Two new species of Paramisophria (Copepoda, Calanoida, Arietellidae) from anchialine caves on the Canary and Galápagos Islands

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TWO NEW SPECIES OF *PARAMISOPHRIA* (COPEPODA, CALANOIDA, ARIETELLIDAE) FROM ANCHIALINE CAVES ON THE CANARY AND GALÁPAGOS ISLANDS

SUSUMU OHTSUKA, AUDUN FOSSHAGEN & THOMAS M. ILIFFE

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Two new species of *Paramisophria, P. reducta* from the Jameos del Agua lava tube, Lanzarote and *P. galapagensis* from an anchialine fissure on Santa Cruz, are the first records of cavernicolous arietellid copepods. They have several advanced characters compared with their congeners, but also exhibit plesiomorphic characters such as the lack of dorsal processes on the last prosomal somite. These species may be derived from neritic hyperbenthic ancestral forms which first invaded caves. An emended diagnosis is given for the genus *Paramisophria*..

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INTRODUCTION

Anchialine cave faunas have drawn considerable attention because these caves are inhabited by numerous endemic organisms and Tethyan relicts (ILIFFE & al. 1983, 1984; HART & al. 1985; WILKENS & al. 1986; BOXSHALL 1989). Cave-dwelling calanoid, platycopioid, cyclopoid, and misophrioid copepods have been investigated by FOSSHAGEN & ILIFFE (1985, 1988, 1991), ROCHA & ILIFFE (1991), BOXSHALL & ILIFFE (1987, 1990) and HUYS (1988).

During expeditions to the Jameos del Agua on Lanzarote, the Canary Islands in 1983 and 1984 and to Grieta de Caleta la Torta on Santa Cruz, the Galápagos Islands in 1987, new cavernicolous arietellids in the genus *Paramisophria* SCOTT, 1897 were recorded from each cave. These are the first records of arietellids from marine caves on oceanic islands. Since *Parapseudocyclops* CAMPANER, 1977 was synonymized with *Paramisophria* (OHTSUKA & al. 1991), the genus comprises 12 species. Most of the species were discovered in recent years (KRISNASWAMY 1959; FOSSHAGEN 1968; CAMPANER 1977, MCKINNON & KIMMERER 1985: OHTSUKA 1985; OHTSUKA & MITSUZUMI 1990; OHTSUKA & al. 1991; OTHMAN & GREENWOOD 1992). They have a wide distribution in the Atlantic and Indo-Pacific regions in both temperate and tropical areas, and are found in the hyperbenthos from the intertidal down to approximately 200 m depth.

The present paper includes the emended diagnosis of the genus *Paramisophria,* the descriptions of two new species of *Paramisophria* from marine caves and a discussion of their origin.

MATERIAL AND METHODS

The Jameos del Agua Cave on Lanzarote in the Canary Islands is an anchialine lava tube which begins on land and continues as a flooded extension for 1600 m away from the island beneath the seafloor. Detailed descriptions of the cave and its fauna are presented in WILKENS & PARZEFALL (1974), ILIFFE & al. (1984), GARCÍA-VALDECASAS (1985), and BOXSHALL & ILIFFE (1987). Salinity and temperature in the cave were close to those in the sea at 37 ‰ and 18–18.5° C. Specimens were collected with a hand-held net or a suction bottle in 1–25 m water depths in the first 250 m of the seaward extension of the tube on 2 March 1983, and with a plankton net in 10–28 m water depths of the first 500 m of the seaward tube on 25 February 1984 using SCUBA.

Grieta de Caleta la Torta is an anchialine tectonic fissure located 7 km west of Puerto Ayora, Santa Cruz Island, the Galápagos Islands, and 100 m inland from a small bay (ILIFFE 1991). A description and map of the cave are given in ILIFFE (1991). Temperature and salinity ranged from 22.8° C and 9.0 ‰ at the surface to 22.3° C and 29.0 ‰ at a depth of 17 m. Copepods were collected with a plankton net in a totally dark section of the cave at using SCUBA on 8 June 1987.

The morphological terminology of copepods is based on HUYS & BOXSHALL (1991).

TAXONOMY

Family Arietellidae SARS, 1902

Genus *Paramisophria* SCOTT, 1897

Diagnosis (emend.). Cephalosome and first pedigerous somite separate. Fourth and fifth pedigerous somite completely fused, with or without a pair of dorsolateral processes. Urosome 4-segmented in female and 5-segmented in male. Genital double somite of female with a pair of gonopores antero-

laterally and single copulatory pore ventromedially or ventrolaterally on the left side. Anal operculum less developed, not pointed posteriorly. Caudal seta I vestigial; setae II–VI well developed. Antennules of female consisting of 20–22 segments, reaching to, at most, the distal end of cephalosome; first to eighth segments fringed with long setules along posterior margin. Left antennule longer than right. Male left antennule geniculate, composed of 19–21 segments. Antennary exopod 3- to 8-segmented, endopod 2-segmented with double distal segment representing fused second and third segments. Mandibular gnathobase with three cusped teeth; endopod fused with basis or consisting of one rudimentary segment. Praecoxal arthrite of maxillule having four or five spines plus one process; coxal endite with or without seta; endopod 1-segmented, bulbous, bearing two or three setae. Basal endite of maxilla bearing one stout spine without spinules along outer margin. Terminal exopod segment of leg 1 with two outer spines. Terminal endopod segments of legs 2 and 3 having 7 or 8 setae; that of leg 4 with 6 or 7 setae. Leg 5 of female: both coxae and intercoxsal plate completely fused to form a common base or separate; endopod completely or incompletely fused with basis, with 0–2 setae terminally; basis and exopod separate or fused; first exopod segment fused with or completely or incompletely separate from second, and second and third segments completely or incompletely fused; exopod furnished with two terminal and two or three lateral spines. Leg 5 of male: coxae and intercoxal plate as in female; right exopod 3-segmented, distal two segments completely or incompletely separate, second segment expanded; left basis with or without 1-segmented, rudimentary endopod; left exopod 3-segmented, third segment with one long, spinulose process terminally.

