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A New Sponge Associated Shrimp of the Genus *Periclimenaeus* Borradaile, 1915 (Decapoda, Palaemonidae) from the Tropical Eastern Atlantic, Cabo Verde Islands

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A new species of the caridean shrimp genus *Periclimenaeus* is described from the Cabo Verde Islands, tropical eastern Atlantic. *Periclimenaeus ramili* sp. nov. is morphologically most similar to the north-eastern Atlantic *P. aurae* dos Santos, Calado & Araújo, 2008, the western Atlantic *P. pearsei* (Schmitt, 1932), and particularly the eastern Pacific *P. hancocki* Holthuis, 1951, all sharing many features, especially the reduced incisor process of the mandible, the general shape of the second pair of chelipeds and ambulatory pereiopods, and the telson armament. Based on these features, a new species group is established here to include these four species. *Periclimenaeus ramili* sp. nov. can be readily distinguished from *P. aurae* and *P. pearsei* by the shape of the dactylus of the first pereiopod chela. From *P. hancocki*, the new species can be distinguished, among other features, by the shorter rostrum armed with lower number of dorsal teeth, the relative length of the scaphocerite to the antennular peduncle, and by the slender distal articles of the third maxilliped. The new species is also reported to excavate its own burrows for living inside its sponge host, a behaviour previously unknown in species of the genus.

Key words: West Africa, Caridea, *Periclimenaeus*, Species group, Sponge.

BACKGROUND

The caridean shrimp genus *Periclimenaeus* Borradaile, 1915 is the second most speciose symbiotic palaemonid shrimp genus, currently comprising 86 species worldwide, the vast majority of them occurring in the shallow tropical waters of the Indo-West Pacific region (Bruce 2013a 2014a b c d; De Grave and Fransen 2011; Park and De Grave 2021a b). Out of these species, 15 are known to occur in the Atlantic Ocean, with only one being reported from the eastern Atlantic so far (dos Santos et al. 2008; Ramos-Tafur and Lemaitre 2017). However, the number of *Periclimenaeus* species occurring in the eastern Atlantic is underestimated, possibly as a consequence of the low sampling effort targeting suitable hosts for this genus in the area and, at least two more species, are present in the Cabo Verde Islands (author's personal observation).

The main diagnostic feature characterizing species belonging to the genus *Periclimenaeus* is the presence of a molar process on the major second cheliped dactylus, with a corresponding fossa on the pollex (see Bruce 2012a for a revised diagnosis of the genus). However, the genus represents an increasing morphologically heterogenous grouping exhibiting remarkable diversity in the molar-fossa arrangement, and in many other features, for instance, in the minor second cheliped and ambulatory pereiopods. Since preliminary molecular analysis do not support the monophyly of *Periclimenaeus* (Gan et al. 2015), it becomes evident that a comprehensive review of the genus using both morphology and molecular analysis, which is beyond

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the scope of the present work, is highly needed to resolve its taxonomy.

Recently, some interesting specimens of *Periclimenaeus*-like shrimps were collected inside demosponges growing under large rocks. After a careful morphological examination, these specimens were recognized as belonging to an undescribed species of *Periclimenaeus*, closely related to the north-eastern Atlantic *P. aurae* dos Santos, Calado and Araújo, 2008, the western Atlantic *P. pearsei* (Schmitt, 1932), and particularly the eastern Pacific *P. hancocki* Holthuis, 1951. The new species, which represents the first record of this genus in the Cabo Verde Archipelago and the tropical eastern Atlantic as a whole, is described and illustrated in the present study.

MATERIALS AND METHODS

Sampling collection

During 2019 and 2020, sporadic samplings were conducted in two localities in the São Vicente Island, Cabo Verde Archipelago, specifically focused on ecologically cryptic shrimps' species. While snorkelling, suitable sponge hosts were manually collected under large rocks between 0.5 and 4 m depth, placed into numbered plastic bags, and transported to the laboratory. The sponges were carefully dissected, and shrimps removed from their internal cavities. When possible, shrimps and sponge hosts were photographed before being preserved in 75% or 96% ethanol, or frozen in seawater.

Morphological study

Morphological characters were examined under dissecting and light microscopes. Drawings were made under a dissecting microscope (Nikon SMZ1000) equipped with a drawing tube, then scanned, vectorized, and arranged into digital plates using Adobe Illustrator CC 2018. Most of the complex setae on the mouthparts have been simplified in the illustrations to show only general setation presence, with most microscopic details omitted. Mouthparts and chelae (held with dactyli laterally) are described in standard position, regardless their real anatomical position. Measurements (in mm) are provided for postorbital carapace length (pocl), measured from the posterior orbital margin to the posterior margin of the carapace in the dorsal midline. About 2–3 mm thick sections of a sponge host were hand-made from different parts of the sponge, cleared with xylol, or dissolved with bleach, mounted on temporary slides, and then observed in light microscope to identify the sponges and observe how the shrimps cut the sponges.

Type material was deposited into the zoological collections of the Naturalis Biodiversity Centre, Leiden (RMNH), the Netherlands and in the reference collection of the Instituto Superior de Engenharias e Ciências do Mar, Universidade Técnica do Atlântico (IECM, UTA), Mindelo, São Vicente Island, Cabo Verde.

RESULTS

TAXONOMY

Family Palaemonidae Rafinesque, 1815
Genus *Periclimenaeus* Borradaile, 1915

Periclimenaeus ramili sp. nov.

(Figs. 1–5)

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Material examined: Holotype. 1 male (pocl 4.2 mm, dissected), Cabo Verde Archipelago, São Vicente Island, Baía das Gatas (16°54'11.0"N 24°54'22.3"W), snorkelling, depth 1 m, in *Spongia* sp. growing under large rock, 12 Dec. 2020, leg. K. Neves (RMNH.CRUS.D.57969). Allotype. 1 ovigerous female (pocl 5.8 mm), same collection data as for holotype (RMNH.CRUS.D.57970). Paratypes. (I) 1 male (pocl 4.0 mm) and 1 ovigerous female (pocl 4.4 mm), same location as for holotype, snorkelling, depth 2–3 m, in *Spongia* sp. growing under large rock, 12 Dec. 2020, leg. K. Neves (RMNH.CRUS.D.57971); (II) 1 male (pocl 4.1 mm) and 1 ovigerous female (pocl 4.4 mm), same location as for holotype, snorkelling, depth 0.5 m, in *Spongia* sp. growing under large rock, 12 Dec. 2020, leg. K. Neves (RMNH.CRUS.D.57972); (III) 1 male (pocl 3.5 mm) and 1 ovigerous female (pocl 4.0 mm), same location as for holotype, snorkelling, depth 2–3 m, in *Spongia* sp. growing under large rock, 12 Dec. 2020, leg. K. Neves (UCV00346); (IV) 1 male (pocl 3.0 mm) and 1 ovigerous female (pocl 4.0 mm), same location as for holotype, snorkelling, depth 2–3 m, in *Spongia* sp. growing under large rock, 12 Dec. 2020, leg. K. Neves (UCV00347); (V) 1 male (pocl 4.1 mm) and 1 ovigerous female (pocl 4.6 mm), Cabo Verde Archipelago, São Vicente Island, Porto Grande Bay, Enseada de Corais da Matiota (16°53'47.6"N 24°59'33.6"W), snorkelling, depth 3 m, in *Spongia* sp. growing under large rock, 21 Sep. 2019, leg. K. Neves (RMNH.CRUS.D.57973); (VI) 1 male (pocl 3.2 mm) and 1 ovigerous female (pocl 4.3 mm), same location as previous specimens,

snorkelling, depth 3 m, in *Spongia* sp. growing under large rock, 20 Jun. 2020, leg. K. Neves (UCV00348); (VII) 1 male (pocl 3.2 mm) and 1 ovigerous female (pocl 4.4 mm), same location as previous specimens, snorkelling, depth 3 m, in *Spongia* sp. growing under large rock, 20 Jun. 2020, leg. K. Neves (UCV00349).

