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Research Article

Laticorophium baconi (Shoemaker, 1934) (Crustacea: Amphipoda: Corophiidae: Corophiini): first record in European marine waters

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Abstract

Laticorophium baconi (Amphipoda, Corophiidae) was recorded for the first time in European marine waters from buoy fouling communities at the Sant Carles de la Ràpita marina (Alfacs Bay, Eastern Mediterranean Spanish coast). Presence of juveniles, adult males, brooding and ovigerous females were indicative of a well-established population. An entire description of the species, together with a dichotomous key to Corophiini genera characterized by urosome segments fused with uropod 1 ventrally inserted, are provided. This record supports the view that *L. baconi* may have been overlooked and/or potentially confused with other Corophiini species such as *Apocorophium acutum* in previous studies.

Key words: fouling community, dichotomous key, Spanish coast, Mediterranean Sea

Introduction

Corophiini Leach, 1814 are generally tube-dwellers amphipods present in various marine, estuarine and freshwater environments where they colonize diverse sandy- to muddy-bottom habitats and are sometimes found as epibionts on epifauna species such as bryozoans, hydrozoans, macroalgae, and bivalves; some species even reside as specialized commensals, although others are cosmopolitan (Shoemaker 1934; Williams and McDermott 2004; Bousfield and Hoover 1997). Bousfield and Hoover (1997) deeply overhauled the Corophiini tribe by describing 12 new genera and many new species. Their identification key was and remains largely used around the world. However, examination of the original descriptions of some Corophiini species has revealed some mistakes, e.g., for the genus *Monocorophium* Bousfield and Hoover, 1997. An update, recently proposed by Gouillieux and Massé (2019), supported the view that meticulous observation of this complex tribe is still a challenging task, as is recognizing species properly and characterizing their ecology (Gouillieux 2019).

Along the northeastern Atlantic European coast, Noël (2011) reported the introduction of four Corophiini species for the period 1930–1965 (*Chelicorophium curvispinum* (G.O. Sars, 1895); *Corophium multisetosum*

Stock, 1952; *Monocorophium acherusicum* (Costa, 1853) and *M. sextonae* (Crawford, 1937)) although only one new introduction, i.e. *M. uenoi* (Stephenson, 1932), was recorded during the last decade (Faasse 2014). This last introduction was thought to be linked to aquaculture in shellfish ecosystems where the species was recorded, i.e. Yerseke in the Oosterschelde, The Netherlands (Faasse 2014) and Arcachon Bay, Southwestern France (Gouillieux and Massé 2019), as already reported for many other non-indigenous species (NIS) by Goulletquer et al. (2002) and Noël (2011) along the Atlantic coasts.

The Mediterranean Amphipoda fauna has been extensively studied for a long time (e.g. Bellan-Santini et al. 1982). However, knowledge about NIS Corophiidae fauna appears to be not uniform throughout the entire Mediterranean. Most of the NIS introductions into Spanish coasts were linked to shipping (Nunes et al. 2014); indicating that in European waters, as well as in the world, the main introduction factor of NIS differs depending on local and regional socio-economic activities. According to the most up-to-date reviews (Zenetos et al. 2017; Galil et al. 2018), there are no NIS Corophiidae in the Mediterranean Sea, although a few Corophiidae species such as *Laticorophium baconi* (Shoemaker, 1934) and *Monocorophium uenoi* may be good potential invaders due to their ecology and recognized valid NIS status outside the Mediterranean Sea (Marchini and Cardeccia 2017).

Corophiidae have a relatively small body size, leading to a high risk of confusion with endemic and/or cryptogenic species. Therefore, directed sampling efforts devoted to particular artificial habitats or potential vectors for NIS Corophiidae can be useful in determining species assemblages. A recent large-scale study of biofouling peracarid crustaceans on boats in Mediterranean marinas highlighted the potential role of recreational boating as vectors for NIS and cryptogenic species, including the three Corophiidae species *Apocorophium acutum* (Chevreux, 1908), *Monocorophium acherusicum* and *M. sextonae* (Martínez-Laiz et al. 2019).

The Corophiini amphipod, *Laticorophium baconi*, is herein recorded for the first time in the western Mediterranean Sea, east coast of Spain. Since this is the first record of the species from the Mediterranean Sea and therefore the first record of the genus *Laticorophium* Bousfield and Hoover, 1997 in European marine waters, an entire description of the species is provided. It includes a revised Bousfield and Hoover (1997) key to Corophiini species, which are characterized by urosome segments fused with uropod 1 arising mainly ventrally.