DESCRIPTIONS

Paramisophria reducta sp.n. (Figs 1–4)

Material. Two adult females (2 March 1983) and one male (25 February 1984) from Jameos del Agua, Lanzarote, the Canary Islands.

Holotype. Adult female, total length 1.71 mm from Jameos del Agua, 2 March 1983, from a depth of 1–25 m. Dissected and mounted on 13 slides. Deposited in the British Museum (Natural History), London, BM (NH) Reg. No. 1992.1092.

Allotype. Adult male, total length 1.60 mm from Jameos del Agua, 25 February 1984, from a depth of 10–28 m. Dissected and mounted on 12 slides. Deposited in BM (NH) Reg. No. 1992.1093.

Paratype. One whole female from the same locality as the holotype. BM (NH) Reg. No. 1992.1094.

Female (Holotype). Body (Fig. 1A, B) robust, 1.71 mm long. Prosome about 2.5 times longer than urosome; fourth and fifth pedigerous somites completely fused, smoothly curved in lateral view, and without dorsolateral and lateral processes which are present in all other species of *Paramisophria* (Fig. 1C).

Urosome 4-segmented; genital double somite (Fig. 1E) large, copulatory pore located ventromedially and a pair of gonopores present anterolaterally; caudal ramus with an anterolateral accessory seta, a dorsal, a subterminal and four terminal setae, second innermost seta over twice as long as the length of urosome. Rostrum (Fig. 1D) with a pair of filaments.

Antennules asymmetrical, right antennule shorter than left. Left antennule (Fig. 1F), 22-segmented, reaching to at most distal end of cephalosome; first to eighth segments fringed with long setules along posterior margin. Fusion pattern and armature elements as follows: I–III-7 + 2 aesthetascs, IV-2, V-2 + aesthetasc, VI-2, VII-2 + aesthetasc, VIII-2, IX-2 + aesthetasc, X-2 + spiniform seta, XI-2 + aesthetasc, XII-2, XIII-2 + aesthetasc, XIV-2 + aesthetasc, XV-2 + aesthetasc, XVI-2 + aesthetasc, XVII-2 + aesthetasc, XVIII-2 + aesthetasc, XIX-2 + aesthetasc, XX-2 + aesthetasc, XXI-2 + aesthetasc, XXII-1, XXIII–XXVIII-13 + 2 aesthetascs. Right antennule (Fig. 1G) the same armature as left antennule; first to eighth segments fringed with long setules along posterior margin.

Antenna (Fig. 2A): coxa unarmed and basis with inner subterminal seta; endopod 2-segmented, first segment elongated, bearing subterminal seta and distal compoud segment with three inner medial setae of unequal lengths and six terminal setae. Exopod indistinctly 8-segmented, basal segments almost fused; terminal segment small, bearing minute prominence; setal formula: 0, 1, 1, 1, 1, 1, 0, 2.

Mandibular gnathobase (Fig. 2C) with three cusped teeth, ventralmost tooth large and dorsalmost tooth bifid at tip. Mandibular palp (Fig. 2B): basis large, fringed with a row of setules along inner margin; basal endites lacking; endopod represented by rudimentary bulbous segment with two setae of unequal lengths; exopod 5-segmented, first to fourth segments each bearing one seta and fifth segment with two setae.

Maxillule (Fig. 2D): praecoxal arthrite bearing five spines and one process; coxal endite unarmed; coxal epipodite bearing eight plumose setae; endopod 1-segmented, bulbous, with two small setae of unequal lengths; exopod 1-segmented, fan-like, bearing three long setae terminally.

