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A NEW GENUS OF ARIETELLOIDEA (COPEPODA, CALANOIDA), *FRANKFERRARIUS*, FROM DEEP WATERS OF THE ATLANTIC OCEAN

BY

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ABSTRACT

A new calanoid copepod genus *Frankferrarius* is based on the female and male of a new species described herein. The specimens were collected in the North and South Atlantic from abyssal depths close to the sea bed during the German expedition DIVA III in 2009. *Frankferrarius admirabilis* gen. et sp. nov. is a representative of the superfamily Arietelloidea with the praecoxal arthrite of the maxillule heavily sclerotized and a highly specialized, huge maxilla with a well-pronounced articulation between the coxa and basis and with long, grouped endopod setae apparently designed for piercing and grasping prey. This new genus, *Frankferrarius*, does not completely fit any known family of the Arietelloidea, but is provisionally placed in the Augaptilidae as it shares with this family the general pattern of segmentation and setation of its swimming legs, and a single genital operculum positioned medially on the ventral part of the genital double-somite.

RÉSUMÉ

Un nouveau genre de copépode calanoïde *Frankferrarius* est décrit à partir de la femelle et du mâle d'une nouvelle espèce, décrite ici. Les spécimens ont été collectés dans l'Atlantique Nord et Sud à des profondeurs abyssales, près du fond, au cours de l'expédition allemande DIVA III en 2009. *Frankferrarius admirabilis* gen. et sp. nov. est un représentant de la superfamille des Arietelloidea, avec l'arthrite précoxal de la maxillule fortement sclérotisé et une maxille de grande taille, hautement spécialisée avec une articulation bien prononcée entre la coxa et le basis et avec des soies de l'endopodite longues, groupées, visiblement adaptées pour percer et saisir les proies. Le nouveau genre, *Frankferrarius*, ne correspond complètement à aucune famille connue des Arietelloidea, mais est provisoirement placée chez les Augaptilidae car il partage avec cette famille le patron général de segmentation et de sétation de ses pattes natatoires, et un opercule génital unique situé au centre de la partie ventrale du double somite génital.

INTRODUCTION

Studies of deep-water benthopelagic collections in the Atlantic Ocean, performed under the German DIVA III (Latitudinal Gradients of Deep-Sea Biodi-

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versity in the Atlantic Ocean) project, continue to produce original taxonomic and faunistic research on near-bottom calanoids (e.g., Markhaseva & Ferrari, 2005; Markhaseva & Schulz, 2006, 2007, 2008; Markhaseva et al., 2008; Markhaseva & Renz, 2011; Renz et al., 2012; and others). Compilations of original and literature data show that the diversity and proportion of Clausocalanoidea (50 genera and 261 species, 64% and 59%, respectively) in the near-bottom calanoid community is the greatest compared to other calanoid superfamilies. Also common in the vicinity of the sea bed are species of the calanoid superfamily Arietelloidea — 15 genera and 41 species, 19% and 9%, respectively (Grice, 1973; Ohtsuka, 1984, 1985; Ohtsuka et al., 1993, 1994, 2005; Soh, 1998; Jaume et al., 2000; Ohtsuka & Boxshall, 2004 and others). Benthopelagic genera from the other calanoid superfamilies are much rarer near the bottom of the sea. The new species and genus described below belongs to the superfamily Arietelloidea.

METHODS AND TERMINOLOGY

Specimens of a new species and genus of benthopelagic calanoid copepod, *Frankferrarius admirabilis* sp. nov., were collected by R/V "Meteor" during the DIVA III expedition in 2009. Near-bottom samples were collected at abyssal depths between 4339 and 5148 m in the North and South Atlantic, with a closing epibenthic sledge (Brandt & Barthel, 1995). The specimens were fixed in 96% ethanol and later stained by adding a solution of Chlorazol black E dissolved in 70% ethanol/30% water. The oral parts and the swimming legs were dissected, and drawings were prepared of the specimen in glycerine using a camera lucida.

The following abbreviations are used in the descriptions: P1-P5, swimming legs 1-5; the free segments of the antennule are designated by Arabic numerals, ancestral segments by Roman numerals; one seta and one aesthetasc on a segment of the antennule are designated as: 1s + 1ae; A1, antennule; A2 antenna; sa, soft appendage; Mdgn, mandible gnathobase; Prgn, paragnaths; Mx1, maxillule; Mx2, maxilla; end 1-2, endopod segments 1 and 2. Type specimens are deposited in the Zoological Museum Hamburg (ZMH) and Zoological Institute of the Russian Academy of Sciences (ZIN RAS). Description of the antennule segmentation follows Huys & Boxshall (1991).

TAXONOMY

Frankferrarius gen. nov.

Diagnosis.— Rostrum a plate with two thin filaments. Cephalosome and pediger 1 separate, pedigers 4 and 5 partly separate in female, fused in male. Posterior

corners of prosome with small terminal spine. Caudal rami with four terminal setae, one lateral seta, one small dorsal seta and, in male, one vestigial proximolateral seta. Antennule ancestral segments I to XXIII with thin sensilla: one to three sensilla in females and up to 50 sensilla on proximal segments in males. Male antennule geniculation on left. Oral parts of female and male identical. Antenna coxa with one seta, basis with two setae, exopod of eight segments with 0, 1, 1, 1, 1, 1, 1 and 1 + 3 setae. Mandible cutting edge wide, with six teeth and one seta. Maxillule praecoxal arthrite strongly sclerotized and enlarged, coxal epipodite without setae and exopod with two setae. Maxilla strongly modified; praecoxa and basis of nearly same size, more than three times as long as coxa; praecoxa with endite bearing two setae; coxa without endites; well-developed articulation between coxa and basis; endopod compressed with long and tightly grouped setae. Maxilliped much smaller than maxilla; syncoxa without setae; basis without setae. P1-P4 as described for Augaptilidae, except for P1 basis without setae and P3 endopod segment 3 with 2, 2, and 3 setae (versus 2, 2 and 4 setae in augaptilids). P5 biramous, exopods 3-segmented; endopods one-segmented in female and in male right P5; male left P5 endopod 3-segmented.

Autapomorphies for the genus are: antennule segments supplied with one to three sensilla in females and up to 50 sensilla in males; maxilla strongly modified; maxilliped reduced as described above and P1 basis lacking setae.

Type species.— *Frankferrarius admirabilis* gen. et sp. nov., by monotypy.

