U2), III (U3) and peraeopod VII (P7). Scale bars 1 mm.
Figure 6. Comparison between *Ptilohyale littoralis* and *Parhyale plumicornis* diagnostic characters and distributions. *Ptilohyale littoralis*: A illustration of male (Bousfield and Hendrycks 2002) B antenna II male with brush-setae starting at the 5th peduncular segment C right uropod I with peduncular distomedial robust seta D species distribution along the Atlantic coast. *Parhyale plumicornis*: E illustration of male (Iaciofano and Lo Brutto 2017) F antenna II male with brush setae starting at the 4th peduncular segment G right uropod I with peduncular distolateral robust seta H species distribution along the Mediterranean and Red Sea coasts.

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References

Arresti A (1989) *Parhyale explorator*, a new species of talitroid amphipod from the bay of Arcachon, France. Bulletin du Muséum national d’Histoire naturelle. Section A, Zoologie, biologie et écologie animales 11: 101–115.

Bakir K, Katağan T, Sezgin M (2008) *Parhyale explorator* Arresti, 1989 (Amphipoda, Talitroidea): First Mediterranean record of this Atlantic amphipod. Crustaceana 81: 557–562. https://doi.org/10.1163/156854008784092247

Bakir K, Katağan T, Sezgin M (2013) Correction about the existence of *Parhyale explorator* Arresti, 1989 (Amphipoda, Talitroidea) in the Mediterranean Sea. Crustaceana 86: 1297–1298. https://doi.org/10.1163/15685403-00003225

Bakir K, Sezgin M, Katağan T (2010) Alien amphipods on the Turkish Coasts. Zoologica bætica 21: 191–196.

Barnard JL (1970) Sublittoral Gammaridea (Amphipoda) of the Hawaiian Islands. Smithsonian Contributions to Zoology 34: 1–286. https://doi.org/10.5479/si.00810282.34

Barnard JL (1979) Littoral gammaridean Amphipoda from the Gulf of California and the Galapagos Islands. Smithsonian Contributions to Zoology 271: 1–149. https://doi.org/10.5479/si.00810282.271

Barnard JL, Karaman GS (1991) The families and genera of marine gammaridean Amphipoda (except marine gammaroïds). Part 2. Records of the Australian Museum 13: 1–866. https://doi.org/10.3853/j.0812-7387.13.1991.91

Barnard KH (1916) Contributions to the crustacean fauna of South Africa. 5. The Amphipoda. Annals of the South Africa Museum 15: 105–302. https://doi.org/10.5962/bhl.part.22196

Bousfield EL (1973) Shallow-water Gammaridean Amphipods of New England. Comstock Publishing Associates, Cornell University Press, Ithaca and London, 312 pp.

Bousfield EL (2001) Phyletic classification as applied to amphipod crustaceans of North America. Amphipacifica 3: 49–119.

Bousfield EL, Hendrycks EA (2002) The Talitroidean amphipod family Hyalidae revised, with emphasis on the North Pacific fauna: Systematics and distributional ecology. Amphipacifica 3: 17–134.

Bulycheva AI (1957) Beach-fleas of the seas of the USSR and adjacent waters (Amphipoda- Talitroidea). Akademiya Nauk SSSR, Opredeliteli po Faune SSSR 65: 1–185.

Chevreux E (1925) Amphipodes I. Gammariens (suite). Voyage de la goélette *Melita* aux Canaries et au Senegal 1889–1890. Bulletin de la Société zoologique de France 50: 365–398.
Choi FM, Murray CC, Therriault TW, Pakhomov EA (2016) Intertidal invasion patterns in Canadian ports. Marine Biology 163: 183. https://doi.org/10.1007/s00227-016-2957-0

Christodoulou M, Paraskevopoulou S, Syranidou E, Koukouras A (2013) The amphipod (Crustacea: Peracarida) fauna of the Aegean Sea, and comparison with those of the neighbouring seas. Journal of the Marine Biological Association of the United Kingdom 93: 1303–1327. https://doi.org/10.1017/S002531541200183X

Costa A (1857) Ricerche sui crostacei amfipodi del regno di Napoli. Memorie della Reale Accademia delle Scienze di Napoli, 1: 181–183. https://doi.org/10.5962/bhl.title.2070

Dana JD (1853) Crustacea, Part II United States Exploring Expedition during the years 1838, 1839, 1840, 1841, 1842, under the command of Charles Wilkes. U.S. Navy 14: 686–1618. https://doi.org/10.5962/bhl.title.63979

Della Valle A (1893) Gammarini del golfo di Napoli. Fauna und Flora des Golfes von Neapel und der angrenzenden Meeres-Abschnitte. Herausgegeben von der Zoologischen Station zu Neapel 20: XI–948.