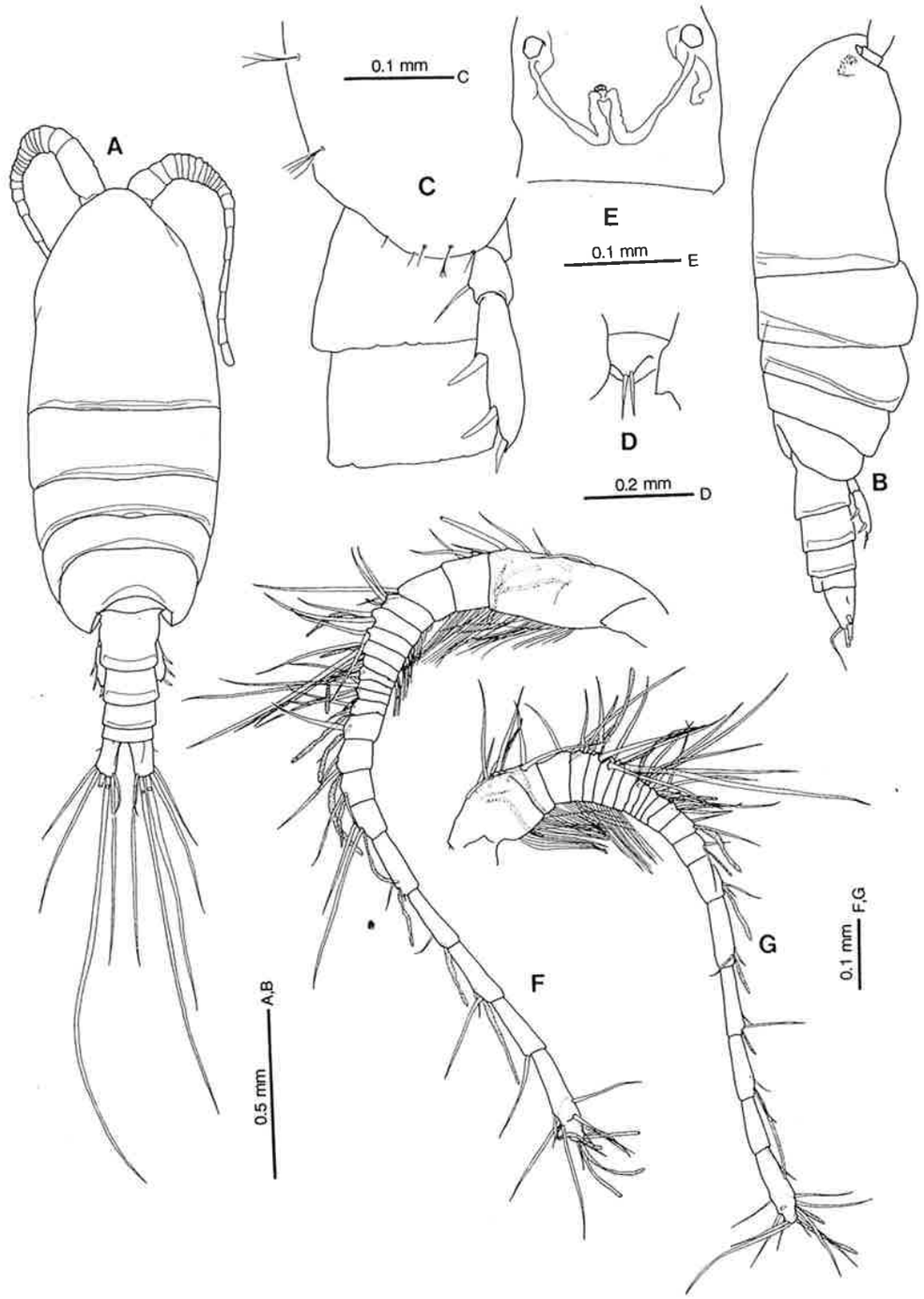

Fig. 1. *Paramisophria reducta* sp.n. Female (holotype). A. Habitus, dorsal view. B. Habitus, lateral view. C. Last prosomal somite and leg 5, lateral view. D. Rostrum, ventral view. E. Genital double somite, ventral view. F. Left antennule. G. Right antennule.

