Zoosystematics and Evolution

92 (1) 2016

PENSOFT.

museum für naturkunde

ISSN 1435-1935 Zoosyst. Evol. 92 (1) 2016, 1–152

Zoosystematics and Evolution
A Bulletin of Zoology since 1898

Instructions for authors

Scope

Zoosystematics and Evolution (formerly Mitteilungen aus dem Museum für Naturkunde in Berlin, Zoologische Reihe) edited by the *Museum für Naturkunde, Leibniz Institute for Research on Evolution and Biodiversity at the Humboldt University Berlin* is an international, peer-reviewed, life science journal, devoted to whole-organism biology. It mainly publishes original research and review articles in the field of Metazoan taxonomy, biosystematics, evolution, morphology, development and biogeography at all taxonomic levels. Its scope encompasses primary information from collection-related research, viz. taxonomic descriptions and discoveries, revisions, annotated type catalogues, aspects of the history of science, and contributions on new methods and principles of systematics. Entomological papers will also be accepted for review, but authors should first consider submission to the Deutsche Entomologische Zeitschrift. Articles whose main topic is ecology, functional anatomy, physiology, or ethology are only acceptable when of clear systematic or evolutionary relevance and perspective. Review articles and contributions to a discussion forum are welcome, but authors are asked to contact the editors beforehand.

Authors and submission

- Conflicts of interest: Authors must disclose relevant compet- ing interests, both financial and personal.
- Ownership: Authors must declare that the submitted work is their own and that copyright has not been breached in seeking its publication.
- Originality: Authors must declare that the submitted work has not previously been published, and is not being consid- ered for publication elsewhere.

Language and style

- The language of publication is English. There is no general limitation of the length of manuscripts, but please contact the editor before submitting papers exceeding 30 printed pages (approximately 60 manuscript pages including figures).
- Manuscripts should be written in a clear, straightforward style and must not have been published or submitted elsewhere.
- The text should be 12 pt, double-spaced, one-sided, left justified and with a margin of at least 3 cm.
- Use a standard typeface, e.g. Times New Roman as little formatted as possible (without tabulators, several blank spaces, etc.). Avoid footnotes.
- Divide the text into sections using headlines and subheadlines. Do not number the headlines. Inline headers should be set in italics and followed by a full stop.
- The names of genera and species must be in italics.
- Taxonomic descriptions must comply with the rules of the 4th edition of the ICZN (see http://www.iczn.org/).
- Enter the page number on every page.
- Submit figures with a minimum resolution of 300 dpi.
- The preferred file formats are PSD (Photoshop) and TIFF for colour and grayscale illustrations, and EPS for vector graphics.
- JPG files are only accepted in high resolution.

General manuscript structure

If appropriate, the manuscript should be structured using headlines and sub-headlines, but without numbering, according to the following sections:

- Title page
- Abstract
- Introduction
- Materials and Methods
- Results
- Discussion
- Acknowledgements
- References
- Tables with captions
- Figure captions

The publication process

Peer reviewing

Manuscripts are subject to peer review. All manuscripts submitted will be reviewed by at least two experts. Authors are welcome to make suggestions for competent reviewers.

Proofs

Prior to publication of your manuscript you will receive proofs in PDF format. Please correct and return the proofs within two weeks to the editorial office.
We recommend using the standard proofreading marks or – in the case of a few corrections – using page and line numbers.
Do not change the contents of your article. Corrections extending beyond production errors will be carried out at the expense of the author.
The editorial office reserves the right to publish your article with only the editor‘s corrections, if your corrections do not reach us in time.

Publishing

The print and the online versions of your paper are published simultaneously. It is accessible in open access at Pensoft: http://zse.pensoft.net

COPE Membership

This journal endorses the COPE (Committee on Publication Ethics) guidelines and will pursue cases of suspected research and publication misconduct (e.g. falsification, unethical experimentation, plagiarism, inappropriate image manipulation, redundant publication). For further informa- tion about COPE, please see the website for COPE at http://www.publicationethics.org.uk

Zoosystematics and Evolution

92 (1) 2016

PENSOFT.

museum für naturkunde

Zoosystematics and Evolution
A Bulletin of Zoology since 1898

Editor-in-Chief

Managing Editor

Editorial Secretary

Editorial Board

Zoosystematics and Evolution

2016. Volume 92. 1 Issues

ISSN: 1435-1935 (print), 1860-0743 (online)
Abbreviated keys title: Zoosyst. Evol.

In Focus

The cover picture shows a live specimens of *Mantophryne insignis* sp. n. from Woodlark Island, Papua New Guinea.

See paper of **Günther & Richards** Description of a striking new *Mantophryne* species (Amphibia, Anura, Microhylidae) from Woodlark Island, Papua New Guinea

Cover design
Pensoft

Publisher

PENSOFT.

Zoosystematics and Evolution
A Bulletin of Zoology since 1898

Content of volume 92 (1) 2016

Abstract & Indexing Information

Biological Abstracts® (Thompson ISI)
BIOSIS Previews® (Thompson ISI)
Camgridge Scientific Abstracts (CSA/CIG)
Web of Science® (Thompson ISI)
Zoological Record™ (Thompson ISI)

Zoosyst. Evol. 92 (1) 2016, 1–12 | DOI 10.3897/zse.92.5581

PENSOFT. museum für naturkunde

Oahutanais makalii, a new genus and species of colletteid tanaidacean (Crustacea, Peracarida) from shelf-waters off Hawaii, with a taxonomic key

Andrés G. Morales-Núñez[1], Kim Larsen[2], William J. Cooke[3]

1 *NSF CREST Center for the Integrated Study of Coastal Ecosystem Processes and Dynamics in the Mid-Atlantic Region, Department of Natural Sciences, University of Maryland Eastern Shore, Princess Anne, MD 21853, USA*
2 *ENSPAC Department of Environmental, Social and Spatial Change, 11.2, Roskilde University Center. DK-4000 Roskilde, Denmark*
3 *Marine Environmental Research, Kailua. Hawaii, 96734; Ad hoc Faculty Biology Program, University of Hawaii at Manoa, HI 96822, USA*

http://zoobank.org/F8F8D8A7-BBD5-4A58-81EC-48DA1B09A88B

Corresponding author: *Andrés G. Morales-Núñez* (agmorales@umes.edu)

Received 3 July 2015
Accepted 5 October 2015
Published 8 January 2016

Academic editor:
Michael Ohl

Key Words

Tanaidacea
Colletteidae
Oahutanais makalii
new species
Pacific Ocean
taxonomy

Abstract

A new colletteid tanaidacean, *Oahutanais makalii* **gen. et sp. n.**, is described from Hawaiian coastal waters at depths ranging from 19 to 102 m. The new taxon is tentatively designated as a new genus, although it displays many features in common with the genus *Leptognathiella*. The new species is distinguished from the morphologically similar tanaidomorphans by having (1) a small body, less than 1.0 mm (reproductively active specimens), (2) a maxillule with two bifid spiniform setae; (3) a maxilliped palp article-2 with geniculate, finely pectinate spiniform seta on sub-distal inner margin, (4) a cheliped attachment ventrally via sclerite not connected to the carapace, and (5) the pereopods 1 to 6 with ischial seta shorter than the merus. A key to the five extant genera of Colletteidae in the North Pacific Ocean is presented herein.

Resumen

Un nuevo tanaidáceo, *Oahutanais makalii* **gen. et sp. n.**, es descrito de las aguas costeras Hawaianas a un rango de profundidad de 19 a 102. La nueva especie es tentativamente designada como un nuevo género, aunque presenta muchas características en común con el género *Leptognathiella*. La nueva especie puede ser distinguida de especies morfológicamente similares por tener (1) cuerpo pequeño, menor a un 1.0 mm (especímenes reproductivamente activos), (2) maxílula con dos setas espiniformes bífidas, (3) margen interno subdistal del segundo artejo del palpo del maxillípedo con una seta espiniforme doblada y finamente pectinada, (4) quelípedo adjunto ventralmente por medio del esclerito no conectado al caparazón, and (5) isquio de los pereiópodos 1 al 6 con una seta más corta que el mero. Una clave es presentada para separar los cinco géneros de la familia Colletteidae presentes en el norte del océano Pacífico.

Introduction

The Tanaidacean fauna from the Hawaiian Islands has received little attention so far. Recently, David and Heard (2015) described a new metapseudid, *Cryptapseudes lerory* David & Heard, 2015 from Niihau Island. They presented a detailed list on the current status of twelve species of tanaidaceans previously reported from the Hawaiian archipelago. A small, blind undescribed genus and species of tanaidacean belonging to the family Colletteidae Larsen & Wilson, 2002 was repeatedly collected throughout two decades of annual-US-EPA-mandated-benthic-community-monitoring at four Honolulu wastewater treatment plant outfalls (Fig. 1).

The family Colletteidae was erected during a phylogenetic revision of the superfamily Paratanaoidea Lang, 1949 to accommodate genera not assigned to any family, most being anarthurids (*sensu* Guţu and Sieg 1999) and leptognathiids: nevertheless, the systematic support for creating this family was admittedly weak (Larsen and Wilson 2002: 215) and incomplete (Larsen 2005; Bird and Larsen 2009). After thirteen years, the family currently holds 15 genera, which have been reported from the North and South Pacific Ocean, North and South Atlantic Ocean, Gulf of Mexico, Indian Ocean, Arctic Ocean and Antarctic Ocean (Table 1). The description of this new Hawaiian genus and species as well as an identification key to the five extant genera of Colletteidae in the North Pacific Ocean is presented here.

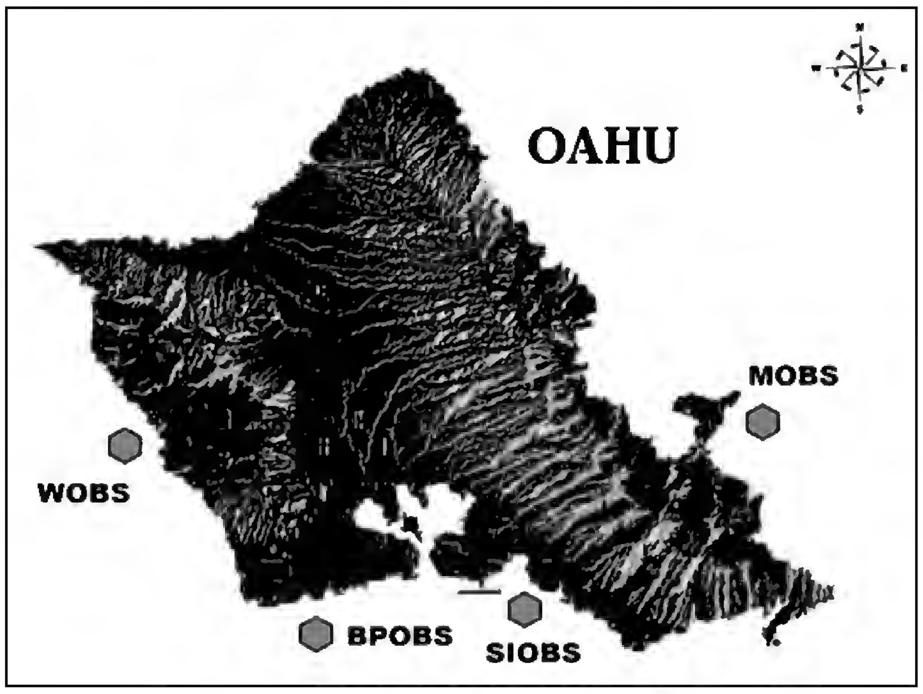


Figure 1. Map of study area, indicating the sampling stations where *Oahutanais makalii* gen. et sp. n., were found.

Table 1. Listing of the 16 currently recognized genera within the family Colletteidae, including information on distribution and depth range. NW = northwest; NE = northeast; SW = southwest; SE = southeast; and GoM = Gulf of Mexico.

Genus	Geographical area	Depth range (m)
Bascestus Błażewicz-Paszkowycz & Bamber, 2012	SW Pacific (Tasmania Sea)	37–49
Caudalonga Larsen, 2005	NW Atlantic (GoM)	625
Cetiopyge Larsen & Heard, 2002	NW Atlantic (GoM)	213–2060
Cheliasetosatanais Larsen & Araújo-Silva, 2014	North Equatorial Pacific	4259–4261
Collettea Lang, 1973	NW and North Equatorial Pacific; NE Atlantic and GoM; SW Indian Ocean; Artic and Antarctic Ocean	291–6142
Filitanais Kudinova-Pasternak, 1973	NW and NE Pacific; NW and SE Atlantic, and GoM; SE Indian Ocean; Artic and Antarctic Ocean	1070–6109
Haplocope Sars, 1882	NE Atlantic	22–1632
Isopodidus Larsen & Heard, 2002	NW Atlantic (GoM)	860–983
Leptognathiella Hansen, 1913	NE Atlantic	213–4822
Leptognathiopsis Holdich & Bird, 1986	NE Atlantic	22–5622
Macrinella Lang, 1971	NE Atlantic	1870
Nematotanais Bird & Holdich, 1985	NE Atlantic	1378–1510
Nippognathiopsis Błażewicz-Paszkowycz, Bamber & Jóźwiak, 2013	NW Pacific (Japan)	517–521
Oahutanais gen. n.	North Central Pacific (Hawaii)	19–102
Pseudoleptognathia Sieg, 1986	Artic Ocean	70–106
Subulella Holdich & Bird, 1986	Atlantic Ocean	12–2610

Materials and methods

Bulk sediment collections were made by divers or with benthic grabs, depending upon depth, sieved through 0.5 mm screens and preserved in 10% buffered formalin.

Specimens were dissected under an Olympus ZS-16 stereomicroscope. Appendages were mounted on glass slides in glycerine and observed with an Olympus BX41 microscope, and drawings were made with a camera Lucida. Additional material was examined under the Hitachi S-4800 Scanning Electron Microscope (SEM) at the Pacific Biosciences Research Center (PBRC) Biological Electron Microscope Facility (BEMF). Illustrations were prepared with Adobe Illustrator CS6 Extended.

Type material has been deposited in the National Museum of Natural History, Smithsonian Institution, Washington DC, (USNM), Gulf Coast Research Laboratory Museum, Ocean Springs, Mississippi MS, (GCRL), and the Bernice Pauahi Bishop Museum (BPBM), Honolulu Hawaii. All measurements are in millimetres (mm). Total body length (TL) is measured from the tip of the rostrum to the end or tip of the telson. Terminology used in this description follows that of Larsen (2003). In our description the total length of the dactylus includes the unguis.

Systematics

Order Tanaidacea Dana, 1849
Suborder Tanaidomorpha Sieg, 1980
Superfamily Paratanaoidea Lang, 1949
Family Colletteidae Larsen & Wilson, 2002

Oahutanais gen. n.

http://zoobank.org/14D4711E-DF66-4CFB-8530-437AA7F9F4AB

Generic diagnosis. *Female:* Small, 0.8–0.9 mm, slender body, parallel-sided. Carapace extending laterally to cover (dorsally) the cheliped attachments. Carapace not connected with the cheliped sclerites Pereonites wider than long. Antennule with four articles and minute terminal segment, shorter than carapace, article-2 with dorsal symmetric projection overlapping basal part of article-3, terminal segment minute and covered by article-4 (only visible with scanning electron microscope image). Antenna with six articles. Labium without distolateral spines. Maxillule with seven distal spiniform setae (two bifid); maxillipedal palp article-2 with geniculate, finely-pectinate spiniform seta on distal inner margin (serrations visible at magnification 100×). Cheliped attached via sclerite just anterior to the posterior margin of the cephalothorax, very close to the midventral line. Pereopods 1 to 6 attached ventrally. Pereopods 1–3 relatively slender; ischial seta shorter than merus. Pereopods 4–6 not stouter than pereopods 1–3; ischial setae shorter than merus. Pleopods absent in females. Uropods longer than pleotelson; basal article shorter than pleotelson, without distal apophyses; exopod uni-articulated, slightly longer than endopod article-1.

Male unknown.

Type species. *Oahutanais makalii* sp. n.

Etymology. Named after "O'ahu Island", where the material used in this study was collected, plus suffix - tanais.

Gender. Masculine.

Distribution. Hawaii Islands at depths ranging from 19 to 102 meters.

Remarks. The family Colletteidae has been considered as polyphyletic (Larsen and Wilson 2002; Błażewicz-Paszkowycz and Poore 2008; Błażewicz-Paszkowycz et al. 2013) and it is currently composed of 15 genera (WoRMS); unfortunately, most of the genera included within this diverse family need revision (e.g. *Leptognathiella* Hansen, 1913 and *Filitanais* Kudinova-Pasternak, 1973). The females of *Oahutanais* gen. n. can be identified by having a small body (less than 1 mm in length of reproductively active specimens), cheliped attached just anterior to the posterior margin of the cephalothorax, very close to the midventral line, not in contact with carapace lateral margin, and pereopods 1 to 6 attached ventrally. *Oahutanais* gen. n. appears to be most closely related to the genera, *Leptognathiella* Bird and Holdich, 1984 from the Atlantic or Gulf of México (Larsen 2005; Larsen et al. 2006), *Leptognathiopsis* Holdich & Bird, 1986 from the North Atlantic (Holdich and Bird 1986), and several species of *Leptognathia* G.O. Sars, 1882 *sensu stricto* (see Larsen and Shimomura 2007: 12) in having pereonites wider than long, pointed molars, females without pleopods (only in some species of *Leptognathiella* and *Leptognathia*), and uropod structure. However, the *Oahutanais* can be distinguished from the Atlantic species of *Leptognathiopsis* and *Leptognathiella* by having 1) the maxilliped palp article-2 with geniculate, finely pectinate spiniform seta on sub-distal margin, 2) pereopods 1–3 with basis slender, and 3) pereopod ischial setae shorter than merus.

The new genus also shows similarities with the monotypic genus *Nippognathiopsis* Błażewicz-Paszkowycz, Bamber & Jóźwiak, 2013, recently described from 517–1356 m in waters off Japan. However, *Oahutanais* can be differentiated by 1) its pereonites are wider than long, 2) the antennal article-1 is longer than the distal three articles and minute terminal segment combined (shorter in *Nippognathiopsis*), 3) the maxilliped endites have a medial small process (two oval tubercles in *Nippognathiopsis*), 4) the maxilliped palp article-2 has a geniculate, finely pectinate spiniform seta on the sub-distal margin, and 5) pereopods 1–6 are slender. Although the presence of the geniculate, finely pectinate spiniform seta in the maxilliped palp article-2 separates *Oahutanais* from the other genera within the family Colletteidae, it is possible that this spiniform seta has been overlooked in the original description of *Nippognathiopsis*, as well as in other colletteids due to their small overall size. Unfortunately, no information is available on the form of the cheliped attachment in *Nippognathiopsis*.

Bird and Larsen (2009) mentioned that this character, the cheliped-cephalothorax attachment position, is an important feature that has been overlooked or has not been recorded or illustrated by many authors, even today. So far within the family Colletteidae, only Błażewicz-Paszkowycz and Bamber (2012) and this study have included detailed information and illustrations showing the real point of insertion of the cheliped and how far it is located from pereonite-1. Thus, *Oahutanais* can be separated from *Bascestus* Błażewicz-Paszkowycz & Bamber, 2012 by having 1) the cheliped attached just anterior to the posterior margin of the cephalothorax (more anterior in *Bascestus*), 2) females without pleopods (pleopods present in *Bascestus*), and 3) exopod uni-articulated (bi-articulated in *Bascestus*).

The ventral cheliped attachment without contact with the carapace lateral margin (Fig. 8B–C) is an interesting and rare character among tanaidomorphans, and it has so far only been recorded from another colletteid, *Isopodidus* Larsen & Heard, 2002, but this highly modified genus differs in many other aspects from *Oahutanais*.

Oahutanais makalii sp. n.

http://zoobank.org/934BF56A-4CE7-40FE-B1DC-1F93E8EDD24B
Figures 2–8

Type material. *Holotype* Adult ♀, length 0.9 mm, (USMN 1283305), BPOBS Station (Stn) HB4-R1 (21° 16’47.7”N – 158° 01’38.1”W), depth 62 m, substrata: “predominantly fine and medium sand”, coll. by City and County of Honolulu Oceanographic Team, March 2013.

Paratypes. Four ♀♀ (USMN 1283306); four ♀♀ (GCRL 06534); and six ♀♀ (BPBM 2015.097; four on SEM stubs and two in alcohol), SIOBS Stn D3A (21° 16’55.3’’N – 157° 53’49.9’’W), depth 49 m, substrata “primarily coarse sediment including shell fragments”, coll. by City and County of Honolulu Oceanographic Team, October 2014. Additional specimens from the type locality are in the collection of the authors.

Other material examined. Thirteen ♀♀, one ovigerous ♀, two ♀♀ with remains of marsupium, SIOBS Stn D3A (21° 16’55.3’N – 157° 53’49.9’W), depth 49 m, substrata “primarily coarse sediment including shell fragments”, coll. by City and County of Honolulu Oceanographic Team, October 2014; 27 specimens (spec), MOBS Stn D (21° 25’ 32.3”N – 157° 42’ 53.6”W), depth 30 m, October 2013; two spec, SIOBS Stn C1A (21° 17’ 38.3”N – 157° 55’ 28.3”W), depth 19.2 m, October 2014; one spec, SIOBS Stn C5A (21° 16’ 53.9”N – 157° 51’ 25.4”W), depth 20.1 m, October 2014; two spec, SIOBS Stn D1 (21° 17’ 23.2”N – 157° 55’ 29.8”W), depth 49.1 m, October 2014; three spec, SIOBS Stn D2 (21° 16’ 55.2”N – 157° 54’ 36.3”W), depth 56.4 m, October 2014; 40 spec, SIOBS Stn D3A (21° 16’ 55.9”N – 157° 53’ 48.8”W), depth 50 m, October 2014; 16 spec, SIOBS Stn D5 (21° 16’ 36.8”N – 157° 51’ 33.9”W) depth 52.1 m, October 2014; eight spec, SIOBS – Stn D6 (21° 16’ 02.5”N – 157° 50’ 46.4”W) depth 50.0 m, October 2014; two spec, SIOBS Stn E1 (21° 17’ 09.5”N – 157° 55’ 32.2”W), depth 102.4 m, October 2014; 49 spec, SIOBS Stn E3 (21° 16’ 42.9”N – 157° 53’ 49.5”W), depth 84.4 m, October 2014; three spec, SIOBS Stn E5 (21° 16’ 22.5”N – 157° 51’ 40.3”W) 101.5 m, October 2014; four spec, SIOBS Stn E6 (21° 15’ 51.1”N – 157° 50’ 57.2”W) depth102.4 m, October 2014; 7 spec, WOBS Stn Z (21° 25’ 38.8”N – 158° 11’ 48.1”W) depth 29.3 m, October 2014.

Diagnosis. As the generic diagnosis above.

Etymology. The species name, *makali’i*, is Hawaiian for tiny or minute and reflects both where the material used in this study was collected and its small size relative to other tanaidaceans within this benthic community.

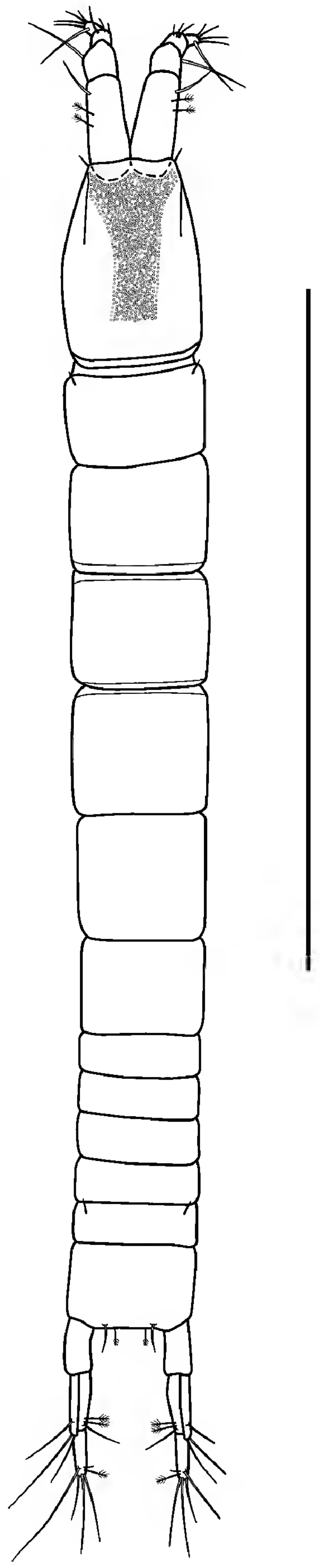


Figure 2. *Oahutanais makalii* gen. et sp. n., holotype female: dorsal view. Scale bar: 0.5 mm.

Type locality. Off Barbers Point Oahu, BPOBS study area (21° 16’47.7”N – 158° 01’38.1”W), Hawaii, May 2013.

Description. Based in holotype female, length 0.9 mm (USMN 1283305).).

Body (Fig. 2) length about 0.9 mm, about 8.6 times width.

Cephalothorax (Figs 2, 6A–B) about 15% of TL, slightly longer than first two pereonites combined, about 1.5 times longer than wide, oval shape (Fig. 6B); with distolateral seta. Eye-lobes absent.

Pereon (Fig. 2): about 60% of TL; pereonites 1–3 and 6 sub-rectangular, wider than long; pereonites 4–5 quadrate.

Pleon (Figs 2, 7A): about 20% of TL; combined length of pleonites 1 to 5 slightly shorter to that of pereonites 5 and 6 combined; all pleonites subequal, much wider than long; pereonite-1 with two simple setae distally.

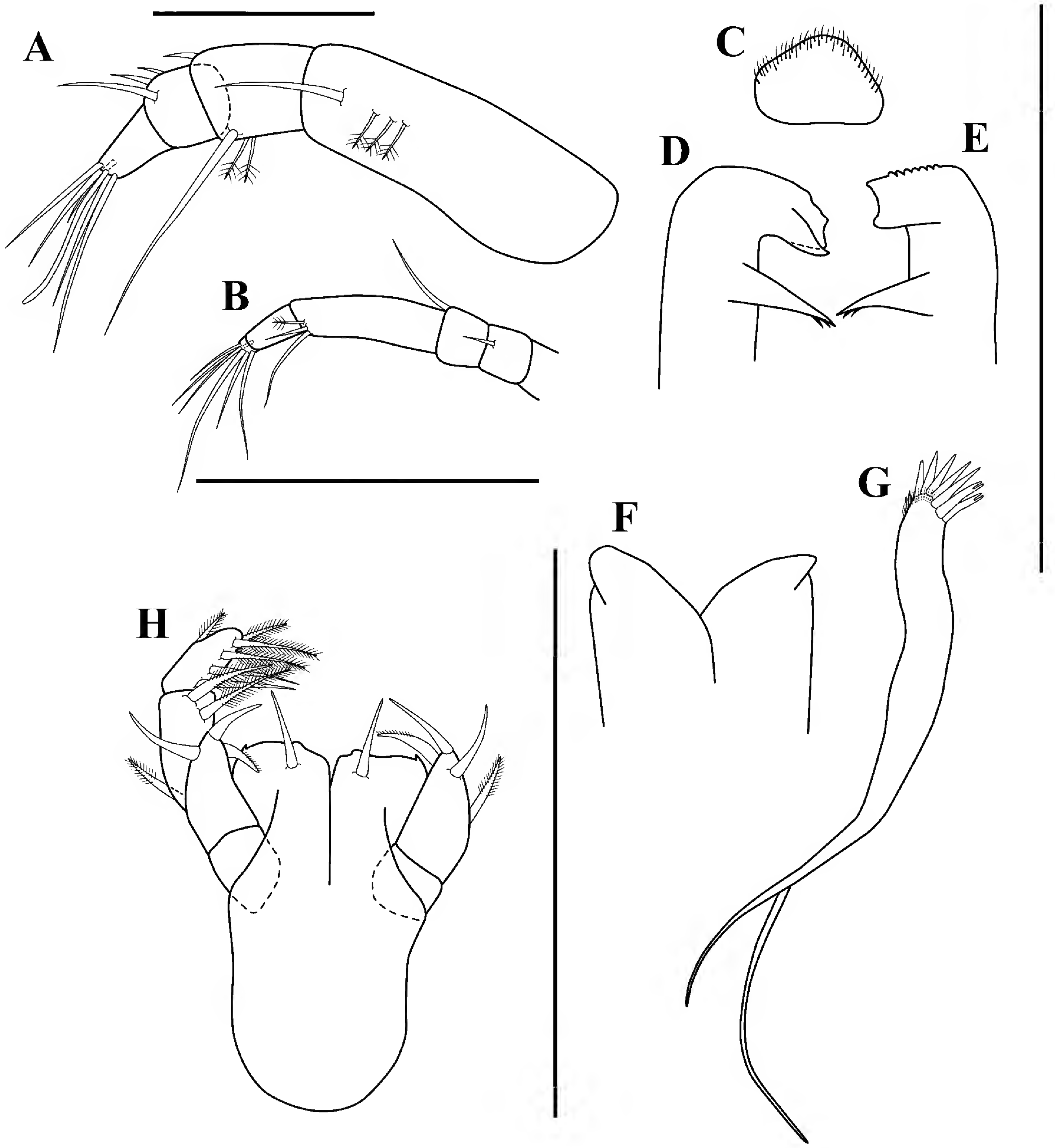


Figure 3. *Oahutanais makalii* gen. et sp. n., holotype female: **A** antennule, lateral view; **B** antenna, lateral view; **C** labrum; **D** left mandible; **E** right mandible; **F** labium; **G** maxillule; **H** maxilliped. Scale bars: 0.1 mm.

Pleotelson (Figs 2, 5B) about 5% of TL, same length of pleonites 5 and 6 combined; sub-rectangular, with two broom setae and two simple setae, apex blunt; pleonite-5 with two simple setae distally.

Antennule (Figs 3A, 6A–B): slightly longer than 2/3 length of cephalothorax. Article-1 about 3.1 times long than wide, longer than distal three articles, with three setulose setae and one simple seta along lateral margin. Article-2 about 1.1 times longer than wide, with distodorsal simple seta; with two setulose setae and one long (longer than articles 2 to 4 combined) simple seta on distoventral margin. Article-3 about 1.5 times wider than long, with two simple setae dorsally and one simple seta lateral. Article-4 about 1.4 times longer than wide, with four simple setae of different length. Terminal segment minute and covered by article-4, with one seta and one aesthetasc (only visible with SEM images) (Fig. 6B).

Antenna (Figs 3B, 6B): article-1 short, asetose. Article-2 about 1.2 times wider than long, with distolateral short seta. Article-3 about 1.3 times wider than long, with distodorsal long simple seta. Article-4 about 3.0 times longer than wide, longer than articles 2 and 3 combined,

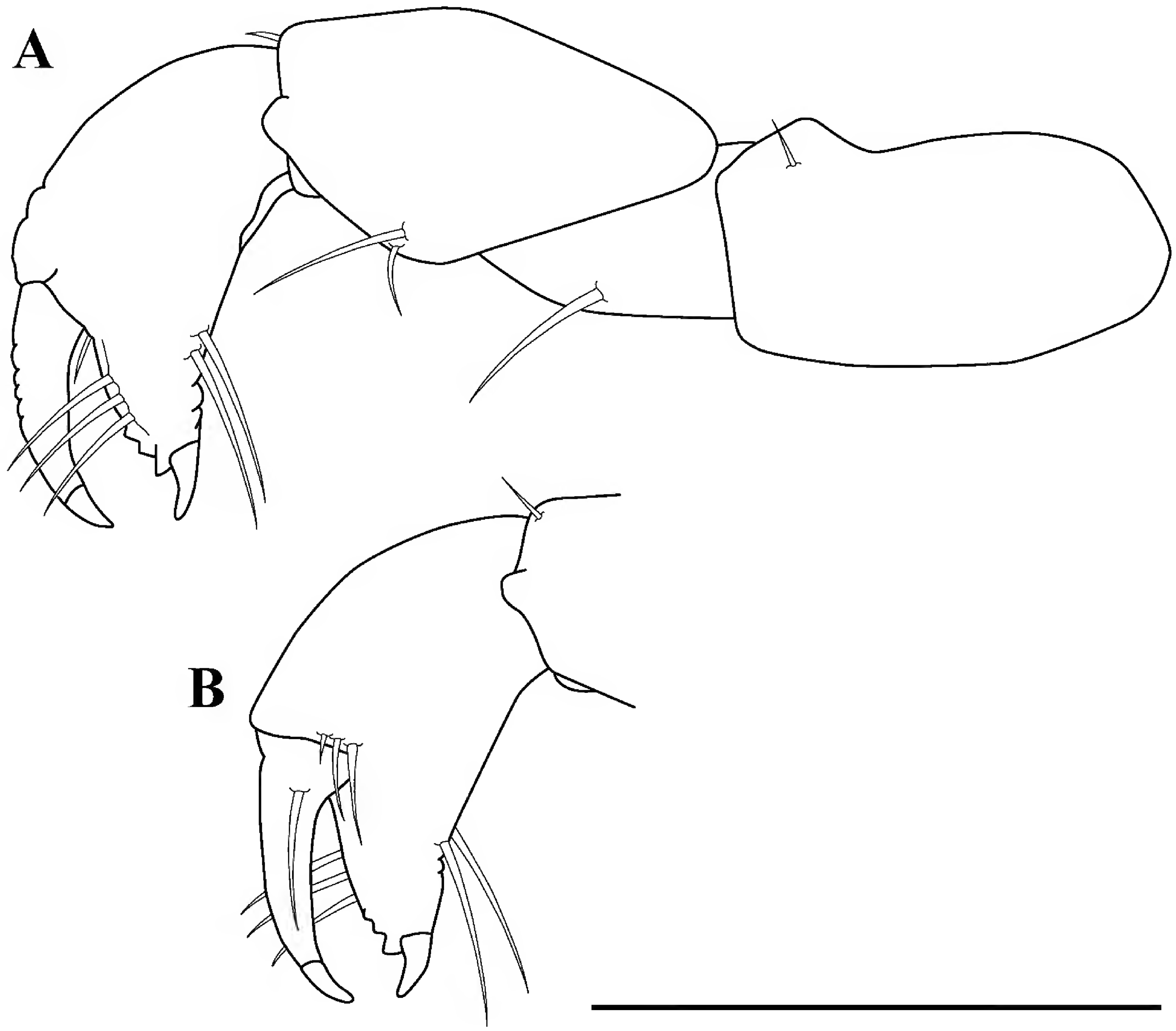


Figure 4. *Oahutanais makalii* gen. et sp. n., holotype female: **A** left cheliped, lateral view; **B** left chela, inner view. Scale bar: 0.1 mm.

with one setulose seta and two simple setae on distoventral setae margin. Article-5 about 2.0 times longer than wide, with one simple seta on distolateral margin. Article-6 minute, with five simple setae of unequal length.

Mouthparts: Labrum (Figs 3C, 7A): hood-shaped and finely setose. Mandibles (Fig. 3D–E): left mandible, incisor with two to three uneven denticles; lacinia mobilis narrow, apparently smooth (Fig. 3D). Right mandible incisor with broad and crenulate upper margin (Fig. 3E). Molar process pointed, with small distoventral spines (Fig. 3D–E). Labium (Figs 3F, 6B, 7A): bilobed with distolateral processes. Maxillule (Figs 3G, 6B, 7A): endite with seven distal spiniform setae (two bifid), two sub-distal simple setae, and cluster of setules on distal margin; palp bearing two long terminal setae of unequal length. Maxilla: not recovered.

Maxilliped (Figs 3H, 7A): basis fused, apparently asetose. Endites unfused, with one simple seta and medial small process, outer margin with small spine. Palp: Article-1 asetose. Article-2 with setulose seta on outer margin, inner sub-distal margin with two simple setae and geniculate, finely-pectinate spiniform seta (serrations visible at magnification 100x). Article-3 with two setulose setae on inner margin. Article-4 with subdistal setulose setae and cluster of setules on outer margin (Fig. 7A), inner and distal margin with five setulose setae.

Epignath: not recovered.

Cheliped: (Figs 4A–B, 6A–C, 8): cheliped attached just anterior to the posterior margin of cephalothorax and very close to the midventral line, via sclerite (Figs 6B–C, 8). Basis about 1.9 times longer than wide, with subdistal short seta. Merus triangular, with simple seta on ventral margin. Carpus about 1.8 times longer than wide, anterior margin with distodorsal seta; ventral margin with two simple setae of different length. Propodus about 1.4 times longer than wide, with small simple seta near insertion of dactylus. Fixed finger with crenulated ventral margin, with two ventral setae and three simple

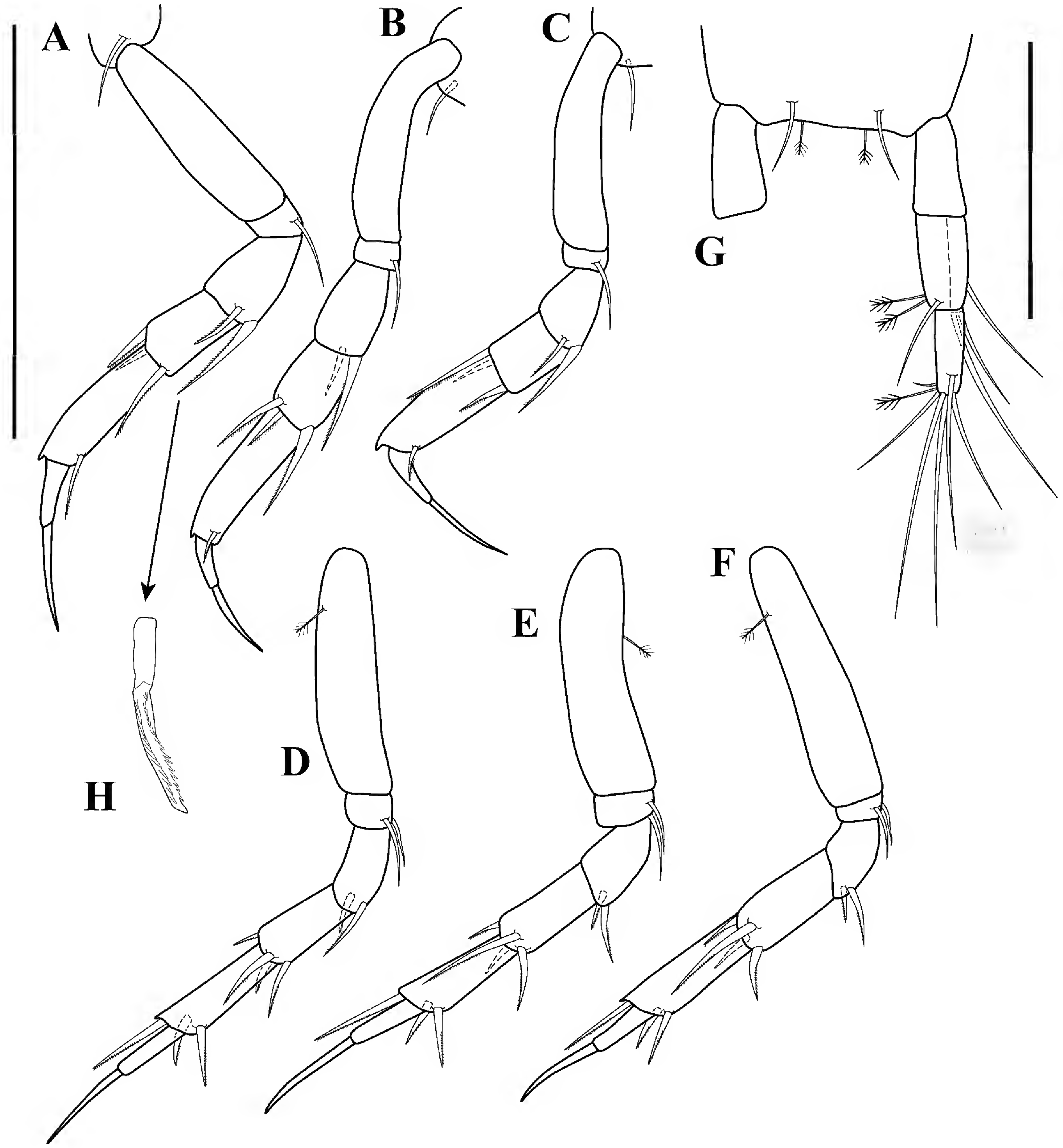


Figure 5. *Oahutanais makalii* gen. et sp. n., holotype female: **A** pereopod-1; **B** pereopod-2; **C** pereopod-3; **D** pereopod-4; **E** pereopod-5: **F** pereopod-6; **G** uropod; **H** pectinate seta. Scale bars: 0.1 mm.

setae on outer incisive margin, with two to three sharp denticles on inner margin. Inner surface (Fig. 4B) with three short simple setae (one distinctly longest) at articulation with dactylus. Dactylus with long simple proximal seta on inner side.

Pereopod-1 (Figs 5A, 8): attached ventrally, coxa with simple seta on anterodistal margin. Basis about 4.0 times longer than wide, asetose. Ischium wider than long, with simple seta shorter than merus. Merus about 1.5 times longer than wide, with two distoventral pectinate setae (Fig. 5H) (one short and one robust, just longer than carpus). Carpus about 1.7 times longer than wide; two pectinate distodorsal setae and one robust pectinate distoventral seta (Fig. 5D). Propodus about 3.1 times longer than wide; distodorsal margin with spine-like apophysis; distoventral margin with one pectinate subdistal seta. Dactylus elongate, together with unguis longer than propodus, dactylus shorter than unguis.

Pereopod-2 (Fig. 5B): similar to pereopod-1, except basis and propodus longer. Propodus with ventrodistal pectinate small seta. Dactylus and unguis shorter than propodus.

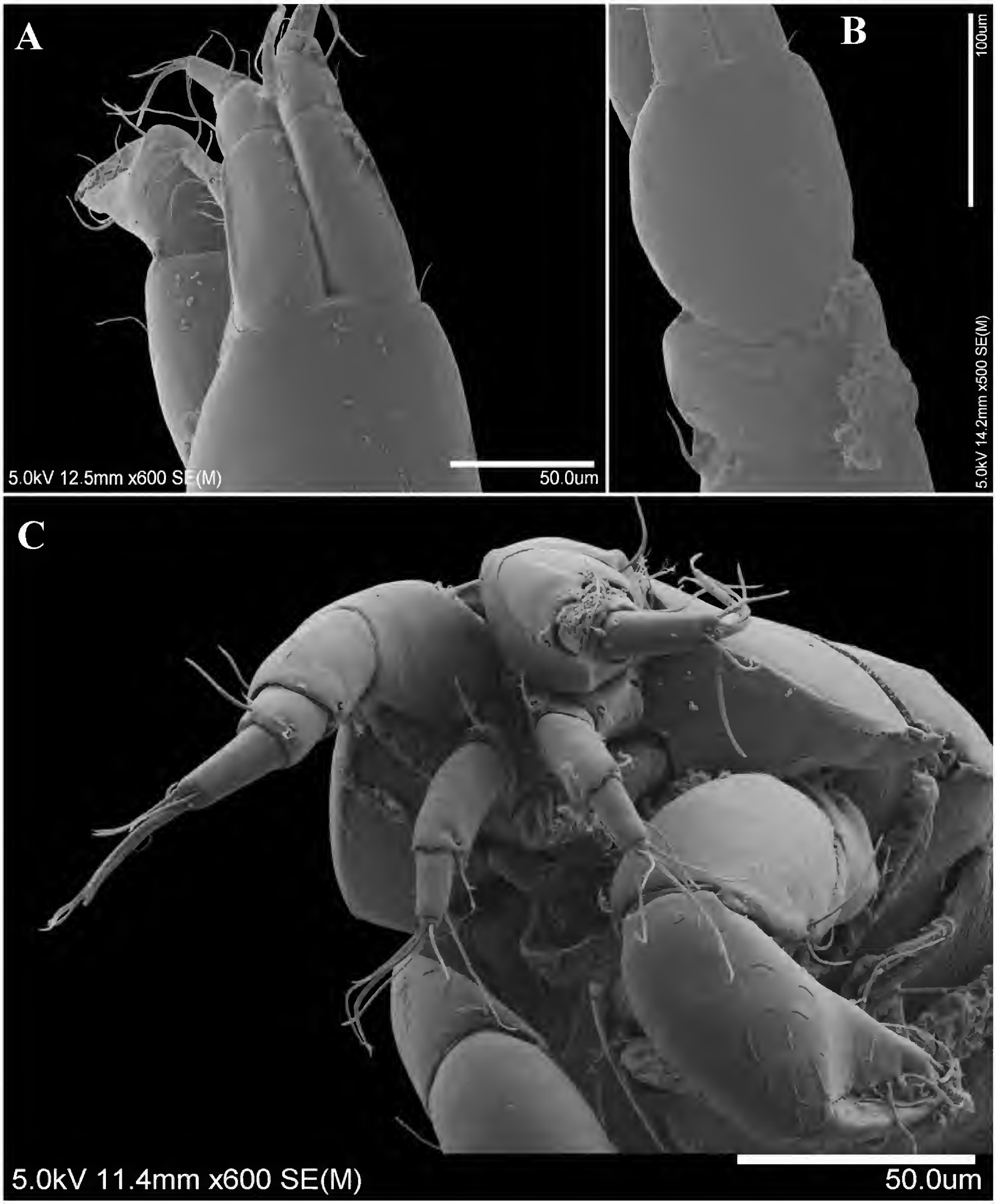


Figure 6. *Oahutanais makalii* gen. et sp. n., paratype female (SEM images): **A** enlargement of anterior end showing part of the carapace, antennules, and carpus to dactylus of left cheliped, dorsal view; **B** enlargement of the cephalothorax and pereonites-1; **C** enlargement of anterior part showing how the carapace covers the antennules, antennas, mouthparts, and left cheliped, ventral view.

