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New records of poecilostomatoid copepods (Crustacea) from a coastal system in the Colombian Caribbean with notes on morphology

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Abstract
Seven species of free-living poecilostomatoid copepods are recorded from a coastal system in northern Colombia; one of these records, *Oncaea scottodicarloi* Heron and Bradford-Grieve, is new for Colombia. The poecilostome copepod fauna from the surveyed area is represented mostly by widespread species commonly found in neritic and oceanic waters of tropical latitudes, but local morphologic data are scarce in the regional literature. Brief diagnostic descriptions of the species recorded for the Colombian copepod fauna are provided together with illustrations of taxonomically important appendages, morphologic remarks, notes on the variability of some species, and their distribution.

Key words
Taxonomy; new records; Rodadero Bay; zooplankton; crustaceans.

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Introduction

Copepods are a numerically important group in the costal, neritic, and oceanic zooplankton communities (Boxshall and Halsey 2004). The order Poecilostomatoida has widespread, representative species in these marine habitats. The systematic position of this order is unclear and some authors include them in the Cyclopoida (Boxshall and Halsey 2004), but others treat it as a valid independent order (Melic 2015, Walter and Boxshall 2016). For the purposes of this work, we considered it as a valid order.

Poecilostome copepods inhabit marine, brackish, freshwater environments and comprise free-living and symbiotic forms (Melic 2015, Walter and Boxshall 2016). At present, 65 families are recognized as valid (Walter and Boxshall 2016), but only 7 are represented in the marine zooplankton: Clausidiidae, Corycaeidae, Lubbockiidae, Oncaeidae, Sapphirinidae, Paralubbockiidae, and Urocopiidae (Vives and Shmeleva 2010). Of these, members of the first 5 families are known to occur in Colombian waters, with 9 genera and 27 species recorded from different areas of the country (Medellín-Mora and Navas 2010). Unfortunately, no illustrations or descriptions are provided for most of these species, thus hampering further morphologic comparisons among populations. The Colombian literature also contains some doubtful records (i.e., *Corycaeus* (*Ditrichocorycaeus*) *subulatus* Herrick, 1887, *C.* (*Ditrichocorycaeus*) *amazonicus* F. Dahl, 1894, *C.* (*Agetus*) *limbatus* Brady, 1883, and *Sapphirina auronitens* Claus, 1863) that need to be confirmed (Medellín-Mora and Navas 2010).

Studies on the poecilostomatoids of Colombian

marine, brackish or freshwater habitats are numerous but fractionary and in some cases only marginal or in reference to symbiotic forms (Cressey and Collette 1970, Thatcher 1984, Giraldo and Gutiérrez 2007 , Medellín-Mora and Navas 2010, Fuentes-Reinés et al. 2012, López 2012, Jaimes and López 2014, López and Mojica 2015, Muriel-Hoyos et al. 2015). It is recognized that the knowledge about the diversity of this group, particularly of the free-living taxa, is still lagging in the entire Caribbean region. This study is aimed to investigate the poecilostomatoid copepod fauna of Rodadero Bay, northern Colombia and provide descriptions and helpful illustrations for each species recorded based on local specimens, and thus increase the knowledge of this group in Colombia and the Neotropical region.

Methods

Study site. Samples were collected in the inshore areas covered by vegetation (mangrove) and a bank of oysters from Rodadero Bay, Magdalena, northern Colombia (11°14′10″ N, 074°12′06″ W) (Figure 1) from August 2015 to March 2016.

Data Collection. Water salinity, pH, and temperature were measured with a multiparameter WTW 350i. Four hundred and thirty two (432) liters of water were taken using a bucket of 25 L, filtered with a zooplankton net (45 µm), and preserved in 70% ethanol. Samples were taken to the laboratory and stained with Bengal rose. Filtered samples were concentrated to 50 ml and specimens were sorted with a Bogorov camera and measured in ventral position, from the anterior end of the rostral area to the posterior margin of the caudal ramus. Some copepods were dissected and the appendages with taxonomic relevance were mounted on slides with glycerine and sealed with Canada balsam. The dissected appendages were photographed using a Kodak Easy Share C140 digital camera adapted to a compound microscope. The specimens examined were deposited at the Museo de Colecciones Biológicas at the Universidad del Atlántico, Barranquilla- Atlántico, Colombia, where they are available for consultation and/or further examination. Morphological terminology follows Huys and Boxshall (1991). The following abbreviations are used in the description: P1–P6= first to sixth legs, EXP= exopod, ENP= endopod.

The identification of the poecilostomatoid copepods obtained during these samplings followed Motoda (1963), Heron and Damkaer (1978), Heron et al. (1984), Heron and Bradford-Grieve (1995), Suárez-Morales and León-Oropeza (1999), Böttger-Schnack and Huys (2001), Böttger-Schnack and Huys (2004), Gómez (2006); Suárez-Morales and Fuentes-Reinés (2015), and the advice from Dr Ruth Böttger-Schnack.

