A new species of the deep-sea copepod genus Scutogerulus (Calanoida: Arietellidae) from the hyperbenthic waters of Okinawa, Japan

Article *in* Systematics and Biodiversity · March 2004

DOI: 10.1017/S1477200004001331

CITATIONS
12

READS
117

2 authors, including:

Susumu Ohtsuka
Hiroshima University
263 PUBLICATIONS **3,404** CITATIONS

SEE PROFILE

Systematics and Biodiversity **2** (1): 49–55
DOI: 10.1017/S1477200004001331 Printed in the United Kingdom

Issued 24 August 2004

Susumu Ohtsuka[1] & Geoffrey A. Boxshall[2]
[1]Takehara Marine Science Station, Setouchi Field Science Center, Graduate School of Biosphere Science, Hiroshima University, 5-8-1 Minato-machi, Takehara, Hiroshima 725-0024, Japan
[2]Department of Zoology, The Natural History Museum, Cromwell Road, London SW7 5BD, UK

submitted November 2003
accepted February 2004

A new species of the deep-sea copepod genus *Scutogerulus* (Calanoida: Arietellidae) from the hyperbenthic waters of Okinawa, Japan

Abstract A new species of the rare arietellid genus *Scutogerulus* is described from deep hyperbenthic waters off Okinawa, southwestern Japan. This is the second species of the genus. Phylogenetically significant characteristics known only on the basis of the type species are confirmed by the discovery of the new congener, in particular: (1) the genital system of the female exhibits the most plesiomorphic condition of any arietellid genus; (2) the well developed setae on the endopodal segments of the maxillae and maxillipeds are modified into 'shield-like setae' similar to the 'button setae' in another arietelloidean family, the Augaptilidae; (3) the outer distal spine on the first exopodal segment of leg 1 is absent.

Key words Hyperbenthic, Crustacea, Copepoda, Calanoida, marine plankton

Introduction

The oceans cover 71% of the Earth's surface to an average depth of 3.7 km and the fauna of this vast pelagic biome, the largest on the planet, is dominated by the copepod crustaceans. At its base, between the pelagic and the surface of the sea bed is a transition zone, the hyperbenthic. It is relatively difficult to sample, especially in deep waters, and the inhabitants of the hyperbenthic zone are poorly known. During a faunistic survey of the hyperbenthic copepods around Okinawa, southwestern Japan, a new species of the rare arietellid genus *Scutogerulus* was discovered from Japanese waters. Arietellids are a basal family within the Calanoida and this is only the second species of the genus. The type species *S. pelophilus* Bradford, 1969 was collected from the hyperbenthic waters of the New Zealand slope (Bradford, 1969). The male of *S. pelophilus* described by Bradford (1969) was assigned to a different monotypic genus, *Campaneria* Ohtsuka, Boxshall & Roe, 1994 (Ohtsuka *et al*., 1994), as already suggested in Bradford's original description. The female genital system of *Scutogerulus* was interpreted as the most plesiomorphic condition found in all the arietellid genera (Ohtsuka *et al*., 1994). In contrast the genus also bears specialised structures on setae of the maxillae and maxillipeds, which were referred to as 'shield-shaped appendages' by Bradford (1969).

The hyperbenthic calanoid copepods of the subtropical waters of Japan seem to be highly diversified. A new species of the enigmatic clausocalanoidean genus *Neoscolecithrix* has recently been recorded from off Okinawa, in addition to common hyperbenthic members of the families Pseudocyclopidae, Ridgewayiidae, Arietellidae, Pseudodiaptomidae, Phaennidae, Scolecitrichidae, Tharybidae and Aetideidae (Barthélémy *et al*., 1998; Ohtsuka *et al*., 1991, 1994, 1996, 2002, 2003; Walter *et al*., 2002; Ohtsuka, unpublished data). The present paper describes the new species of *Scutogerulus* using both light and scanning electron microscopy.

Materials and methods

The copepods were collected from hyperbenthic waters off Kuroshima Island, Okinawa, southwestern Japan (26°19.18′N, 127°25.56′E) at a depth of 596–606 m, on 24 May 2003, using a NORPAC plankton net (mesh size: 0.33 mm) attached to the mouth of a beam trawl. These were fixed in 10% neutralized formalin/sea-water immediately after capture, and transferred into 70% ethanol. Dissected appendages were mounted on glass slides in CMC-10 mounting media (Masters Company, Inc.). All drawings were made with the aid of a camera lucida attached to a differential interference microscope (Nikon Optiphoto). One female of the new species was observed with a scanning electron microscope (Jeol T-20).

Terminology follows Huys & Boxshall (1991). Type specimens are deposited at the Natural History Museum, London (BMNH), and at the Kitakyushu Museum of Natural History and Human History, Kokura (KMNH).