Materials and methods

Study area

The Sant Carles de la Ràpita and Vinarós marinas are located along the northern Spanish Mediterranean coast within and South to the Alfacs Bay,

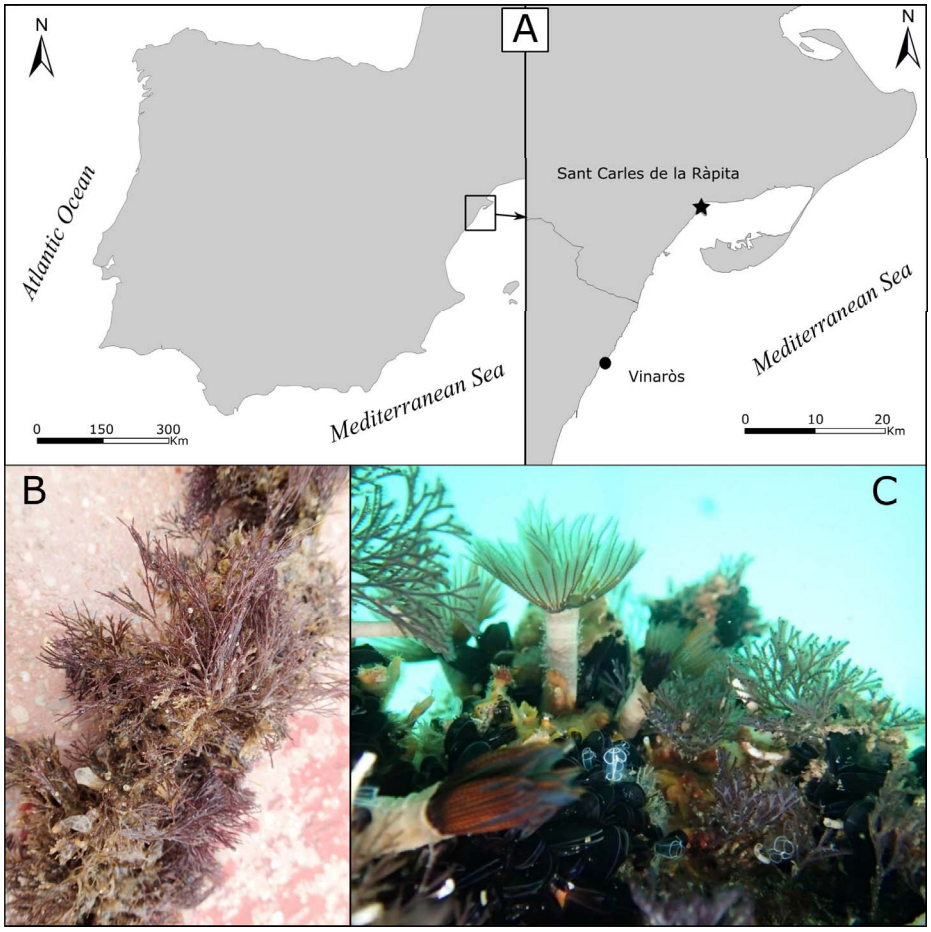

Figure 1. Stations (A) and habitats sampled in Sant Carles de la Ràpita (B) and Vinaròs (C), Spanish Mediterranean coast. Presence (black star) or absence (black dot) of *Laticorophium baconi* (Shoemaker, 1934) is indicated. Photos by P.-G. Sauriau.

respectively (Figure 1). The Alfacs Bay is a microtidal semi-enclosed estuary at the south side of the Ebro River Delta, from which it receives irrigation freshwater coming from rice fields and lagoons through discharge channels located on its northern shore (Camp and Delgado 1987). Benthic habitats mostly consist of sandy bottoms and seagrass meadows (Pérez and Camp 1986). The Alfacs Bay plays a major economic role due to its large fish and shellfish raft farming activities, particularly oysters and the mussel *Mytilus galloprovincialis* Lamarck, 1819 (Galimany et al. 2011). Marine waters within the Sant Carles de la Ràpita marina are silty, leading to the development of fouling communities adapted to estuarine conditions; although in the Vinaròs marina, fouling of pontoons was composed by typical clear marine water species.

Material examined

Fouling communities from buoys and pontoons, where recreational boats were moored, were collected by hand from ropes hanging in both marinas and immediately preserved in 95% ethanol. *Laticorophium baconi* specimens were subsequently examined with a Nikon SMZ 25 stereomicroscope and a

Nikon Eclipse E400 microscope with up to 112,5 and 400x magnifications (and transmitted light) respectively. Body length (BL) was measured with NIS-Elements Analysis software from the anterior margin of head to the posterior end of telson. For Scanning Electron Microscope (SEM) studies, specimens were dehydrated in a graded ethanol series, critical point dried, sputter coated with gold and examined with a Hitachi TM3030Plus scanning electron microscope. More than 50 specimens were deposited in the Muséum National d'Histoire Naturelle (MNHN, Paris).

Results

In the Vinarós marina, the fouling fauna collected from under the pontoons was composed of typical marine water species, mainly *Mytilus* sp. Linnaeus, 1758; Serpulidae Rafinesque, 1815 and Clavelinidae Forbes and Hanley, 1848. No specimens of *Laticorophium baconi* were collected, but individuals of the isopod *Paranthura japonica* Richardson, 1909 and the amphipods C*aprella scaura* Templeton, 1836; *Elasmopus rapax* Costa, 1853; *Lysianassa ceratina* (Walker, 1889) and *Quadrimaera inaequipes* (A. Costa in Hope, 1851) were collected. In the Sant Carles de la Ràpita marina, which has much more silty waters, more than 300 specimens of *Laticorophium baconi* were collected from a buoy covered with hydroids and red algae; *L. baconi* was the main amphipod species in the sample. Other crustacean species were also collected (i.e., the isopod *Paranthura japonica* and the amphipods C*aprella scaura*, *Elasmopus brasiliensis* (Dana, 1855) and *E. rapax*).