Other material examined

Male (not measured; mouthparts dissected for comparison) and ovigerous female (not measured; stomach dissected for analysis of content and mouthparts dissected for comparation), same location as for holotype, snorkelling, depth 4 m, in *Spongia* sp. growing under large rock, 12 Dec. 2020, leg. K. Neves (not deposited); 2 immature specimens (pocl 1.0, 1.2 mm) same location as for the previous specimens (not deposited).

Description of male holotype: Median sized palaemonid shrimp of subcylindrical body (Fig. 5A).

Rostrum (Fig. 1A–C) short, slender, compressed, 0.2 of post orbital carapace length, directed downwards, with tip failing to reach end of first segment of antennular peduncle; with 4 slender, acute dorsal teeth, all anterior to posterior orbital margin; tip short, acute; ventral margin nearly straight, unarmed.

Carapace (Fig. 1B–C) smooth, without epigastric, supraorbital, or hepatic spines; antennal spine present, well developed; inferior orbital angle not produced, with distinct angular process; pterygostomial angle broadly rounded.

Pleon smooth (Fig. 1D); first segment (Fig. 1E) with shallow, almost indistinct anteromedian dorsal lobe; pleura rounded, anteriorly rounded on third segment, posteriorly produced, rounded on fourth and fifth segments, sixth segment (Fig. 1F) 1.25 length of 5th segment, about 0.5 telson length, with posterolateral angle small, rounded, posteroventral angle produced, acutely rounded.

Telson (Fig. 1F–G) almost twice as long as maximal width; lateral margins convex, posteriorly convergent; dorsal surface with 2 pairs of spines, about 0.1 of telson length, situated at 0.1 and 0.55 of telson length, respectively; posterior margin convex, with 3 pairs of spiniform setae, outer pair short, intermediate pair long, slender, median pair slightly shorter than intermediate pair, setulose.

Eyes (Fig. 1B–C) well developed, cornea rounded, set obliquely on stalks, without accessory pigmented spot; stalk short, mesial length subequal to corneal diameter; distal margin of cornea reaching to about 0.8 length of first antennular segment.

Antennule (Fig. 1H) well developed; peduncle with basal article 2.7 times as long as central width, without ventromedial tooth; statocyst well developed, with statolith; stylocerite short, acute, broad, not reaching middle of segment; lateral margin of article forming a blunt angle at level of stylocerite tip, slightly tapering distally, distolateral tooth well developed, reaching middle of intermediate article; intermediate article about 0.3 of proximal article length, almost as long as wide; distal article slightly longer than preceding, length subequal to width; upper flagellum biramous, 7 proximal articles fused, short free ramus with three articles, about 10 groups of aesthetascs, longer free ramus slender, with about 9 subdivisions; lower flagellum similar, slender, broken off, with at least 12 subdivisions.

Antenna (Fig. 1I) with rounded boss proximo-mesially on coxa; stout, unarmed basicerite; ischiocerite and merocerite with few simple setae, otherwise without special features; carpocerite subcylindrical, with some small simple setae distally, longer than scaphocerite; scaphocerite short, about twice as long as broad, broadest at about 0.7 of length, rounded distally, reaching to about end of second article of antennular peduncle, lateral margin slightly convex, with distal tooth not overreaching lamella; flagellum moderately long.

Mouthparts from left side dissected.

Right mandible (left damaged during dissection) (Fig. 2A) without palp; incisor process strongly reduced, short, simple, tapering to single rather blunt distal tooth, mesial margin unarmed; molar process well developed, subcylindrical, truncate distally, with spine-like tuft of long setae proximally on dorsal margin, with dense brushes of short setae and single, blunt tooth distally; inferior margin with dense rows of setae.

Maxillula (Fig. 2B) with feebly bilobed palp, lower lobe slightly produced with simple terminal seta; upper lacinia short, moderately broad, dorsal margin convex, distal margin truncate, with about 7 stout marginal spines, and some slender setae; lower lacinia elongate, slender, distally rounded, with about 12 simple setae.

Maxilla (Fig. 2C) with non-setose tapering palp, distally rounded, about 3.3 times longer than basal width; basal endite with lobes fused, slender, tapering, rounded distally, with nine setae distally; coxal endite obsolete, non-setose; scaphognathite normal, broad, length about 3 times central width, anterior lobe 1.2 times longer than wide, mesial margin slightly convex, posterior lobe broadly rounded, 2 times longer than basal width; all margins bearing short plumose setae.

First maxilliped (Fig. 2D) with slender flattened palp, tapering, distally rounded, about 4 times longer than central width, with single seta on mesial margin; basal and coxal endites completely fused, distally

