ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/233224855

A new species of cave-living calanoid copepod from Grand Bahama

Article *in* Sarsia North Atlantic Marine Science · October 2004

DOI: 10.1080/00364820410002613

CITATIONS
5

READS
138

2 authors, including:

Thomas M Iliffe
Texas A&M University - Galveston
308 PUBLICATIONS **5,477** CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Studies on West Indian marine molluscs View project

A new insight into the Stygofauna Mundi: assembling a global dataset for aquatic fauna in subterranean environments. View project

All content following this page was uploaded by Thomas M Iliffe on 05 June 2014.

The user has requested enhancement of the downloaded file.

Published in collaboration with the University of Bergen and the Institute of Marine Research, Norway

A new species of cave-living calanoid copepod from Grand Bahama

Audun Fosshagen & Thomas M. Iliffe

SARSIA

Fosshagen A, Iliffe TM. 2004. A new species of cave-living calanoid copepod from Grand Bahama. *Sarsia* 89:346–354.

A new species of *Fosshagenia* Suárez-Morales & Iliffe, *F. suarezi*, is described from anchialine caves in Grand Bahama. It is compared with *F. ferrarii* Suárez-Morales & Iliffe which has been re-examined. The two species are considered closely related, mainly distinguished by the fifth legs of both sexes and by the genital double segment of the female. Owing to the close relationship of *Fosshagenia* to *Temoropia* T. Scott it is inferred that its ancestors may have invaded caves from plankton in deep water.

Audun Fosshagen, Department of Biology, University of Bergen, P.O. Box 7800, N-5020, Bergen, Norway.
E-mail: audun.fosshagen@bio.uib.no
Thomas M. Iliffe, Department of Marine Biology, Texas A&M University at Galveston, Galveston, TX 77553-1675, USA.
E-mail: iliffet@tamug.tamu.edu

Keywords: Calanoida; Fosshageniidae; taxonomy; anchialine caves; Bahamas.

INTRODUCTION

In recent years, several new taxa of calanoid copepods have been discovered from submerged marine caves around the world. Most of the material has been obtained by cave divers towing plankton nets, but some was taken in various traps. Among the most common, diverse and predominantly cave-living families are the Ridgewayiidae and Epacteriscidae, the first with eight known genera and the second with 17 genera (Fosshagen & al. 2001; Fosshagen & Iliffe 2003, 2004). These are among the most primitive calanoids and show features attributed to ancestral calanoids (Huys & Boxshall 1991), such as a 27-segmented antennule and all legs with three-segmented rami. Other families with species recorded from caves include the Arietellidae, Stephidae, Pseudocyclopidae and Pseudocyclopiidae (Boxshall & al. 1990; Ohtsuka & al. 1993; Jaume & al. 1999). One family, the Boholinidae, with two species, is exclusively restricted to one cave in the Philippines (Fosshagen & Iliffe 1989).

The Fosshageniidae is represented by *Fosshagenia* Suárez-Morales & Iliffe and *Temoropia* T. Scott (Boxshall & Halsey 2004); the first genus with one species, *F. ferrarii*, from a cave in the Caicos Islands (Suárez-Morales & Iliffe 1996) and the second genus with three species from plankton in deep oceanic waters (Schulz 1986).

Recently, a new species of *Fosshagenia* closely related to *F. ferrarii* was recorded from caves in Grand Bahama. This species is described below, together with a re-examination of *F. ferrarii* from its type locality, and a discussion on the taxonomic status of the genus.

MATERIAL AND METHODS

The new species was obtained from three caves on Sweetings Cay, Grand Bahama and *F. ferrarii* was re-collected from its type locality in Conch Bar Cave, Middle Caicos Island using advanced diving techniques and dragging a fine-mesh net (*Ca* 100 μm) through the water, or by using suction bottles.

The material is kept in the Natural History Museum (BMNH), London. The terminology used is that of Huys & Boxshall (1991).

SYSTEMATICS

Family Fosshageniidae Suárez-Morales & Iliffe, 1996

The family consists of the two genera *Fosshagenia* Suárez-Morales & Iliffe, 1996 and *Temoropia* T. Scott, 1894 and is included in the superfamily Diaptomoidea (Boxshall & Halsey 2004).

Genus Fosshagenia *emended*

Diagnosis

Female. Prosome with all pedigerous somites free. Rostrum blunt with no filaments. Urosome four-segmented, genital double-somite may be asymmetrical, caudal rami each with three terminal setae, middle seta on left side elongate, medially on inner margin

Taylor & Francis
Taylor & Francis Group

DOI 10.1080/00364820410002613 © 2004 Taylor & Francis

minute fourth seta. Antennule 23-segmented, well equipped with aesthetascs and with segment 8 (X and XI) not completely fused. Segments I–II and III–IV of antennary exopod fused into two double segments. Mouthparts generally unmodified with some reduction in number and size of setae on syncoxa of maxilliped. Leg 1 with two-segmented endopod. Legs 2–4 with identical spine and seta formula.