Systematics

Family Corophiidae Leach, 1814
Subfamily Corophiinae Bousfield and Hoover, 1997
Genus *Laticorophium* Bousfield and Hoover, 1997

***Laticorophium baconi* (Shoemaker, 1934)**

Corophium baconi Shoemaker 1934: 356 (original description), fig. 1.—1949: 82, figs. 5g, h.—Crawford 1937: 626.—Barnard 1969: 101.—1970: 100, fig. 53.— 1971: 59, fig. 26b.—Otte 1975: 11, fig. 8.—Hirayama 1986: 472, figs. 12–14.—Barnard 1979: 24.—Barnard and Karaman 1991: 185. —Ishimaru 1994: 35.

Laticorophium baconi Bousfield and Hoover 1997: 126, figs. 37.—Lecroy 2004: 462, fig. 425.—Chapman 2007: 573, figs. 255U, 269G, 270L-N

Doubtful *Laticorophium baconi* Bousfield and Hoover 1997: 126, figs. 36.—Valério-Berardo and De Souza 2009: 61, fig. 4.

Material examined: San Carles de la Ràpita, Spain, 40°36.933′N; 0°35.659′E, subtidal, on mooring buoy (Figure 1), col. Sauriau, P.-G., 05/05/2018, MNHN-IU-2016-3402 to MNHN-IU-2016-3405.

Description based on male BL = 2.47 mm and female BL = 2.73 mm, illustrations from supplementary material.

Head (Figures 2E, 3B) rostrum short, broad, not exceeding lateral head lobes; eyes developed. Male (Figure 2) antenna 1 peduncle articles sparsely

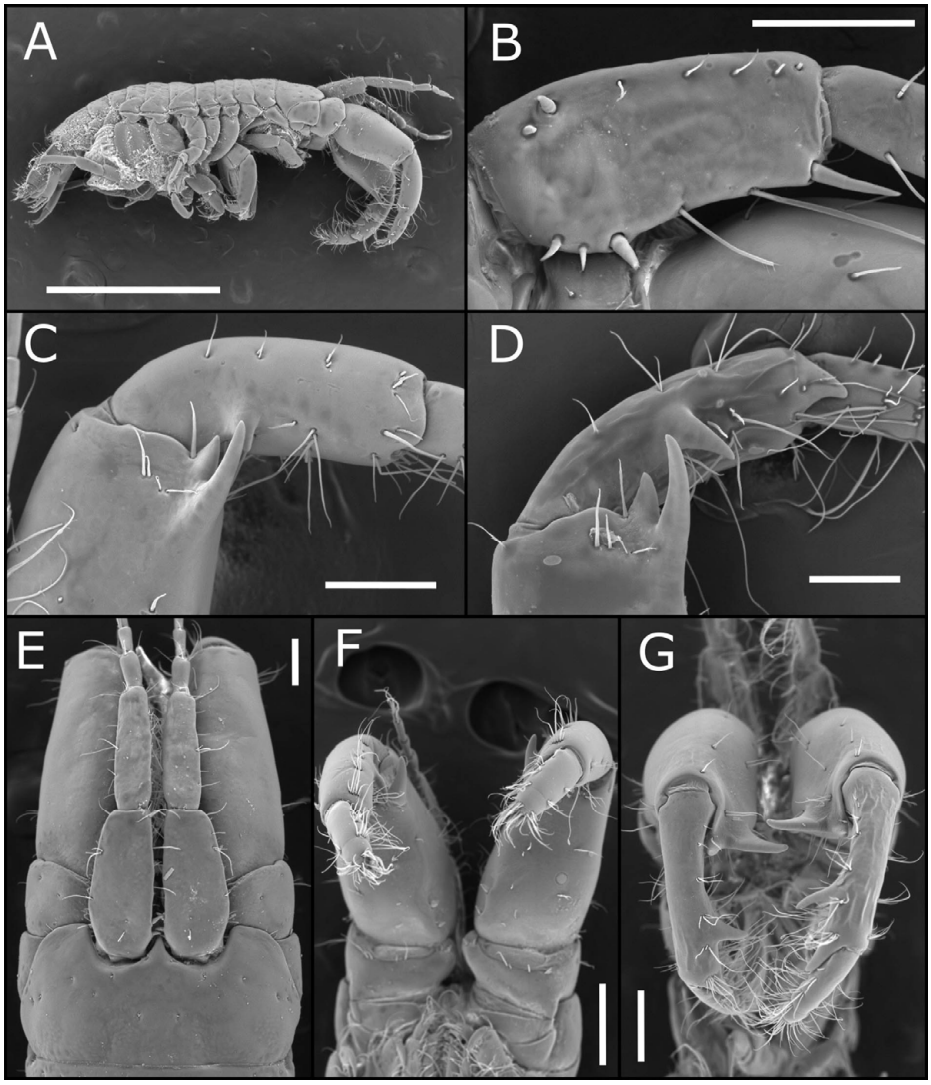

Figure 2. *Laticorophium baconi* (Shoemaker, 1934), male specimens from Sant Carles de la Ràpita, Spain, 5/vi/2018. (A) Lateral view; (B) antenna 1 peduncle article 1 inner view; (C) antenna 2 peduncle article 4 (end) and 5 inner view from male BL = 1.79 mm; (D) antenna 2 peduncle article 4 (end) and 5 inner view from male BL = 2.54 mm; (E) head dorsal view; (F–G) antenna 2 anteroventral view. Scale bars: (A): 1 mm; (B–G): 0.1 mm. Photos by B. Gouillieux.