Results

The taxonomic analysis of the poecilostomatoid copepods collected in the surveyed area resulted in the identification

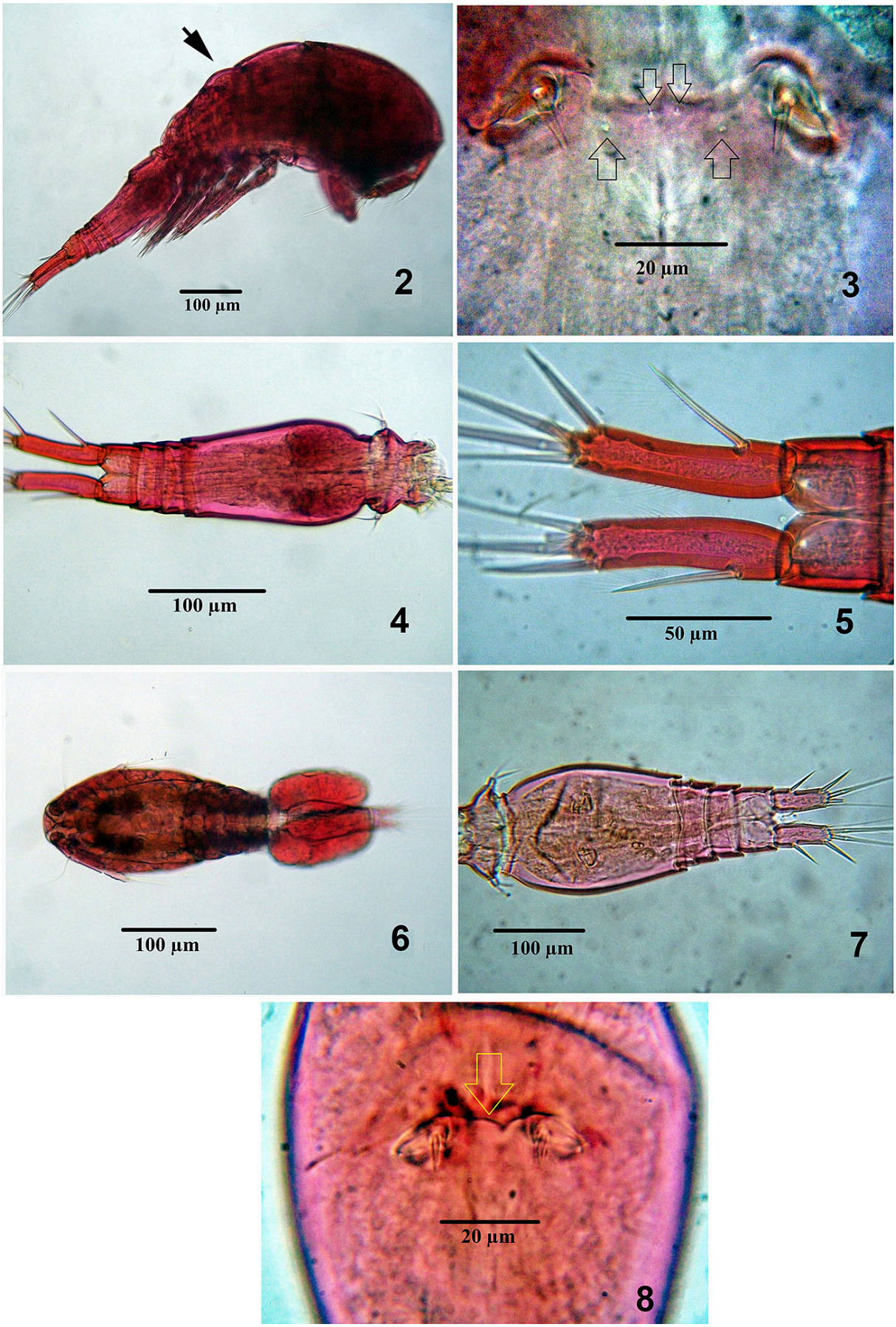
Figure 1. Location of the surveyed area in northern Colombia.

of 7 species belonging to 4 families and 5 genera. These are all new records for Rodadero Bay and 1 of them has not been hitherto recorded from Colombian waters. The family Oncaeidae was represented by 2 species and the remaining families by 1 species each. Among the 5 genera recorded, *Oncaea* Philippi 1843 was represented by 2 species and the remaining 4 genera by 1 species each.

Family Oncaeidae Giesbrecht, 1893
Genus *Oncaea* Philippi, 1843

Oncaea venusta Philippi, 1843
Figures 2–5

Synonymy (Medellín-Mora and Navas 2010: 302): *Antaria coerulescens* Claus, 1866; *Antaria gracilis* Dana, 1849; *Oncäa venusta* Giesbrecht, 1892; *Oncaea obtusa* Brady, 1883; *Oncaea praeclara* Humes, 1988; *Oncaea pyriformis* Lubbock, 1860



Figures 2–5. *Oncaea venusta*, adult female from Rodadero Bay, Colombia. **2.** Habitus, lateral view, arrow indicates the small dorsal protuberance on the second pedigerous somite. **3.** P6, arrows points at the four ventral pores adjacent to P6. **4.** Urosome, dorsal view. **5.** Anal somite and caudal rami, dorsal view. **6–8.** *Oncaea scottodicarloi*, adult female. **6.** Habitus, dorsal view. **7.** Urosome, ventral view. **8.** Genital double-somite showing ventral sclerotization (arrowed).

Material examined. Fifteen adult females undissected, 2 dissected (UARC284M).

Remarks. The specimen from Colombia bears the diagnostic features of *O. venusta* as reported by Böttger-Schnack (2001) and Böttger-Schnack and Huys (2004). The body is cyclopiform, robust, habitus as in Figure 2. Body length, excluding caudal setae = 940–965µm, average: 0.95 µm (n = 15). Colombian specimens are characterized by 1) prosome tapering posteriorly, with small dorsal swelling on the P2-bearing somite (Fig. 2), 2) P6 with 4 pores on surface of genital double-somite (arrowed, Fig. 3), 3) genital double-somite about 1.8 times as long as wide (Fig. 4), anal somite with paired dorsal pore on posterior margin (Fig. 5). Caudal ramus about 3.5 times as long as wide (Fig. 5).