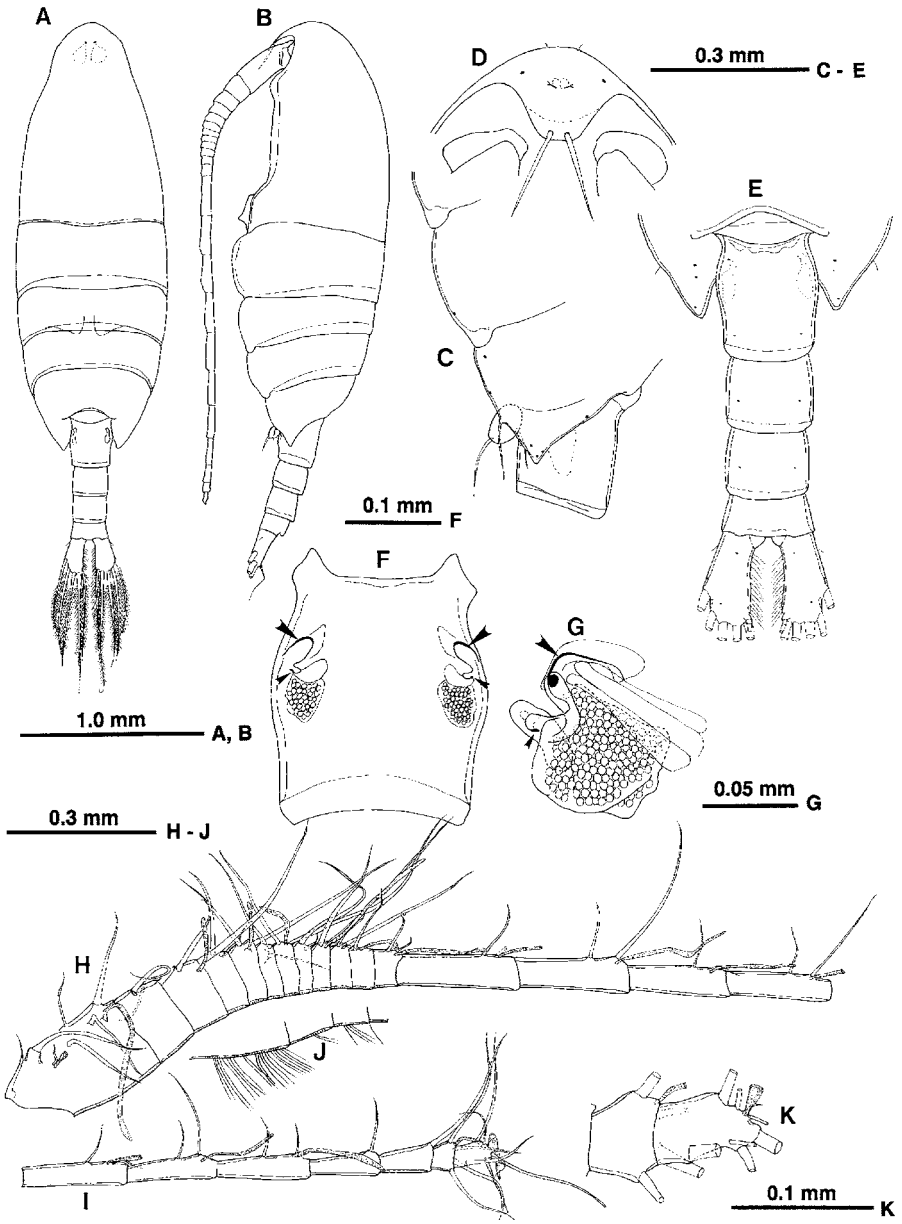

Figure 1 *Scutogerulus boettgerschnackae* n. sp., female, holotype. A. Habitus, dorsal view; B. Habitus, lateral view; C. Posterior margin of prosome and genital double-somite, lateral view; D. Rostrum; E. Urosome and posterior margin of prosome, dorsal view; F. Genital double-somite, ventral view, gonopore (indicated by large arrowhead) and copulatory pore (by small arrowhead); G. Genital system, gonopore (indicated by large arrowhead) and copulatory pore (small arrowhead); H. Antennule, first (I–III) to 16th (XVIII) segments, posterior row of setules missing; I. Antennule 17th (XIX) to 23rd (XXVI–XXVIII) segments; J. Posterior row of setules on first three segments; K. Last two antennulary segments (XXIV–XXV and XXVI–XXVIII).

Systematics

Family Arietellidae Sars, 1902
Genus *Scutogerulus* Bradford, 1969

Scutogerulus boettgerschnackae n. sp. (Figs 1–4)

Material examined. 6♀♀, near bottom off Kuroshima Island, Okinawa, southwestern Japan (26°19.18′N, 127°25.56′E; 596–606 m depth), 24 May 2003. Collector: S. Ohtsuka.

