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Bopyrid isopods of the genus *Aporobopyrus* infesting porcellanid crabs (Decapoda: Anomura) in the Gulf of California, Mexico: new host and parasite records

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Abstract.—Based on examination of porcellanid crabs from the Gulf of California, Mexico, deposited in the Colección Nacional de Crustáceos of the Instituto de Biología, Universidad Nacional Autónoma de México, we document *Petrolisthes crenulatus, P. hirtispinosus* and *P. galapagensis* as hosts of bopyrid isopods belonging to the genus *Aporobopyrus* for the first time. The new records increase to 42 the number of known hosts for these ectoparasites. Further, this report provides the first record of *Aporobopyrus curtatus* for the coasts of Mexico and the eastern Pacific, becoming the second species of the genus with an Amphiamerican distribution. The distribution ranges of *A. bourdonis*, *A. muguensis* and *A. trilobatus* are extended and morphological remarks and a key to the four bopyrid species are provided.

Keywords: Bopyridae, eastern Pacific coast, Epicaridea, host-parasite association, Isopoda

The infraorder Anomura is one of the most abundant and diverse groups of decapods in the Gulf of California, and the crabs of the family Porcellanidae are a numerically dominant group in the intertidal zones due in part to their high diversity (Villalobos & Álvarez 2002). Anomurans are the group second most commonly infested by bopyrid isopods, after caridean shrimps (Boyko & Williams 2009). Within Anomura, porcellanid crabs are mainly parasitized by members of the genus *Aporobopyrus* Nobili, 1906 (Williams & Madad 2010), but also by species of the pseudionine genera *Anuropodione* Bourdon, 1967, *Aporobopyrina* Shiino, 1934, *Parionella* Nierstrasz & Brender à Brandis, 1923, *Pleurocrypta* Hesse, 1865 and *Pseudione* Kossmann, 1881 (Boyko et al. 2012). All of them live ectoparasitically in their hosts' branchial chambers and can partially or completely inhibit their hosts' growth and reproduction (Van Wyk 1982, Oliveira & Masunari 1998). *Aporobopyrus* currently contains 20 described species worldwide (Boyko et al. 2008 onwards), of which only *A. gracilis* Nierstrasz & Brender à Brandis, 1929 and *A. retrorsa* (Richardson, 1910) parasitize non-porcellanid hosts (Williams & Madad 2010).

Markham (1992) pointed out that there are relatively few species of bopyrid isopods known from the Pacific coast of the Americas, a pattern that becomes evident when the number of species reported for the Western Pacific (166) and those reported for the eastern Pacific (37) are compared (Williams & Boyko 2012). Twenty species of bopyrids are recognized from the Pacific coast of Mexico, five belonging to the subfamily Pseudioninae and only three to *Aporobopyrus*: *A. bourdonis* Markham, 2008 on

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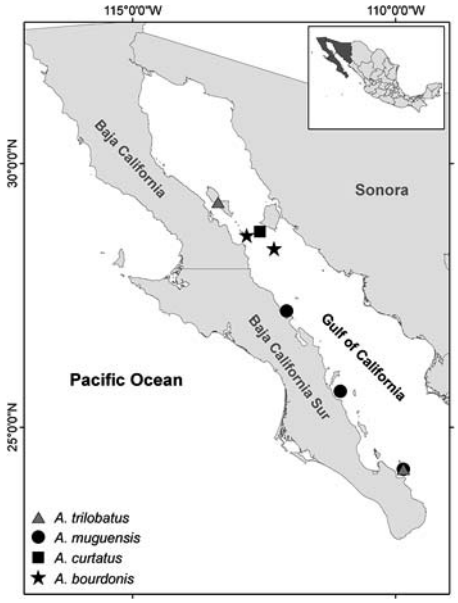

Fig. 1. Sampling sites of porcellanid crabs parasitized with bopyrids (*Aporobopyrus* spp.) in the Gulf of California, Mexico.

Petrolisthes edwardsii (de Saussure, 1853), *A. muguensis* Shiino, 1964 parasitizing *Pachycheles rudis* Stimpson, 1859 and *A. trilobatus* (Nierstrasz & Brender à Brandis, 1925) parasitizing *Petrolisthes hians* Nobili, 1901 (Markham 2008, Román-Contreras 2008), but no bopyrids on porcellanids have so far been recorded in the Gulf of California. Only three species of pseudionines are known from the Gulf of California: *Pseudione galacanthae* Hansen, 1897 on *Galacantha diomedae* Faxon, 1893, *Progebiophilus bruscai* Salazar-Vallejo & Leija-Tristan, 1990 on *Upogebia dawsoni* Williams, 1986 and *Ione cornuta* Bate, 1865 on *Neotrypaea gigas* (Dana, 1852) (Román-Contreras 2008, Boyko et al. 2017).

Notwithstanding the fact that taxonomic or ecological data on diverse potential hosts of bopyrids is abundant in the literature, their associated parasites are often overlooked (Boyko & Williams 2009), hence the reappraisal of material already deposited in museums or institutional collections can provide an opportunity to increase the records and the knowledge about this group of parasites (Markham 2008). The present study is based on material collected during the "Conservación de las islas en un mar en el desierto, Golfo de California" project, which was conducted from 1985 to 1987 to create an inventory of the plant and animal species that inhabit the islands of the Gulf of California (Villalobos et al. 1992). All crustaceans collected were deposited in the Colección Nacional de Crustáceos (CNCR) of the Instituto de Biología, Universidad Nacional Autónoma de México, in Mexico City. We present herein the results of a study of the porcellanid crabs parasitized by bopyrids, with notes on their morphological variability, distribution and host specificity.

Materials and methods

Porcellanid crabs were collected every 3 months by hand, between May 1985 and May 1987, from beneath rocks and coral rubble in the intertidal zones of 23 islands in the Gulf of California, Mexico. Twelve islands are in the northern gulf and 11 are situated along the east coast of the Baja California Peninsula in the southern portion; the sampling sites were located in the protected zone of the islands (Fig. 1). The crabs were preserved in 70% ethanol, identified to species, sexed, and deposited in the CNCR. For more details on the methods and a description of the sampling sites see Villalobos et al. (1989) and Villalobos & Álvarez (2002).

Measurements taken from each host were carapace length (CL), from the anterior margin of the rostrum to the posterior margin of the carapace, and carapace width (CW), as the maximum distance between the lateral margins of the carapace (Britto-Mata et al. 2017). The parasites were removed from the hosts' branchial chambers and the total length

(TL) of males and symmetrical females were measured from the anteromedial margin of the head to the posterior margin of the pleon; in asymmetrical females TL was considered as the anterior margin of the first peromere of the longer side to the posterior margin of the pleon. The width (W) was measured across the widest pereomere (Romero-Rodríguez & Martínez-Mayén 2018). Length and width of the head and pleon of each specimen are also provided (Table 1). Measurements were made using an ocular micrometer attached to a compound microscope with a 0.1 mm precision. Comments on morphological variation or on characters that were not mentioned in previous studies are provided for all species.