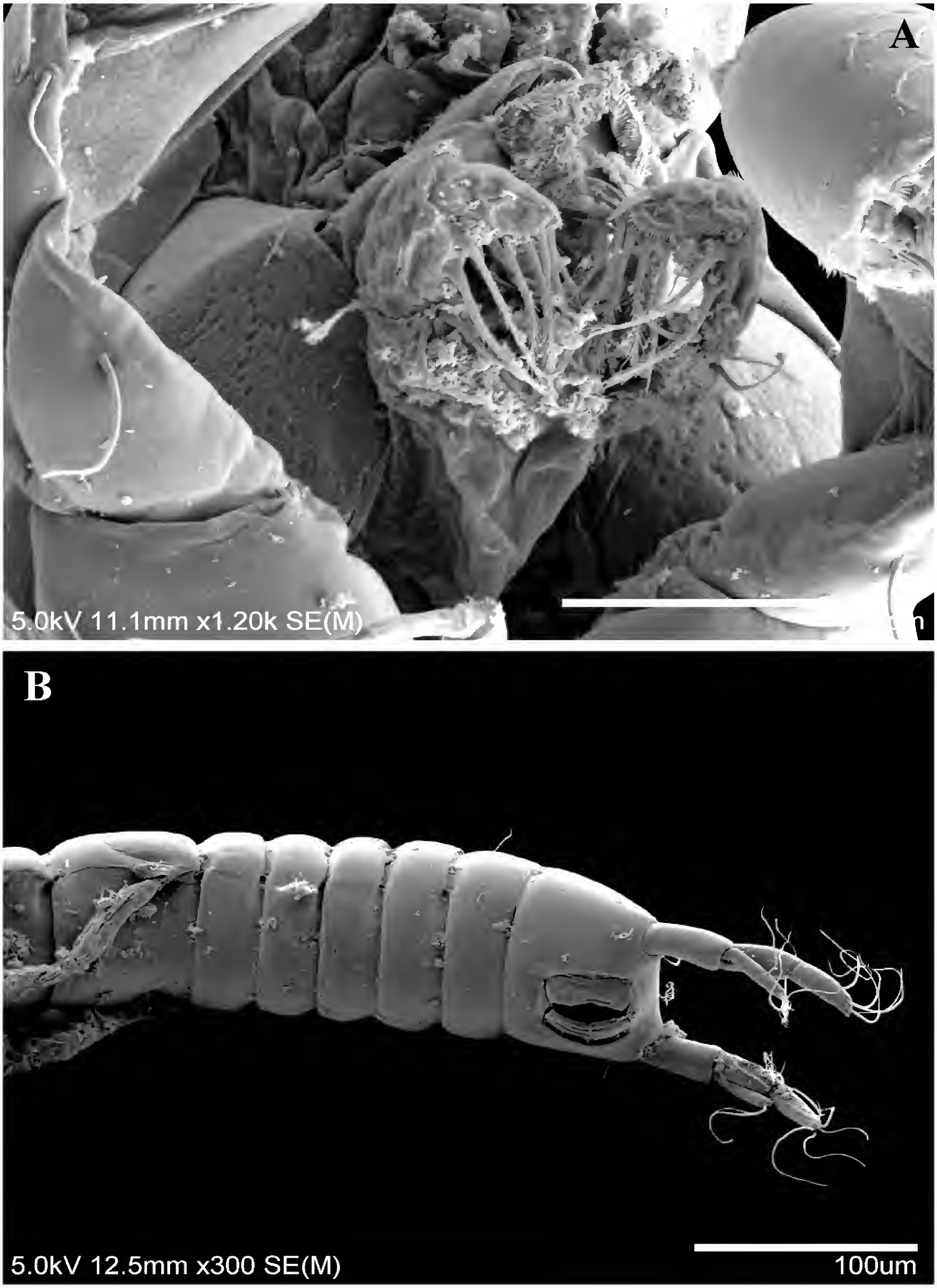


Figure 7. *Oahutanais makalii* gen. et sp. n., paratype female (SEM images): **A** enlargement of mouthparts; **B** enlargement of posterior end showing pleonites 1 to 5, pleotelson, and uropods.

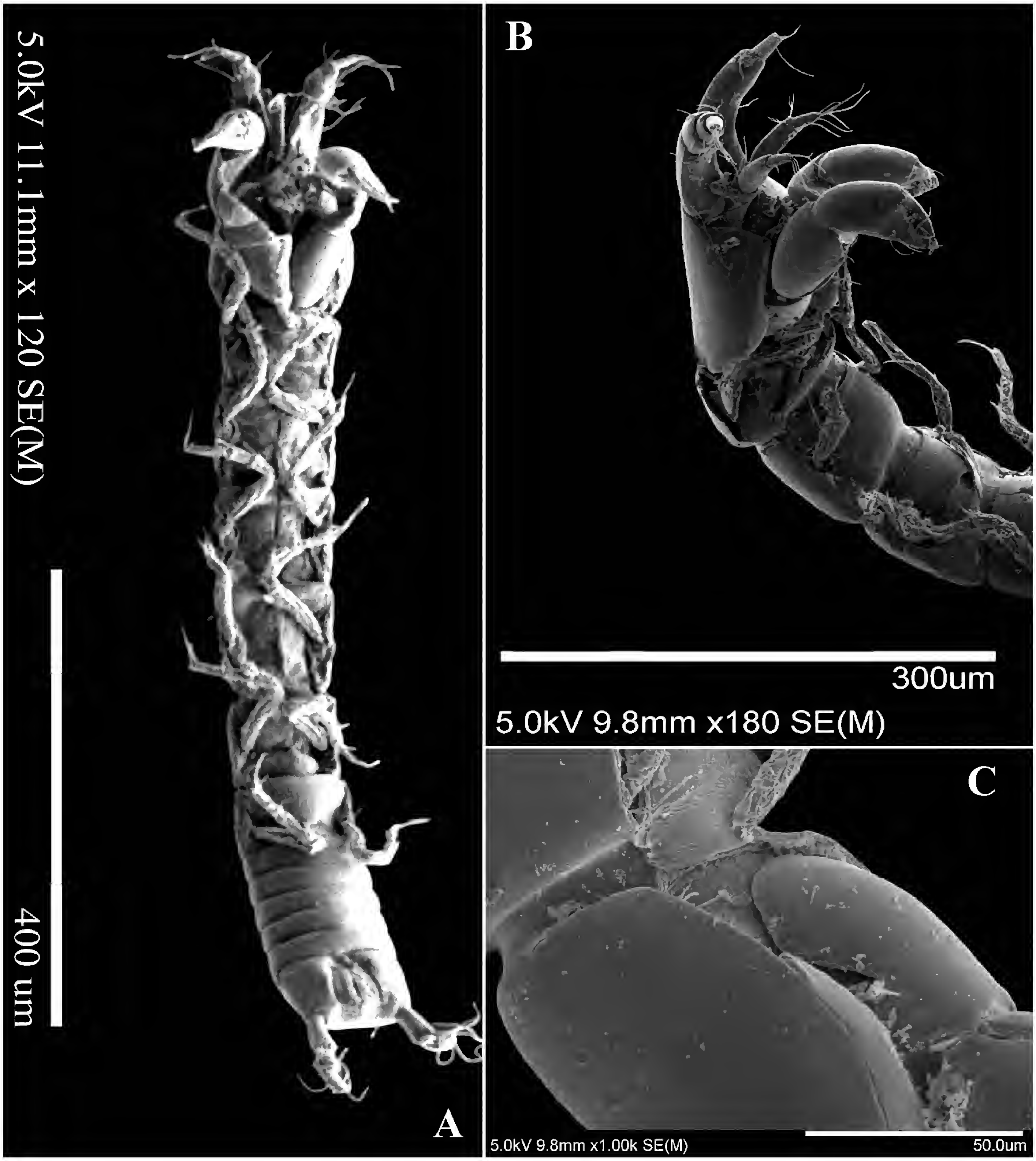


Figure 8. *Oahutanais makalii* gen. et sp. n., paratype female (SEM images): **A** ventral view of habitus; **B** enlargement of mid-anterior part of habitus, lateral view; **C** enlargement of union of cephalothorax and pereonite-1.

Pereopod-3 (Fig. 5C): similar in form to pereopod-2, except shorter than other five pereopods.

Pereopod-4 (Figs 5D, 8): attached ventrally, basis about 4.0 times longer than wide, with setulose seta on proximal dorsal margin. Ischium wider than long with two simple setae of unequal length on posterior margin, long seta shorter than merus. Merus about 2.0 times longer than wide, with two distoventral pectinate setae. Carpus about 2.0 times longer than wide, with four pectinate setae of unequal length. Propodus about 3.5 times longer than wide; distodorsal margin with long pectinate setae, reaching beyond the dactylus; distoventral margin with two pectinate setae. Dactylus and unguis longer than propodus, dactylus shorter than unguis.

Pereopod-5 (Fig. 5E): Similar to pereopod-4, except carpus and dactylus longer. Basis with setulose seta on mid-ventral margin.

Pereopod-6 (Fig. 5F): similar to pereopod-5, except basis, carpus, and propodus slightly longer; ischium, merus, and dactylus shorter.

Pleopods: Absent. (Fig. 7B)

Uropod (Figs 5G, 7B): biramous, twice as long as pleotelson, but half as long as entire pleon. Basal article shorter than pleotelson, without distal apophyses. Exopod uni-articulate, slightly longer than endopod article-1, with simple seta on mid-lateral? margin, and two simple distal setae (one longer). Endopod biarticulate, article-1 with three setae (two setulose and one simple) on subdistal inner margin; article-2 with subdistal simple lateral seta, with one setulose and five (four long and one short) simple setae distally.

Male. Unknown.

Ovigerous female. As above. When embryos were present, six (smaller embryos) was the most observed; typically only three or fewer were present.

Remarks. Among the family Colletteidae, *Oahutanais makalii* sp. n. shows some similarities with *Cetiopyge mira* Larsen and Heard, 2002, *Isopodidus janum* Larsen and Heard, 2002, and *Collettea minima* Hansen, 1913 (see Larsen 2000) in having the unusual presence of bifurcate spiniform terminal setae on the maxillule endite; however, the presence of this kind of setae has also been reported in some species of other families such as the Tanaellidae Larsen & Wilson, 2002 (*Arthrura andriashevi* Kudinova-Pasternak, 1966), Cryptocopidae Sieg, 1977 (*Curtichelia expressa* Kudinova-Pasternak, 1987), and Paratanaoidea *incertae sedis* (*Parafilitanais mexicanus* Larsen, 2002). Larsen and Heard (2002) suggested that this setal character could have a wider occurrence in the deep-sea species, since it has only been reported in specimens collected in deep waters. Our results indicated that the presence of these unusual setae is not restricted to deep-sea Tanaidacea, since *Oahutanais makalii* was found in shallow waters (<105 m).

Key to the genera of Colletteidae in the North Pacific Ocean (females only)

1 Pleotelson terminating in a dorsal plate covering the uropods 2
– Pleonites not terminating in a dorsal plate covering the uropods 3
2 Pleonites almost as long as individual pereonites and pleotelson .... *Filitanais* [western and eastern North Pacific]
– Pleonites not as long as individual pereonites and pleotelson .... *Collettea* [western North Pacific]
3 Propodus of pereopod-6 with three distodorsal spiniform seta .... *Cheliasetosatanais* [equatorial North Pacific]
– Propodus of pereopod-6 with one distodorsal spiniform seta 4
4 Antennal article-1 longer than distal three articles. Maxilliped endites with medial small process .... *Oahutanais* gen. n. [north Central Pacific]
– Antennal article-1 shorter than distal three articles. Endites with two oval tubercles .... *Nippognathiopsis* [western North Pacific]

Remarks on ecology. A complete description of the surrounding benthic communities at these four study areas is beyond the scope of this paper, although the following observations are offered. *Oahutanais makalii* occurs from 19 to 102 m. A single specimen per replicate correlated to a minimum density of 220 ind.m^2. The maximum density for this species observed at any station was 5,070 ind.m^2; far below densities recorded for the most abundant small crustaceans (over 50,000 ind.m^2). No associated tubes were observed with the specimens.

Acknowledgments

Processing, sorting, preliminary identification and enumeration for all specimens described herein was supported by the City and County of Honolulu, Department of Environmental Services contract SC-ENV-1200115 to the Water Resources Research Center University of Hawaii (WJC). AGM-N and KL were not supported by any funding grant. The invaluable assistance in preparation and examination of the SEM material by Tina M. (Weatherby) Carvalho, (PBRC-BEMF) is gratefully acknowledged. We wish to express our gratitude to Graham Bird for his comments and suggestions on the early version of this paper. We are most grateful for the helpful and constructive criticism provided by the three anonymous reviews. We take full responsibility for any differing systematic or taxonomic interpretations.

References

Bird GJ, Holdich DM (1984) New deep-sea leptognathiid tanaids (Crustacea, Tanaidacea) from the north-east Atlantic. Zoologica Scripta 13: 285–315. doi: 10.1111/j.1463-6409.1984.tb00044.x

Bird GJ, Holdich DM (1985) A remarkable tubicolous tanaid (Crustacea: Tanaidacea) from the Rockall Trough. Journal of the Marine Biological Association of the United Kingdom 65(3): 563–572.

Bird GJ, Larsen K (2009) Tanaidacean Phylogeny – the Second Step: the Basal Paratanaoidean Families (Crustacea: Malacostraca). Arthropod Systematics and Phylogeny 67(2): 137–158.

Błażewicz-Paszkowycz M, Bamber RN (2012) The Shallow-water Tanaidacea (Arthropoda: Malacostraca: Peracarida) of the Bass Strait, Victoria, Australia (other than the Tanaidae). Memoirs of Museum Victoria 69: 1–235.

Błażewicz-Paszkowycz M, Poore GCB (2008) Observations on phylogenetic relationships in Paratanaoidea (Tanaidacea: Tanaidomorpha). Advances in Crustacean Phylogenetics, International Symposium, Rostock, Germany, 68–69.

Błażewicz-Paszkowycz M, Bamber RN, Jóźwiak P (2013) Tanaidaceans (Crustacea: Peracarida) from the SoJaBio joint expedition in slope and deeper waters in the Sea of Japan. Deep-Sea Research II 86-87: 181–213. doi: 10.1016/j.dsr2.2012.08.006

Dana JD (1849) Conspectus Crustaceorum. Conspectus of the Crustacea of the Exploring Expedition. The American Journal Sciences and Arts 2(8): 424–428.

David SE, Heard RW (2015) *Cryptapseudes leroyi*, a new species of apseudomorphan tanaidacean (Crustacea: Peracarida: Metapseudidae) from the Hawaiian archipelago. Pacific Sciences 69(2): 279–289.

Guţu M, Sieg J (1999) 9 Ordre des Tanaïdacés (Tanaidacea Hansen, 1895). In: Forest J, Băcescu M, Bellan-Santini D, Boxshall GA, Cals PH, Casanova JP, Dalens H, Guţu M, Hessler RR, Lagardère JP, Monod TH, Nouvel H, Petrescu I, Roman ML, Sieg J, Trilles JP, Watling L (Eds) Traité de Zoologie: Anatomie, Systématique, Biologie, 7, Crustacés, 3A. Péracarides [Treatise on Zoology: Anatomy, Systematics, Biology, 7, Crustaceans, 3A. Peracarida]. Mémoires de l´Institut Océanographique, Monaco, 19. Musée Océanographique de Monaco, Monaco, 353–389.

Hansen HJ (1913) Crustacea, Malacostraca. II. IV. The Order Tanaidacea. The Danish Ingolf Expedition 3(2): 1–145.

Holdich DM, Bird GJ (1986) Tanaidacea (Crustacea) from sublittoral waters off west Scotland, including the description of two new genera. Journal of Natural History 20: 70–100.

Kudinova-Pasternak RK (1973) Tanaidacea (Crustacea, Malacostraca) collected on the R/V "Vitjas" in regions of the Aleutian Trench and Alaska. Trudy Instituta Okeanologii [= Transactions of the Institute of Oceanology] 86: 341–381. doi: 10.1111/j.1463-6409.1974.tb00752.x

Lang K (1949) Contribution to the systematics and synonymics of the Tanaidacea. Arkiv för Zoologie 42: 1–14.

Lang K (1971) Taxonomische und phylogenetische Untersuchungen über die Tanaidaceen. 6. Revision der Gattung Paranarthrura Hansen, 1913, und Aufstellung von zwei neuen Familien, vier neuen Gattungen und zwei neuen Arten. Arkiv för Zoologi, Series 2(23): 361–401.

Lang K (1973) Taxonomische und phylogenetische Untersuchungen über die Tanaidaceen (Crustacea). 8. Die Gattungen Leptochelia Dana, Paratanais Dana, Heterotanais G.O. Sars und Nototanais Richardson. Dazu einige Bermerkungen über die Monokonophora und ein Nachtrag. Zoologica Scripta 2: 197–229.

Larsen K (2000) Revision of the genus *Collettea* (Crustacea: Tanaidacea). Invertebrate Taxonomy 14: 681–693. doi: 10.1071/IT98015

Larsen K (2003) Proposed new standardized anatomical terminology for the Tanaidacea (Peracarida). Journal of Crustacean biology 23(3): 644–661. doi: 10.1651/c-2363

Larsen K (2005) Deep-Sea Tanaidacea (Crustacea; Peracarida) from the Gulf of Mexico. Crustacean Monographs 5: 1–387.

Larsen K, Araújo-Silva C (2014) A new genus of Colletteidae (Crustacea: Peracarida: Tanaidacea) from the Pacific with comments on dimorphic males with species specific characters. Journal of the Marine Biological Association of the United Kingdom 94(5): 969–974. doi:10.1017/S0025315414000101

Larsen K, Heard RW (2002) Two new deep-sea tanaidacean genera, *Isopodidus* and *Cetiopyge* (Crustacea: Peracarida) from the Gulf of Mexico. Proceedings of the Biological Society of Washington 115(2): 403–411.

Larsen K, Shimomura M (2007) Tanaidacea (Crustacea: Peracarida) from Japan. II. Tanaidomorpha from the East China Sea, the West Pacific Ocean, and the Nansei Islands. Zootaxa 1464: 1–43.

Larsen K, Wilson GDF (2002) Tanaidacean phylogeny, the first step: the superfamily Paratanoidea. Journal of Zoological Systematics and Evolutionary Research 40: 205–222. doi: 10.1046/j.1439-0469.2002.00193.x

Larsen K, Błażewicz-Paszkowycz M, Cunha MR (2006) Tanaidacean (Crustacea: Peracarida) fauna from chemically reduced habitats- the lucky strike hydrothermal vent system, mid-Atlantic ridge. Zootaxa 1187: 1–36.

Sars GO (1882) Revision af gruppen: Isopoda Chelifera med charakteristik af nye herhen hørende arter og slægter. Archiv for Mathematik og Naturvidenskab 7: 1–54.

Sieg J (1986) Crustacea Tanaidacea of the Antarctic and the Subantarctic. 1. On material collected at Tierra del Fuego, Isla de los Estados, and the west coast of the Antarctic Peninsula. In: Korniker LS (Ed.) Biology of the Antarctic Seas 18. Volume 45 in the Antarctic Research Series. American Geophysical Union, Washington, D.C., 1–180.

WoRMS (2015) Tanaidacea. World Register of Marine Species. http://www.marinespecies.org/aphia.php?p=taxdetails&id=1133 [accessed 15 June 2015]

Zoosyst. Evol. 92 (1) 2016, 13–21 | DOI 10.3897/zse.92.6464

PENSOFT. museum für naturkunde

No longer single! Description of female *Calumma vatosoa* (Squamata, Chamaeleonidae) including a review of the species and its systematic position

David Prötzel[1], Bernhard Ruthensteiner[1], Frank Glaw[1]

[1] *Zoologische Staatssammlung München (ZSM-SNSB), Münchhausenstr. 21, 81247 München, Germany*

http://zoobank.org/CFD64DFB-D085-4D1A-9AA9-1916DB6B4043

Corresponding author: *David Prötzel* (david.proetzel@mail.de)

Received 3 September 2015
Accepted 26 November 2015
Published 8 January 2016

Academic editor:
Johannes Penner

Abstract

Calumma vatosoa is a Malagasy chameleon species that has until now been known only from the male holotype and a photograph of an additional male specimen. In this paper we describe females of the chameleon *Calumma vatosoa* for the first time, as well as the skull osteology of this species. The analysed females were collected many years before the description of *C. vatosoa*, and were originally described as female *C. linotum*. According to external morphology, osteology, and distribution these specimens are assigned to *C. vatosoa*. Furthermore we discuss the species group assignment of *C. vatosoa* and transfer it from the *C. furcifer* group to the *C. nasutum* group. A comparison of the external morphology of species of both groups revealed that *C. vatosoa* has a relatively shorter distance from the anterior margin of the orbit to the snout tip, more heterogeneous scalation at the lower arm, a significantly lower number of supralabial and infralabial scales, and a relatively longer tail than the members of the *C. furcifer* group. These characters are, however, in line with the species of the *C. nasutum* group. In addition the systematic position of *C. peyrierasi* also discussed, based on its morphology.

Key Words

Madagascar
chameleon
Calumma
Calumma nasutum group
X-ray micro-computed tomography
osteology

Introduction

Madagascar is a hotspot of chameleon diversity and endemism (Tolley et al. 2013). Of the currently described 202 chameleon species, 86 species belong to the four Malagasy genera *Brookesia* Gray, 1865, *Calumma* Gray, 1865, *Furcifer* Fitzinger, 1843, and *Palleon* Glaw, Hawlitschek & Ruthensteiner, 2013, and all but two Comorian species of *Furcifer* are endemic to Madagascar (Glaw 2015). Although the Seychelles chameleon, *Archaius tigris* (Kuhl, 1820), was included in the genus *Calumma* until recently, Townsend et al. (2011) demonstrated that it represents a different African lineage and that *Calumma* is endemic to Madagascar. The Malagasy chameleons were relatively intensively studied in the past (Brygoo 1971, 1978), but still many new species are regularly discovered and described (e. g. Raxworthy and Nussbaum 2006, Gehring et al. 2010, Gehring et al. 2011, Glaw et al. 2012), and several species are only known by a single or a few specimens. Within the genus *Calumma*, currently comprising 33 species (Glaw 2015), *C. hafahafa* Raxworthy & Nussbaum, 2006, *C. linotum* (Müller, 1924), *C. peyrierasi* (Brygoo, Blanc & Domergue, 1974), and *C. vatosoa* Andreone, Mattioli, Jesu & Randrianirina, 2001 are such poorly known species. *Calumma linotum* for example was described on the basis of a single male without locality (Müller 1924) and it took more than 90 years to clarify its identity (Prötzel et al. 2015). In the same way, *C. vatosoa* was known only from the male holotype until Lutzmann et al. (2010) made a further record of *C. vatosoa* and presented a photograph of a male individual from near Ampokafo, approximately 50 km southeast of the type locality (Forêt de Tsararano). So far, no female individual of this species has been recorded. *Calumma vatosoa* is a medium-sized chameleon species and was tentatively assigned to the *C. furcifer* group (sensu Glaw and Vences 1994) due to the absence of occipital lobes, gular and ventral crests and its markedly acute rostral profile, and greenish colouration (Andreone et al. 2001). These authors did not assign it to the *C. nasutum* group (sensu Glaw and Vences 1994), because of the absence of a rostral appendage, absence of a dorsal crest, and presence of axillary pockets. The *C. nasutum* group was recently found to be non-monophyletic (Tolley et al. 2013) and to include *C. peyrierasi*, a species formerly assigned to the *C. furcifer* group. The hemipenis ornamentation of *C. vatosoa* differs from that of all other species of the genus *Calumma* by the coexistence of three pairs of rotulae (Andreone et al. 2001).

In 1931, Bluntschli collected four female chameleons at Col Pierre Radama that were assigned to *Calumma linotum* by Mertens (1933), despite the absence of a rostral appendage and occipital lobes. Mertens (1933) justified this classification due to the absence of a dorsal crest, larger scales at the extremities, the regular gular folds, and the absence of the rostral appendage in the females. As the proper identification of *C. linotum* was recently clarified (Prötzel et al. 2015), we were able to reassign these female specimens to *C. vatosoa*. In this paper we describe for the first time females of *Calumma vatosoa* including the osteology of the species and review its assignment to the *C. furcifer* group. By identifying and reclassifying these individuals, we correct their taxonomic identity and enhance the knowledge about morphology and distribution of this poorly known species.

Material and methods

We studied the male holotype of *Calumma vatosoa* and three females from the Senckenberg Museum at Frankfurt/Main which were labeled as *C. linotum*. Of the four females originally collected (Mertens 1933) only three are still present in the museum collection. In addition, we investigated the external morphology of one adult male and (if available) one female of the species *C. andringitraense* (Brygoo, Blanc & Domergue, 1974), *C. furcifer* (Vaillant & Grandidier, 1880), *C. gastrotaenia* (Boulenger, 1888), *C. glawi* Böhme, 1997, *C. guillaumeti* (Brygoo, Blanc & Domergue, 1974), *C.* cf. *marojezense*, *C. tarzan* Gehring, Pabijan, Ratsoavina, Köhler, Vences & Glaw, 2010, and *C. vencesi* Andreone, Mattioli, Jesu & Randrianirina, 2001 of the *C. furcifer* group, and *C. boettgeri* (Boulenger, 1888), *C. fallax* (Mocquard, 1900), *C. gallus* (Günther, 1877), *C. guibei* (Hillenius, 1959), *C. linotum, C. nasutum* (Duméril & Bibron, 1836), and *C. vohibola* Gehring, Ratsoavina, Vences & Glaw, 2011 of the *C. nasutum* group. *Calumma cucullatum* (Gray, 1831) is not considered a part of the *C. furcifer* group in the strict sense (see phylogeny in Tolley et al. 2013). In addition *C. peyrierasi* was investigated according to its phylogenetic position in the *C. nasutum* group – but it is clearly separated from the other species of the *C. nasutum* group (Tolley et al. 2013). The same specimen, which was analysed genetically in Tolley et al. (2013), was used for morphological measurements together with three more specimens of the same series. The other comparative specimens were chosen randomly, if several specimens were available, as typical representatives of their species. The studied specimens originated from the collections of the Museo Regionale di Scienze Naturali, Torino, Italy (MRSN), Senckenberg Museum, Frankfurt am Main, Germany (SMF), and from the Zoologische Staatssammlung München (ZSM), Germany (see Table 1 for details).

The following characters (Fig. 1) were measured with a digital calliper to the nearest of 0.1 mm or counted using a binocular dissecting microscope: snout-vent length (SVL) from the snout tip (not including the rostral appendage) to the cloaca; tail length (TaL) from the cloaca to the tail tip; total length (TL) as a sum of SVL + TaL; ratio of TaL to SVL (RTaSV); length of rostral appendage (LRA); snout-casque length (SCL), measured from the tip of the snout to the posterior end of the casque; ratio of SCL to SVL (RSCSV); head width (HW); ratio of HW to SVL (RHWSV); distance from the anterior margin of the orbit to the snout tip (DOS); ratio of DOS to SCL (ROSSC); occipital lobes (OL) presence (+) or absence (–); length of lateral crest, starting from the eye horizontally (LC); length of temporal crest that starts upwards from the LC (TC); parietal crest (PC) absence (–) or presence (+); casque height (CH); dorsal crest (DC) absence (–) or presence (+); axillary pits (AP) of the forelimbs presence (+) or absence (–); diameter of largest scale on lower arm (DSA, defined as the area from the elbow to the manus in lateral view); number of scales on lower arm in a line from elbow to manus (NSA); scalation on lower arm (SL), heterogeneous (het) or homogenous (hom); number of supralabial scales (NSL; counted from the first scale next to the rostral to the last scale that borders directly and entirely (with one complete side) to the mouth slit of the upper jaw) on the right side; number of infralabial scales (NIL, analogous to the definition of NSL above, on the right side).

For skeletal morphology, X-ray micro-computed tomography scans (micro-CT scans) of the head of the holotype of *Calumma vatosoa* (MRSN R1628, locality Forêt de Tsararano) and of one presumed female *C. vatosoa* (SMF 26357, from Col Pierre Radama) were prepared. During micro-CT scanning, each specimen was placed in a sealed plastic vessel slightly larger than the specimen itself, with the head oriented upwards, and was stabilised with ethanol-soaked paper. To provide an undisturbed external surface of the head, it was ensured that the paper did not cover this area. Micro-CT scanning was performed with a phoenix nanotom m (GE Measurement & Control, phoenix|x-ray, Wunstorf, Germany) at a voltage of 130 kV and a current of 80 µA for 29 minutes (1800 projections). 3D data sets were processed with VG Studio Max

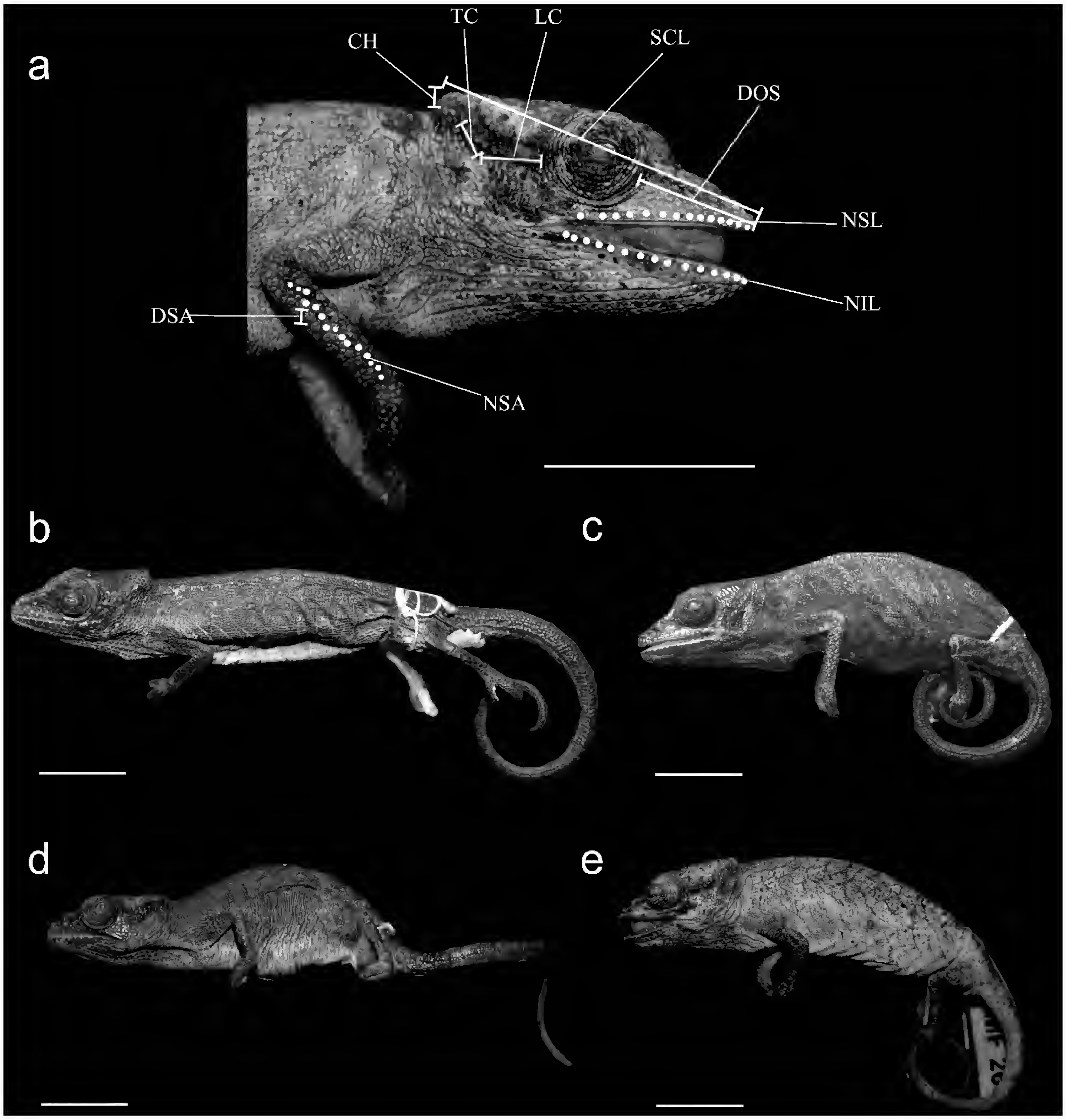


Figure 1. Preserved specimens of *Calumma vatosoa*; (**a**) Landmarks for morphometric measurements and pholidosis, shown in lateral view of the head region and forelegs of a female (SMF 26357, locality Ambatond'Radama); (**b**) male holotype of *C. vatosoa* (MRSN R1628, Forêt de Tsararano) in lateral view; (**c**) female (SMF 26359, Ambatond'Radama) in lateral view; (**d**) female (SMF 26358, Ambatond'Radama) in lateral view; (**e**) female (SMF 26357, Ambatond'Radama) in lateral view. Scale bar = 10 mm. See Materials and Methods for abbreviations.

2.2 software (Visual Graphics GmbH, Heidelberg, Germany); the data were visualised using the Phong volume renderer to show the surface of the skull. Measurements were taken with VG Studio Max 2.2. Osteological terminology follows Rieppel and Crumly (1997). Principal component analyses (PCA) was performed for 11 measurements/ counts (SVL, TaL, LRA, RSCSV, RHWSV, ROSSC, CH, DSA, NSA, NSL and NIL, see above) of all investigated specimens using the statistical analysis software PAST 3.08 (Hammer et al. 2001).

Results

External morphology of females. The three female specimens of *Calumma vatosoa* (SMF 26357, SMF 26358, and SMF 26359 are in a good state of preservation except a slit on the ventral side of the body (Fig. 1); SMF 26357 with mouth open and tip of the tongue between the jaws; SMF 26358 of smaller size and with poorly developed crests – presumably not full-grown; SMF 26359 blackened, presumably due to formalin injection.

Table 1. Morphological measurements of the male holotype and three female *Calumma vatosoa* and *C. peyrierasi* (one male, three females) in comparison with the species of the *C. furcifer* and *C. nasutum* group (represented as one male and one female if possible).

Species	Collection no.	Locality	Sex	SVL	TaL	TL	RTaSV	LRA	SCL	RSCSV	HW	RHWSV	DOS	ROSSC	OL	LC	TC	PC	CH	DC	AP	DSA	NSA	SL	NSL	NIL
***C. furcifer* group**																										
C. andringitraense	ZSM 554/2001	Andringitra	m	45.7	48.4	94.1	1.06	-	16.5	0.36	3.5	0.077	5.5	0.33	-	-	-	-	0.2	-	+	0.3	27	hom	17	20
C. furcifer	ZSM 656/2014	Mahasoa forest	m	58.3	58.6	116.9	1.01	-	21.0	0.36	4.0	0.069	8.3	0.40	-	3.8	-	-	0.0	+	+	0.4	29	hom	21	20
C. furcifer	ZSM 657/2014	Mahasoa forest	f	61.2	54.3	115.5	0.89	-	19.7	0.32	5.1	0.083	8.2	0.42	-	3.6	-	-	0.0	-	+	0.4	25	hom	20	20
C. gastrotaenia	ZSM 1719/2010	Analabe forest	m	65.5	66.0	131.5	1.01	-	23.8	0.36	4.8	0.073	8.5	0.36	-	2.7	-	-	2.2	+	+	0.6	23	hom	17	18
C. gastrotaenia	ZSM 1718/2010	Analabe forest	f	61.7	53.9	115.6	0.87	-	19.7	0.32	5.7	0.092	7.9	0.40	-	-	-	-	0.0	-	+	0.4	22	hom	18	18
C. glawi	ZSM 2042/2008	Ranomafana	m	59.6	64.0	123.6	1.07	-	21.0	0.35	5.3	0.089	8.1	0.39	+	-	-	-	2.4	-	+	0.6	21	hom	16	17
C. guillaumeti	ZSM 1701/2012	Sorata	m	52.8	56.2	109.0	1.06	-	18.7	0.35	3.9	0.074	7.2	0.39	-	-	-	-	0.7	+	+	0.6	24	hom	15	18
C. guillaumeti	ZSM 1702/2012	Sorata	f	57.2	52.9	110.1	0.92	-	18.9	0.33	4.3	0.075	7.5	0.40	-	1.8	-	-	0.0	-	+	0.6	23	hom	15	16
C. cf. *marojezense*	ZSM 461/2010	Ambodivohangy	m	66.9	65.0	131.9	0.97	-	19.4	0.29	4.6	0.069	7.4	0.38	-	4	-	-	0.0	-	+	0.4	40	hom	17	18
C. tarzan	ZSM 219/2010	Tarzanville	m	72.6	78.0	150.6	1.07	-	22.6	0.31	4.1	0.056	9.3	0.41	-	3.2	-	-	0.6	-	+	0.5	33	hom	18	18
C. tarzan	ZSM 222/2010	Tarzanville	f	67.4	60.0	127.4	0.89	-	20.7	0.31	4.3	0.064	8.6	0.42	-	3.1	-	-	0.6	-	+	0.4	40	hom	20	20
C. vencesi	ZSM 50/2011	F. d'Amboloko-patrika	m	69.3	72.0	141.3	1.04	-	21.9	0.32	4.6	0.066	8.6	0.39	-	5.1	1.5	-	0.6	+	+	0.5	32	hom	18	20
***C. nasutum* group**																										
C. boettgeri	ZSM 444/2000	Nosy Be	m	51.9	55.0	106.9	1.06	2.93	17.0	0.33	3.2	0.062	5.3	0.31	+	3.9	-	-	1.4	+	-	0.4	26	het	12	12
C. boettgeri	ZSM 441/2000	Nosy Be	f	45.5	43.4	88.9	0.95	2.73	15.3	0.34	2.9	0.064	5.0	0.33	+	3.2	-	-	1.4	-	-	0.4	27	het	12	12
C. fallax	ZSM 286/2010	Tsinjoarivo	m	48.8	57.3	106.1	1.17	3.60	16.6	0.34	3.5	0.072	5.2	0.31	-	2.7	2.0	+	1.9	+	-	0.9	11	het	14	15
C. guibei	ZSM 2855/2010	Tsaratanana	m	48.9	61.5	110.4	1.26	3.6	15.6	0.32	3.6	0.074	5.5	0.35	+	2.8	1.1	-	1.0	-	-	0.7	15	het	11	12
C. guibei	ZSM 2856/2010	Tsaratanana	f	45.9	46.5	92.4	1.01	1.3	14.9	0.32	3.1	0.068	4.8	0.32	+	2.6	1.0	-	1.0	-	-	0.6	17	het	12	13
C. gallus	ZSM 321/2000	Vohidrazana	m	45.0	43.7	88.7	0.97	9.7	15.4	0.34	3.1	0.069	4.8	0.31	-	2.9	-	-	1.1	-	+	0.7	16	het	15	14
C. linotum	ZSM 2073/2007	M. d'Ambre	m	59.6	64.8	124.4	0.92	4.50	16.8	0.28	3.1	0.052	5.2	0.31	+	2.3	-	+	1.3	+	-	0.8	16	het	-	12
C. linotum	ZSM 551/2001	Andampy	f	50.6	50.7	101.3	1.00	2.00	15.8	0.31	3.1	0.061	5.0	0.32	+	2.5	-	+	0.8	+	-	0.8	22	het	13	13
C. cf. *nasutum*	ZSM 924/2003	Andasibe	m	43.7	45.3	89.0	1.04	2.2	13.8	0.32	2.7	0.062	4.6	0.33	-	2.0	0.8	+	1.7	+	-	0.5	14	het	12	13
*C.*cf. *nasutum*	SMF 68273	Andasibe	f	46.2	45.8	92.0	0.99	1.8	12.5	0.27	2.8	0.061	4.2	0.34	-	1.5	-	+	1.5	-	-	0.6	15	het	12	12
C. vohibola	ZSM 645/2009	Vohibola	m	46.9	42.1	89.0	0.90	1.1	14.1	0.30	3.1	0.066	4.8	0.34	-	2.6	1.1	-	1.3	+	-	0.9	17	het	15	18
C. vohibola	ZSM 643/2009	Vohibola	f	45.5	40.4	85.9	0.89	0.3	14.2	0.31	2.3	0.051	4.7	0.33	-	2.7	0.7	-	1.3	-	-	0.8	16	het	14	14
C. vatosoa	MRSN R1628	F. de Tsararano	m	57.9	66.6	124.5	1.15	-	18.5	0.32	4.8	0.083	6.4	0.35	-	2.1	3.1	-	1.8	-	+	0.8	15	het	13	14
C. vatosoa	SMF 26357	Col Pierre R.	f	53.8	56.0	109.8	1.04	-	17.3	0.32	4.3	0.080	5.9	0.34	-	3.0	2.4	-	1.0	-	+	0.8	15	het	14	14
C. vatosoa	SMF 26358	Col Pierre R.	f	45.7	51.2	96.9	1.12	-	16.3	0.36	4.7	0.103	5.7	0.35	-	1.5	3.1	-	1.0	-	+	0.9	14	het	14	13
C. vatosoa	SMF 26359	Col Pierre R.	f	47.9	51.4	99.3	1.07	-	16.5	0.34	3.9	0.081	5.4	0.33	-	2.8	2.2	-	0.5	-	+	0.9	20	het	13	13
C. peyrierasi	ZSM 522/2014	Tsaratanana	m	51.1	55.2	106.3	1.08	-	19.9	0.39	4.9	0.096	6.5	0.33	-	3.6	2.4	-	2.5	+	+	0.7	18	hom	12	12
C. peyrierasi	ZSM 1726/2010	Tsaratanana	f	53.2	52.8	106.0	0.99	-	16.2	0.30	4.9	0.093	5.3	0.33	-	3.8	2.1	-	1.4	+	+	0.8	21	hom	12	12
C. peyrierasi	ZSM 17272010	Tsaratanana	f	56.0	54.6	110.6	0.98	-	15.6	0.28	4.9	0.088	5.8	0.37	-	3.5	2.2	-	0.9	+	+	0.7	17	hom	12	14
C. peyrierasi	ZSM 523/2014	Tsaratanana	f	56.4	52.5	108.9	0.93	-	15.2	0.27	4.8	0.085	5.4	0.36	-	3.2	2.1	-	1.2	+	+	0.7	22	hom	13	13

The morphological features of the three female *C. vatosoa* specimens ranged from: SVL 45.7–53.8 mm; tail length 51.2–56.0 mm; tail length 104–112 % of SVL; snout-casque length 16.3–17.3 mm, head width 3.9–4.7 mm; diameter of the orbit 4.7–5.1 mm; number of supralabial and infralabial scales 13 or 14; line of upper labials serrated; distinct rostral ridges that fuse on the anterior snout; no rostral appendage; lateral crest poorly developed and pointing straight posteriorly, fusing to form the poorly developed temporal crest that curves upwards and fading to the highest point of the casque; height of the casque 0.5–1.0 mm; no occipital lobes; no traces of parietal, dorsal, gular, and ventral crest; body laterally compressed with fine homogeneous scalation with the exception of the extremities and head region; legs with enlarged rounded tubercle scales (diameter 0.7–1.0 mm) bordering each other; heterogeneous scalation on the head; upper arm diameter 2.3–2.6 mm; axillary pits evident. Full morphological measurements in comparison to the holotype are provided in Table 1.

Skull osteology of the male holotype (MRSN R1628) (Fig. 2). Strongly developed maxillae extending anteriorly with tubercles at the lateral margin; small nasal bones (length 1.7 mm, width 0.3 mm) paired and meeting anteriorly; anterior tip of the frontal bone not exceeding more than a half of the naris and meeting the maxillae mid-dorsally; naris extending posteriorly up to the frontal bone (apomorphic state of *C. nasutum* according to Rieppel and Crumly 1997) and laterally bordered by the massive prefrontals with distal tubercles; prefrontal not meeting the maxilla; smooth frontal in the shape of a triangle, with a length of 8.4 mm and a width of 5.1 mm at the widest distance; parietal irregularly spotted with a few tubercles and tapering posteriorly from 4.2 mm (largest diameter) to 0.2 mm (smallest diameter); parietal meeting the squamosal and building the casque.

Skull osteology of the female (SMF 26357) (Fig. 2). Smooth maxillae without tubercles; narrow nasal bones (length 1.8 mm, width 0.2 mm) paired and meeting anteriorly; anterior tip of the frontal bone not exceeding more than a half of the naris and meeting the maxillae mid-dorsally; naris extending posteriorly up to the frontal bone and laterally bordered by the massive prefrontals with distal tubercles; prefrontal not meeting the maxilla; smooth frontal in the shape of a triangle with a length of 6.7 mm and a width of 4.9 mm at the widest distance; parietal irregularly spotted with a few tubercles and tapering posteriorly from 4.6 mm (largest diameter) to 0.5 mm (smallest diameter); parietal meeting the squamosal and building the casque.