setose, peduncle article 1 with 3 robust setae on ventral margin, proximal could be slightly curved, and 2 robust setae on proximal dorsomedial margin; peduncle article 2 shorter in length to article 1 without robust setae; peduncle article 3 the shorter; flagellum with 4 articles, second article the longest, second and third articles with 1 distal aesthetascs. Male antenna 2 pediform; peduncle article 3 almost rectangular with a ventrodistal pair of robust setae; peduncle article 4 longer than article 5, distal ventromedial corner with 1 short and 1 long acute process and 2 robust setae on proximal part of ventromedial margin; peduncle article 5 with 1 acute ventromedial and 1 distal falcate process; flagellum short and 3-articulate, distal article with 2 distal robust setae. Female antennae (Figure 3) as in males, except for antenna 2 peduncle article 4 slender, without process and with 3 single robust setae on ventral margin; peduncle article 5 without process or robust setae.

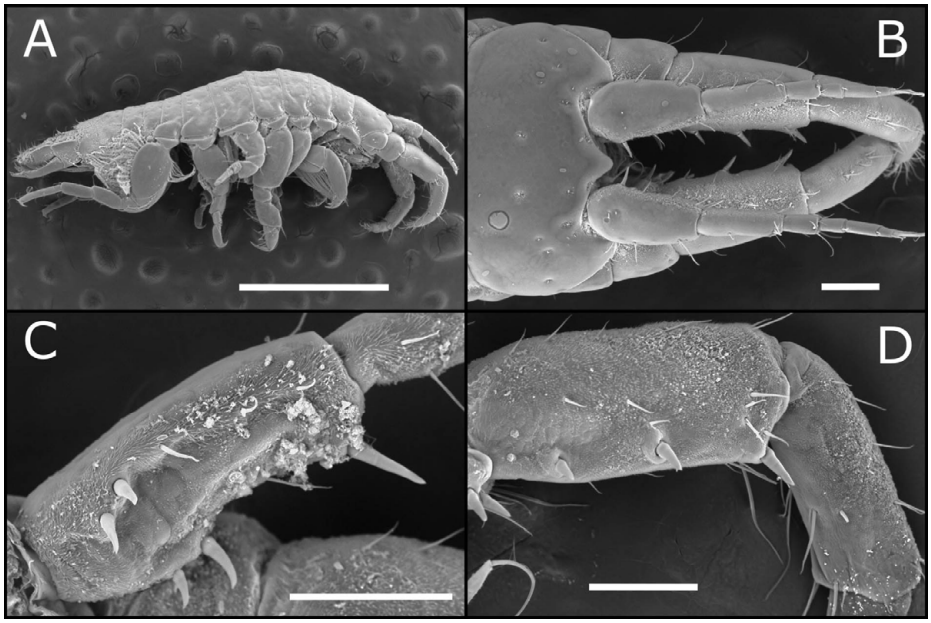

Figure 3. *Laticorophium baconi* (Shoemaker, 1934), female specimens from Sant Carles de la Ràpita, Spain, 5/vi/2018. (A) Lateral view; (B) head dorsal view; (C) antenna 1 peduncle article 1 inner view; (D) antenna 2 peduncle article 4 (end) and 5 inner view. Scale bars: (A): 1 mm; (B–D): 0.1 mm. Photos by B. Gouillieux.

