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# A new genus of the Ridgewayiidae (Copepoda, Calanoida) from an anchialine cave in the Bahamas

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**Abstract**

*Exumellina bucculenta* gen. et sp. nov. was obtained in plankton in Norman's Pond Cave, Norman's Pond Cay, Exuma Cays, Bahamas. It shows some affinities to *Exumella* though differing much in mouthparts. The rostrum is a rounded plate with no filaments. The endopods of the mandible and maxillule are elongated and modified into thin and leaf-like structures furnished with weak setae. The 1st to 4th legs bear two outer spines on the third segment of the exopod. The exopods of the male 5th legs are modified, endopods only slightly transformed. The five genera in the Ridgewayiidae are recorded in a variety of environments such as plankton, hyperbenthos, and epibenthos. The structure of the 1st to 4th legs, and in particular the size of the outer spines of the exopods, differ greatly among the genera and seem to reflect their different habitats. © 1998 Elsevier Science B.V. All rights reserved.

*Keywords:* Copepoda; Calanoida; Anchialine caves; Bahamas

## 1. Introduction

Copepods belonging to the family Ridgewayiidae have mostly been obtained in shallow warm water in the vicinity of the bottom or on the bottom, and often in caves. At present, including the new genus to be described below, five genera are known.

The Ridgewayiidae show many primitive features of the antennules and the swimming legs, however, with great variations in the mouthparts. In common, all genera have distinctly modified 5th legs of the female with the last segment of exopod clearly set off from the middle of preceding segment.

*Ridgewayia* Thompson and A. Scott, 1903 includes 10 nominal species distributed in the Atlantic and Indo-Pacific regions (Ferrari, 1995). Recently, a new subspecies, *R. marki minorcaensis*, has been described by Razouls and Carola (1996) from the Mediterranean. Certain members of the genus have been observed in swarms in the vicinity of corals and actiniarians and an association is indicated (Humes and Smith, 1974).

*Exumella* Fosshagen, 1970 contains three species, two in the Caribbean region (Fosshagen, 1970; Grahame, 1979) and one from the Mediterranean (Jaume and Boxshall, 1995). *Exumella* is a raptorial and opportunistic feeder and was often taken in baited traps.

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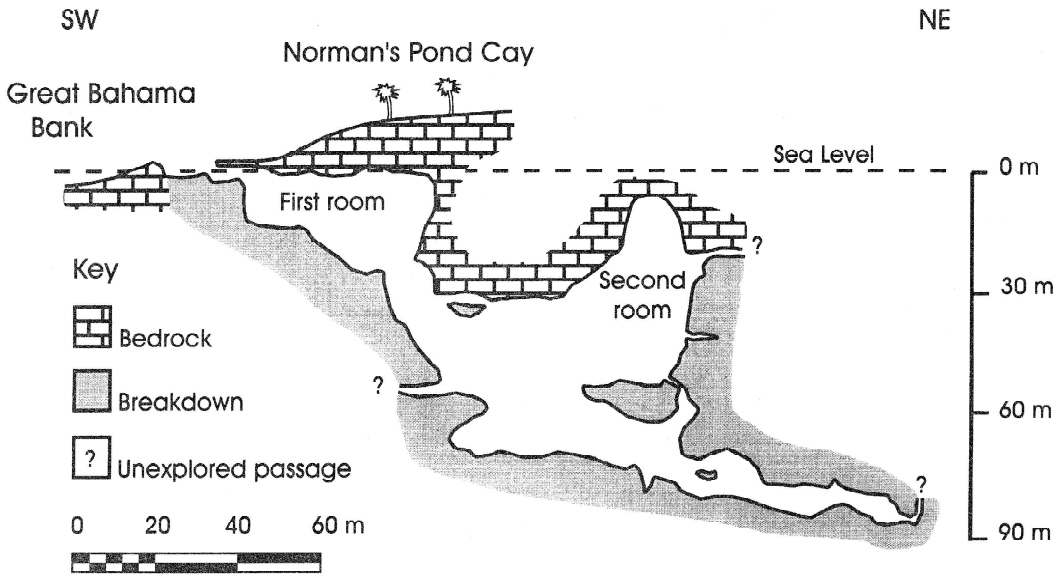



Fig. 1. Cross section of Norman's Pond Cave at Norman's Pond Cay, Exuma Cays, Bahamas.

