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Parasitic isopods (Crustacea: Dajidae) of euphausiids (Crustacea: Euphausiacea) in the western Caribbean Sea

Iván A. Castellanos-Osorio and Eduardo Suárez-Morales

El Colegio de la Frontera Sur (ECOSUR), Unidad Chetumal, Chetumal, Mexico

ABSTRACT

In this work, we provide new data on the parasitic isopods infecting euphausiid species in the western Caribbean Sea, Northwestern Tropical Atlantic (NWTA). Our study was based on the examination of a total of 211 zooplankton samples obtained in 1999, 2010 and 2011 from the western Caribbean Sea (i.e. the eastern coast of the Yucatan Peninsula, off the southwest coast of Cuba and Honduras) with different sampling gears at a depth range of 0–200 m. Euphausiid species were examined to detect parasitic isopods. Three species of these parasites were identified. One of them, *Heterophryxus appendiculatus* G. O. Sars, 1885 has been hitherto reported exclusively as a parasite of the species of *Euphausia* Dana, 1852; quite unexpectedly, this species was found as a parasite of *Thysanopoda aequalis* Hansen, 1905, thus expanding its known host range to a different euphausiid genus. We also report the finding of two specimens of *Oculophryxus bicaulis* Shields and Gómez-Gutiérrez, 1996, only known as a parasite of *Stylocheiron* G. O. Sars, 1883. Accordingly, *O. bicaulis* was observed on *S. affine* G. O. Sars, 1883 in the western Caribbean. The third isopod species herein reported is the rare *Branchiophryxus koehleri* Nierstrasz & Brender à Brandis, 1931. We found only one female individual of this species attached to *S. longicorne*. Members of this dajid genus have been recorded only a few times and this is the first record in the NWTA. We report a new host record at the genus level of *Heterophryxus appendiculatus*. *Oculophryxus bicaulis* was confirmed as a parasite of *Stylocheiron* species. The rare *Branchiophryxus koehleri* was first recorded for the NWTA region. We presume that some of these isopods indeed have a wide distribution in tropical and subtropical areas but tend to be overlooked in routine examination of zooplankton samples.

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Introduction

Members of the family Euphausiidae Dana, 1852 are among the numerically dominant groups of the crustacean zooplankton community, mainly occurring in cold and temperate latitudes, but can also occur in tropical latitudes (see Antezana and Brinton 1981; Gibbons et al. 1999). They have a broad vertical distribution from the surface layers to bathyal depths (Gibbons et al. 1999). They can form large reproductive aggregations that increase the population protection and foraging efficiency (Antezana and Brinton 1981); aggregations can also increase the transmission rates of parasites (Nicol 1984).

CONTACT Eduardo Suárez-Morales  esuarez@ecosur.mx

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Euphausiids can be infected by different groups of endo- and ectoparasites including protozoans (Ellobiopsidae), dajid isopods and helminths larvae (González-Solís et al. 2013). Parasites have been reported for only seven genera and 28 species of euphausiids worldwide (Gómez-Gutiérrez et al. 2017).

The parasitic fauna of the widely distributed and highly diverse genus *Euphausia* Dana, 1852 is the best known (see Gómez-Gutiérrez and Castellanos-Osorio 2010). There are records of various ectoparasites infecting this genus, like the dajid isopod *Heterophryxus appendiculatus* G. O. Sars 1885, originally described as a parasite of the nominal *Euphausia pellucida* Dana (syn.: *E. krohni* [Brandt, 1851]) off the Cape Verde Islands (Mauchline 1980). Subsequently, it was reported from the same host in the Mediterranean (Lo Bianco 1902) on *E. distinguenda* Hansen, 1908 in the Arabian Sea (Sebastian 1970), *E. americana* Hansen, 1911 in the North Atlantic (Tattersall 1905, 1911; Gotto 1983) and recently also on *E. recurva* Hansen, 1905 from Japanese waters (Shimomura and Ohtsuka 2008).