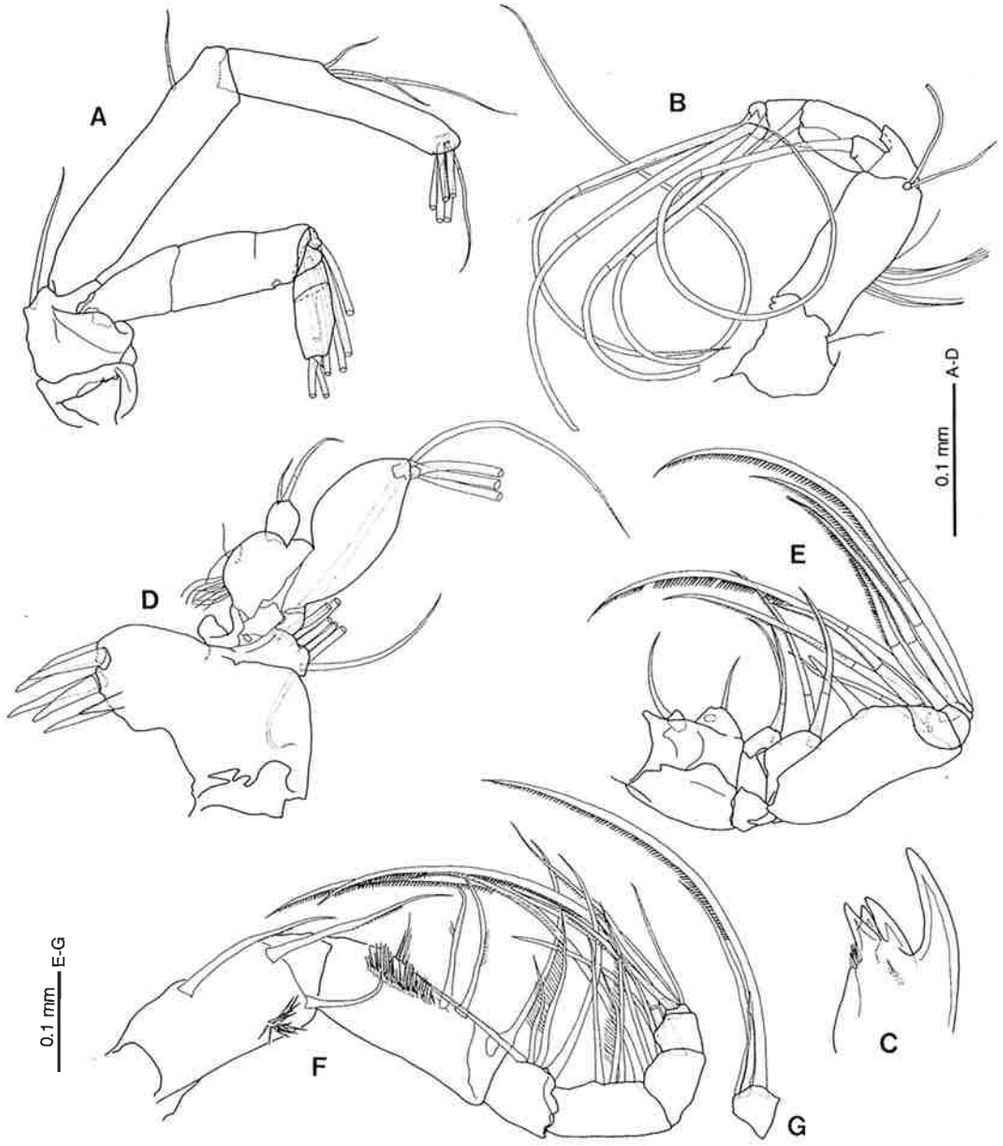

Fig. 2. *Paramisophria reducta* sp.n. Female (holotype). A. Antenna. B. Mandibular palp. C. Mandibular cutting edge. D. Maxillule. E. Maxilla. F. Maxilliped. G. Fifth endopod segment of maxilliped.

Maxilla (Fig. 2E): first and second praecoxal endites having one and two setae (one seta missing in Fig. 2E) respectively; each coxal endite with two setae; basal endite bearing one naked stout spine; endopod 4-segmented, first to fourth segments having one, three, two and two setae, respectively.

Maxilliped (Fig. 2F, G): syncoxa with one medial and two subterminal setae and a patch of long spinules; basis fused with first endopodal segment to form allobasis, ornamented with two patches of spinules and bearing two basal and one endopodal setae of unequal lengths; second, third and sixth endopod segments each with four setae; fourth and fifth (Fig. 2G) segments with three setae.

Legs 1 to 4 each with 3-segmented rami; setation and spinulation the same as in other species of

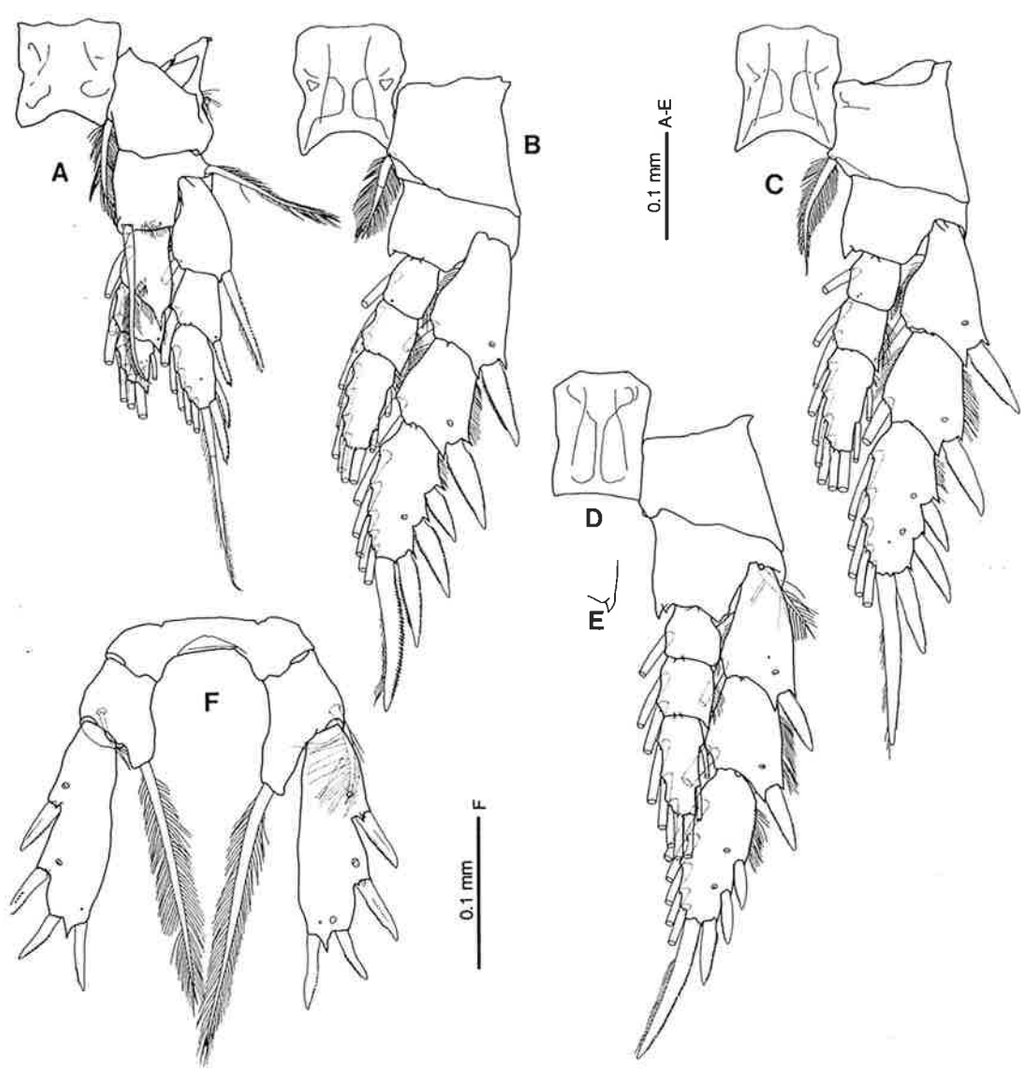

Fig. 3. *Paramisophria reducta* sp.n. Female (holotype). A. Leg 1, anterior surface. B. Leg 2, anterior surface. C. Leg 3, anterior surface. D. Leg 4, anterior surface. E. Inner distal corner of basis of right leg 4. F. Leg 5, anterior surface.