Derzhavin AN (1937) Talitridae of the Soviet coast of the Japan Sea. Issledovaniya Morei SSSR 3: 87–112.

Eun Y, Kim YH, Hendrycks EA, Lee KS (2014) The family Hyalidae (Crustacea: Amphipoda: Talitroidea) from Korean waters. 1. Genus Ptilohyale Bousfield & Hendrycks, 2002. Zootaxa 3802: 583–595. https://doi.org/10.11646/zootaxa.3802.4.8

Faasse MA (2014) Introduction of Ptilohyale littoralis to The Netherlands. Marine Biodiversity Records 7: e28. https://doi.org/10.1017/S1755267214000293

Haswell WA (1879) On Australian Amphipoda. Proceedings of the Linnean Society of New South Wales 4: 245–279. https://doi.org/10.5962/bhl.part.22848

Heller C (1866) Beiträge zur näheren Kenntniss der Amphipoden des Adriatischen Meeres. Denkschriften der Kaiserlichen Akademie der Wissenschaften, Mathematisch Naturwissenschaftliche Klasse 26: 1–62. https://doi.org/10.5962/bhl.title.6483

Heerhartz SM, Toft JD, Cordell JR, Dethier MN, Ogston AS (2016) Shoreline armoring in an estuary constrains wrack-associated invertebrate communities. Estuaries and Coasts 39: 171–188. https://doi.org/10.5962/bhl.part.22848

Hiwatari T, Kajihara T (1981) A new species of the genus Hyale. Ibid 20: 35–40.

Holmes SJ (1905) The amphipods of southern New England. Bulletin of the United State. Fish Commission 24: 459–529.

Horton T, Lowry J, De Broyer C, Bellan-Santini D, Zeidler W (2017) World Amphipoda Database. http://www.marinespecies.org/ amphipoda [accessed on 2017-08-01]

Hutchings P, Ahyong S, Ashcroft M, McGrouther M, Reid A (2013) Sydney Harbour: its diverse biodiversity. Australian Zoologist 36: 255–320. https://doi.org/10.7882/AZ.2012.031

Iaciofano D, Lo Brutto S (2017) Parhyale plumicornis (Heller, 1866) (Crustacea: Amphipoda: Hyalidae): is this an anti-lessepsian Mediterranean species? Morphological remarks, molecular markers and ecological notes as tools for future records. Systematics and Biodiversity 15: 238–252. https://doi.org/10.1080/14772000.2016.1248519

Kim HS, Kim CB (1987) Marine gammaridean Amphipoda (Crustacea) of Cheju Island and its adjacent waters, Korea. The Korean Journal of Systematic Zoology 3: 1–23.
Kim W, Kim CB (1991) The marine amphipod crustaceans of Ulreung Island, Korea: Part II. The Korean Journal of Systematic Zoology 7: 13–38.

Krapp-Schickel G (1974) Camill HELLERS Sammlung adriatischer Amphipoden – 1866 und heute. Annalen des Naturhistorischen Museums in Wien 78: 319–379.

Lowry J (2010) Ptilohyale Bousfield & Hendrycks, 2002. In: Horton T, Lowry J, De Broyer C, Bellan-Santini D, Coleman CO, Zeidler W (Eds) World Amphipoda Database. http://www.marinespecies.org/amphipoda/ [accessed on 12 Jan 2017]

Lowry J, Costello M, Bellan-Santini D (2010) Parhyale Stebbing, 1897. In: Horton T, Lowry J, De Broyer C, Bellan-Santini D, Coleman CO, Zeidler W (2016) World Amphipoda Database. http://www.marinespecies.org/amphipoda/ [accessed on 12 Jan 2017]

Lowry JK, Myers AA (2013) Phylogeny and Classification of the Senticaudata subord. nov. (Crustacea: Amphipoda). Zootaxa 3610: 1–80. https://doi.org/10.11646/zootaxa.3610.1.1

Marchini A, Cardeccia A (2017) Alien amphipods in a sea of troubles: cryptogenic species, unresolved taxonomy and overlooked introductions. Marine Biology 164(4): 69. https://doi.org/10.1007/s00227-017-3093-1

McDermott JJ (1998) The western Pacific brachyuran (Hemigrapsus sanguineus: Grapsidae), in its new habitat along the Atlantic coast of the United States: geographic distribution and ecology. ICES Journal of Marine Science: Journal du Conseil 55: 289–298. https://doi.org/10.1006/jmsc.1997.0273

Macnae W (1953) On a small collection of amphipods from Tristan da Cunha. Proceedings of the Zoological Society of London 122: 1025–1033. https://doi.org/10.1111/j.1096-3642.1953.tb00361.x

Miner RW (1950) Field book of seashore life. Putnam & Sons, New York, 890 pp. [251 pls]