Results

Systematics.—

Suborder Cymothoida Wägele, 1989
Infraorder Epicaridea Latreille, 1825
Superfamily Bopyroidea Rafinesque, 1815
Family Bopyridae Rafinesque, 1815
Subfamily Pseudioninae Codreanu, 1967
Genus *Aporobopyrus* Nobili, 1906
Aporobopyrus bourdonis Markham, 2008
(Figs. 2A, 3A, 4; Table 1)

"a bopyrid" Haig 1968: 61.
"Pseudioninae sur *Petrolisthes edwarsi* (de Saussure)" Bourdon 1976: 236–238, 241 (in table), fig. 43.
"Bopírido indeterminado" Campos & Campos 1989: table 2.
"Pseudioninae, gen. sp.?" Salazar-Vallejo & Leija-Tristán 1990: 430 (appendix 1).
Aporobopyrus bourdonis Markham 2008: 146–148, 154, fig. 1.—Boyko et al. 2012: 5, 22 (in table).

Material examined.—1 adult female (host: *Petrolisthes galapagensis* Haig, 1960, CNCR 4161) Isla San Pedro Mártir, Sonora, Mexico (28°22′49″N, 112°18′25″W), J.C. Nates and A. Cantú coll.; 04 May 1985, CNCR 19408. 1 juvenile female, 1 male (host unknown; parasite detached); Isla San Lorenzo, Baja California, Mexico (28°37′44″N, 112°49′34″W), J.C. Nates and E. Lira coll., 14 Feb 1986, CNCR 19446.

Distribution.—Isla San Lorenzo and Isla San Pedro Mártir, Baja California, Mexico (this study); Bahía de Chamela, Jalisco, Mexico (Bourdon 1976) and Guanacaste, Costa Rica (Markham 2008).

Remarks.—The head of both adult and juvenile females is wider than long, broadly rounded anteriorly with a narrow but well defined frontal lamina, slightly curved on its posterior end (Fig. 2A). Antennules and antennae are composed of 3 and 5 segments each, respectively. In both females, the pereomeres are distinct and bear coxal plates and tergal projections on pereomeres 1–4 on both sides, those of the adult female are more evident on the longer side (Fig. 2A), whereas in the juvenile female the coxal plates are well developed and discernible on pereomeres 1–5 but the tergal projections are barely developed, with those on pereomere 1 being the most conspicuous, and becoming less prominent posteriorly to pereomere 4.

The oostegites close completely the brood pouch of the adult female, the posterior margin of oostegites 2–4 bear small setae whilst the fifth bears a row of long setae, agreeing with previous reports (Bourdon 1976, Markham 2008). Oostegites 2–5 of the juvenile female are not entirely developed, they are rectangular, do not reach the ventral midline of the female and lack setae on their posterior margins. The shape of the first pair of oostegites of the adult female matches those described by Bourdon (1976) and Markham (2008), except for a row of small setae on its posterior margin not previously reported (Fig. 4A, B); in the juvenile female the anterior and posterior lobes are ovoid and triangular, respectively. The shape of the inner ridge of oostegite 1 is variable because Bourdon (1976) described

Table 1.—Measurements (mm) of the bopyrids of the genus *Aporobopyrus* and their hosts recorded in the Gulf of California, Mexico: CNCR, catalogue number of the Colección Nacional de Crustáceos, IB-UNAM; TL, total length; CL, carapace length; CW, carapace width; Juv., juvenile; Ov., ovigerous.

					Head		Pleon					
Parasite	CNCR	Sex	TL	W	Length	Width	Length	Width	Host	Sex	CL	CW
A. bourdonis	19408	Adult female	4.30	2.80	1.25	2.05	0.75	2.12	*P. galapagensis*	Male	6.33	8.40
	19446	Juv. female	4.00	2.63	0.93	1.70	1.00	1.86	Detached from host			
		Male	1.98	0.70	0.27	0.49	0.50	0.61				
A. curtatus	19450	Ov. female	7.10	4.30	1.62	2.87	1.48	2.70	*P. hirtispinosus*	Female	10.57	12.43
		Male	3.90	1.03	0.37	0.87	0.47	0.91				
A. muguensis	21876	Adult female	2.40	1.72	0.79	1.19	0.54	1.06	*P. crenulatus**			
		Male	1.29	0.64	0.20	0.49	0.43	0.54				
	22189	Juv. female	2.53	1.58	0.80	1.07	0.71	1.00	*P. crenulatus* *			
		Male	2.17	0.70	0.26	0.50	0.56	0.69				
	22195	Juv. female	1.76	1.03	0.43	0.74	0.50	0.73	Detached from host			
		Male	1.36	0.46	0.13	0.33	0.29	0.39				
A. trilobatus	19411	Adult female	3.27	2.37	1.25	1.60	0.86	1.45	*P. crenulatus*	Female	6.50	7.20
		Male	2.53	0.83	0.34	0.61	0.60	0.74				
	20074	Juv. female	1.16	0.71	0.34	0.54	0.26	0.47	*P. ortmanni*	Male	2.73	2.63
		Male	1.09	0.34	0.11	0.26	0.27	0.29				

* No host data measurement available, parasites were detached and none of the crabs in the lot showed a clear bulging of the carapace.