Paramisophria. Leg 1 (Fig. 3A): minute pores near outer distal angles of first and second endopod segments. Leg 2 (Fig. 3B): inner distal angle of basis pronounced; outer distal angle of second endopod segment not as pronounced as in *P. platysoma* Ohtsuka & Mitsuzumi, 1990. Leg 3 (Fig. 3C): inner distal angle of basis indistinctly bifid. Leg 4 (Fig. 3D, E): inner distal angle of basis bifid in left leg and with low round and acute processes in right leg. Leg 5 (Fig. 3F): both coxae completely fused with intercoxal plate to form a common base; right and left legs slightly asymmetrical: outer seta on basis more developed and plumose in left leg than in right; endopod represented by blunt inner process with large plumose seta terminally, fused with basis, slightly larger in left leg, distal outer angle more pronounced in left leg than in right; exopod 1-segmented, with two lateral and two distal spines.

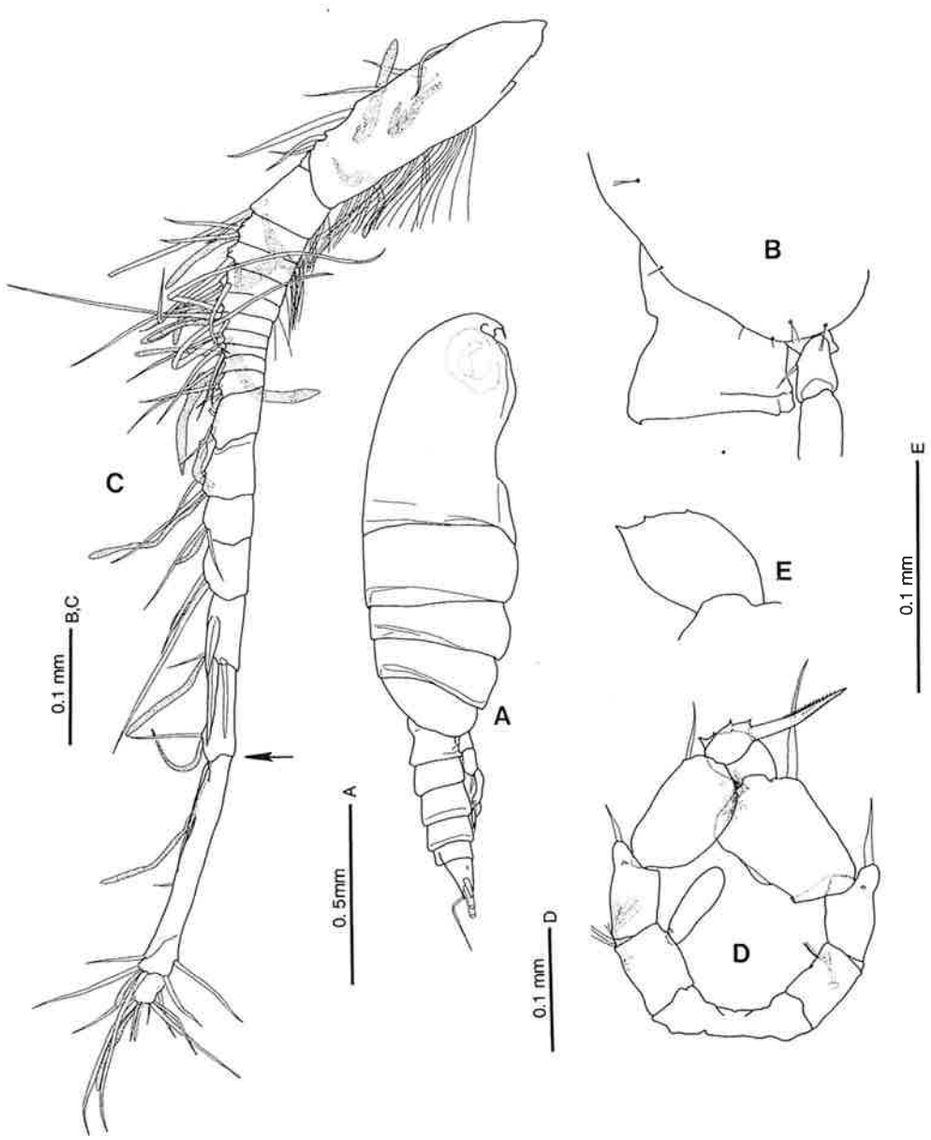

Fig. 4. *Paramisophria reducta* sp.n. Male (allotype). A. Habitus, lateral view. B. Last prosomal somite, lateral view. C. Left antennule, with position of geniculation indicated by arrow. D. Leg 5, anterior surface. E. Third exopod segment of right leg 5.

Male (Allotype). Body (Fig. 4A) similar to that of the female, 1.60 mm long. Fourth and fifth pedigerous somites fused and lacking dorsolateral processes (Fig. 4B) as in the female. Urosome 5-segmented.