Among the oncaeid copepods, *O. venusta* was the most frequently found species in the surveyed area. It is an epipelagic form (Böttger-Schnack 2001) but it has been collected also from bathypelagic depths (Böttger-Schnack 1996, Nishibe et al. 2009), and our data indicate that they can dwell locally in shallow littoral conditions as well, probably as a result of passive transportation processes from adjacent shelf waters. The species is known for its high variability in total body length, ranging from 0.75 to 1.4 mm in the female and from 0.55 to 0.98 mm in the male (Böttger-Schnack and Huys 2004). Based on its size range the species has been categorized into 3 groups (Böttger-Schnack 2001, Böttger-Schnack and Huys 2004). Molecular studies using of 2 DNA markers (cyt b and ITS1) could differentiate 4 genetic clades where the small and large size groups were separated genetically and both could be deemed as distinct species (see Elvers et al. 2006, fig. 2, table 4). Therefore, some authors prefer to designate the group with the large size as *O. venusta* (960–1260 µm) and the smaller forms as *O. venella* (800–830 µm) (Wi et al. 2008); our specimens could be included in the first group.

The maximum size of our Colombian specimens (ca 0.96 mm) is not within the range of the typical form of the species, which is usually larger than 1 mm (see Böttger-Schnack and Huys 2004; table 1). In addition, these specimens possess a small dorsal swelling on the second pedigerous somite which is visible in lateral view (arrowed in Fig. 2) and indicates that the local population of *O. venusta* from Colombia belongs to the Atlantic form of the medium-sized group of the species (see Böttger-Schnack and Huys 2004; table 1).

Distribution. It is considered a cosmopolitan species (Razouls et al. 2005–2016) and has been recorded in the Indian, Atlantic, and Pacific Oceans at latitudes between 65° N and 45°S (Farran 1929, Malt 1983, Böttger-Schnack et al. 1989, Heron 2002, Böttger-Schnack and Huys 2004). In Colombia this species has been reported in the Pacific coast and in oceanic waters of the Colombian Caribbean: Magdalena, Guajira, and San Andres Island (Michel and Foyo 1976, Campos and Plata 1990, Bernal and Zea 2000, Martínez-Barragán et al. 2009, López and Mojica 2015). This is the first record from Rodadero Bay.

Oncaea scottodicarloi Heron & Bradford-Grieve, 1995
Figures 6–8

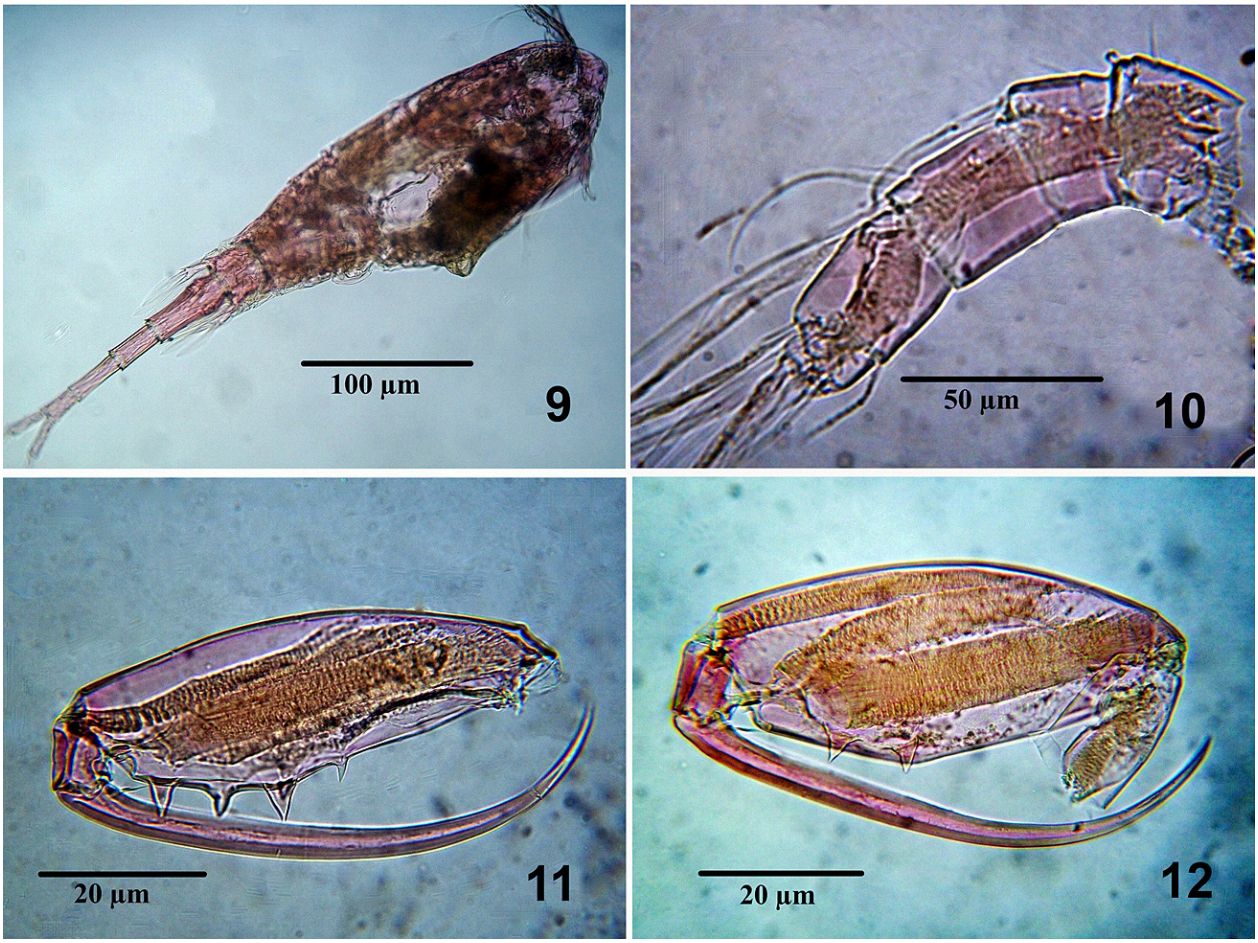
Synonymy (Böttger-Schnack 2001): *Oncaea media* Giesbrecht, 1892.