The skull differs between the sexes in following characters (Fig. 2): The skull of the male holotype is ornamented with more tubercles and appears more robust than the skull of the female. Especially the shape of the maxilla differs with distal tubercles in the male and a smooth surface in the female. Further, the nasals are slightly broader in the male (0.3 mm vs. 0.2 mm in the female) and the parietal tapers more sharply in the male, to 0.2 mm (vs. 0.5 mm). In conclusion, there is only weak sexual dimorphism in this species.

Colouration in preservative (Fig. 1). The colour of the specimens is faded after storage in alcohol for more than 80 years. The body of the female SMF 26357 is now of beige and bluish grey colour. A black stripe from the snout tip to the casque, crossing the eye, is clearly recognisable (a similar stripe is present in the holotype and on the photograph of the second individual, suggesting that it is characteristic for *C. vatosoa*). The eyelid is covered with light blue and purple spots. A midlateral white stripe runs from the upper lip to the pelvis on either side of the body. The body colour is bluish grey, becoming paler at the throat and venter (lacking a distinct white stripe) and darker at the extremities and the tail. On the legs there are blue tubercle scales, especially on the forearm region. The body is covered with a network of fine black lines. SMF 26358 is homogeneous bluish grey coloured with beige on the belly, the throat, and the inner side of the extremities. The legs bear blue-coloured tubercle scales; no other pattern is visible. The female SMF 26359 is completely coloured black, presumably due to exposure to formalin. Only the inner side of the extremities are of beige in colour. None of the three females shows any traces a yellowish spot on the flanks (which is recognisable on photographs of the living male holotype and the male photographed near Ampokafo). Neither the male holotype nor the three females show any pattern of a beige midventral stripe that is bordered by a white line on each side.

Distribution (Fig. 3**).** *Calumma vatosoa* is known from a small area of approximately 425 km^2 (Jenkins et al. 2011) in north-eastern Madagascar. The type locality is Forêt de Tsararano (14°54.8'S, 49°42.6'E, 665 m a.s.l.) between the Anjanaharibe-Sud Massif and the Masoala Peninsula (Andreone et al. 2001). Lutzmann et al. (2010) presented a photograph of one male individual from next to Ampokafo (15°15.4'S, 50°2.5'E, 400 m a.s.l.) which is located 50–60 kilometers south east of the type locality between Maroantsetra and Antalaha. We here add Ambatond'Radama (=Col Pierre Radama, 35–40 km north-east of Maroantsetra, N.E. Madagascar according to Viette (1991); coordinates approximately: 15°17.4'S, 50° 0.2'E) as a third locality of this species. Presumably *C. vatosoa* occurs in the forest among the three known localities.

Systematic position of *Calumma vatosoa*. Morphological measurements and pholidosis of *Calumma vatosoa* revealed substantial differences compared to the species of the *C. furcifer* group (see Table 1 for measurements). *Calumma vatosoa* differs from the species of the *C. furcifer* group in the following characters: heterogeneous scalation on lower arm vs. homogeneous scalation; larger diameter of tubercles on lower arm (DSA, 0.8–0.9 mm vs. 0.3–0.6 mm); lower number of scales in a line on the lower arm (NSA, 14–20 vs. 21–40); lower number of supralabials (NSL, 13–14 vs. 15–21) and infralabials (NIL,

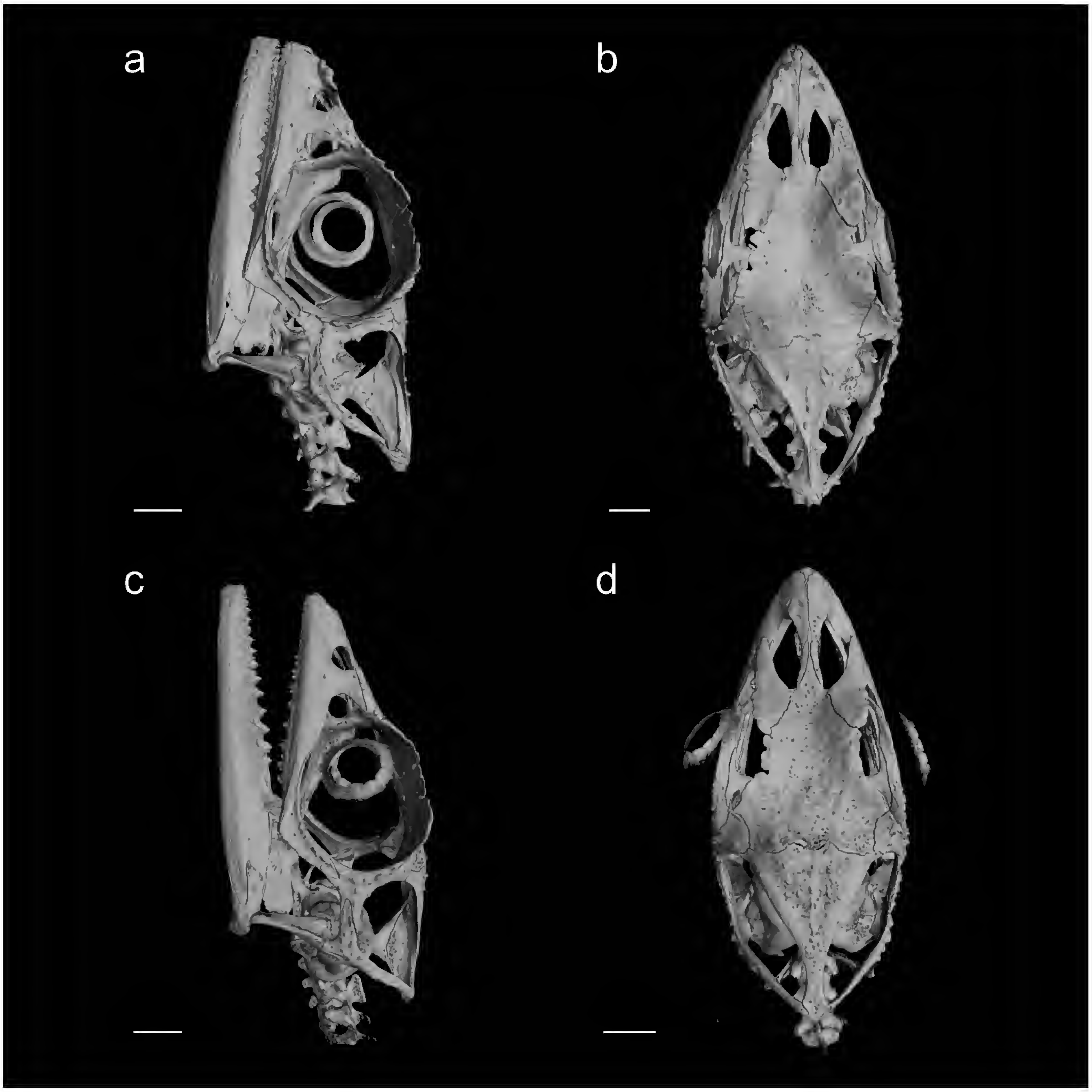


Figure 2. Micro-CT images of skulls of *Calumma vatosoa*; male holotype of *C. vatosoa* (MRSN R1628, Forêt de Tsararano) in (**a**) lateral and (**b**) dorsal view; female (SMF 26357, Ambatond'Radama) in lateral (**c**) and dorsal view (**d**). Scale bar = 2.0 mm.

13–14 vs. 16–20); longer tail relative to SVL, especially in the females (RTaSV, males 115 % vs. 101–107 %, females 104–112 % vs. 87–92 %); shorter distance from the anterior margin of the orbit to the snout tip related to snout-casque length (RSCSV, 0.33–0.35 vs. 0.33–0.42). In terms of colouration all species of the *C. furcifer* group show a distinct pattern of a beige midventral stripe that is bordered by a white line on each side. In *C. vatosoa* the venter is of paler colour than the body but it lacks any striped pattern.

These same measurements in the *Calumma nasutum* group were as follows: distance from the anterior margin of the orbit to the snout tip related to snout-casque length of 0.31–0.35 (RSCSV); heterogeneous scalation at the lower arm, consisting mostly of tubercles of large diameter (DSA, 0.4–0.9 mm); number of scales in a line on the lower arm 11–26 (NSA); 11–15 supralabials (NSL); 12–15 infralabials (NIL; with an exception of the male *C. vohibola* with 18); tail length related to SVL with a maximum of 126 % (RTaSV) in a male *C.* cf. *guibei*. Occipital lobes (OL) and dorsal crests (DC) can occur in both groups (see Table 1). As it is typical for all other species of the *C. nasutum* group, *C. vatosoa* does not show any striped midventral pattern.

Despite the complete absence of a rostral appendage in *Calumma vatosoa*, our data demonstrate that this species is morphologically much more similar to the other species of the *C. nasutum* group than to the species of the *C. furcifer* group (see Table 1) and we, therefore, suggest transferring

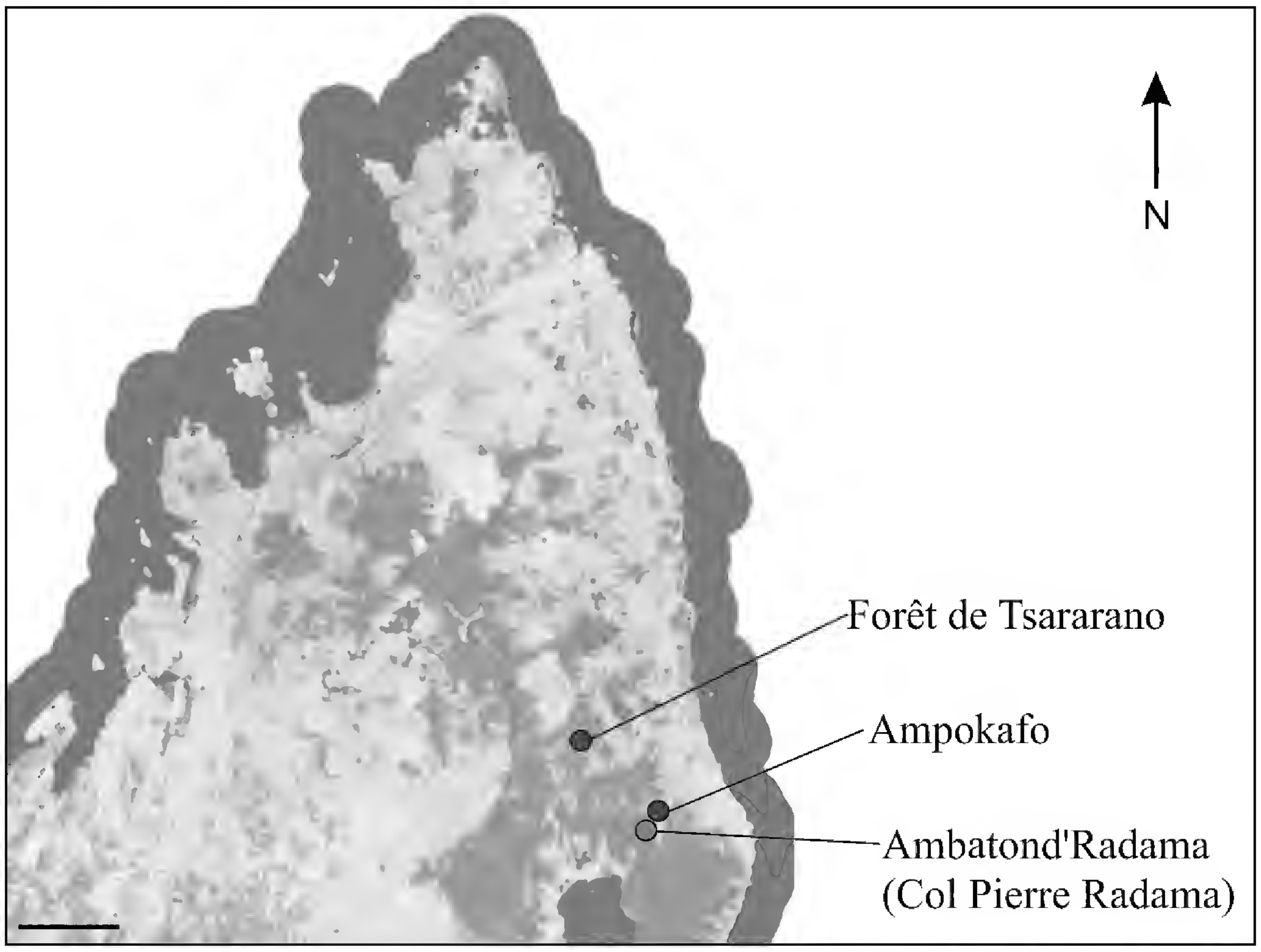


Figure 3. Map of northern Madagascar with previously known localities of *Calumma vatosoa* (purple circles) and the new locality of the females (red circle). Vegetation legend: humid forest (green), wooded grassland-bushland mosaic (beige), plateau grassland-wooded grassland mosaic (light beige), western dry forest (red), mangroves (pink), cultivation (light pink), littoral forest (purple), wetlands (grey). Scale bar = 50 km. Map from www.vegmad.org.

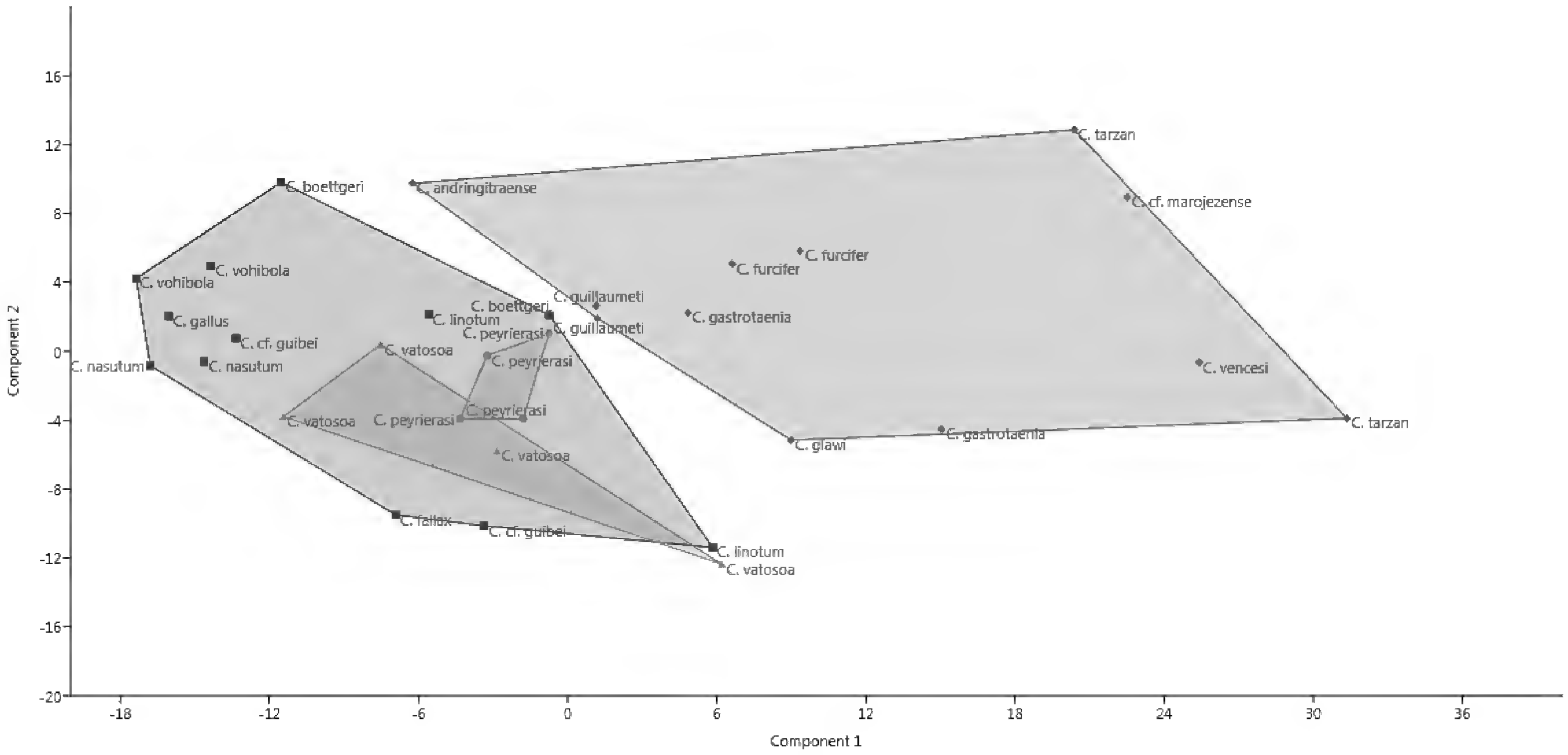


Figure 4. PCA of the species of the *Calumma furcifer* group (n = 12; blue diamonds), the *C. nasutum* group (n = 12; green squares), *C. vatosoa* (n = 4, red triangles) and *C. peyrierasi* (n = 4; yellow dots) based on 11 measurements/counts (SVL, TaL, LRA, RSCSV, RHWSV, ROSSC, CH, DSA, NSA, NSL and NIL of Table 1); Component 1 explains 73.93 % and Component 2 17.49 % of the variance.

it to the *C. nasutum* group. A PCA (Fig. 4, Table 2) clearly separates both groups explaining 73.93 % and 17.49 % of the total variance in PC I and PC II and places *C. vatosoa* within the *C. nasutum* group. Excluding body and tail length, important characters to differentiate between the *C. furcifer* and *C. nasutum* group (NSA, NIL, ROSSC and DSA) are shown in the graphs of Fig. 5, comfirming that, *C. vatosoa* is placed among the species of the *C. nasutum* group.

Systematic position of *Calumma peyrierasi*. As an additional part of this work, the morphological similarity of *C. peyrierasi* to either the *C. nasutum* or *C. furcifer* group was investigated. The following morphological differences from the species of the *C. furcifer* group were identified (see Table 1): larger diameter of tubercles on lower arm (DSA, 0.7–0.8 mm vs. 0.3–0.6 mm); lower number of scales in a line on the lower arm (NSA, 17–22

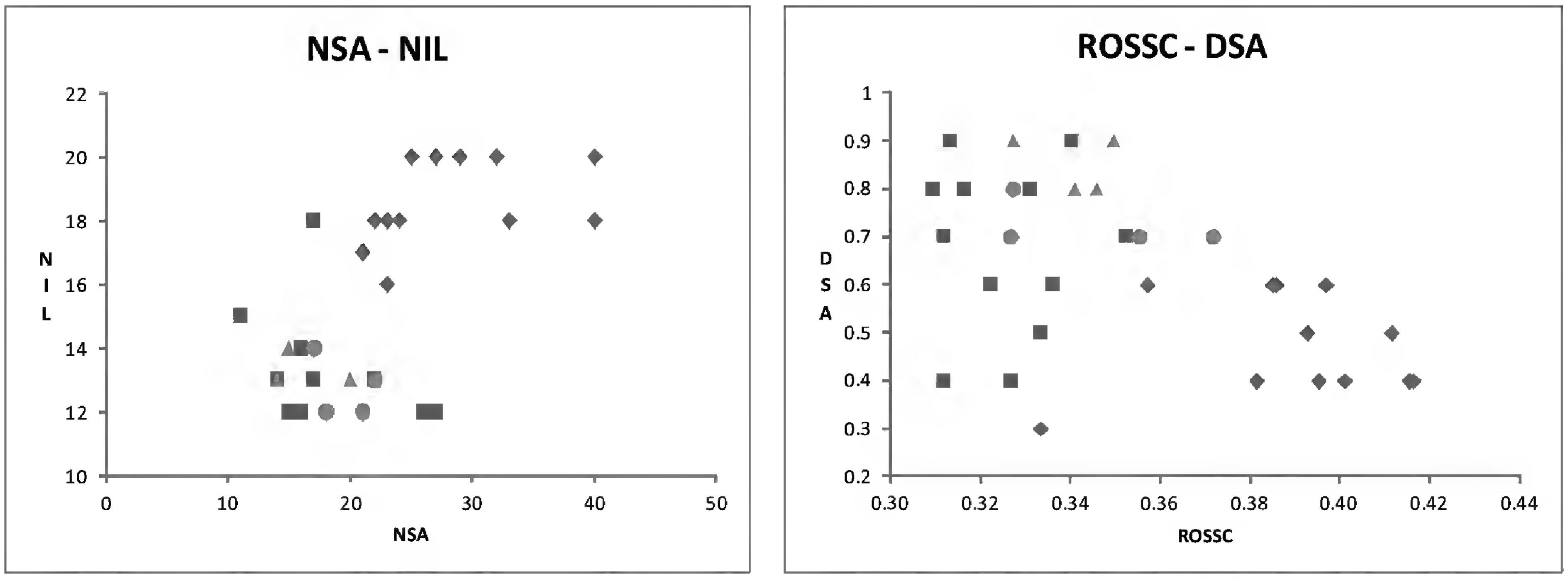


Figure 5. Important characters for the distinction of the *Calumma furcifer* group (n = 12; blue diamonds) and the *C. nasutum* group (n = 12; green squares), including the assignment of *C. vatosoa* (n = 4, red triangles) and *C. peyrierasi* (n = 4; yellow dots). Abbreviations: NSA, number of scales on lower arm in a line from elbow to manus; NIL, number of infralabial scales; DSA, diameter of largest scale on lower arm; ROSSC, ratio of distance from the anterior margin of the orbit to the snout tip and snout-casque length.

Table 2. Factor loadings for PC I–III for the investigated species of *Calumma furcifer* group and *C. nasutum* group (n = 28, Fig. 4)

	PC 1	PC 2	PC 3
SVL	0.6191	0.0197	0.4210
TaL	0.6271	0.5870	0.3080
LRA	0.0623	0.0506	0.1596
RSCSV	0.0001	0.0001	0.0001
RHWSV	0.0001	0.0004	0.0009
ROSSC	0.0019	0.0015	0.0045
CH	0.0155	0.0590	0.0350
DSA	0.0061	0.0171	0.0043
NSA	0.4238	0.7522	0.4997
NSL	0.1388	0.2008	0.4582
NIL	0.1429	0.2062	0.4914
Eigenvalue	161.885	38.306	9.210
%variance	73.928	17.493	4.206

vs. 21–40); lower number of supralabials (NSL, 12–13 vs. 15–21) and infralabials (NIL, 12–14 vs. 16–20). In terms of colouration, all species of the *C. furcifer* group show a distinct pattern of a beige midventral stripe that is bordered by a white line on each side. In *C. peyrierasi* there is only one distinct ventral stripe of white colour.

Compared to the species of the *Calumma nasutum* group the complete absence of a rostral appendage, the homogeneous scalation on the extremities, the predominantly greenish colouration, and the ventral stripe are atypical characters. Nevertheless, *C. peyrierasi* is placed among the species of the *C. nasutum* group in the PCA (Fig. 4) and in the graphs showing the distinctive characters of both groups (Fig. 5).

Discussion

In this work we have enlarged the knowledge of the poorly known chameleon species *Calumma vatosoa* and improved the systematics within the *C. nasutum* group and the *C. furcifer* group. On the basis of external morphology, osteology, and distribution we assign the specimens, which were collected by Bluntschli, to *C. vatosoa* instead of *C. linotum*, and provide the first description of females of this species. Andreone et al. (2001) tentatively assigned *C. vatosoa* to the *C. furcifer* group; however, after comparing the morphology and osteology of the investigated females and the holotype of *C. vatosoa* to all other species of the *C. furcifer* group, we demonstrate that the analysed characters of *C. vatosoa* are more typical of the *C. nasutum* group (Table 1) except for the absence of a rostral appendage and the presence of axillary pits. These characters appear to be variable, because axillary pits occur occasionally within the *C. nasutum* group (Prötzel, unpublished data) and the rostral appendage is strongly reduced in *C. vohibola* (see Table 1) and other members of the *C. nasutum* group (Prötzel, unpublished data). Molecular analyses are necessary to clarify the phylogenetic position of *C. vatosoa* in the *nasutum* group and if the appendage was secondarily reduced as was shown in *Furcifer campani* and *F. lateralis* by the phylogeny in Tolley et al. (2013). In the *C. nasutum* group the rostral appendage is relevant for sexual selection as demonstrated for *C. nasutum* (Parcher 1974), but sexual dimorphism in the length or the shape of the rostral appendage is weak or absent (e.g. in *C. boettgeri* according to Eckhardt et al. 2012). This is true for all members of the *C. nasutum* group with the exception of *C. gallus*. Accordingly the rostral appendage may play an important role in interspecific communication and species recognition as some species respectively candidate species of the *C. nasutum* group live sympatrically (Gehring et al. 2012).

The osteology of the skull of *Calumma vatosoa* is similar to other members of the *C. nasutum* group, e.g. the shape of the nasalia and the frontal (Prötzel, unpublished data) and shows only weak sexual dimorphism. In contrary to Mertens (1933) within the *C. nasutum* group the dorsal crest is not a constant character either, as this character can be present or absent in male *C. boettgeri* (Prötzel et al. 2015). Andreone et al. (2001) described the hemipenis ornamentation of *C. vatosoa* as exclusive within the genus *Calumma* due to their three pairs of rotulae. However, in our study on *C. linotum* (Prötzel et al. 2015) a hemipenis showed, in addition to the two pairs of rotulae that are typical for *C. boettgeri* and *C. linotum*, a third pair of rotulae. Consequently, even the morphology of hemipenes can be variable within a species, and three pairs of rotulae is not a unique character of *C. vatosoa*.

In conclusion, *C. vatosoa* is assigned as a member of the multifaceted *C. nasutum* group. A molecular study of the species would be helpful to confirm this assignment. Similarly, the morphological analyses of *C. peyrierasi* confirm its phylogenetic position in the *C. nasutum* group as revealed by Tolley et al. (2013)

Acknowledgements

We are grateful to Franco Andreone from the Museo Regionale di Scienze Naturali (Torino, Italy) and Gunther Köhler and Linda Acker from the Senckenberg Museum, Frankfurt/ Main (Germany), for loaning us specimens under their care. We furthermore thank Franco Andreone, Joachim Nopper, Johannes Penner and Krystal Tolley for reviewing the manuscript. Our thanks also go to Julia Forster, Inbar Maayan, and Mark D. Scherz for their support in writing the manuscript.

References

Andreone F, Mattioli F, Jesu R, Randrianirina JE (2001) Two new chameleons of the genus *Calumma* from north-east Madagascar, with observations on hemipenal morphology in the *Calumma furcifer* group (Reptilia, Squamata, Chamaeleonidae). Herpetological Journal 11: 53–68.

Brygoo ER (1971) Reptiles Sauriens Chamaeleonidae – genre *Chamaeleo*. Faune de Madagascar 33: 1–318.

Brygoo ER (1978) Reptiles Sauriens Chamaeleonidae – genre *Brookesia* et complément pour le genre *Chamaeleo*. Faune de Madagascar 47: 1–173.

Eckhardt FS, Gehring PS, Bartel L, Bellmann J, Beuker J, Hahne D, Korte J, Knittel V, Mensch M, Nagel D, Pohl M, Rostosky C, Vierath V, Wilms V, Zenk J, Vences M (2012) Assessing sexual dimorphism in a species of Malagasy chameleon (*Calumma boettgeri*) with a newly defined set of morphometric and meristic measurements. Herpetology Notes 5: 335–344.

Gehring PS, Pabijan M, Ratsoavina FM, Köhler J, Vences M, Glaw F (2010) A Tarzan yell for conservation: a new chameleon, *Calumma tarzan* sp. n., proposed as a flagship species for the creation of new nature reserves in Madagascar. Salamandra 46(3): 167–179.

Gehring PS, Ratsoavina FM, Vences M, Glaw F (2011) *Calumma vohibola*, a new chameleon species (Squamata: Chamaeleonidae) from the littoral forests of eastern Madagascar. African Journal of Herpetology 60: 130–154. doi: 10.1080/21564574.2011.628412

Gehring PS, Tolley KA, Eckhardt FS, Townsend TM, Ziegler T, Ratsoavina F, Glaw F, Vences M (2012) Hiding deep in the trees: discovery of divergent mitochondrial lineages in Malagasy chameleons of the *Calumma nasutum* group. Ecology and Evolution 2: 1468–1479. doi: 10.1002/ece3.269

Glaw F (2015) Taxonomic checklist of chameleons (Squamata: Chamaeleonidae). Vertebrate Zoology 65(2): 167–246.

Glaw F, Köhler J, Townsend TM, Vences M (2012) Rivaling the world's smallest reptiles: Discovery of miniaturized and microendemic new species of leaf chameleons (*Brookesia*) from northern Madagascar. PLoS ONE 7(2): e31314. doi: 10.1371/journal.pone.0031314

Glaw F, Vences M (1994) A fieldguide to the amphibians and reptiles of Madagascar. Vences & Glaw Verlag, Köln, 480 pp.

Hammer Ø, Harper DAT, Ryan PD (2001) PAST: paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 9.

Jenkins RKB, Andreone F, Andriamazava A, Anjeriniaina M, Brady L, Glaw F, Griffiths RA, Rabibisoa N, Rakotomalala D, Randrianantoandro JC, Randrianiriana J, Randrianizahana H, Ratsoavina F, Robsomanitrandrasana E (2011) *Calumma vatosoa*. The IUCN Red List of Threatened Species 2011: e.T172928A6943225. [downloaded on 12 November 2015]

Lutzmann N, MacKinnon J, Gehring PS, Wilms TM (2010) A new record of the rarely found Chameleon, *Calumma vatosoa* Andreone, Mattioli, Jesu & Randrianirina 2001. Sauria 32(4): 65–66.

Mertens R (1933) Die Reptilien der Madagaskar-Expedition Prof. Dr. H. Bluntschli's. Senckenbergiana biologica 15: 260–274.

Müller L (1924) Ueber ein neues Chamaeleon aus Madagaskar. Mitteilungen aus dem Zoologischen Museum in Berlin 11: 95–96.

Parcher SR (1974) Observations on the natural histories of six Malagasy Chamaeleontidae. Zeitschrift für Tierpsychologie 34: 500–523. doi: 10.1111/j.1439-0310.1974.tb01818.x

Prötzel D, Ruthensteiner B, Scherz MD, Glaw F (2015) Systematic revision of the Malagasy chameleons *Calumma boettgeri* and *Calumma linotum* (Squamata: Chamaeleonidae). Zootaxa 4048(2): 211–231. doi: 10.11646/zootaxa.4048.2.4

Raxworthy CJ, Nussbaum RA (2006) Six new species of occipital-lobed *Calumma* chameleons (Squamata: Chamaeleonidae) from montane regions of Madagascar, with a new description and revision of *Calumma brevicorne*. Copeia 2006(4): 711–734. doi: 10.1643/0045-8511(2006)6[711:SNSOOC]2.0.CO;2

Rieppel O, Crumly C (1997) Paedomorphosis and skull structure in Malagasy chamaeleons (Reptilia: Chamaeleoninae). Journal of Zoology 243(2): 351–380. doi: 10.1111/j.1469-7998.1997.tb02788.x

Tolley KA, Townsend TM, Vences M (2013) Large-scale phylogeny of chameleons suggests African origins and Eocene diversification. Proceedings of the Royal Society 280(1759): 20130184. doi: 10.1098/rspb.2013.0184

Townsend TM, Tolley KA, Glaw F, Böhme W, Vences M (2011) Eastward from Africa: palaeocurrent-mediated chameleon dispersal to the Seychelles islands. Biology Letters 7(2): 225–228. doi: 10.1098/rsbl.2010.0701

Viette P (1991) Principales localités où des insectes ont été recueillis à Madagascar: Chief field stations where insects were collected in Madagascar. Faune de Madagascar, supplement 2: 1–88.

Zoosyst. Evol. 92 (1) 2016, 23–31 | DOI 10.3897/zse.92.5789

PENSOFT. museum für naturkunde

Polycheria josephensis, a new species of symbiotic amphipod (Crustacea, Amphipoda, Dexaminidae) from the Northern Gulf of Mexico, with notes on its ecology

John M. Foster[1], Brent P. Thoma[2,3]

1 *Marine Taxonomy Associates, PO Box 35672 Panama City, Florida 32412*
2 *Department of Biology, PO Box 43602, University of Louisiana-Lafayette, Lafayette, Louisiana 70504-3602*
3 *Present Address: Department of Biology, Jackson State University, 1400 J. R. Lynch St., P.O. Box 18540, Jackson, MS 39217*

http://zoobank.org/B1FF8521-2845-4EAE-A8D8-295ECB9C4881

Corresponding author: *Brent P. Thoma* (brent.thoma@gmail.com)

Received 1 August 2015
Accepted 26 November 2015
Published 29 January 2016

Academic editor:
Michael Ohl

Key Words

Amphipoda
commensal
ascidian
Florida
taxonomy
new species

Abstract

Polycheria josephensis **sp. n.** (Dexaminidae), an ascidian symbiont, is described from St. Joseph Bay, Florida and other locations in the Gulf of Mexico and the nearshore Atlantic Ocean from South Carolina to northern Florida. Observations on its ecology, behavior, and distribution are provided. *Polycheria josephensis* **sp. n.** is morphologically most similar to *Polycheria osborni* Calman, 1898 from the Pacific coast of North America. *Polycheria josephensis* **sp. n.** differs from *P. osborni* in the number, spacing and size of the spines on the inner plate of the maxilliped and the shape of the distal margins of coxae 1-7.

Introduction

More than twenty nominal species or "forms" attributed to the dexaminid amphipod genus *Polycheria* Haswell, 1879 have been reported from coastal marine waters of Africa, Antarctica, East Asia, North America, South America, Australia, New Zealand, Indonesia, the Indian Ocean and the Southern Ocean near Antarctica (Barnard and Karaman 1991; Debroyer and Jazdzewski 1993; Bousfield and Kendall 1994; Myers and LeCroy 2009). The type species, *Polycheria tenuipes*, was described from Port Jackson, Australia by Haswell (1879). Although specimens conforming to the genus *Polycheria* have been reported from sites throughout the Gulf of Mexico, the Caribbean Sea, and along the Atlantic coast from Florida to South Carolina, these specimens do not appear to be attributable to any known species (LeCroy 2004).

Species of *Polycheria* are known to create and occupy cavities on the surfaces of compound ascidians and sponges (Skogsberg and Vansell 1928, Arndt 1933, Lambert 1979). However, the genus is not exclusive to the sponge and ascidian substrata as there are reports of *Polycheria* living among algae, stones, and gravel (Schellenberg 1931) and two reports of it occurring on a gorgonian (Dauby et al. 2001; LeCroy 2004).

During recent surveys of the crustacean fauna of St. Joseph Bay, located on the Florida Panhandle in the northeastern Gulf of Mexico, specimens of an undescribed species of the genus *Polycheria* were found associated with several species of compound ascidians. Herein we describe this new species and provide observations on the ecology and range.

Abbreviations. Institutions and museums from which material was borrowed are abbreviated as follows: USNM

– Smithsonian Institution, Washington, D.C; GCRL – Gulf Coast Research Laboratory, University of Southern Mississippi; SERTC – Southeast Regional Taxonomic Center, South Carolina Department of Natural Resources, Charleston, South Carolina. Depth, when given, is in meters (m); ppt refers to salinity in parts per thousand. Additional abbreviations used in this study include: MX1 – maxilla 1; MX2 – maxilla 2; rMD – right mandible; lMD – left mandible; UL – upper lip; LL – lower lip; MP – maxilliped; GN1 – gnathopod 1; GN2 – gnathopod 2; P3-P7 – pereopods 3 through 7; URO – urosome; U1-U3 – uropods 1 through 3; T – telson.

Systematic account

Family Dexaminidae Leach

Genus *Polycheria* Haswell, 1879

Polycheria josephensis sp. n.

http://zoobank.org/043D6B70-275D-40C3-8074-01C94503A821
Figs 1–4

Polycheria sp. A, LeCroy 2004: 480
Polycheria sp. Camp et al. 1998: 128

Type material. Holotype: male, 4.2 mm, USNM 1297736, host - *Eudistoma* sp., 11 June 2004, St. Joseph Bay, Florida, 200 m northwest of Blacks Island, 29°43.73'N 85°19.23'W, depth 1.0 m, 35 ppt, 32°C, coll. J.M. Foster and B.P. Thoma.

Paratypes: 5 vials. 4 males, 14 females, 6 females, 7 males, 26 unsexed; USNM 1297737-1297741, host *Didemnum* sp., St. Joseph Bay, Florida, 200 meters north of Blacks Island, 29°47.73 N 85°19.82 W, depth 1.0-2.0 m, 35 ppt, 32°C, coll. J Foster and B. Thoma.

Other materials. 1 male, 2 females, 1 ovigerous female, USNM 1297742 host *Aplidium stellatum* Verrill, 20 July 2004, St. Joseph Bay, Florida, 400 m west of Blacks Island, 29°43.62'N 85°20.00'W, depth 1 m, 30 ppt, 30°C, coll. J.M. Foster and B.P. Thoma; 1 male, 1 female, 1 ovigerous female, USNM 1297743, host *Eudistoma hepaticum* (Van Name), 14 July 2004, St. Joseph Bay, Florida, 200 m northwest of Blacks Island, 29°43.73'N 85°19.23'W, depth 1 m, 33 ppt, 29°C, coll. J.M Foster and B.P. Thoma; 6 ovigerous females, 23 juveniles, GCRL 06535, host *Didemnum* sp., 20 July 2004, St. Joseph Bay, Florida, 200 m northwest of Blacks Island, 29°43.73'N 85°19.23'W, depth 1 m, 33 ppt, 29°C, coll. J.M. Foster and B.P. Thoma; 6 males, 5 females, USNM 1297744, beach wash-up of *Didemnum* sp. and algae, 25 December 1997, St. Joseph Bay, Florida, Palm Point, 29°50.45'N 85°20.10'W, 27 ppt, 19°C, coll. J.M. Foster; 4 males, 1 female, 1 juvenile, USNM 1297745, host *Eudistoma* sp., on artificial substrate, 4 December 2004, St. Joseph Bay, Florida, 0.6 km southwest of Blacks Island, 29°43.21'N 85°20.40'W, depth less than 1.0 m, 29 ppt, 10°C, coll. J.M. Foster and B.P. Thoma. 6 females, USNM 205641, host *Distaplia bermudensis* (Van Name), Apalachee Bay, 8 km off Alligator Point, Florida, 4 February 1955, coll. E.L. Pierce; 1 male, host unknown, USNM 238408, Apalachee Bay, 8 km off Alligator Point, Florida, February, 1960, coll. C.E. King; 1 male, USNM 221129, Western Atlantic, off Georgia, 31°23'35"N 80°53'12"W, 20 January 1980, 19 m, suction sample; 1 male, NOAA w194MR31, Florida Bay, core sample; 2 males. 4 females, 1 juvenile, SERTC S 849, 32 km off St. Catherine's Island, Georgia, 31°03'47"N 80°03'36"W, 20 m, 20 September 1982; 5 males, 10 females, 1 juveniles, SERTC S 847, off Amelia Island, Florida, 30°06.3'N 81°01.7'W, 20 m, 4 August 1980, suction device; 2 males, SERTC S 848, off Sapelo Island, Georgia, 31°03.9'N 81°08.6'W, 19 m, 30 January 1980, suction device.

Diagnosis. Male (not terminal male) - Head with anteroventral margin rounded, eye one-third width of head. Pereopod 3 coxa with acute anteroventral process, length 2-3 times basal width. Pereopod 7 coxa with lobate posteroventral margin. Epimeral plates 2-3 without ventral spines; epimeral plate 1 with 2-3 short posterodistal spines; epimeral plate 2-3 with posteroventral setules; epimeral plate 3 rounded posteroventrally, ventral margins with plumed setae. Urosomite 1 with a short, elevated process projected posteriorly; urosomites 2-3 with dorsolateral carinae. Epimeron 3 ventral margin with slender plumed setae; uropod 1 peduncle with ventral a proximal fringe of slender plumed setae.

Description. Male (not terminal male) – Head with anteroventral margin rounded, slightly shorter than pereonites 1 and 2 combined; eye one-third width of head, ovate, red in life, brown in alcohol; rostrum absent.

Antennae subequal; antenna 1 with peduncle article 1 shorter than 2, flagellum of 10–20 articles. Antenna 2 with peduncular article 5 shorter than 4; flagellum of 14–15 articles. Mandible with 4 spines on left side, 3 on right side. Molars triturative and unequal in size, palp absent. Lower lip with outer lobe not projecting laterally. Upper lip with apical margin broadly rounded with fine lateral and facial setae. Maxilla 1 with inner plate having apex rounded, one terminal setule; outer plate truncate terminally with 6-8 spines; palp subequal to outer plate, sublinear, not tapering distally, 5–6 terminal and subterminal setae. Maxilla 2 inner plate expanded distally, half the length of outer plate with 3–4 stiff setae and a few terminal plumed setae. Maxilliped palp with 4 present articles, subequal in length to outer plate, article 4 with nail; outer plate with inner margin having 15 spines and facial setae proximally; inner plate greater than one-third length of outer plate, with distal setae.

Gnathopod 1 coxa with anteroventral margin produced into a strong tooth, basis sublinear, equal to distal segments combined, anteromedial margin with 4-5 elongate

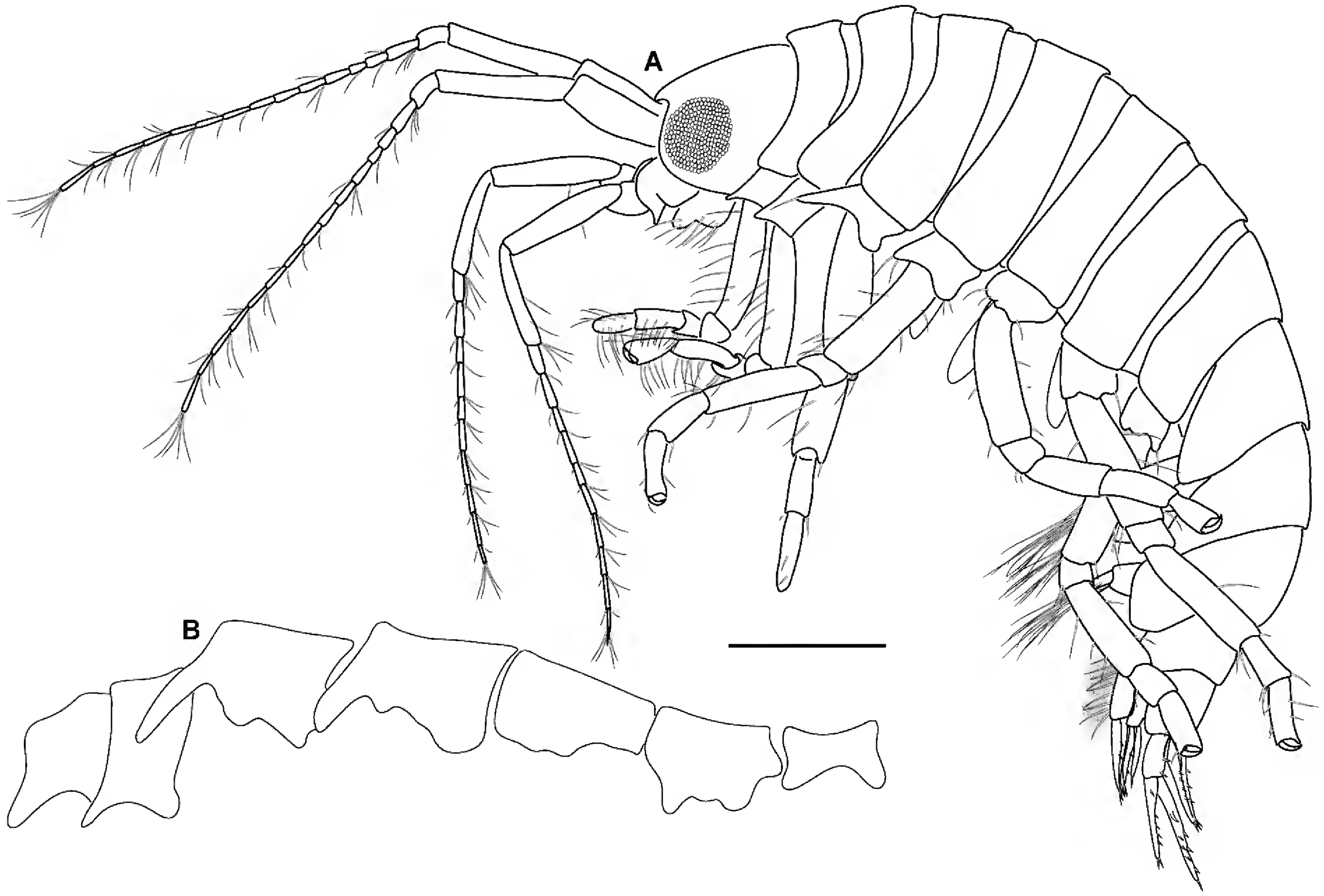


Figure 1. *Polycheria josephensis* sp. n. (St. Joseph Bay, Florida) **A** whole animal **B** coxae 1-7: female, 5.0 mm, Paratype, USNM 1297737, 200 meters north of Blacks Island, St. Joseph Bay, Florida. Scale = 1.0 mm (**A**), 0.5 mm (**B**).