Types. Holotype: 1♀, partly dissected and appendages mounted on glass slides, body in vial, BMNH 2003.964. Paratypes: 1♀, partly dissected and appendages mounted on glass slides, body in vial, BMNH 2003.965; 2♀♀, whole specimens, BMNH 2003.966-967; 2♀♀, whole specimens, KMNH IvR 500,101 and 500,102.

Body length. Holotype 3.01 mm; paratypes 2.79, 2.84, 2.90, 2.90, 2.93 mm.

Description

Female

Body (Fig. 1A, B) compact, with postero-lateral angles of prosome ends produced into round processes reaching beyond

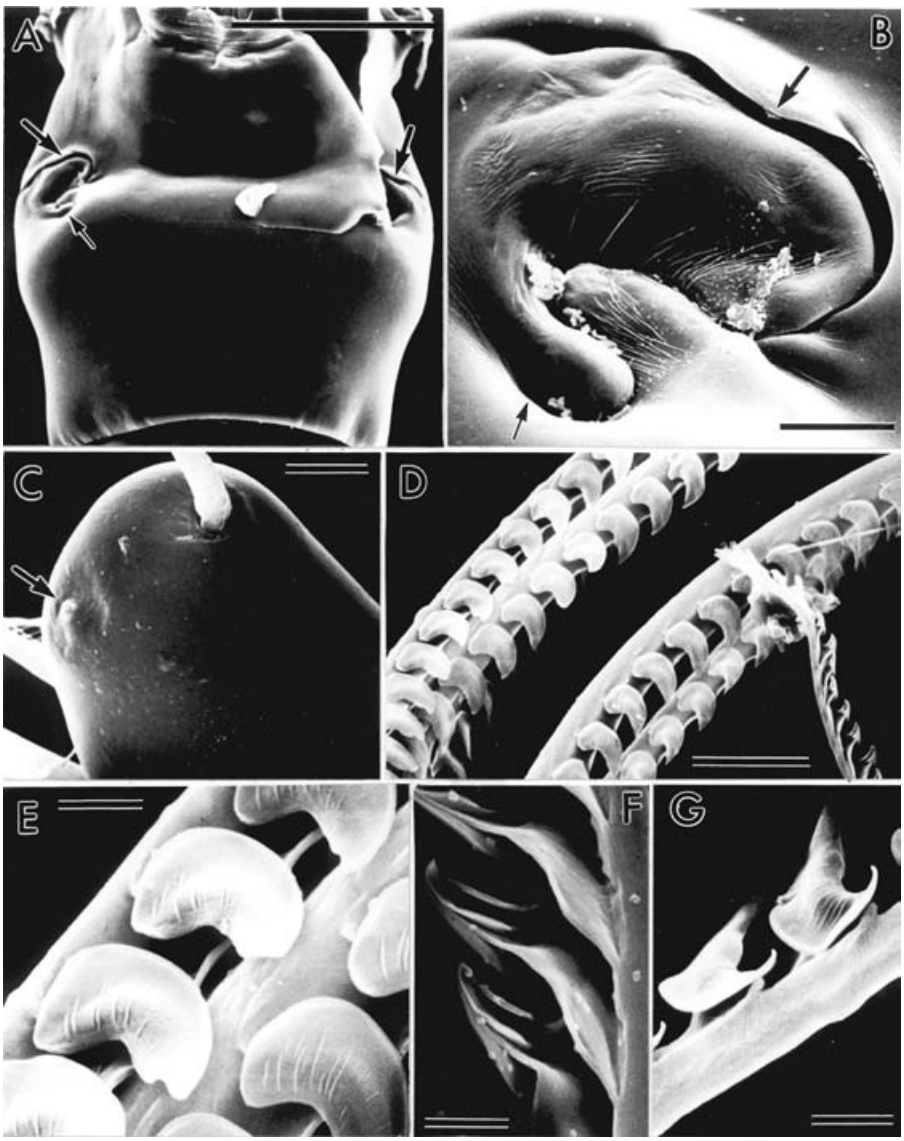

Figure 2 SEM micrographs of *Scutogerulus boettgerschnackae* n. sp., female. A. Genital double-somite, ventral view, gonopores and copulatory pore indicated large and small arrows, respectively, left side damaged; B. Right gonopore (indicated by large arrow) and copulatory pore (by small arrow); C. Left leg 5, anterior surface, vestigial exopod (?) indicated by arrow; D–G. 'Shield setae' on maxillary endopod. Scales: 0.1 mm (A); 0.01 mm (B, D); 0.02 mm (C); 0.002 mm (E–G).