Left antennule (Fig. 4C) geniculate, 20-segmented; geniculation present between segments 17 and 18, segments 16 and 17 each with cuticular ridge along anterior margin; segment 18 with two cuticular ridges along proximal anterior margin; first to sixth segments fringed with a row of long setules posteriorly. Fusion pattern and armature elements as follows: I–IV-7 + 4 aesthetascs, V-2 + aesthetasc, VI-2 + aesthetasc, VII-2 + aesthetasc, VIII-2 + aesthetasc, IX-2 + aesthetasc, X-2 + aesthetasc, XI-2 + aesthetasc, XII-2 + aesthetasc, XIII-2 + aesthetasc, XIV-2 + aesthetasc, XV-2 + aesthetasc, XVI-2 + aesthetasc, XVII-2 + aesthetasc, XVIII-2 + aesthetasc, XIX-1 + aesthetasc + 2 processes, XX-1 + aesthetasc + process, XXI–XXV-6 + 2 aesthetascs + 2 processes, XXVI–XXVIII-8 + aesthetasc, segment 19 incompletely fused with preceding segment. Right antennule 22-segmented as in female; last two segments incompletely fused.

Mouthparts and legs 1 to 4 similar to those of female. Leg 5 (Fig. 4D, E): both coxae fused with intercoxal plate. Right leg: basis with short plumose seta medially on posterior surface; first exopod segment produced at outer distal angle to blunt process with short, thick spine; second exopod segment expanded, lamellar, bearing a tuft of setules at inner distal corner and an outer distal seta; third exopod segment (Fig. 4E) laminate, with three minute prominences, two outer lateral and one terminal. Left leg: oval, 1-segmented endopod near inner distal angle of basis; first exopod segment produced as in right leg; second exopod segment swollen, with outer distal seta; third exopod segment small, bearing thick, serrate terminal seta and two minute outer prominences.

Etymology. The specific name *reducta* is derived from the Latin *reductus,* meaning reduced, because the female leg 5 bears only two outer lateral spines on the exopod, while its congeners have three. The male right leg 5 has a reduced terminal segment in comparison with congeneric males.

Remarks. The new species is easily distinguished from its congeners by the following characters: (1) the relatively long antennules reaching to the end of cephalosome; (2) no lateral and dorsolateral processes on the last prosomal somite; (3) endopod of the female leg 5 without acute terminal tip; (4) only two lateral spines on the exopod of the leg 5 of the female; (5) the reduced outer and terminal prominences on third exopod segment of the right leg 5 of the male.

The mouthparts and legs 1 to 4 are quite similar to those of other species of *Paramisophria,* indicating the same feeding habit and swimming behaviour. The gut of the holotype was full of copepod fragments, suggesting that this species is carnivorous like *P. itoi* Ohtsuka, 1985 and *P. platysoma* (Ohtsuka 1985; Ohtsuka & Mitsuzumi 1990).

Paramisophria galapagensis sp.n. (Figs 5, 6)

Material. One adult male from Grieta de Caleta la Torta, Santa Cruz, the Galápagos Islands.

Holotype. Adult male, total length 1.50 mm from Grieta de Caleta la Torta, 8 June 1987 from a depth of 17–29 m. Dissected and mounted on 13 slides. Deposited in BM (NH) Reg. No. 1992. 1095.

Male (Holotype). Body (Fig. 5A) 1.50 mm long. Last prosomal somite (Fig. 5B) without dorsolateral process as in *Paramisophria reducta* sp.n.

Left antennule (Fig. 5C,D) 19-segmented, geniculate; posterior row of setules ranging from first to seventh segment; segments 16, 17 and 18 bearing one, one and two anterior ridges, respectively; segment 18 relatively shorter than in *P. reducta.* Fusion pattern and armature elements as follows: I–IV-7 + 4 aesthetascs, V-2 + aesthetasc, VI-2 + aesthetasc, VII-2 + aesthetasc, VIII-2 + aesthetasc, IX-2 + aesthetasc, X-2 + aesthetasc, XI-2 + aesthetasc, XII-2 + aesthetasc, XIII-2 + aesthetasc, XIV-2 + aesthetasc, XV-2 + aesthetasc, XVI-2 + aesthetasc, XVII-2 + aesthetasc, XVIII-2 + aesthetasc, XIX-1 + aesthetasc + process, XX-1 + aesthetasc + process, XXI–XXV-6 + 2 aesthetascs + 2 processes, XXVI–XXVIII-7 + aesthetasc. Antenna (Fig. 5E): exopod indistinctly 8-segmented, proximal three segments almost fused; armature elements of exopod as in *P. reducta.* Mandible (Fig. 5F,G): endopod consisting of one rudimentary segment, with two setae of unequal lengths. Maxillule (Fig. 5H): praecoxal arthrite with four spines and one acute process; coxal endite with no seta; endopod 1-segmented, with two setae. Maxilla (Fig. 5I): basal endite with stout, unarmed spine. Maxilliped as in *P. reducta.*

Leg 1 (Fig. 6A): second exopod segment with a patch of short setules distally; third endopod segment bearing a patch of minute spinules on anterior surface. Leg 2 (Fig. 6B): third endopod segment with seven setae; third exopod segment with minute spinules distally on anterior surface. Leg 3 (Fig. 6C): basis produced inwards into two blunt prominences; third endopod segment with seven setae; third exopod segment bearing minute spinules along outer margin on anterior surface. Leg 4 (Fig. 6D): third endopod segment with six setae. Leg 5 (Fig. 6E,F). Right leg: second exopod segment remarkably produced inwards; third exopod segment segment with terminal and subterminal processes and one spine at outer margin. Left leg: endopod 1-segmented, bulb-like; third exopod segment (Fig. 6F) with elongate, serrate terminal process and two short outer spines.