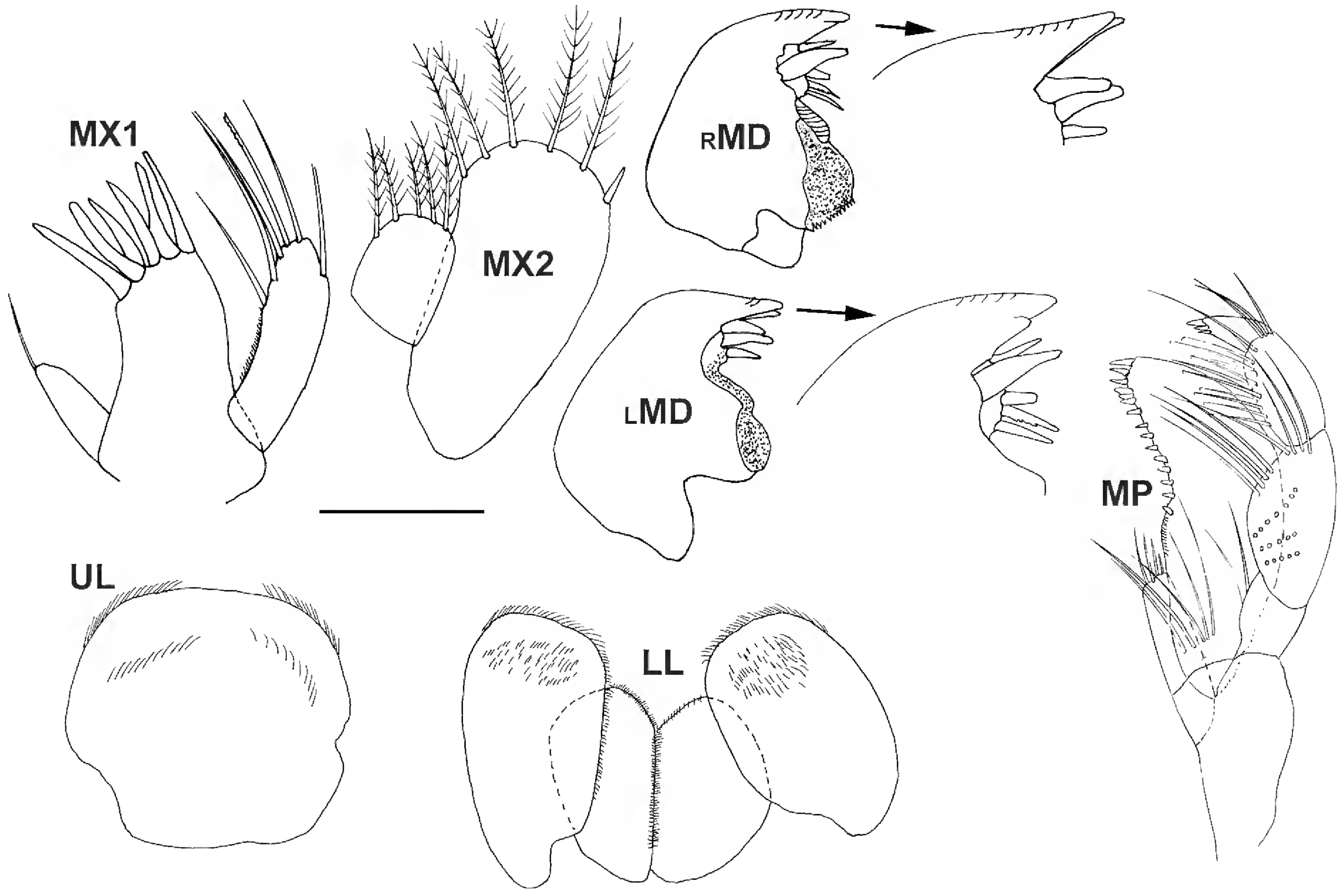


Figure 2. *Polycheria josephensis* sp. n. ♂, 5.0 mm, Paratype, USNM 1297738, 200 meters north of Blacks Island, St. Joseph Bay, Florida. Scale = 0.10 mm; MP = 0.25 mm.

setae and several shorter setae; merus shorter than carpus, carpus slightly longer than propodus, anterior and posterior margins with long simple and plumed setae; palm much shorter than dactyl and finely pectinate; dactyl broadly curved.

Gnathopod 2 coxa with anteroventral margin with a small triangular tooth, produced ventrally; basis as in gnathopod 1; merus shorter than carpus, posterior margin with elongate setae; carpus longer than propodus, ventral margin with a row of elongate simple setae; propodus expanded distally, ventral margin with pectinate setae, dorsal margin with distal elongate simple setae; palm short and broadly convex, dactyl falcate and finely pectinate, less than half the length of palm.

Pereopod 3 with anteroventral margin of coxa produced into a strong ventrally directed tooth, length twice its basal width; posteroventral margin of coxa rounded; basis with posterodistal setae, merus shorter than basis, subequal to carpus and propodus combined, with one short posterodistal spine and 2-3 posterior marginal setae; carpus slightly shorter than propodus, posterodistal and anterodistal angles with short spines; propodus with posterodistal margin produced with 2-3 spines, anterior margin with 2-3 distal spines; palm with one short distomedial spine.

Pereopod 4 with anteroventral margin of coxa produced into a blunt tooth, posteroventral margin broadly lobate, produced; basis with slender anteromarginal and posteromarginal setae; merus linear, longer than carpus and propodus combined, with 3 short anteromarginal spines.

Pereopod 5 with anteroventral and posteroventral margins of coxa rounded, not produced; basis with long anteromarginal and posteromarginal simple setae; merus longer than carpus, with anteromarginal and posteromarginal simple setae; carpus longer than propodus with posteromarginal setae; propodus with short spines and long setae on anterior and posterior margins.

Pereopod 6 coxa with ventral angles rounded, not produced; basis subequal to merus, with a small proximal expansion on the posterior and anterior margins, with 2-3 posterodistal spines; carpus subequal to propodus with one long anterodistal spine; merus with 3-4 anteromarginal setae and 4-5 short, stiff anteromarginal spines; propodus with a cluster of 2-3 anteromarginal spines, palm with one short distomedial spine, posterior margins produced into a short tooth at dactyl closure.

Pereopod 7 with posteroventral margin of coxa strongly produced into a narrow lobe, with length equal to basal width; basis linear with anteromarginal and posteromarginal setae; merus shorter than basis with a cluster of anterodistal spines; carpus short, less than half the length of merus, with anterodistal and posterodistal spines; posterior margin of propodus produced distally, with 2-3 spines, anterior margin with 1 short spine and a cluster of simple setae, distomedial margin with one strong spine; dactyl falcate, closing on posterodistal spine cluster.

Epimeron 1 with posteroventrally acuminate, ventral margin with 2–3 short, curved spines; Epimeron 2 with anteroventral margin with simple setae; Epimeron 3 with posteroventral margin quadrate; ventral margin with elongate plumed setae. Urosomite 1 with posteroventral margin with several long plumed setae; dorsal marginal keel bearing an acute posterior process. Urosomites 2–3 fused to a mid-dorsal saddle-shaped indentation; with 0–3 dorsal spines and with dorsolateral margins forming keels, running out to form acute lobes. Uropod 1 shorter than uropod 3; peduncle fringed with ventral plumed setae; rami subequal; subequal to inner ramus; rami with marginal spines and long apical spines on both rami. Uropod 2 shorter than uropod 1; peduncle less than half the length of inner ramus; inner ramus shorter than outer ramus; rami with long apical spines. Uropod 3 with peduncle shorter than rami, 2 spines distally; rami wide proximally, tapering to apices; both rami strongly spinose marginally; inner ramus longer than outer ramus; longer than uropod 1 and telson. Telson broadly lanceolate, acute distally; length more than twice its width; cleft at least 90 percent to base; with 4–6 lateral spines; apical spines present, equal to marginal spines.

Females are indistinguishable from non-copulatory males, except for the presence of penes in the male or brood plates in the female.

The terminal male is characterized by the following: (1) dense pubescence on antenna 2, article 3; (2) long marginal setae on rami of uropod 3; (2) strong row of dorsolateral spines on the peduncle of uropod 1; (4) a row of short spines on the ventral margin of epimera 1-2-3; (5) coxal plates reduced, especially coxa 3 which has no strong anteroventral process, with the exception of coxa 1 which has well developed anteroventral process; (6) uropod 2 with marginal spines at least twice width of the rami.

Habitat. Symbiotic with compound ascidians (*Eudistoma hepaticum*, *Eudistoma* sp., *Didemnum* sp., *Distaplia bermudensis*, *Aplidium stellatum*) in sand and seagrass (*Thalassia testudinum*) communities.

Depth range. 1–20 meters.

Distribution. Gulf of Mexico-Florida: St. Joseph Bay, Alligator Harbor, Seahorse Key, Florida Bay. Western Atlantic: Amelia Island, Florida; Sapelo Island, Georgia; Gray's Reef off Charleston, South Carolina.

Etymology. This species is named for its type locality, St. Joseph Bay, Florida (Gulf County, Florida).

Discussion. Specimens of *Polycheria josephensis* sp. n. from St. Joseph Bay, Florida conform morphologically to *Polycheria* sp. A of LeCroy (2004) from the same locality. Males are similar to females except in the terminal form. Material examined from the Atlantic coast off Georgia (Gray's Reef; Sapelo Island) and from the Gulf of Mexico (Amelia Island, Florida Bay, and Alligator Harbor) appear to be assignable to *Polycheria josephensis* sp. n. (LeCroy 2004); however, these individuals may

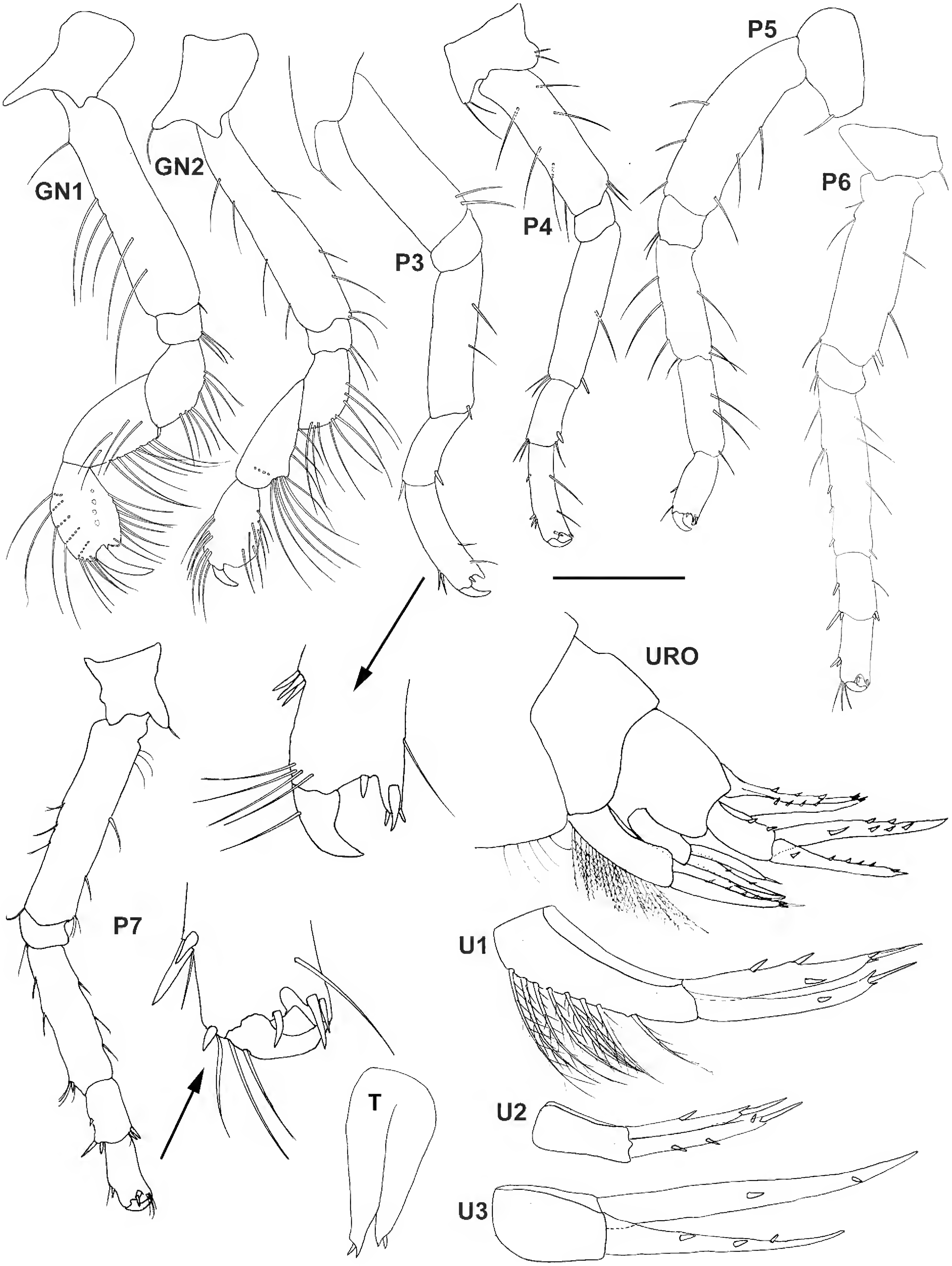


Figure 3. *Polycheria josephensis* sp. n. ♂, 5.0 mm, Paratype, USNM 1297738, 200 meters north of Blacks Island, St. Joseph Bay, Florida. Scale = 0.5 mm GN1 – P7; 1.0 mm URO; 0.3 mm U1-T.

represent cryptic species and warrant further investigation using molecular techniques.

Polycheria josephensis sp. n. is most similar to *Polycheria osborni* Calman, 1898 in both male and female forms but can easily be separated by the number of spines on the inner plate of the maxilliped and the shape of coxae 1 and 7. The inner plate of the maxilliped of *P. josephensis* sp. n. bears 14-15 short, stout spines on the inner margin, while *P. osborni* has 8 larger, wider spaced marginal spines. Additionally, the anteroventral margin of coxa 1 is projected anteriorly, but blunt in shape in *P. osborni*, while in *P. josephensis* sp. n. coxa 1 it is acute and strongly projected. Coxa 7 differs in shape between the two species with the anteroventral margin being unproduced and rounded in *P. josephensis* sp. n. versus produced and acute in *P. osborni*.

When examining materials of *P. osborni* from the Gulf of California, Bousfield and Kendall (1994) described and illustrated the terminal, or copulatory, male and the female, but did not differentiate the copulatory male from the sub-terminal males. In both of these species, the sub-terminal males are quite similar to females, but can be differentiated by the presence of a larger number of spines on the uropods, epimeral plates, and pereopods. Additionally, the male antennae are much more setose.

Representatives of the genus *Polycheria* are typified by conservative sexual dimorphism. With the exception of the terminal males, non-ovigerous females and sub-terminal males of *P. josephensis* sp. n. are superficially identical. Sex of specimens was determined by the presence of oostegites or of penes on the mesial surface of the basis of pereopod 7. Additionally, the sexes differ in antenna length (females have subequal antennae and males have shorter first antennae) and eye size, with males having slightly larger eyes. The latter character has limited value when differentiating large non-ovigerous females from smaller males.

In the collections from St. Joseph Bay, Florida during a four-year study (2004–2008), males tended to occur in collections less frequently than females. The terminal male form was quite rare, with only two specimens observed from more than 500 specimens examined during 2004. The typical sex ratio throughout the collection, performed on individual tunicates, was: Terminal males: 2; males (with penes): 286; females (with and without eggs): 288.This ratio suggests that terminal supermales are capable of supporting a large population of *P. josephensis* sp. n. in St. Joseph Bay, Florida, which raises the question of the function of the supermale form, if not required exclusively for copulation and fertilization. Further studies of population ratios and laboratory observations of mating behaviour will clarify this issue.

Undescribed *Polycheria* material from several areas of the Caribbean Sea bear distinct similarities to *P. josephensis.* Material from Curacao conforms to *P. josephensis* sp. n. in the presence of a strong tooth on the anteroventral margin of coxae 1 and 3, the rounded anteroventral margin of the head, the presence of plumed setae on the ventral margins of epimera 3 and the peduncle of uropod 1. This undescribed material differs from *P. josephensis* sp. n. by its strongly produced posteroventral lobe on coxa 7 and its fewer marginal spines on the telson. *Polycheria josephensis* sp. n. is the only material of *Polycheria* examined from the Gulf of Mexico, Caribbean Sea, and the U.S. Atlantic coast with a rounded posteroventral margin on coxa 7. The significance of this character will be assessed as more material is examined from the region. Undescribed material from Puerto Rico varies considerably from *P. josephensis* in the length of the anteroventral projection of coxa 1 having a projection at least three times the length of *P. josephensis*. The material consists of only a single specimen, so the significance of this character will become evident upon the examination of more materials from Puerto Rico.

Ecological notes. *Polycheria josephensis* sp. n. is a common member of the marine invertebrate community of St. Joseph Bay, Florida where it occupies excavations, or burrows, on the tough, semi-transparent tunicin layer of several species of compound ascidians including *Eudistoma hepaticum, E. obscuratum*, *Aplidium stellatum,* and *Didemnum* sp. These records are in addition to the previous records of occurrence with *Aplidium* sp., reported by LeCroy (2004) from the same body of water and the other records from Apalachee Bay. The exact nature of these relationships, such as the structural adaptations between the hosts and the amphipod, is not well known.

In June, 2004, the examination of more than 20 specimens of *Eudistoma hepaticum*, a massive tunicate reaching lengths greater than 20 cm, indicated that *Polycheria josephensis* sp. n. constructs cavities on the exposed surfaces of the tunicate host rather than in folds of the tunic or on the undersides (Figure 4A–C). *Didemnum* sp., colonies are usually found attached to seagrass blades rather than in unattached, discrete colonies like *Eudistoma* spp. Members of this genus are also found as fouling on dead and living pen shells (*Atrina* spp.) or other available hard substrates. Observations of *Polycheria josephensis* sp. n. burrowed in *Didemnum* spp. indicate behavior similar to those individuals found on *Eudistoma*, where the amphipods form excavations on the test (Figure 4D–E).

Laboratory observations indicate that domicile cavities are similar in shape and size to that of the amphipod. When in the excavation, *Polycheria* lies on its back with antennae, uropods, and pereopods (except pereopod 5) facing the opening of the shallow cavity it occupies. The fifth pereopod usually projects downward toward the host and splayed slightly from each side of the body. A possible explanation for this behavior is to provide stability or attachment in the burrow. The amphipod is capable of creating feeding currents with its appendages and filtering food materials from the water. The pleopods beat continuously, providing a current of water toward the antennae. According to Skogsberg and Vansell (1928) and personal observations, the first and second antennae are held vertically and still during this feeding process. At a

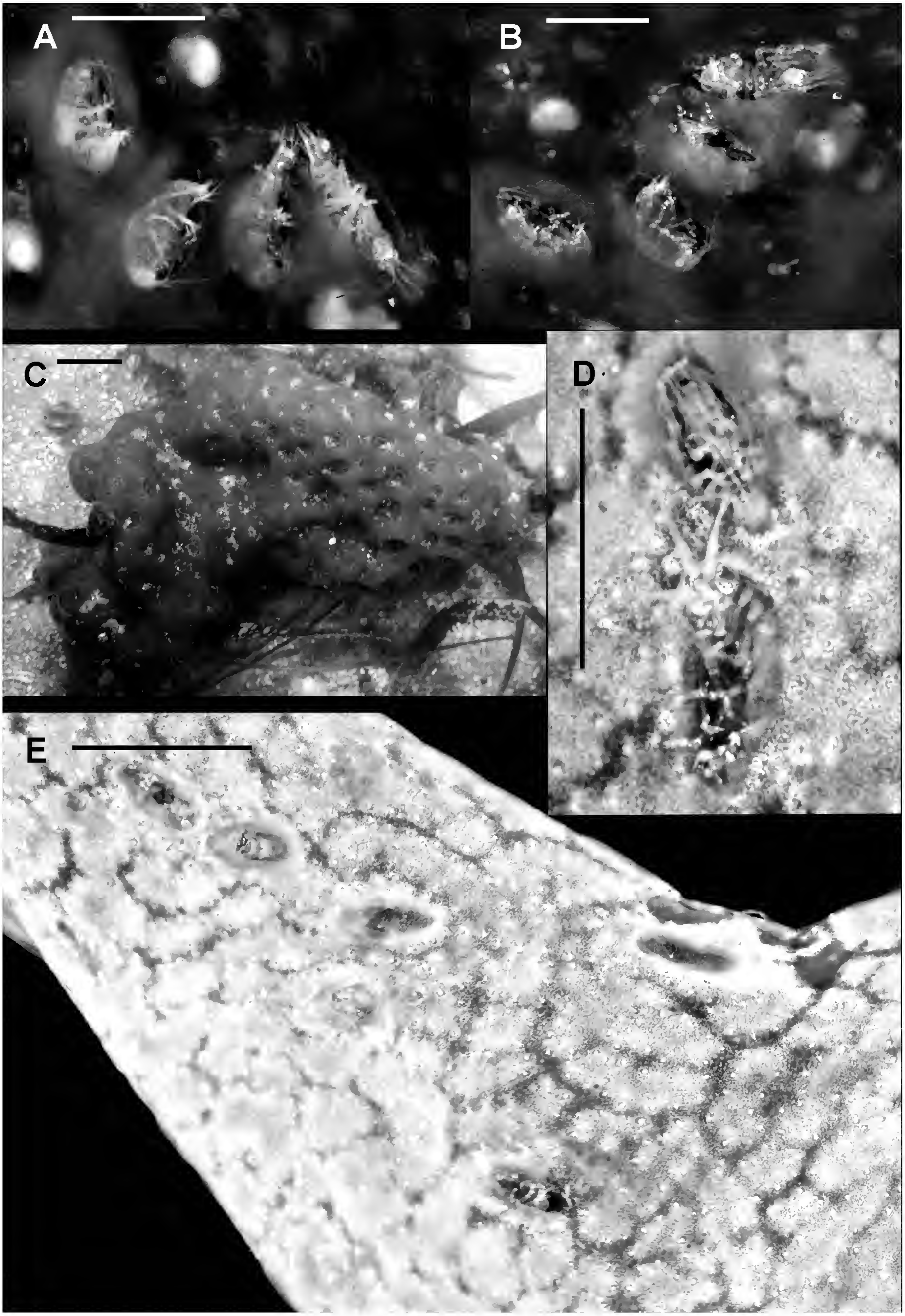


Figure 4. **A–B** closeup of *Polycheria josephensis* sp. n. *in situ* in tunicin of *Eudistoma hepaticum* **C** *in situ* photo of *E. hepaticum* **D** close-up of *Polycheria josephensis* sp. n. *in situ* in tunicin of *Didemnum* sp. **E** *Polycheria josephensis* sp. n. *in situ* in tunicin of *Didemnum* sp. Scale = 5 mm (**A, B, D**); 25 mm (**C**); 10 mm (**E**).

point when food is detected and captured from the passing water current by the posterior setae of the antennae, the flagellum bends at the last peduncular segment and drawn toward the body. The gnathopods and maxilliped seize the antennae and comb the setae for food, which is then transferred to the mouthparts. Microscopic gut analyses show *Polycheria josephensis* sp. n. feeds mainly on diatoms, which it filters from in the current as described several workers (Skogsberg and Vansell 1928; Ricketts et al. 1968; Bousfield and Kendall 1994; and Dauby et al. 2001) for other related species.

The amphipod controls exposure of the burrow to the outside environment by opening and closing the edges of tunic with the prehensile dactyls of the pereopods 3-7. Observations made in St. Joseph Bay, Florida of *Polycheria josephensis* sp. n. opening and closing the excavation conform to those reported from California for the species *P. osborni*. *Polycheria josephensis* sp. n. does not appear to be a motile feeder and seldom leaves its burrow except in response to stress created by reduced oxygen or physical disturbance.

In St. Joseph Bay, Florida, dense populations of *Polycheria josephensis* sp. n. are often found as clusters of adult and juvenile burrows on the tunicate's test (Figure 4A–B, D–E). The clustering condition may result from the behavior of juveniles clinging to the tunicate upon leaving the mother's oostegites until they can make burrows of their own or find refuge in abandoned cavities. As juveniles likely have limited ability to burrow, individuals that cannot locate existing, unoccupied burrows may be washed away by currents thus providing a potential mechanism for dispersal (Skogsberg and Vansell 1928; Ricketts et al. 1968; Barnard 1975). However, this pattern of juveniles clustered near adults, along with a lack of morphological adaptations potentially linked with increased motility (ie., dense setation on, or flattening of, the pereopods) suggests that this mechanism is likely of limited capacity. As a result of this limited dispersal potential, individual host specimens may act as islands of suitable habitat and thus may result in decreased rates of gene flow between groups of *Polycheria* from different host specimens. Future studies investigating the population genomics and connectivity of this species, particularly on small geographic scales, are warranted as they may reveal increased rates of molecular diversification and endemism than what is expected based solely on morphological diversity.

The density of burrowed amphipods on several *Eudistoma* specimens (averaging 10 cm by 5 cm) from St. Joseph Bay, Florida was about 6–12 occupied burrows per square centimeter of total surface area. This level was the highest among all the density observations in the present study. It corresponds to the reported 10–12 amphipods per sq. cm. on several species of the sponge *Ircinia* in Tunisia (Rutzler 1976). No other reports of tunicate density of *Polycheria* have been located in the literature. Although species of *Polycheria* are a common commensal of sponges in the Southern Ocean (Dauby et al. 2001), representatives of the genus have not been observed in sponges in the current study. Furthermore, field notes on museum specimens and literature searches have revealed no records of *Polycheria* associated with sponges from the Gulf of Mexico and Caribbean Sea. This may suggest that greater phylogenetic diversity than is evidenced by present systematic schemes.

Available information about the host selection and feeding behavior of *Polycheria*, drawn from the literature, field observations, and notes from museum collections indicate that members of the genus primarily live symbiotically with sponges and ascidians. There is no firm consensus, supported by data, regarding the nature of those relationships, particularly as to whether the interactions are commensal, as defined in classical terms (Dauby et al. 2001; McClintock et al. 2009; Schmidt et al. 1995), or ectoparasitic, including the consumption the host's biomass (Skogsberg and Vansell 1928; Kunzmann 1996).

In a study of sponge dwelling Crustacea from the Weddell Sea, Kunzmann (1996) characterized *Polycheria* as an ectoparasite due to the presence of sponge spicules in the gut. However, Dauby et al. (2001) reported *Polycheria antarctica* to be a commensal organism since only diatoms and organic debris were found in the gut contents of specimens collected in their study. Presumably, an ectoparasite, feeding on the host sponge would have spicule fragments in its gut, but feeding on host tissues does not constitute the only reliable evidence of parasitism (R.W. Overstreet, pers. comm.) The nature of the symbiosis between sponges and tunicates and amphipods of the genus *Polycheria* remains open to future research as investigations thus far have resulted in conflicting results.

Acknowledgements

The authors thank R. W. Heard, R.W. Overstreet, and S. E. LeCroy (University of Southern Mississippi, Gulf Coast Research Laboratory), J.D. Thomas (Nova Southeastern University), and Katrin Linse (British Antarctic Survey) for their helpful comments and encouragement.

References

Arndt W (1933) Die biologischen Beziehungen zwischen Schwämmen und Krebsen. Mitteilungen aus dem Zoologischen Museum in Berlin 19: 221–325.

Barnard JL (1975) Amphipoda Gammaridea. In: Smith RI, Carlton JT (Eds) Light's Manual. Intertidal Invertebrates of the Central California Coast, 3rd edition, University of California Press, Berkeley, 313–366, pls. 70–85.

Barnard JL, Karaman GS (1991) The families and genera of marine gammaridean Amphipoda (except marine gammaroids). Records of the Australian Museum. Supplement 13, parts 1 and 2. The Australian Museum, Sydney, 866 pp.

Bousfield EL, Kendall JA (1994) The amphipod superfamily Dexaminoidea on the North American coast: Families Atylidae and Dexaminidae: Systematics and distributional ecology. Amphipacifica 1(3): 3–66.

Calman WT (1898) On a collection of Crustacea from Puget Sound. Annals of the New York Academy of Science 11: 259–292. doi: 10.1111/j.1749-6632.1898.tb54972.x

Camp DK (1998) Checklist of shallow-water marine malacostracan Crustacea of Florida. In: Camp DK, Lyons WG, Perkins TH (Eds) Checklists of selected shallow-water marine invertebrates of Florida. Florida Marine Research Institute Technical Reports No. TR-3, 123–189.

Dauby Y, Scailteur Y, DeBroyer C (2001) Trophic type diversity within the eastern Weddell Sea amphipod community. Hydrobiologia 443(1–3): 69–86. doi: 10.1023/A:1017596120422

Debroyer C, Jazdzewski K (1993) Contribution to the marine Biodiversity Inventory: a check list of the Amphipoda (Crustacea) of the Southern Ocean. Studiedocumenten van het K.B.I.N.: Documents de Travail de l'l R. Sc. N. B., 73. Koninklijk Belgisch Institut voor Natuurwetenschappen, Brussels, Belgium, 154 pp.

Haswell WA (1879) On some additional new genera and species of amphipodous crustaceans. Proceedings of the Linnaean Society of New South Wales 4: 319–350, plates 18–24.

Kunzmann K (1996) Die mit ausgewählten Schwämmen (Hexactinellida und Demospongiae) aus dem Weddellmeer, Antarktis, vergesellschaftete Fauna. Ber Polarforsch 210: 1–93.

Lambert G (1979) Early post-metamorphic growth, budding and spicule formation in the compound ascidian Cystodytes lobatus. Biological Bulletin 157: 464–477. doi: 10.2307/1541031

LeCroy SE (2004) An illustrated identification guide to the nearshore marine and estuarine gammaridean Amphipoda of Florida: Volume 3, Families Bateidae, Biancolinidae, Cheluridae, Colomastigidae, Corophiidae, Cyproideidae and Dexaminidae. Florida, 618 pp.

McClintock JB, Amsler MO, Koplovitz G, Amsler CD, Baker BJ (2009) Observations on an association between the dexaminid amphipod *Polycheria antarctica* form *acanthopoda* and its ascidian host *Distaplia cylindrica*. Journal of Crustacean Biology 29: 605–608. doi: 10.1651/09-3146.1

Myers AA, LeCroy SE (2009) Dexaminidae. In: Lowry JK, Myers AA (Eds) Benthic Amphipoda (Crustacea: Peracarida) of the Great Barrier Reef, Australia. Zootaxa 2260: 393–424.

Ricketts EF, Calvin J, Hedgpeth J (1968) Between Pacific Tides, Fourth Edition. Stanford University Press, Stanford, California, 614 pp.

Rutzler K (1976) Ecology of Tunisian commercial sponges. Tethys 7(2–3): 249–264.

Schellenberg A (1931) Gammariden und Caprelliden des Magellangebietes, Sudgeorgiens und der Westantarktis. Further Zoological Results of the Swedish Antarctic Expedition 1901–1903 2(6): 1–290.

Schmidt GD, Roberts LS, Janovy J (1995) Foundations of Parasitology. 5th edition. William Brown Publishers, 659 pp.

Skogsberg T, Vansell GH (1928) Structure and behavior of the amphipod, *Polycheria osborni*. Proceedings of the California Academy of Sciences, series 4, 17: 267–295, 26 Figs.

Zoosyst. Evol. 92 (1) 2016, 33–78 | DOI 10.3897/zse.92.5936

PENSOFT. museum für naturkunde

Annotated catalogue of the types of Triphoridae (Mollusca, Gastropoda) in the Museum für Naturkunde, Berlin, with lectotype designations

Paolo G. Albano[1], Piet A.J. Bakker[1,2]

1 *Department of Palaeontology, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria*
2 *Naturalis Biodiversity Center, Darwinweg 2, 2333 CR Leiden, The Netherlands*

http://zoobank.org/71689C6B-D5AB-48CB-8785-8B43999F6379

Corresponding author: *Paolo G. Albano* (pgalbano@gmail.com)

Received 29 August 2015
Accepted 9 December 2015
Published 19 February 2016

Academic editor:
Matthias Glaubrecht

Key Words

Type specimens
Indo-Pacific province
South Africa
Western Australia
Cuba
Wilhelm Dunker
Eduard von Martens
Johannes Thiele

Abstract

Triphoridae is a family of marine caenogastropods with worldwide distribution. Its maximum diversity is in the Indo-Pacific province, where it is among the five most species-rich families. Taxonomic knowledge is scant and complicated by the high diversity and intra-specific variability. Knowledge of type specimens of described taxa is the fundamental first step for a taxonomic revision of the family. The Museum für Naturkunde hosts one of the most significant triphorid collections, which includes material described by W. Dunker, L. Pfeiffer, J. Thiele and E. von Martens. Type material of 29 species is described and illustrated; where appropriate, lectotypes have been designated to stabilize nomenclature. The specimens of one species, *Triforis delicatula* Thiele, do not fully match the original description and we refrain from selecting a lectotype, although we profusely illustrate them. Although not type material, specimens of *Triforis tricincta* Dunker have been included in this work to contribute to the knowledge on Dunker's species. For all species, the original descriptions in German or Latin are reported, with a full translation into English, and remarks have been added where appropriate.

Introduction

Triphoridae Gray, 1847 is a family of marine caenogastropods, whose adult shell ranges in size from 2 to 10 mm, but exceptionally reaches up to 50 mm. A characteristic feature of this family is that most species have a sinistral shell. Their maximum diversity and abundance extends from the intertidal zone to offshore in 200–500 m depth, and few species live in truly deep water below 1,000 m. Numerous anecdotal in situ observations (e.g., Lebour 1937, Marshall 1994, Poppe 2009) point to a close association with Porifera, but no specific study has been conducted on sponge-triphorid interactions. Triphorids are distributed world-wide, but the highest diversity is found in the tropical seas, and especially in the Indo-Pacific province, where they are regarded as one of the five most species-rich families (Bouchet et al. 2002). Taxonomically, the family is regarded as one of the most difficult among gastropods, because of the high number of species and the poorly understood intra- and inter-specific variability. Moreover, with few exceptions (e.g., Janssen 1993 for some Dunker's taxa; Higo et al. 1999 for some taxa described by Kosuge; Jay 2007 for Deshayes' and Jousseaume's taxa from Réunion Island) no published information is available on historical type material, which is often in bad condition (Bouchet and Strong 2010). Therefore, the thorough analysis of type material is a priority, especially in the perspective of describing the many new species which await a name: 70% of the 259 morphospecies segregated from the "Santo 2006" expedition to Vanuatu are supposed to be new to science (Albano et al. 2011). The most significant museum collections hosting triphorid type material are in the Natural History Museum of the United Kingdom (NHMUK), London, in the Muséum national d'Histoire naturelle (MNHN), Paris, in the Australian Museum (AM), Sydney, in the National Science Museum (NSMT), Tokyo, in the United States National Museum of Natural History (USNM), Washington, and in the Museum für Naturkunde (ZMB), Berlin. This paper aims to document all type material of Triphoridae housed in the Museum für Naturkunde as a first step towards a thorough revision of the family.

Methods

This work is based on an inventory carried out by the first author in the malacological collection of the Museum für Naturkunde. A catalogue of the whole collection, whether type material or not, has been compiled. This thorough analysis allowed the recognition of material unrecognized as type so far, such as syntypes of *Cerithium pusillum* Pfeiffer L., 1840. Also specimens belonging to species described by W.R. Dunker have been thoroughly analysed: some belong to described taxa (*T. fusca*, *T. tricincta*), while others bear a name which does not appear to have been formally introduced anywhere. The former have been included in this catalogue, even if not recognized as type material, while the latter belong to the long list of *nomina nuda* introduced on the basis of material provided by the Museum Godeffroy (Bieler and Petit 2012) and are not treated here.

In the catalogue below, the species name in its original combination is given, followed by bibliographic details of the original description. Lectotypes have been selected from syntypes in several cases to stabilize the nomenclature in the perspective of a full revision of the family. Lectotype designation follows the provisions of Art. 74 of the International Code of Zoological Nomenclature, 4th Edition. The type locality is given as stated in the original description, with the original orthography; the modern English name and geographic coordinates are provided. Depths were rarely reported in Thiele's original descriptions and were also gathered from Michaelsen and Hartmeyer (1907) for south-western Australian taxa, and from other monographs of the "Wissenschaftliche Ergebnisse der Deutschen Tiefsee-Expedition..." series. One special case is station 81 "Große Fischbucht" of the German Deep-sea Expedition, which is located off Baía dos Tigres in Angola. Samples from this location could, however, been mislabelled and refer to a sampling event in Agulhas Bank (Kilburn 1996). The coordinates of the station 100 are also reported differently: Thiele (1925: 6[40]) stated that its latitude is 34°38.9'S (for Fissuridea algoensis), but other volumes of the series on the German Deep-sea Expedition reported 34°8.9'S (e.g., the monograph on Gorgonaria, Kükenthal 1919). Original descriptions in the original language (German or Latin) are reported, with a full translation into English. A diagnosis is provided, focusing on the most significant diagnostic characters as discussed by Marshall (1983). These include chirality (sinistral, dextral), order of appearance of teleoconch spiral cords (in particular to separate species in which the second cord appears last versus those in which the first cord appears last), size, number of whorls (to discriminate species with planktotrophic from those with non-planktotrophic development) and sculpture (number of keels, spacing of axial riblets, microsculpture of first whorl) of the protoconch, shell profile (pupoid vs. narrowly elongated), colour of the teleoconch, number and sculpture of teleoconch spiral cords, and microsculpture between them; characters of the last adult whorl: number and sculpture of cords on base and behind outer lip, development and position of posterior siphonal canal/tube. Where appropriate, additional remarks are given. Species are listed in the text grouped by major biogeographical province, i.e.: Caribbean, South Africa, Indo-Pacific province, and Antarctica, to improve usability to readers. A taxon list in alphabetical order is provided in Table 1.

For each species, a plate has been mounted with both digital and SEM photos to illustrate the overall appearance of the species as well as details (e.g., peristome, apex, microsculpture). The holotype or lectotype is always illustrated, but often photos of paralectotypes or their details have been added. The original figure and

Table 1. List of treated taxa in alphabetic order, with original name, author and date, type locality and page and figure in this paper.

Taxon	Author and date	Type locality	Page, figure
adela, *Triphora*	Thiele, 1930	Shark Bay, Station 25 (-0.5/3.5 m), Western Australia	Page 19, Figure 12
aequatorialis, *Triphora*	Thiele, 1925	Off Zanzibar, East Africa Station 244 (5°55.8'S, 39°1.2'E, -50 m)	Page 21, Figure 13
aethiopica, *Triphora*	Thiele, 1925	Off Zanzibar, East Africa Station 244 (5°55.8'S, 39°1.2'E, -50 m)	Page 22, Figure 14
agulhasensis, *Triphora*	Thiele, 1925	Cape Agulhas, South Africa Station 95 (34°51'S, 19°37.8'E, -80 m)	Page 5, Figure 2
albina, *Triphora*	Thiele, 1930	Shark Bay, Station 1 (-7/8 m), Western Australia	Page 22, Figure 15
alboapicata, *Triphora*	Thiele, 1930	Shark Bay, Station 3 (-3 m), Western Australia	Page 23, Figure 16
algoensis, *Triphora*	Thiele, 1925	South Africa Stations 81 (16°26.5'S, 11°41.5'E), 95 (34°51'S, 19°37.8'E, -80 m), 100 (34°38.9'S, 24°59.3'E, -100 m), 101 (33°50.5'S, 25°48.8'E, -40 m)	Page 7, Figure 3

Taxon	Author and date	Type locality	Page, figure
brevis, *Triphora*	Thiele, 1925	Algoa Bay, South Africa 101 (33°50.5'S, 25°48.8'E, - 40 m)	Page 7, Figure 4
brunnescens, *Triphora*	Thiele, 1930	Shark Bay, Stations 16 (-11/12.5 m) and 20 (-0/3.5 m),Western Australia	Page 26, Figure 17
capensis, *Triphora*	Thiele, 1925	South Africa Stations 81 (16°26.5'S, 11°41.5'E), 95 (34°51'S, 19°37.8'E, -80 m), 100 (34°38.9'S, 24°59.3'E, -100 m), 101 (33°50.5'S, 25°48.8'E, -40 m)	Page 8, Figure 5
castaneofusca, *Triphora*	Thiele, 1930	Shark Bay, Station 3 (-3 m), Western Australia	Page 26, Figure 18
cingulata, *Triforis*	Dunker, 1860	Japan	Page 41, Figure 28
crassula, *Triforis*	Martens, 1880	Mauritius	Page 26, Figure 19
delicatula, *Triforis*	Thiele, 1912	Antarctica, -385 m	Page 44, Figure 31
dilecta, *Triphora*	Thiele, 1925	Cape Agulhas, South Africa Station 95 (34°51'S, 19°37.8'E, -80 m)	Page 10, Figure 6
dives, *Triphora*	Thiele, 1925	Off Zanzibar, East Africa Station 244 (5°55.8'S, 39°1.2'E, -50 m)	Page 30, Figure 20
elata, *Triphora*	Thiele, 1930	Shark Bay, Station 25 (-0.5/3.5 m), Western Australia	Page 30, Figure 21
erecta, *Triphora*	Thiele, 1925	Agulhas Bank, South Africa Station 104 (35°16'S, 22°26.7'E, -155 m)	Page 13, Figure 7
fusca, *Triforis*	Dunker, 1860	Japan	Page 26, Figure 22
fuscoapicata, *Metaxia*	Thiele, 1930	Shark Bay, Station 10 (-7/11 m), Western Australia	Page 32, Figure 23
ignobilis, *Triphora*	Thiele, 1925	Off Zanzibar, East Africa Station 244 (5°55.8'S, 39°1.2'E, -50 m)	Page 34, Figure 24
innocens, *Triphora*	Thiele, 1925	South Africa Stations 95 (34°51'S, 19°37.8'E, -80 m) and 106 (35°26.8'S, 20°56.2'E, -100 m)	Page 13, Figure 8
patricia, *Triphora*	Thiele, 1925	South Africa Stations 95 (34°51'S, 19°37.8'E, -80 m), 105 (35°29'S, 21°2.5'E, -102 m) and 106 (35°26.8'S, 20°56.2'E, -100 m)	Page 16, Figure 9
plebeja, *Triphora*	Thiele, 1925	South Africa Stations 100 (34°38.9'S, 24°59.3'E, -100 m), 101 (33°50.5'S, 25°48.8'E, -40 m) and 106 (35°26.8'S, 20°56.2'E, -100 m)	Page 16, Figure 10
pusillum, *Cerithium*	Pfeiffer, 1840	Cuba	Page 3, Figure 15
regia, *Triphora*	Thiele, 1925	Zanzibar Channel, East Africa Station 245 (5°27.9'S, 39°18.8'E, -463 m)	Page 36, Figure 25
sceptrum, *Triphora*	Thiele, 1925	Dar es Salaam, Tanzania, East Africa Station 242 (6°34.8'S, 39°35.5'E, -404 m)	Page 38, Figure 26
subulata, *Triphora*	Thiele, 1930	Shark Bay, Stations 1 (-7/8 m), 3 (-3 m), 9 (-3.5/11 m), 12 (-7/11 m), 14 (-11/16 m), 16 (-11/12.5 m) and 20 (-0/3.5 m), Western Australia	Page 38, Figure 27
superba, *Triphora*	Thiele, 1925	Agulhas Bank, South Africa Station 104 (35°16'S, 22°26.7'E, -155 m)	Page 18, Figure 11
tricincta, *Triforis*	Dunker, 1882	-	Page 41, Figure 28
tubifera, *Triphora*	Thiele, 1925	West Sumatra, Indonesia Station 193 (0°30.2' N, 97°59.7'E, -132 m)	Page 41, Figure 29
virginalis, *Triphora*	Thiele, 1925	Sumatra, Indonesia	Page 43, Figure 30

photos of the labels have been added as well. Specimens have been photographed with a Leica Z16-APO-A motorized microscope and DFC-490 camera, while SEM images have been taken without gold coating with a low vacuum ZEISS EVO-LS-10 microscope.

Abbreviations

NHMUK	Natural History Museum of the United Kingdom, London
ZMB	Museum für Naturkunde, Berlin
SMF	Naturmuseum Senckenberg, Frankfurt.

Catalogue of type material of Triphoridae

Caribbean species

Cerithium pusillum Pfeiffer L., 1840

Figure 1
Cerithium pusillum L. Pfeiffer, 1840: 256, not illustrated.

Type specimens. Lectotype: ZMB/Moll no. 117874a, here designated. Paralectotype A: ZMB/Moll no. 117874b; further 49 paralectotypes (ZMB/Moll no. 117874).