Etymology.— The genus honours copepodologist Dr. Frank Ferrari for his contributions to the morphological studies, phylogeny and systematics of copepods and other crustaceans. Gender masculine.

Remarks.— *Frankferrarius* shares with Augaptilidae the following combination of characters: (i) single genital operculum positioned medially on the ventral part of the genital double-somite; (ii) P2 and P4 endopod segment 3 armament: 2, 2 and 3 setae; (iii) female P5 with 3-segmented exopod armament: I-0, I-1, II, I, 3; (iv) male left P5 of augaptilid type (e.g., *Euaugaptilus bullifer* (Giesbrecht, 1889)).

This new genus shares an enlarged and strongly sclerotized maxillule praecoxal arthrite with *Hyperbionyx* of the Hyperbionichidae and all species of Nullosetigeridae. With the representatives of the latter family it also shares an unarmed maxillule coxal epipodite. However, *Frankferrarius* does not share basic diagnostic features of these two families and, apparently, is a more distant relative.

Frankferrarius admirabilis gen. et sp. nov.
(figs. 1-8)

Material examined.— Holotype, adult female, dissected, body length 7.00 mm (ZMH K-43190). South Atlantic, 14°59.41′S 29°56.57′W, DIVA III Expedition Sta. 583, 30 July 2009, above the sea bed at a depth of 5148 m. Paratype, adult male, dissected, body length 11.20 mm (ZIN RAS 91111).

South Atlantic, 14°58.9′S 29°56.49′W, DIVA III Expedition Sta. 580, 30 July 2009, above the sea bed at a depth of 5131 m. Additional materials: 1CII, same label data as for paratype; 1 female CV, same label data as for holotype, and 1CV, North Atlantic, 29°19.24′N 28°37.94′W, DIVA III Expedition Sta. 636, 18 August 2009, above the sea bed at a depth of 4338.6 m.

Description.— Adult female, total length 7.00 mm; prosome 3.1 times as long as urosome. Rostrum a plate with 2 very thin filaments (figs. 1C, 2A). Labrum with soft appendage (sa) laterally (figs. 1C, 2A). Cephalosome and pediger 1 separate, pedigers 4 and 5 partly separate (figs. 1A-B, 2C); posterior corner of prosome with small terminal spine (figs. 1A-B, 2C-D). Caudal rami with four terminal setae, one small dorsal seta, and a long lateral seta (fig. 2B-D).

Antennule distal part broken, ancestral segment XXIII reaching anterior part of pediger 4. Antennule (fig. 3A-B) armature of 21 free segments (ancestral segments I-XXIII) as follows: I-III, 4s + 2 ae + 2?; IV-VII, 2s + 1 sensillum; VIII-XIII, 2s + 2 sensilla; XIV-XIX, 2s + 3 sensilla; XX-XXI, 2s + 2 sensilla; XXII-XXIII, 2s + 1 sensillum. Sensilla are poorly sclerotized and, probably, perform an aesthetasc function.

Antenna (fig. 3C-D), coxa and basis with one and two setae, respectively; endopod segment 1 with one seta, segment 2 with 13 setae; exopod 8-segmented with 0, 1, 1, 1, 1, 1, 1 and 3 + 1 setae, respectively.

Mandible (fig. 3E-F), gnathobase cutting edge wide, with six teeth and one seta, two teeth with bifid apices; exopod of five segments with 1, 1, 1, 1 and 2 setae; endopod segment 1 with one seta, segment 2 with seven setae; basis without setae.

Paragnaths (figs. 1C, 2A) distally bearing terminal small spine-like attenuations and located posterior to the mandible.

Maxillule (figs. 1C, 2A, 3G), praecoxal arthrite heavily sclerotized, large with 15 setae; coxal endite with three setae, coxal epipodite without setae; proximal basal endite with two setae; distal basal endite with three setae; endopod one-segmented with four setae; exopod with two setae.

Maxilla (figs. 1B-C, 4A-C), huge, strongly modified; praecoxa and basis of nearly equal length, more than three times as long as coxa; praecoxa with endite bearing two setae; very well-developed articulation between coxa and basis, coxa lacking endites; basis with one distal seta; endopod 2-segmented, endopod segment 1 with two strong sclerotized setae, endopod segment 2 with three strong sclerotized and three shorter and less sclerotized setae; endopod setae tightly grouped together.

Maxilliped (figs. 1B, 4D), syncoxa and basis of nearly same size, without setae. Endopod of five segments, with 1, 2, 2, 1 and 4 setae.

P1 (fig. 2E), coxa with medial seta; basis without setae, pore present on anterior surface; endopod 3-segmented; segment 1 with one medial seta, segment 2 with two medial setae; segment 3 with one lateral, two distal and two medial setae.