Material examined. Ten adult females, undissected, 2 dissected (UARC285M).

Remarks. The body is cyclopiform, robust, habitus as in Figure 6. Body length, excluding caudal setae = 532–588 µm, average: 562 µm (n = 10). This species was originally described by Heron and Bradford-Grieve (1995) from the Gulf of Naples and redescribed by Böttger-Schnack (2001) based on specimens from the Gulf of Naples, the Red Sea, and the Gulf of Aden. It can be found in the epi-mesopelagic layer (Böttger-Schnack 2001) and our data shows its occurrence in shallow littoral areas, as observed for *O. venusta*.

The specimens from Colombia have the diagnostic features of *O. scottodicarloi* as described by Heron and Bradford-Grieve (1995) and Böttger-Schnack (2001). There are, however, some subtle differences in our specimens: 1) length/width ratio of genital double-somite is 1.5 in populations from the Red Sea and Gulf of Aden (Böttger-Schnack 2001, fig. 22A, C), 1.4 in those from the Gulf of Naples (Heron and Bradford-Grieve 1995, fig. 17K) and this ratio is somewhat smaller (1.27) in the Colombian specimens (Fig. 7); 2) the length ratio of the genital double-somite with respect to the rest of urosomites is 2.5 in Red Sea and Gulf of Aden specimens (Böttger-Schnack 2001, figs 22A,C), 2.3 (Gulf of Naples) (Heron and Bradford-Grieve 1995, fig. 17K), and 2.2 in the Colombian specimens (Fig. 7). Overall, these differences are deemed to be intraspecific variations and thus expand the knowledge on the morphometric variability of this species.

In the Americas, this species can be confused with *O. media* Giesbrecht, 1891 and *O. waldemari* Bersano & Boxshall 1996 but they can be distinguished by several characters: 1) the length/ width ratio of the genital double-somite is about 1.27–1.50 in *O. scottodicarloi* (Heron and Bradford-Grieve 1995, fig. 17K; present data, Fig. 7), 1.7 in *O. waldemari* (Böttger-Schnack 2001, fig. 24C), and 1.9 in *O. media* (Heron and Bradford-Grieve 1995, fig. 16A; Böttger-Schnack 2001, fig. 15C), 2) the length ratio genital double-somite/ rest of urosomites is 2.2–2.5 in *O. scottodicarloi* (Heron and Bradford-Grieve 1995, fig. 17K; Böttger-Schnack 2001, fig. 22A, C; present data, Fig. 7), 1.9 in *O. waldemari* (Böttger-Schnack 2001, table 1), and 3.9 in *O. media* (Heron and Bradford-Grieve 1995, fig. 16A; Böttger-Schnack 2001, fig. 15A, C), 3) the shape and location of the sclerotization differs among these species, in *O. scottodicarloi*, it is a line connected to the genital aperture (Heron and Bradford-Grieve 1995, fig. 17K; Böttger-Schnack 2001, fig. 22 C; Wi et al. 2009, fig. 10A; present data, Fig. 8), whereas in both *O. media*



Figures 9–12. *Lubbockia squillimana*, female from Rodadero Bay, Colombia. **9.** Habitus, dorsal view. **10.** Antennule. **11.** Left maxilliped. **12.** Right maxilliped with reduced number (2) of spiniform processes.

and *O. waldemari* sclerotization is absent (Heron and Bradford-Grieve 1995, fig. 16A; Böttger-Schnack 2001, fig. 15C, Wi et al. 2009, figs 8A, 11A).

Distribution. It has been recorded in the Indian, Atlantic, and Pacific Oceans (Heron and Bradford-Grieve 1995, Böttger-Schnack 2001). This is the first record of this species in Colombian waters and in the Caribbean.

Family Lubbockiidae Huys & Böttger-Schnack, 1997
Genus *Lubbockia* Claus, 1863

Lubbockia squillimana Claus, 1863
Figures 9–17

Synonymy (Heron and Bradford 1995): *Lubbockia minuta* Marukawua 1927; *Lubbockia marukawuai* Mori, 1937.