middle of genital double-somite (Fig. 1C); prosome 2.5 times longer than urosome; cephalosome incompletely fused to first pediger; rostrum (Fig. 1D) relatively wide, with paired filaments at tip; second and third pedigers each produced posteroventrolaterally into round projection; fourth and fifth pedigers completely coalescent. Urosome (Fig. 1A, E) 4-segmented; genital double-somite swollen laterally at midlength; genital system paired and symmetrically arranged (Fig. 1F, G); gonopore and copulatory pore sharing common slit (see Fig. 2A, B), located anteriorly and posteriorly, respectively; seminal receptacle compact (Fig. 1F, G); second urosomite nearly as long as third; caudal rami symmetrical, inner margins ornamented with fine setules; minute seta I located anterolaterally; seta V longest; seta VII originating dorsally from inner distal corner.

Antennule (Fig. 1H–K) indistinctly 23-segmented, extending to distal margin of third urosomite (Fig. 1B); first to 12th (XIV) segments each with long setules along posterior margin (Fig. 1J; all missing in Fig. 1H). Fusion pattern and armature elements as follows (compiled from both antennules): I–III = 7 + 2 ae, IV = 2, V = 2 + ae, VI = 2, VII = 2 + ae, VIII = 2, IX = 2 + ae, X = 2 (1 spiniform) + ae, XI–XII = 4 + 2 ae (ae on XII rudimentary), XIII = 2 + ae, XIV–XV = 4 + 2 ae, XVI = 2 + ae, XVII = 2 + ae, XVIII = 2 + ae, XIX = 2 + ae, XX = 2 + ae, XXI = 2 + ae, XXII = 1, XXIII = 1, XXIV–XXV = 2 + 2 + ae, XXVI–XXVIII = 8 + ae. Antenna (Fig. 3A, B) with 2-segmented endopod and indistinctly 9-segmented exopod; setal formula of exopod 0, 0, 1, 1, 1, 1, 1, 0, 3; proximal endopodal segment unarmed, distal segment with 2 unequal setae subterminally (representing armature of second endopodal segment) and 5 setae terminally. Mandibular cutting edge (Fig. 3C) with 1 mono-, 1 bi- and 1 tri-cuspidate teeth and 2 patches of short spinules. Mandibular