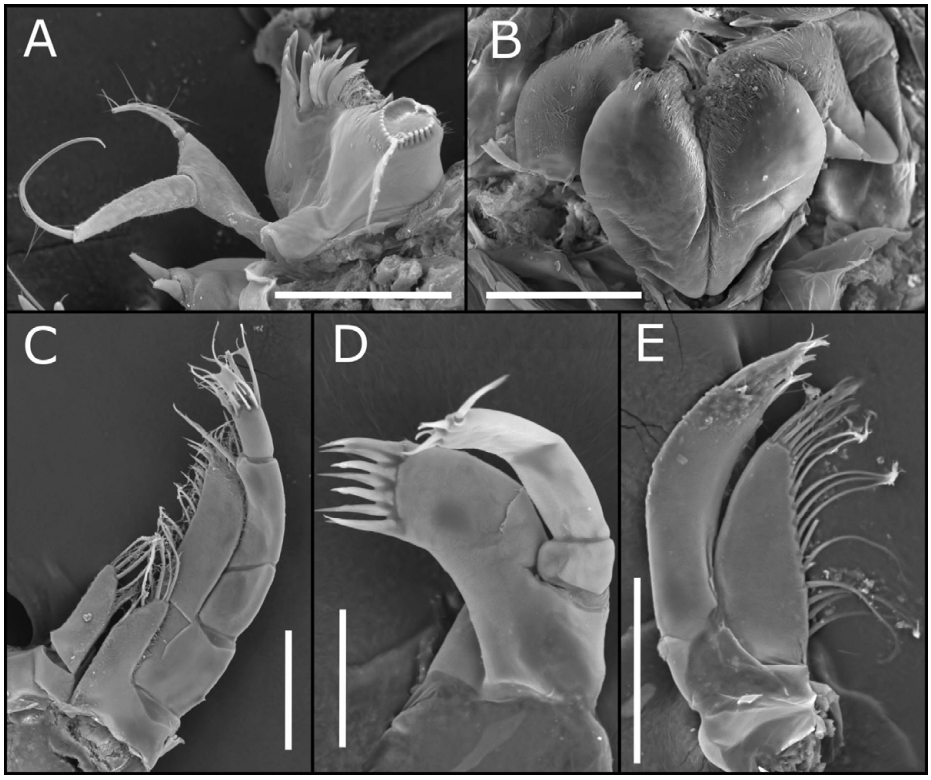

Figure 4. *Laticorophium baconi* (Shoemaker, 1934), specimens from Sant Carles de la Ràpita, Spain, 5/vi/2018. (A) Mandible; (B) lower lip; (C) maxilliped; (D) maxilla 1; (E) maxilla 2. Scale bars: (A–C, E): 0.1 mm; (D): 0.05 mm. Photos by B. Gouillieux.

Mouthparts (Figure 4): Mandible molar process with 1 long seta; palp article 1 distal margin produced distally, with 1 long pinnate seta (type P5 in Hirayama 1987b). Maxilla 1 palp exceeding outer plate, distal margin with 7 robust setae; outer plate with 7 robust setae. Maxilla 2 inner plate with

facial and apical plumose setae, outer plate with a row of apical plumose setae and many setules along outer margin. Maxilliped inner plate short, not broad, with distolateral plumose setae; outer plate with 10 plumose setae along inner and distal margin; palp 4-articulate, articles 2 and 3 with a row of plumose setae on distal and inner margins, article 4 with 1 distal strong robust seta.

Gnathopod 1 parachelate; coxa anterior margin acute, with 3 anterodistal plumose setae and 5 dorsal simple seta; basis slender, length 3.5 X breadth, with 1 simple seta on posterodistal margin; ischium with many plumose setae on posterodistal margin; merus subtriangular, subequal in length to ischium, with 3 posterodistal plumose setae; carpus length 2 X breadth, with 1 anterior and 3 anterodistal simple setae and a row of plumose along posterior margin; propodus subequal in length to carpus, with simple setae along posterior margin, 1 robust seta on palmar margin, palmar margin serrate; dactylus tip little exceeding palm, with 1 tooth on flexor margin (Figure 5A). Gnathopod 2 simple; coxa anterior margin acute, with 1 simple seta on distal margin; basis broad, length 1,5 X breadth, with 1 posterordistal and 1 anterodistal simple setae; ischium subrectangular, short, with 1 simple seta on posterodistal corner; merus with a row of long plumose setae along posterior margin; carpus subtriangular with 6 posterodistal long plumose setae; propodus 2 X longer than carpus, with 2 simple setae on anterior margin and a cluster of setae on anterodistal corner, 2 simple setae on posterior margin and a row of 8 plumose setae in proximal part of inner face; dactylus with 1 tooth on flexor margin (Figure 5B).

Coxae 3–5 with 1 long simple seta on ventral margin. Pereopod 3 coxa short and subtriangular; basis broad, 1.7 X longer than broad, anterior margin inflated medially and with 4 simple seta, 1 posterior and 2 posterodistal simple setae; ischium rectangular, with 3 simple seta on posterodistal corner; merus longer than wide, anterodistal margin slightly produced, with 1 simple seta on anterior margin, a cluster of simple setae on anterodistal corner, 2 simple seta on posterior margin and a 2 simple setae on posterodistal corner; carpus broader than longer with simple and plumose setae on posterior margin; propodus shorter in length to merus, with simple and plumose setae on posterior margin and 2 simple setae on anterodistal corner; dactylus as long as propodus. Pereopod 4 (Figure 5C) basis broad, length 1.9 X breadth, with 3 simple setae along anterior margin; others articles similar to pereopod 3, except for number of setae. Pereopod 5 (Figure 5D) coxa bilobed; basis broad, length 1.5 X breadth with 2 anterior and 5 posterior margins simple setae, 3 posterodistal and 3 anterodistal simple setae; ischium short, with 2 simple setae on posterodistal margin; merus with 2 simple setae on posterior margin, and clusters of setae on antero and posterodistal corners; carpus with 1 and 2 simple seta on antero and posterodistal corner respectively, 2 clusters of robust setae on outer face; propodus elongate, with 1 robust and 2 simple setae on anterior margin;