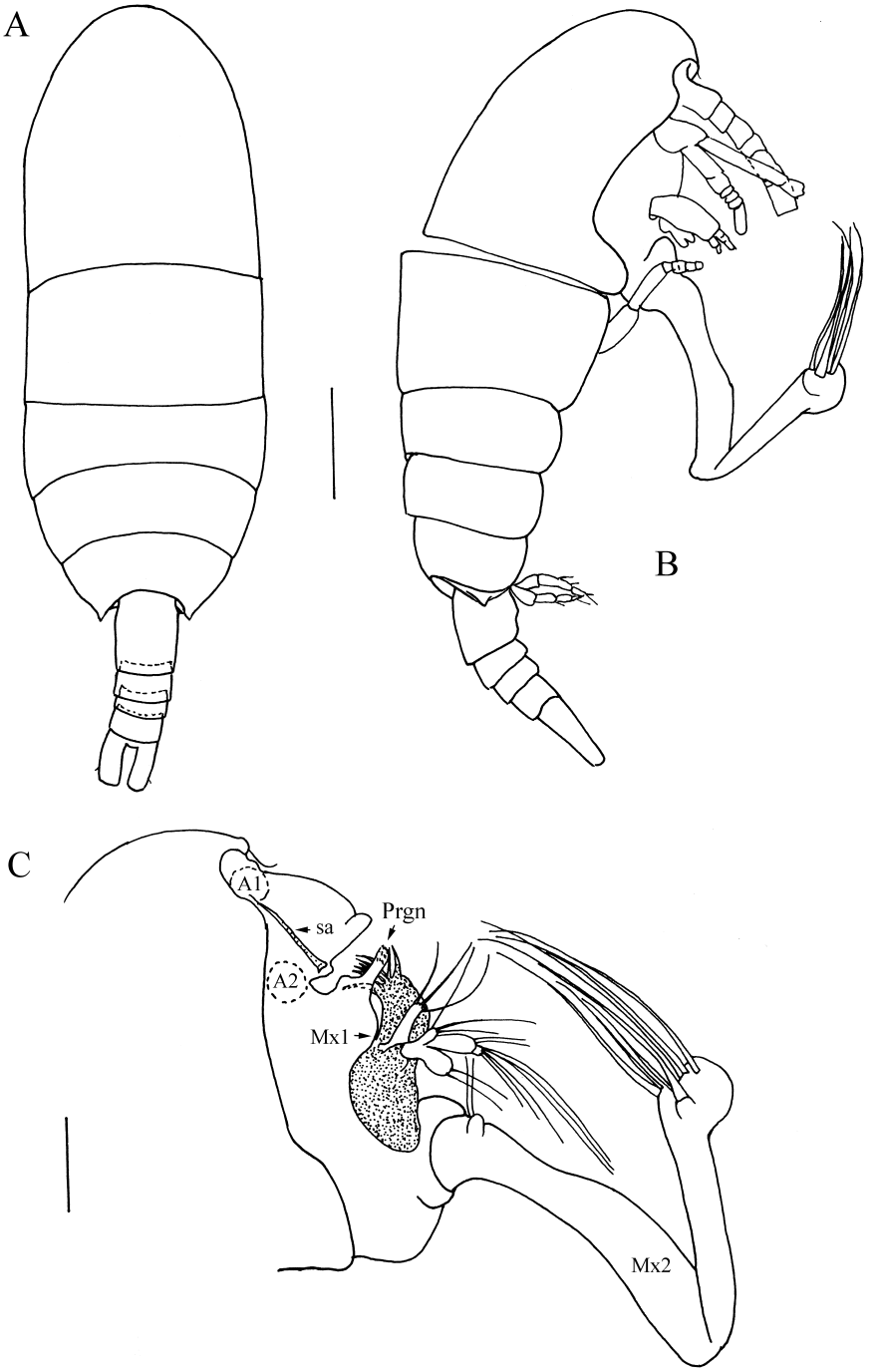

Fig. 1. *Frankferrarius admirabilis* gen. et sp. nov. Female, holotype. A, habitus, dorsal; B, habitus, lateral; C, cephalon, lateral. Scale bars: A, B = 1 mm; C = 0.5 mm.

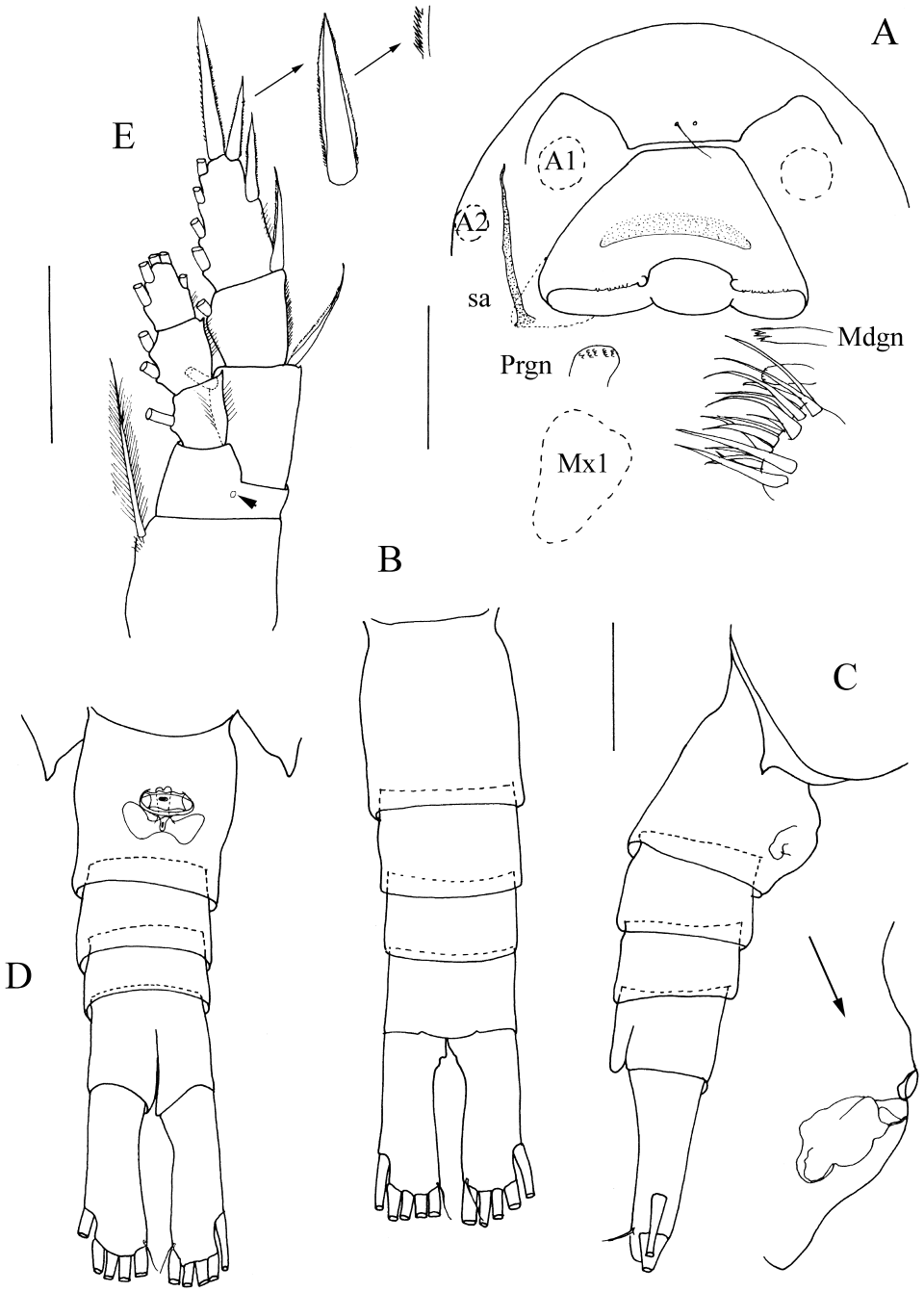

Fig. 2. *Frankferrarius admirabilis* gen. et sp. nov. Female, holotype. A, cephalon, ventral view; B, urosome, dorsal view; C, posterior corner of prosome and ursome, lateral view; D, posterior corner of prosome and ursome, ventral view; E, P1, arrow marks chitinous pore. Scale bars = 0.5 mm.