Spine and seta formula for legs 1–4:

	Coxa	Basis	Exopodal segments	Endopodal segments
Leg 1	0-1	0-0	I-1; I-1; II,1,4	0-1; 0,2,2
Legs 2–4	0-1	0-0	I-1; I-1; III,I,5	0-1; 0-1; 2,2,3

Leg 5 uniramous and three-segmented, middle segment with or without inner element, distal segment with strong spine in middle of inner margin and with terminal spine or spines.

Male. Differs from female in urosome, antennulae and leg 5. Urosome five-segmented with somites about equal in length. Right antennule geniculate and 18-segmented, weak proximal geniculation between segments 10 and 11 and distal geniculation between segments 14 and 15; some more aesthetascs than in female in proximal part of both antennulae. Leg 5 grasping organ with coxa and basis expressed; exopods elongate, right exopod three-segmented and rather simple, left exopod two- or three-segmented with bulbous terminal segment; endopods reduced, one- or two-segmented, tip digitiform or with long seta.

Type species: *Fosshagenia ferrarii* Suárez-Moralez & Iliffe, 1996.

Fosshagenia suarezi sp. nov. (Figs 1–4)

Etymology

The species is named after Dr Eduardo Suárez-Morales at ECOSUR, Chetumal, Quintana Roo, Mexico.

Material examined

Virgo Blue Hole, 2 December 2001: 23 females, 17 males and five copepodids from 15–21 m depth of large room. Sagittarius Blue Hole, 3 December 2001: one female and three copepodids from 18–25 m depth. Lucy's Cave, 4 December 2001: one female from 18–25 m depth.

Type

Holotype: Adult female, body length 0.64 mm, from Virgo Blue Hole, Sweetings Cay, Grand Bahama, 2 December 2001 from 15–21 m depth in large room. One vial BMNH reg. no. 2004.2503. Paratypes: two adult females and three adult males on six slides, five females and four males in one vial, all from same locality and date as holotype. BMNH reg. no. 2004.2504.

Description

Female. Body lengths of eight females ranging between 0.61 and 0.69 mm, with a mean of 0.64 mm. Rostrum blunt.

Urosome (Fig. 1A, B) four-segmented, about half length of prosome; genital double-somite largest, slightly expanded ventrally and laterally; other urosomites of about the same length. Caudal rami elongate with three terminal setae, middle seta on left ramus enlarged and twice the length of adjacent setae; medially on inner margin left ramus bears thin fourth seta directed backwards and in corresponding place on right ramus seta directed ventrally.

Antennule (Fig. 1C) 23-segmented, aesthetascs on most segments, reaching slightly beyond caudal rami. In proximal third of limb, some fusion of segments and loss of elements, including: segment 2 representing fused ancestral segments II–IV; aesthetascs lacking on segments 4 and 6; segment 8 representing partially fused ancestral segments X and XI, with two small setae on segment X and weak suture between segments near anterior margin; apical segment 23 representing ancestral segments XXVI–XXVIII.

Antenna (Fig. 1D) with endopod and exopod of about the same length. Coxa with one seta, basis and first endopod segment each with two unequal setae, second endopod segment with eight setae on inner lobe and seven setae on distal lobe. Exopod seven-segmented with nine setae along inner margin and three terminal ones, first and second segments double, each bearing two setae.

Mandible (Fig. 2A) with rather simple and short teeth on gnathobase. Basis with four inner setae; endopod two-segmented with four setae on first segment and 10 terminal setae on second segment. Exopod of usual shape; indistinctly segmented in middle part, with six setae in total.

Maxillule (Fig. 2B) rather well developed with 11 relatively weak setae on praecoxal arthrite; coxal endite, first and second endites with three, four and four setae, respectively. Endopod fused to basis, third segment expressed, segments 1–3 with two, two and five setae, respectively. Exopod bearing 11 setae.