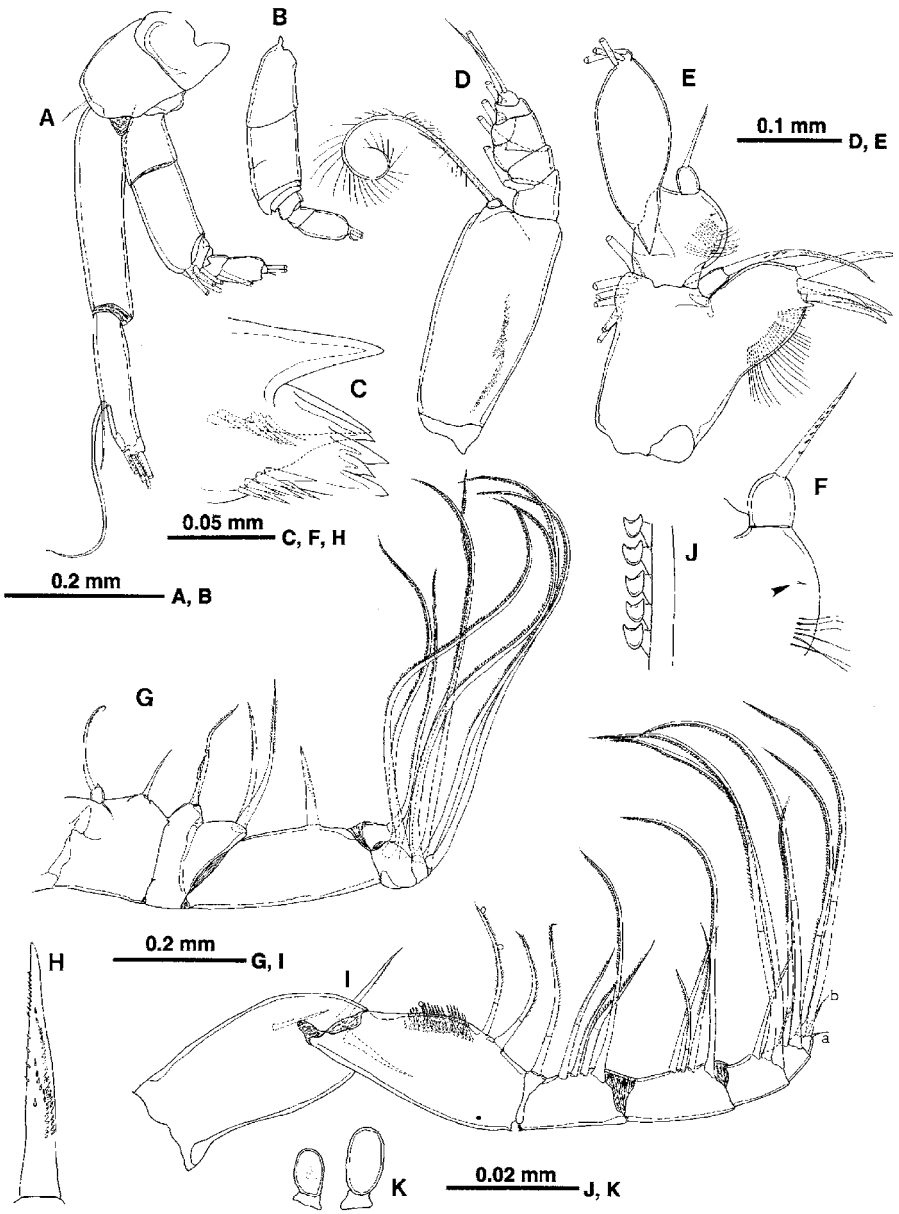

Figure 3 *Scutogerulus boettgerschnackae* n. sp., female, holotype. A. Antenna; B. Antennary exopod; C. Mandibular cutting edge; D. Mandibular palp; E. Maxillule; F. Maxillulary basis and endopod (vestigial seta on basis arrowed); G. Maxilla; H. Basal spine of maxilla; I. Maxilliped (with setae a and b labelled); J. Seta of maxillipedal endopod with modified 'shield-shaped' setules; K. Two apostome phoronts (?) on maxillipedal setae.

palp (Fig. 3D) with basis bearing row of setules; endopod rudimentary, 1-segmented, with 2 unequal setae terminally; exopod 5-segmented, setal formula 1, 1, 1, 1, 2. Maxillule (Fig. 3E, F) with praecoxal arthrite bearing 1 short process, 4 spinulose spines and row of fine setules; coxal epipodite with 6 setae; coxal endite with 1 long spinulose seta; basis bearing 1 vestigial element (see Fig. 3F, arrowed) and 2 rows of fine setules; endopod bulbous, with 1 short, spinulose seta terminally; exopod lamellar, with 3 long, plumose setae at tip. Maxilla (Fig. 3G) relatively delicate in comparison to those of other arietellids; first praecoxal endite with 1 spinulose seta and rudimentary element; second praecoxal endite with single seta; first and second coxal endites each with 2 spinulose setae; basis bearing stout, spinulose spine (Fig. 3H); endopod 4-segmented, setal formula 1, 3, 2, 2; all endopodal setae ornamented with row of modified 'shield-like' setules (see Fig. 2D–G). Maxilliped (Fig. 3I) with syncoxa bearing 3 spinulose setae subterminally; basis with 2 spinulose setae and dense patch of short spinules; first endopodal segment incompletely incorporated into basis, with 1 spinulose seta; second to sixth endopodal segments with setation 4, 4, 3, 3, 4, including 1, 1, 2, 2, 2 shield-like setae (Fig. 3J), respectively; setae 'a' and'b' (see Ohtsuka *et al.*, 1994) rudimentary.