*Placocalanus* Ohtsuka et al., 1996 includes five species, two from the Bahamas (Fosshagen, 1970) and three from Japan (Ohtsuka et al., 1996). The species have been obtained in soft sediments from shallow water down to 244 m depth in the Bahamas (A. Fosshagen, unpubl. data).

*Brattstromia* Fosshagen, 1991 is monotypic and was taken in two caves in Belize both in plankton and in baited traps (Fosshagen and Iliffe, 1991).

The new genus to be described below has only been obtained in plankton in one cave in the Bahamas and it shows some unique characters of the mouthparts.

## 2. Material and methods

The new genus was obtained only in Norman's Pond Cave, Norman's Pond Cay, Exuma Cays, Bahamas (Fig. 1). It was taken with a hand-held fine-meshed plankton net (90 μm) in the water column from five samples in the first room: 4 May 1993, 10–6 m, 25–10 m; 6 May 1993, 35–15 m; 14 May 1994, 15–12 m; and 18 May 1994, 18–10 m. Several hundred specimens were present altogether, only the sample from 4 May 1993 10–6 m contained a few specimens.

The type material is kept in The Natural History Museum, London.

The terminology used is that by Huys and Boxshall (1991).

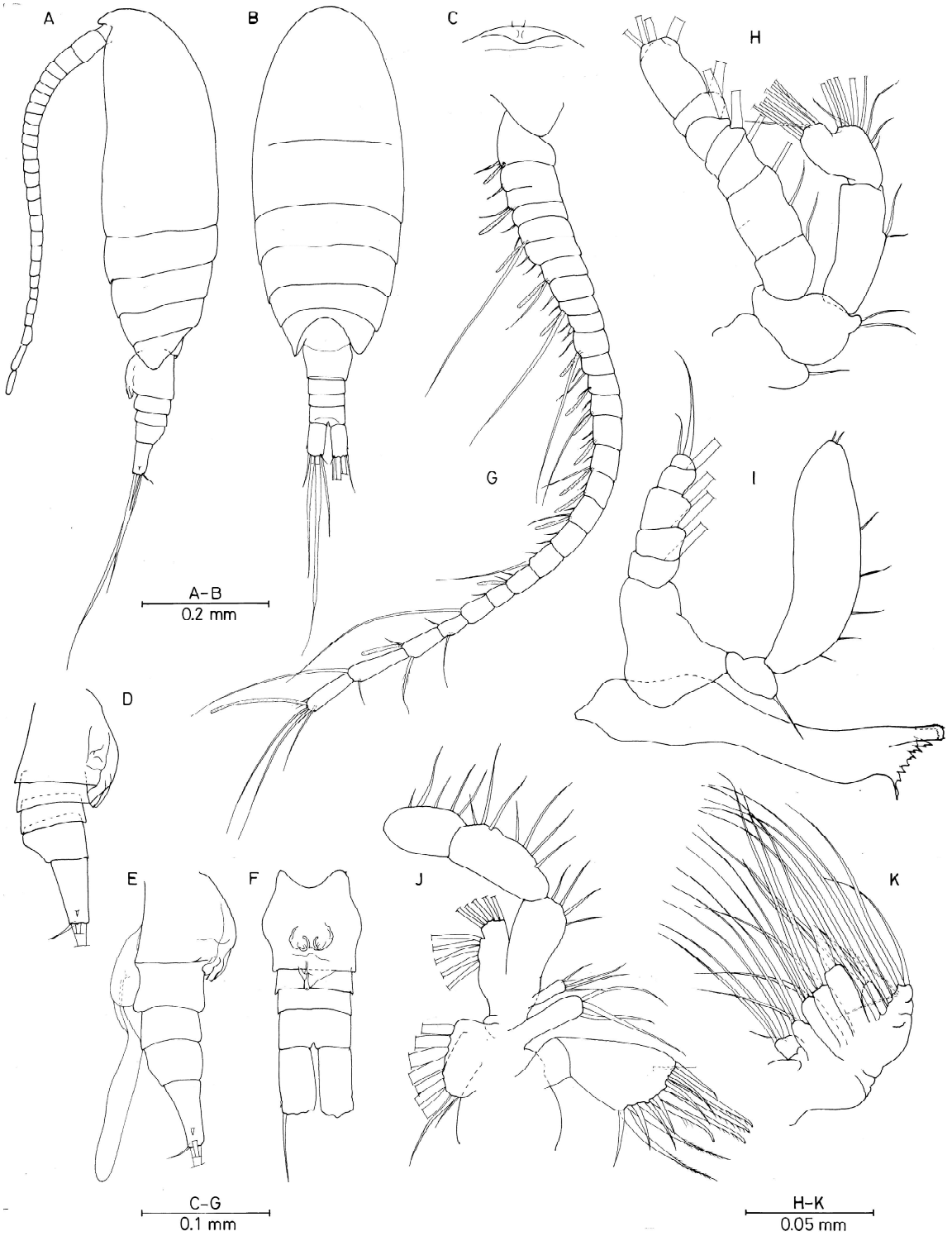
## 3. Taxonomic part

Family RIDGEWAYIIDAE M.S. Wilson, 1958

*EXUMELLINA* Fosshagen, gen. nov.

*Diagnosis*: Rostrum a small rounded plate without filaments. Urosome 4-segmented in female and 5-segmented in male. Genital double somite with lobe-like extensions ventrally. Last segment of endopod of mandible a leaf-like structure bearing weak

Fig. 2. *Exumellina bucculenta* gen. et sp. nov. Female (paratypes). (A) Lateral view. (B) Dorsal view. (C) Rostrum and frontal part of head. (D) Urosome lateral view. (E) Urosome with spermatophore lateral view. (F) Urosome ventral view. (G) Antennule. (H) Antenna. (I) Mandible. (J) Maxillule. (K) Maxilla.


A
B
C
H
G
I
A–B
0.2 mm
D
E
F
J
K
C–G
0.1 mm
H–K
0.05 mm

setae. Endopod of maxillule greatly elongated and thin. Legs 1–4 with two outer spines on last segment of exopod. Leg 5 of male with modified exopods; endopods only slightly modified. Gender feminine.

*Type species*: *Exumellina bucculenta* Fosshagen, sp. nov., by monotypy.