The impact and prevalence of parasites on tropical and subtropical euphausiid populations remain largely unknown. Studies on the euphausiid ectoparasites in the Northwestern Tropical Atlantic (NWTa) are very scarce; the only extant work from this region is the contribution by Gómez-Gutiérrez and Castellanos-Osorio (2010), who reported free females of *H. appendiculatus* and *Oculophryxus bicaulis* in the northern zone of the Mexican Caribbean. Also, Shields and Gómez-Gutiérrez (1996) reported a female individual of *O. bicaulis* on a species of *Stylocheiron* in the Gulf of Mexico. It is important to perform studies on the isopod ectoparasites in these poorly studied regions, where the incidence of isopod parasites on euphausiids is probably underestimated as they can be easily overlooked in routine examination of zooplankton samples. In this work, we report our observations on the isopod ectoparasites from zooplankton samples obtained in the western Caribbean Sea, including notes on hosts and geographic distribution of these parasites.

Materials and methods

A total of 211 zooplankton samples were obtained from the upper 200 m at several locations of the western Caribbean Sea during different zooplankton surveys (Figure 1(a–d), Table 2), including the highly diverse and physiographically unique (see Suárez-Morales and Camarena-Luhrs 2003) Chinchorro Bank (CB) oceanic atoll, on the southern part of the Mexican Caribbean (Figure 1(d)). It was sampled in February 1999 (10 samples) and April 2010 (6) with a standard plankton net (mouth diameter = 50 cm, mesh size = 0.3 mm). Additional samples were obtained with a Bongo net (1 mm mesh size) and with a neuston net (mesh size = 0.33 mm) during the oceanographic cruise GG1001 along the central and northern Caribbean coast of Mexico (Figure 1(b)) on board NOAA's oceanographic ship Gordon Gunter. A second NOAA oceanographic cruise (GG1101) included sampling stations along the western and eastern Caribbean coasts, including the waters of Mexico, Belize, Honduras, Cayman Islands, Jamaica, Haiti and Cuba (Figure 1(a)). Stratified samples (upper 100 m) were also obtained using a MOCNESS net system (0.3 mm mesh size, 1.8 m² mouth) in November 2011 (GG1101).

Parasitised euphausiids were sorted from the original zooplankton samples for further examination. Euphausiid species were identified following Mauchline (1980) and Baker