Peart RA (2004) Amphipoda (Crustacea) collected from the Dampier Archipelago, Western Australia. Records of the Western Australian Museum Supplement 66: 159–167. https://doi.org/10.18195/issn.0313-122x.66.2004.159-167

Plicanti A, Iacofano D, Bertocci I, Lo Brutto S (2016) The amphipod assemblages of Sabellaria alveolata reefs from the NW coast of Portugal: An account of the present knowledge, new records, and some biogeographic considerations. Marine Biodiversity 47(2): 521–534. https://doi.org/10.1007/s12526-016-0474-5

Pollock LW (1998) A practical guide to the marine animals of northeastern North America. Rutgers University Press, New Brunswick, New Jersey, 371 pp.

Rafinesque CS (1815) Analyse de la nature ou tableau de l’université des corps organisés par C.S. Rafinesque. Palerme. https://doi.org/10.5962/bhl.title.106607

Ride Chairman WDL, Cogger HG, Dupuis C, Kraus O, Minelli A, Thompson FC, Tubbs PK (Eds) (1999) International Code of Zoological Nomenclature. International Trust for Zoological Nomenclature. The Natural History Museum, London, 1–106.

Salman SO (1986) Parhyale basrensis, a new species of talitrid amphipod from the Shutt Al-Arab region, Iraq. Crustaceana 50: 287–294. https://doi.org/10.1163/156854086X00313

Shoemaker CR (1956) Observations of the amphipod genus. Proceedings of the United States National Museum 106: 345–358. https://doi.org/10.5479/si.00963801.106-3372.345

Smith SI (1873) Crustacea ex Isopoda. In: Verrill AE (Ed.) Report upon the invertebrate animals of Vineyard Sound. Report of the United States Commissioner of Fisheries 1: 295–778.
Spilmont N, Hachet A, Faasse MA, Jourde J, Luczak C, Seuront L, Rolet C (2016) First records of *Ptilohyale littoralis* (Amphipoda: Hyalidae) and *Boccardia proboscidea* (Polychaeta: Spionidae) from the coast of the English Channel: habitat use and coexistence with other species. Marine Biodiversity, 1–11. https://doi.org/10.1007/s12526-016-0557-3

Stebbing TR (1897) II. Amphipoda from the Copenhagen Museum and other Sources. Transactions of the Linnean Society of London, 2nd Series: Zoology 7: 25–45. https://doi.org/10.1111/j.1096-3642.1897.tb00400.x

Stebbing TRR (1906) Amphipoda. I. Gammaridea. Das Tierreich 21: XXXIX–806.

Stimpson W (1853) Synopsis of the marine invertebrate of Grand Manan: or the region about the mouth of the Bay of Fundy. Smithsonian Contributions to Zoology 6: 5–66.

Stimpson W (1857) The Crustacea and Echinodermata of the Pacific shores of North America. Boston Society of Natural History 6: 1–92.

Stock JH (1987) Stygofauna of the Canary Islands. 5. A hypogean population of *Parhyale* (Amphipoda) in the Jameos del agua Lava Tunnel (Lanzarote) a supposed case of recent evolution. Stygologia 3: 167–184.

Tsoi KH, Chu KH (2005) Sexual dimorphism and reproduction of the amphipod *Hyale crassicornis* Haswell (Gammaridea: Hyalidae). Zoological studies 44: 382–392.

Tunnell KD, Withers K (2009) Macrofauna Associate with Ungrounded Prop Roots of *Rhizophora mangle* in Veracruz and Quintana Roo, Mexico. Gulf and Caribbean Research 21: 67–72. https://doi.org/10.18785/gcr.2101.08

Turberville JM, Caplins SA (2010) First record for *Prosorhochmus americanus* (Nemertea Hoplonemertea) in Virginia with notes on its natural history and morphology. Banisteria 35: 61–65.

Zenetos A (2010) Trend in aliens species in the Mediterranean. An answer to Galil, 2009 «Taking stock: inventory of alien species in the Mediterranean Sea». Biological invasions 12: 3379–3381. https://doi.org/10.1007/s10530-009-9679-x

Zenetos A, Gofas S, Verlaque M, Cinar ME, Garcia Raso JE, Bianchi CN, Morri C, Azzurro E, Bilecenoglu M, Froglia C, Siokou I, Violanti D, Sfriso A, San Martin G, Giangrande A, Katagan T, Ballesteros E, Ramos-Esplaa AA, Mastrotartaro F, Ocana O, Zingone A, Gambi MC, Strefiaris N (2010) Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union’s Marine Strategy Framework Directive (MSFD). Part I. Spatial distribution. Mediterranean Marine Science 11: 381–493. https://doi.org/10.12681/mms.87