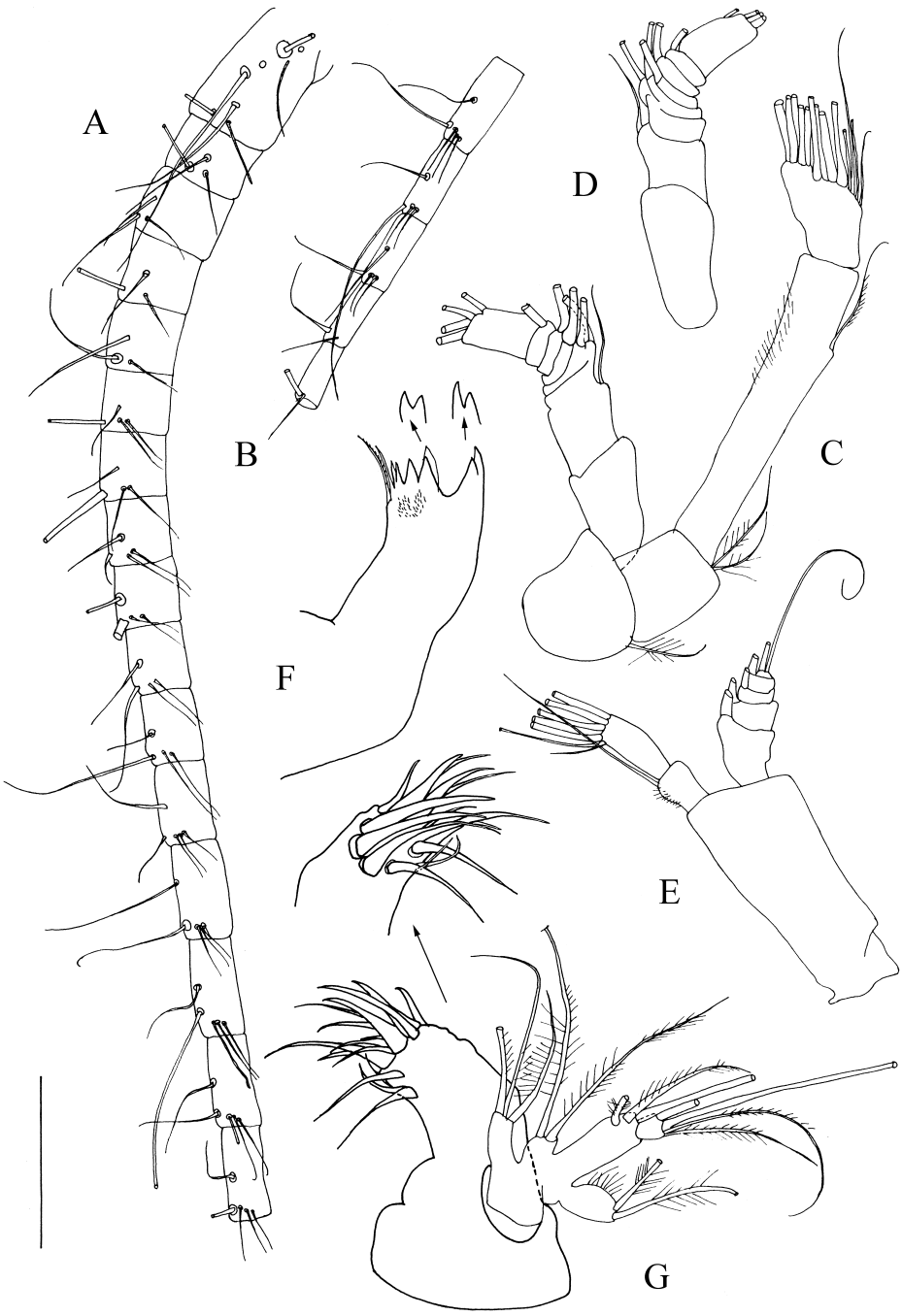

Fig. 3. *Frankferrarius admirabilis* gen. et sp. nov. Female, holotype. A, antennule, segments I-XVIII (16^{th}); B, antennule, segments XIX (17^{th}) to XXIII (21^{st}); C, antenna; D, antenna, exopod; E, mandible, palp; F, mandible, gnathobase; G, maxillule. Scale bar = 0.5 mm.