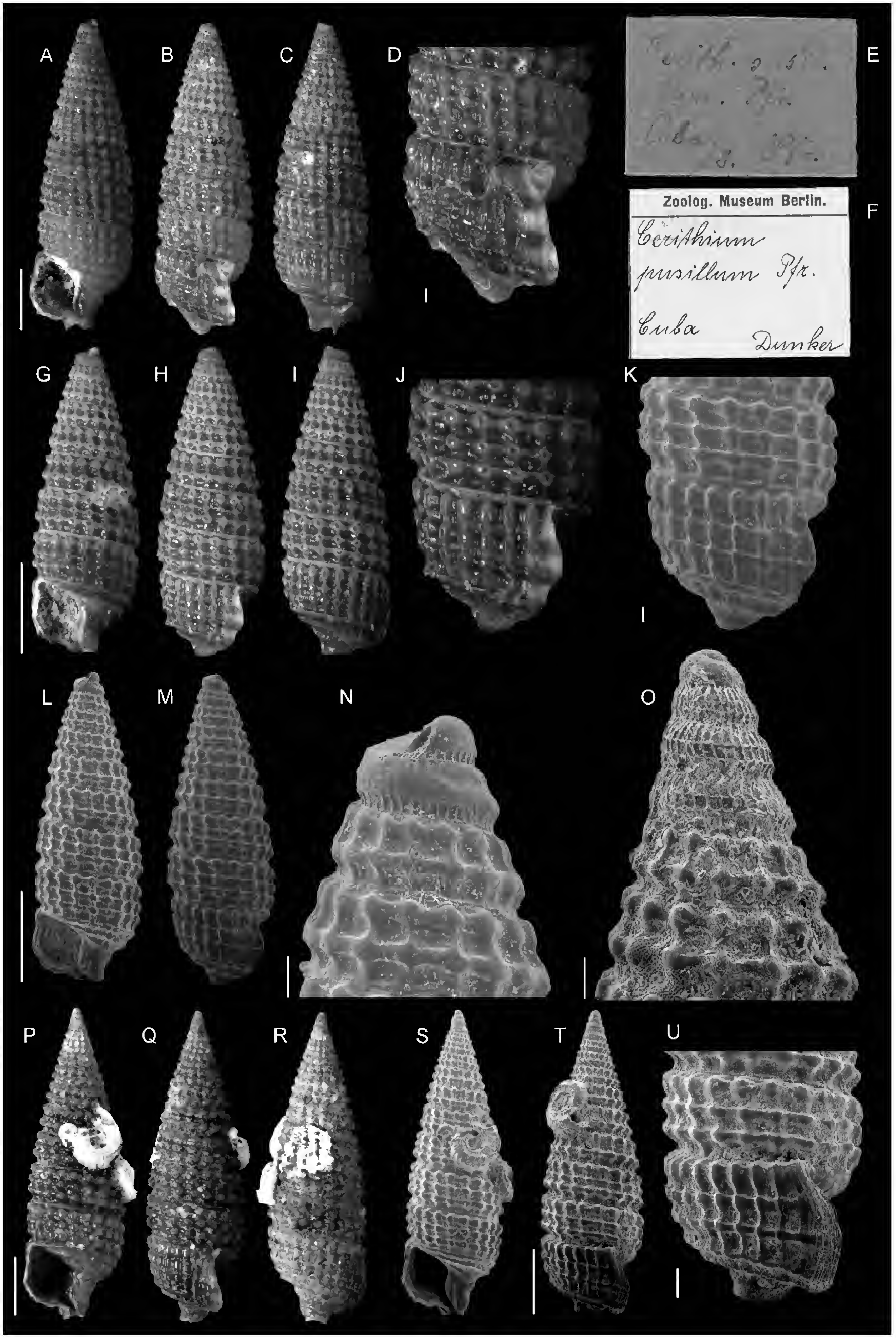


Figure 1. *Cerithium pusillum* Pfeiffer L., 1840. **A-D**. Lectotype, Cuba, ZMB/Moll no. 117874a: front (**A**), left side (**B**), back (**C**) and peristome (**D**). **E-F**. Original labels. **G-N**. Paralectotype A, Cuba, ZMB/Moll no. 117874b: front (**G, L**), left side (**H, M**), back (**I**) peristome (**J-K**), apex (**N**). **O-S**. *Cerithium pusillum* Pfeiffer, 1840. "Westindien", Dunker Collection, ZMB/Moll no. 117875a: front (**P, S**), side (**Q**), back (**R**) and apex (**O**). **T-U**. *Cerithium pusillum* Pfeiffer, 1840. "Westindien", Dunker Collection, ZMB/Moll no.117875b: side (**T**) and peristome (**U**). Scale bar: 1 mm, except **D**, **J-K**, **N-O**, **U**: 0.1 mm.

Type locality. Cuba.

Original description. *Testa sinistrorsa turrita tenui cinnamomea; anfract. 11 planis, sulcis longitudinalibus et transversis granuloso-decussatis; sutura profunda; canali brevissimo, vix recurvo; labro simplice, expanso. Long. 2½, diam. ¾ lin.*

Translation. A light brown sinistral shell composed of 11 flat whorls with tubercled spiral ribs. Deep suture. Siphonal canal very short, barely bent. Lip simple, expanded. Length 2.5 *linien ("lines")*, diameter 0.75 *linie* (L. Pfeiffer probably used the "Preussische Mass" widely used after 1816 until introduction of the metric system; a *linie* is equivalent to 2.179 mm).

Diagnosis. Lectotype height 5.2 mm, but shells up to 6 mm are present in the type material. Pupoid shape, with deep sutures. Teleconch of 7-9 whorls. Three granulated spiral cords present: the second appears later, in the second half of the spire. A smooth suprasutural cord also present. The last whorl has a fourth weakly tubercled spiral cord, and the base has further two smooth spiral cords. Peristome simple, without bifurcating cords. Multispiral apex of 4-5 whorls, the lower three with two spiral keels and axial riblets. Colour brown; lip white with brown bands.

Remarks. Rolán and Fernández-Garcés (2008) considered this taxon a *nomen dubium*. Indeed, L. Pfeiffer's type specimens were thought to be in the Cuming collection (NHMUK) or in the Dhorn collection in the Stettin Museum, which was totally destroyed during the II World War (Dance 1966). Rolán visited the NHMUK without reporting any material on this species (Rolán and Fernández-Garcés 2008). Pfeiffer did not illustrate the species, and the original description is very brief.

In the ZMB/Moll there are two lots of this species from the Dunker collection. The first lot is labelled *Cerithium pusillum* (Fig. 1, E) and composed of 51 mostly worn specimens from Cuba, and obtained from Pfeiffer ("Pfr." on label). This material is consistent with the original description. These specimens are therefore considered to belong to the type series. To stabilize nomenclature, the best preserved specimen is here designated as the lectotype (Fig. 1, A-D, ZMB/Moll no. 117874a). Among the 50 paralectotypes, another well preserved specimen was segregated as 'paralectotype A' and here illustrated (Fig. 1, G-M, ZMB/Moll no. 117874b). The second lot contains 13 far better preserved specimens labelled as coming from "Westindien" (= Western Indies) and also from the Dunker collection. They are clearly conspecific with *Cerithium pusillum*, and provide a useful addition for a better illustration of fine diagnostic characters (e.g. apex sculpture) but are not considered to be types.

South African species

Triphora agulhasensis Thiele, 1925

Figure 2
Triphora agulhasensis Thiele, 1925: 128 (94), plate XXII (X), figure 17.

Type specimens. Lectotype: ZMB/Moll no. 109268a, here designated. Paralectotype A: ZMB/Moll no. 109268b.

Type locality. "Station 95 [Cap Agulhas]" (South Africa).

Original description. *Zwei Schalen von Station 95 sind der vorigen Art [*Triphora patricia*] zwar recht ähnlich, aber weniger schlank, die Kante der letzten Windung ist weniger scharf und darunter noch ein zweiter Reifen. Es sind etwa 9 Windungen vorhanden, deren erste wie bei der vorigen Art geformt und skulptiert sind, auch hier haben die folgenden 3 Körnerreihen und einen glatten Reifen. Dieser bildet bei der letzten Windung die untere Kante, die etwas stumpfwinklig ist, unter ihr sind noch 2 Reifen sichtbar. Spindelfortsatz mäßig lang, gerade, Mündung rautenförmig. Höhe 5 mm, Durchmesser 1,6 mm.*

Translation. Two shells from Station 95 are quite similar to the previous species [*Triphora patricia*], but less slender; the edge of the last whorl is less pronounced and even includes a second thread. There are about 9 whorls, which are initially shaped and sculptured as in the previous species, again having three rows of tubercles and a smooth thread. This forms on the last whorl an edge, which is somewhat obtuse, under this edge there are still two threads visible. Siphonal canal moderately long, straight; diamond-shaped aperture. Height 5 mm, diameter 1.6 mm.

Diagnosis. Lectotype height 4.8 mm. Shell weakly conical; teleoconch with 5-6 whorls with three tubercled spiral cords and a fourth suprasutural, smooth cord. Two further smooth spiral cords on the base. Simple peristome, without bifurcating cords. Paucispiral large apex of 2-3 whorls; the transition to teleoconch is difficult to spot. The first protoconch whorl is ornamented by three strong smooth spiral cords; the two lower cords develop strong granules on the second whorl. Colour white.

Remarks. The type lot contains three specimens. Two are conspecific and belong to *T. agulhasensis*; a third one has strong tubercles on the first protoconch whorl instead of the smooth keels in *T. agulhasensis*, and does not belong to this species.

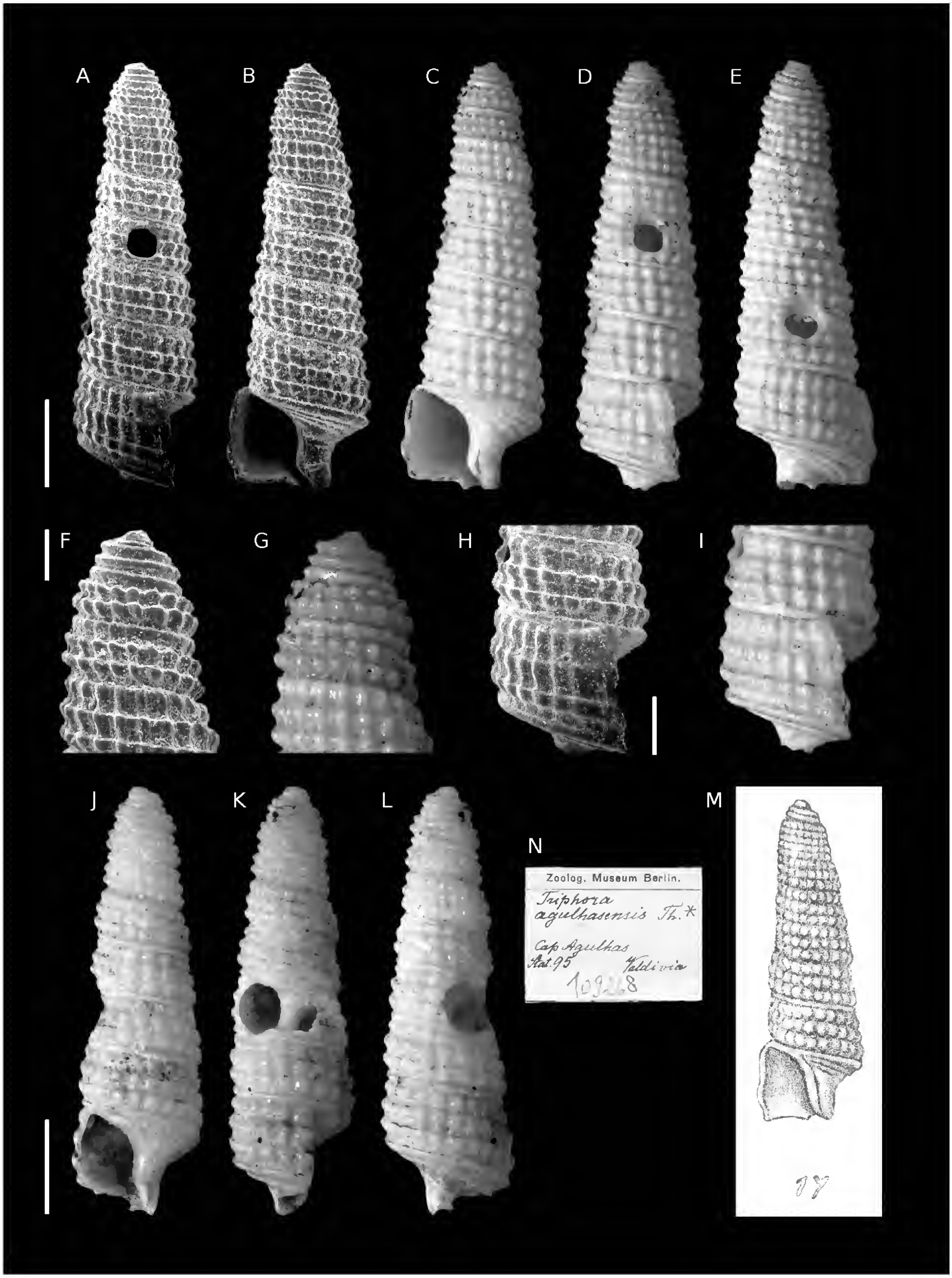


Figure 2. *Triphora agulhasensis* Thiele, 1925, Station 95 (Cape Agulhas). **A-I**. Lectotype, ZMB/Moll no. 109268a: left side (**A, D**), front (**B-C**), left side (**D**), back (**E**), protoconch (**F-G**), peristome (**H-I**). **J-L**. Paralectotype A, ZMB/Moll no.109268b: front (**J**), side (**K**), back (**L**). **M**. Original figure in Thiele 1925. **N**. Original label. Scale bar: **A-E**: 1 mm, **F-G**: 0.3 mm, **H-I**: 0.5 mm, **J-L**: 1 mm.

Triphora algoensis Thiele, 1925

Figure 3
Triphora algoensis Thiele, 1925: 128-129 (94-95), plate XXII (X), figure 19.
Type specimens. Lectotype: ZMB/Moll no. 109270a, from Station 100 (Francis Bay), here designated. Paralectotypes A-D ZMB/Moll no. 109270b-e.

Type locality. "Stationen 81 [Große Fischbucht], 95 [Cap Agulhas], 100 [Francis-Bucht], 101 [Algoa-Bucht]" (South Africa).

Original description. *Schalen von denselben Stationen 81, 95, 100 und 101 sind denen der vorigen Art [*Triphora capensis*] in Größe und Skulptur ähnlich, aber durch folgende Merkmale unterschieden: die Form ist etwas schlanker, die Anfangswindungen zeigen bereits deutliche Knoten und zwar in 2 Reihen, zwischen die sich alsdann eine dritte einschiebt, die 12½ Windungen der abgebildeten Schale sind nicht gewölbt, die letzte unten kantig und nur mit 3 Reifen unter der Kante besetzt, die Mündung ist niedriger, der Mundrand etwas flügelartig vorgezogen, oben zurücktretend, die untere Rinne etwas gebogen. Färbung braun. Auffällig ist allerdings die ganz gleiche Verbreitung, doch scheinen die angegeben Merkmale dagegen zu sprechen, daß beide Formen zu derselben Art gehören.*

Translation. Shells from stations 81, 95, 100 and 101 are similar to the ones of previous species [*Triphora capensis*] in size and sculpture, but distinguished by the following features: the shape is slightly slimmer, the protoconch whorls already show two rows of tubercles, between those the third row develops, the 12½ whorls of the shell are flat, the last whorl is angulated and bears three cords under the edge, the aperture is shorter, the peristome has a winged shape, with a developed posterior sinus, the siphonal canal bent slightly. The colour is brown. The overlap in distribution is remarkable, however the described characters show that both forms do not belong to the same species.

Diagnosis. Lectotype height 8.8 mm. Conical shell, with very flat sides. Teleoconch of nine whorls, which have three tubercled spiral cords: the second develops later and is fully visible on the third whorl. A fourth suprasutural smooth cord is also present. The base has two further smooth spiral cords. Peristome simple, without bifurcating cords. A deep posterior siphonal canal is present. Paucispiral large apex of three whorls; the transition to teleoconch is difficult to spot. The protoconch is ornamented by two strong tubercled spiral cords. Colour light brown, apex slightly darker.

Remarks. The specimen figured in Thiele's work lacks the lower part of the last whorl near the aperture, like the best syntype available, which is here designated as lectotype. Station 81 is probably located in Agulhas Bank and not in Angola as the geographic coordinates would suggest (Kilburn 1996) (see Materials and methods).

Triphora brevis Thiele, 1925

Figure 4
Triphora brevis Thiele, 1925: 129 (95), plate XXII (X), figure 20.
Type specimens. Holotype: ZMB/Moll no. 109271, fixed by monotypy.

Type locality. "Station 101 [Algoa-Bucht]" (South Africa).

Original description. *Eine kleine und anscheinend ausgewachsene Schale von Station 101 (Algoa-Bucht) scheint gleichfalls zu einer noch nicht bekannten Art zu gehören. Sie ist bräunlich, ziemlich kurz spindelförmig, oben kurz zugespitzt, von den 8 Windungen zeigt die erste einen Besatz mit herablaufenden, zweimal stark geknickten Fäden, die folgenden haben anfangs 2, dann 3 Reihen starker Knoten. Bei der letzten ist der Reifen an der unteren Kante noch deutlich knotig, darunter finden sich noch 2 glatte Reifen. Spindelfortsatz ziemlich kurz und breit, Mündung klein, Mundrand unten etwas vorgezogen. Höhe 3,3 mm, Durchmesser 1,25 mm.*

Translation. One small and seemingly adult shell from station 101 (Algoa Bay) seems also to belong to a not yet known species. It is brownish, quite small and fusiform, with an obtuse top; of the eight whorls, the first shows two strong undulated cords, while the following whorls have initially 2, then 3 cords with tubercles. The last whorl is still clearly tubercled, but two smooth cords are present below it. Siphonal canal quite short and large, aperture small; the aperture is slightly rounded. Height 3.3 mm, diameter 1.25 mm.

Diagnosis. Holotype height 3.4 mm. Conical shell, with deep sutures. Teleoconch of five whorls, which have three tubercled spiral cords: the second develops later and is fully visible at half shell height. A very fine suprasutural smooth cord is also present. The last whorl has a fourth weakly tubercled cord, and the base has a further smooth spiral cord. Peristome simple, without bifurcating cords. Paucispiral large apex of two whorls. The first whorl is smooth, while the second is slightly angulated and ornamented by flexuous axial ribs. Colour light brown, but the holotype is worn and the colour may be faded.

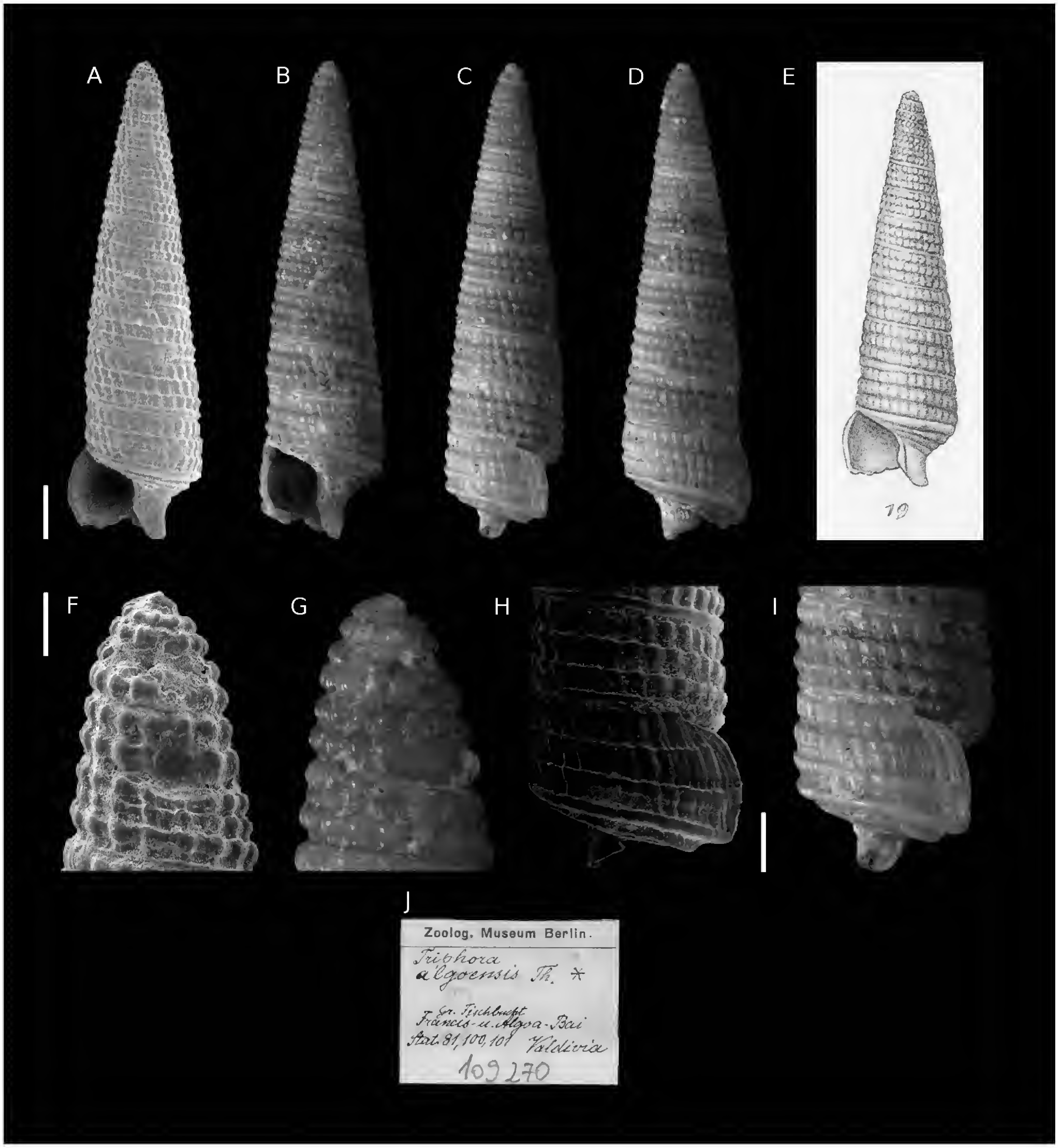


Figure 3. *Triphora algoensis* Thiele, 1925, Station 100 (Francis Bay). **A-D**, **F-I**. Lectotype, ZMB/Moll no. 109270a: front (**A-B**), side (**C**), back (**D**), protoconch (**F-G**), peristome (**H-I**). **E**. Original figure in Thiele 1925. **J**. Original label. Scale bar: **A-D**: 1 mm, **F-G**: 0.3 mm, **H-I**: 0.6 mm.

Triphora capensis Thiele, 1925

Figure 5

Triphora capensis Thiele, 1925: 128 (94), plate XXII (X), figures 18 and 18a.

Type specimens. Lectotype: ZMB/Moll no. 109269a, here designated from station 101 (Algoa Bay). Paralectotype A: ZMB/Moll no. 109269b; further 11 paralectotypes: ZMB/Moll no. 109269.

Type locality. "Stationen 81 (Große Fischbucht), 95 (Cap Agulhas), 100 (Francis-Bucht) und 101 (Algoa-Bucht)" (South Africa).

Original description. *Stationen 81 (Große Fischbucht), 95 (Cap Agulhas), 100 (Francis-Bucht) und 101 (Algoa-Bucht). Einige Schalen, z. T. unvollkommen erhalten, kann ich auf keine bekannte Art beziehen, sie gehören in die Gruppe der* T. perversa, *von der sie deutlich verschieden*

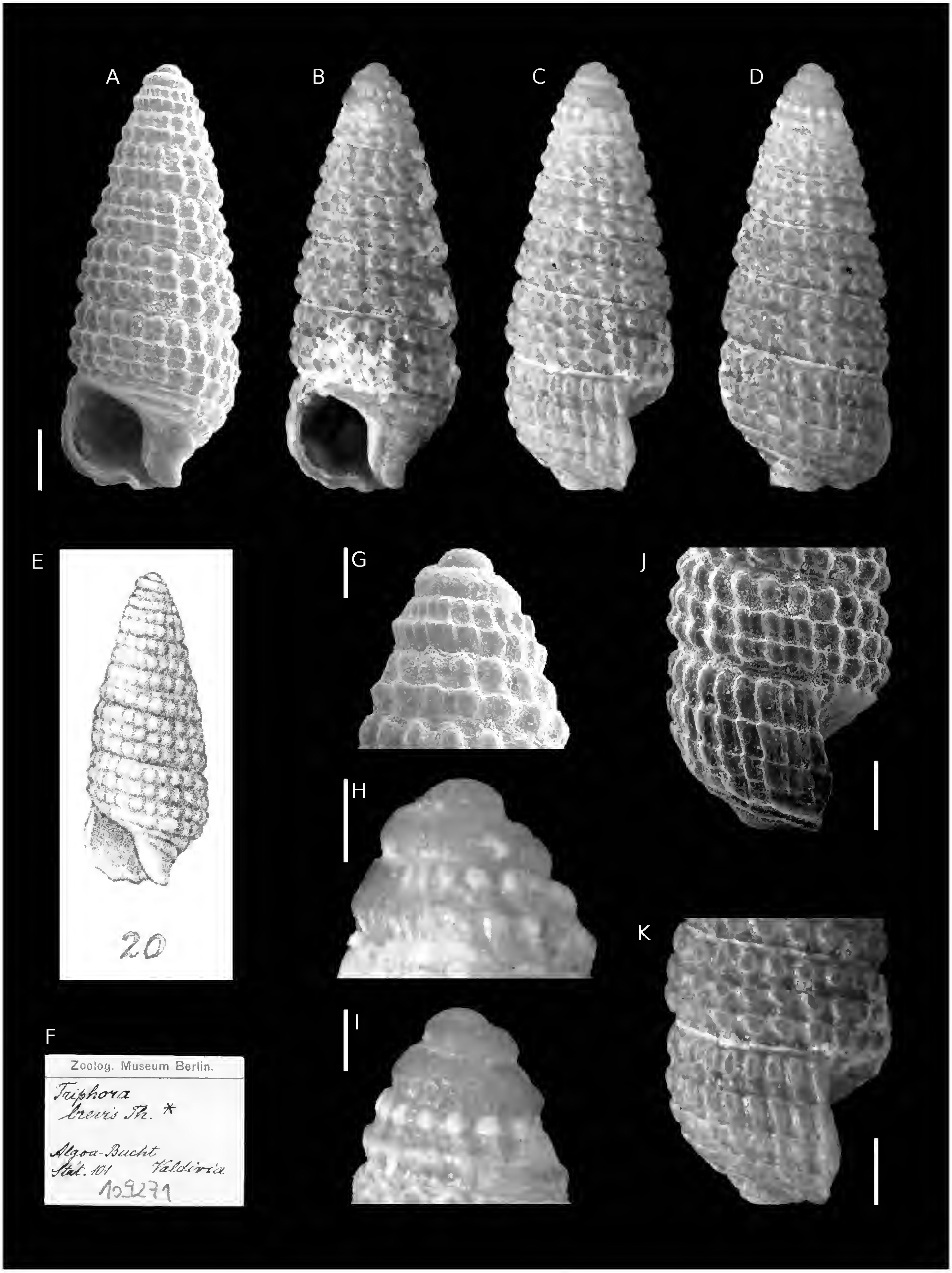


Figure 4. *Triphora brevis* Thiele, 1925, Station 101 (Algoa Bay). **A-D**, **G-K**. Holotype, ZMB/Moll no. 109271: front (**A-B**), side (**C**), back (**D**), protoconch (**G-H**), protoconch backside (**I**), peristome (**J-K**). **E**. Original figure in Thiele 1925. **F**. Original label. Scale bar: **A-D**: 0.5 mm, **G-I**: 0.2 mm, **J-K**: 0.4 mm.

sind. Die etwas bräunlichen Schalen sind hoch kegelförmig, aus 11 kaum gewölbten Windungen gebildet, deren erste abgerundet und mit 3 Reifen skulptiert einen etwas abgestumpften Apex bilden, während die übrigen außer den 3 Reifen noch herablaufende Falten zeigen, die an den Schnittpunkten deutliche Knoten bilden, an der Naht ist noch ein glatter Reifen sichtbar. Letzte Windung mit einem großen geraden Spindelfortsatz und mit 4 Reifen an der Unterseite, die in einem stumpfen Winkel zum oberen Teil steht; Mündung ziemlich groß, abgerundet rautenförmig. Höhe 8 mm, Durchmesser 2,25 mm.

Translation. Stations 81 ("Große Fischbucht"), 95 (Cape Agulhas), 100 (Francis Bay) and 101 (Algoa Bay). I obtained some imperfect shells, which I cannot relate with any known species; they belong to the group of *T. perversa,* but they are clearly different. The slightly brownish shells are high and conical, and have 11 slightly inflated whorls, the first whorl is rounded and sculptured by 3 cords, forming an obtuse apex, while the following whorls have axial ribs which bear tubercles at the intersection with the spiral cords; at the suture a further smooth thread is visible. The last whorl has a big straight siphonal canal and with 4 cords on the base, the last whorl has a blunt angle between the lower and upper part; aperture rather large, diamond-shaped. Height 8 mm, diameter 2.25 mm.

Diagnosis. Lectotype height 8 mm. Shell conical, with rather flat whorls. Teleoconch of nine whorls, which have three tubercled spiral cords, present since the first teleoconch whorl. A fourth suprasutural smooth cord is also present. The base has five smooth spiral cords. The peristome is not complete in the type material, but it does not seem to bear bifurcated spiral cords. Paucispiral large apex of two whorls with three large spiral cords which are initially smooth and then become tubercled. Colour brownish, with the first spiral cord on whorls paler (colour pattern clearly visible in paralectotype A, Fig. 5 I-K).

Remarks. The sample from station 81 contains specimens which are broken or juvenile and difficult to assign to any species. At least one specimen is certainly not *T. capensis*, because it bears a planktotrophic apex. Station 81 is probably located in Agulhas Bank and not in Angola as the geographic coordinates would suggest (Kilburn 1996) (see Materials and methods).

Triphora dilecta Thiele, 1925

Figure 6

Triphora dilecta Thiele, 1925: 126 (92), plate XXII (X), figure 12.

Type specimens. Lectotype: ZMB/Moll no. 109263a, here designated. Paralectotypes A-C: ZMB/Moll no. 109263b-d.

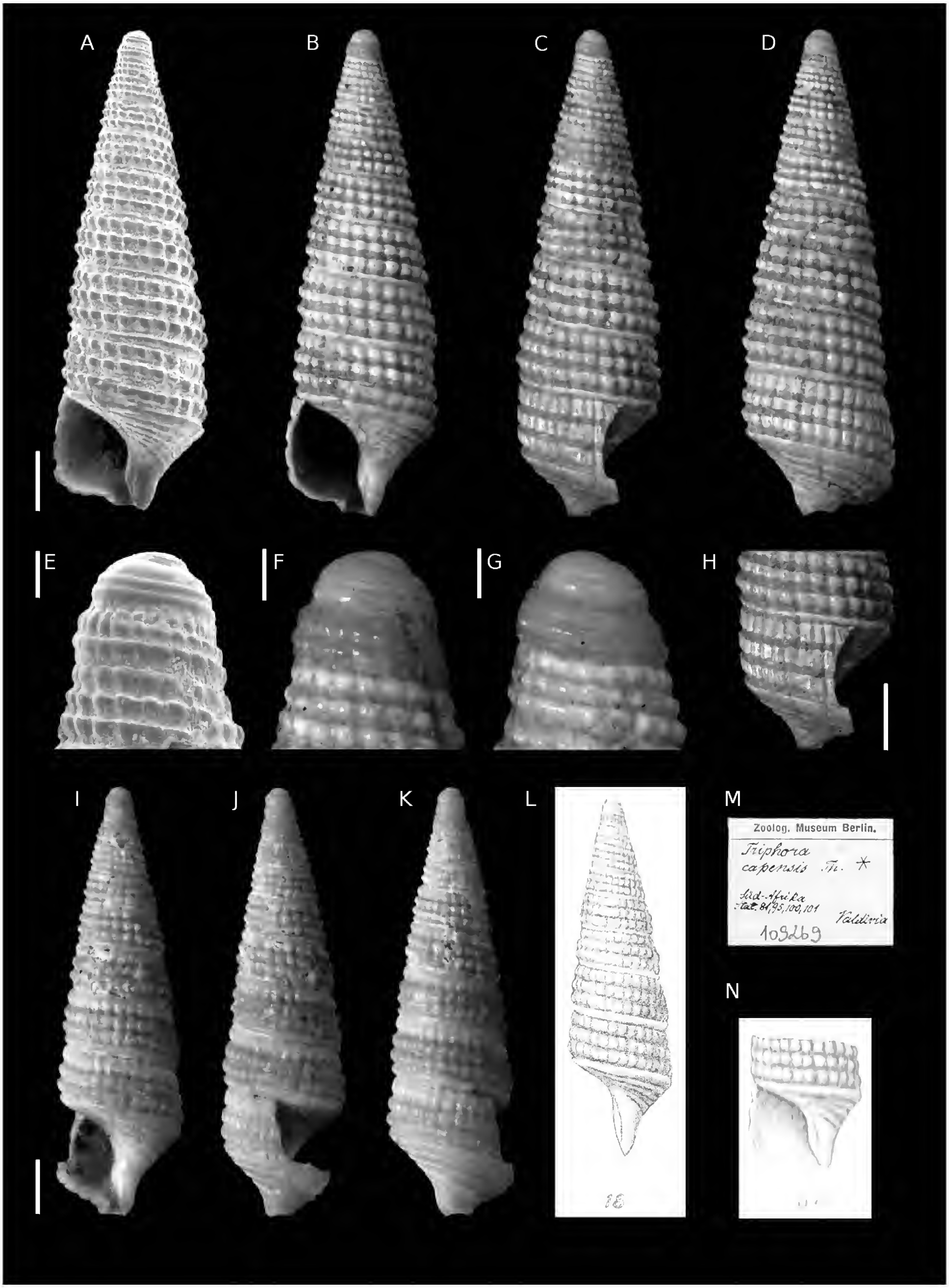
Type locality. "Station 95 (34°51'Südl. Br., 19°37,8' östl. L., 80 m Tiefe, bei Cap Agulhas)" (South Africa).

Original description. *Von Station 95 (34°51' südl. Br., 19°37,8' östl. L., 80 m Tiefe, bei Cap Agulhas) liegen 4 meistens schlecht erhaltene Schalen vor, deren beste ich abbilde. Die Art, der ich den obigen Namen gebe, ist durch ihre schlanke, gerade Form und ihre geringe Skulptur sehr ausgezeichnet. Die Schal ist weiß, glatt und glänzend, hoch getürmt und schmal; die gezeichnete Schale zeigt 12 Windungen, von denen die erste ziemlich groß, glatt und rundlich ist, während die folgenden nur 2 Spiralfurchen aufweisen, deren eine feinere dicht über der Naht verläuft, während die andere etwas darüber gelegen und merklich breiter ist, die obere Hälfte zeigt nur eine leichte Einschnürung infolge des etwas wulstigen oberen Randes. Auch die letzte Windung hat weiter keine Skulptur, die Spindel ist gerade und ziemlich lang, die vielleicht noch unfertige Mündung einfach rautenförmig mit kurzer Rinne. Höhe 6 mm, Durchmesser 1,4 mm.*

Translation. From station 95 (34°51'S, 19°37.8'E, 80 m depth, near Cape Agulhas) there are four poorly preserved shells, of which I figure the best. The species, to which I give a name here, is very slender, the very straight shape and the fine sculpture are very typical. The shell is white, smooth and shiny, high and slender; the figured shell has 12 whorls, of which the first is quite large, smooth and rounded, while the following whorls have two spiral grooves, a finer groove is visible just above the suture, while the other is located higher on the whorl and much wider, the upper part of the shell shows a slight constriction [because the protoconch whorls are larger than the first teleoconch whorl]. Also the last whorl has not any other sculpture, the siphonal canal is straight and quite long, and the probably undeveloped aperture is diamond-shaped with a short canal. Height 6 mm, diameter 1.4 mm.

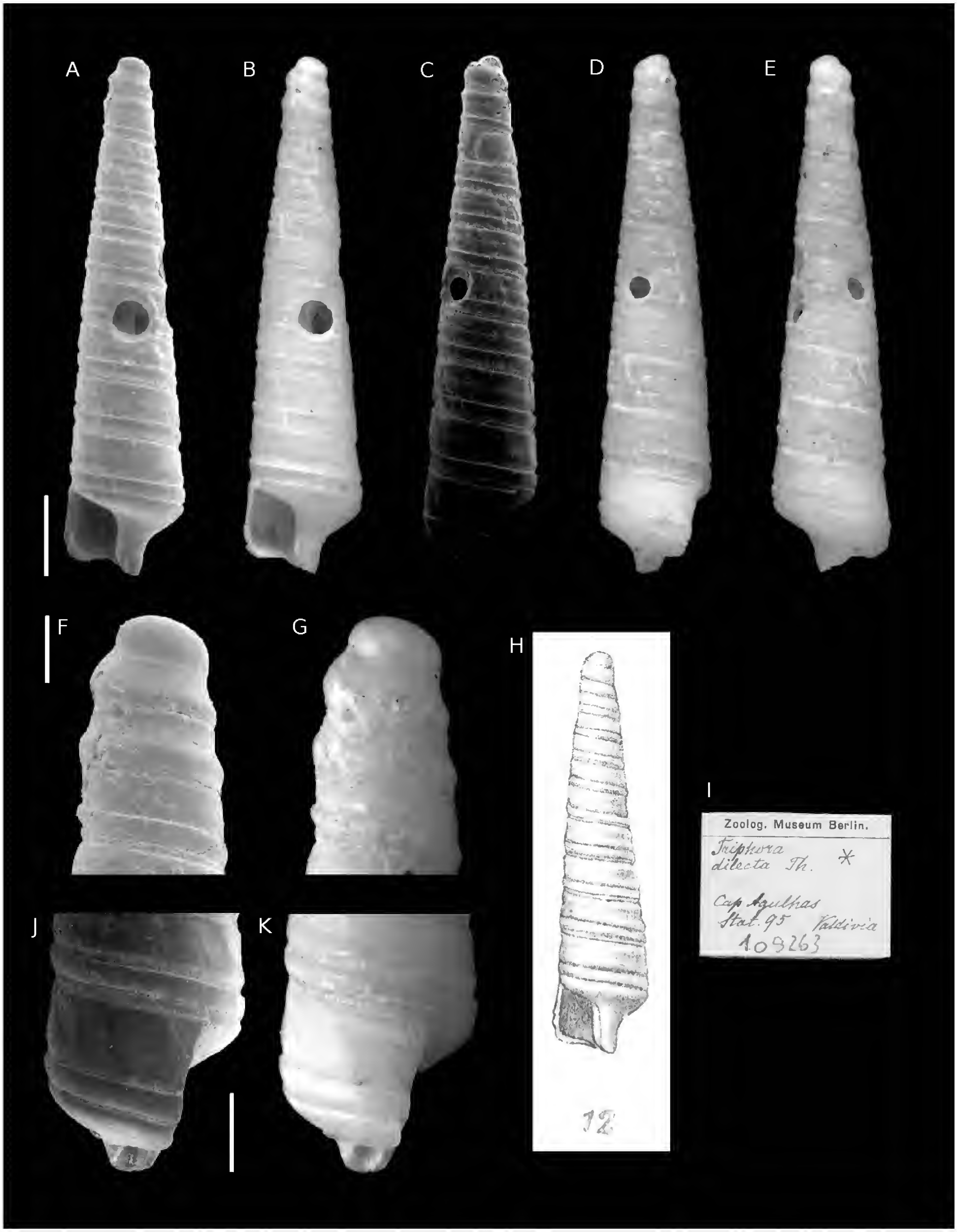
Diagnosis. Lectotype height 6.3 mm. Shell very slender, conical, with flat whorls. Teleoconch of nine whorls, which have three flat broad spiral cords; the first two become a single broader one towards the last whorl. A fine suprasutural smooth cord is also present. The base is smooth. The peristome without any specific ornamentation, lip very thin (it may not be fully developed in the lectotype, although the base is fully developed, thus the specimen is adult). Paucispiral large apex of three whorls; the first whorl is smooth, while the other two bear a strong keel. Colour white.

Remarks. This species is remarkable because of the lack of tubercles, which are present in most triphorids.



Zoolog. Museum Berlin.
Triphora
capensis Th. *
Süd-Afrika
Stat. 81,95,100,101
Valdivia
109269

Figure 5. *Triphora capensis* Thiele, 1925, Station 101 (Algoa Bay). **A-H**. Lectotype, ZMB/Moll no. 109269a: front (**A-B**), side (**C**), back (**D**), protoconch (**E-F**), protoconch side (**G**) and peristome (**H**). **I-K**. Paralectotype A, same stations as lectotype, ZMB/Moll no. 109269b: front (**I**), side (**J**), back (K). **L**, **N**. Original figure in Thiele 1925. **M**. Original label. Scale bar: **A-D**: 1 mm, **E-F**: 0.2 mm, **G-H**: 1 mm, **I-K**: 1 mm.



Zoolog. Museum Berlin.
Triphora
dilecta Th. *
Cap Agulhas
Stat. 95 Valdivia
109263

Figure 6. *Triphora dilecta* Thiele, 1925, Station 95 (34°51'S, 19°37.8'E, 80 m depth, near Cape Agulhas). **A-G**, **J-K**. Lectotype, ZMB/Moll no. 109263a: front (**A-B**), side (**C-D**), back (**E**), protoconch (**F-G**), peristome (**J-K**). **H**. Original figure in Thiele 1925. **I**. Original label. Scale bar: **A-E**: 1.0 mm, **F-G**: 0.3 mm, **J-K**: 0.4 mm.

Triphora erecta Thiele, 1925

Figure 7
Triphora erecta Thiele, 1925: 127 (93), plate XXII (X), figure 14.

Type specimens. Holotype: ZMB/Moll no. 109265, fixed by monotypy.

Type locality. "Station 104 (35°16' südl. Br., 22°26,7' östl. L., 155 m Tiefe, bei der Agulhasbank)" (South Africa).

Original description. *Eine mangelhaft erhaltene Schale von Station 104 (35°16' südl. Br., 22°26.7' östl. L., 155 m Tiefe, bei der Agulhasbank) erinnert in der Skulptur und Mündungsform an* Laecochlis granosa *(S. Wood), es muß dahingestellt bleiben, ob sie zu dieser Gruppe gehört. Der Schale fehlt das obere Ende, es sind nur 8-9 Windungen vorhanden, auch der Mündungsrand ist beschädigt. Die Windungen nehmen sehr langsam zu, daher ist die Schale sehr hoch und schlank, die Windungen sind deutlich gewölbt, die Naht eingedrückt. Die Oberfläche ist mit 5 glatten Reifen besetzt, die etwa so breit sind wie ihre Zwischenräume. Unterseite der letzten Windung glatt, Spindel ziemlich lang, etwas gedreht, unterer Kanal ziemlich lang, schräg abwärts gerichtet. Durchmesser fast 3 mm.*

Translation. A poorly preserved shell from station 104 (35°16'S, 22°26.7'E, 155 m depth, near Agulhas Bank), which reminds the sculpture and aperture of *Laecochlis granosa* (S. Wood); it is unclear if the species belongs to this group [Triphoridae]. The shell misses the apical part, there are 8-9 whorls visible, and also the aperture is damaged. The whorls slowly increase in size, this makes the shell very long and slender, the whorls are clearly convex, and the suture is deep. The surface of the whorls has five smooth spiral cords, which are about as wide as their interspaces. The lower part of the last whorl is smooth, the columella is fairly long, a little bit twisted, the siphonal canal fairly long, with its end bent. Diameter almost 3 mm.

Diagnosis. Teleoconch of the holotype of seven whorls and 11.8 mm high, but the species is certainly much longer, because the holotype is just a fragment. Very slender shell, with poorly inflated whorls. Teleoconch whorls have four flat broad spiral cords and a suprasutural smooth cord. The holotype is probably a subadult, hence little can be said on the peristome and the base. Also the apex is missing. Colour greyish, but the specimen is definitely poorly preserved.

Remarks. Also this species bears a striking ornamentation of smooth spiral cords like *T. dilecta*, but can be easily distinguished for its size, shape, and arrangement of cords.

Triphora innocens Thiele, 1925

Figure 8
Triphora innocens Thiele, 1925: 127 (93), plate XXII (X), figures 13 and 13a.

Type specimens. Lectotype ZMB/Moll no. 109264a (from Station 95), here designated. Further two badly preserved specimens in lot from station 95, two specimens from station 105 and 3 specimens from station 106 whose conspecificity is questionable (see Remarks).

Type locality. "Station 95 [34°51' südl. Br., 19°37,8' östl. L., 80 m Tiefe, bei Cap Agulhas] und von Station 106 (35°26,8' südl. Br., 20°56,2' östl. L., Agulhas-Bank)" (South Africa).