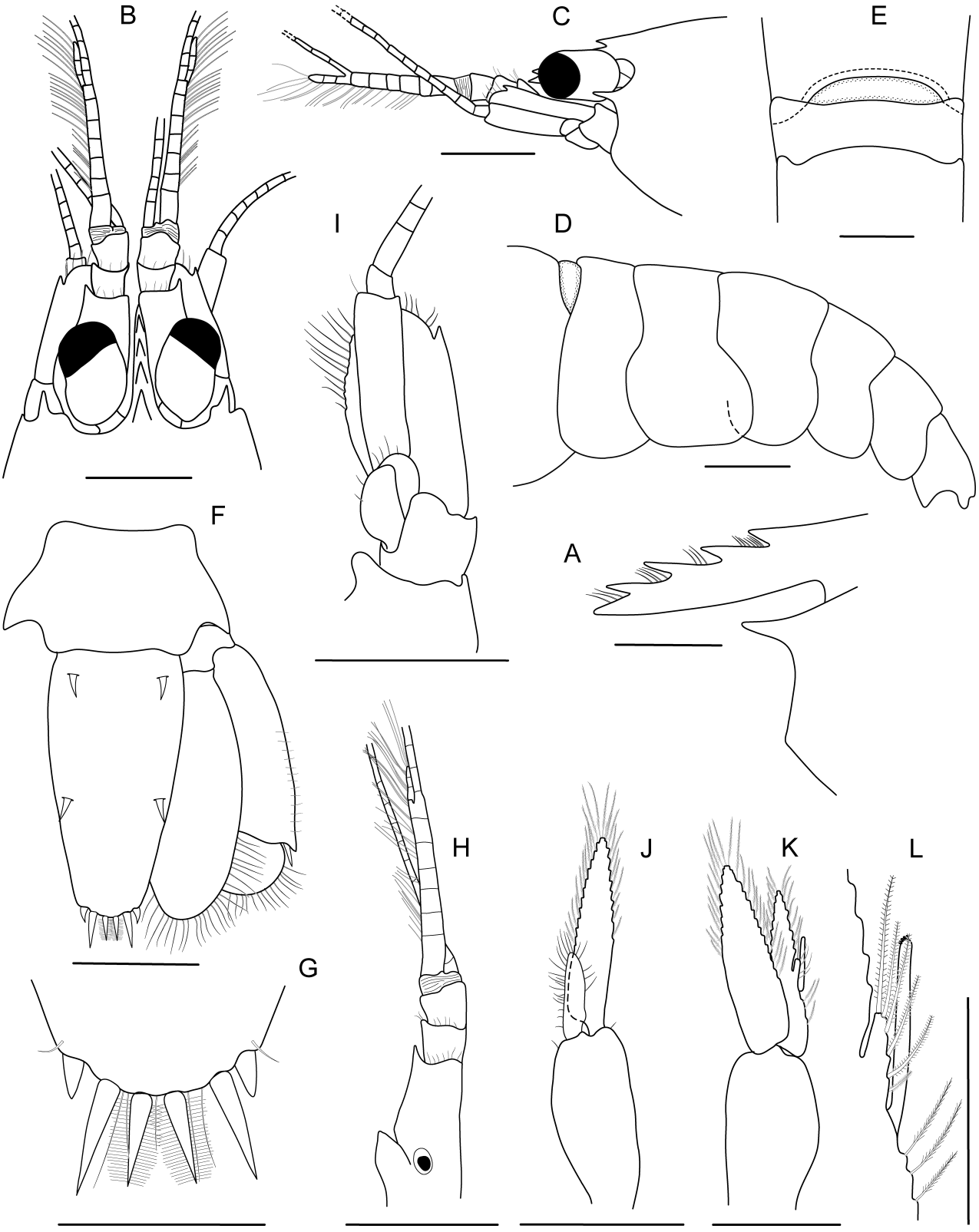

Fig. 1. *Periclimenaeus ramili* sp. nov., male holotype (RMNH.CRUS.D.57969): A, rostrum, lateral; B, frontal region of carapace and appendages, dorsal view; C, same, lateral view; D, pleon, lateral view; E, posterior carapace and first pleonite, dorsal view; F, sixth pleonite, telson and uropod, dorsal view; G, posterior margin of telson, dorsal; H, antennule, dorsal view; I, antenna, ventral view; J, first pleopod; K, second pleopod; L, same, appendices masculina and interna. Scale bar: B–F, H–K = 1 mm; A, G, L = 0.5 mm.

rounded, mesial margin almost straight, with numerous slender setae; exopod with normal flagellum, with 11 plumose setae distally; caridean lobe large, 2.5 times longer than central width; epipod well developed, rounded, bilobed.

Second maxilliped (Fig. 2E) with normally developed endopod, dactylar segment narrow, about 3 times longer than maximal width, distomesial margin almost straight, with rows of long marginal setae; propodal segment with distomesial margin slightly produced, bearing 8 setae; carpus, merus and ischiobasis without special features; coxa mesially rounded; exopod normal, with 13 plumose setae distally; epipod small, elongate, rounded distally, without podobranch.

Third maxilliped (Fig. 2F) with slender endopod; coxa non-setose, lateral plate short, broadly rounded, arthrobranch absent; basis with ventral margin rounded; ischiomerus completely fused to basis, without suture, combined segment 3.3 times longer than basal width, tapering distally, with series of long and short setae mesially and short distolateral seta; penultimate segment slender, 4.15 times longer than wide, 0.7 of ischiomerus and basis length combined, with numerous long setae mesially and long distomesial setae, distolateral margin with four simple setae; terminal segment about 0.7 of penultimate segment length, slender, tapering distally, with dense tuff of setae medially, lateral margin with long and short setae; exopod well developed, reaching to distal half of penultimate segment, distal third with 6 and 5 plumose setae laterally and mesially, respectively, and 4 stouter and longer terminal plumose setae.

Thoracic sternites narrow, unarmed.

First pereiopod (Fig. 3A–B) moderately robust, overreaching scaphocerite by length of chela and carpus. Chela with palm subcylindrical, compressed, 1.3 times longer than deep; fingers about as long as palm, stout, subspatulate, cutting edges entire, tips with three terminal teeth, central tooth larger than adjacent teeth, bearing dense tufts of serrulate setae, dorsal margin of dactylus regularly sloping towards tip; carpus about 4 times longer than distal width, 1.3 times as long as chela, tapering proximally; merus 3.5 times longer than maximal width at about half length of segment and as long as carpus; ischium short, stout, about as broad as merus, 1.6 times longer than broad, about half as long as merus; basis and coxa without special features.

Second pereiopods well developed, robust, unequal in size, dissimilar in shape. Major second pereiopod (Fig. 3C–E) with chela about 1.8 of pocl; palm bearing minute granules mesially, outer surface smooth, 1.8 times longer than maximal depth, swollen proximally, oval in cross-section, tapering slightly distally; fingers 0.25 of palm length, distal parts strongly twisted mesially, sparsely setose; dactylus slightly exceeding fixed finger, high, compressed, about 1.6 times as long as central depth, dorsal margin strongly convex, with stout, sharp, hooked tip, cutting edge convex, entire, laminar, sharp, thickened proximally in a compressed, low and poorly demarcated small molar process, which is indistinct is lateral view; fixed finger tapering distally, with blunt tip, about 1.2 times as long as basal depth, with fossa proximally for reception of dactylar molar process, mesial margin with triangular process, distal part of cutting edge concave, sharp, entire; carpus short, about 0.3 of palm length, distally expanded, approximately as long as distal width, strongly tapering proximally, unarmed; merus 1.7 times as long as broad, 0.9 of carpus length and 0.3 of palm length, with 6 blunt tubercles ventrally; ischium about as long as merus, tapering proximally, 1.7 times longer than distal width, unarmed; basis and coxa robust, short, without special features.

Minor second pereiopod (Fig. 3F–G) smaller than major second pereiopod, with chela about 0.7 of pocl and 0.4 of major chela length; palm bearing small tubercles mesially, otherwise smooth, sub-rectangular in lateral view, 2.4 times as long as maximal height, tapering slightly distally; fingers about 0.3 of palm length; dactylus compressed, somewhat longer than fixed finger, about 1.6 times longer than maximal depth at midlength, dorsal margin strongly convex, with stout, sharp, strongly hooked tip, cutting edge slightly convex, entire, laminar, sharp; fixed finger tapering distally, with blunt tip, about 1.1 times as long as basal depth; carpus about 0.4 of palm length, distally expanded, about 1.4 times as long as high, smooth; merus stout, about as long as carpus, 1.8 times as long as central depth, unarmed; ischium slightly longer than merus, unarmed; basis and coxa short, without special features.