*Exumellina bucculenta* fits well into the Ridgewayiidae on account of the distinctly modified 5th legs of the females. Unique characters of the species are the ventral extensions of the genital double somite, the enlarged and modified endopods of the mandible and maxillule, the presence of only two outer spines of the last exopodal segment of the 2nd to 4th swimming legs, and the 5th legs of the male. These characters clearly justify the erection of a new genus.

***Exumellina bucculenta*** Fosshagen sp. nov.

*Material examined*: The species was obtained at Norman's Pond Cave, Exuma Cays, Bahamas on several occasions. Specimens from 18 May 1994, 18–10 m depth, were used for descriptions and as type material.

*Holotype*: Adult female, total length 0.74 mm from Norman's Pond Cave 18 May 1994 taken at a depth of 18–10 m. One vial deposited in BM(NH) Cat. No. 1997.218.

*Paratypes*: Twenty females and 20 males in 1 vial, and 2 females and 2 males dissected on 9 slides from the same sample as the holotype. Deposited in BM(NH) Cat. Nos. 1997.219–258.

*Etymology*: The generic name is derived from the group of islands, the Exumas, with the diminutive suffix -ina. The specific name comes from *bucculentus* L.—a large mouth.

*Adult female* (Figs. 2 and 3A–F): Total length of 17 individuals from Norman's Pond Cave 18 May 1994 ranged between 0.69 and 0.77 mm, mean 0.74 mm. In dorsal view prosome oval, about 3.2 times the length of urosome (Fig. 2A, B). Cephalosome separated from first pedigerous somite only by a weak dorsal suture. Rostrum (Fig. 2C) small and rounded. Lappet of fifth pedigerous somite tapering backwards to about middle of genital double somite. Genital double somite (Fig. 2D–F) with a lateral swelling in its middle and ventral irregular lappets extending slightly beyond next somite. One specimen with a spermatophore attached dorsally on urosome, covering parts of genital and first postgenital somites (Fig. 2E). Caudal rami about twice as long as wide and with six elements, one being a small posterolateral outer spine. Terminal longest seta tapers abruptly and ends in a thin flexible part.

Antennule (Fig. 2G) 27-segmented with segments II and III partially separated, extending backward to end of genital double somite. Particularly long setae present on segments V, IX, XI, XIV, XX, XII, XVI, and on terminal segment.

Antenna (Fig. 2H) with exopod about 1.5 times longer than endopod. Exopod 7-segmented with 11 setae; two proximal setae small. Endopod 2-segmented and compressed with last segment having distinct inner lobe bearing 9 setae.