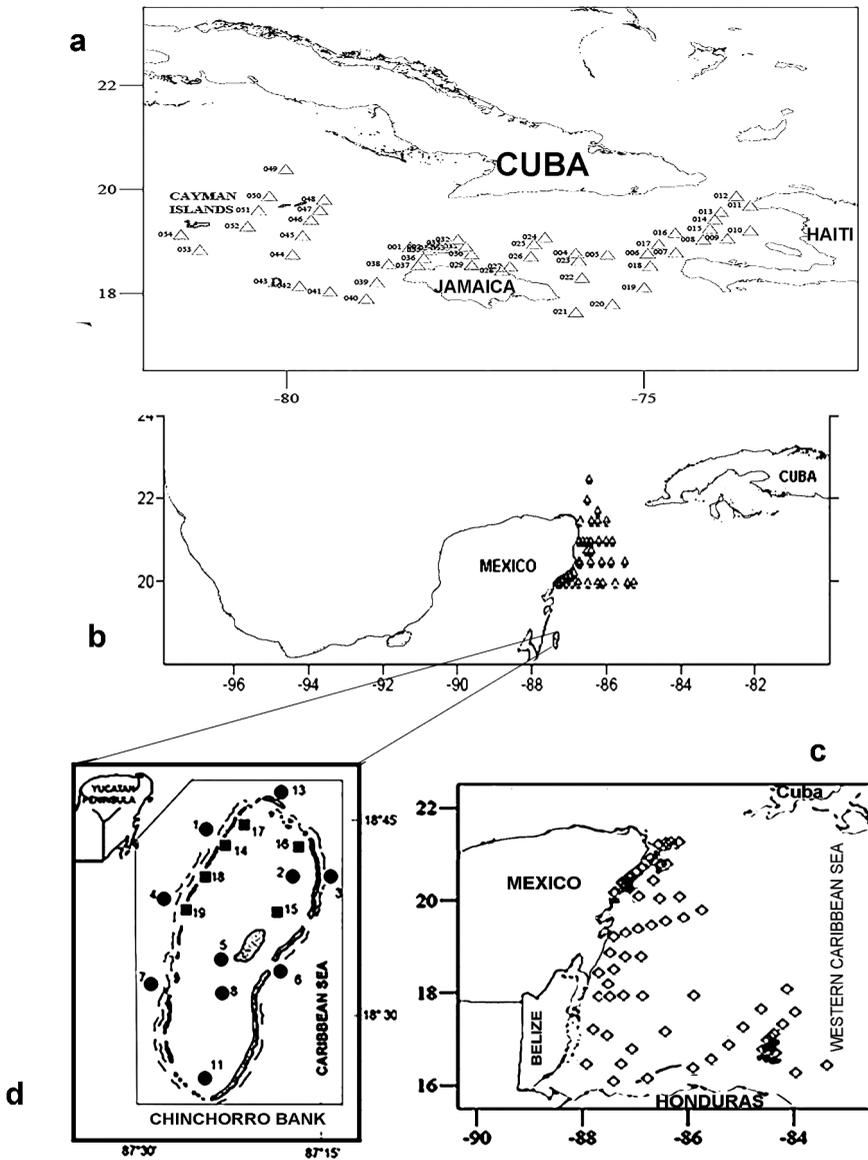


Figure 1. Areas and zooplankton stations grids in the western Caribbean from which the examined samples were obtained. (a) NOAA oceanographic cruise GG1101. (b) oceanographic cruise GG1001. (c) Zooplankton survey of the northwestern Caribbean. (d) Zooplankton survey of Chinchorro Bank.

et al. (1990). The parasitic isopods were identified following Sars (1885), Caullery (1897), Lo Bianco (1902), Koehler (1911), Sebastian (1970) and Shields and Gómez-Gutiérrez (1996).

Results

From the examination of the zooplankton samples collected in the western Caribbean, we found 13 specimens of ectoparasitic isopods. All isopods found in the surveyed area are

assignable to the isopod family Dajidae. Overall, our material included three parasitic isopod species and three host euphausiid species. Both the parasites and their hosts were deposited in the collection of zooplanktons held at El Colegio de la Frontera Sur (ECOSUR), Chetumal, Mexico.

We sorted and measured 10 female specimens of *Heterophryxus appendiculatus* G. O. Sars 1885, nine of them from off CB (Table 1); specimens were measured with the aid of a millimetre ruler. Some of the females carried epicaridium larvae (see Figure 2(a,b,d); Table 1). The tenth specimen of *H. appendiculatus* was found attached to the euphausiid host *Thysanopoda aequalis* (Figure 2(c); Table 1). The specimen was found in the Yucatan Channel in the upper 200 m. Both the isopod and the euphausiid host were deposited in the collection of zooplanktons held at El Colegio de la Frontera Sur (ECOSUR), Chetumal, Mexico (ECO-CH-Z-06587). The collected female had a reddish-brown colouration before preservation.

The second parasitic isopod species observed in our samples from the western Caribbean was *Oculophryxus bicaulis* Shields & Gómez-Gutiérrez, 1996. We found only two specimens of this species attached to the eye peduncles of *S. affine*. The first specimen (an adult female) measured 0.92 mm long \times 0.4 mm wide. The host euphausiid individual was 5.64 mm long (Figure 3(e); Table 1), collected from off the Honduran coast, between Roatan island and Utila. The second specimen of *O. bicaulis* was an ovigerous female (0.9 mm long \times 0.48 mm wide) (Figure 3(a,b); Table 1) with an attached male (0.27 mm long, arrowed in Figure 3(a)). It was observed in the same host species, *S. affine* (body length = 5.6 mm) southwest of the Cayman Islands. These are the first records of this species in the Caribbean Sea.