Ambulatory pereiopods of usual shape for genus, similar, with third pereiopod strongest. Third pereiopod (Fig. 4A–B) with dactylus biunguiculate, short, 0.2 of propodus length, compressed, with apex recurved; unguis distinctly demarcated from corpus, curved, 2.6 times longer than basal width and 0.3 of dorsal corpus length, simple; corpus about as long as deep, dorsal border convex, ventral margin concave, armed with large, acute, recurved distal accessory tooth slightly shorter and stouter than unguis; ventral margin posterior to accessory tooth smooth; propodus 6.3 times as long as distal width and about 4.9 times longer than dactylus, with pair of stout distoventral spiniform setae and 3 irregularly spaced spiniform setae along ventral margin decreasing in size posteriorly, with setae distally on dorsal, lateral and mesial margins; carpus about as stout as propodus, slightly tapering proximally, 0.9 of propodus length, 3.5 times as long as distal width, unarmed; merus very stout, about 3 times as long as

broad, 1.25 of propodus length and 1.4 times as long as carpus, unarmed; ischium about twice as long as distal deep, 0.6 times length of merus, tapering proximally, unarmed; basis and coxa short, without special features.

Fourth pereiopod (Fig. 4C–D) similar and subequal in length to third pereiopod, slenderer; dactylus biunguiculate, short, 0.27 of propodus length, recurved and compressed; unguis distinctly demarcated from corpus, curved, simple; corpus about as long as deep, dorsal border convex, ventral margin concave, simple, with large, acute distal accessory tooth, strongly curved, subequal to unguis; propodus 7 times as long as distal width and 3.75 times longer than dactylus, with pair of stout distoventral spiniform setae and two

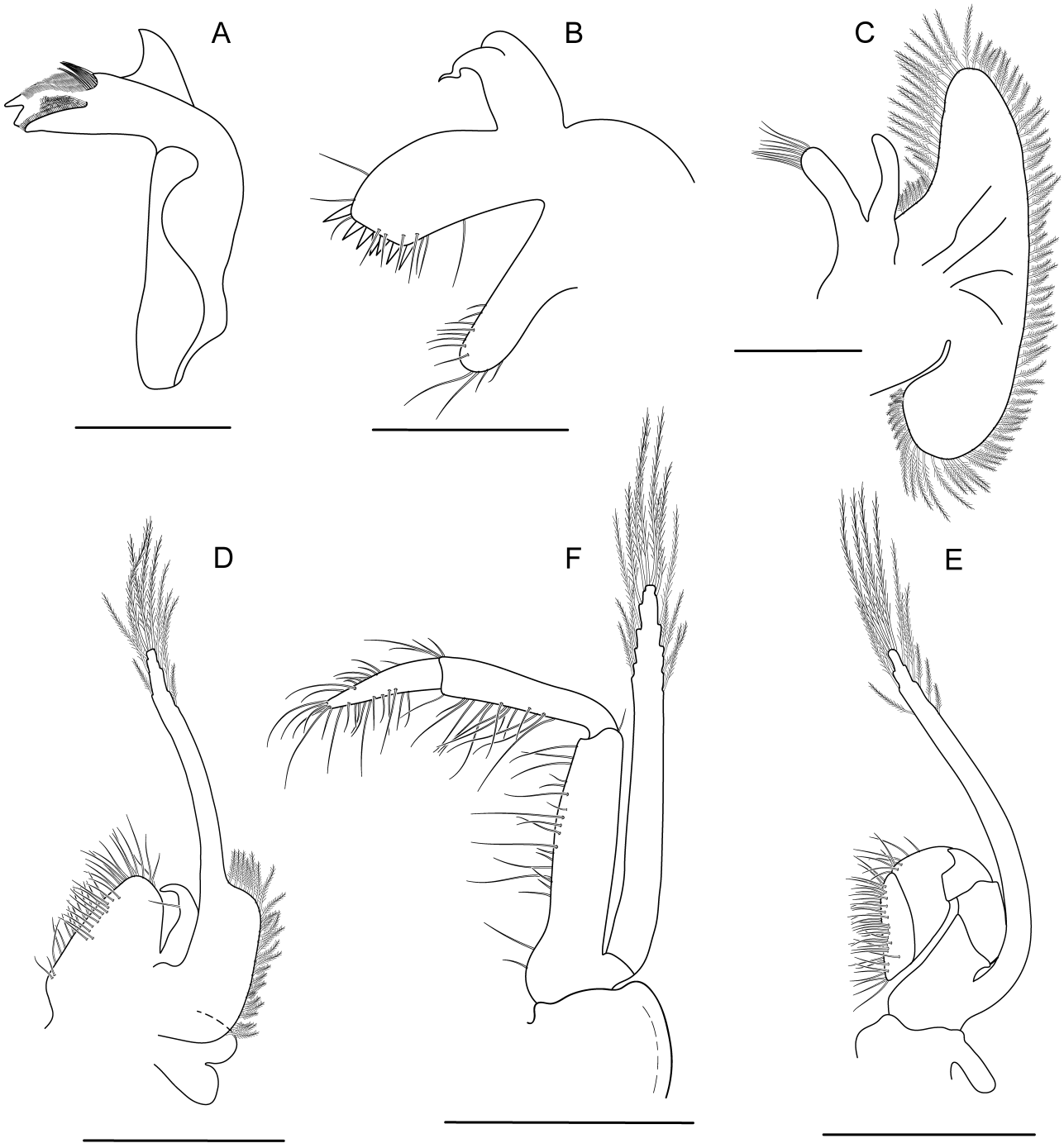

Fig. 2. *Periclimenaeus ramili* sp. nov., male holotype (RMNH.CRUS.D.57969): A, right mandible; B, left maxillula; C, left maxilla; D, left first maxilliped; E, left second maxilliped; F, left third maxilliped. Scale bar: A–C = 0.5 mm; D–E = 1 mm.

spiniform setae along ventral margin, with setae distally on dorsal, lateral and mesial margins; carpus 0.87 times of length of propodus, 3.7 times as long as distal width, unarmed; merus stout, about 3.3 times as long as broad and 1.4 times length of carpus, unarmed; ischium 2.7 times as long as distal width, 0.7 of length of merus, unarmed; basis and coxa short, without special features.

Fifth pereiopod (Fig. 4E–F) slenderer than third and fourth pereiopods, subequal in length; dactylus biunguiculate, short, 0.15 of propodus length, recurved and compressed; unguis distinctly demarcated from corpus, curved, simple; corpus slightly longer than depth, dorsal border convex, ventral margin concave, simple, with large, acute distal accessory tooth strongly curved, subequal to unguis; propodus 8.3 times as long as wide and 6.4 times longer than dactylus, with distoventral tufts of setulose setae and with setae distally on dorsal, lateral and mesial margins; carpus 0.8 of length of propodus, 4.3 times as long as distal width, unarmed; merus about 4.2 as long as mesial width and 1.4 times length of carpus, unarmed; ischium about half as long as merus and twice as long as wide, unarmed;