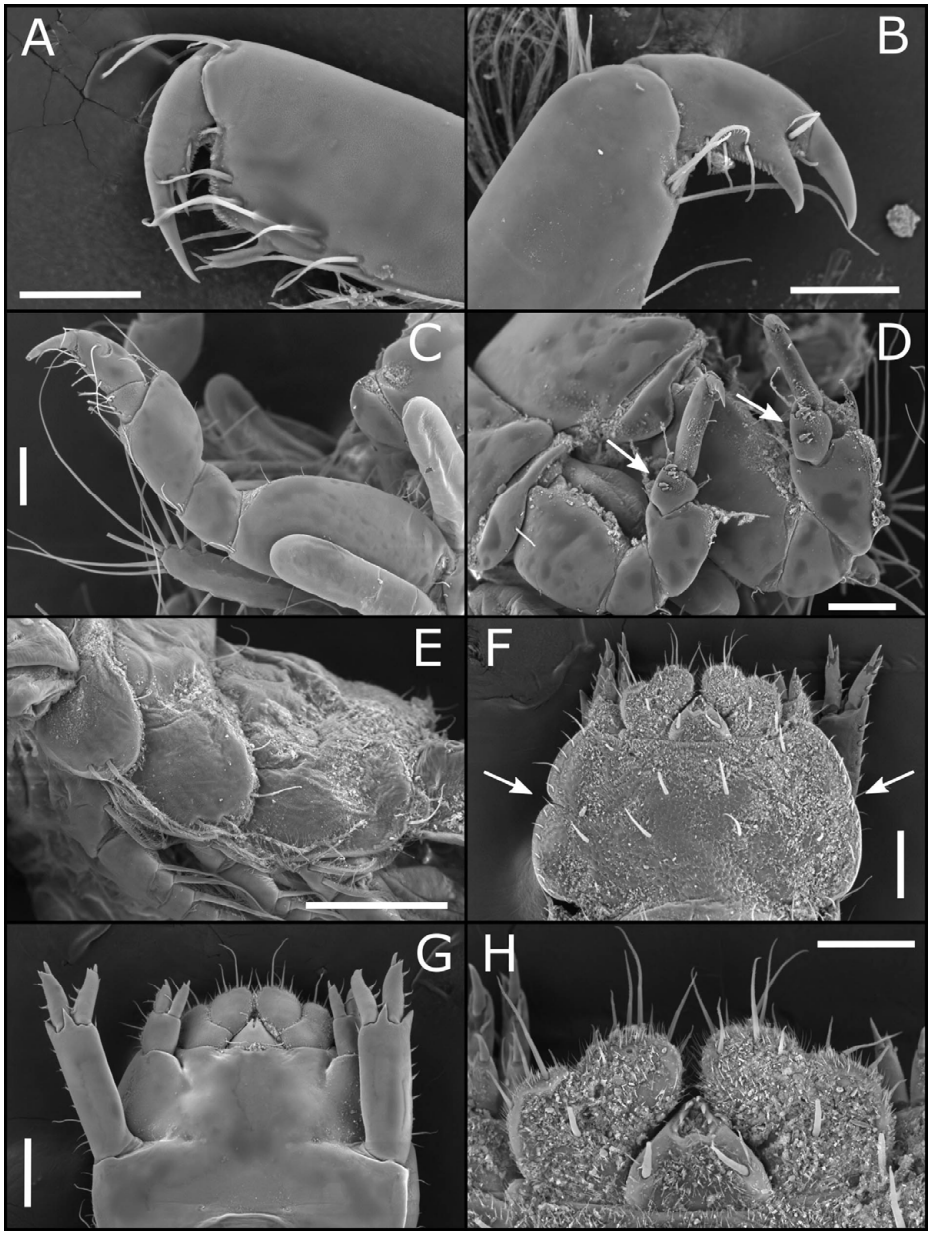

Figure 5. *Laticorophium baconi* (Shoemaker, 1934), specimens from Sant Carles de la Ràpita, Spain, 5/vi/2018. (A) Gnathopod 1 distal end of propodus and dactylus; (B) gnathopod 2 distal end of propodus and dactylus; (C) pereopod 4; (D) pereopods 5 and 6 with clusters of robust setae on carpus (white arrows); (E) left epimeral plates 1–3; (F) pleotelson dorsal view with lateral notches (white arrows); (G) pleotelson ventral view; (H) uropod 3 and telson dorsal view. Scale bars: (A, B, H): 0.05 mm; (C–G): 0.1 mm. Photos by B. Gouillieux.

dactylus short, with 1 seta on posterior margin. Pereopod 6 (Figure 5D) coxa bilobed; basis 1.7 X longer than broader, with 5 simple setae and a row of 5 plumose setae along anterior margin, 2 simple setae along posterior margin and 3 simple setae on posterodistal corner; ischium with 2 simple seta on posterodistal corner; merus with 2 simple, 3 finely plumose setae and many setule along posterior margin, 1 simple setae on anterior margin and a cluster on anterodistal corner; carpus with simple setae on distal part and 2 clusters of robust setae on outer face; propodus elongate, with 2 simple setae on posterior margin and 2 simple setae on

anterodistal margin; dactylus curved anteriorly. Pereopod 7 coxa bilobed; basis length 1.5 X breadth, with a row of plumose setae on both of margins; ischium about ½ merus length, with 2 simple setae on anterodistal corner; merus with 3 and 4 simple setae along anterior and posterior margin respectively; carpus subequal to merus, with 3 and 5 simple setae on anterior and posterior margins respectively; propodus elongate, longer than carpus, with simple setae along posterior and anterior margin, setae on posterior margin long; dactylus curved anteriorly.