Original description. *Einige mangelhaft erhaltene Schalen von derselben Station 95 und von Station 106 (35°26,8' südl. Br., 20°56,2' östl. L., Agulhas-Bank) gehören zu derselben Gruppe, wie die vorige Art [*Triphora dilecta*], sind aber durch 3 gleichstarke Reifen ausgezeichnet in Verbindung mit ihrer weißen Färbung; die vorher genannte* T. cingulata *A. Ad. ist grau, ihr Mittelreifen schwächer als die beiden anderen und die Zwischenräume sind stark längsgestreift, danach kann sie nicht unsere Art sein. Nach dem vorliegenden Material kann ich die Zahl der Windungen nicht sicher angeben, bei dem in Figur 13 dargestellten Endstück dürfte sie 12-13 betragen. Die mehr oder weniger aufgetriebene Anfangswindung zeigt schon die Reifen, die bis zum Ende verlaufen, die unteren Windungen lassen noch einen Teil eines vierten Reifens erkennen, dem sich die folgende anheftet, und bei der letzten sind an der Unterseite noch 2 Reifchen sichtbar, so daß diese im ganzen 6 Reifen trägt. Spindel kurz, Mündung einfach mit kurzem schrägem Kanal. Der Durchmesser des abgebildeten Stücks beträgt 1,6 mm, seine Höhe dürfte 8-9 mm betragen.*

Translation. Some poorly preserved shells from the station 95 and 106 (35°26.8'S, 20°56.2'E, Agulhas Bank) belong to the same group as the previous species [*Triphora dilecta*], they are very distinguishable because of the three spiral threads of equal strength and their white colour; the previously referred species *T. cingulata* A. Adams [Thiele referred to *T. cingulata* in the introduction to Triphoridae] is grey, its middle thread is weaker than the other two and between the threads there are vertical stripes visible, it cannot be our species. With the available material it is not possible to count the exact number of whorls, in figure 13 I have drawn a shell with 12-13 whorls. The few embryonal whorls show already the three spiral threads that run along the whorls until the lip, the teleoconch whorls show in the lower whorls even a fourth soprasutural spiral cord, on the base there are two other spiral cords visible, this brings the total

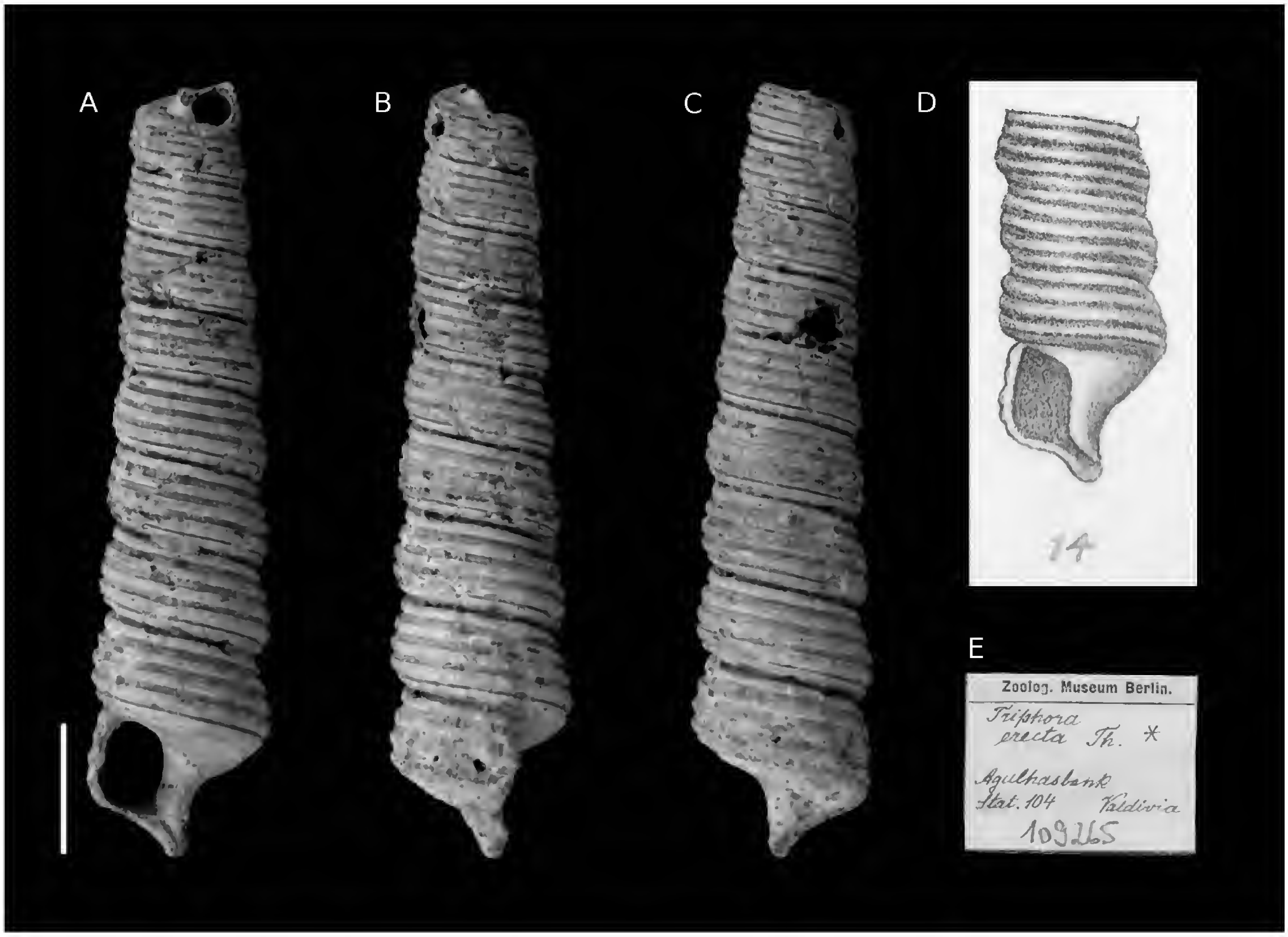


Figure 7. *Triphora erecta* Thiele, 1925, Station 104 (35°16'S, 22°26.7'E, 155 m depth, near Agulhas Bank). **A-C**. Holotype. ZMB/Moll no. 109265: front (A), side (B), back (C). **D**. Original figure in Thiele 1925. **E**. Original label. Scale bar: **A-C**: 2 mm.

number of spiral cords to six. The columella is short, the aperture is simple with a slightly twisted siphonal canal. The diameter of the figured specimens is 1.6 mm, the height might be 8-9 mm.

Diagnosis. Lectotype height 5.9 mm. Shell conical, with flat whorls. Teleoconch of nine whorls, which have three smooth spiral cords; a fine fourth suprasutural smooth cord is also present. Paucispiral large apex of three whorls, with two spiral keels and one subsutural one. Colour white. Base and peristome cannot be properly described on the basis of the type material.

Remarks. The material labelled as *Triphora innocens* contains three vials, collected at three different stations: 95, 105 and 106. Station 105 is not cited in the original description. The specimens under this name bear different apex morphologies. Specimens from station 95 have a protoconch with a first whorl wider than the second, and ornamented by two strong keels (Fig. 8 F-G), while the specimens in lots 105 and 106 have the first protoconch whorl much smaller than the others and have two strong spiral keels and one subsutural keel (Fig. 8 H-I). Also teleoconch profiles are different, to the extent that can be judged by subadult specimens. Specimens from station 95 have a more slender teleoconch (Fig. 8 A-D), while specimens from stations 105 and 106 are more conical, and probably larger at adult size (Fig. 8 J-K).

It is unclear if this can be regarded as infraspecific variability or suggests that multiple species were mixed up in the lot. The lack of fully adult specimens, although figure 13 apparently shows a fully grown shell, is a further impediment to a thorough understanding of the species variability. Nonetheless, the original figure 13 represents the apical part similar to the largest specimen of station 95; it is indeed the specimen in best condition, although not fully adult, and is here designated as lectotype. The sample from station 95 also contained fragments of adult specimens, but without apex. Due to the importance of apex morphology for species identification in Triphoridae, we did not select as lectotype any of such specimens.

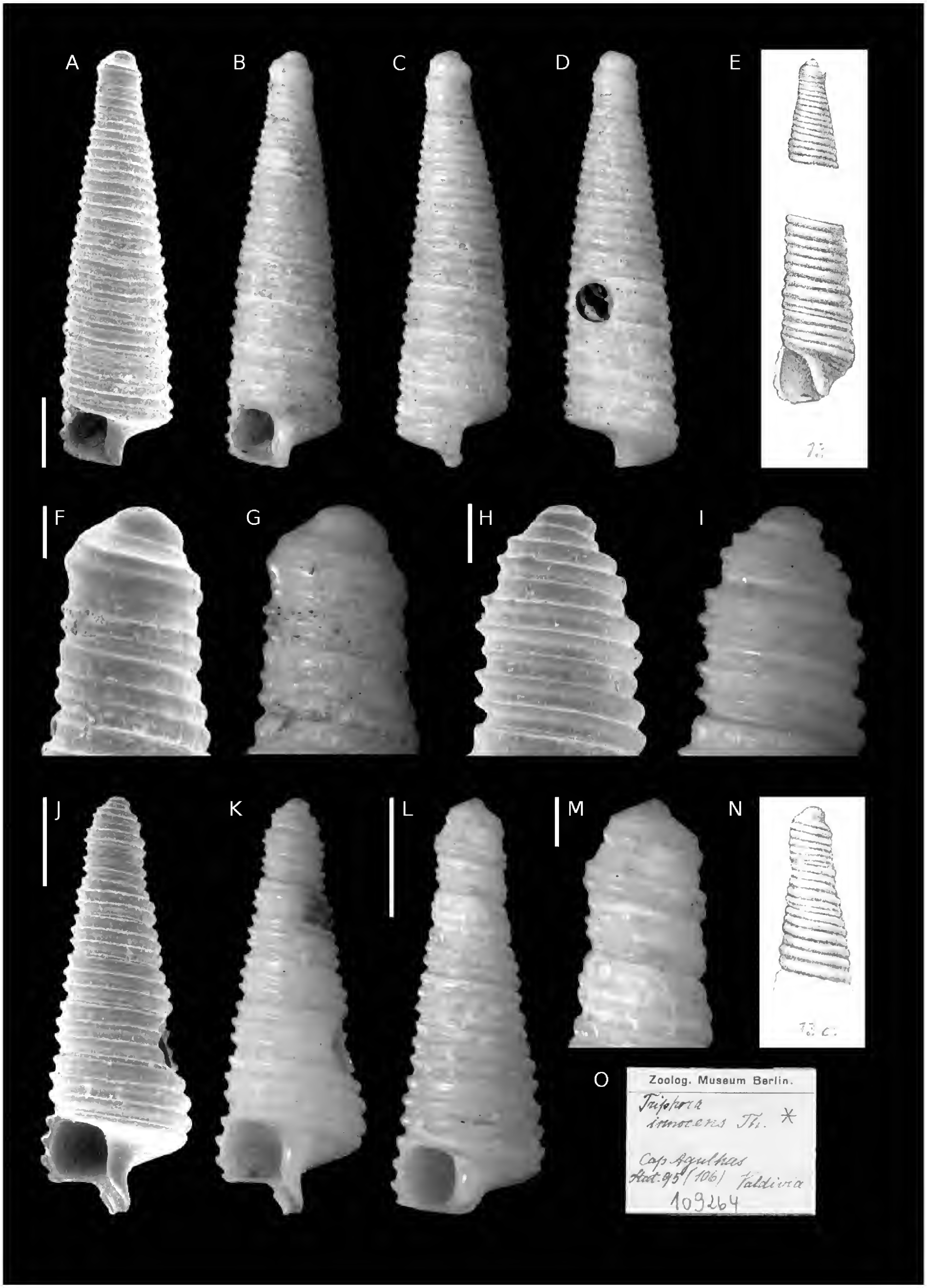


Figure 8. *Triphora innocens* Thiele, 1925. **A-D**, **F-G**. Lectotype, Station 95 (Agulhas Bank), ZMB/Moll no. 109264a: front (**A-B**), side (**C**), back (**D**), protoconch (**F-G**). **E, N**. Original figure in Thiele 1925. **H-K**. Station 106 (Agulhas Bank), ZMB/Moll no. 1090264a: protoconch (**H-I**), front (**J-K**). **L-M**. Station 95 (Agulhas Bank), ZMB/Moll no. 1090264: front (**L**), protoconch (**M**). **O**. Original label. Scale bar: **A-D**, **J-L**: 1 mm. **F-I**, **M**: 0.25 mm.

Triphora patricia Thiele, 1925

Figure 9
Triphora patricia Thiele, 1925: 128 (94), plate XXII (X), figure 16.

Type specimens. Lectotype: ZMB/Moll no. 109267a (Station 95), here designated. Paralectotype A: ZMB/Moll no. 109267b (Station 105); paralectotypes B-D: ZMB/Moll no. 109267c-e (Station 106).

Type locality. "Station 95 (Cap Agulhas), Station 105 (35°29' südl. Br., 21°2,5' östl. L., 102 m Tiefe) und Station 106 (35°26,8' südl. Br., 20°56,2' östl. L., Agulhasbank)" (South Africa).

Original description. *Station 95 (Cap Agulhas), Station 105 (35°29' südl. Br., 21°2,5' östl. L., 102 m Tiefe) und Station 106 (35°26,8' südl. Br., 20°56,2' östl. L., Agulhasbank), einige, meist junge Schalen haben einige Aehnlichkeit mit der westindischen* T. triserialis *Dall, die aber oben mehr zugespitzt ist. Die weißen Schalen sind sehr schlank mit kaum gewölbten, wenig zunehmenden Windungen, deren erste und zweite kurz abgerundet und mit 2 Reifen besetzt sind, während alle folgenden 3 Spiralreihen von rundlichen Körnchen tragen, an der Naht ist noch ein schmaler glatter Reifen sichtbar. Dieser bildet bei der letzten Windung eine starke Kante und unter ihm ist noch ein Reifen vorhanden. Spindelfortsatz gerade, mäßig lang, Mündung viereckig (bei der abgebildeten Schale beschädigt). Höhe 7 mm, Durchmesser 1,6 mm.*

Translation. Station 95 (Cape Agulhas), station 105 (35°29'S, 21°2.5'E, 102 m depth) and station 106 (35°26.8'S, 20°56.2'E, Agulhas Bank), some of the mostly juvenile shells have some resemblance with the West Indian species *T. triserialis* Dall, which has a more pointed top. The white shells are very slender with slightly rounded whorls which increase little in size; the first and second embryonal whorls are slightly rounded and sculptured with two spiral keels, while all the following whorls show three spiral cords with tubercles; on the suture, another finer smooth cord is visible. The sutural cord forms on the last whorl a strong edge and underneath this edge another spiral cord is visible. The siphonal canal is straight, moderately long and the aperture is sub-quadrangular (the aperture is damaged on the figured shell). Height 7 mm, diameter 1.6 mm.

Diagnosis. Lectotype height 7.0 mm. Shell very slender, conical, with almost flat whorls. Teleoconch of nine whorls, which have three tubercled spiral cords, well developed since the first teleoconch whorl. A very fine suprasutural smooth cord is also present, but barely visible in most apical whorls. Paucispiral large apex of four whorls; the first whorl bears two strong smooth spiral cords, while the others bear three tubercled cords. Colour white. Base and peristome cannot be properly described on the basis of the studied type material.

Triphora plebeja Thiele, 1925

Figure 10
Triphora plebeja Thiele, 1925: 129 (95), plate XXII (X), figure 21.

Type specimens. Lectotype: ZMB/Moll no. 109272a from Station 100, here designated. Paralectotype A: ZMB/Moll no. 109272b from Station 100; Paralectotype B: ZMB/Moll no. 109272c from Station 101; Paralectotype C: ZMB/Moll no. 109272d from Station 106.

Type locality. "Stationen 100 (Francis-Bucht), 101 (Algoa-Bucht) und 106 (Agulhasbank)" (South Africa).

Original description. *Schalen von den Stationen 100 (Francis-Bucht), 101 (Algoa-Bucht) und 106 (Agulhasbank) unterscheiden sich von den bisher genannten Arten durch ihre spitze, aus 5 Windungen bestehende Embryonalschale mit einer aus herablaufenden Fäden und 2 Spiralreifen bestehenden Skulptur, sie sind braun, lang kegelförmig, im ganzen mit 11 Windungen, von denen die auf die Embryonalschale folgenden 2, die übrigen 3 Reihen von Knoten aufweisen; die letzten werden kaum breiter, bei ihnen ist ein schmaler Reifen über der Naht sichtbar. Außer diesem, der die untere Kante bildet, hat die letzte Windung noch 3 glatte Reifen an der Unterseite. Spindelfortsatz und Mundrand sind beschädigt. Höhe 4,5 mm, Durchmesser 1,25 mm.*

Translation. Shells from station 100 (Francis Bay), 101 (Algoa Bay) and 106 (Agulhas Bank) are distinguishable from all the previous species by their pointy protoconch, composed of 5 embryonal whorls with two spiral keels and axial riblets; the shells are brown, long and conical, in total 11 whorls, of which the first whorls after the embryonal whorls have two rows of tubercles and the lower whorls 3 rows, the last one is barely wider, above the suture a smaller cord is visible. The base has further three smooth cords visible. Siphonal canal and aperture are damaged. Height 4.5 mm, diameter 1.25 mm.

Diagnosis. Lectotype height 4.5 mm. Shell conical, with flat whorls. Teleoconch of nine whorls, which have three tubercled broad spiral cords; the second one appears lately, on the fifth whorl. A fine suprasutural smooth cord is also present. The last whorl has a fourth smooth spiral cord, and the base has further three smooth spiral cords. The peristome of the lectotype has been rebuilt after breaking (there is a scar, likely due to a predatory attempt), hence it is not fully reliable. Nonetheless, the sculpture of the peristome seems not to bear bifurcating ribs. Multispiral apex of five whorls; a bit worn in the lectotype; nonetheless, it clearly bears two keels and fine axial riblets on the lower three whorls. Colour light brown, the first tubercled cord looks lighter, but colours may be faded, because the specimens were dead collected.

Remarks. This is the only species with planktotrophic apex described by Thiele from South Africa.

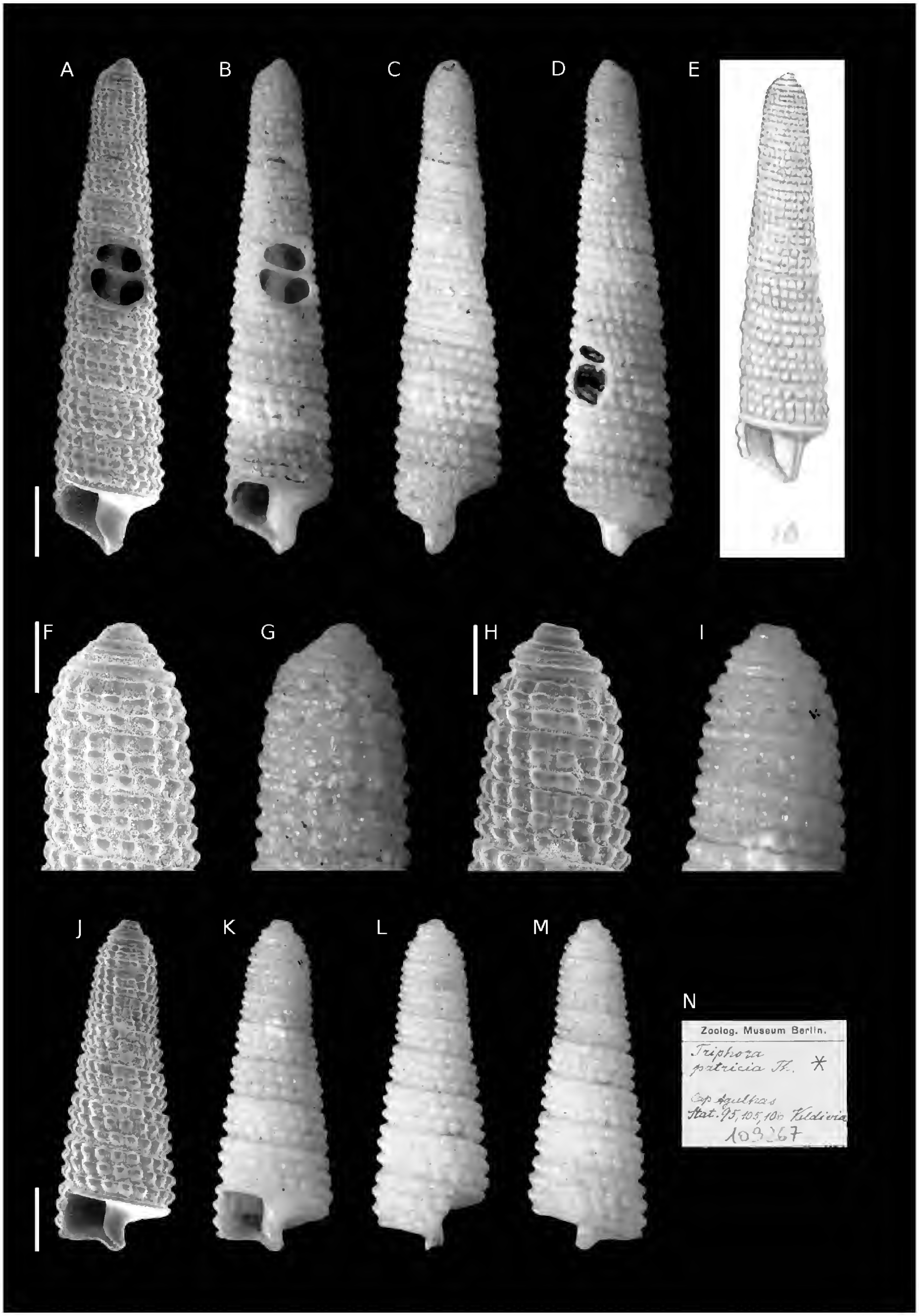


Figure 9. *Triphora patricia* Thiele, 1925. **A-D**, **F-G.** Lectotype, Station 95 (Cape Agulhas), ZMB/Moll no. 109267a: front (**A-B**), side (**C**), back (**D**), protoconch (**F-G**). **H-M**. Paralectotype A, Station 105 (35°29'S, 21°2.5'E) ZMB/Moll no. 109267b : protoconch (**H-I**), front (**J-K**), side (**L**), back (**M**). **E**. Original figure in Thiele 1925. **N**. Original label. Scale bar: **A-D**: 1 mm, **F-I**: 0.4 mm, **J-M**: 0.8 mm.

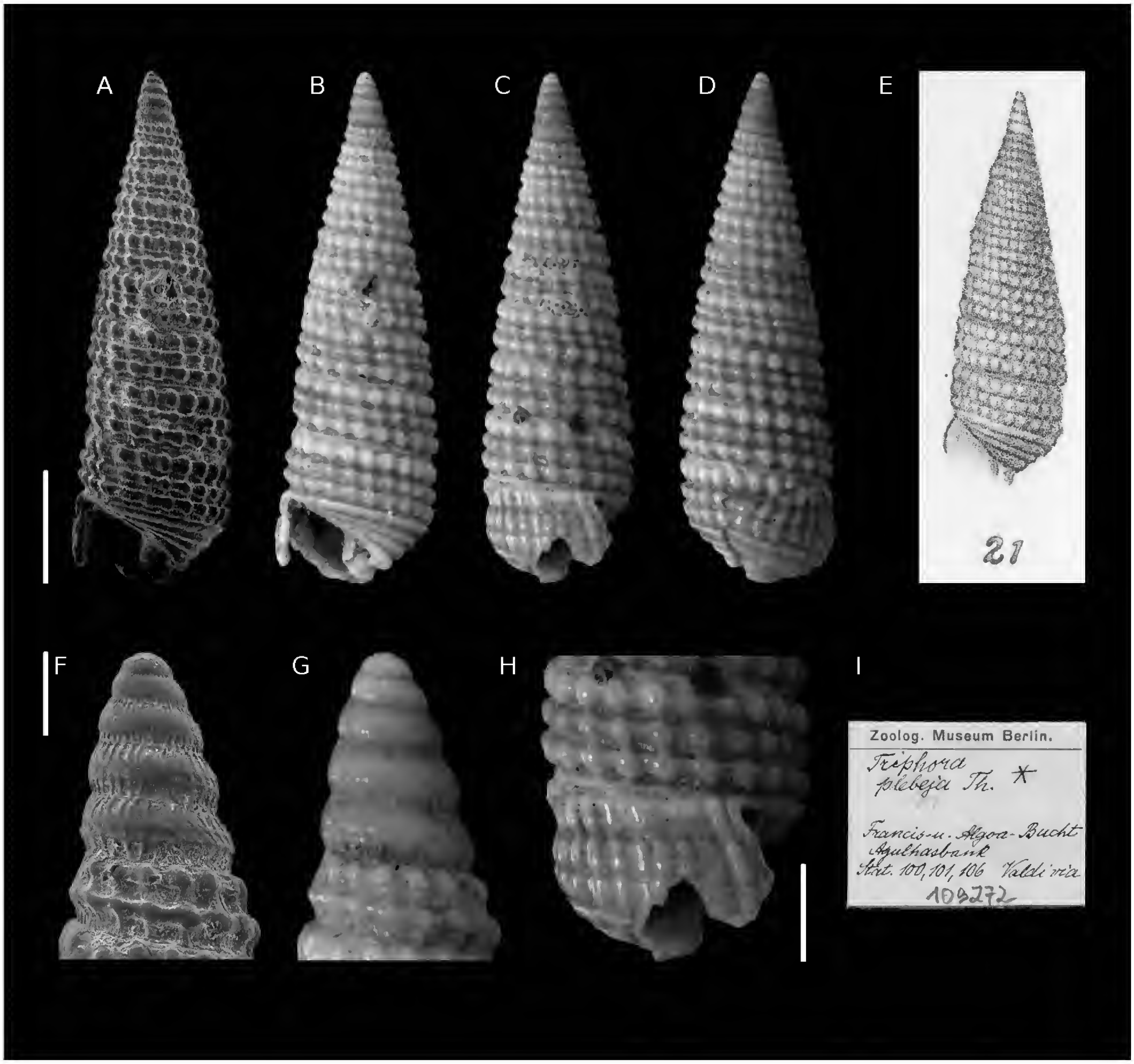


Figure 10. *Triphora plebeja* Thiele, 1925, Station 100 (Francis Bay). **A-D**, **F-H**. Lectotype. ZMB/Moll no. 109272a: front (**A-B**), side (**C**), back (**D**), protoconch (**F-G**), peristome (**H**). **E**. Original figure in Thiele 1925. **I**. Original label. Scale bar: **A-D**: 1 mm, **F-G**: 0.2 mm, **H**: 0.5 mm.

Triphora superba Thiele, 1925

Figure 11
Triphora superba Thiele, 1925: 127 (93), plate XXII (X), figure 15.

Type specimens. Holotype: ZMB/Moll no. 109266, fixed by monotypy.

Type locality. "Station 104 [35°16' südl. Br., 22°267' östl. L., 155 m Tiefe, bei der Agulhasbank]" (South Africa).

Original description. *Eine jedenfalls noch nicht ausgewachsene Schale von derselben Station 104 erinnert durch ihre schlanke Form und die 2 Warzenreihen an die westindische* T. colon *Dall, von der die Anfangswindungen unbekannt sind. Die weiße Schale besteht aus 10 langsam zunehmenden, nicht gewölbten Windungen, deren erste groß und anfangs glatt, dann mit 2 Reifen besetzt ist, die sich auf die beiden nächsten Windungen fortsetzen, um weiterhin in 2 Körnerreihen überzugehen, über der Naht ist der glatte Reifen sichtbar, dem sich die folgende Windung ansetzt. Die letzte Windung ist unten flach und glatt, der Spindelfortsatz kurz, die Mündung klein und viereckig. Höhe 3,3 mm, Durchmesser 0,8 mm.*

Translation. A shell that is definitely not yet adult from the same station 104 [Agulhas Bank] resembles the West-Indian species *T. colon* Dall, because of the slim shape and the two rows of tubercles; the apex of *T. colon*

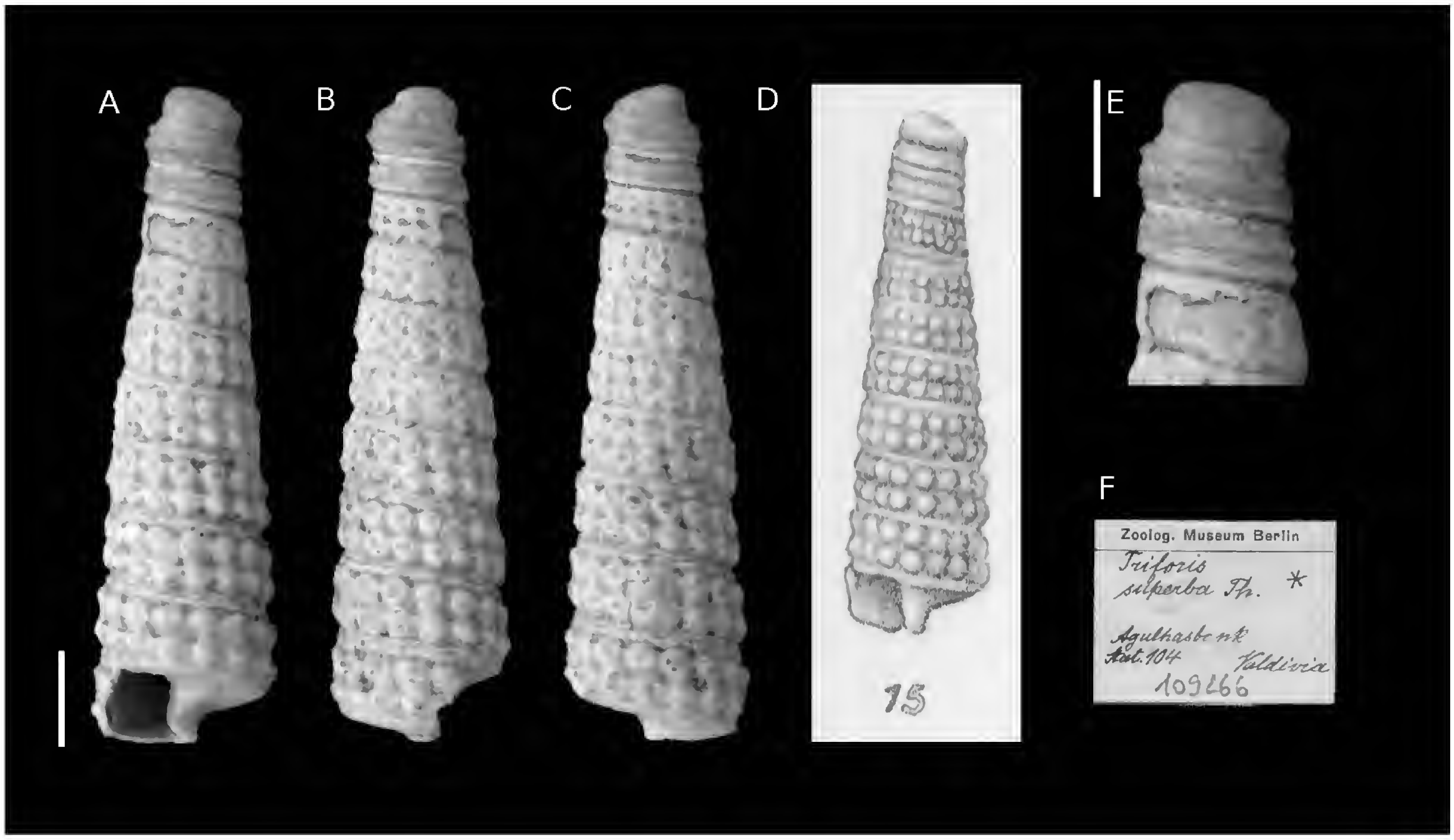


Figure 11. *Triphora superba* Thiele, 1925, Station 104 (Agulhas Bank). **A-C**, **E**. Holotype, ZMB/Moll no. 109266: front (**A**), side (**B**), back (**C**), protoconch (**E**). **D**. Original figure in Thiele 1925. **F**. Original label. Scale bar: **A-C**: 0.5 mm, **E**: 0.2 mm.

is not known. The white shell has 10 flat whorls which slowly increase in size; the first [protoconch] whorl is big and initially smooth, then sculptured with two keels, which continue on the next two whorls to become two cords with tubercles; above the suture a further smooth cord is visible. The last whorl is on the underside flat and smooth, the siphonal canal is short, the aperture is small and quadrangular. Height 3.3 mm, diameter 0.8 mm.

Diagnosis. Holotype height 3.4 mm and teleoconch of seven whorls, but the holotype is clearly a subadult specimen. Shell slender, with flat whorls. Teleoconch whorls have two tubercled spiral cords; a fine suprasutural smooth cord is also present. Paucispiral large apex of three whorls: the first whorl is smooth, while the other two bear two strong spiral cords. Colour white, but the specimen is worn, therefore the colour cannot be reliably described. Base and peristome cannot be properly described on the basis of the type material.

Indo-Pacific species

Triphora adela Thiele, 1930

Figure 12

Triphora adela Thiele, 1930: 577, plate IV, figure 38.

Type specimens. Holotype: ZMB/Moll no. 67493, fixed by monotypy.

Type locality. "Station 25 (Sharks Bay)" (Western Australia).

Original description. *Eine Schale von Station 25 (Sharks Bay) hat etwa 11 mäßig schnell zunehmende Windungen, sie ist daher ziemlich breit, im ganzen hell bräunlich, auf der Endwindung sind die Zwischenräume zwischen den Knoten und hauptsächlich die Unterseite dunkelbraun. Die Embryonalwindungen sind mit einer Mittelkante und herablaufenden Fäden skulptiert, die folgenden Windungen mit 2 Knotenreihen zwischen denen ein allmählich stärker und knotig werdender Reifen gelegen ist, die Unterseite der Endwindung hat 3 glatte Reifen, die Mündung ist oben spitzwinklig. Höhe 3 mm, Durchmesser 0,9 mm.*

Translation. A single shell from Station 25 (Shark Bay), which has about 11 whorls which increase moderately fast in size, it is therefore fairly broad; the shell is light brownish, but dark brown between the tubercles on the last whorl and on the base. The embryonal whorls have a spiral keel in the middle and axial riblets, the following whorls have two rows of tubercles and between them a tubercled row develops and gradually becomes stronger; the base has three smooth cords, the aperture has an acute angle on the upper part. Height 3 mm, diameter 0.9 mm.

Diagnosis. Lectotype height is 3.0 mm. Shell conical, with flat whorls. The teleoconch has six whorls with three tubercled spiral cords; the second is present since the first teleoconch whorl, but it gains its full size only on the last whorl. Suture deep, a very fine suprasutural smooth cord is visible. The last whorl has

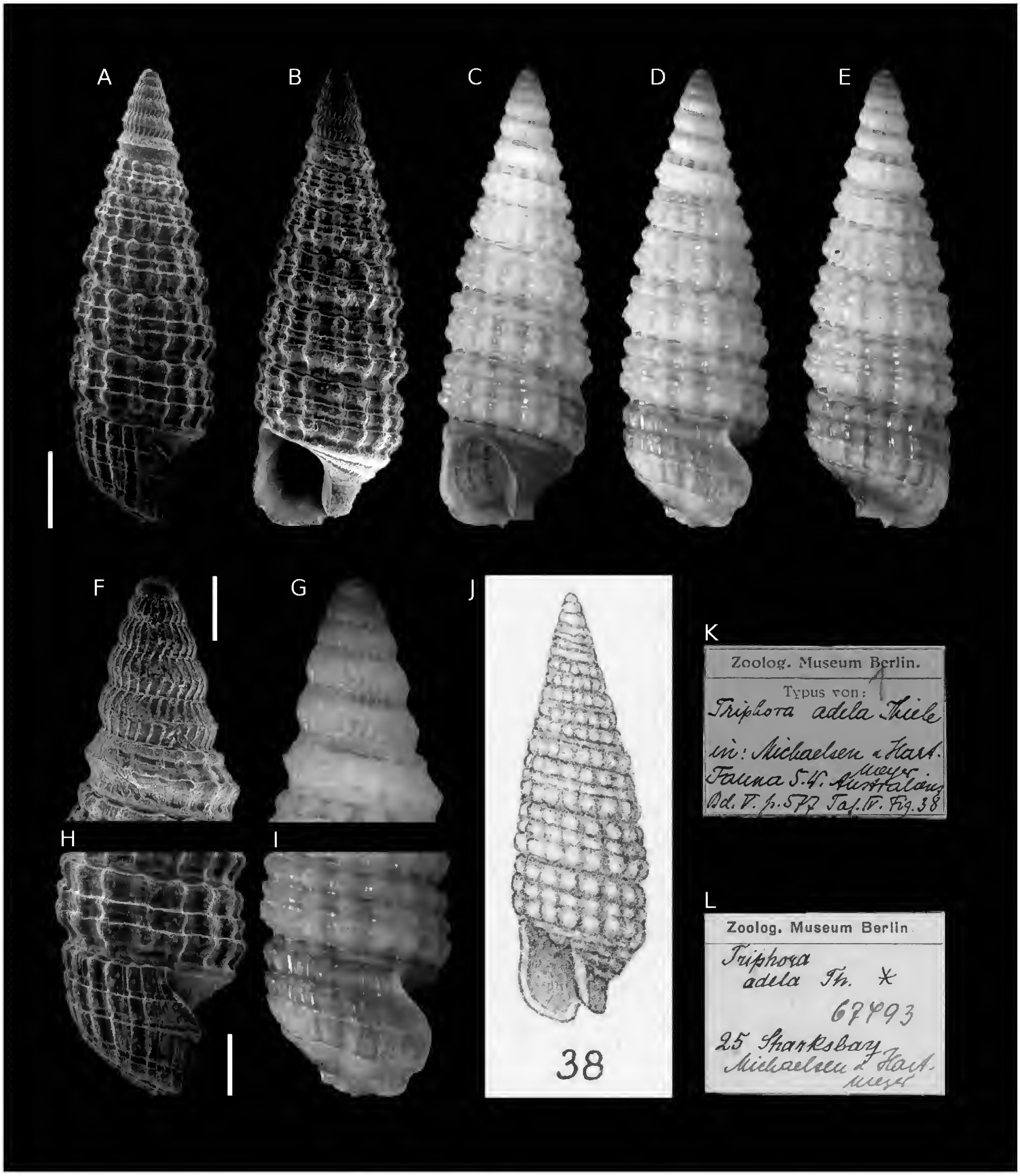


Figure 12. *Triphora adela* Thiele, 1930, Station 25 (Shark Bay). **A-I**. Holotype, ZMB/Moll no. 67493: left side (**A, D**), front (**B-C**), back (**E**), protoconch (**F-G**), peristome (**H-I**). **J**. Original figure in Thiele 1930. **K-L**. Original labels. Scale bar: **A-E**: 0.5 mm, **F-G**: 0.2 mm, **H-I**: 0.3 mm.

a fourth almost smooth spiral cord, and the base has two further smooth cords. A posterior sinus is well visible on the peristome. Multispiral apex of five whorls; the first whorl is smooth, while the others bear axial riblets and a strong keel. Protoconch whorls brownish at the beginning, then white like the first teleoconch whorls. The rest of the teleoconch is light brownish with white tubercles. The last whorl has the two first cords on brown background, the third is white, and the base deep brown.

Triphora aequatorialis Thiele, 1925

Figure 13
Triphora aequatorialis Thiele, 1925: 131-132 (97-98), plate XXII (X), figure 27.

Type specimens. Holotype: ZMB/Moll no. 109278, fixed by monotypy.

Type locality. "Station 244 [5°55.8' südl. Br., 39°1.2' östl. L., 50 m Tiefe, bei Ost-afrika]" (off Zanzibar, East Africa).

Original description. *Eine schale von derselben Station 244, die wohl verblaßt ist, zeigt noch am oberen Teil der Windungen, etwa an der oberen Knotenreihe, sowie an der Unterseite und am Mundrande braune Färbung, während sie im übrigen weißlich ist, hierin hat sie etwas Aehnlichkeit mit* T. angasi, *die aber schlanker ist; die Art scheint noch nicht bekannt zu sein. Die Schale ist ziemlich breit und etwas rundlich getürmt, die äußerste Spitze fehlt, es sind fast 11 Windungen erhalten, die sämtlich mit 3 Knotenreihen besetzt sind, die nicht sehr dicht stehen, die Knoten liegen übereinander, die letzten Windungen sind deutlich gewölbt und durch eine vertiefte Naht getrennt, die letzte ist kaum kantig, außer den 3 Knotenreihen noch mit 3 Reifen besetzt, von denen die beiden oberen noch knotig sind, der unterste umgibt die Wurzel des etwas gekrümmten Spindelfortsatzes. Mundrand vorgezogen, außen kaum knotig, unten dem Spindelfortsatz genähert, daher ist der Kanal fast geschlossen, Mündung ziemlich klein, rundlich. Höhe 7,5 mm, Durchmesser 2,25 mm.*

Translation. A single shell from Station 244; it shows again brown colour on the upper part of the whorls, on the upper row of tubercles, on the base and on the peristome. The rest is whitish, being in this respect similar to *T. angasi*, which however is more slender. This species seems not to be described yet. The shell is quite broad and rounded. The first whorl is missing, but the shell is composed by 11 whorls, that are totally covered by three rows of tubercles, which are not too dense. The tubercles are one above the other [probably meaning they are aligned vertically]. The lower whorls are clearly rounded and a deep suture separates them. The periphery at the base is a bit angulated. After the 3 tubercled spiral cords, the base has two rows of tubercles, while a faint lower thread is around the base of the bended columella. The peristome is deformed, externally weakly tubercled. The lower margin of the aperture gets very close to the columella, hence the siphonal canal looks almost closed. Aperture quite small, rounded. Height 7.5 mm, diameter 2.25 mm.

Diagnosis. The holotype is an adult specimen 7.4 mm high. Shell conical with deep sutures. Teleoconch composed by 10 whorls, protoconch missing. Teleoconch sculpture is characterized by three tubercled spiral cords since the very first whorl, the first cord is weaker on the first two-three whorls. A fine suprasutural smooth cord is also visible. The last whorl has a fourth tubercled spiral cord and the base has one more tubercled cord. The peristome has regrown after being broken off, and it is not useful for describing its diagnostic features. Ante-

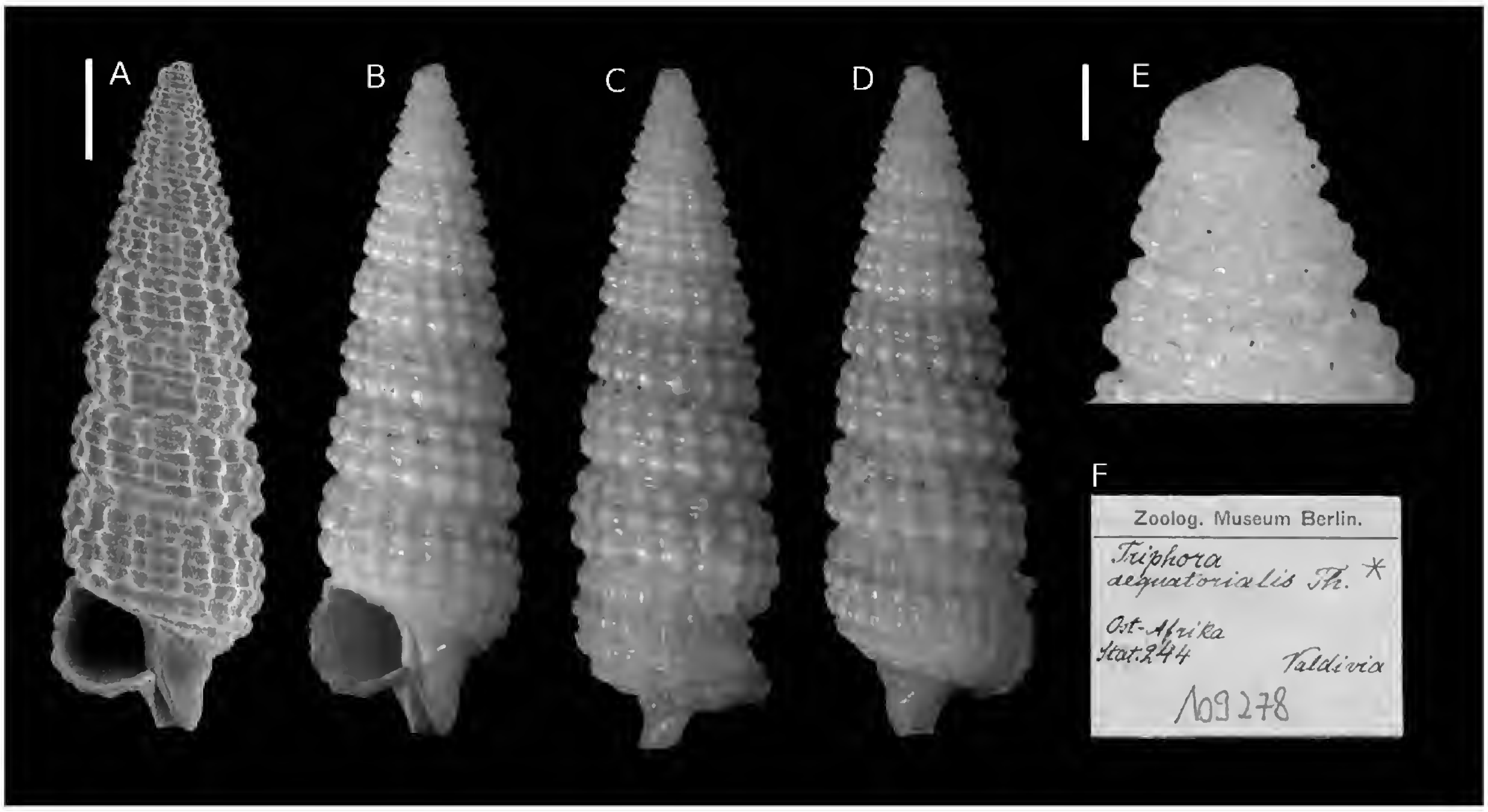


Figure 13. *Triforis aequatorialis* Thiele, 1925, Station 244 (East Africa). **A-E**. Holotype, ZMB/Moll no. 109278: front (**A-B**), left side (**C**), back (**D**), protoconch (**E**). **F**. Original label. Scale bar: **A-D**: 1 mm, **E**: 0.2 mm.

rior siphonal canal quite long. Colour whitish, with a faint light brown band as background colour of the first cord. Tubercles usually lighter and whiter than the background colour.