Mandible (Fig. 2I) with well-developed cutting blade bearing pointed teeth along most of its margin, except for two broad and distally serrated teeth on outer margin. Basis of palp unarmed. Endopod 2-segmented about twice length of exopod. First segment with one inner seta, second transformed into an elongated, flattened thin structure bearing five small setae along inner margin and two small distal ones.

Maxillule (Fig. 2J) with slender praecoxal arthrite having 14 elements. Coxal endite and basal endites with 3 and 4 setae respectively. Exopod with 2 groups of setae, each with 5 setae. Endopod 2-segmented, extremely elongated into flattened and thin structure bearing 3 groups of 4, 3 and 5 small setae, respectively, on inner margin.

Maxilla (Fig. 2K) compressed, with indistinctly segmented terminal part. First praecoxal endite with 4 (5?) setae.

Maxilliped (Fig. 3A) strongly built. Second and third endopodal segments elongated with a few slightly modified setae; most conspicuous on each segment, one seta with a serrated tip. Terminal setae short and weak.

First leg (Fig. 3B) with curved seta on inner margin of basis. Exopod with outer spines of equal length; terminal element of last segment a strong seta. First segment of endopod with no extension on outer margin.

Second to 4th legs (Fig. 3C–E) bearing relatively short spines of equal length along outer margin of exopod; only two outer spines present on last segment of exopod. Minute seta present near outer margin of basis of 4th leg.