The third isopod species found in our Caribbean samples was *Branchiophryxus koehleri* Nierstrasz & Brender à Brandis, 1931 (body 1.68 mm long, 0.76 mm wide) (Figure 3(c–e); Table 1). It was found attached to the pinnulae of the seventh gills of *Stylocheiron longicorne* (body length = 6.36 mm). The body is ovoid, with a relatively narrow anterior half. The mouth and four pairs of subchelate appendages are located anteriorly (Figure 3(c)). Five segments can be distinguished on the dorsal medial surface of the body. This is the first record of this species in the NWT. In Table 2, we provide data on the geographic distribution of *Oculophryxus bicaulis* and *Branchiophryxus koehleri* and their hosts.

Discussion

According to Shields and Gómez-Gutiérrez (1996), up to 18 euphausiid species are currently known to be parasitised by dajid isopods; this isopod family is known to contain 18 genera and 55 species; only 4 dajid genera and 10 species have been reported as parasites of euphausiids. In this work, we provide new observations on three of these four isopod genera (i.e. *Heterophryxus*, *Oculophryxus* and *Branchiophryxus*), and three species of host euphausiids, some of them not hitherto reported as hosts of the isopod species recorded.

Heterophryxus appendiculatus is characterised by having a large, straight frontal margin (Drago and Albertelli 1975) (Figure 2(c)). The female uses the first four pereopods to attach to the host body and the small male attaches to the fifth pereopod. This isopod has been found almost exclusively in species of *Euphausia*. This strong host preference and data provided by Gómez-Gutiérrez and Castellanos-Osorio (2010) suggested that it was more

Table 1. Data from the collection, location and measurements of the female dajid isopods collected in Table 1. Data from the collection, location and measurements of the female dajid isopods collected in the Caribbean Sea during this survey.

Species	Date of collection	Time of collection	Geographic location	Net type (mesh size in mm)	Sampling depth (m)	Body size length x width (mm)
<i>Heterophryxus appendiculatus</i>	02/07/1999	21:25	18°38' 31"N 87°27' 07"W	CalCOFI net 0.3 mm	0-100	1.12 x 0.4 0.57 x 0.21
<i>H. appendiculatus</i>	02/07/1999	22:15	18°32' 01"N 87°28' 02"W	CalCOFI net 0.3 mm	0-100	1.66 x 0.35 1.68 x 0.44 1.59 x 0.62 1.72 x 0.68 1.09 x 0.31 1.28 x 0.35 1.41 x 0.48
<i>H. appendiculatus</i>	02/07/1999	10:45	21°21' 30.6"N 86°14' 16.2"W	Bongo net 0.33 mm	0-200	3.1 x 1.2
<i>Oculophryxus bicaulis</i>	11/04/2010	07:17	16°11' 6.00"N 86°45' 7.13"W	MOCNESS net system 0.5 mm	0-266	0.92 x 0.4
	18/04/2011					
	09/04/2011	02:06	19° 59.77"N 81°28' 28.5"W	MOCNESS Net system	0-308	0.9 x 0.48
<i>Branchiophryxus koehleri</i>	16/04/2011	05:24	16°47' 4.81"N 84°35' 6.83"W	0.5 mm MOCNESS Net system 0.5 mm	0-278	1.68 x 0.76

Table 2. Geographical distribution, host and known records of the parasitic dajid isopods *Oculophryxus bicaulis* and *Branchiophryxus koehleri*.