Etymology. The specific name *galapagensis* refers to the type locality, the Galápagos Islands.

Remarks. Like *Paramisophria reducta* this species is devoid of a process on the last prosomal somite. *P. galapagensis* is readily distinguishable from other *Paramisophria* species in having seven setae on the third endopod segments of legs 2 and 3 and six setae on the third endopod segment of leg 4.

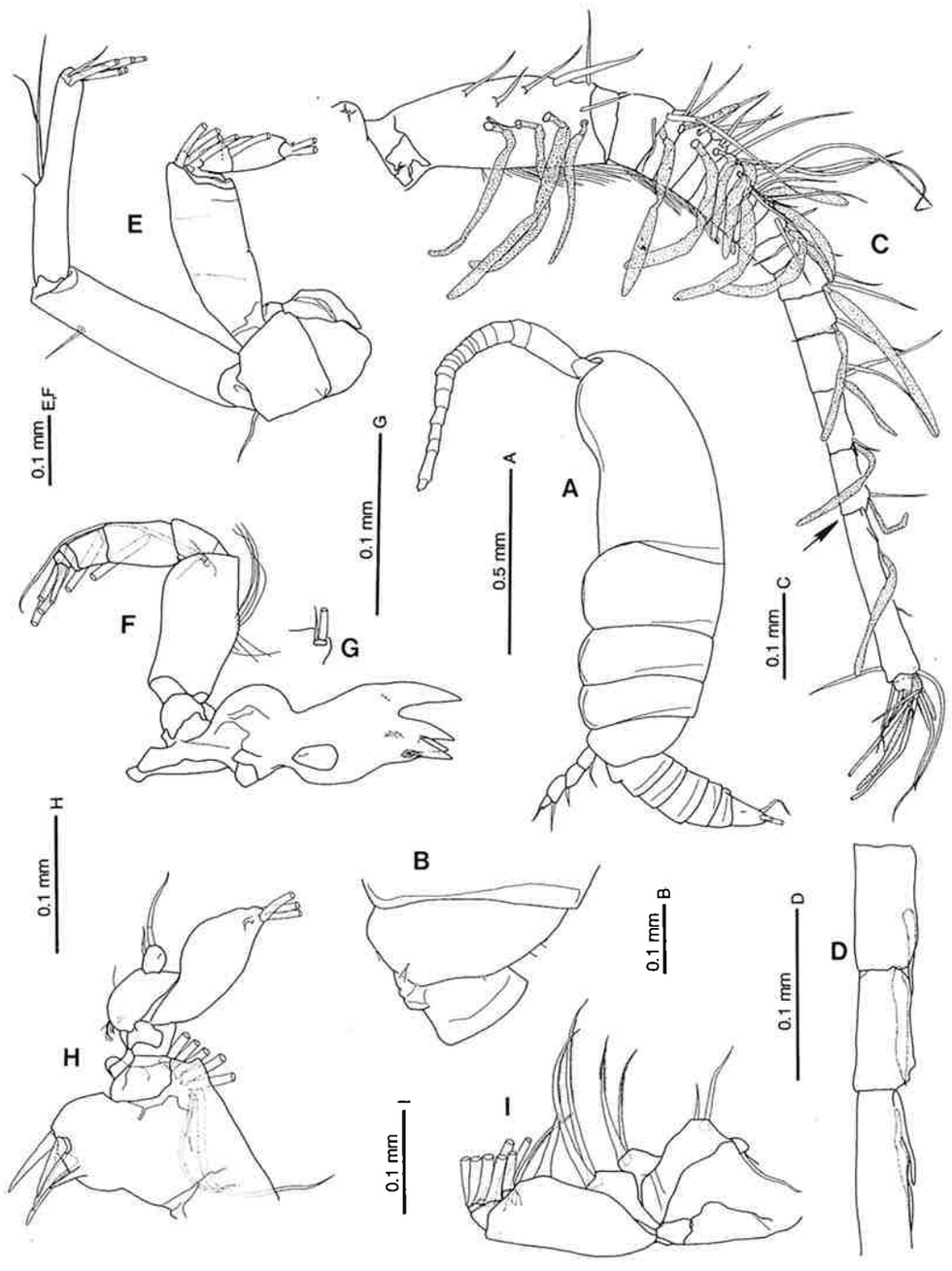

Fig. 5. *Paramisophria galapagensis* sp.n. Male (holotype). A. Habitus, lateral view. B. Last prosomal somite, lateral view. C. Left antennule, with position of geniculation indicated by arrow. D. Segments 16–18 of left antennule, setae and aesthetascs omitted. E. Antenna. F. Mandible. G. Mandibular endopod. H. Maxillule. I. Maxilla.