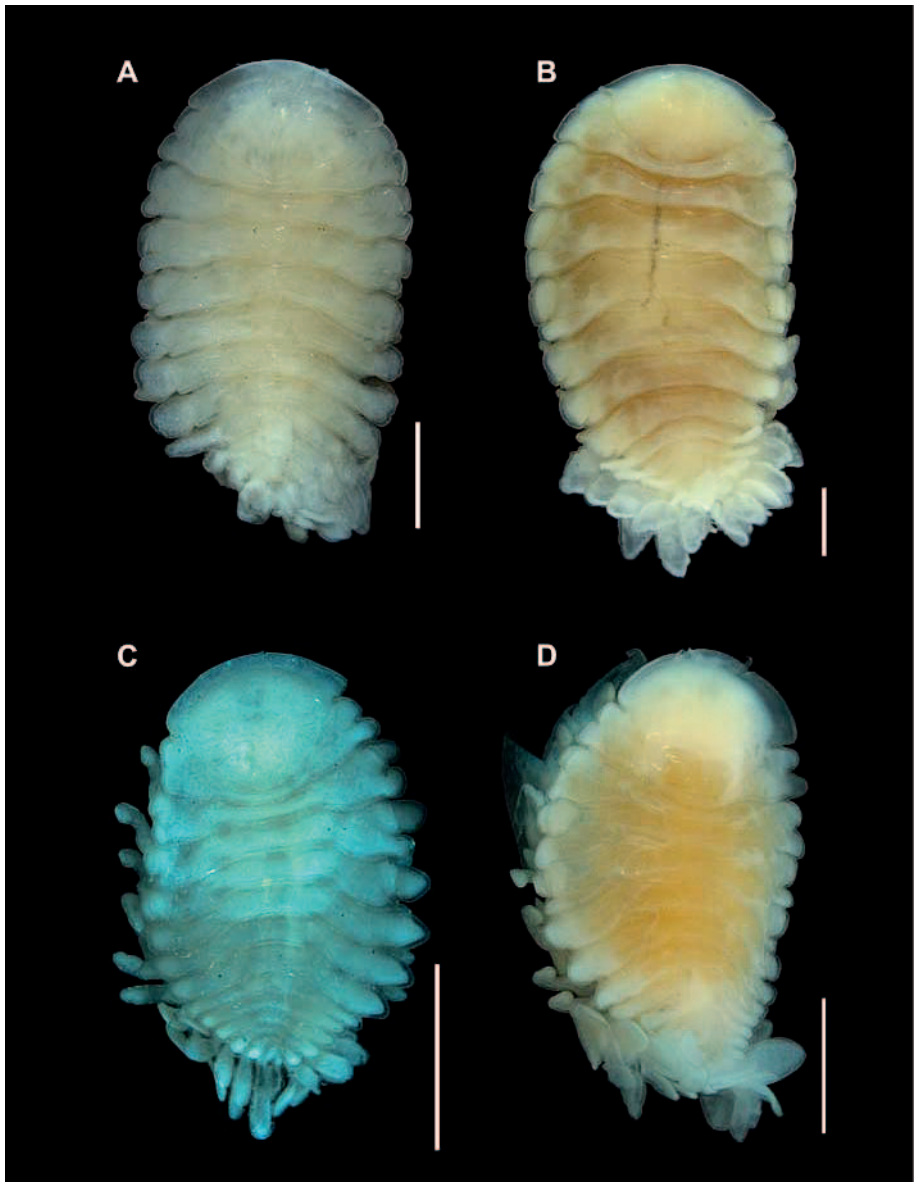

Fig. 2. Bopyrid adult females parasitic on porcellanid crabs in the Gulf of California, Mexico. A, *Aporobopyrus bourdonis* Markham, 2008; B, *Aporobopyrus curtatus* (Richardson, 1904); C, *Aporobopyrus muguensis* Shiino, 1964; *Aporobopyrus trilobatus* (Nierstrasz & Brender à Brandis, 1925). Scale bar = 1.0 mm.

it as having digitate projections, while Markham (2008) stated that it has a slightly sinuate flap overhanging a separating groove. The adult female examined herein fits Markham's (2008) description; in the juvenile female this trait is less evident.

The maxillipeds of the adult female are similar to those described by Markham (2008) but with 2 or 3 setae on the palp's anterior margin (Fig. 4C). In the juvenile female the maxillipeds are triangular with the posterior article wider than the anterior one and with a conspicuous palp. The

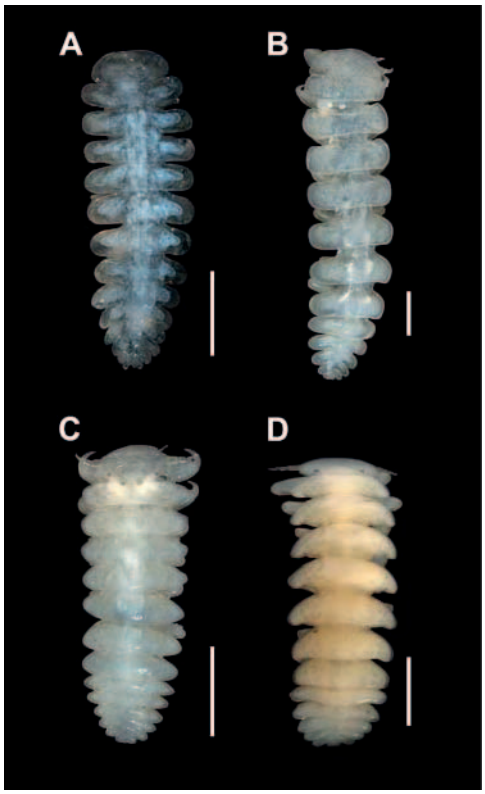

Fig. 3. Bopyrid males parasitic on porcellanid crabs in the Gulf of California, Mexico. A, *Aporobopyrus bourdonis* Markham, 2008; B, *Aporobopyrus curtatus* (Richardson, 1904); C, *Aporobopyrus muguensis* Shiino, 1964; *Aporobopyrus trilobatus* (Nierstrasz & Brender à Brandis, 1925). Scale bar = 0.5 mm.

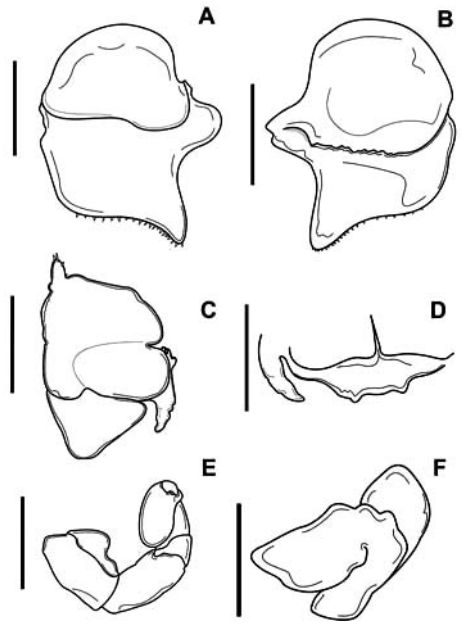

Fig. 4. Adult female of *Aporobopyrus bourdonis* Markham, 2008. A, first oostegite, external view; B, same, internal view; C, maxilliped; D, barbula; E, pereopod 7; F, left first pleopod. Scale bar = 0.5 mm.

barbula of the adult female has one sinuate lateral projection on each side and the medial margin is thick and slightly sinuate; that of the juvenile female has a tiny bulge on each side and a medial margin slightly thick but straight (Fig. 4D). The range of variation of the barbula is not defined yet, because Markham (2008) did not describe or illustrate it and our observations contrast with the barbula reported by Bourdon (1976), which have two lateral projections on each side with digitations on the margins of the external projection and the medial margin.