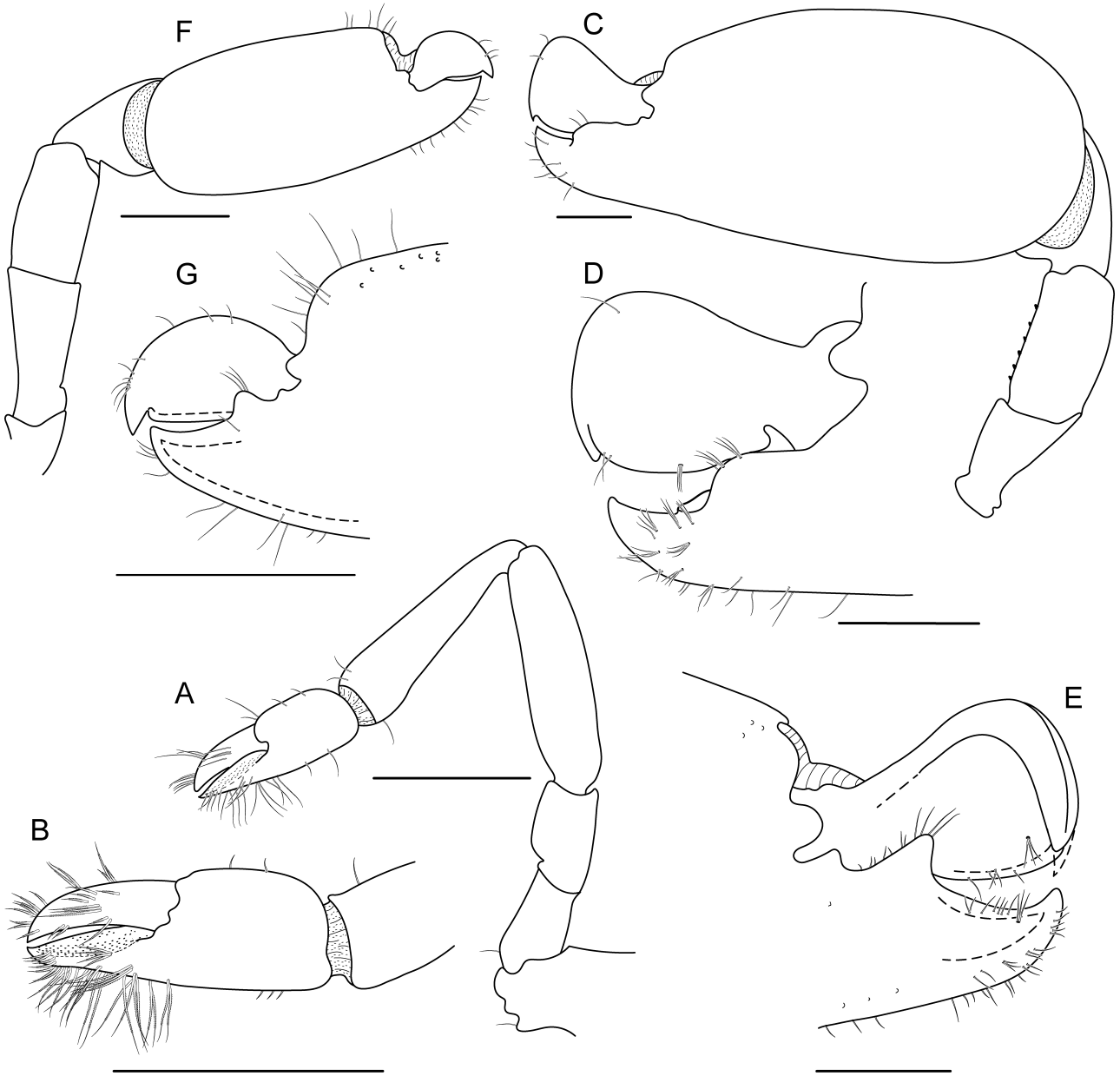

Fig. 3. *Periclimenaeus ramili* sp. nov., male holotype (RMNH.CRUS.D.57969): A, first pereiopod, lateral; B, same, lateral; C, major second pereiopod, lateral; D, same, fingers, lateral; E, same, fingers, mesial; F, minor second pereiopod, lateral; G, same, fingers, mesial. Scale bar: A–G = 1 mm.

basis and coxa short, without special features.

First male pleopod (Fig. 1J) with basipodite bearing two simple setae distally, one on lateral and other on mesial margin; exopod 4.5 times longer than wide, bearing plumose setae on both margins; endopod 0.45 of exopod length, about 3.8 times longer than central width, distally rounded, mesial margin with 15 simple short and long setae, and distomesial long simple seta; apex with pair of long simple seta, lateral margin with five simple setae.

Second male pleopod (Fig. 1K) with non-setose basipodite; endopod 0.9 length of exopod, about 4.5 times longer than central width, with numerous marginal plumose setae; appendices (Fig. 1L) inserted at 0.4 of mesial margin of endopod length, appendix masculina subcylindrical, 3.5 times longer than wide, about 0.09 times length of endopod, with two apical and four lateral serrate setae increasing in length distally, apical seta longest, about 1.5 times length of appendix masculina; appendix interna far exceeding appendix masculina, with few distomesial cincinnuli.