Maxilla (Fig. 2C) with well-developed lobes carrying thin and plumose, mostly long and some medium-sized setae. First praecoxal lobe with five setae; second

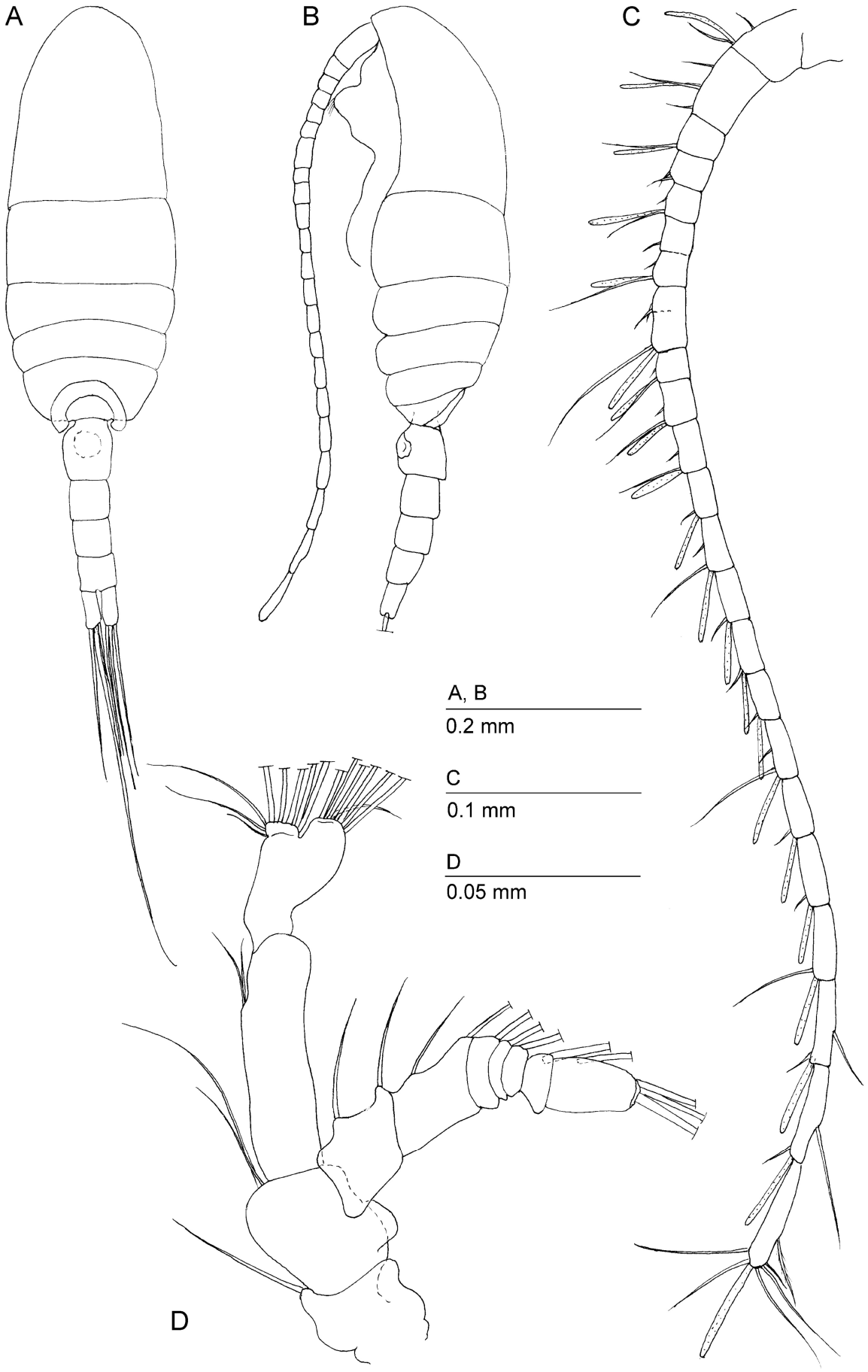

Fig. 1. *Fosshagenia suarezi* sp. n., female. A. Habitus, dorsal view. B. Habitus, lateral view. C. Antennule. D. Antenna.