The pereopods in both adult and juvenile females are similar to those described by Markham (2008), except for the presence of a carina on the basis of each pereopod (Fig. 4E), this character was also noted by Bourdon (1976).

The pleon of both females agrees well with the original description of *A. bourdonis* (Markham 2008), even though that of the adult female is damaged distally. The pleopods are biramous, the endopodites are oblong and larger than the exopodites, which are ovoid in shape (Fig. 4F).

The male (Fig. 3A) that was attached to the ventral pleon region of the juvenile female agrees in size (Table 1) and morphology with Bourdon (1976) and Markham's (2008) descriptions of *A. bourdonis*, with the exception of the sixth pleomere which is not as reduced as noted by the latter author.

Overall, these specimens agree well with the characteristics described for *A. bourdonis*. The observed morphological variability adds to what was known from the

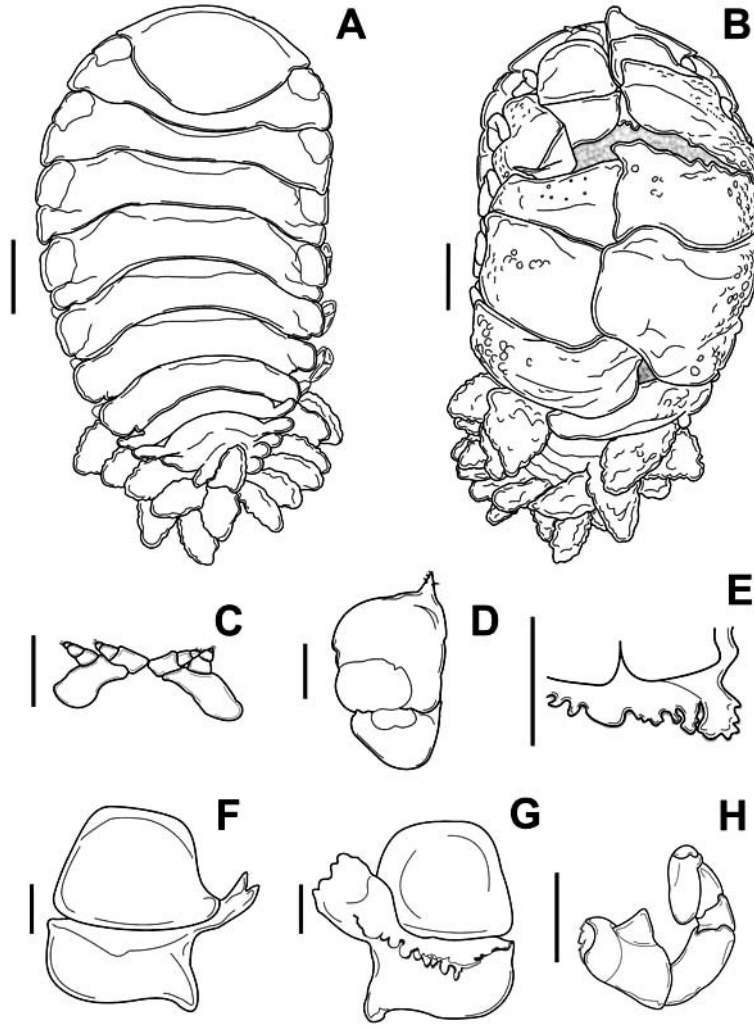

Fig. 5. Adult female of *Aporobopyrus curtatus* (Richardson, 1904). A, dorsal view: B, ventral view; C, antennules and antennae; D, maxilliped; E, barbula; F first oostegite, external view; G, same, internal view; H, barbula; E, pereopod 7; F, left first pleopod. Scale bar = 1.0 mm for A, B; 0.5 mm for C—H.

other two known females of the species, one of them had been described first as a "Pseudioninae sur *Petrolisthes edwardsi*" (Bourdon 1976) but subsequently Markham (2008) identified it as *A. bourdonis*. This is the first record of a bopyrid isopod parasitizing *Petrolisthes galapagensis*, it is also a new host record for *A. bourdonis* and extends its known geographic distribution into the Gulf of California, Mexico.

Aporobopyrus curtatus (Richardson, 1904) (Figs. 2B, 3B, 5, 6; Table 1)

Pseudione curtata Richardson 1904: 80–81, figs. 72–75.—Richardson 1905: 523, 530–531, figs. 574–577.—Nobili 1906: 1108.—Van Name 1920: 72.—Nierstrasz & Brender à Brandis 1923: 72,

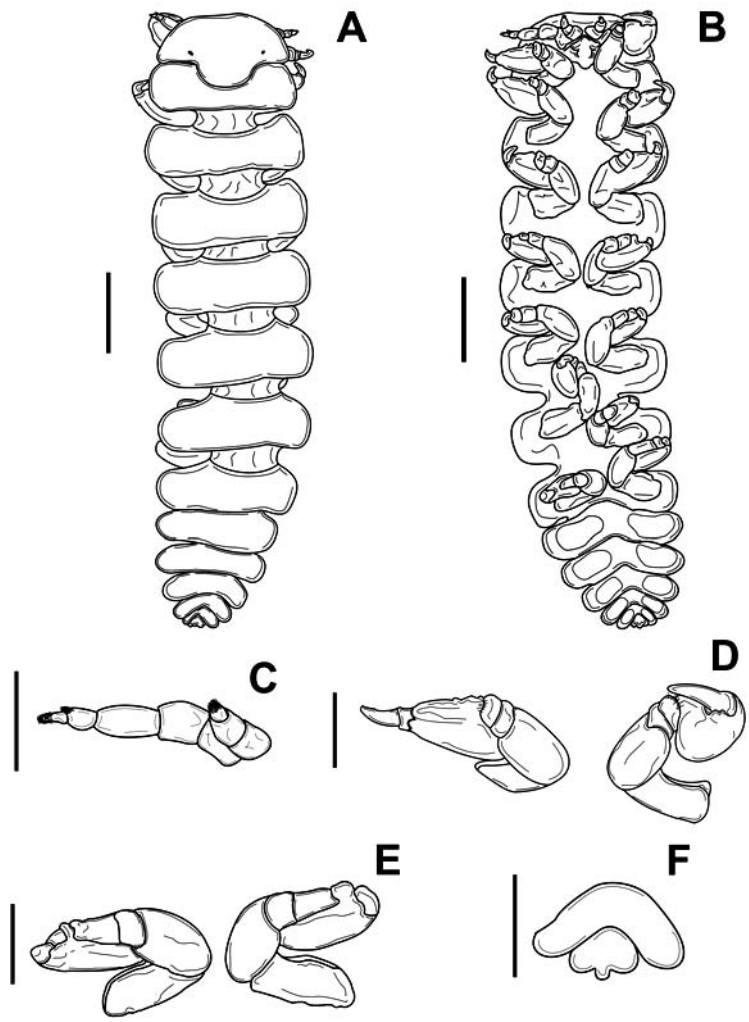

Fig. 6. Adult male of *Aporobopyrus curtatus* (Richardson, 1904). A, dorsal view: B, ventral view; C, antennule and antenna; D, pair of pleopods 1; E, pair of pleopods 7; F, pleomeres 5 and terminal in dorsal view. Scale bar = 0.5 mm for A, B; 0.2 mm for C—F.