Uropods (Fig. 1F) with protopodite postero-

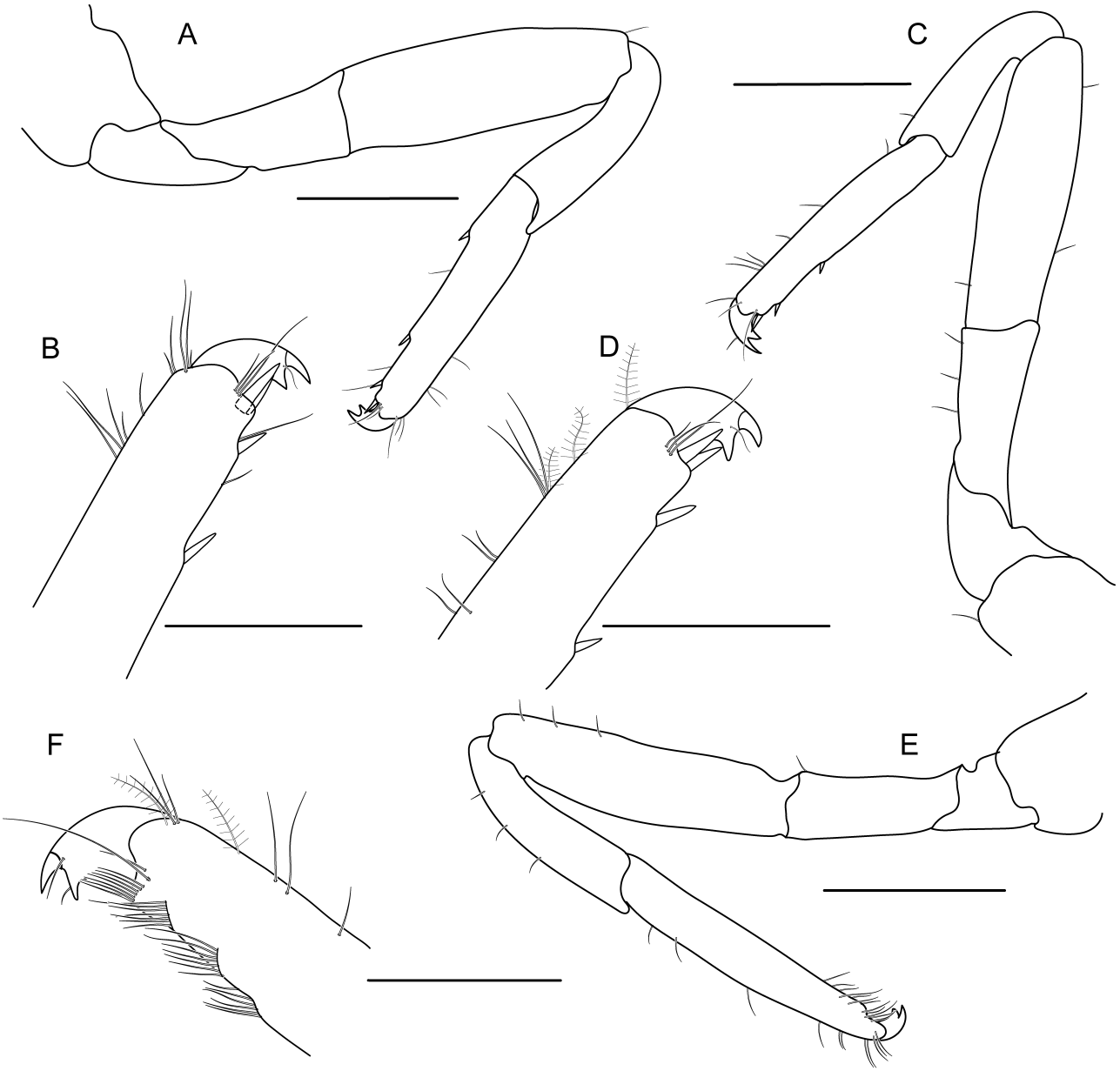

Fig. 4. *Periclimenaeus ramili* sp. nov., male holotype (RMNH.CRUS.D.57969): A, third pereiopod, mesial; B, same, dactylus and distal propodus, mesial; C, fourth pereiopod, lateral; D, same, dactylus and distal propodus, mesial; E, fifth pereiopod, lateral; F, same, dactylus and distal propodus, lateral. Scale bar: A, C, E = 1 mm; B, D, F = 0.5 mm.

laterally unarmed; rami subequal to telson length; exopod broadly ovate, about two times longer than central width, lateral margin slightly convex, bearing few small, thin setae, entire, distolateral angle with acute tooth and larger movable spine mesially; diaeresis distinct; endopod elongate, oval, slightly longer than exopod, 1.8 times longer than maximal width.

Variation: The relatively abundant material available for examination allowed to appreciate the variation exhibited by the new species. Two small immature specimens are morphologically identical to the largest specimens examined, exhibiting most diagnostic features of the new species, and can be distinguished from the closely related species using the same features. The females, although generally similar to males, are larger in size, with a more robust and clumsy body and with relatively smaller and less inflated major second chela. The pleon in the ovigerous females (Fig. 5A) is greatly expanded enclosing a very large number of eggs. In terms of the rostral formula, all examined specimens possess four dorsal teeth, except one ovigerous female which possesses only three. In most specimens, the rostrum does not overreach the cornea as it does in the male holotype, being more downwards curved in some ovigerous females and not reaching as far forward. The upper antennular flagellum has 7 proximal articles fused in the male holotype, while in most specimens only 4 proximal articles are fused. In some specimens, the telson possesses a minute acute median process, while in others, including the holotype, it does not. The distal cutting edges of fingers of the major second cheliped in the male holotype are not so sharp as is most paratypes, and the tip of the dactylus is somewhat blunt, but this is due to abrasion and few damages caused while handling it. Also, the merus of the major second cheliped of the holotype possesses some blunt tubercles in its ventral border, that are absent in most specimens.

Colouration: Semi-transparent whitish, with inconspicuous red chromatophores scattered over the carapace, pleon, second pair of pereiopods chelae, eye stalks and antennular peduncles; second pair of pereiopods with the distal portion of the palm, and dorsal and ventral margins of dactylus and pollex whitish, with cutting edges amber yellow; walking legs and tail fan transparent. Females with light cream-colored ovary and eggs (Figs. 5–6).

Etymology: It is a great pleasure for the author to dedicate this new species to Professor Dr Francisco Ramil, University of Vigo, Spain, who has been a friend and mentor for several years, and for his numerous contributions in the study of marine invertebrates, especially cnidarians.

Distribution: Presently only known with certainty from the type locality (Baía das Gatas) and Enseada de Corais da Matiota, Porto Grande Bay, both in São Vicente Island, Cabo Verde. However, its presence in the Canary Islands is suspected based on a colour photograph of a specimen from Lanzarote Island (see DISCUSSION below; Fig. 6).

Biology: *Periclimenaeus ramili* sp. nov. is, as all other species in the genus, an ecologically highly cryptic species, living inside the demosponge *Spongia* sp. (Porifera: Demospongiae: Spongiidae), in heterosexual pairs. The sponges inhabited by the shrimps (Fig. 5) are typically massive in shape; varying in colour from yellowish to dark grey, depending on exposition to solar light, invariably yellowish internally; with few and very narrow dermal pores (up to 5 mm in diameter) and internal aquiferous channels of about the same diameter as the dermal pores; of firmly compressible consistency, resistant to tearing. When harbouring specimens of the new species, the sponges possess a relatively large internal burrow (Fig. 5, see DISCUSSION) which normally is not opened to the exterior, but in a few cases, it was found to have an aperture at the base of the sponge, of about the same diameter as the gallery (designation used for the burrows excavated by the shrimps). This shrimp species is probably host-specific since all examined specimens were always found in the same host species despite several sponge species were inspected in its type-locality searching for symbiotic shrimps.

When disturbed, specimens of *P. ramili* sp. nov. produces a snapping sound by rapidly closing the dactylus of the major chela.

Taxonomic remarks: *Periclimenaeus ramili* sp. nov. is morphologically closest to *P. aurae*, *P. pearsei* and *P. hancocki*, all sharing: (1) the short ventrally unarmed rostrum with similar dorsal dentition; (2) the absence of supraorbital spines or tubercles; (3) the strongly reduced incisor process of the mandible; (4) the feeble distolateral tooth of the scaphocerite not overreaching the lamina; (5) the general shape of the second pair of chelipeds and ambulatory pereiopods; and (6) the shape and armament of the telson (Holthuis 1951; Ríos 1986; dos Santos et al. 2008). These species also share the presence of numerous plumose setae in the distal part of all maxilliped exopods, excepting for *P. hancocki* where this feature has not been described (but seemingly absent at least in the third maxilliped: cf. Holthuis, 1951, plate 29: Fig. E). Another feature shared by these three species, *i.e.*, *P. aurae*, *P. pearsei*, and *P. ramili* sp. nov., is the slender distal articles of the third maxilliped endopod. Some of the above-mentioned features can be commonly found in species belonging to the genus *Periclimenaeus* whilst others, such as the strongly reduced incisor process of the mandibles, is an unusual feature described in only three others non-