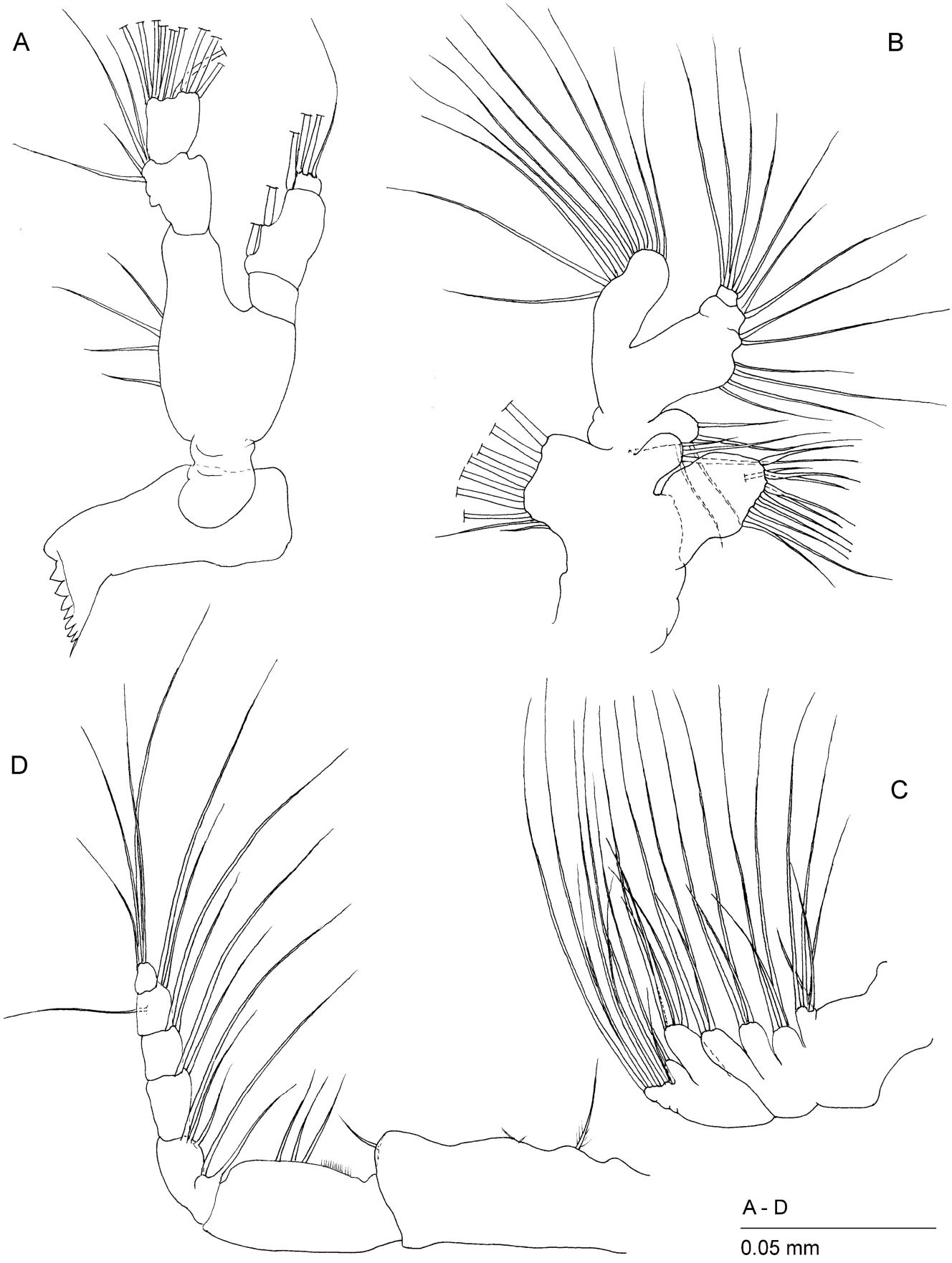

Fig. 2. *Fosshagenia suarezi* sp. n., female. A. Mandible. B. Maxillule. C. Maxilla. D. Maxilliped.