74, 77–78.—Nierstrasz & Brender à Brandis 1925: 3, 7.—Nierstrasz & Brender à Brandis 1931: 169.—Shiino 1933: 271.—Shiino 1952: 41.—Shiino 1958: 35.—Menzies & Glynn 1968: 13.—Schultz 1969: 326, fig. 522.

Aporobopyrus curtatus Nierstrasz & Brender à Brandis 1929: 12.—Monod 1933: 227.—Shiino 1934: 267.—Shiino 1964: 22.—Markham 1975: 257–265, 269, figs. 1–3.—Menzies & Frankenberg 1966: 26.—Bourdon 1976: 166, 175–180, 188, 238, 240–241 (in table), figs. 6–9.—Camp et al. 1977: 17.—Lemos de Castro & Brasil-Lima 1980: 1–4, 6, figs. 1–15.—Duarte & Morgado 1983: 3, 5, 7, 11, fig. 10.—Markham 1988: 22–24, 56 (in table).—Markham & Donath-Hernández 1990: 242.—Boyko et al. 2012: 5, 21–24 (in table).

Aporobopyrus johannis Nierstrasz & Brender à Brandis 1929: 10–11, figs. 9–

10.—Monod 1933: 227.—Shiino 1934: 267.—Shiino 1964: 22.

Pseudione curta [sic] Behre 1950: 18.

"bopyrid parasite" Haig, 1966: 355.

?*Aporobopyrus gracilis* Lemos de Castro 1965: 177–180, figs. 1–10.—Coelho & Koenig 1972: 256 (in table I).

Not *Pseudione curta* [sic] Menzies & Frankenberg 1966: 26 (= *Synsynella choprai* (Pearse 1932)).

?"bopyrid" Gore 1970: 963.

?"bopyrid parasites" Gore 1974: 715.

Material examined.—1 ovigerous female, 1 male (host: *Petrolisthes hirtispinosus* Lockington, 1878, CNCR 5411), Isla San Esteban, Sonora, Mexico (28°42′06″N, 112°34′29″W), J.C. Nates and E. Lira coll., 19 Feb 1986, CNCR 19450.

Distribution.—Along the western Atlantic coast, from North Carolina, USA, to São Paulo, Brazil (Boyko et al. 2012); in the eastern Pacific, Isla San Esteban, Sonora, Mexico (present study).

Redescription.—Female. Measurements shown in Table 1. Body larger than wide (Table 1) with outline smoothly oval and all body regions and segments distinct (Figs. 2B; 5A, B). Head almost twice as broad as long (Table 1), with narrow but well-defined frontal lamina that ends in lateral projections, rounded posteriorly and deeply embedded in pereomere 1 (Figs. 2B; 5A). No eyes. Antennules and antennae composed of 3 and 4 segments each, respectively, neither extending beyond margin of head (Fig. 5C). Terminal segment of each antenna is smallest and tipped with setae. Basal segment of antenna markedly larger than others (Fig. 5C). Maxilliped subtriangular in shape, with conspicuous non-articulated palp that bears small setae on its anterior margin (Fig. 5D). Barbula with two digitate lateral projections on each side, external one larger than internal, medial margin slightly concave with evident digitations (Fig. 5E).

Pereon widest across pereomere 3. Conspicuous dorsolateral bosses and narrow coxal plates on pereomeres 1–4 (Fig. 5A). Oostegites firmly enclosing marsupium (Fig. 5B); first pair with anterior segment oval-shaped and posterior segment rectangular with well defined falcate terminal lobe on posterolateral corner (Fig. 5F, G), digitate projections on internal ridge (Fig. 5G). Oostegites 2–4 with small setae on posterior margins, fifth one with row of larger setae. Pereopods slightly larger in size posteriorly, each with evident basal carina (Fig. 5H).

Abdomen of 6 pleomeres, each produced into lateral plates (Fig. 5A). Ventrally covered in part by five pairs of biramous, triangular and tuberculate pleopods, with margins bulging into fleshy bead (Fig. 5B). Endopodite larger than exopodite in all five pairs, both rami progressively smaller from first to fifth pleopods (Fig. 5B). Pair of uniramous uropods similar to pleopods.

Male. Measurements shown in Table 1. Body slightly tapered with all body regions and segments distinct. Head oval-shaped and twice as wide as long but narrower than first pereomere; anterior margin almost straight (Figs. 3B; 6A). Tiny eyes near posterior border (Fig. 6A). Antennules and antennae composed of three and five articles each, respectively; both tipped with setae on distal and subdistal segments (Fig. 6C).

Pereon widest on pereomeres 2 and 3, but other pereomeres not markedly narrower. All pereomeres with rounded edges and deeply separated by anterolateral indentations (Figs. 3B; 6A). Pereopods differ in size, first two pairs are largest with dactyli and propodi larger than others, all pereopods progressively decreasing in size posteriorly (Fig. 6B). Bases of all pereopods each with conspicuous carina (Fig. 6D, E).

Pleon of six distinct pleomeres, ventrally without pleopods or uropods but with faint swellings on five pleomeres (Fig. 6B).

Terminal pleomere with three-pointed structure having lateral edges directed posteriorly and partly surrounded by fifth pleomere (Fig. 6F).

Remarks.—The morphology of the female examined fits well with previous descriptions of *A. curtatus* (Richardson 1904, Markham 1975, Bourdon 1976), except that the palps on the maxillipeds and the lateral plates on the pleomeres are more conspicuous than those illustrated by Markham (1975: Fig. 1D and 1A, respectively). Overall, the characteristics of the male also agree with those reported for *A. curtatus*. The anterolateral indentation between pereomeres is an evident difference with respect to the males illustrated in the original description (Richardson 1904: Fig. 75) and redescription (Markham 1975: Fig. 3) of this species, but is similar to that noted by Markham (1988) for males of *Aporobopyrus bonairensis* Markham, 1988, a species that occurs in the same range of *A. curtatus* and infest the same host species on the western Atlantic coast (Markham, 1988). However, the indentation between pereomeres was also observed in some males of *A. curtatus* from the western Atlantic (Markham 1975; 1988). Moreover, the general structure of the pereopods matches with previous reports (Markham 1975; 1988) and the meri and carpi of all of them are distinct (Fig. 6D, E), as was illustrated by Markham (1975: Fig. 3D, E), which differs from the meri and carpi being fused on *A. bonairensis* (Markham 1988).