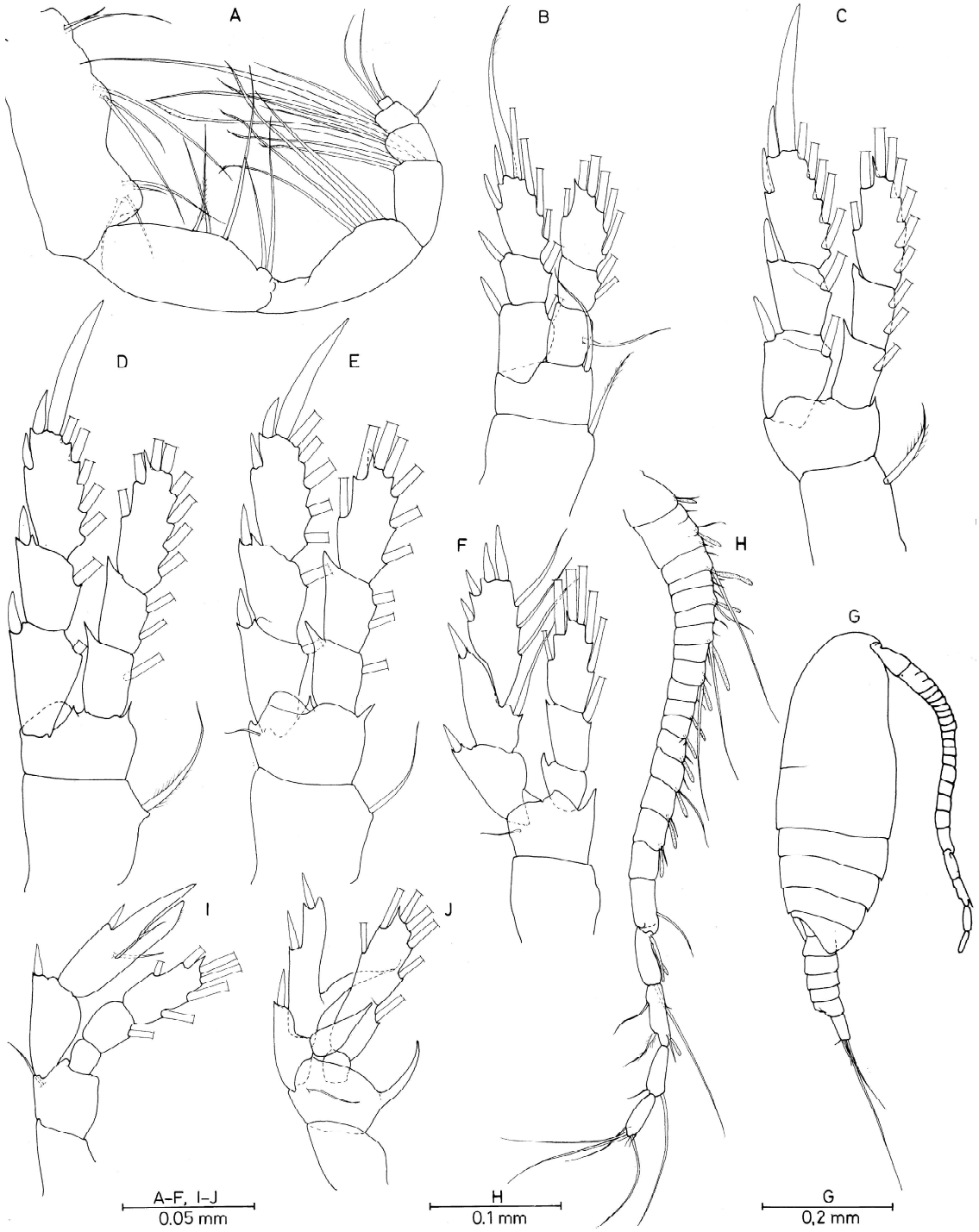



Fig. 3. *Exumellina bucculenta* gen. et sp. nov. (A–F) Female (paratypes). (G–J) Male (paratypes). (A) Maxilliped. (B) 1st leg. (C) 2nd leg. (D) 3rd leg. (E) 4th leg. (F) 5th leg. (G) Lateral view. (H) Right antennule. (I) Left 5th leg anterior view. (J) Right 5th leg posterior view.

Fifth leg (Fig. 3F) very similar to that of *Exumella*, however, with smaller outer spines on exopod, weaker seta on basis, and without inner seta on first segment of both exopod and endopod.

*Adult male* (Fig. 3G–J): Total length of 16 individuals from Norman's Pond Cave 18 May 1994 ranged between 0.61 and 0.69 mm, mean 0.63 mm. Differing from female in its 5-segmented urosome, geniculate right antennule, and in 5th leg.

Right antennule (Fig. 3H) 22-segmented with two partial divisions of segment 2. Segment 22 armed with stylet-like process and an aesthetasc distally on anterior margin.

Fifth legs with modified exopods, endopods only slightly modified. Both bases with an outer seta. Right leg (Fig. 3J): basis with strong curved and pointed process on its inner margin; exopod 2-segmented with three spines of equal length along outer margin, one distally on first segment and two on distal half of second segment. First segment with inner appendage-like pointed process, swollen basally. Second segment with inner proximal slender process, flexible at its tip. Endopod 2-segmented; first segment short and unarmed, second segment with 7 setae.

Left leg (Fig. 3I): exopod 2-segmented with two outer spines, one distally on first segment, other at midlength on second segment; second segment with two terminal processes, outer one, longer, gradually tapering to its pointed tip; other, more abruptly tapering and rounded at its tip bearing some marginal setules. Endopod 3-segmented; first segment unarmed, second with one seta, and third with 6 setae.

## 4. Remarks

The species was collected from an anchialine cave in the Exuma Islands. The Exuma Islands and Cays are situated along the eastern rim of the Great Bahama Bank bordering Exuma Sound, a steep-sided submarine valley reaching oceanic depths to more than 1800 m. Shallow waters covering the Great Bahama Bank have a surface area of more than 10,000 $km^2$. The islands, cays and hard grounds consist of Pleistocene limestone covered by a thin veneer of Holocene carbonate reefs and sediments. Underlying these younger limestones is a continuous section of Tertiary and Cretaceous limestones and dolomites exceeding 11,000 m in thickness.

Extensive anchialine and submarine cave systems are present along the margins of the platform (Sealey, 1994). The development of these caves may be related to joint systems in the Pleistocene bedrock. Viewed from the air, the deep blue colour of these sinkholes in contrast to the lighter bluish-green of the shallow bank has caused them to be named 'blue holes'. Water depths to nearly 100 m have been reported from some blue holes. Their considerable depth, combined with the presence of underwater stalactites and stalagmites which must have formed in air, suggest that these caves developed during Pleistocene glacial periods when sea level was at least 100 m lower than today.

One of the more notable blue holes in the Exumas is Norman's Pond Cave, located near the north end of Norman's Pond Cay (Fig. 1). The inland entrance to this cave is 2 m wide by 8 m long sinkhole within 2 m of high tide line. The cave consists of a collapse-floored fissure up to 8 m wide that trends under the island, toward the open waters of the Exuma Sound. The explored horizontal extent of this cave is more than 200 m, while water depths to 86 m have been reported (Dill et al., 1990; B. Kakuk, pers. commun.). Due to its close proximity to the coast, waters in the cave are fully marine (35–36 ppt) and fluctuate with the tides. The upper level of the cave is divided into two larger rooms separated by a narrow chasm at 35 m depth.