Euphausiid host	Reference	Location
<i>Oculophryxus bicaulis</i>		
<i>Stylocheiron affine</i> , <i>S. longicorne</i>	Shields and Gómez-Gutiérrez (1996)	México Gulf; west coast of Baja California
<i>S. affine</i>	Gómez-Gutiérrez and Shields (1998)	South China Sea
<i>S. affine</i>	Gómez-Gutiérrez and Castellanos-Osorio (2010)	Mexican Caribbean Sea
<i>S. affine</i>	Gómez-Gutiérrez et al. (2017)	Central Coast of Chile
<i>S. affine</i> , <i>S. longicorne</i>	Brinton (in litt.)	South China Sea
<i>S. affine</i>	This survey	Between Roatan Island and Utila, Honduras
<i>S. affine</i>	This survey	Southwest Cayman Islands
<i>Branchiophryxus koehleri</i>		
<i>S. affine</i> , <i>S. carinatum</i>	Nierstrasz and Brender à Brandis (1931)	Portugal, Morocco, Senegal
<i>S. affine</i> , <i>S. carinatum</i>	Sebastian (1970)	Arabian Sea, South India
<i>S. longicorne</i>	This survey	Northeast of Mangrove Bight, Honduras

likely to find it parasitising other species of the same genus. Quite unexpectedly, in this work we found *H. appendiculatus* parasitising a species of *Thysanopoda* Milne Edwards, 1830, this being the first host record of this parasite from a non-*Euphausia* host. Gómez-Gutiérrez and Castellanos-Osorio (2010) considered that it was unlikely that *H. appendiculatus* would parasitise large krill species. The body length of the parasitised *T. aequalis* is within the size range (8–17 mm) of the other euphausiid species on which this dajid has been found.

The female *H. appendiculatus* collected in the CB atoll (1.41–1.72 mm) and from off Cozumel Island (1.46–2.2 mm) have a similar body length, but these two groups are smaller than the females found on the southern coast of Baja California (1.92 mm) by Gómez-Gutiérrez and Castellanos-Osorio (2010). All are smaller than the specimen observed in *T. aequalis* (3.1 mm) and that reported by Shimomura and Ohtsuka (2008), in Japanese waters (3.5 mm). Gómez-Gutiérrez and Castellanos-Osorio (2010) suggest that these differences in size may be related to the latitude; tropical–subtropical individuals of *H. appendiculatus* are relatively smaller but probably have shorter maturation times than those from higher latitudes. The occurrence of an ovigerous female and three more carrying epicaridium larvae in our survey appears to support this point. According to Gotto (1983), these larvae appear to differ widely from other larval stages of epicarids. The free females of *Heterophryxus appendiculatus* were observed in samples where only species of *Euphausia* (i.e. *E. tenera* and *E. americana*) were found.

The females of *O. bicaulis* attach to *Stylocheiron* host individuals by grasping the antennular peduncles with their hook-like modified antennae (Gómez-Gutiérrez and Shields 1998). Shields and Gómez-Gutiérrez (1996) stated that the unique morphology of the eye in *Stylocheiron*, with a prominent eye peduncle, is an important factor in determining *O. bicaulis*' host specificity to species of *Stylocheiron*. Considering that members of *Stylocheiron* including the two species (i.e. *S. affine* and *S. longicorne*) in which this dajid has been recorded are widely distributed in tropical latitudes, it is likely that *O. bicaulis* also has a wide circumtropical distribution. This is the first record of this parasite in the waters of Honduras and the Cayman Islands, in the western Caribbean Sea. This species has been previously reported in the south China seas, the west coast of Baja California, the southern Gulf of Mexico, the northern Mexican Caribbean and the central