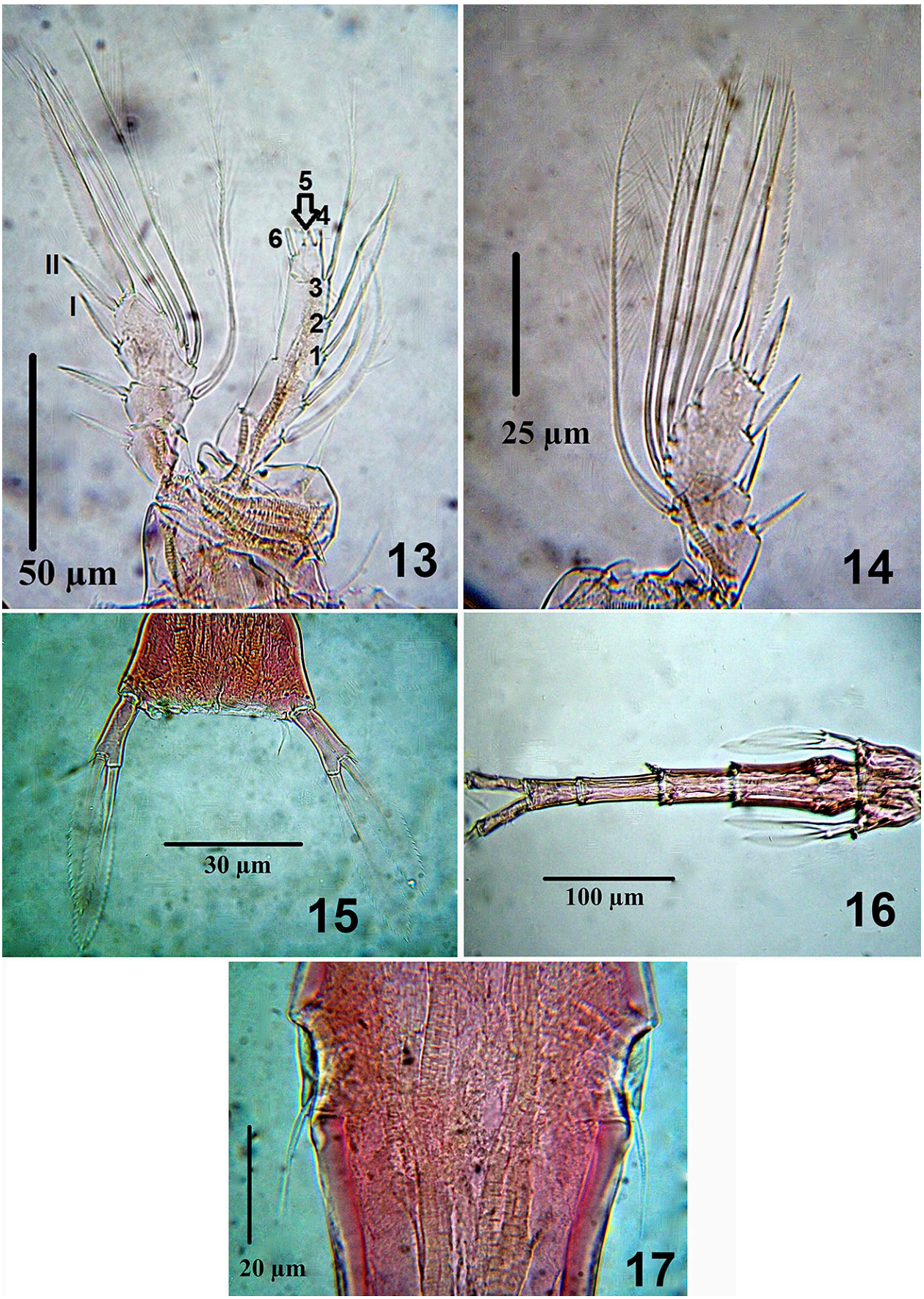
Material examined. One female, dissected (UARC294-UARC301M).

Remarks. Body slender, elongate (Fig. 9). Body length = 1325 µm. The Colombian specimens bear the diagnostic features of *L. squillimana* as reported by Boxshall (1977) and Boxshall and Halsey (2004) and can be easily recognized by: 1) antennule 5-segmented (Fig. 10), 2) maxilliped with large denticles on the basis (Figs 11, 12), 3) P1-2EXP3 with 2 outer spines (Figs 13, 14), 4) P5 elongate, reaching beyond posterior margin of genital double-somite (Figs 15, 16), 5) genital double-somite much longer than succeeding postgenital somite (Fig. 16), 6) P6 represented by single setal element (Fig. 17).

Lubbockiids are oceanic copepods, occurring in open waters and often at great depths (Heron and Damkaer, 1978). *Lubbockia squillimana* is epipelagic (Heron and Bradford-Grieve 1995) but has been also found at mesobathypelagic depths (Berdugo and Kimor 1968). In the Caribbean Sea, *L. squillimana* can be confused with *L. aculeata* Giesbrecht, 1891; they can be separated by: 1) the structure of the female P5 which reaches the posterior border of the genital double-somite in *L. squillimana* and is shorter in *L. aculeata*, 2) *L. squillimana* female maxilliped lacks inner spinous processes on the basis whereas such processes are present in *L. aculeata*.