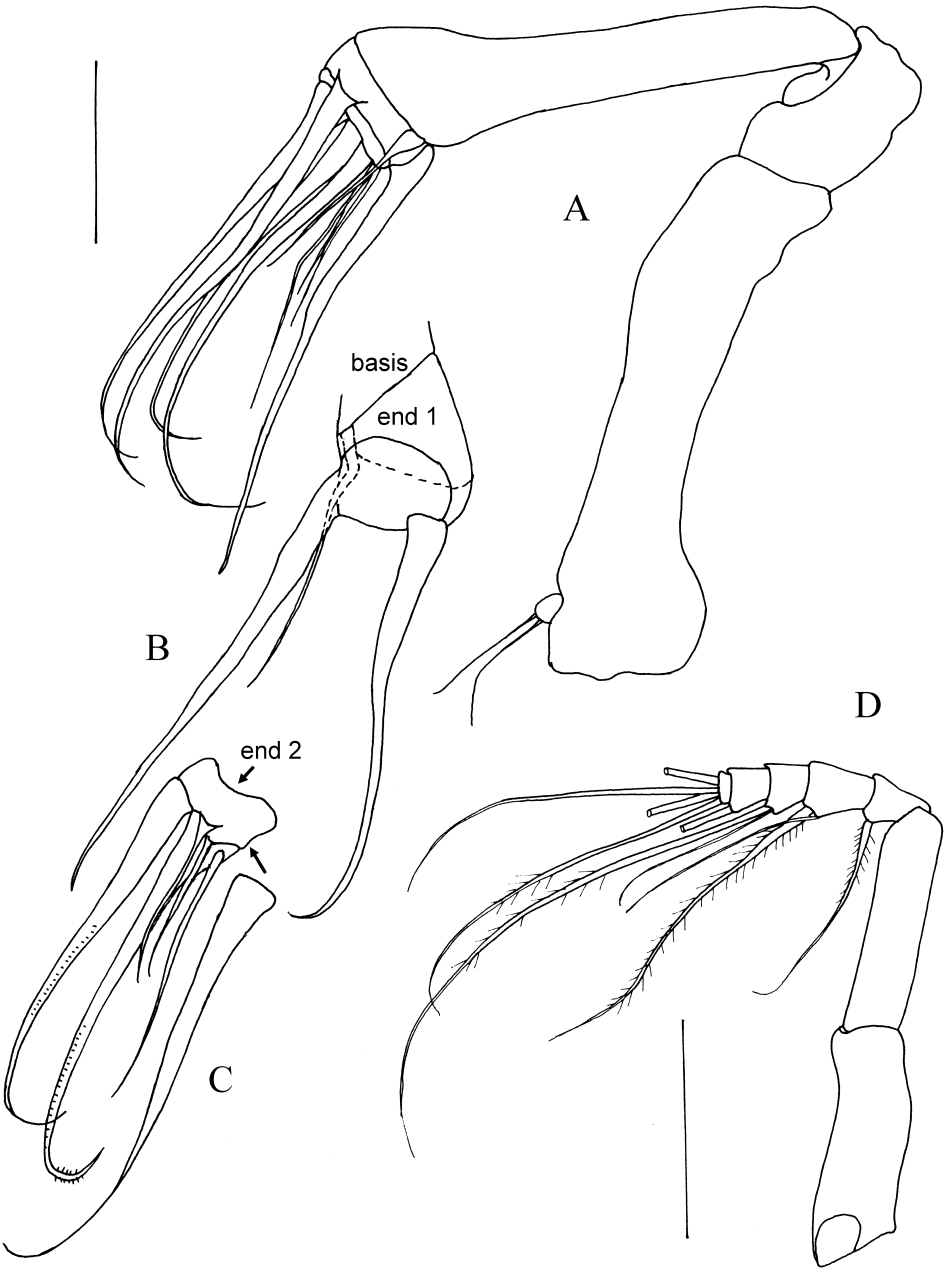

Fig. 4. *Frankferrarius admirabilis* gen. et sp. nov. Female, holotype. A, maxilla; B, maxilla, distal part of basis and endopod segment 1; C, maxilla, endopod segment 2; D, maxilliped. Scale bar = 0.5 mm.

Exopod 3-segmented, segments 1 and 2 with lateral spine and medial seta, segment 3 with two lateral spines, one terminal spine, and four medial setae.

P2-P4 (fig. 5A-C), coxa with medial seta; basis without setae; endopod 3-segmented, segment 1 with one medial seta, segment 2 with two medial setae, segment 3 with three medial, two terminal and two lateral setae. Exopod 3-segmented, segments 1 and 2 each with lateral spine and medial seta, segment 3 with three lateral spines, one terminal spine and five medial setae.

P5 (fig. 5D), biramous; coxa without seta, basis with lateral seta, endopod one-segmented with two setae. Exopod 3-segmented, segment 1 with lateral spine, segment 2 with lateral spine and medial seta, segment 3 with one lateral spine, one terminal spine and four medial setae.

Adult male, total length 11.2 mm; prosome 5.5 times as long as urosome. Rostrum as in female (fig. 6C). Labrum similar to female, but paragnaths are not as visible in lateral view and pair of small chitinous attenuations present posterior to maxillule. Cephalosome and pediger 1 separate, pedigers 4 and 5 fused (fig. 6A-B); posterior corners of prosome as in female (figs. 6A-B, 2C-D). Caudal rami as in female, but vestigial proximolateral seta I present (fig. 6D).

Antennule (figs. 7A-C, 8A-C), geniculate on left. Left and right antennules free segments 1 to 16 (ancestral segments I to XVIII) identical, armature as follows: I-III, 6s + numerous sensilla; IV, 1s + numerous sensilla; V-XIII, 2s + numerous sensilla; XIV-XVIII, 2s + sensilla which are less numerous than on more proximal segments. Armature of the right antennule: segments XIX-XXV, 2s + sensilla; XXII-XXIII, 1s + sensilla; XXIV-XXV, 2s + sensilla; segments XXVI-XXVIII broken off, segment XXV of right antennule exceeding body length by two segments. Left antennulae segments XIX-XXI differ from those on right as geniculation present between segments XX and XXI, armature as follows: XIX, 1s + 1 spine partly fused to segment + sensilla; XX, 1 spine fused to segment + sensilla; XXI, 1 spine + sensilla; XXII, 1 seta + sensilla. Some sensilla are short and sclerotized, other are long, poorly sclerotized and, probably, perform aesthetasc function.

Antenna identical to that of female, except for endopod segment 2 with 14 setae. Mandible, maxillule, maxilla, maxilliped and P2-P4 identical to those of female. P1 as in female, except for lateral spine of exopod segment 2 which is shorter than in female, not exceeding base of proximal lateral spine of exopod segment 3 (fig. 8D).

P5 (fig. 8E) biramous; coxa without seta, basis with lateral seta, endopod 3-segmented in the left leg, endopod segments 1 and 2 without setae, endopod segment 3 with six setae, right endopod one-segmented with one seta. Exopod segments 1 and 2 each with one lateral spine on both sides. Left exopod segment 3 with two lateral spines. Right exopod segment 2 wider than left, with excavation on