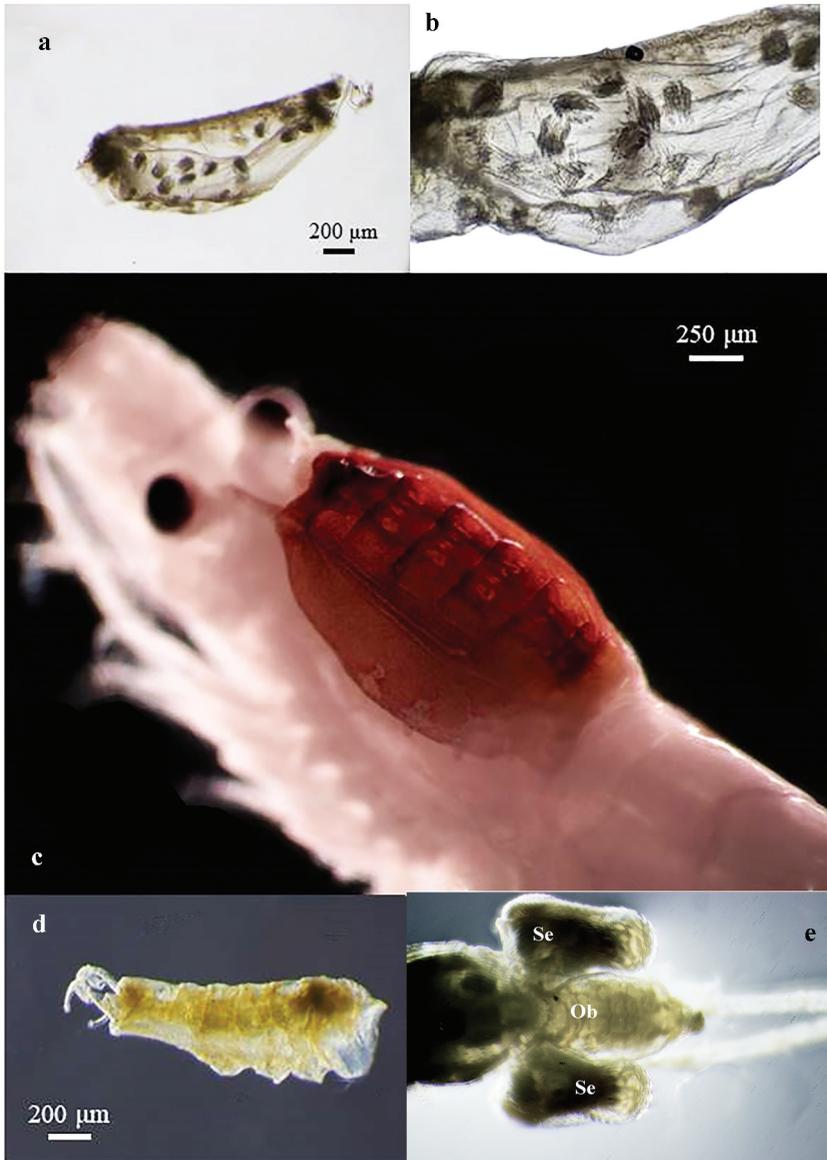


Figure 2. *Heterophryxus appendiculatus*, (a) female with epicaridium larvae; (b) same, detail of epicaridium larvae; (c) ovigerous female attached to cephalothorax of *Thysanopoda aequalis*; (d) juvenile individual, lateral view; (e) female of *Oculophryxus bicaulis* attached to *Stylocheiron affine*.

coast of Chile (Gómez-Gutiérrez and Shields 1998; Shields and Gómez-Gutiérrez 1996; Gómez-Gutiérrez and Castellanos-Osorio 2010; Gómez-Gutiérrez et al. 2017). It seems likely that the apparent disjunct distributional pattern of some of these parasites results from the lack of regional studies on this fauna.