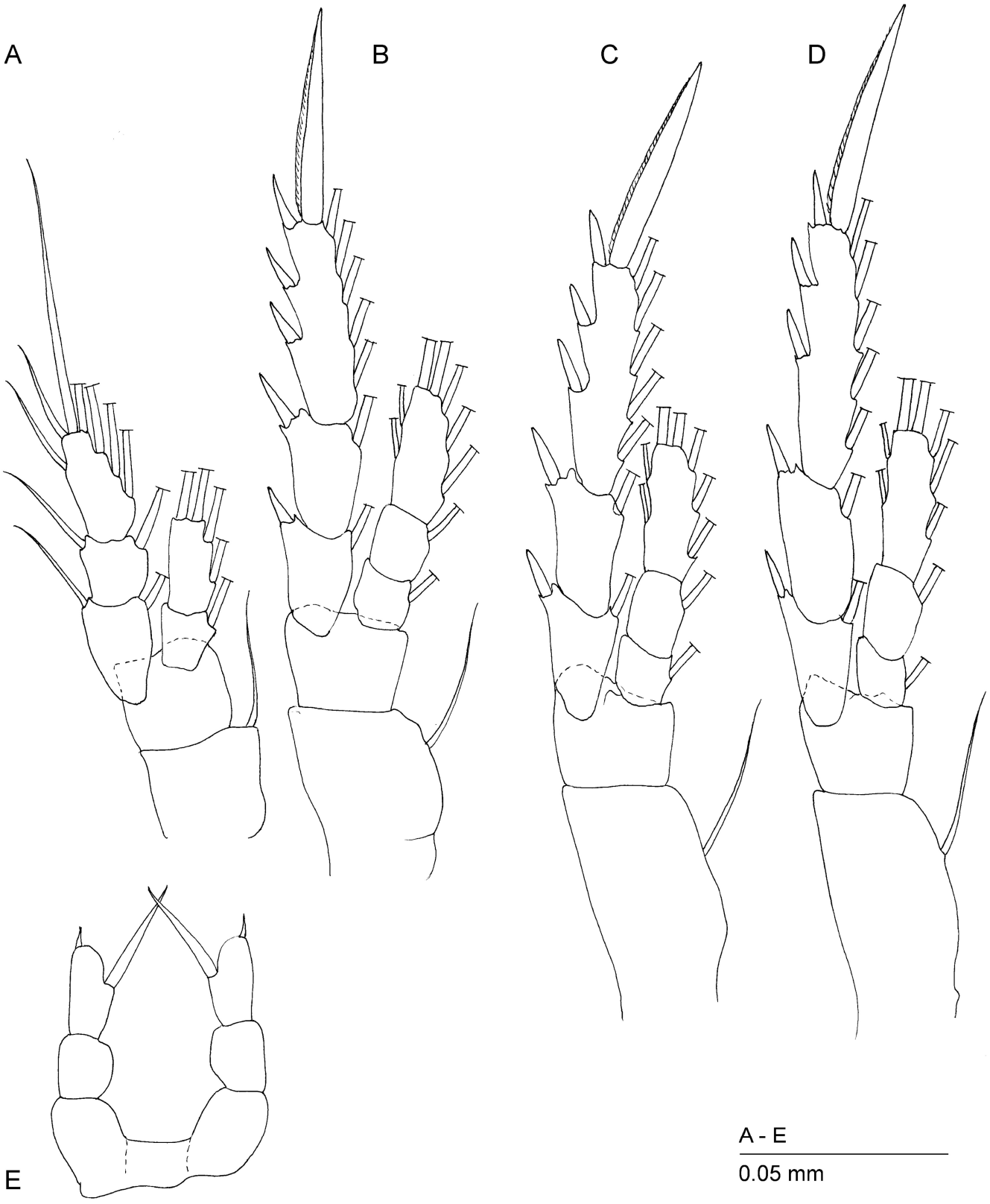

Fig. 3. *Fosshagenia suarezi* sp. n., female. A. Leg 1. B. Leg 2. C. Leg 3. D. Leg 4. E. Leg 5.

praecoxal lobe, first and second coxal lobes and basal endite with three, three, three and four setae, respectively. Endopod indistinctly segmented with eight setae.

Maxilliped (Fig. 2D) with reduced number of setae on syncoxa, well-developed long endopod with thin and plumose, mostly long setae. Syncoxa with one proximal