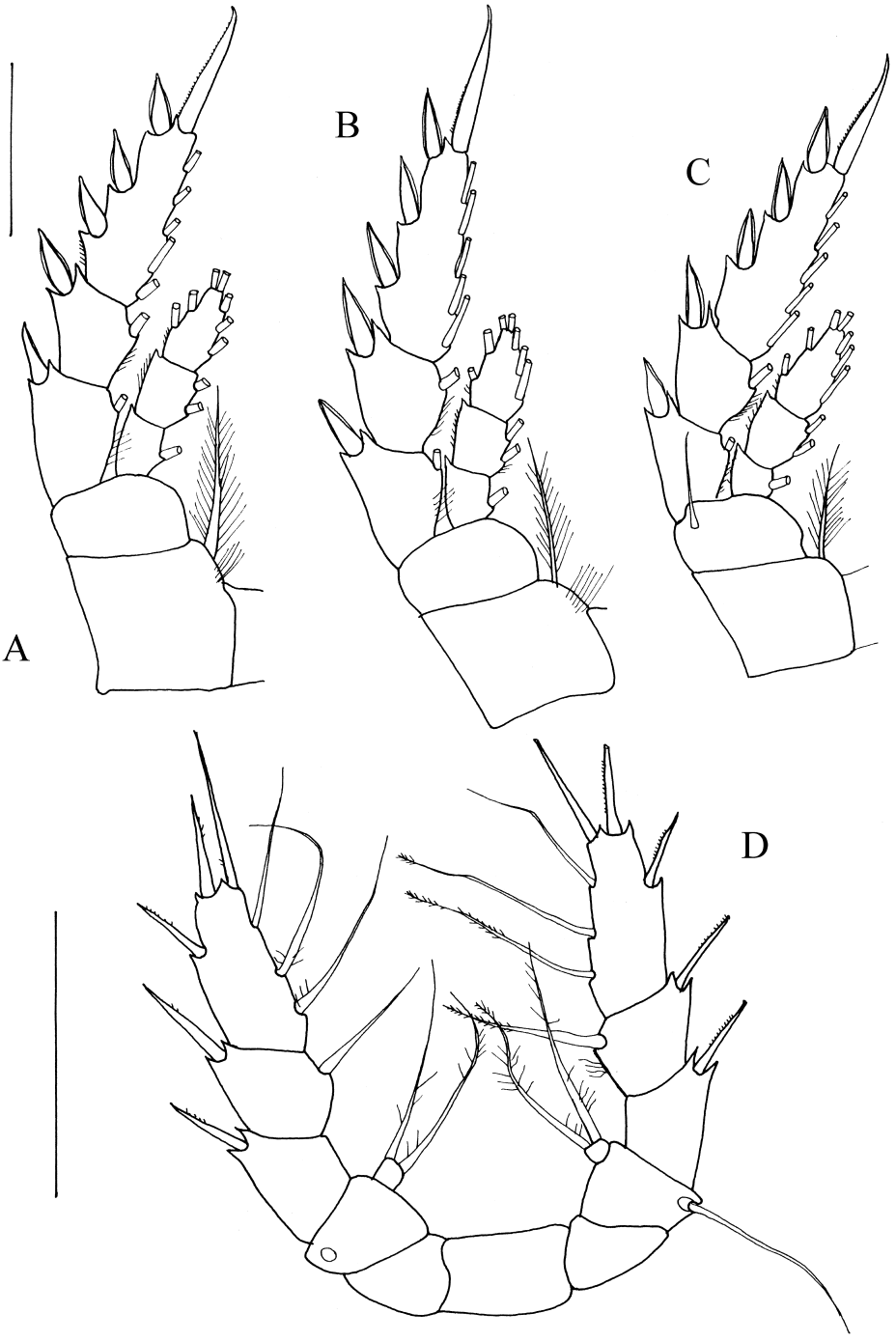

Fig. 5. *Frankferrarius admirabilis* gen. et sp. nov. Female, holotype. A, P2; B, P3; C, P4; D, P5. Scale bar = 0.5 mm.

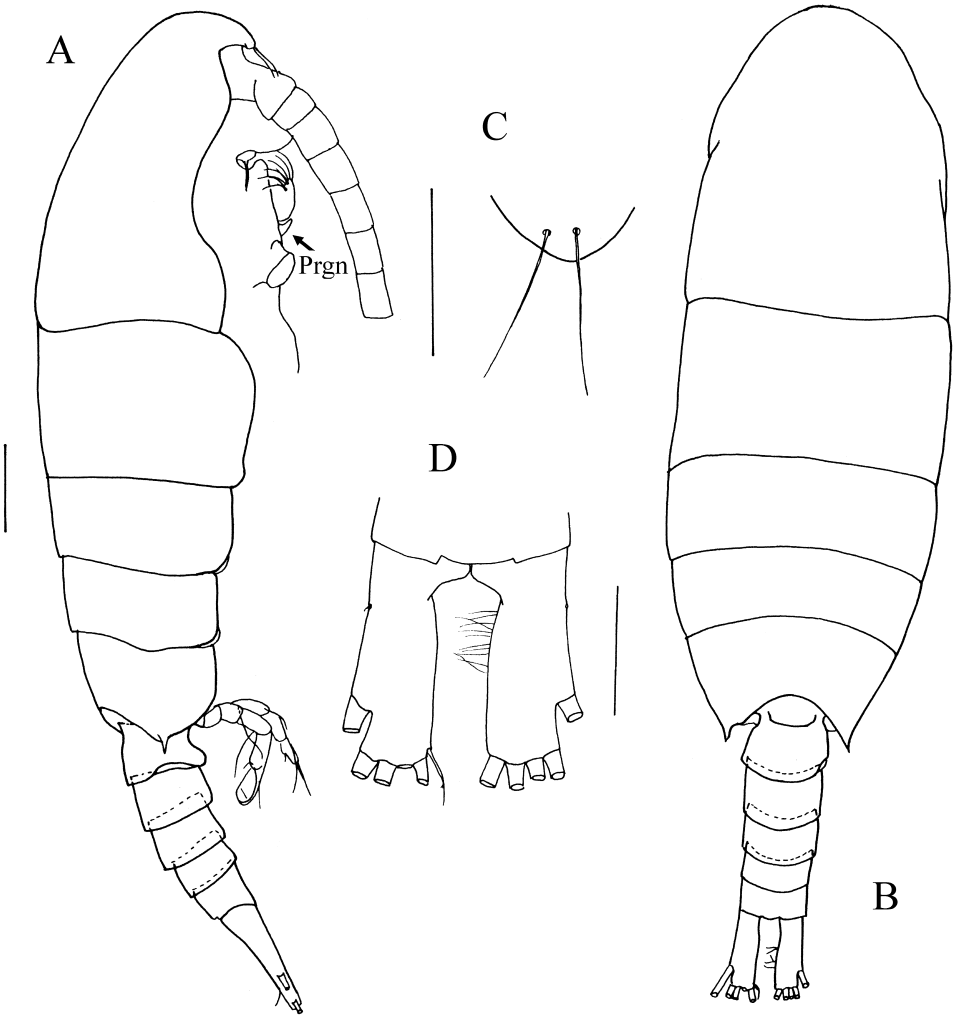

Fig. 6. *Frankferrarius admirabilis* gen. et sp. nov. Male, paratype. A, habitus, lateral; B, habitus, dorsal; C, cephalon, ventral; D, caudal rami, dorsal. Scale bars: A, B = 1 mm; C, D = 0.5 mm.

inner distal edge, excavation densely covered with thin spinules, segment 3 wider than left, with 1 lateral spine and scar marking insertion of broken setal element.