Specimens of *Exumellina bucculenta* were collected in the water column in the first room primarily from 10 down to ca. 30 m depth. On two occasions samples were taken in the second room—15 May 1994 43–30 m and 18 May 1994 32–30 m—however, no specimens of the new species were obtained. A water column profile of salinity, temperature and dissolved oxygen down to ca. 80 m depth was obtained on 10 September 1996 using a diver-carried Hydrolab multiprobe. This profile showed a considerable change in water properties at ca. 20 m depth. Below this depth the dissolved oxygen was constant at ca. 0.2 mg/l down to bottom and the temperature was ca. 26°C. Although there were no water samples from the time when the copepods were caught this may indicate that the copepods

were living in the well-oxygenated water above ca. 20 m depth.

Another abundant calanoid copepod together with *E. bucculenta* was a *Miostephos* species. In addition to copepods, thermosbaenaceans, cumaceans, tanaidaceans, amphipods, halocyprid ostracods, and remipedes have been collected from this cave.

## 5. Discussion

The structure of the mouthparts may indicate some special way of feeding and swimming. The very delicate mandibular and maxillular endopods, in many specimens either broken off or twisted, may suggest a food item that is soft or flimsy. The mandibular gnathobase with its pointed teeth seems to have a piercing function rather than a crushing one. In most calanoids the endopod of the maxillule is compressed and densely setose. In *E. bucculenta* it is elongated and with setae in three groups, pointing to the ancestral 3-segmented condition of the endopod. The two groups of setae in the exopod of the maxillule in this species and in *Brattstromia longicaudata* may be indicative of a 2-segmented ancestral condition of this ramus.

The strong and elongated maxilliped is reminiscent of that of *Brattstromia*, also with modified setae on 2nd and 3rd segments of endopod, though with slightly different tips.

*E. bucculenta* was caught in plankton and exhibits characters which are considered adaptations to a life in the free water masses. Its body is slender and transparent, some mouthparts are very thin and brittle, and the outer spines of the exopods of swimming legs are relatively small.

The other extreme in the family is represented by the benthic *Placocalanus* with its compressed body, short and modified antennule, rather unmodified mouthparts, but with several modifications of the legs. *Placocalanus* has highly modified 1st legs and outer spines on the exopod of 1st to 4th legs of varying size and length while *Exumellina* has an unmodified 1st leg and spines of the legs of a uniform size.

On the basis of the habitat and the legs, *Brattstromia*, *Ridgewayia* and *Exumella* seem to occupy an epibenthic environment and show modifications of the legs in an intermediate position between *Placocalanus* and *Exumellina* (Table 1). In such varied biotopes a different food supply will evidently be available and accordingly their mouthparts may differ.

*Exumella* and *Exumellina* with the most pronounced modifications of the mandible have sharp and pointed teeth on the gnathobase of which the two outer ones are deeply incised and with a broad and serrated tip. These two genera in addition to *Brattstromia* have powerfully developed maxillipeds with differently modified setae on the endopod. The conditions of the mandible and maxilliped point to raptorial habits of the three genera while *Ridgewayia* and *Placocalanus* have less modifications of the mouthparts and are thus in line with most calanoids.

The female 5th legs in ridgewayiids have very much the same structure throughout the five genera, with the characteristic 3-segmented exopod and an 1- to 3-segmented endopod.

Table 1
Main habitats of the Ridgewayiidae and distinguishing features of legs 1–4

| | *Placocalanus* | *Brattstromia* | *Ridgewayia* | *Exumella* | *Exumellina* |
|---|---|---|---|---|---|
| Habitat | Epibenthos | Caves | Hyper- or epibenthos. Occasionally in caves | Hyper- or epibenthos. Occasionally in caves | Plankton in caves |
| First leg | Highly modified | Process on basis. Modified exopod and endopod | Modified exopod and endopod | Modified endopod | No particular modification |
| Outer spines of exopod legs 1–4 | Different shapes. Unequal length | Unequal length | Unequal length | Unequal length | Equal length. Reduced number |

The male 5th legs are modified and differ much from one genus to another. In particular the exopods are transformed and sometimes of a very complex structure. The endopods are always present and may vary from being an unmodified 3-segmented ramus to a reduced unsegmented and unarmed appendage. The least modified rami of the males are present in *Exumella* and *Exumellina* where the apex of left exopod has become somewhat transformed.

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