Aporobopyrus curtatus parasitizes seven species of porcellanid crabs in the western Atlantic (Boyko et al. 2012) and exhibits a certain degree of morphological variation according to the host it is found on; for example, Bourdon (1976) pointed out differences in the inner margin of the first oostegite and the basal carinae of the pereomeres between females that parasitized *Petrolisthes galathinus* (Bosc, 1801) and *Porcellana sayana* (Leach, 1820). In contrast, the female examined here agrees

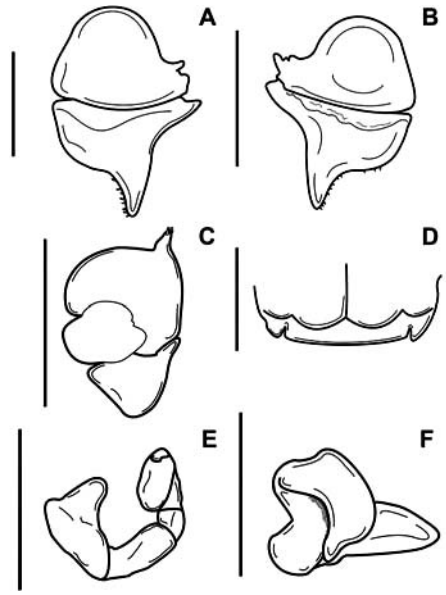

Fig. 7. Adult female of *Aporobopyrus muguensis* Shiino, 1964. A, first oostegite, external view; B, same, internal view; C, maxilliped; D, barbula; E, pereopod 7; F, left first pleopod. Scale bar = 0.5 mm.

well with the redescription presented by Markham (1975), despite that it is recorded in a new host and locality. Likewise, although the female is one of the largest reported to date (Table 1) its size is within with the body length range reported by Markham (1975) (1.7–8.9 mm TL), but the size of the male (Table 1) exceeds almost twice the size of the largest male (2.50 mm TL) previously reported (Lemos de Castro & Brasil-Lima 1980, Markham 1988). No previous records exist of *A. curtatus* for Mexico, and this first report from the Pacific coasts establishes an Amphiamerican distribution pattern, similar to that of *A. trilobatus*, the only species of the genus *Aporobopyrus* reported heretofore on both Atlantic and Pacific coasts (see Boyko et al. 2012). *Petrolisthes hirtispinosus* is a new host for *A. curtatus*.

Aporobopyrus muguensis Shiino, 1964
(Figs. 2C, 3C, 7; Table 1)

Aporobopyrus muguensis Shiino 1964: 20–22, fig. 1.—Schultz 1969: 315, fig. 500

b.—Markham 1975: 265 (in table).—Miller 1975: 285–286, 305, pl. 64, fig. 15.—Bourdon 1976: 166, 187.—Haig & Abott 1980: 589.—Lee & Miller 1980: 544, pl. 57, photograph 21.11.—Wallerstein 1980: 235.—Hart 1982: 32.—Van Wyk 1982: 459–471, figs. 1–5, tables 1–3.—Sassaman et al. 1984: 651, 653.—Austin 1985: 587.—Sassaman 1985: 778, 782, 785, 787.—O'Brien & van Wyk 1985: 196, 197, fig. 2.—Campos-González & Campoy-Favela 1987: 39, 40–41, 42, 47, fig. 1.—Markham 1988: 27.—Campos & Campos 1989: 33 (in table).—Jay 1989: 75.—Salazar-Vallejo & Leija-Tristan 1990: 429 (in table).—Markham 1992: 3 (in table).—Sassaman 1992: 575, 576.—Brusca et al. 2007: 535.—Kuris et al. 2007: 654.—Román-Contreras 2008: 94 (in table).—Markham 2008: 148–150, fig. 2.—Boyko et al. 2012: 6, 21 (in table).

Aporobopyrus m guensis [sic] Bourdon 1976: 240.

Aporobopyrus muquensis [sic] Campos & Campos 1989: 30.

Aparobopyrus [sic] Raibaut & Trilles 1993: 423.

Material examined.—1 adult female, 1 male (host: *Petrolisthes crenulatus* Lockington, 1878, CNCR 7110), Isla San Marcos, Baja California Sur, Mexico (27°11′38″N, 112°04′08″W), E. Lira and M.D. Valle coll., 24 Jan 1987, CNCR 21876. 1 juvenile female, 1 male (host: *P. crenulatus* CNCR-6885), Isla Montserrat, Baja California Sur, Mexico (25°40′47″N, 111°02′43″W), E. Lira and M.D. Valle coll., 16 Jan 1987, CNCR 22189. 1 juvenile female, 1 male (host unknown; parasite detached), Isla Cerralvo, Baja California Sur, Mexico (24°24′00″N, 110°29′00″W), E. Lira and M.D. Valle coll., 27 Jan 1987, CNCR 22195.

Distribution.—Central and southern coasts of California, USA (Markham 2008), Bahía Todos Santos, Baja California (Campos-González & Campoy-Favela 1987) and Gulf of California (present study), Mexico.

Remarks.—The anterior margin of the head in all females is wide and curved, the frontal lamina undifferentiated and the antero-lateral borders are rounded; the head is nearly of the same width as the first pereomere (Fig. 2C). The antennules and antennae are composed of four and five segments each, respectively; the antenna hardly exceeds the margin of the head in the two larger females.

The pereon has seven distinct pereomeres, in the smaller female the coxal plates are inconspicuous whilst in the two adult females they are noticeable on pereomeres 1–4 but are more developed on pereomeres 2–4 of the larger side of body. The tergal projections are visible on pereomeres 1–4, mainly on the larger side of body, but the ones on the first pereomere are the most conspicuous. Oostegites 2–5 of juvenile females are not completely developed and do not reach the medial ventral region, their shapes are rectangular with small setae on their posterior margins. Oostegites 2–4 of adult females have small setae, while the fifth one has a row of larger setae. The anterior segment of the first pair of oostegites is oval and the posterior segment is rectangular with a falcate terminal lobe on its posterolateral corner that bears a row of small setae on its distal margin (Fig. 7A,B), the inner ridge is without ornamentations (Fig. 7B).