Etymology.— The species is named "*admirabilis*", from Latin, meaning 'amazing' referring to the remarkable morphology of the maxilla.

Remarks.— In calanoid copepods males are commonly smaller than females, but, sometimes males are larger, e.g., *Eurytemora affinis* (Poppe, 1880), *Pseudocyclops simplex* Sewell, 1932 and *Byrathis arnei* Schulz, 2006 (Bush & Brenning, 1992; Ohtsuka et al., 1999; Markhaseva & Renz, 2011). In these species difference in size between males and females is less than 1.6 times, as described here

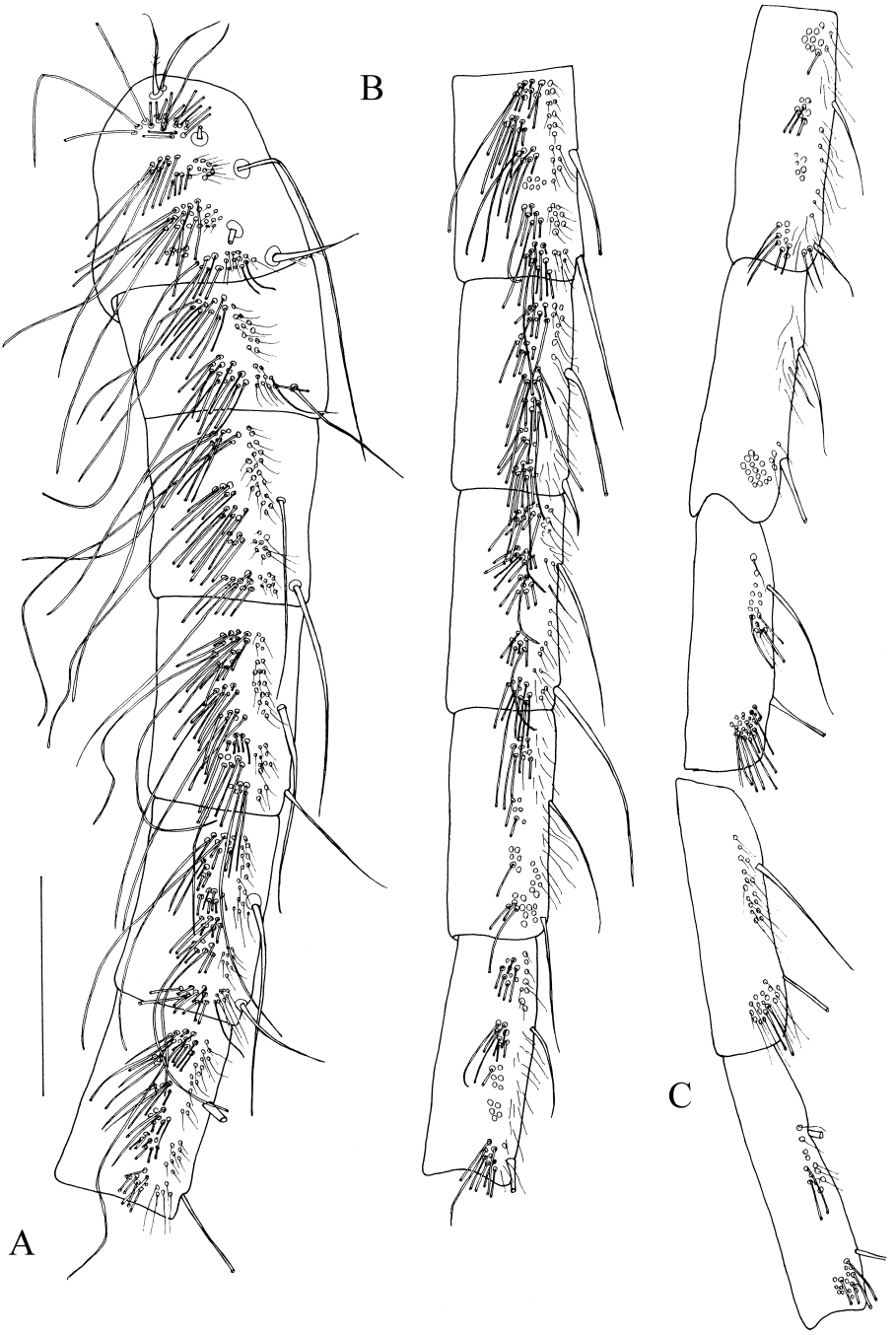

Fig. 7. *Frankferrarius admirabilis* gen. et sp. nov. Male, paratype. A, left antennule, segments I-VIII (6^{th}); B, left antennule, segments IX-XIII (11^{th}); C, left antennule, segments XIV-XVIII (16^{th}). Scale bar = 0.5 mm.