Variability. The right maxilliped of our specimen bears 2 large denticles instead of 4 (Fig. 12). Heron and Damkaer (1969) reported a similar variation of the maxilliped in *L. wilsonae.*

Distribution. *Lubbockia squillimana* has a tropical distribution, but it is also found outside tropical waters (Heron and Damkaer 1978). In Colombia this species has been reported in Providence and Santa Catalina islands (Martínez-Barragán et al. 2009). This is the first record



Figures 13–17. *Lubbockia squillimana*, female from Rodadero Bay, Colombia. **13.** P1. Armature details shown, spines (Roman numerals), setae (Arabic numerals), arrow indicates position of damaged apical seta. **14.** P2EXP. **15.** P5. **16.** Urosome, ventral view. **17.** Detail of genital double-somite, ventral view, showing P6.

of this species in the Magdalena department, northern Colombia.

Family Kelleriidae Humes & Boxshall, 1996
Genus *Kelleria* Gurney, 1927

Kelleria reducta Gómez, 2006
Figures 18–20

Material examined. One adult female undissected, 1 dissected (UARC286M).

Remarks. The specimen from Colombia bears the diagnostic features of *K. reducta* previously reported from the adjacent Guajira department (Suárez-Morales and Fuentes-Reinés 2015). Body cyclopiform, robust (Fig. 18). Body length, excluding caudal setae: 910–994 μm (mean = 952 μm, *n* = 2). It can be easily separated from its congeners by its possession of 2 mediobasal teeth of mandibular blade which are remarkably larger than the others (Fig. 19) and by a maxillipedal claw with 1 long and one reduced accompanying seta (Fig. 20). These 2 distinctive characters are present in the specimen from Rodadero Bay, Magdalena.

Distribution. This species appears to have a widespread distribution in the area as it has been found from sieved sediment samples (Gómez 2006), open water along the water column (Suárez-Morales and Fuentes-Reinés 2015) and littoral zone (present study). Hitherto, *K. reducta* has been recorded from northwestern Mexico (Gómez 2006) and Colombia (Suárez-Morales and Fuentes-Reinés 2015); this is the first record in the Magdalena department, Colombia.

Family Corycaeidae Dana, 1852
Genus *Farranula* Wilson, 1932

Farranula gracilis (Dana, 1849)
Figures 21–24

Synonymy (Razouls et al. 2015–2016). *Corycaeus gracilis* Dana, 1849; *C. pellucidus* Dana, 1849; *C. deplumatus* Dana, 1849; *C. megalops* Brady, 1883; *Corycaeus* (*Corycella*) *gracilis*: M. Dahl, 1912; *Corycella gracilis* Farran, 1929; *C.* (*Farranula*) *gracilis* Marques, 1973

Material examined. Three males, 2 undissected, 1 dissected (UARC287M).

Remarks. Body cyclopiform, robust (Figure 21). Body length, excluding caudal setae, 756–812 μm (mean = 770 μm, *n* = 5). P4EXP 3-segmented, lacking ENP (Fig. 23). In Colombia, the male of this species can be easily confused with *F. carinata*, but these species can be differentiated by the following characters: 1) the distance of the posterior margin of the genital bulge with respect to the posterior part of the urosome, which is over ⅓ of the length of the urosome in *F. gracilis* (Fig. 24) vs about ⅓ in *F. carinata*, 2) the separation of the ocular lenses, which are slightly more spaced in *F. gracilis* (Fig. 22) than in *F. carinata*.

Distribution. It is a cosmopolitan species (Razouls et al. 2005–2016), frequently found in neritic and oceanic waters; it is 1 of the 4 most abundant species in the zooplankton of the western Caribbean (Suárez-Morales and Gasca 1997). In Colombia, this epipelagic copepod has been recorded in Guajira, Magdalena, Sucre, Córdoba, and San Andrés island departments (Medellín-Mora and Navas 2010).

Genus *Corycaeus* Dana, 1845

Corycaeus (***Onychocorycaeus***) ***giesbrechti*** F. Dahl, 1894
Figures 25–28

Synonymy (Razouls et al. 2015–2016). *Corycäus venustus* Giesbrecht, 1891; *Corycaeus venustus* Esterly, 1905.

Material examined. One adult male, dissected (UARC288M).