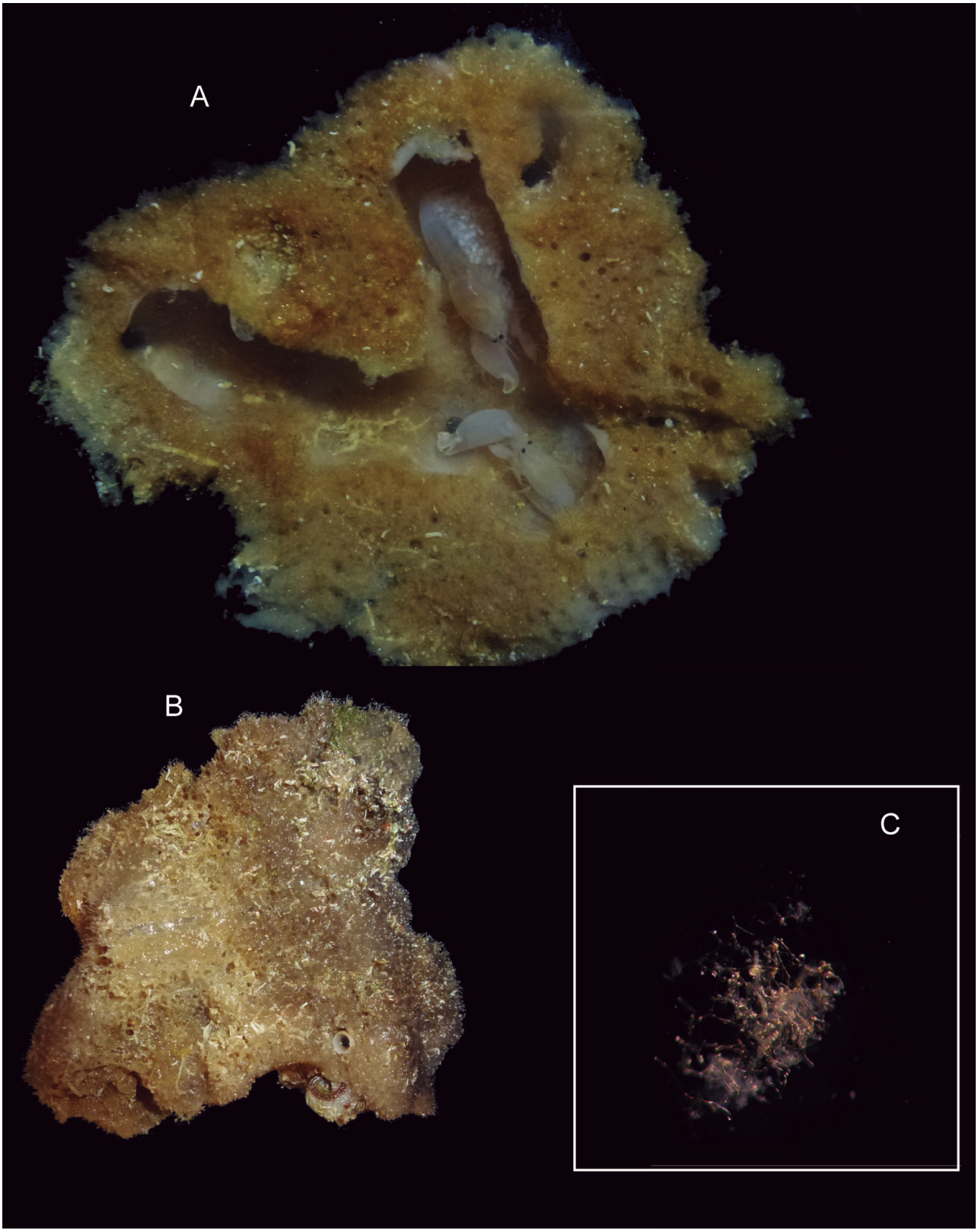

Fig. 5. *Periclimenaeus ramili* sp. nov and host sponge *Spongia* sp. A, male holotype (RMNH.CRUS.D.57969) and female allotype [(RMNH.CRUS.D.57970); B, sponge host: *Spongia* sp.; C, spongin fibers obtained from stomach content of *Periclimenaeus ramili* sp. nov. Scale bar = unscaled.

related congeners, *viz* the eastern Pacific *P. pacificus* Holthuis, 1951, the western Atlantic *P. pectinidactylus* Ďuriš, Horká and Sandford, 2009, and the east African *P. trispinosus* Bruce, 1969 (Bruce 2001; Ďuriš et al. 2009; Holthuis 1951).

Based on these characteristics, *P. aurae*, *P. pearsei*, *P. hancocki* and *P. ramili* sp. nov. form a morphologically homogeneous and well-defined group within the genus *Periclimenaeus*, distributed throughout the Atlantic and Eastern Pacific, which is established here as the *P. pearsei* species group.

Periclimenaeus ramili sp. nov. can be easily distinguished from the only other known eastern Atlantic congener, *P. aurae*, by: (1) the antennular peduncle basal segment (Fig. 1H) with a well-developed distolateral tooth reaching to the middle of the second segment (*versus* distinct but small tooth; dos Santos et al. 2008: Fig. 2B); (2) the incisor process of the mandible (Fig. 2A) lacking a tooth in its mesial margin in *P. ramili* sp. nov. (*versus* incisor process of the mandible bearing one tooth in its mesial margin; dos Santos et al. 2008: Fig. 2D); (3) the scaphognathite posterior lobe (Fig. 2C) broad in *P. ramili* sp. nov. (*versus* posterior lobe of scaphognathite very slender; dos Santos et al. 2008: Fig. 2F); (4) the third maxilliped (Fig. 2F) with penultimate article slenderer (*versus* somewhat broader; dos Santos et al. 2008: Fig. 3B); (5) the first cheliped fingers (Fig. 3A–B) as long as the palm and the dactylus with the upper margin regularly sloping towards the tip in *P. ramili* sp. nov. (*versus* the fingers 0.8 length of palm and dactylus with upper margin convex; dos Santos et al. 2008: Fig. 3C); and (5) the minor second cheliped dactylus (Fig. 3F–G) with the upper margin strongly convex, being almost semi-circular in *P. ramili* sp. nov. (*versus* convex distally but not semi-circular; dos Santos et al. 2008: Fig. 3E–F).

Periclimenaeus ramili sp. nov. can be distinguished from *P. pearsei* by: (1) the slender rostrum (Fig. 1A–C) reaching beyond middle of the first segment of the antennular peduncle (*versus* rostrum

Fig. 6. *Periclimenaeus* cf. *ramili* sp. nov. from Lanzarote, Canary Islands. Photographic Credits: Leopoldo Moro.

triangular shaped in lateral view in the latter, reaching to about middle of the first segment of the antennular peduncle; Holthuis 1951, pl. 28: fig. R; dos Santos et al. 2008: figs. 5A–B, D); (2) the incisor process of the mandible lacking a tooth in its mesial margin in *P. ramili* sp. nov. (*versus* incisor process bearing one or two teeth); (3) the first cheliped fingers (Fig. 3A–B) as long as the palm and the dactylus with the upper margin regularly sloping towards the tip in *P. ramili* sp. nov. (*versus* fingers slightly shorter than palm and dactylus with upper margin strongly convex; Holthuis 1951, pl. 28: Fig. J) and (4) by the less clumsy body.