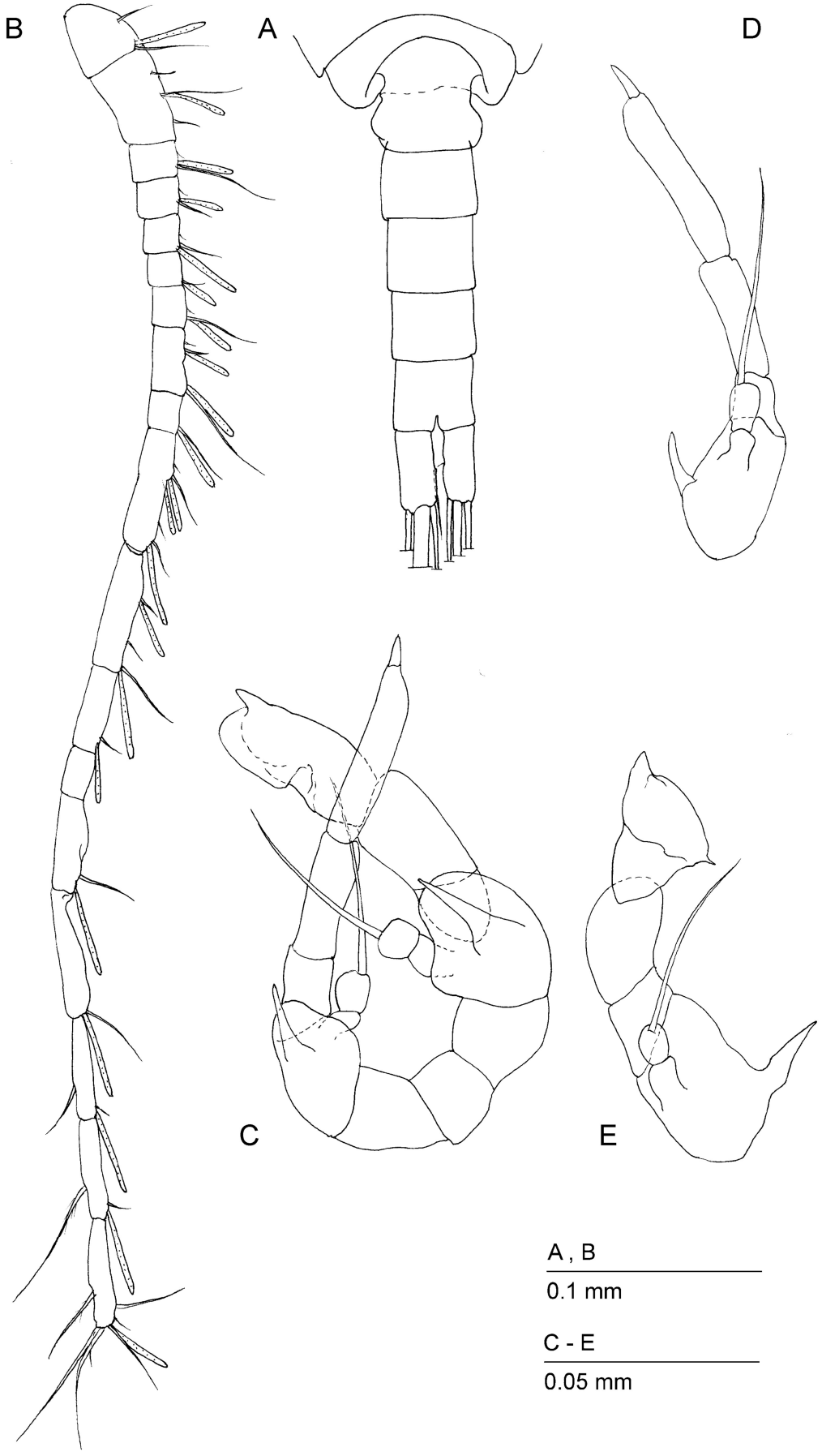

Fig. 4. *Fosshagenia suarezi* sp. n., male. A. Urosome, dorsal view. B. Right antennule. C. Leg 5, posterior view. D. Right leg 5, lateral view from inner side (coxa omitted). E. Left leg 5, lateral view from inner side (coxa omitted).

setose seta, two small setae medially and one on inner distal margin; basis with three equal setae medially. Endopod six-segmented with first segment partially fused with second segment and bearing two setae, second to sixth segments carrying three, two, two, three and four setae, respectively; fifth segment with relatively long outer seta.

Spine and seta formula for legs 1–4 as in diagnosis.

Leg 1 (Fig. 3A) with two-segmented endopod, long smooth and equally long outer spines with flexible tip on exopod.

Legs 2–4 (Fig. 3B–D) with same spine and seta formula, increasing gradually in length towards urosome, distal long spine on third exopodal segment with weakly serrated outer margin.

Leg 5 (Fig. 3E) uniramous, three-segmented and with strong inner medial and short distal spine on terminal segment.

Male. Body length of six males ranging between 0.61 and 0.65 mm, with a mean of 0.63 mm. Urosome (Fig. 4A) five-segmented with somites subequal in length; caudal rami as in female. Right antennule (Fig. 4B) 18-segmented; weak proximal geniculation between segments 10 and 11 representing ancestral segments XIII–XV and XVI–XVII, respectively; stronger distal geniculation between segments 14 and 15; left antennule segmented as in female but both antennulae differ from female in bearing one aesthetasc on segments 4 (VI) and 6 (VIII) and two on segment 8 (trithek on X).

Leg 5 (Fig. 4C) with unequal, strong and modified three-segmented exopods and equal, reduced simple two-segmented endopods with terminal long seta. Each basis with strong pointed process medially on posterior side; endopods fused to basis and with long seta on terminal segment. Right exopod (Fig. 4D) slender, with segments increasing in length from proximal to distal and ending in terminal stout spine; left exopod (Fig. 4E) irregular, last segment broad and bulbous with inner medial notch and rounded terminal part with outer process.

Ecological notes

Virgo Blue IIole on Sweetings Cay at the east end of Grand Bahama Island is part of the Zodiac Caverns, an underwater cave system discovered by Rob Palmer in 1983 (Palmer 1985). The entrance to Virgo Blue Hole is in a submerged depression along the shore of a shallow inland lake near the centre of Sweetings Cay. The low, silty entrance passage to the cave opens onto a series of large chambers, well decorated with stalactites and stalagmites, at 15–22 m depth. Calanoids collected in the cave were: *Brattstromia longicaudata* Fosshagen & Iliffe, 1991, previously only recorded from Belize (Fosshagen & Iliffe 1991), unidentified ridgewayiids and the epacteriscids *Balinella ornata* Fosshagen, Boxshall & Iliffe, 2001 only observed from Norman's Pond Cave, Exumas, and *Cryptonectes brachyceratus* Fosshagen & Iliffe, 2004. Also collected from this cave were halocyprid ostracods, cirolanid isopods, amphipods, thermosbaenaceans and remipedes.