Epimeral plate 1 ovate with 1 posterior simple and 2 ventral plumose setae; epimeral plate 2 with 2 posterior simple and 2 ventral plumose setae; epimeral plate 3 subrectangular, hind corner rounded, with 1 posterior simple and 1 ventral plumose setae (Figure 5E). Pleopods 1–3 similar to each other; peduncle stout, outer margins with plumose setae, inner margins with 2 coupling spines; rami with basal articles longer and broader than distal articles, inner ramus little longer than outer ramus. Urosomites 1–3 (Figure 5F–G) fused, with distinct lateral marginal convex and notch. Uropod 1 biramous, inserted ventrally; peduncle with 1 outer and 1 interramal acute teeth, simple proximal and 3 or 4 robust setae along outer margin; rami with 3 robust setae along outer margin, 1 subapical robust seta on inner margin, 1 short and 1 very long robust setae on apex. Uropods 2–3 with many setules on posterior and dorsal margins. Uropod 2 biramous, peduncle with 4 simple setae on outer margin; rami with 2 or 3 simple setae on outers margins and 1 robust seta on apex. Uropod 3 uniramous; peduncle slightly produced distally, with 1–2 simple setae on outer and dorsal margins; ramus ovate, shorter to peduncle, rounded apically, with a row of simple setae along distal margin. Telson small, rounded apically, with robust setae tooth-like on the dorsodistal depression (Figure 5H).

Variability

Antenna 1 peduncular article 1 ventral margin with 2 to 4 of robust setae, with sometimes no left-right symmetry, number of robust setae inversely proportional to maturity, first(s) one(s) could be curved for young specimens; proximal dorsomedial margin with 1 or 2 robust setae. Widest male antenna 1 peduncle article 1 and 2, antenna 2 peduncle article 5 and flagellum with distinctly more and longer simple setae. Male antenna 2 peduncular article 4 and 5 distal teeth size and orientation, as well as peduncular article 5 position, size and orientation of median tooth depending of maturity (Figure 2C, D, F, G). Gnathopod 1 propodus with or without setae on anterior margin. Number of simple and plumose setae on pereopods and epimeral plates 1–3 function of sex and maturity, as well as number of robust setae composing the clusters on carpus of pereopod 5 and 6. Urosome lateral notch more or less pronounced.

Discussion

Laticorophium

The genus *Laticorophium* was originally composed of only one species: *Laticorophium baconi*, present in North American Pacific and Atlantic coasts, North Asiatic Pacific region, Brazilan waters, and Australian waters (Hirayama 1986; Bousfield and Hoover 1997; Lecroy 2004; Valério-Berardo and De Souza 2009; Ahyong and Wilkens 2011). In 2016, Myers and Nithyanandan described a new *Laticorophium* species from Sea City (Kuwait): *Laticorophium bifurcatum*. They distinguished their species from *L. baconi* by (1) the presence of a strong process in male A2 article 5, (2) the absence of robust setae in male A2 article 4 and (3) the process in male A2 article 4 opposed to recurved. Size, disposition and orientation of male antenna 2 article 4 and 5 process is function of maturity, as observed by Shoemaker (1949), Otte (1975) and in the present paper. Indeed, the only character which distinguished the two species was the absence of robust setae in male antenna 2 article 4. Based on this observation, *Laticorophium baconi* records by Bousfield and Hoover (1997) and Valério-Berardo and De Souza (2009) probably refer to *L. bifurcatum*, but further study is recommended to confirm this hypothesis.

Laticorophium baconi was originally well described and illustrated by Shoemaker (1934) from California, North East Pacific Ocean. The species has since been recorded from the Peru coasts to the Bering Sea, Hawaii, Gulf of Mexico, Brazil coast and China Sea (Barnard 1970, 1971; Hirayama 1986; Otte 1975; Bousfield and Hoover 1997; Lecroy 2004; Valério-Berardo and De Souza 2009). The present specimens are in agreement with the original and subsequent descriptions (Supplementary material Table S1) except for Bousfield and Hoover (1997) and Valério-Berardo and De Souza (2009) (see above). The presence of the species in a marina, which had been observed in other areas (Chapman 2007; see the review by Marchini and Cardeccia 2017), on a buoy with fouling, suggests its presence is probably due to shipping. The large sampled population, with brooding and ovigerous females, implies a well-established population in the marina, and individuals are potentially present in adjacent marinas. Due to its resemblance with the cosmopolitan species *Apocorophium acutum* (Chevreux, 1908), with urosome segments fused, uropod 1 inserted ventrally and male antenna 2 process, the two species can be easily confused, and misidentifications may have been done in previous studies.

Laticorophium baconi was previously considered as a species of the open sea (Barnard 1971), but has been sampled on mussel beds and on metal panels which had been immersed (Hirayama 1986). In the present study, *L. baconi* was recorded with hydroids and red algae on a buoy in a silted marina situated in a bay, whereas in Vinaròs marina, an open sea marina, no specimens were recorded. The absence of *L. baconi* in Vinaròs marina

could be explained by the difference in habitat, or due to non-introduction of the species in this area for the moment. A monitoring of Corophiini species in the adjacent marinas to San Carles de la Ràpita would therefore be appropriate to follow the spread of *L. baconi* in Spanish waters, and therefore in other European waters (see the recent study by Martínez-Laiz et al. 2019 across the Mediterranean Sea).