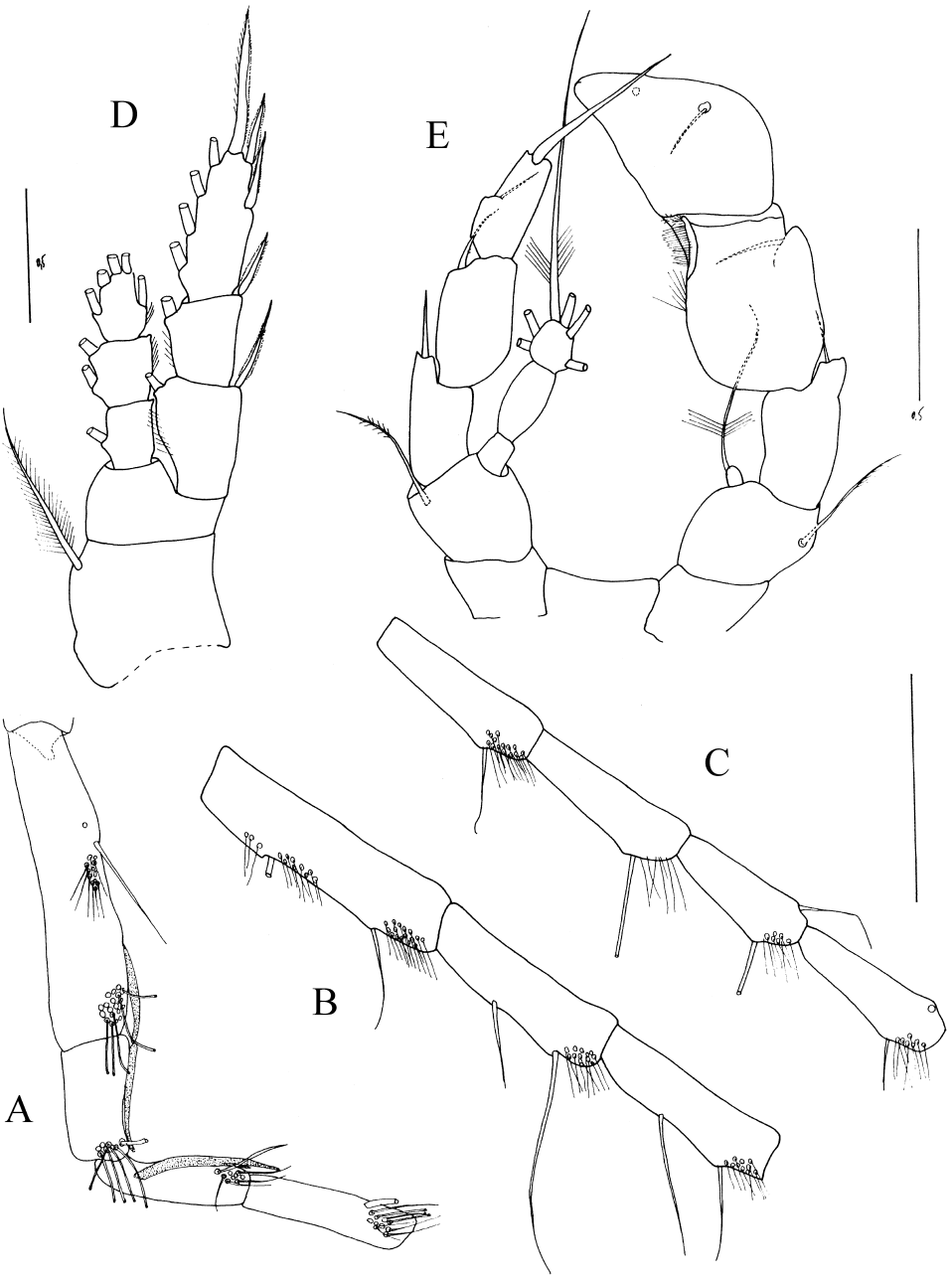

Fig. 8. *Frankferrarius admirabilis* gen. et sp. nov. Male, paratype. A, left antennule, segments XIX-XXII (20^{th}); B, right antennule, segments XIX-XXI (19^{th}); C, right antennule, segments XXII-XXV (23^{rd}); D, P1; E, P5. Scale bar = 0.5 mm.

for *Frankferrarius*. While both sexes of *Frankferrarius* are very close morphologically, the possibility that the male might not be the same species as the female is considered; however, until new specimens will be found they are attributed to the same species.

DISCUSSION

Frankferrarius admirabilis gen. et sp. nov. does not fit within any known arietelloidean family and is distinguished by several autapomorphies: the maxilla is huge and highly specialized with a well-developed articulation between the coxa and basis as well as having long, grouped endopod setae apparently designed for piercing and grasping prey and antennule segments supplied with one to three sensilla in females and up to 50 sensilla in males, among others.

Three arietelloidean families inhabit the near-bottom of the world's oceans: Hyperbionichidae with two genera included, *Hyperbionyx* Ohtsuka, Roe & Boxshall, 1993 (two species) and monotypic *Lamiantennula* Markhaseva & Schulz, 2006; and the taxonomically-rich family Arietellidae with 36 benthopelagic species of 12 genera (*Camapaneria* Ohtsuka, Boxshall & Roe, 1994, *Crassiarietellus* Ohtsuka, Boxshall & Roe, 1994, *Griceus* Ferrari & Markhaseva, 2000, *Metacalanalis* Ohtsuka, Nishida & Machida, 2005, *Metacalanus*, Cleve, 1901, *Paramisophria* T. Scott, 1897, *Paraugaptiloides* Ohtsuka, Boxshall & Roe, 1994, *Paraugaptilus* Wolfenden, 1904 (part.), *Pilarella* Alvarez, 1985, *Protoparamisophria* Ohtsuka, Nishida & Machida, 2005, *Sarsarietellus* Campaner, 1984, *Scutogerulus* Bradford, 1969) and a putative Augaptilidae (*Alrhabdus* Grice, 1973). However, true Augaptilidae in benthopelagic waters have not been found. Only the doubtful augaptilid *Alrhabdus* is common in our benthopelagic samples. This genus differs from all other Augaptilidae by the presence of three (instead of two) setae on the maxilliped basis (Boxshall & Halsey, 2004: 68); thus, *Alrhabdus* is only tentatively placed in the Augaptilidae (Ohtsuka, pers. commun., cited after Boxshall & Halsey, 2004).

Frankferrarius admirabilis shares an enlarged and strongly sclerotized maxillule praecoxal arthrite with *Hyperbionyx* in the Hyperbionichidae and all species of Nullosetigeridae. With the representatives of the later family, it also shares an unarmed maxillule coxal epipodite. However, *Frankferrarius* does not share basic diagnostic features of these two families and is apparently a more distant relative. Therefore, it is provisionally placed in the Augaptilidae as it shares with this family: (i) the general pattern of segmentation and setation of its swimming legs although P3 endopod segment 3 armament is 2, 2 and 3 setae (versus 2,2 and 4 setae in augaptilids), (ii) a single genital operculum positioned medially on the ventral part of the genital double-somite, (iii) the female P5 has a 3-segmented

exopod with armament of I-0, I-1, II, I, 3 and (iv) the male left P5 is of the augaptilid type. Nevertheless, *Frankferrarius admirabilis* differs from other augaptilids in being without setae on the maxilliped basis and in details of morphology and setation of oral parts and basis of P1. This new genus and species probably should be placed in a new family but this must await a revision of the Augaptilidae within the Arietelloidea (Boxshall & Halsey, 2004).

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