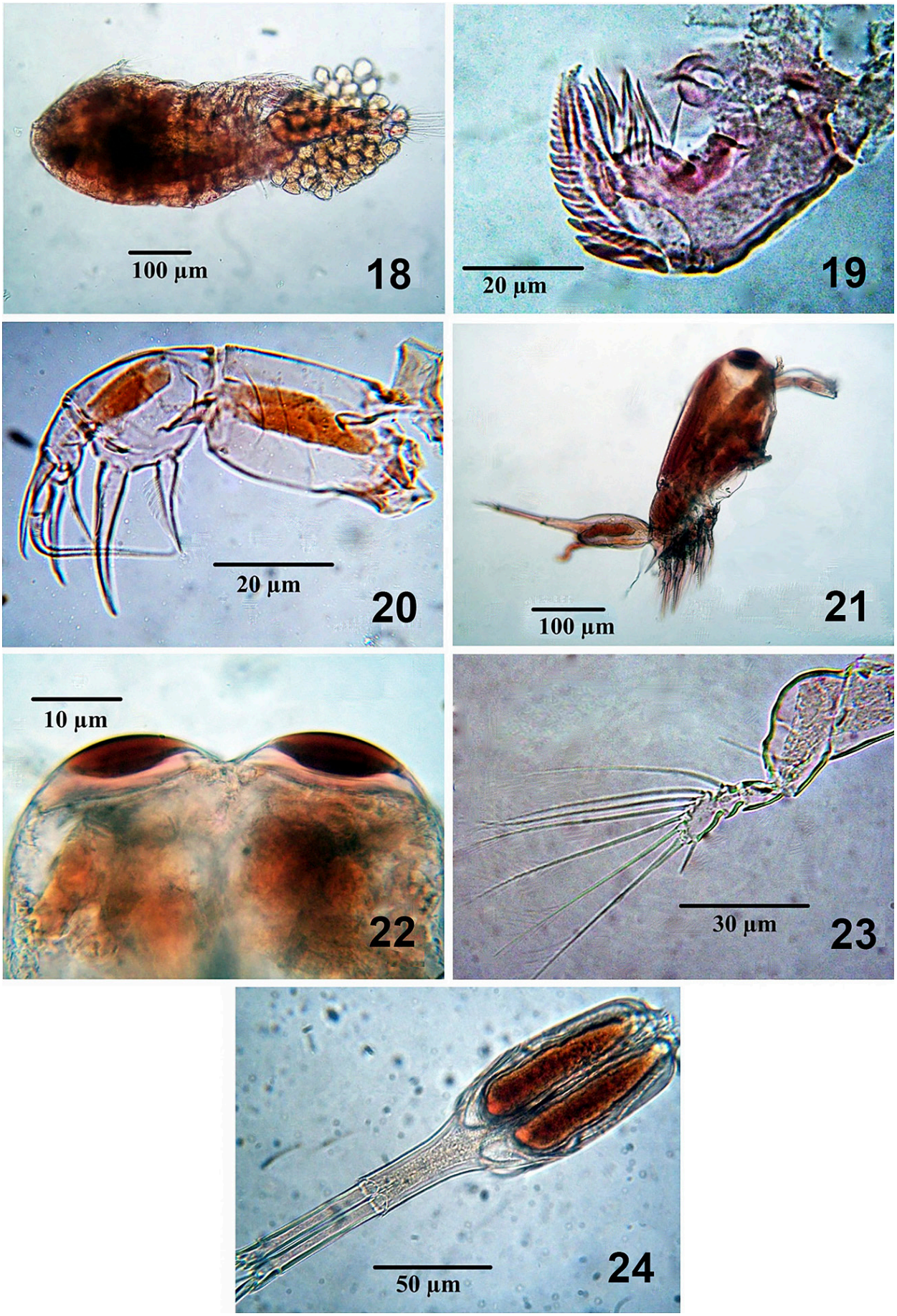
Remarks. The male specimen from Colombia shares the diagnostic features of *C. giesbrechti* reported and illustrated from specimens found in the Gulf of Mexico (Suárez-Morales and León-Oropeza 1999). Body cyclopiform, robust (Fig. 25). Body length, excluding caudal setae: 742 μm. It can be easily distinguished from its congeners by 1) the presence of small medium-sized hook on the anterior surface of genital somite (Fig. 26); 2) dorsal margin of the genital somite straight (Fig. 26); 3) anal somite as long as caudal rami (Fig. 27); 4) fourth leg with 2 unequally long basipodal setae (Fig. 28).

Distribution. It is a widespread epipelagic species (Campos-Hernández and Suárez-Morales 1994, Suárez-Morales and León-Oropeza 1999) that has been frequently recorded in tropical areas of the Atlantic, Pacific, and the Indian oceans (Márquez-Rojas et al. 2014, Razouls et al. 2016). In Colombia, this species has been recorded in the Guajira and Magdalena departments (Medellín-Mora and Navas, 2010). This is the first record in Rodadero Bay.