Tribe Corophiini

Bousfield and Hoover (1997) provided a revision for the tribe Corophiini. They described many new genera and species and proposed a key to world genera based on type species. The record of *Laticorophium baconi* on the Mediterranean coast of Spain led to studying the species characterized by urosome segments fused with uropod 1 arising mainly ventrally: *Apocorophium* Bousfield and Hoover, 1997, *Hirayamaia* Bousfield and Hoover, 1997, *Laticorophium* and *Lobatocorophium* Bousfield and Hoover, 1997. *Lobatocorophium* can be easily distinguished from the other genera by a grossly enlarged uropod 2, and *Laticorophium* by gnathopod 2 dactylus with one tooth on the flexor margin and a urosome with the lateral margin notched. *Apocorophium* and *Hirayamaia* are two close morphological genera. The genus *Hirayamaia* is represented by three species: *H. hongkongensis* (Hirayama, 1986), *H. mortoni* (Hirayama, 1986) (type species) and *H. tridentia* (Hirayama, 1986). Following the Bousfield and Hoover (1997) key, *Hirayamaia* can be distinguished from *Apocorophium* by having straight or slightly indented (versus convex) urosome lateral margins, a gnathopod 2 propodus with minute palm and cusp (versus propodus lacking palm or cusp), and a dactylus with 1 (2) tooth on the flexor margin (versus 2–4 teeth). Unfortunately, *H. hongkongensis* is characterized by convex urosome lateral margins, while *H. tridentia* has a dactylus with three teeth on the flexor margin. The morphology of the urosome margin (i.e., between straight and slightly convex) can sometimes be subjective, whereas the dactylus tooth is a relatively stable character within a species: without / with one / with two or more teeth. *H. tridentia* presents one tooth on the gnathopod 2 dactylus flexor margin and uropod 2 has rami that are marginally not bare (*vs* bare in *Hirayamaia* genus diagnose). Due to these two morphological characters which are closer to *Apocorophium* than *Hirayamaia* diagnoses, we propose to change *Hirayamaia tridentia* to *Apocorophium tridentia* and modify the Bousfield and Hoover (1997) key for Corophiini species characterized by urosome segments fused with uropod 1 arising mainly ventrally as follows:

10. Uropod 2 large, broad, larger than uropod 1 (Figure 6A) ....*Lobatocorophium*

— Uropod 2 relatively inconspicuous, distinctly smaller than uropod 1 (Figure 6B) 11

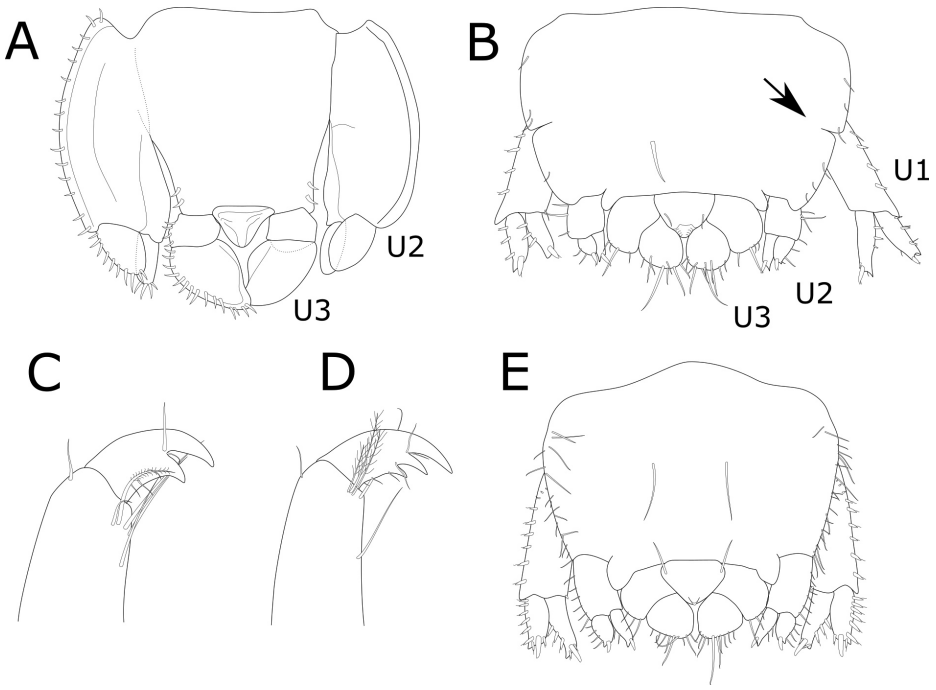

Figure 6. A, B, E: pleotelson, dorsal view; C, D: gnathopod 2 distal end of propodus and dactylus. (A) *Lobatocorophium lobatum* (Hirayama, 1987), after Hirayama 1987a; (B–C) *Laticorophium baconi* (Shoemaker, 1934), specimen from Sant Carles de la Ràpita, Spain, 5/vi/2018; (D–E) *Hirayamaia mortoni* (Hirayama, 1986), after Hirayama 1986.

11. Gnathopod 2 dactylus with 1 tooth on flexor margin (Figure 6C) 12
— Gnathopod 2 dactylus with 2 or 3 teeth on flexor margin (Figure 6D) ..... *Apocorophium*
12. Urosome lateral margin notched (Figure 6B, black arrow) .... *Laticorophium*
— Urosome lateral margin smooth (Figure 6E) ..... *Hirayamaia*

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Supplementary material

The following supplementary material is available for this article:

Table S1. Main morphological characters for *Laticorophium baconi* (Shoemaker, 1934) in original and subsequent descriptions and for *Laticorophium bifurcatum* Myers and Nithyanandan, 2016.

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