The relatively high number of *F. suarezi* from plankton in Virgo Blue Hole, of a species with rather primitive and unmodified mouthparts, suggests suspension-feeding habits. This is supported by a gnathobase of the mandible armed with uniform and rather short teeth, and with the setae of the maxilla and maxilliped being plumose and unmodified.

Fosshagenia ferrarii Suárez-Morales & Iliffe, 1996

Material examined

Conch Bar Cave, 9 June 2003: 13 females, 18 males and six copepodids from 0.5–15 m depth (six females, eight males BMNH reg. no. 2004.2514), and one female and one male from the same cave in May 1991 (type material).

Because of observed discrepancies between the two species, *F. ferrarii* has been re-examined from its type locality. The major differences are in the sexual characters of the urosome and fifth legs; other characters are very similar in both species. Accordingly, *F. ferrarii* has a distinct dividing line between the cephalosome and first pedigerous somite. The urosome is four-segmented in the female and the left caudal ramus bears an elongate middle seta (not as drawn in Suárez-Morales & Iliffe 1996: fig. 3A). The antennule in the female is 23-segmented; the antenna bears a seven-segmented exopod; the mandible has four inner setae on the basis; the maxilla bears five setae on the first praecoxal lobe, and legs 2–4 have an inner seta on the first exopodal segment (armature formula not as in Suárez-Morales & Iliffe 1996).

Remarks

The two species are closely related. The best distinguishing characters are in the genital double-somite of the females with a dorsal lateral process on the left side in *F. ferrarii* and none in *F. suarezi*, and in the distinctive fifth legs of both sexes.

Suárez-Morales & Iliffe (1996) suggested a new family and superfamily for *F. ferrarii*, mainly based on the scheme by Andronov (1974). We follow the suggestions by Boxshall & Halsey (2004) and include

Fosshagenia and *Temoropia* in the family Fosshageniidae within the superfamily Diaptomoidea.

Suárez-Morales & Iliffe (1996) state that *F. ferrarii* diverge from the Diaptomoidea in having less than three segments on endopod leg 1, antennular segment 8 consists of fused segments X and XI, the middle endopodal segment of legs 3 and 4 has one seta, and the distal endopodal segment of legs 3 and 4 has seven setae. However, there are several families within the Diaptomoidea, e.g. Diaptomidae, Pontellidae, Temoridae and Tortanidae, in which species have less than three segments on endopod leg 1. Fusion or not between segments X and XI seems to be a rather labile character. As pointed out by Bowman (1978), there are different states of partial fusion and sutures between the two segments within Diaptomoidea, as well as among Clausocalanoidea and Calanoidea.

One seta on the middle endopodal segment of legs 3 and 4 is present among the Temoridae. However, in some genera of the family, the endopods are fused into one or two segments; seven setae on the terminal endopodal segment of legs 3 and 4 are found among species in the Diaptomidae, Sulcanidae, Acartiidae and Tortanidae in Diaptomoidea (Andronov 1974). Thus, some of the characters mentioned by Suárez-Morales & Iliffe (1996) as unique for *Fosshagenia* are present in Diaptomoidea.

The close resemblance between *Fosshagenia* and *Temoropia* was pointed out by Boxshall & Halsey (2004), mainly in the segmentation of the antenna with the two proximal segments each derived from two fused segments and in the two-segmented endopod of leg 1.

Temoropia has all segments of the prosome well defined; caudal rami with three setae, in *T. setosa* Schulz also the middle one on the left side is elongate; mouthparts generally unmodified; slight reductions in the number and size of setae on syncoxa of maxilliped; and bearing one seta on the middle endopodal segment of legs 2–4.

The main differences between the genera are the absence of rostral filaments in *Fosshagenia*, the not ventrally extended genital double-somite in the female of *Fosshagenia*, the lack of inner seta on the basis of leg 1 in *Fosshagenia*, seven setae on the third endopodal segment of legs 2–4 in *Fosshagenia* (five setae in *Temoropia* except for leg 4 in *T. minor* which has seven setae; Deevey 1972), and in legs 5, particularly in the male, where endopods are developed in *Fosshagenia* and apparently absent in *Temoropia*.

Temoropia T. Scott is a genus with a wide distribution (Deevey 1972; Schulz 1986). All three species have been obtained in deep-water plankton samples, two of them from the Sargasso Sea, with *T. mayumbaensis* T. Scott most abundant in the upper 500 m and *T. minor* Deevey predominantly between 500 and 1500 m depth.

A character which is conspicuous in *Fosshagenia* is the presence of well-developed aesthetascs on the antennule of both sexes, in addition some extra aesthetascs are present proximally in the male. The possession of abundant aesthetascs in females might be a troglobitic adaptation and is present in typical cave-living calanoid families like the Ridgewayiidae and Epacteriscidae (Fosshagen & al. 2001; Fosshagen & Iliffe 2003).