Periclimenaeus ramili sp. nov. is morphologically even closer to the eastern Pacific *P. hancocki*, with the differences between these two species being rather subtle, and besides the above-mentioned features, the new species also resembles *P. hancocki* in the strong distolateral tooth on the first antennular segment (also shared with *P. pearsei*), the absence of tooth on the mesial margin of the incisor process of mandible and the general shape and proportions of the first cheliped dactylus and palm. Nevertheless, the new species can be distinguished from *P. hancocki* by: (1) the relatively shorter rostrum (Fig. 1A–C) not reaching distal margin of the first segment of the antennular peduncle in *P. ramili* sp. nov. (*versus* longer rostrum, reaching to or slightly overreaching the end of the first segment of the antennular peduncle in *P. hancocki*; Ríos 1986: Fig. 2B); (2) the dorsal margin of the rostrum (Fig. 1A–B) armed with four teeth (rarely three) in the new species (*versus* dorsal margin of the rostrum armed with five teeth in the former; Holthuis 1951, pl. 28: fig. A); (3) more reduced incisor process of the mandible (Fig. 2A) in the new species (*versus* more developed; Holthuis 1951, pl. 29: fig. D); (4) the scaphocerite (Fig. 1B–C) reaching to the distal margin of second segment of the antennular peduncle in *P. ramili* sp. nov. (*versus* reaching beyond middle of the third segment; Ríos 1986: Fig. 2B); (4) very slender two distal articles of the third maxilliped (Fig. 2F) in *P. ramili* sp. nov. (*versus* two distal articles broad*;* Holthuis 1951, pl. 29: fig. D); (5) the sinuous cutting edge of the major second cheliped dactylus (Fig. 3C–E) in *P. ramili* sp. nov. (*versus* straight; Holthuis 1951, pl. 29: fig. I); and (7) the relatively shorter dorsal telson spines (Fig. 1F) (*versus* longer and slenderer; Ríos 1986: fig. 2H). These two species also seem to differ in number of plumose setae in the third maxilliped exopod. While *P. ramili* sp. nov. possesses 15 plumose setae in the distal third of the flagellum (Fig. 2F), *P. hancocki* apparently has only the typical four plumose setae (Holthuis, 1951, pl. 29: fig. E).

Another feature that seems to be important to separate these four species is the number and position of setae on the appendix masculina. In male specimens of *P. ramili* sp. nov. (three males checked), the appendix masculina possesses two apical and four lateral serrate setae, whereas the appendix masculina of *P. aurae* possesses one apical and three lateral setae, *P. hancocki* has two apical and two lateral setae, and *P. pearsei* bears there two apical and seven lateral setae (Ríos 1986; dos Santos et al. 2008).

Among the Indo-West Pacific congeners, only three species, *Periclimenaeus marini* Bruce, 2013, *Periclimenaeus quadridentatus* (Rathbun, 1906) and *Periclimenaeus stylirostris* Bruce, 1969, showed some affinity to the herein established species group. However, they do not appear to belong to this grouping, and can be easily distinguished from all four currently included species using important morphological features, especially the shape of the rostrum and the peculiar shape of the minor second chela fingers (Bruce 1969 1972 2012b 2013b; Marin et al. 2004).

DISCUSSION

Periclimenaeus ramili sp. nov. is a cryptic species living inside burrows in its sponge host. Considering that sponges without shrimps do not have such burrows, I suggest that the shrimps excavate the burrows themselves. Moreover, microscopic examination of thick sections of the walls of the burrows has shown that the spongin fibres on their inner sides are sheared off, providing thus further evidence for this statement. The shrimps certainly enter the sponge in their post-larval stage occupying firstly the narrow internal channels of the sponges and excavating larger ones as they grow. The morphology of the major second cheliped (fingers mesially curved with sharp cutting edges) suggests that it may also play a major role in cutting (excavating the burrows), alongside with the minor second chela, in both males and females. The use of both claws for shearing has also been reported in few others palaemonid shrimps (see Ďuriš et al. 2011).

Even though that several species of palaemonid shrimps have been recorded inhabiting sponges' internal cavities (*e.g.*, Bruce 1969 1996 2013b; Chace 1972; Chace and Bruce 1993; Ďuriš et al. 2011; Holthuis 1951; Marin 2007; Marin and Chan 2013; Neves 2020), to the best of the author's knowledge, no other species of the family has been documented excavating its own burrows for living inside their sponges' hosts. However, it is worth noting that the relationship between shrimp and sponge host remains largely unknown in most cases. This behaviour is most likely an evolutionary adaptation to avoid competition for hosts with other sponge-dwelling shrimps species occurring in the same area since, despite intensive sampling, no other shrimp

species were found in the same host species whether harbouring or not specimens of *P. ramili* sp. nov. and individuals of the new species were not found in any other potentially suitable sponge host.

Examination of the stomach contents of *P. ramili* sp. nov. (Fig. 5C) revealed the presence of spongin fibres, indicating thus that its host is a primary food source and strongly suggesting that this species is an internal parasite of the sponge corroborating the results obtained by Ďuriš et al. (2011). Ďuriš et al. (2011) suggest that the shrimps may balance the damage caused to the sponge host when feeding, possibly providing some benefits, such as defence against more harmful animals. However, in the case of *P. ramili* sp. nov., such benefits were not directly observed nor could they be inferred since any other species was found living inside the sponge host whether harbouring or not individuals of *P. ramili* sp. nov. (more than 20 specimens checked). Besides, the sponge host seems to be highly toxic, at least for others sponge-dwelling shrimp species occurring in the same area, belonging to the genera *Typton* Costa, 1844 and *Periclimenaeus*, once when they are exposed to the sponges' organic compounds (obtained by squeezing the sponges), they quickly die (author's personal observation). Nevertheless, the new species apparently do not cause any major damage to the host since there are no visible differences in the sponges—regardless of whether or not they harbour shrimps—and in both cases they grow similarly. All these evidences strongly suggest that this could be a case of host specific parasitism.

The full-grown females of *P. ramili* sp. nov. produce a large number of small eggs (Fig. 5), almost certainly to compensate for the low reproductive success derived from its lifestyle.

Periclimenaeus ramili sp. nov. is currently known for sure only from two localities in São Vicente Island, Cabo Verde. However, a picture of a specimen of *Periclimenaeus* from the Canary Islands (Fig. 6) is tentatively identified as belonging to the new species. As in *P. ramili* sp. nov., that specimen also possesses a short rostrum not overreaching the cornea and with four dorsal teeth, a strong distolateral tooth on the first segment of the antennular peduncle reaching about middle of the second segment, the distolateral margin of the scaphocerite with a small distal tooth not overreaching the lamella and the shallow anteromedian dorsal lobe on the first abdominal tergite. The first and second pair of chelipeds, and the telson seem to be similar to those in the new species, although, it was not possible to confirm this in detail from the picture. Unfortunately, the ambulatory pereiopods that could provide further insights on the identification of this specimen were not completely visible in the picture and its mouthparts remain unknown. Since it was not possible to examine that material, the true identity of the specimen remains uncertain. Nonetheless, from the features available in the picture, the Canary specimen can be readily distinguished from the geographically closer *P. aurae* by the strong distolateral tooth on the first segment of the antennular peduncle, the upper margin of the first cheliped dactylus regularly sloping towards the tip, and the strongly convex upper margin of the minor second chela. It is noteworthy that the genus *Periclimenaeus* had not been reported from the Canary Islands so far.

CONCLUSIONS

A new sponge-dwelling palaemonid shrimp in the genus *Periclimenaeus* is described and illustrated from the Cabo Verde Islands. This finding represents the first record of this genus in the Cabo Verde Islands and the tropical eastern Atlantic. *Periclimenaeus ramili* sp. nov. is morphologically closer to three other sponge associated species distributed in the Atlantic and eastern Pacific, and a new species group is established herein to accommodate these species.

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Competing interests: The author declares that he has no competing interests.

Availability of data and materials: Type series were deposited into the zoological collections of the Naturalis Biodiversity Centre, Leiden (RMNH) and in the reference collection of the Instituto Superior de Engenharias e Ciências do Mar, Universidade Técnica do Atlântico (IECM, UTA).

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