Remarks. The apex is missing, but the size of the first teleoconch whorl suggests a multispiral apex.

Triphora aethiopica Thiele, 1925

Figure 14

Triphora aethiopica Thiele, 1925: 131 (97), plate XXII (X), figure 25.

Type specimens. Holotype: ZMB/Moll no. 109276, fixed by monotypy.

Type locality. "Station 244 [5°55.8' südl. Br., 39°1.2' östl. L., 50 m Tiefe, bei Ost-afrika]" (off Zanzibar, East Africa).

Original description. *Eine Schale von Station 244 gehört in dieselbe Gruppe wie die vorigen Arten [*Triphora sceptrum*], von Denen sie sich durch beträchtlich geringere Größe unterscheidet, ihre Anfangswindungen sind ähnlich wie bei* T. regia*, deren Skulptur bedeutend gröber ist;* T. concatenata *Melv. (Proc. malac. Soc. London, v. 6 p. 162 t. 10 f. 9) aus dem Golf von Oman ist auch ähnlich, doch soll diese nur einen Kiel auf den braunen Anfangswindungen haben. Die äußerste Spitze (etwa 1-2 Windungen) fehlt, es sind etwa 16 erhalten, die zuletzt kaum zunehmen und ein hoch getürmtes Gehäuse bilden. Die ersten sind gelbbraun, mit 2 ziemlich entfernten Reifen und herablaufenden Fäden skulptiert, die folgenden sind weißlich, stark glänzend, mit einem etwas knotigen Reifen unter der Naht und 2 gleichstarken Reihen etwas zusammengedrückter Knoten von mäßiger Größe, die grade übereinander liegen. Die letzte Windung hat an der unteren scharfen Kante einen kantigen Reifen und an der stark eingezogenen Unterseite noch 2 Reifen. Spindelfortsatz etwas gekrümmt. Der Mundrand ist etwas beschädigt. Höhe 6,25 mm, Durchmesser 1,25 mm.*

Translation. A single shell from Station 244 belongs to the same group as the previous species [*Triphora sceptrum*], from which it differs by its considerably smaller size, the apex is similar to the one of *T. regia*, whose sculpture is much coarser; *T. concatenata* Melv. (Proc. malac. Soc. London, v. 6 p. 162 t. 10 f. 9) from the Gulf of Oman is also similar, but this species has only one keel on the apex. The first few whorls (about 1-2 whorls) of the protoconch are missing, there are about 16 whorls, the last ones are slightly larger and form a slender shell. The first whorls [apex] are yellowish-brown, with two spiral keels and axial riblets, the following whorls are whitish, very shiny, with a slightly tubercled cord under the suture and two cords of equal size with compressed tubercles of moderate size, which lie just one above the other. The last whorl is angulated, and on the base there are two strongly drawn cords. The siphonal canal is slightly curved. The aperture is slightly damaged. Height 6.25 mm, diameter 1.25 mm.

Diagnosis. Holotype height 6.4 mm. Shell very slender, conical, with flat whorls. Teleoconch of 12 whorls, which have three tubercled spiral cords; the first is present since the first teleoconch whorl, and always smaller than the other two. Last whorl with a fourth weakly tubercled spiral cord while the base has two finer and smoother cords. Multispiral apex of at least three whorls, but the very first ones are missing; the protoconch whorls bear two strong keels and axial riblets. Teleoconch colour white, whereas the protoconch is yellowish; however, both colours may be faded, because the holotype was dead collected.

Triphora albina Thiele, 1930

Figure 15

Triphora albina Thiele, 1930: 577-578, plate IV, figure 39.

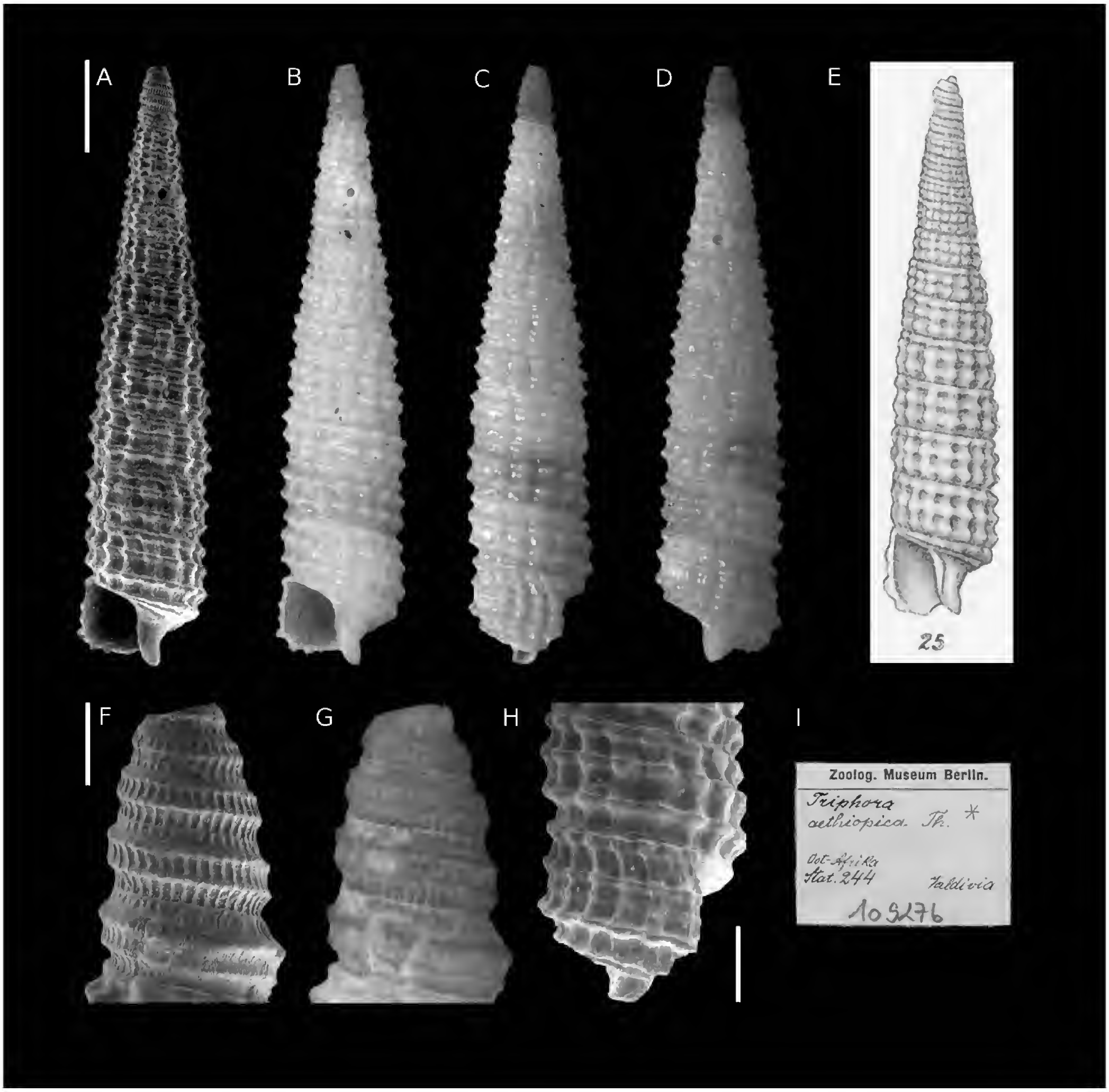
Type specimens. Lectotype: ZMB/Moll no. 67494a, here designated. Paralectotypes A-B: ZMB/Moll no. 67494b-c.

Type locality. "Station 1 (Sharks Bay)" (Western Australia).

Original description. *Eine Schale von Station 1 (Sharks Bay) ist weiß, die Embryonalschale bräunlich, mit 4½ kantigen und mit herablaufenden Fäden skulptierten Windungen, die folgenden 6 Windungen langsam zunehmend, anfangs mit 2, dann mit 3 Knotenreihen, Endwindung nach unten verschmälert und abgerundet, hier mit 3 Reifen, Mündung ziemlich schmal, oben spitzwinklig. Höhe 2,6 mm, Durchmesser 0,8 mm.*

Translation. One shell from Station 1 (Shark Bay) is white, the protoconch whorls brownish, of 4½ whorls with a spiral keel and axial riblets; the following 6 whorls slowly increase in size and have two tubercled cords at the beginning, which later become three; the base is rounded, with three threads; aperture rather narrow, with an acute angle on the upper part. Height 2.6 mm, diameter 0.8 mm.

Diagnosis. Lectotype height 2.6 mm. Shell pupoid, with flat whorls. Teleoconch of six whorls, which have three tubercled spiral cords. The second cord develops later and is fully visible from the fourth row. A fine suprasutural smooth cord also present. The last whorl has a fourth weakly tubercled spiral cord. The base has two more spiral cords: one is weakly tubercled, while the other is smooth. Peristome with a posterior sinus. Multispiral apex of five whorls: the first is smooth, while the others bear a single strong keel and axial riblets. Teleoconch white, apex white to light brownish.



Zoolog. Museum Berlin.
Triphora
aethiopica Th. *
Ost-Afrika
Stat. 244 Valdivia
109276

Figure 14. *Triphora aethiopica* Thiele, 1925, Station 244 (5°55.8’S, 39°1.2’E, 50 m depth, off East Africa). **A-D**, **F-H**. Holotype, ZMB/Moll no. 109276: front (**A-B**), side (**C**), back (**D**), protoconch (**F-G**), peristome (**H**). **E**. Original figure in Thiele 1925. **I**. Original label. Scale bar: **A-D**: 1 mm, **F-G**: 0.2 mm, **H**: 0.5 mm.

Triphora alboapicata Thiele, 1930

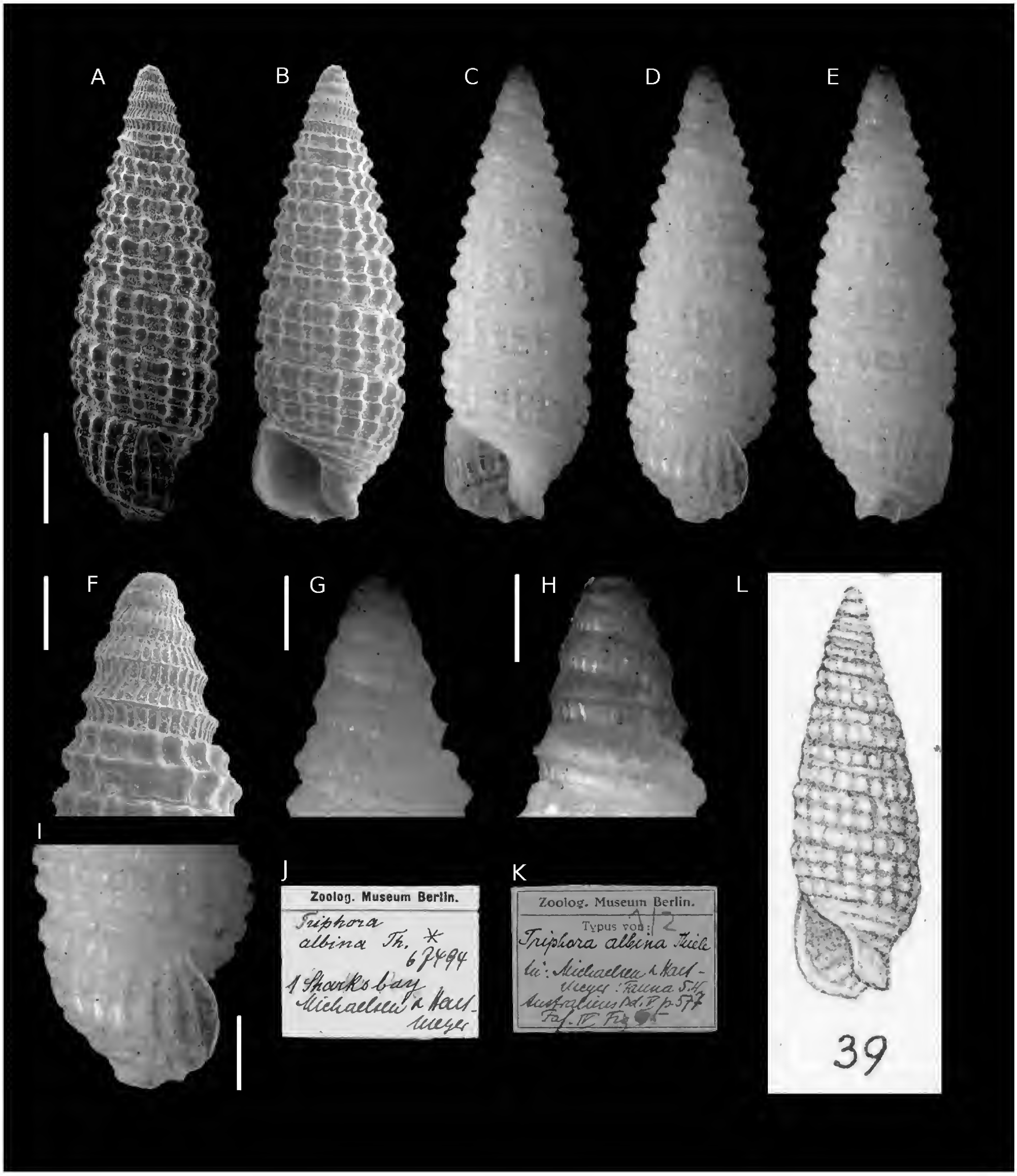
Figure 16
Triphora alboapicata Thiele, 1930: 577, plate IV, figure 35.

Type specimens. Holotype: ZMB/Moll no. 67490, fixed by monotypy.

Type locality. “Station 3 (Sharks Bay)” (Western Australia).

Original description. *Eine schale von Station 3 (Sharks Bay) ist durch ihre anfangs weiße, nachher schwarze Färbung ausgezeichnet. Die aus 2½ Windungen bestehende Embryonalschale ist oben stumpf, dann etwas kantig, die herablaufenden Fäden sind undeutlich; die folgenden 8 Windungen haben 2 Knotenreihen, zwischen die sich auf den unteren Windungen allmählich noch eine dritte Reihe einschiebt, die Endwindung hat 6 Reihen; die Mündung ist oben spitzwinklig. Höhe 4 mm, Durchmesser 1,3 mm.*

Translation. One shell from Station 3 (Shark Bay) is in its starting whorls white, while the lower whorls are black. The first 2½ embryonic whorls are not pointed, a bit angulated, the axial sculpture is unclear; the following



Zoolog. Museum Berlin.
Triphora
albina Th. *
67494
1 Shark's bay
Michaelsen & Hart-
meyer

Zoolog. Museum Berlin.
Typus von: A12
Triphora albina Thiele
in: Michaelsen & Hart-
meyer: Fauna S.W.
Australiens Bd. V p. 577
Taf. IV Fig.

Figure 15. *Triphora albina* Thiele, 1930, Station 1 (Shark Bay). **A-G**, **I**. Lectotype, ZMB/Moll no. 67494a: left side (**A, D**), front (**B-C**), back (**E**), protoconch (**F-G**), peristome (**I**). **H**. Paralectotype B, ZMB/Moll no. 67494b: protoconch. **J-K**. Original labels. **L**. Original figure in Thiele 1930. Scale bar: **A-E**: 0.5 mm, **F-H**: 0.2 mm, **I**: 0.3 mm.

eight whorls have two rows of tubercles, gradually a third cord develops on the lower whorls, between the first two; the last whorl has six threads; the aperture has an acute angle on the upper part. Height 4 mm, diameter 1.3 mm.

Diagnosis. Holotype height 4.0 mm. Shell pupoid. The teleoconch has seven flat whorls, which have three tubercled spiral cords; the second cord appears later along the spire, and is visible on the sixth whorl and well developed only on the last one. A very fine suprasutural cord also present. The last whorl has a fourth tubercled cord. The base has

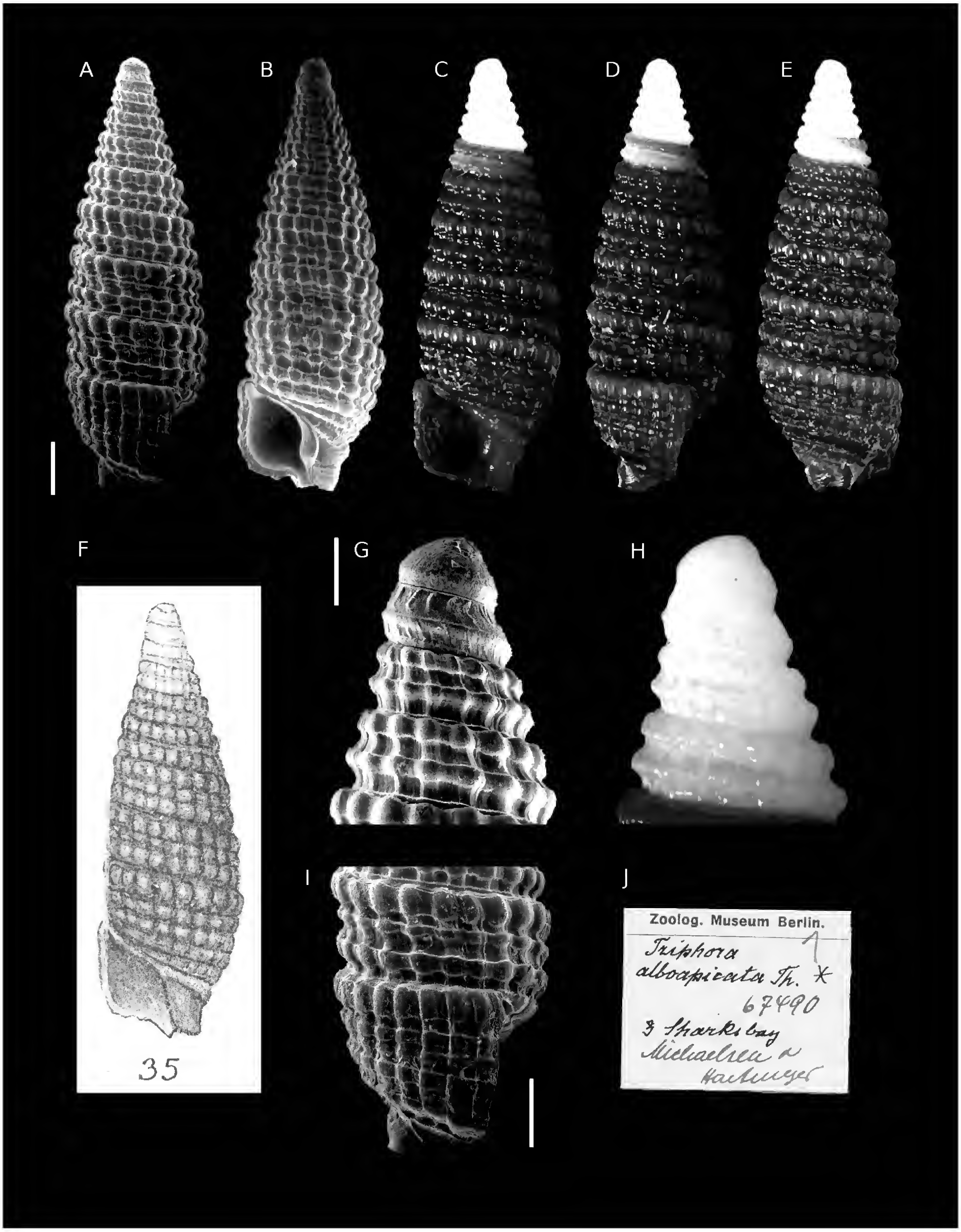


Figure 16. *Triphora albopicata* Thiele, 1930, Station 3 (Shark Bay). **A-E**, **G-I**. Holotype, ZMB/Moll no. 67490: left side (**A, D**), front (**B-C**), back (**E**), protoconch (**G-H**), peristome (**I**). **F**. Original figure in Thiele 1925. **J**. Original label. Scale bar: **A-E**: 0.5 mm, **G-I**: 0.2 mm, **H**: 0.4 mm.

two spiral cords: the first is tubercled, while the second is almost smooth. On the peristome, additional spiral cords appear between the main ones. Paucispiral apex of two whorls; the first whorl has a keel on the periphery, while on the second, axial riblets are also present. Teleoconch dark brown, protoconch and the first two whorls white.

Triphora brunnescens Thiele, 1930

Figure 17
Triphora brunnescens Thiele, 1930: 577, plate IV, figure 36.

Type specimens. Lectotype: ZMB/Moll no. 67491a, here designated. Paralectotype A: ZMB/Moll no. 67491b.

Type locality. "Stationen 16 und 20 (Sharks Bay)" (Western Australia).

Original description. *Ein Paar Schalen von den Stationen 16 und 20 (Sharks Bay) sind hellbräunlich, spitz, turmförmig, mit etwa 15 langsam und gleichmäßig zunehmenden Windungen, von denen die 5 Embryonalwindungen mit 2 Spiralfäden und herablaufenden Fäden, die folgenden mit 3 Knotenreihen skulptiert sind, die Endwindung hat unten 3 glatte Reifen, der Spindelfortsatz ist kurz, die Mündung oben spitzwinklig. Höhe 5 mm, Durchmesser 1,3 mm, andere Schalen sind nur 3,25 mm hoch.*

Translation. Two shells from the stations 16 and 20 (Shark Bay), which are light brown of colour, pointed, slender, with about 15 slowly and steadily increasing whorls, of which the 5 embryonic whorls have 2 spiral keels and axial riblets; the following whorls are sculptured with 3 tubercled cords; the last whorl has 3 smooth cords on the base; the siphonal canal is short, the aperture has an acute angle in the upper part. Height 5 mm, diameter 1.3 mm, other shells are only 3.25 mm high.

Diagnosis. Lectotype height 5.1 mm. Shell conical, with flat whorls. Teleoconch of 11 whorls. Paralectotype is 3.3 mm high and has eight whorls. Teleoconch whorls have three tubercled spiral cords, well visible since the first whorl. A fine suprasutural smooth cord is also present. The last whorl has a fourth tubercled spiral cord, and the base further two, but smooth. The peristome has a posterior sinus. The protoconch is broken and lacks the very first whorls, but it is clearly multispiral: three whorls are clearly visible and are ornamented by two spiral keels and axial riblets. Protoconch light brown. The teleoconch has the first whorl white, then it is brown until the sixth row; the lower whorls have the first row of tubercles light brown, while the other two are white. Base light brown.

Remarks. The lectotype and paralectotype are both fully mature, but show significantly different sizes, 5.1 and 3.3 mm respectively, as observed in several other species (Marshall 1983).

Triphora castaneofusca Thiele, 1930

Figure 18
Triphora castaneofusca Thiele, 1930: 576-577, plate IV, figure 33.

Type specimens. Holotype: ZMB/Moll no. 67451, fixed by monotypy.

Type locality. "Station 3 (Sharks Bay)" (Western Australia).

Original description. *Eine noch nicht ganz ausgewachsene Schale von Station 3 (Sharks Bay) ist ziemlich groß, einfarbig kastanienbraun, mit etwa 15 gleichmäßig zunehmenden Windungen, ihre Embryonalschale zeigt die typische Skulptur mit 2 Spiralfäden, die von herablaufenden Fäden gekreuzt werden, während die folgenden Windungen mit 3 Knotenreihen skulptiert sind, die Endwindung hat an der unteren Kante noch einen Reifen und 3 glatte Reifen an der Unterseite. Höhe 7 mm, Durchmesser 2,3 mm.*

Translation. A not fully grown shell from station 3 (Shark Bay) which is pretty large, brown in colour, with about 15 evenly increasing whorls; the protoconch shows the typical sculpture of two spiral keels, which are crossed by axial riblets, while the following whorls are sculptured with three cords of tubercles, the last whorl has on the base another tubercled cord and three smooth cords. Height 7 mm, diameter 2.3 mm.

Diagnosis. Holotype height 7.0 mm. Shape of the shell initially conical; the last two whorls are inflated, but this shape may not be typical: it may be due to a failed predatory attempt and shell regrowth. Teleoconch of 10 whorls, which have three tubercled spiral cords; the first cord appears on the second whorl. A fine barely visible suprasutural smooth cord is also present. A fourth slightly tubercled spiral cord is present on the last whorl, and three further almost smooth cords are present on the base. Peristome not fully developed, because the specimen is sub-adult. Only the last whorl of the protoconch is present; due to its size, it is likely multispiral. It bears two keels and axial riblets. Colour brown; tubercles lighter on the lower half of the shell.

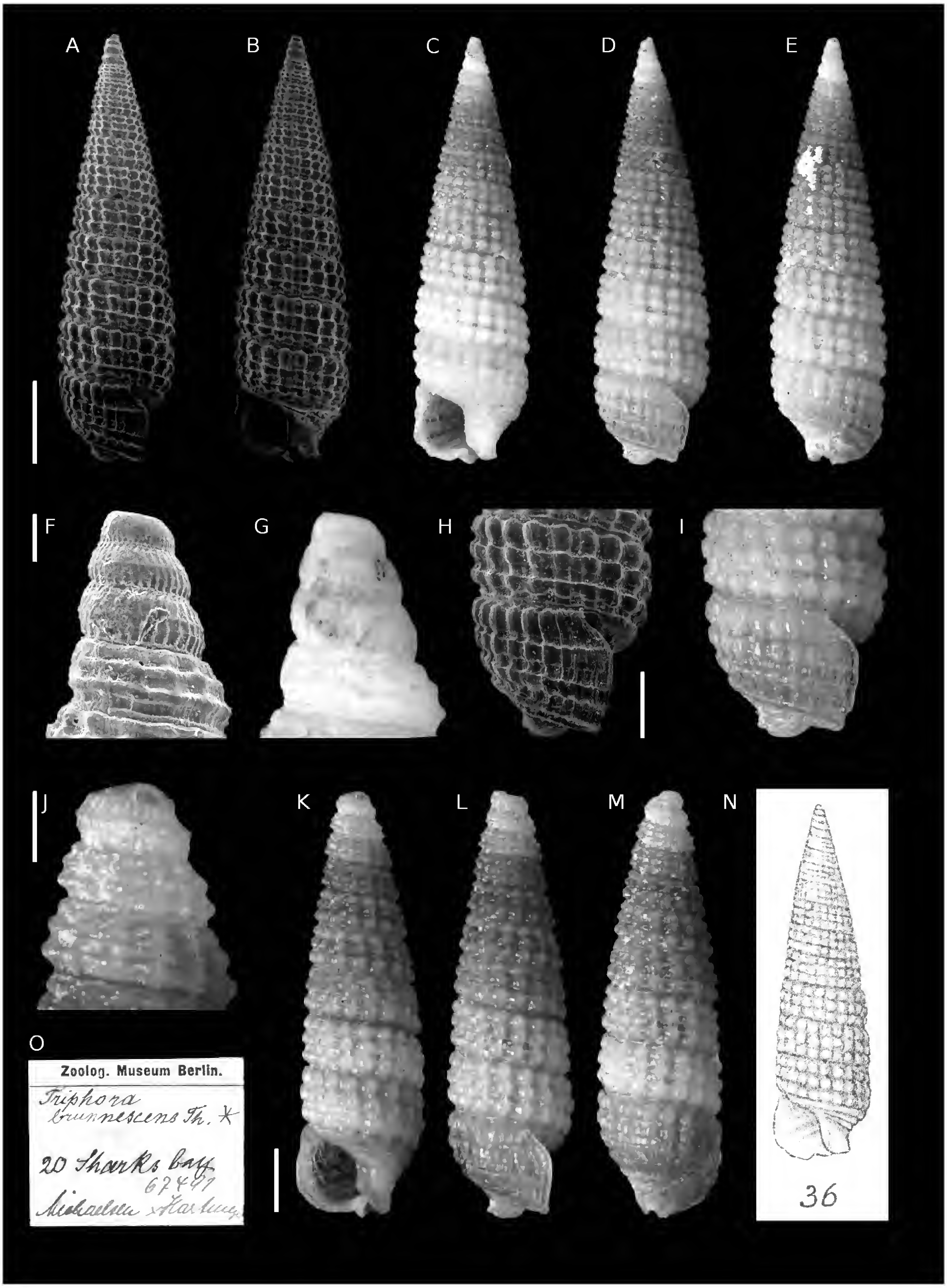
Triforis crassula Martens, E. von, 1880

Figure 19
Triforis crassula Martens, E. von, 1880: 282, plate XXII, figure 1.

Type specimens. Lectotype: ZMB/Moll no. 31774a, here designated. Paralectotypes A-D: ZMB/Moll no. 31774b-e.

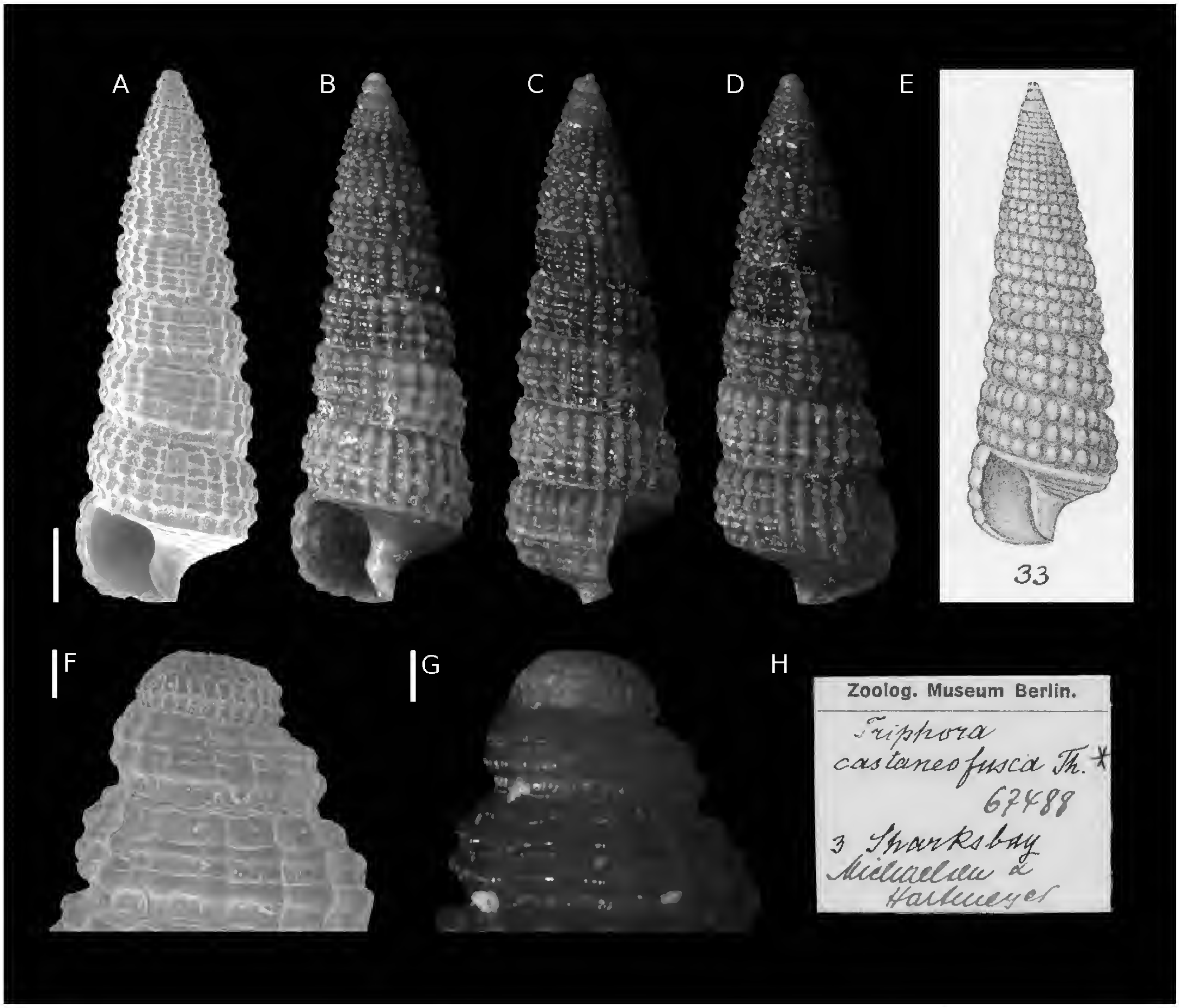
Type locality. "Mauritius, im Sand".

Original description. *Testa ventricosa, conico-ovata, granulis supra suturam biseriatis, fusconigricans, apice pallide flavescente; anfr. circa 6, sat celeriter crescents,*



Zoolog. Museum Berlin.
Triphora
brunnescens Th. *
20 Sharks bay
67491
Michaelsen & Hartmeyer

Figure 17. *Triphora brunnescens* Thiele, 1930, stations 16 and 20 (Shark Bay). **A-I**. Lectotype, ZMB/Moll no. 67491a: left side (**A, D**), front (**B-C**), back (**E**), protoconch (**F-G**), peristome (**H-I**). **J-M**. Paralectotype A, ZMB/Moll no. 67491b: protoconch (**J**), front (**K**), side (**L**), back (**M**). **N**. Original figure in Thiele 1930. **O**. Original label. Scale bar: **A-E**: 1 mm, **F-G**: 0.1 mm, **H-I**: 0.5 mm, **J**: 0.2 mm, **K-M**: 1 mm.



Zoolog. Museum Berlin.
Triphora
castaneofusca Th. *
67488
3 Sharksbay
Michaelsen &
Hartmeyer

Figure 18. *Triphora castaneofusca* Thiele, 1930, Station 3 (Shark Bay). **A-D**, **F-G**. Holotype, ZMB/Moll no. 67488: front (**A-B**), left side (**C**), back (**D**), protoconch (**F-G**). **E**. Original figure in Thiele 1925. **H**. Original label. Scale bar: **A-D**: 1 mm, **F-G**: 0.1 mm.

ultimus angustus, basi liris circa 3 granosis cinctus, apertura parva, simplice.

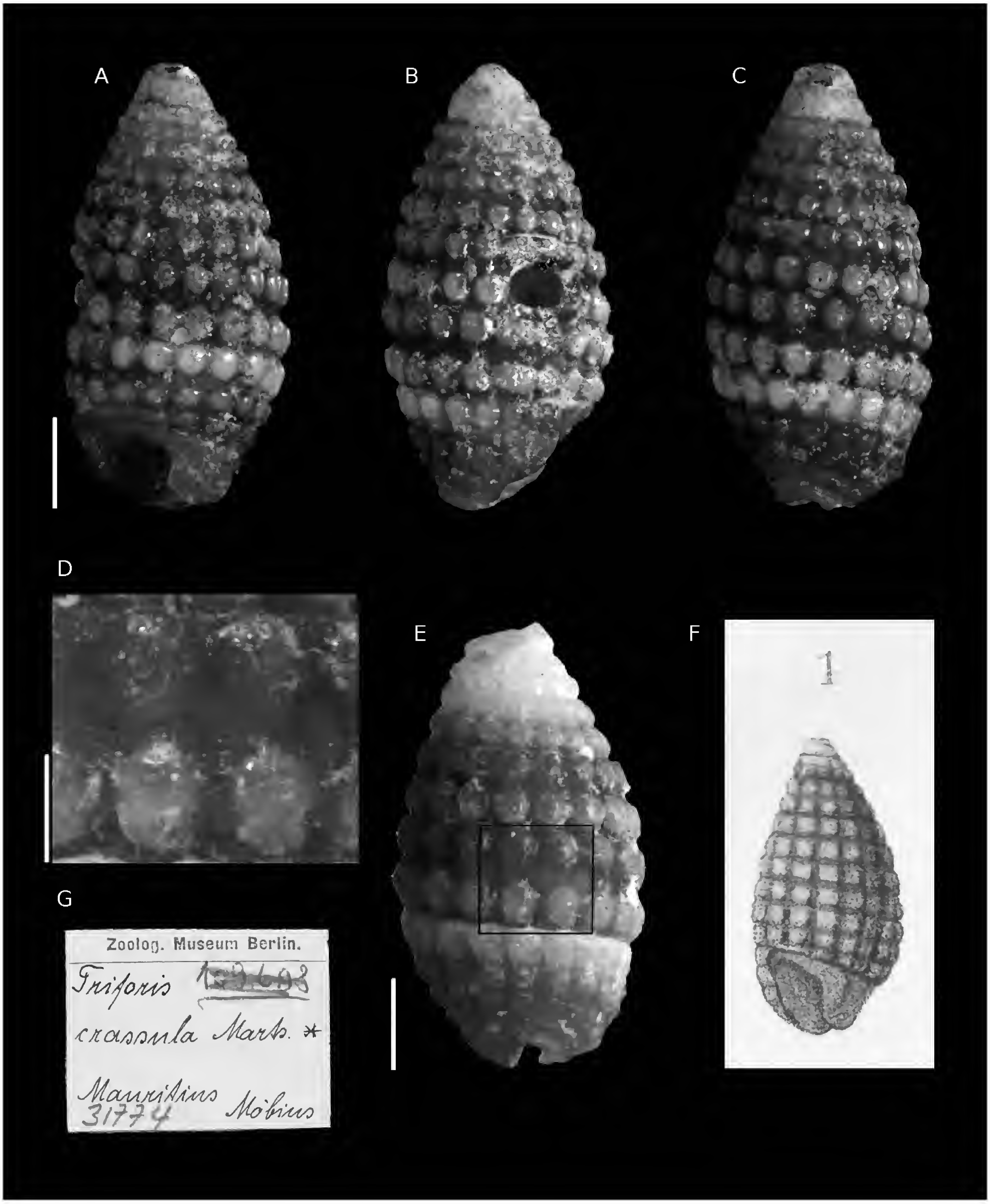
Long. 2½, diam. 1⅓, apert. ⅔ mm.

Mauritius, im Sand, Prof. Möbius.

Der obere Gürtel ist öfters heller gefärbt, aschgrau. Obgleich nur unvollkommene Exemplare vorliegen, so ist der Gesammthabitus doch so eigenthümlich, dass ich ihnen einen Artnamen nicht versagen wollte. Nächstverwandt sind Trif. pupaeformis *Desh. moll. de Reunion pl. 12, fig. 3, 4, welche durch die helle Färbung und die ungekörnte Basis sich unterscheidet, und* T. atomus *Issel malacologia del mar rosso pl. 4, Fig. 4, p. 280 fossil und noch kleiner, 1½ mm lang, ¾ breit.*

Translation. Inflated shell, ovate cone shaped, with two series of tubercles above the suture, deep brown with apex light yellowish; approximately 6 whorls, which grow fast, the last whorl is smaller, the base has 3 tubercled spiral cords, the aperture is small and simple. Length 2½ mm, diameter 1⅓ mm, aperture ⅔ mm. Mauritius, in sand, Prof. Möbius. The first thread is often light ash-grey of colour. Although, only imperfect specimens are present, the overall look of the specimens are so unusual, that I could not leave them without a name. Related species are *T. pupaeformis* Desh. (Moll. de Reunion pl. 12, fig. 3, 4), which is distinguishable by its light colouring and base without tubercles, and *T. atomus* Issel (Malacologia del Mar Rosso pl. 4, fig. 4, p. 280) which is a fossil species and even smaller, 1½ mm in length and ¾ in width.

Diagnosis. Lectotype height 2.4 mm. Shell oval, with the last whorl of smaller diameter than the penultimate one. Teleoconch of six whorls, which have two tubercled spiral cords; a fine spiral microsculpture is present between the cords (Fig. 19 D). A third tubercled spiral cord present on the last whorl. The base with two further smooth spiral cords. Whorls rather flat. Due to the overall bad conditions of the specimens, it is not easy to



Zoolog. Museum Berlin.
Triforis [illegible]
crassula Mart. *
Mauritius Möbius
31774

Figure 19. *Triphora crassula* von Martens, 1880, Mauritius. **A-C**. Lectotype, ZMB/Moll no. 31774a: front (**A**), side (**B**), back (**C**). **D-E**. Paralectotype C, ZMB/Moll no. 31774d: microsculpture (**D**), back (**E**). **F**. Original figure in von Martens 1880. **G**. Original label. Scale bar: **A-C**: 0.5 mm, **D**: 0.2 mm, **E**: 0.4 mm.

observe the peristome, which, however, seems to have additional spiral cords. The apex is missing. The first teleoconch whorls are yellowish; the rest of the shell is brown with grey tubercles.

Remarks. The lot contains also two triphorid specimens belonging to a distinctly different species, and five cerithiopsids, all quite worn.

Triphora dives Thiele, 1925

Figure 20
Triphora dives Thiele, 1925: 130 (96), plate XXII (X), figure 22.

Type specimens. Holotype: ZMB/Moll no. 109273, fixed by monotypy.

Type locality. "Station 244 (5°55.8' südl. Br., 39°1.2' östl. L., 50 m Tiefe, bei Ost-Afrika)" (off Zanzibar, East Africa).

Original description. *Eine Schale von Station 244 (5°55,8' südl. Br., 39°1.2' östl. L., 50 m Tiefe, bei Ost-Afrika) gehört zu einer ausgezeichneten neuen Art, sie ist lang kegelförmig, etwas gelblich, in den Kerben der Spiralreifen undeutlich braun gefärbt.*

Die äußerste Spitze ist abgebrochen, 16 Windungen sind vorhanden, die gleichmäßig zunehmen, die glänzende Oberfläche zeigt feine und dichte Spirallinien und 4 wellige kielartige Reifen, von denen der zweite und der über der Naht sichtbare vierte nur schwach, der dritte am stärksten ist, seine Entfernung vom zweiten ist am größten, in den Zwischenräumen sind niedrige und breite herablaufende Falten vorhanden. Bei der letzten Windung verstärkt sich der unterste Reifen zu einer deutlichen Kante, unter der die Schale plötzlich stark eingeschnürt ist, an der Unterseite ist noch ein ziemlich starker, braun gegliederter Reifen vorhanden, Spindelfortsatz sehr schräg. Mundrand vorgezogen, auf ihm hat sich in der Mitte zwischen den auseinandergehenden 2. und 3. Reifen noch einer eingeschoben. Höhe 13,5 mm, Durchmesser etwa 3,5 mm.

Translation. One shell from station 244 (5°55.8'S, 39°1.2'E, 50 m depth, off East Africa) belongs to an undescribed new species, it is long and conical in shape, a bit yellowish, with a faint brown colour between the tubercles of the spiral cords. The protoconch is missing; the shell has 16 whorls, which regularly increase in size, the glossy surface has fine and dense spiral cords and four strong keeled threads, of which the second and the fourth are less prominent, the third keeled cord is the most prominent, and there is a large distance between the second and third cord; in the interspaces between the cords there are wide axial ribs. On the last whorl, the lowest cord forms a sharp edge, under which the base suddenly constricts; on the base there is another spiral cord with faint brown colour between the tubercles; the siphonal canal is very oblique. The peristome is expanded, and it bears an additional spiral cord between the second and third cord. Height 13.5 mm, diameter 3.5 mm.

Diagnosis. Holotype height 13.1 mm. Shell slender, conical, with flat whorls. The teleoconch has 16 whorls, but the apex is broken and it may have a few more whorls. Teleoconch whorls have three sharp weakly tubercled spiral cords; the second develops later along the spire, on the fifth whorl. A fine suprasutural smooth cord is also present. The last whorl has a prominent fourth sharp and weakly tubercled cord, the profile of the last whorl is much angulated. The base has a further weakly tubercled spiral cord. The peristome has a posterior pallial sinus and has an additional spiral cord between the second and the third. Protoconch missing in the holotype. Colour yellowish-light brown, but the specimen was collected dead, and the colours may have faded away.

Triphora elata Thiele, 1930

Figure 21
Triphora elata Thiele, 1930: 577, plate IV, figure 37.

Type specimens. Holotype: ZMB/Moll no. 67492, fixed by monotypy.

Type locality. "Station 25 (Sharks Bay)" (Western Australia).

Original description. *Eine Schale von Station 25 (Sharks Bay) ist schlank getürmt, kastanienbraun, mit 15 langsam und gleichmäßig zunehmenden Windungen, die embryonalen zeigen eine Mittelkante und herablaufende Fäden, die folgenden 2 Knotenreihen, zwischen die sich weiterhin ein allmählich stärker und knotig werdender Spiralfaden einschiebt, die Endwindung hat unten 2 glatte Reifen. Höhe 4,3 mm, Durchmesser 1 mm.*

Translation. One shell from station 25 (Shark Bay) is slender, brown, with 15 whorls which slowly but regularly increase in size, the protoconch has a single spiral keel and axial riblets; the following teleoconch whorls have two rows of tubercles, a third row develops between the first and second row, which gradually becomes stronger on lower whorls; on the base there are two smooth spiral cords. Height 4.3 mm, diameter 1 mm.