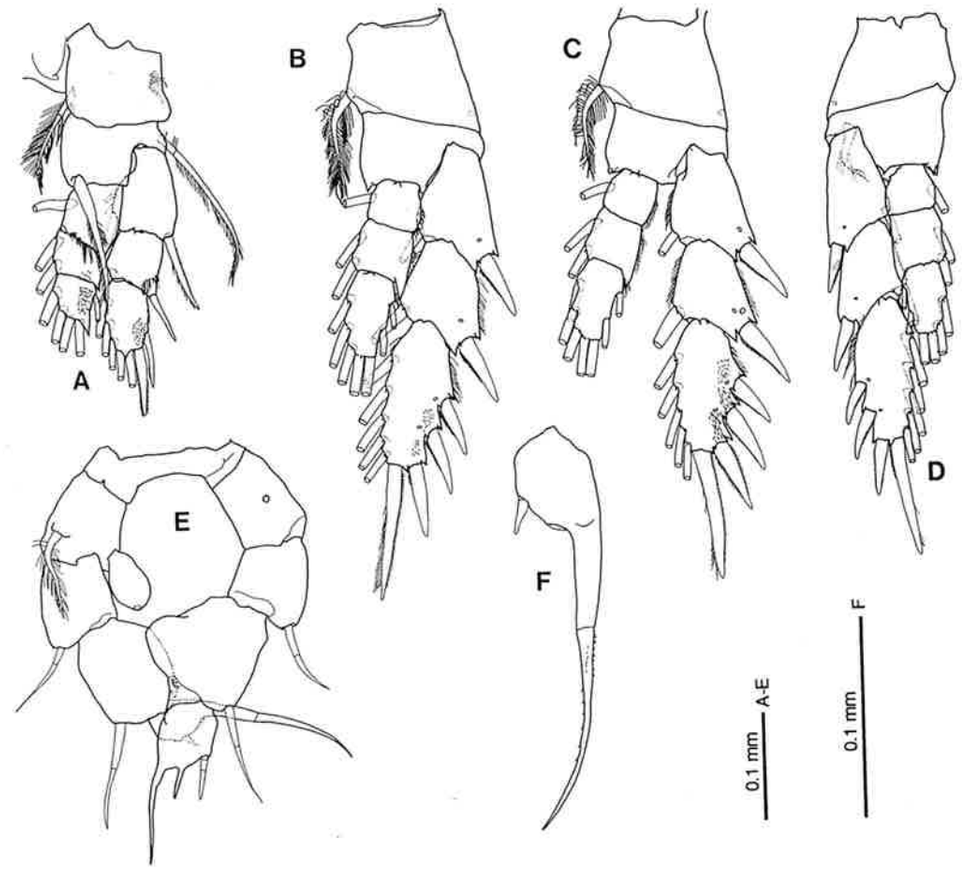

Fig. 6. *Paramisophria galapagensis* sp.n. Male (holotype). A. Leg 1, anterior surface. B. Leg 2, anterior surface. C. Leg 3, anterior surface. D. Leg 4, anterior surface. E. Leg 5, posterior surface. F. Third exopod segment of left leg 5.

The holotypic male had remnants of a harpacticoid copepod in its gut, suggesting that this species also preys on epibenthic organisms.

DISCUSSION

The species of *Paramisophria* can be subdivided into two groups according to the setation of legs 2–4. The following 10 species retain the plesiomorphic state and have eight setae on the terminal endopod segments of legs 2 and 3 and seven on that of leg 4: *P. ammophila* Fosshagen, 1968; *P. cluthae* Scott, 1897; *P. cluthae* sensu Tanaka, 1966; *P. fosshageni* Othman & Greenwood, 1992; *P. giselae* (Campaner, 1977); *P. itoi*; *P. japonica* Ohtsuka & al, 1991; *P. platysoma*; *P. reducta* sp.n.; *P. variabilis* McKinnon & Kimmerer, 1985. Only *P. galapagensis* sp.n. has seven setae on the terminal endopod segments of legs 2 and 3 and six on that of leg 4. *Paramisophria spooneri* Krishnaswamy, 1959 cannot be assigned to either of these groups, because it is not adequately described (Krishnaswamy 1959).

Ohtsuka & al. (1991) noted that the most plesiomorphic, *P. giselae* from Brazil, and *P. japonica,* and *Paramisophria* sp. from Japan are distributed near the edge of continental shelf, while the most apomorphic species, *P. platysoma,* is found in the lower intertidal and upper subtidal zones.

The cave-dwelling species, in particular *P. galapagensis* sp.n., also exhibit several apomorphic characters such as the reduction of elements in legs. However, both cave-dwelling species of *Paramisophria* lack the dorsolateral processes on the last prosomal somite which are present in all congeners; the absence of processes probably represents the primitive

condition among calanoids. Both species apparently show a mosaic of plesiomorphic and apomorphic characters. The absence of the prosomal processes in the cave-dwelling *Paramisophria* might suggest that an invasion of the caves occurred at a time before the processes became developed. It seems rather unlikely that a reversal should have taken place after invasion since these caves are geologically young and were formed at most several thousand years ago by a volucanic eruption or by tectonic faults (ILIFFE & al. 1984; ILIFFE 1991). These two species of *Paramisophria* show different setation patterns in legs, suggesting that they might have invaded caves independently. Among arietellids there are neritic species, as well as bathypelagic and deep-sea hyperbenthic species (CAMPANER 1984). The occurrence of *Paramisophria* and one as yet undescribed species of *Metacalanus* (= *Scottula*) from Jameos del Agua may indicate an invasion into the cave from shallow waters because species of both genera occur in those waters.

Among misophrioids BOXSHALL (1989) considered that cave species might be derived from deep-sea taxa through interior voids in seamounts or in crevicular habitats. In Jameos del Agua there is a remarkable assemblage of at least four species of misophrioids in three different genera. None of the species is known to have closely related members from neritic water outside caves. One of the misophrioid genera from Jameos, *Expansophria,* like *Paramisophria* has a congener from caves in Santa Cruz, Galápagos Islands (BOXHALL & ILIFFE 1990). It is probable that copepods colonize caves by a number of different routes.

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