The maxilliped of the adult female has a wider anterior region (Fig. 7C), similar to that illustrated by Markham (2008: Fig. 2G), whilst in the juvenile females this arrangement is reversed. The barbula has a smooth and straight medial margin with one projection on each side (Fig. 7D); in the juvenile female there is only a tiny bulge while the adult female carries a larger projection (Fig. 7D) but not as slender as that illustrated by Markham (2008: 149, Fig. 2F).

In all females the pereopods are slightly larger posteriorly. The first has an inconspicuous carina that increases in size posteriorly until it becomes in a blunt carina on pereopod 7 (Fig. 7E).

The first two pairs of pleopods of the larger females are broad and leaf-like (Fig. 7F), the posterior pairs have a narrow base and become wider from the middle portion to its distal end, similar to those described by Shiino (1964). Both rami of the uropods are similar in size and touch each other medially, as was noted by Markham (2008).

The pereomeres in all males are distinct, in male CNCR 22189 they are spaced with rounded borders, while in male CNCR 21876 they are closer to each other with more acute borders. The first two pairs of pereopods are the largest bearing stout and acute dactyli (Fig. 3C).

The pleon is of six pleomeres, the first one about the same length as the last pereomere; the sixth pleomere is comprised of two short lobes, with a small anal projection between the lobes.

Shiino (1964) pointed out that *A. muguensis* is distinguished from its congeners because it has very narrow coxal plates only on the third and fourth pereomeres of the longer side of the female, and by the bilobed pleotelson of the male; both features were observed in the specimens examined. According to Markham (2008), the known hosts for this bopyrid are *Pachycheles holosericus* Schmitt, 1921, *P. pubescens* Holmes, 1900, *P. rudis* Stimpson, 1859, and now, reported for the first time as a host of bopyrids, *Petrolisthes crenulatus*. Further, this record of *A. muguensis* extends its geographic range into the Gulf of California. As was noted by Markham (2008), no comments on the morphology of this species were published after its original description (Shiino 1964), despite the fact that it has been collected several times throughout its distribution range. Thus, the new geographic record, the comments on its morphological variation and the figures presented herein improve our knowledge of the species.

Aporobopyrus trilobatus (Nierstrasz & Brender à Brandis, 1925)
(Figs. 2D, 3D, 8; Table 1)

Pseudione trilobata Nierstrasz & Brender à Brandis 1925: 2–3, 7, figs. 7–10.—Monod 1933: 227.—Shiino 1933: 271.—Schultz 1969: 325, fig. 519.—Bourdon 1976: 165, 167–171, 240, 241, figs. 1–3.—Markham 1978: 489.—Adkison 1988: 579.—Markham 1988: 3, 4, 17–18, fig. 7.—Campos & Campos 1989: 33 (in table).—Salazar-Vallejo & Leija-Tristán 1990: 430 (in appendix 1).

"[a] bopyrid" Haig 1968: 67.

Pseudione tridentata [sic] Markham 1988: 56 (in table).

Aporobopyrus trilobotata [sic] Adkison 1988: 579.

Aporobopyrus trilobata [sic] Markham 1992: 3 (in table).—Espinosa-Pérez & Hendrickx 2001: 50.—Román-Contreras 2008: 94 (in table).

Aporobopyrus trilobatus: Markham 2008: 150–152.—Boyko et al. 2012: 7, 21–23 (in table).

Material examined.—1 adult female, 1 male (host: *Petrolisthes crenulatus*, CNCR 5078), Isla Ángel de la Guarda, Baja California, Mexico (29°15′36″N, 113°22′13″W), J.C. Nates and E. Lira coll.; 08 Nov 1985, CNCR 19411. 1 juvenile female, 1 male (host: *P. ortmanni* Nobili, 1901, CNCR 20073), Isla Cerralvo, Baja California Sur, Mexico (24°12′00″N, 109°50′53″W), J.C. Nates and E. Lira coll., 04 Aug 1986, CNCR 20074.

Distribution.—In the western Atlantic: Curaçao, Netherland Antilles (Nierstrasz & Brender à Brandis 1925, Bourdon 1976, Markham 1988); in the eastern Pacific: Gulf of California (present study), Zihuatanejo, Guerrero, Mexico (Bourdon 1976),

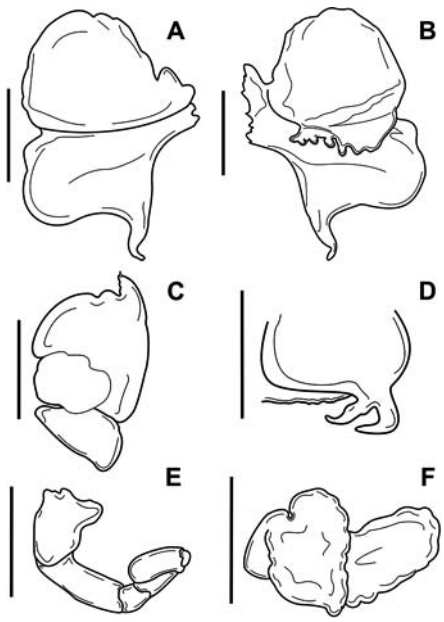

Fig. 8. Adult female of *Aporobopyrus trilobatus* (Nierstraz & Brender à Brandis, 1925). A, first oostegite, external view; B, same, internal view; C, maxilliped; D, barbula; E, pereopod 7; F, left first pleopod. Scale bar = 0.5 mm.

and Punta Arenas, Costa Rica (Markham 2008).

Remarks.—The heads of both females are wide, rounded and markedly convex, but only the adult female has a well-defined frontal lamina as well as two notches on the anterior margin of the head that gives it a trilobed shape (Fig. 2D). The antennules and antennae are composed of 3 and 6 segments each, respectively.

The pereomeres of the juvenile female are without coxal plates or dorsolateral bosses and have weakly-developed tergal projection on pereomeres 1 and 2. Pereomeres 2–4 are pigmented with a pair of tiny spots near each medial region. The adult female has narrow coxal plates and tergal projections on pereomeres 1–4 on both sides (Fig. 2D). The marsupium of the adult female is closed by well-developed oostegites, the second to fourth bearing tiny setae on their posterior margins, the fifth has a row of larger setae. The first pair of oostegites of the adult female (Fig. 8A, B) agrees in shape with those previously described (Nierstrasz & Brender à Brandis 1925) and illustrated (Bourdon 1976: 168, Fig. 1B), and its internal ridge is slightly digitate (Fig. 8B). The juvenile female is without developed oostegites.