The body size range of the female *O. bicaulis* examined in this study (0.9–0.92 mm) is similar to that reported by Shields and Gómez-Gutiérrez (1996) in Baja Californian females

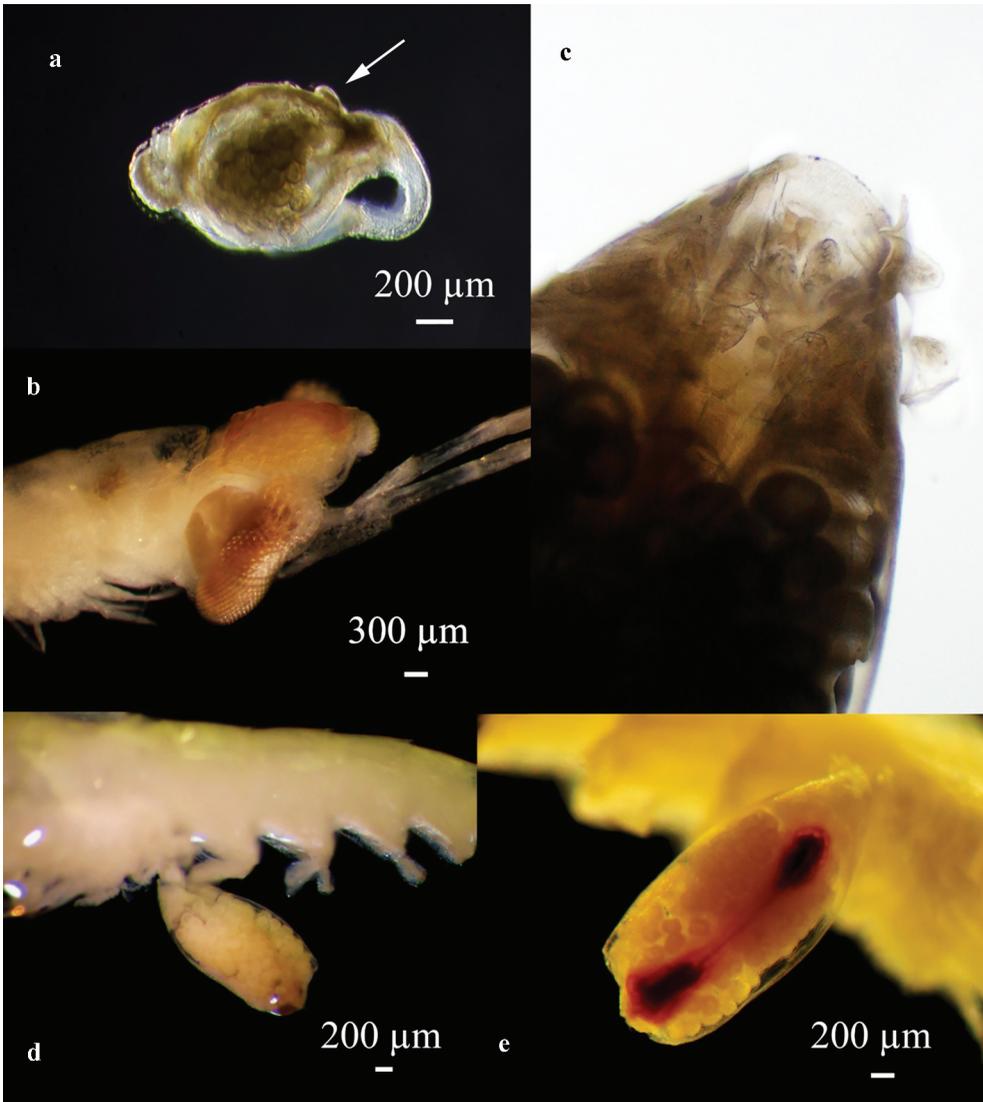


Figure 3. *Oculophryxus bicaulis*, (a) free ovigerous female with dwarf male (arrow), showing its modified curved antennules to grasp the host eye peduncle; (b) ovigerous female with male, attached to *Stylocheiron affine* eye peduncles; (c) *Branchiophryxus koehleri*, adult female, detail of anterior part of body, with four pairs of pereopods; (d) *B. koehleri*, ovigerous female, ventro-lateral view; (e) *B. koehleri*, female attached to branchial pinnules of *S. longicorne*.