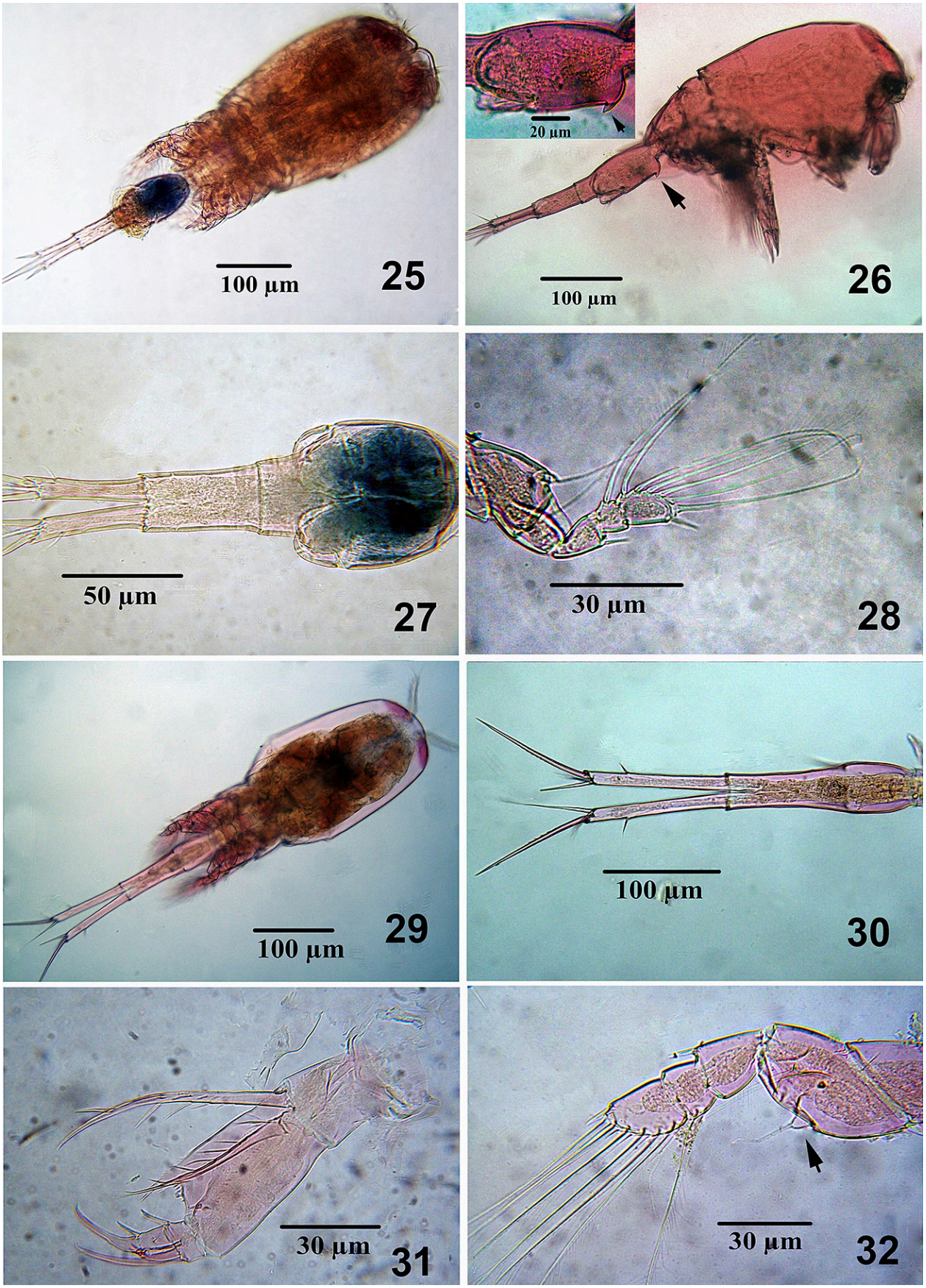
Corycaeus sp. Dana, 1845
Figures 29–32

Material examined. Seven immature specimens, dissected (UARC289M).

Remarks. These specimens were considered as young stages of *Corycaeus*; the body shape, segmentation (Fig. 29) and urosome (Fig. 30) details resembles much those depicted by Motoda (1963, figs 18–21) and reported as immature individuals. The anterior part of the body of these young forms resemble much that of adults, but the urosome shows certain undeveloped features: the immature urosome is 1-segmented (Fig. 30), more slender than in the adults, in our specimens the partially fused genital somite has no expansions or processes, with straight lateral margins; the basal antennary bristles have spinules as in adults, but in young males the terminal claw of the antenna is not yet elongated (Fig. 31) as in the adult stage. Our specimens have a small leg 4 endopodite (Fig. 32,



Figures 18–20. *Kelleria reducta*, female from Rodadero Bay, Colombia. **18.** Habitus. **19.** Mandible. **20.** Maxilliped. **21–24.** *Farranula gracilis*, adult male from Rodadero Bay, Colombia. **21.** Habitus, lateral view. **22.** Anteriormost section of cephalosome showing apical ocular lenses. **23.** P4. **24.** Urosome and caudal rami, ventral view.



Figures 25–28. *Corycaeus (Onychocorycaeus) giesbrechti,* male from Rodadero Bay, Colombia. **25.** Habitus, dorsal view, **26.** Habitus, lateral view, proximo-ventral spiniform process arrowed. **27.** Urosome, ventral view. **28.** P4. **29–32.** *Corycaeus* sp., immature specimen from Rodadero Bay. **29.** Habitus, ventral view. **30.** Urosome, ventral view. **31.** Antenna. **32.** P4 showing reduced endopodal lobe (arrowed).

arrowed), but in some species like *C. gracilis,* the endopodite is absent in young specimens. It is expected that adult individuals will be collected from future samplings at the outermost neritic waters in the area.

Discussion

The local community of poecilostomatoid copepods from Rodadero Bay, Caribbean coast of Colombia, was found in association with a mangrove ecosystem and with a small oyster bank, at 0.70 m depth where water temperature varies over the seasons in the range of 30–32 °C, water salinity is 36.1 psu, and pH 8.3. Poecilostomatoids from Rodadero Bay are represented mostly by widespread species commonly found in adjacent neritic and oceanic waters; their presence in the innermost reaches of this shallow coastal system suggests the influence of offshore waters, probably resulting from local advective processes. The same effect has been reported in other coastal systems and embayments of the western Caribbean (Suárez-Morales and Gasca 1996, Ruíz-Pineda et al., 2016). Considering the records presented by Medellín-Mora and Navas (2010), Fuentes-Reinés et al. (2012), Suárez-Morales and Fuentes-Reinés (2015), and the new record of *Oncaea scottodicarloi* herein presented, there are 30 valid free-living marine/estuarine species of poecilostomatoid copepods present in Colombian marine waters. With 5 species (i.e., *O. conifera*, *O. media*, *O. mediterranea*, *O. venusta*, and *O. scottodicarloi*) recorded in Colombia, the genus *Oncaea* is the most species-rich poecilostomatoid in the country. The knowledge of the poecilostomatoid copepod fauna in northern Colombia is currently represented by a neritic-oceanic community; local listings are expected to grow and reveal additional records from further sampling of the offshore zooplankton and epibenthic communities.

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Authors' Contributions

JF collected the samples; JF and ES-M identified the specimens and wrote the text.

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