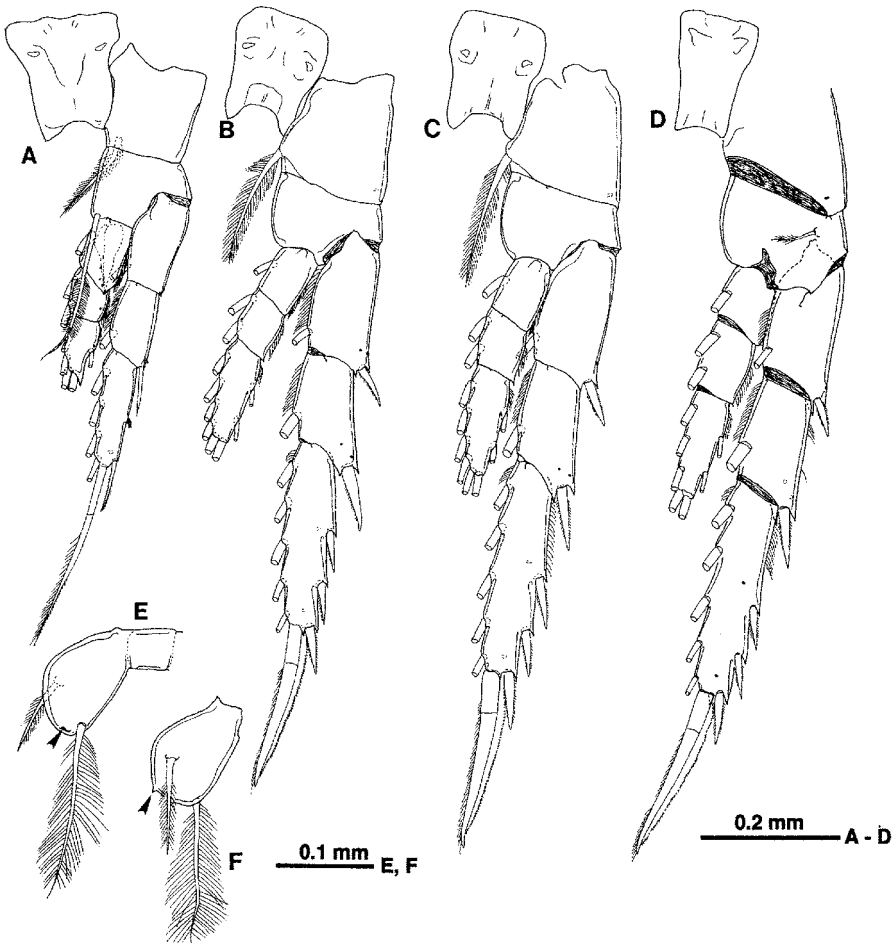

Figure 4 *Scutogerulus boettgerschnackae* n. sp., female, holotype. A. Leg 1, anterior; B. Leg 2, anterior; C. Leg 3, anterior; D. Leg 4, posterior; E. Right leg 5 and intercoxal sclerite, anterior (arrowhead showing putative vestigial exopod); F. Left leg 5, posterior.

Seta and spine formula of legs 1 to 4 (Fig. 4A–D) as follows:

	Coxa	Basis	Exopod			Endopod
			1	2	3	
Leg 1	0-1	0-1	0-1;	I-1;	I, I, 4	0-1; 0-2; 2, 2, 1
Leg 2	0-1	0-0	I-1;	I-1;	III, I, 5	0-1; 0-2; 2, 2, 4
Leg 3	0-1	0-0	I-1;	I-1;	III, I, 5	0-1; 0-2; 2, 2, 4
Leg 4	0-0	1-0	I-1;	I-1;	III, I, 5	0-1; 0-2; 2, 2, 3

Leg 1 (Fig. 4A) lacking outer element on first exopodal segment; tuft of fine setules present midway along margin of third exopodal segment. Legs 2 (Fig. 4B) and 3 (Fig. 4C) each with outer distal corner of second endopodal segment produced into minute prominence. Legs 5 (Figs 2C, 4E) nearly symmetrical, each leg consisting of lamellar plate incompletely fused to intercoxal sclerite; lamellar plate with long plumose seta subterminally and shorter one on posterior surface; small, subterminal or terminal knob on each plate possibly representing exopod (see Fig. 2C).

Male

Unknown.

Remarks

The new species is easily distinguished from the type species *Scutogerulus pelophilus* (characters in parentheses) by: (1) female leg 5 more reduced, comprising only lamellar plates incompletely fused to intercoxal sclerite (2-segmented exopod and 1-segmented endopod); (2) proximal process on maxillulary praecoxal arthrite shorter; (3) inner basal element of maxillule reduced (a distinct short seta); (4) leg 1 without outer basal seta.

The type species *S. pelophilus* was redescribed on the basis of one paratypic female by Ohtsuka *et al.* (1994), but the fusion pattern and armature elements of the antennule of the type species were incorrectly described in part: (XIV = 2 + ae, XV–XVI = 4 + 2 ae) should be replaced by (XIV–XV = 4 + 2 ae, XVI = 2 + ae). The row of long setules along the posterior margin of the antennule extends from the first (I–III) to the 12th (XIV) segments in the new species, but only from the first to the 11th (XIII) in *S. pelophilus*. However, since scars of missing setules are easily overlooked, the setular row may well have extended to the 12th (XIV) segment in the latter species.

Cysts, probably phoronts of apostome ciliates (cf. Sewell, 1951; Grimes & Bradbury, 1992), were observed attached to

setae on the maxillipeds (Fig. 3K). Each cyst was about 7–10 μm in long axis with a short stalk of ca. 2 μm. Apostome phoronts have been found on the body surfaces of both shallow- and deep-water planktonic copepods (Sewell, 1951; Grimes & Bradbury, 1992; Ohtsuka *et al*., 2003, unpublished data). According to Sewell (1951), the frequency of occurrence of these cysts on copepods increased with depth (~1500 m) by comparison with the surface waters. However, attached stages are very common in the shallow waters of the USA and Japan (Grimes & Bradbury, 1992; Ohtsuka *et al*., unpublished data). A unique life cycle of the apostome *Vampyrophyra pelagica* (Chatton & Lwoff, 1930) carried on coastal planktonic copepods was proposed by Grimes & Bradbury (1992). We have found a clear seasonal pattern in the occurrence and host specificity of this apostome in the Seto Inland Sea, western Japan (Ohtsuka *et al*., unpublished data).