The appearance of *Fosshagenia*, with a transparent body, long antennule, unmodified mouthparts, and not particularly strong outer spines on swimming legs, suggests a planktonic existence in caves.

For the time being it seems most relevant to keep *Fosshagenia* as a cave-adapted genus belonging to the superfamily Diaptomoidea. It does not seem unlikely that some ancestral deep-water species closely related to *Temoropia* have invaded caves quite recently in geological terms and become established in an environment also characterized by darkness and scarcity of food.

ACKNOWLEDGEMENTS

We thank Dr T. Chad Walter at Smithsonian Institution, Washington DC for sending type material of *Fosshagenia ferrarii*. Dr Vladimir Andronov, P. P. Shirshov Institute of Oceanology RAS, Kaliningrad provided useful information. This research was supported by National Science Foundation, Biotic Surveys and Inventories Program award #9870219 to T. Iliffe. Cave divers Brian Kakuk and Paul Hobbs assisted with the collection of specimens from Virgo Blue Hole, while the captain and crew of the M/V *Ocean Explorer* provided essential logistical assistance. We thank Dan Malone, owner of the M/V *Ocean Explorer*, and Brian Kakuk, Director of the Bahama Caves Research Foundation, for inviting the junior author to participate in their Sweetings Cay expedition. Specimens described here were collected under marine resource collecting permits issued by the Bahamas Department of Fisheries to T. Iliffe and B. Kakuk. This paper is a contribution to DIVERSITAS-IBOY project "Exploration and Conservation of Anchialine Faunas".

REFERENCES

Andronov VN. 1974. Phylogenetic relation of the large taxa within the suborder Calanoida (Crustacea, Calanoida). *Zoologicheskii Zhurnal* 53:1002–1012. [in Russian, English summary].

Bowman TE. 1978. The modified suture between segments 8 and 9 on the first antenna of some calanoid copepods. *Crustaceana* 35:113–118.

Boxshall GA, Halsey SH. 2004. *An introduction to copepod diversity*. London: The Ray Society. 966 p.

Boxshall GA, Stock JH, Sanchez E. 1990. A new species of *Stephos* Scott, 1892 (Copepoda: Calanoida) from an anchihaline lava pool on Lanzarote, Canary Islands. *Stygologia* 5:33–41.

Deevey GB. 1972. A new species of *Temoropia* (Copepoda: Calanoida) from the Sargasso Sea. *Proceedings of the Biological Society of Washington* 84:359–370.

Fosshagen A, Boxshall GA, Iliffe TM. 2001. The Epacteriscidae, a cave-living family of calanoid copepods. *Sarsia* 86:245–318.

Fosshagen A, Iliffe TM. 1989. *Boholina*, a new genus (Copepoda: Calanoida) with two new species from an anchialine cave in the Philippines. *Sarsia* 74:201–208.

Fosshagen A, Iliffe TM. 1991. A new genus of calanoid copepod from an anchialine cave in Belize. *Bulletin of the Plankton Society of Japan.* Special Volume (1991):346–354.

Fosshagen A, Iliffe TM. 2003. Three new genera of the Ridgewayiidae (Copepoda, Calanoida) from anchialine caves in the Bahamas. *Sarsia* 88:16–35.

Fosshagen A, Iliffe TM. 2004. New epacteriscids (Copepoda, Calanoida) from anchialine caves in the Bahamas. *Sarsia* 89:117–136.

Huys R, Boxshall GA. 1991. *Copepod evolution*. London: The Ray Society 468 p.

Jaume D, Fosshagen A, Iliffe TM. 1999. New cave-dwelling pseudocyclopiids (Copepoda, Calanoida, Pseudocyclopiidae) from the Balearic, Canary, and Philippine archipelagos. *Sarsia* 84:391–417.

Ohtsuka S, Fosshagen A, Iliffe TM. 1993. Two new species of *Paramisophria* (Copepoda, Calanoida, Arietellidae) from anchialine caves on the Canary and Galapagos Islands. *Sarsia* 78:57–67.

Palmer RJ. 1985. The blue holes of eastern Grand Bahama. *Cave Science* 12:85–92.

Schulz K. 1986. *Temoropia setosa* sp. n. (Copepoda: Calanoida: Temoridae) aus dem Kanarenstromgebiet (Nordost-Atlantik) mit Anmerkungen zur Gattung *Temoropia* T. Scott. *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut* 83:139–146.

Suárez-Morales E, Iliffe TM. 1996. New superfamily of Calanoida (Copepoda) from an anchialine cave in the Bahamas. *Journal of Crustacean Biology* 16:754–762.

Accepted 13 July 2004 – Printed 1 October 2004
Editorial responsibility: Egil Karlsbakk

View publication stats