The maxillipeds (Fig. 8C), even those in the juvenile female, are small and not entirely developed, similar to previously published illustrations and descriptions (Bourdon 1976, Markham 1988). The barbula of the adult female has two slightly sinuate projections (Fig. 8D), similar to those illustrated by Markham (1988: 18, Fig. 7C), except that in our material the external projection is the largest and its medial margin differs from that reported by Bourdon (1976) as it is slightly sinuous. The barbula of the juvenile female has only a tiny bulge on its right corner and the medial margin is straight and smooth.

The pereopods of the juvenile female and those on the short side of the adult female each have a small basal carina, like a tiny bulge, but those on the long side of the adult female (Fig. 8E) are similar to those described by Bourdon (1976).

The pleopods of the adult female are oval-shaped (Fig. 8F), with a narrow basal section and their outlines are slightly digitate, similar to those illustrated by Markham (1988: 18, Fig. 7B), and decreasing in size posteriorly as shown by Bourdon (1976: 168, Fig. 1D–H). The exopod and endopod on the short side of the female are similar in size but those on the long side are with the exopod larger than the endopod. All pleopods of the juvenile female are similar in size, of tubular shape, with a distal region that becomes slightly wider and rounded.

The heads of both males are semi-circular and narrower than pereomere 1, with eyespots near the posterolateral border. The antennules and antennae are composed of 3 and 5 segments each, respectively; the antennae extend far be-

yond the margins of the head. All pereomeres are well separated laterally with rounded borders and narrower posteriorly (Fig. 3D). Pereomeres 2–5 of one male (CNCR 19411) are pigmented with tiny spots near their left borders; similar spots are located on the right border of pleomeres 2 and 5. Pleomeres 1 and 2 are the largest and are provided with stout and acute dactyli, pereomeres 3–7 decrease in size posteriorly, with their dactyli becoming shorter and blunter.

The pleon has five distinct pleomeres and a bilobed final pleomere, this structure in one male (CNCR 20074) has small setae on its posterior border. Each pleomere has a pair of tiny pleopods.

The differences observed in our specimens fall within the range of variation mentioned by Bourdon (1976), who noted some morphological variation between the specimens from Guerrero, Mexico, and those from Curaçao. *Petrolisthes crenulatus* is reported for the first time as host of *A. trilobatus* but *P. ortmanni* was already reported as host of a juvenile female from Punta Arenas, Costa Rica (Markham 2008). This report extends the geographical range of distribution of this bopyrid into the north of the eastern Pacific coast, now ranging from Costa Rica to the Gulf of California, Mexico.

Discussion

Sixty-three crab species belonging to Porcellanidae are parasitized by pseudionines, of which 39 are hosts of bopyrids of the genus *Aporobopyrus* (Boyko et al. 2012), but only six host species have been documented from the Pacific coast of the Americas (see Markham 2008). Thus, the report of *Petrolisthes crenulatus*, *P. galapagensis* and *P. hirtispinosus* increase to 42 the known hosts for this group of branchial parasites, and to nine the number of hosts distributed along the Pacific coast of the continent. Boyko et al. (2012) noted that approximately 11% of bopyrids occurring in porcellanid crabs parasitize more than one host species, but all four parasite species reported here have been reported in more than one host: *A. bourdonis* parasitizes two hosts, *A. curtatus* eight and *A. muguensis* and *A. trilobatus* four each (Boyko et al. 2012). Bopyrids increase their distribution ranges by infesting multiple hosts (Boyko & Williams 2009), for example *A. curtatus* occurs throughout the western Atlantic coast, from North Carolina, USA, to São Paulo, Brazil, and now is also reported for the first time in the eastern Pacific; while *A. bourdonis* occurs in a more restricted region since its two hosts have a similar distribution, from the Gulf of California, Mexico, to Ecuador (Villalobos et al. 1989, Hiller et al. 2004).

The extent of morphological variability in some *Aporobopyrus* species is unknown, as the number of records is limited to a few pairs of individuals for each species, which is the case for *A. bourdonis*. Even when bopyrids are reported in high numbers, no morphological notes are often given, as was the case for *A. muguensis* until Markham (2008) provided additional descriptive notes. In the present paper, we compare some morphological characters (Table 2) and provide a key of the species of *Aporobopyrus* infesting porcellanid crabs from the islands of the Gulf of California.

Key to females of the species of *Aporobopyrus* recorded in the Gulf of California, Mexico.

1a. Pereomeres 1–4 with evident coxal plates and tergal projections, mainly on the larger side of body, or with narrow coxal plates and dorsolateral bosses on both sides of body..... 2

1b. Pereomeres 1–4 of both sides of body with coxal plates and tergal

Table 2.—Morphological characteristics of bopyrid females of the genus *Aporobopyrus* recorded in the Gulf of California, Mexico.

Trait	*A. bourdonis*	*A. muguensis*	*A. curtatus*	*A. trilobatus*
Head	Wider than long, broadly rounded anteriorly	Wide and curve anteriorly	Wider than long, broadly rounded anteriorly	Wide and rounded both anteriorly and posteriorly
Frontal lamina	Narrow and well defined	Undifferentiated with antero-lateral borders	Narrow and well defined, ends into lateral projections	Narrow and well defined, sometimes with notches that provides it a trilobate shape
Barbula	1 or 2 lateral projections, with or without margins digitated	1 lateral projection	2 digitate lateral projections	2 lateral projections, with slightly sinuous margins
Pereomeres	Coxal plates and tergal projections in 1 to 4 of both body sides	Coxal plates and tergal projection perceptible in 1 to 4, mainly on the larger side of body	Conspicuous dorsolateral bosses and narrow coxal plates in 1 to 4	Narrow coxal plates and tergal projection in 1 to 4 of both body sides, occasionally with dorsolateral bosses in 1 to 4
Inner ridge of first oostegite	Slightly sinuous, occasionally with digitate projections	Slightly thick, sometimes slightly ornamented	With digitate projections	Slightly digitate
Pleopods	Endopods oblongs and larger than exopods, which are ovoid	Both rami similar in size, first 2 pairs broad and leaf like shape, the following narrow and shorter	Endopods larger than exopods, of triangular shape and tuberculate	Endopods smaller than exopods, mainly in the long side of body, of oval shape with outlines faintly digitate

projections but no dorsolateral bosses . . *A. bourdonis* Markham, 2008

2a. Barbula with two lateral projections on each side, each one with sinuous or digitate margins 3

2b. Barbula with one smooth lateral projection on each side . . . . . *A. muguensis* Shiino, 1964

3a. Pleopods triangular in shape and tuberculate, endopods larger than exopods . . . . . *A. curtatus* (Richardson, 1904)

3b. Pleopods oval-shaped with outlines faintly digitate, endopods smaller than exopods . . . . . *A. trilobatus* (Nierstraz & Brender à Brandis, 1925)

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