Etymology. The new specific name is named in honor of Dr Ruth Böttger-Schnack of the Institut für Meereskunde an der Universität Kiel.

Discussion

In their phylogenetic study of the Arietellidae, Ohtsuka *et al*. (1994) recognised the monotypic genus *Scutogerulus* as distinct. The following phylogenetically important, generic characteristics are rigorously reconfirmed by the discovery of the new species: (1) the primitive female genital system (plesiomorphy); (2) the presence of modified 'shield-shaped setules (Bradford, 1969)' on the setae on the maxillary and maxillipedal endopods (autapomorphy); (3) the loss of the outer distal spine from the first exopodal segment of leg 1 (autapomorphy). The first of these is significant with reference to the phylogeny of calanoids. The type of female genital system in which a gonopore and a copulatory pore share a common slit is retained in the most primitive calanoid family Pseudocyclopidae (Huys & Boxshall, 1991; Haridas *et al*., 1994; Cuoc *et al*., 1997; Ohtsuka *et al*., 1999) and probably in the Boholinidae. In the Arietellidae only *Scutogerulus* retains such a system (see Ohtsuka *et al*., 1994). This symplesiomorphy has previously been regarded as evidence of a close relationship between the Arietellidae and the Pseudocyclopidae by Andronov (1974), Park (1986) and Bradford-Grieve (2002).

The modified 'shield-shaped' setules are not found in other calanoids. The fine structure of the 'button setae' on the maxillae and maxillipeds of the carnivorous arietelloidean family Augaptilidae, in particular the genus *Euaugaptilus*, has been examined by Boxshall (1985) and Matsuura & Nishida (2000). They concluded from a functional morphological point of view that these unique structures may function as shock absorbers during prey capture. The 'shield' shape of the maxillae and maxillipeds of *Scutogerulus* is superficially similar to the 'disc' shape on the setae of *Euaugaptilus*. However, these structures differ remarkably in: (1) the 'shield' is crescent-shaped in *Scutogerulus* (see Fig. 2D–G), while the 'disc' is semicircular or circular in *Euaugaptilus* (see Matsuura & Nishida, 2000: their Fig. 2); (2) the 'shields' are arranged in a single row in *Scutogerulus*, whereas two rows of 'discs' arranged either side-by-side or alternately are present in *Euaugaptilus*; (3) each 'shield' is furnished with two supplementary plates beneath it (see Fig. 2F), which are absent in *Euaugaptilus*; (4) the 'stalk' connecting the 'shield' to a seta is lamellar in *Scutogerulus*, but columnar in *Euaugaptilus* (see Matsuura & Nishida, 2000: their Figs 3, 4); (5) the 'shield' is positioned obliquely to the seta, while the 'disc' is parallel to it; (6) the outer surface of 'shield' is wrinkled (this may have been an artefact caused during SEM processing) in *Scutogerulus* but smooth in *Euaugaptilus*. Since the internal structure of the 'shield' has not yet been examined, its function cannot be addressed in detail.

The genus *Scutogerulus* appears to be carnivorous based on gut contents containing copepod fragments (present study) as in other arietellid genera (Ohtsuka & Mitsuzumi, 1990; Ohtsuka *et al*., 1991, 1994). Shallow-water arietellid genera such as *Paramisophria* Scott, 1897 and *Metacalanus* Cleve, 1901 bear relatively simple spinulose setae on the maxillae and maxillipeds, while deep-sea forms such as *Arietellus* Giesbrecht, 1892 and *Scutogerulus* carry specialized setae on these feeding appendages (Ohtsuka *et al*., 1994; present study). This seems to be an adaptive strategy of calanoids in the oligotrophic deep-sea environment: efficient capture on prey and/or some kind of specialised feeding. This hypothesis is supported by a fact that only oceanic carnivorous calanoid families such as Augaptilidae (Boxshall, 1985; Matsuura & Nishida, 2000) and Candaciidae (Ohtsuka & Onbé, 1989) bear exclusively specialised structures on setae on the maxillae and/or maxillipeds.

Acknowledgements

Thanks are due to the captain and crew of the TRV Toyoshiomaru, Hiroshima University for their cooperation at sea. This work was supported in part by a grant-in-aid from the Japan Society for the Promotion of Science awarded to SO (No. 1456151).

References

Andronov, V.N. 1974. Phylogenetic relation of large taxa within the suborder Calanoida (Crustacea, Copepoda). *Zoologicheskii Zhurnal* **53**, 1002–1012. [In Russian with English abstract]

Barthélémy, R., Ohtsuka, S. & Cuoc, C. 1998. Description and female genital structures of a new species of the demersal calanoid copepod *Ridgewayia* from southern Japan. *Journal of Natural History* **32**, 1303–1318.