(0.92–1.28 mm). Unfortunately, most other published records of this species do not include size data. A female with a male *O. bicaulis* collected from *S. affine* in the Gulf of Mexico was 0.92 mm long (IC-O, pers. obs.). Males of *O. bicaulis* observed in the western Caribbean, off Baja California (Shields and Gómez-Gutiérrez 1996), and in the Gulf of Mexico (pers. obs., IC-O), have reported sizes of 0.27, 0.3 and 0.3 mm, respectively.

Branchiophryxus koehleri has not been hitherto reported from the NWT region; this species and its other two known congeners (i.e. *B. caulleryi* Koehler, 1911 and

B. nyctiphanae; Caullery, 1897) have been recorded from the eastern Atlantic, Arabian Sea, central western Pacific, central Pacific Ocean and southern China seas (Caullery 1897; Lo Bianco 1902; Koehler 1911; Nierstrasz and Brender à Brandis 1931; Sebastian 1970; Gómez-Gutiérrez et al. 2017).

The genus *Branchiophryxus* is clearly distinguished from other dajid isopod genera by its possession of only four pairs of thoracopods and four pairs of incubatory plates (Richardson 1905). The body is short and robust. The specimen observed in this study has an ovoid body tapering anteriorly, whereas in *B. caulleryi*, the frontal margin is distinctly truncated, with a narrow straight edge (Caullery 1897); in *B. nyctiphanae*, the frontal margin is clearly rounded and much wider (Koehler 1911). Our Caribbean specimen resembles *B. koehleri* as reported by Sebastian (1970) in the Arabian Sea, with an ovoid body and a rounded frontal margin. One female individual of *Branchiophryxus* sp. (with attached male), collected in the Gulf of Mexico, differs from the other three known species in the body shape, the structure of the frontal margin (distinctly hexagonal), the presence of body constrictions and separate lateral margins of the incubation pouch. This specimen from the Gulf of Mexico will be re-examined to determine if it represents an undescribed species.

The single female recorded by Sebastian (1970) in the Indian Ocean was 0.95 mm in length, whereas our specimen from Honduran waters was much larger (1.68 mm). It was also larger than the female (1.2 mm) observed in the Gulf of Mexico. Both Caribbean specimens are noticeably larger than those mentioned in the Indian Ocean reports, but we cannot advance an explanation for this size difference.

As in other crustacean parasites (Williams and Boyko 2012; de Almeida Alves-júnior et al. 2018), dajid isopods appear to have a high host specificity: *Oculophryxus bicaulis* parasitises only species of *Stylocheiron*; *Notophryxus globularis* is known only from *Thysanoessa gregaria* G. O. Sars, 1883; *Notophryxus lateralis* infests only species of *Nematoscelis*; *Branchiophryxus nyctiphanae* is known only as a parasite of *Meganyctiphanes norvegica*; *H. appendiculatus* was long deemed to be exclusive of *Euphausia* (i.e. Sars 1885; Shields and Gómez-Gutiérrez 1996; Gómez-Gutiérrez & Castellanos-Osorio 2010; Gómez-Gutiérrez et al. 2017), but in this study, we recorded it as a parasite of a member of a different genus: *Thysanopoda*, thus expanding the host range of this isopod to a different genus. As proposed by Gómez-Gutiérrez and Castellanos-Osorio (2010), it is likely that dajid isopods are able to infect species of euphausiids with a similar body size regardless of the genus. Based on our examination of 210 zooplankton samples from the Western Caribbean, in this work, we report a new host record at the genus level, of *Heterophryxus appendiculatus*, which we found as a parasite of a species of *Thysanopoda*. *Oculophryxus bicaulis* was confirmed as a parasite of *Stylocheiron* species. The rare *Branchiophryxus koehleri* was first recorded for the NWT region.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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