Boxshall, G.A. 1985. The comparative anatomy of two copepods, a predatory calanoid and a particle-feeding mormonilloid. *Philosophical Transactions of the Royal Society of London* (Series B) **311**, 303–377.

Bradford, J. 1969. New genera and species of benthic calanoid copepods from the New Zealand slope. *New Zealand Journal of Marine and Freshwater Research* **3**, 473–505.

Bradford-Grieve, J.M. 2002. Colonization of the pelagic realm by calanoid copepods. *Hydrobiologia* **485**, 223–244.

Cuoc, C., Defaye, D., Brunet, M., Notonier, R. & Mazza, J. 1997. Female genital structures of Metridinidae (Copepoda: Calanoida). *Marine Biology* **129**, 651–665.

GRIMES, B.H. & BRADBURY, P.C. 1992. The biology of *Vampyrophyra pelagica* (Chatton & Lwoff, 1930), a histophagous aspostome ciliate associated with marine calanoid copepods. *Journal of Protozoology* **39**, 65–79.

HARIDAS, P., MADHUPRATAP, M. & OHTSUKA, S. 1994. *Pseudocyclops lakshmi*, a new species (Pseudocyclopidae: Calanoida: Copepoda) from the Laccadives, India. *Proceedings of the Biological Society of Washington* **107**, 151–163.

HUYS, R. & BOXSHALL, G.A. 1991. *Copepod Evolution*. 468 pp. The Ray Society, London.

MATSUURA, H. & NISHIDA, S. 2000. Fine structure of the "button setae" in the deep-sea pelagic copepods of the genus *Euaugaptilus* (Calanoida: Augaptilidae). *Marine Biology* **137**, 339–345.

OHTSUKA, S., BOXSHALL, G.A. & FOSSHAGEN, A. 2003. A new species of *Neoscolecithrix* (Crustacea; Copepoda; Calanoida) from off Okinawa, southwestern Japan, with comments on the generic position in the superfamily Clausocalanoidea. *Bulletin of the National Science Museum, Tokyo* (Series A) **29**, 53–63.

OHTSUKA, S., BOXSHALL, G.A. & ROE, H.S.J. 1994. Phylogenetic relationships between arietellid genera (Copepoda: Calanoida), with establishment of three new genera. *Bulletin of the Natural History Museum* (Zoology Series) **60**, 105–172.

OHTSUKA, S., FOSSHAGEN, A. & GO, A. 1991. The hyperbenthic calanoid copepod *Paramisophria* from Okinawa, South Japan. *Zoological Science* **8**, 287–306.

OHTSUKA, S., FOSSHAGEN, A. & PUTCHAKARN, S. 1999. Three new species of the demersal calanoid copepod *Pseudocyclops* from Phuket, Thailand. *Plankton Biology and Ecology* **46**, 132–147.

OHTSUKA, S., FOSSHAGEN, A. & SOH, H.Y. 1996. Three new species of the demersal calanoid copepod *Placocalanus* (Ridgewayiidae) from Okinawa, southwestern Japan. *Sarsia* **81**, 247–263.

OHTSUKA, S. & MITSUZUMI, C. 1990. A new asymmetrical near-bottom calanoid copepod, *Paramisophria platysoma*, with observations of its integumental organs, behavior and in-situ feeding habit. *Bulletin of the Plankton Society of Japan* **36**, 87–101.

OHTSUKA, S., NISHIDA, S. & NAKAGUCHI, K. 2002. Three new species of the genus *Macandrewella* (Copepoda: Calanoida: Scolecitrichidae) from the Pacific Ocean, with notes on distribution and feeding habits. *Journal of Natural History* **3**, 531–564.

OHTSUKA, S. & ONBÉ, T. 1989. Evidence of selective feeding on larvaceans by the pelagic copepod *Candacia bipinnata* (Calanoida: Candaciidae). *Journal of Plankton Research* **11**, 869–872.

PARK, T.S. 1986. Phylogeny of calanoid copepods. *Syllogeus* **58**, 191–196.

SEWELL, R.B.S. 1951. The epibionts and parasites of the planktonic Copepoda of the Arabian Sea. *Scientific Reports of John Murray Expedition* **9**, 255–394.

WALTER, T.C., OHTSUKA, S., PUTCHAKARN, S., PINKAEW, K. & CHULLASORN, S. 2002. Redescription of two species of *Pseudodiaptomus* from Asia and Australia (Crustacea: Copepoda: Calanoida: Pseudodiaptomidae) with discussion of the female genital structure and zoogeography of Indo-West Pacific species. *Proceedings of the Biological Society of Washington* **115**, 650–669.