Diagnosis. Holotype height 4.0 mm. Shell conical. The teleoconch has nine whorls, with three tubercled spiral cords; the second cord develops later along the spire and is well visible only on the penultimate whorl. A fine suprasutural smooth cord is also present. The last whorl has a fourth smooth spiral cord and the base has one further smooth cord. Peristome missing. Also the protoconch is incomplete, but clearly multispiral; on the three visible whorls there is a single sharp keel and axial riblets. Colour brown, the first row of tubercles is lighter, almost grey.

Triforis fusca Dunker, 1860

Figure 22
Triforis fusca Dunker, 1860: 237; figured in Dunker 1861: 10, plate 2, figure 22.

Type specimens. Lectotype: ZMB/Moll no. 101922a (designated by Marshall (1983)). Paralectotype: ZMB/Moll no. 101922b. Further paralectotypes: SMF no. 304814 (Janssen, 1993).

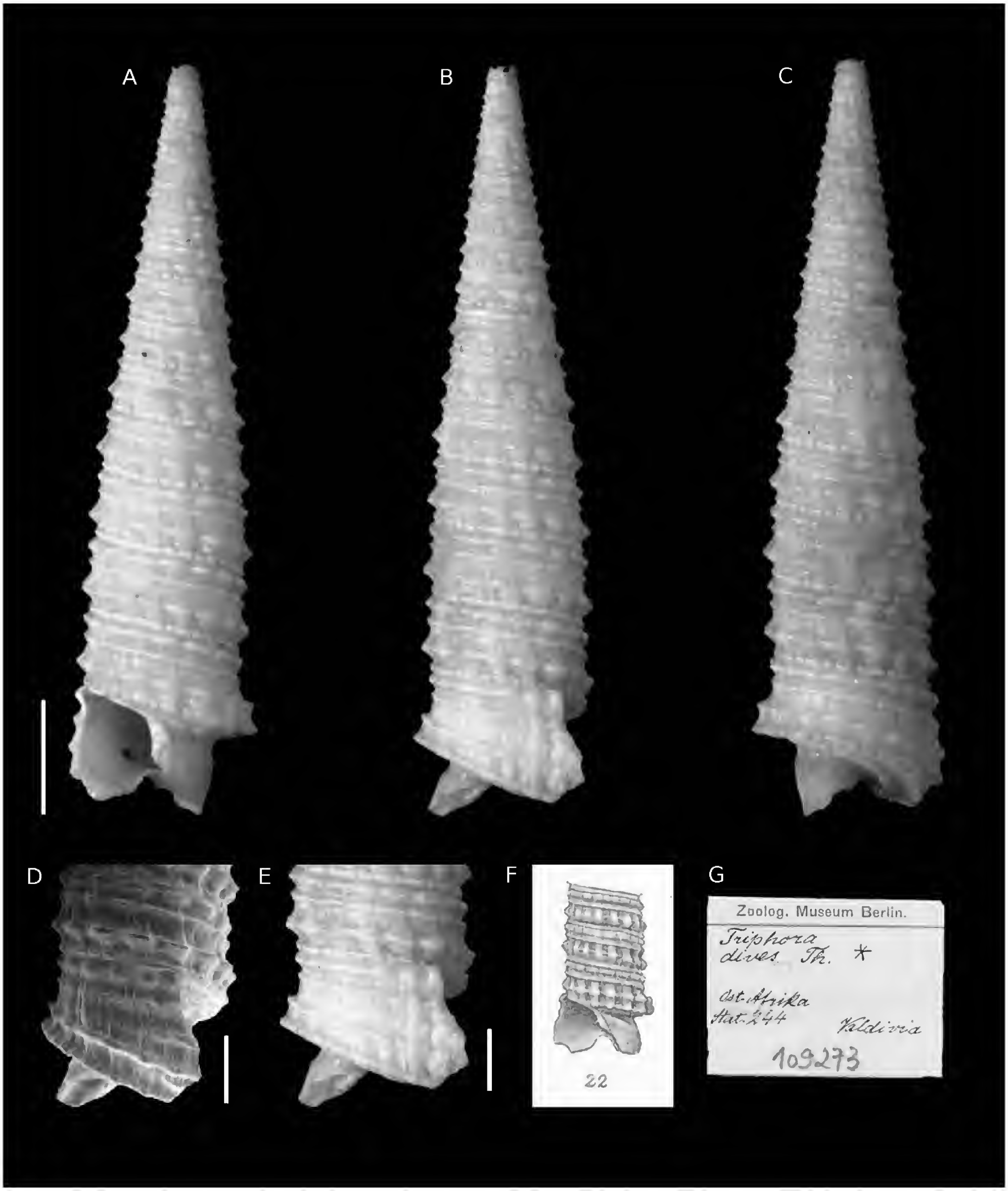


Figure 20. *Triforis dives* Thiele, 1925, Station 244 (5°55.8'S, 39°1.2'E, 50 m depth, off East Africa). **A-E**. Holotype, ZMB/Moll no. 109273: front (**A**), side (**B**), back (**C**), peristome (**D-E**). **F**. Original label. **G**. Original figure in Thiele 1925. Scale bar: **A-C**: 2 mm, **D-E**: 1 mm.

Type locality. Japan.

Original description. *T. testa solidula, fusca, gracili, in medio paullulum ventrosa; anfractibus 12 – 14 sutura distincta divisis, triseriatim granosis; serie intermedia angustiore obsoleta; granulis confertis ex parte confluentibus. – Alt. 10 – 11, lat. 2 mill. Alle vorliegenden Exemplare sind einfarbig dunkelbraun und in ihrer Skulptur ganz übereinstimmend.*

Translation. Solid, dark, slender shell, in the middle slightly inflated; 12-14 whorls divided by a deep suture

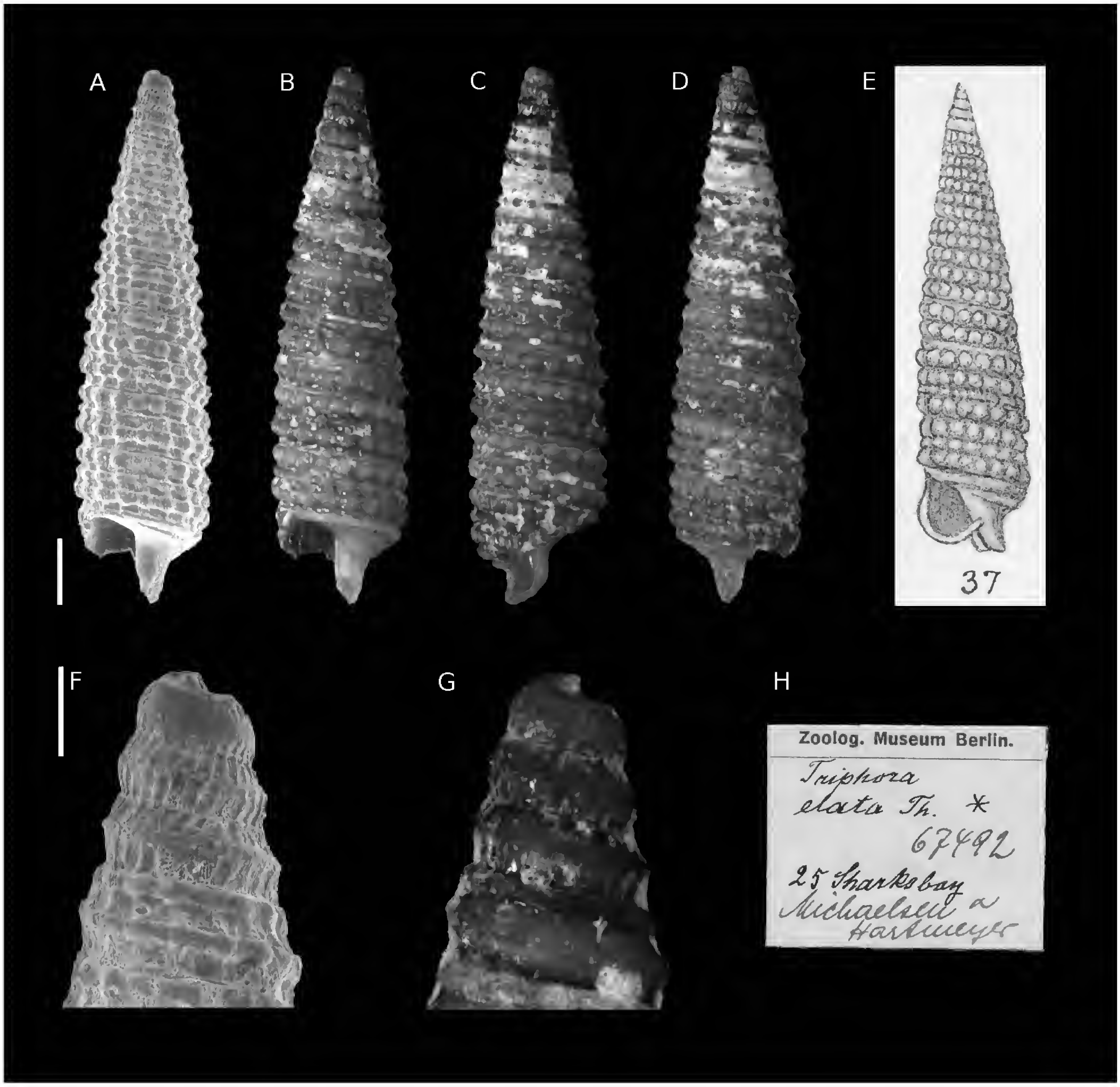


Figure 21. *Triphora elata* Thiele, 1930, Station 25 (Shark Bay). **A-D**, **F-G**. Holotype, ZMB/Moll no. 67492: front (**A-B**), left side (**C**), back (**D**), protoconch (**F-G**). **E**. Original figure in Thiele 1930. **H**. Original label. Scale bar: **A-D**: 0.5 mm, **F-G**: 0.2 mm.

with three rows of tubercles; the second row less developed; the granules are close on the side of the confluence [it may refer to the fact that the second row of tubercles is closer to the first row]. All specimens are monochrome dark brown of colour and the sculpture is of the same colour tone.

Diagnosis. Lectotype height 7.6 mm. Conical shell with flat sides. Teleoconch of at least 10 whorls, with three tubercled spiral cords; the second is visible only on the eighth whorl. A fine suprasutural smooth cord is also present. The last whorl has a fourth smooth spiral cord, and the base bears two more smooth cords. The peristome has additional spiral cords among the main ones, a character well visible in the paralectotype, while the lectotype has the peristome rebuilt after breakage and its sculpture is not reliable. Apex missing in both available specimens, hence the shape and sculpture of the protoconch cannot be described. Brown in colour.

Metaxia fuscoapicata Thiele, 1930

Figure 23
Metaxia fuscoapicata Thiele, 1930: 575, plate IV, figure 26.

Type specimens. Holotype: ZMB/Moll no. 67481, fixed by monotypy.

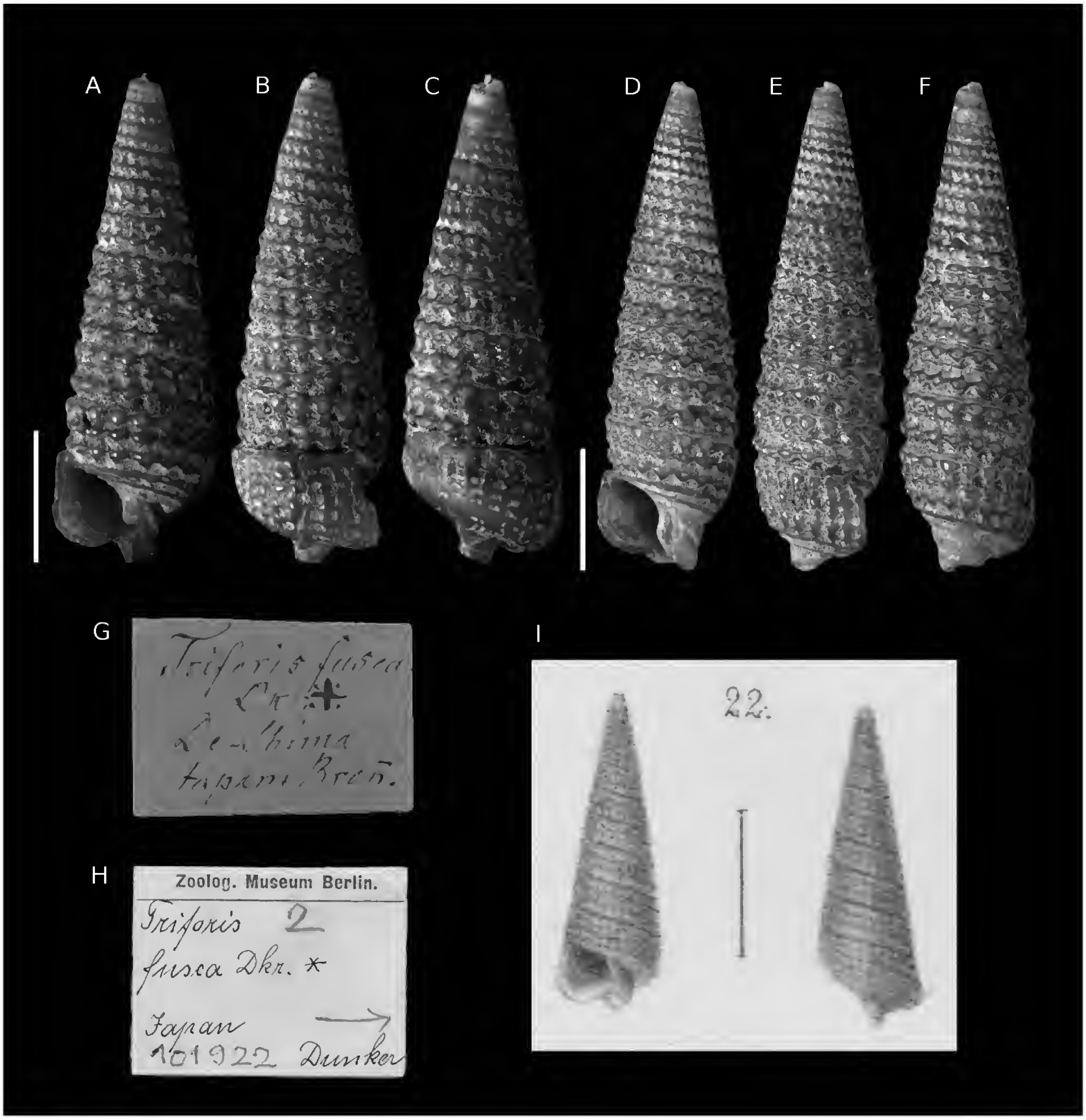


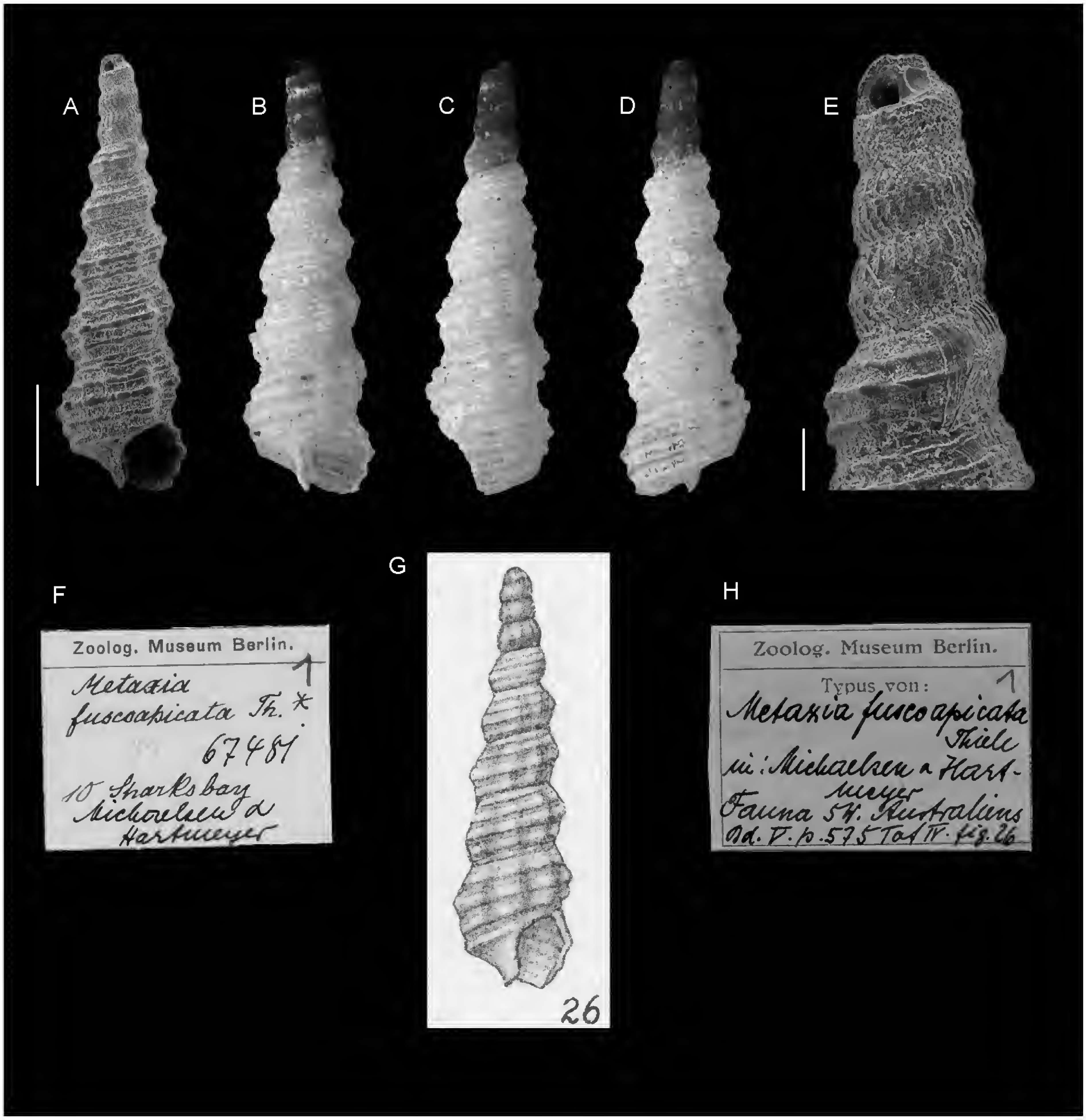
Figure 22. *Triforis fusca* Dunker, 1860, Japan. **A-C**. Lectotype, ZMB/Moll no. 101922: front (**A**), left side (**B**), back (**C**). **D-F**, Paralectotype, ZMB/Moll no. 101922: front (**D**), left side (E), back (**F**). **G**. Original label by Dunker. **H**. Original museum label. **I**. Original figure in a later publication by Dunker (1861). Scale bar: **A-F**: 2 mm.

Type locality. "Station 10 (Sharks Bay)" [Western Australia].

Original description. *Eine wahrscheinlich junge Schale von Station 10 (Sharks Bay) ist durch ihre braune, aus 4 kaum zunehmenden, etwas rauhen Windungen bestehende Embryonalschale ausgezeichnet, von der sich die folgenden farblosen Windungen scharf absetzen; diese, von denen 5 vorhanden sind, haben 4 starke Spiralreifen und einige breite, wellen förmige Rippenfalten, sie sind deutlich gewölbt und in der Mitte etwas kantig; Spindelfortsatz kurz, untere Bucht der Mündung breit. Höhe 2,4 mm, Durchmesser 0,65 mm.*

Translation. A probably young shell from Station 10 (Shark Bay) is characterized by an embryonal shell composed of almost 4 brown whorls. The teleoconch whorls are without colour and start after the larval shell abruptly. The teleoconch is composed of 5 clearly convex whorls with an angulated profile. The whorls have 4 strong spiral cords and some broad, wave-like, axial ribs. The columella is short, the siphonal canal broad. Height 2.4 mm, diameter 0.65 mm.

Diagnosis. Shell dextrally coiled. Holotype 2.4 mm high, teleoconch composed of five whorls; however, this specimen is likely a subadult. Whorls have eight orthocline



Zoolog. Museum Berlin.
1
Metaxia
fuscoapicata Th. *
67481
10 Sharksbay
Michaelsen & Hartmeyer

Zoolog. Museum Berlin.
Typus von: 1
Metaxia fuscoapicata
Thiele
m.: Michaelsen & Hart-
meyer
Fauna SW. Australiens
Bd. V. p. 575 Taf IV. fig. 26

Figure 23. *Metaxia fuscoapicata* Thiele, 1930. **A-E**. Holotype, Station 10 (Shark Bay), ZMB/Moll no. 67481: front (**A-B**), side (**C**), back (**D**), apex (**E**). **F**. Original illustration. **G-H**. Original labels. Scale bar: **A-D**: 1 mm, **E**: 0.1 mm.

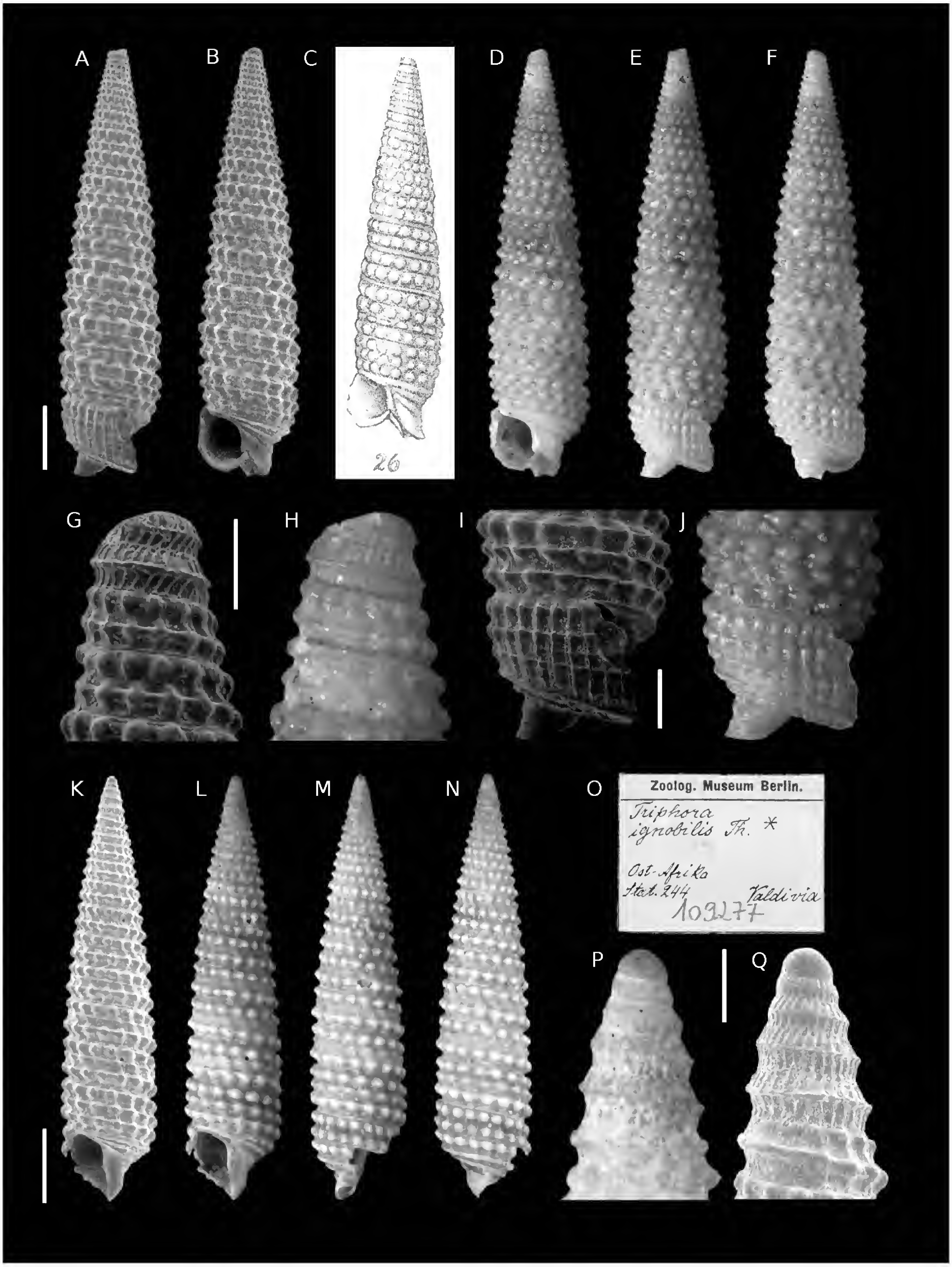
axial ribs and three main flat spiral cords; the last two whorls have a sub- and supra-sutural cord. The whorl profile is angulated due to the prominence of the cord in the middle of the whorl. Protoconch multispiral, composed of at least four whorls (but holotype apex is damaged), with zigzag threads on the first and second whorl, followed by axial riblets. Protoconch brown, teleoconch white with occasional tiny faint brown patches on spiral cords between axial ribs.

Remarks. Although the examined type specimen is likely a sub-adult, the specimen identified as *Metaxia fuscoapicata* illustrated by Marshall (1983, figure 9 A-C) may not actually be this species: the holotype has much more convex teleoconch whorls (although juvenile), a lower number of axial ribs, a less angulated protoconch periphery and the zig-zag threads still clearly visible on the second protoconch whorl. More adult and complete specimens from the type locality would be needed to better define this taxon and discriminate it from closely related ones.

Triphora ignobilis Thiele, 1925

Figure 24

Triphora ignobilis Thiele, 1925: 131 (97), plate XXII (X), figures 26 and 26a.



Zoolog. Museum Berlin.
Triphora
ignobilis Th. *
Ost-Afrika
Stat. 244
Valdivia
109277

Figure 24. *Triforis ignobilis* Thiele, 1925, Station 244 (5°55.8’S, 39°1.2’E, 50 m depth, off East Africa). **A-B**, **D-J**. Lectotype, ZMB/Moll no. 109277: side (**A, E**), front (**B, D**), back (**F**), protoconch (**G-H**), peristome (**I-J**). **C**. Original figure in Thiele 1925. **K-N**, **P-Q**. Paralectotype, ZMB/Moll no. 109277: front (**K-L**), side (M), back (**N**), protoconch (**P-Q**). **O**. Original label in Thiele 1925. Scale bar: **A-B**, **D-F**: 1 mm, **G-H**: 0.3 mm, **I-J**: 0.5 mm, **K-N**: 1 mm, **P-Q**: 0.2 mm.

Type specimens. Lectotype: ZMB/Moll no. 109277a, here designated. Paralectotypes A-C: ZMB/Moll no. 109277b-d.

Type locality. "Station 244 [5°55.8' südl. Br., 39°1.2' östl. L., 50 m Tiefe, bei Ost-afrika]" (off Zanzibar, East Africa).

Original description. *Vier Schalen von derselben Station 244, die eine gelbbraune Färbung zeigen, scheinen zu keiner bekannten Art zu gehören, sie haben eine gewisse Aehnlichkeit mit* T. perversa, *sind aber bedeutend kleiner. Die abgebildete Schale, der die äußerste Spitze (etwa 2 Windungen) fehlt, zeigt 15 Windungen, sie ist etwas spindelförmig, oben spitz; die Anfangswindungen (nach einer anderen Schale 4-5) haben einen Mittelkiel und herablaufende Fäden, die folgenden haben 2 Reihen rundlicher Knoten, zwischen denen sich ein Faden einschiebt, der sich erst ziemlich weit abwärts zu größeren Knoten umbildet, letzte Windung etwas schmaler als die vorletzte, an der ziemlich stumpfen unteren Kante mit einem Reifen und 2 anderen darunter. Spindelfortsatz schräg gerichtet, Mündung rundlich gegen den Kanal fast geschlossen, Mundrand oben zurücktretend. Höhe 7 mm, Durchmesser 1,5 mm.*

Translation. Four shells from the same station 244, yellow-brown of colour; it seems that they do not belong to an already described species, they show some similarity with *T. perversa*, but are definitely smaller. The figured shell lacks the top of the apex (approximately two whorls), it has 15 whorls, it is slender and the top is pointy; the first whorls (4-5 according to other shells) have a single keel in the middle of the whorl and axial riblets, the following whorls have two rows of tubercles, between them a third fine row develops which bears larger tubercles only on the last few whorls; the last whorl is a bit slender than the penultimate whorl, it has a blunt edge with a spiral cord and two spiral cords underneath. The siphonal canal is oblique, the aperture is rounded and the siphonal canal is narrow, there is an ample posterior canal. Height 7 mm, diameter 1.5 mm.

Diagnosis. Lectotype height 6.7 mm. Shell slender, with flat sides. Teleoconch of 13 whorls, which have two main tubercled spiral cords. Among them, a further cord develops along the spire: it is visible as a simple thread at mid shell height, and becomes a full sized tubercled cord only on the last whorl. A fine suprasutural smooth cord is also present. The last whorl has a fourth weakly tubercled spiral cord, and the base two further almost smooth cords. The peristome shows a well-developed posterior sinus and additional spiral cords between the main ones. The protoconch has five whorls; the first whorl appears smooth, the other whorls have a single strong keel and axial riblets. Background colour light brown with yellowish tubercles and brown interspaces. Both available specimens were, however, dead collected and colours may have faded.

Triforis regia Thiele, 1925

Figure 25
Triphora regia Thiele, 1925: 130 (96), plate XXII (X), figure 23.

Type specimens. Lectotype: ZMB/Moll no. 109274a, here designated. Paralectotype A: ZMB/Moll no. 109274b.

Type locality. "Station 245 (5°27,9' südl. Br., 39°18,8' östl. L., 463 m Tiefe, im Sansibar-Kanal)", [Zanzibar Channel, East Africa].

Original description. *Zwei Schalen von Station 245 (5°27,9' südl. Br., 39°18,8' östl. L., 463 m Tiefe, im Sansibar-Kanal) zeigen ähnlich wie* Argyropeza divina *einen starken Glanz in Verbindung mit einer gelblichweißen Färbung, die Spitze ist braun, aber unvollständig erhalten, mit herablaufenden Fäden und 2 Spiralreifen fein skulptiert; die eine Schale hat 19 Windungen, von denen noch 2 zum braunen Teil gehören, sie ist schlank getürmt, mit geraden Seiten. Die Skulptur besteht aus 3 ungleich starken Knotenreihen, die oberste ist am schwächsten, die unterste am stärksten, die Knoten liegen schräg übereinander und sind etwas von oben zusammengedrückt; auf der letzten Windung werden die Knoten schwächer und zwischen der 2. und 3. Reihe schiebt sich eine schwache ein. Der glatte Reifen der letzten Windung bildet eine starke Kante, unter der ein deutlicher und ein undeutlicher Reifen sichtbar sind. Spindelfortsatz gebogen, Mundrand vorgezogen, unten ein fast geschlossenes kurzes Rohr bildend. Höhe 11 mm, Durchmesser 2 mm.*

Translation. Two shells from station 245 (5°27.9'S, 39°18.8'E, 463 m depth, in Zanzibar Channel) show similarities with *Argyropeza divina* due to its glossy appearance and yellowish/white colouring; the protoconch is brown, but incomplete, sculptured with two spiral keels and axial riblets; one shell has up to 19 whorls, of which two belongs to the protoconch, slender, with flat whorls. The teleoconch is sculptured with three rows of tubercles of unequal strength, the first row is the least pronounced, the third row is the most pronounced, the tubercles lay diagonally one above the other and are slightly compressed on the upper side, on the last whorl the tubercles become less pronounced and a fourth row develops between the second and the third row. The smooth spiral cord on the last whorl forms a strong angle, under which a well developed and an underdeveloped cord are visible. The siphonal canal is curved, the peristome expanded, under which a short siphonal canal is present. Height 11 mm, diameter 2 mm.

Diagnosis. Lectotype height 10.3 mm. Shell very slender and pointed. Teleoconch of 17 whorls, which have two spiral cords with pointed tubercles. A subsutural weakly tubercled spiral cord is present, while a fine suprasutural smooth cord is present, but poorly visible. The last whorl has a fourth smooth strong cord, and the base is smooth. The peristome has additional weakly tubercled spiral cords. Apex in

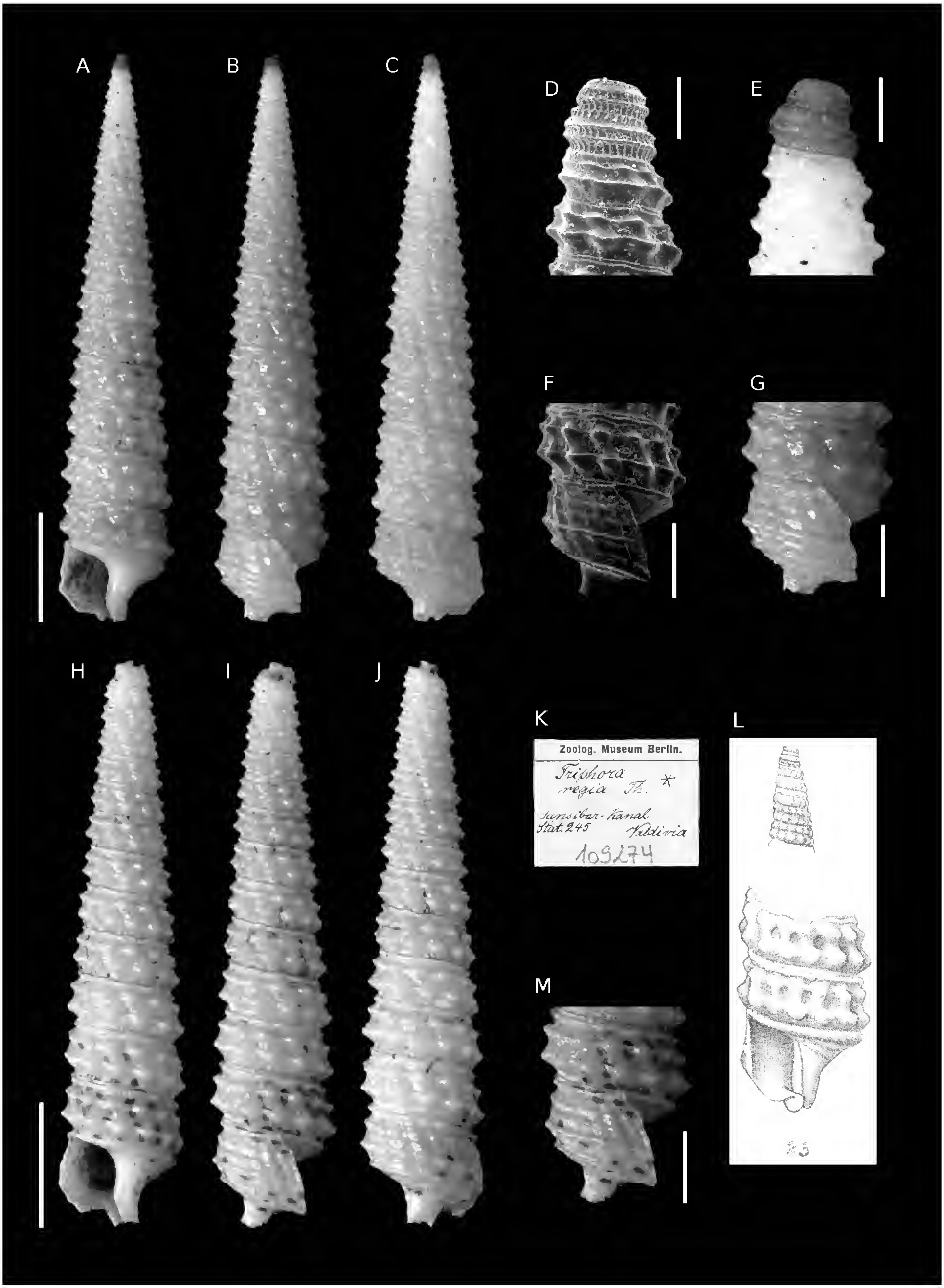


Figure 25. *Triforis regia* Thiele, 1925, Station 245 (5°27.9'S, 39°18.8'E, 463 m depth, in Zanzibar Canal). **A-G**. Lectotype, ZMB/Moll no. 109274a: front (**A**), left side (**B**), back (**C**), protoconch (**D-E**), peristome (**F-G**). **L**. Original figure in Thiele 1925. **H-J**, **M**, Paralectotype A, ZMB/Moll no. 109274b: front (**H**), left side (**I**), back (**J**), peristome (**M**). **K**. Original label. Scale bar: **A-C**: 2 mm, **D-E**: 0.25 mm, **F-G**: 1 mm, **H-J**, 2 mm, **M**, 1 mm.

the lectotype incomplete, but protoconch clearly multispiral. The two whorls which are present have two strong keels and axial riblets. Teleoconch colour light yellowish, with the very first whorls pure white; protoconch brown.

Remarks. It can be easily distinguished from the following *T. sceptrum* because of the multispiral protoconch.

Triphora sceptrum Thiele, 1925

Figure 26
Triphora sceptrum Thiele, 1925: 130-131 (96-97), plate XXII (X), figures 24 and 24a.

Type specimens. Lectotype: ZMB/Moll no. 109275, here designated. Paralectotypes A-B: ZMB/Moll no. 109275b-c.

Type locality. "Station 242 (6°34,8' südl. Br., 39°35,5' östl. L., 404 m Tiefe, bei Daressalam)" [Dar es Salaam, Tanzania].

Original description. *Drei Schalen von Station 242 (6°34,8' südl. Br., 39°35,5' östl. L., 404 m Tiefe, bei Daressalam) haben sehr ähnliche Skulptur, wie die vorige Art [*Triphora regia*], von der sie sich indessen durch das Fehlen des eigentümlichen Glanzes, etwas breitere Form und hauptsächlich durch ganz verschiedene Beschaffenheit der Anfangswindungen unterscheiden. Die größte Schale besteht aus 20 langsam zunehmenden Windungen, die ersten sind wie die übrige Schale weiß, etwas glänzend, zuerst ziemlich groß und rundlich, dann gekielt, ohne oberflächliche Skulptur, die weiteren Windungen zeigen einen etwas welligen Reifen unter der Naht und 2 Reihen starker Knoten, die schräg herablaufenden Falten entsprechen; auf der Rückseite der letzten Windung gehen diese beiden Knotenreihen in einfache Reifen über und unter jeder schiebt sich noch ein Reifen ein, die untere Kante wird durch einen glatten Reifen bezeichnet, unter dem noch ein weiterer sichtbar ist. Spindelfortsatz ziemlich stark gekrümmt, Mundrand oben zurück, unten vortretend, Kanal nicht abgeschlossen. Höhe 13 mm, Durchmesser 2,5 mm.*

Translation. Three shells from station 242 (6°34.8'S, 39°35.5'E, 404 m depth, off Dar es Salaam) have a sculpture very similar to the previous species [*Triphora regia*], from which it is distinguishable by the absence of its peculiar glossiness, its slightly wider shape and mainly because of the different protoconch. The biggest shell has 20 whorls, which slowly increase in size, the first whorls are white like the rest of the shell, a bit shiny; the first whorl of the protoconch is large and rounded, the following whorls have a spiral keel, without any other sculpture; the teleoconch whorls have one spiral cord under the suture and 2 more rows of tubercles, which lie on prosocline axial ribs; on the back of the last whorl there is an additional spiral cord above and below each of the two main rows of tubercles, the lowest cord becomes smooth and forms an angle with the base, and a further cord is visible below this. The siphonal canal is quite strongly curved, the upper part of the aperture has a sinus, and the peristome protrudes significantly, the siphonal canal is not closed. Height 13 mm, diameter 2.5 mm.

Diagnosis. Lectotype height 12.7 mm. Shell very slender, conical, with slightly rounded whorls. Teleoconch of 17 whorls, which have three tubercled spiral cords well visible since the very first teleoconch whorls. A very fine suprasutural smooth cord is also present. The last whorl has a fourth smooth cord, the base has a further fine smooth cord. On the last whorl a further almost smooth spiral cord is present between the second and the third. An ample posterior siphonal canal is present. The protoconch is paucispiral and composed of three whorls: the first is smooth, while the other two have a single prominent spiral keel. Colour white.

Remarks. It can be easily distinguished from the previous *T. regia* because of the paucispiral protoconch.

Triphora subulata Thiele, 1930

Figure 27
Triphora subulata Thiele, 1930: 577, plate IV, figure 34.

Type specimens. Lectotype ZMB/Moll no. 67489a from Station 3, here designated. Paralectotype A: ZMB/Moll no. 67489b; further 16 paralectotypes (ZMB/Moll no. 67489).

Type locality. "Sharks Bay, Stations 1, 3, 9, 12, 14, 16 und 20" [Western Australia].

Original description. *Einige Schalen aus der Sharks Bay (Station 1, 3, 9, 12, 14, 16 und 20) sind sehr spitz, mit etwa 16 sehr langsam zunehmenden Windungen, braun, auf den mittleren Windungen mit 2 Reihen starker, hellerer Perlknoten, zwischen denen sich auf der vorletzten Windung noch eine Reihe einschiebt, an der Unterseite der Endwindung sind 3 glatte Reifen vorhanden. Höhe der abgebildeten Schale 6,5 mm, Durchmesser 1,5 mm.*

Translation. Several shells from Shark Bay (stations 1, 3, 9, 12, 14, 16 and 20) are very pointy, with about 16 whorls which slowly increase in size, brown; on the middle whorls there are two rows of tubercles, light grey in colour; on the last whorls another row of tubercles develops between the first two, on the base three smooth threads are visible. Height of the figured shell 6.5 mm, diameter 1.5 mm.

Diagnosis. Lectotype height 4.2 mm. Shell conical and quite slender. Teleoconch of 10 whorls, which have two main tubercled spiral cords. Between them, a third cord is visible as a fine thread at mid height, and then it develops into a spiral cord only on the last whorl. A very

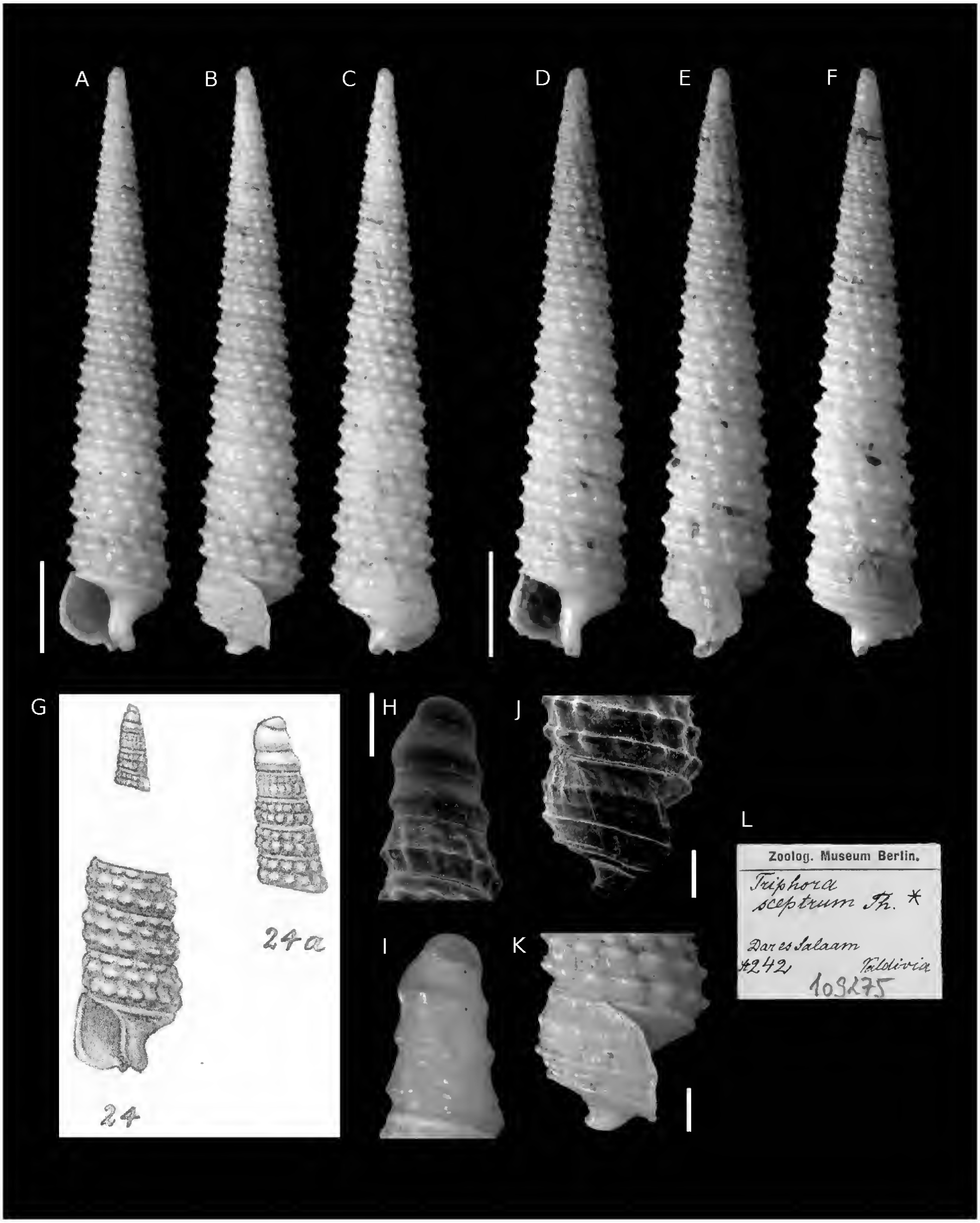
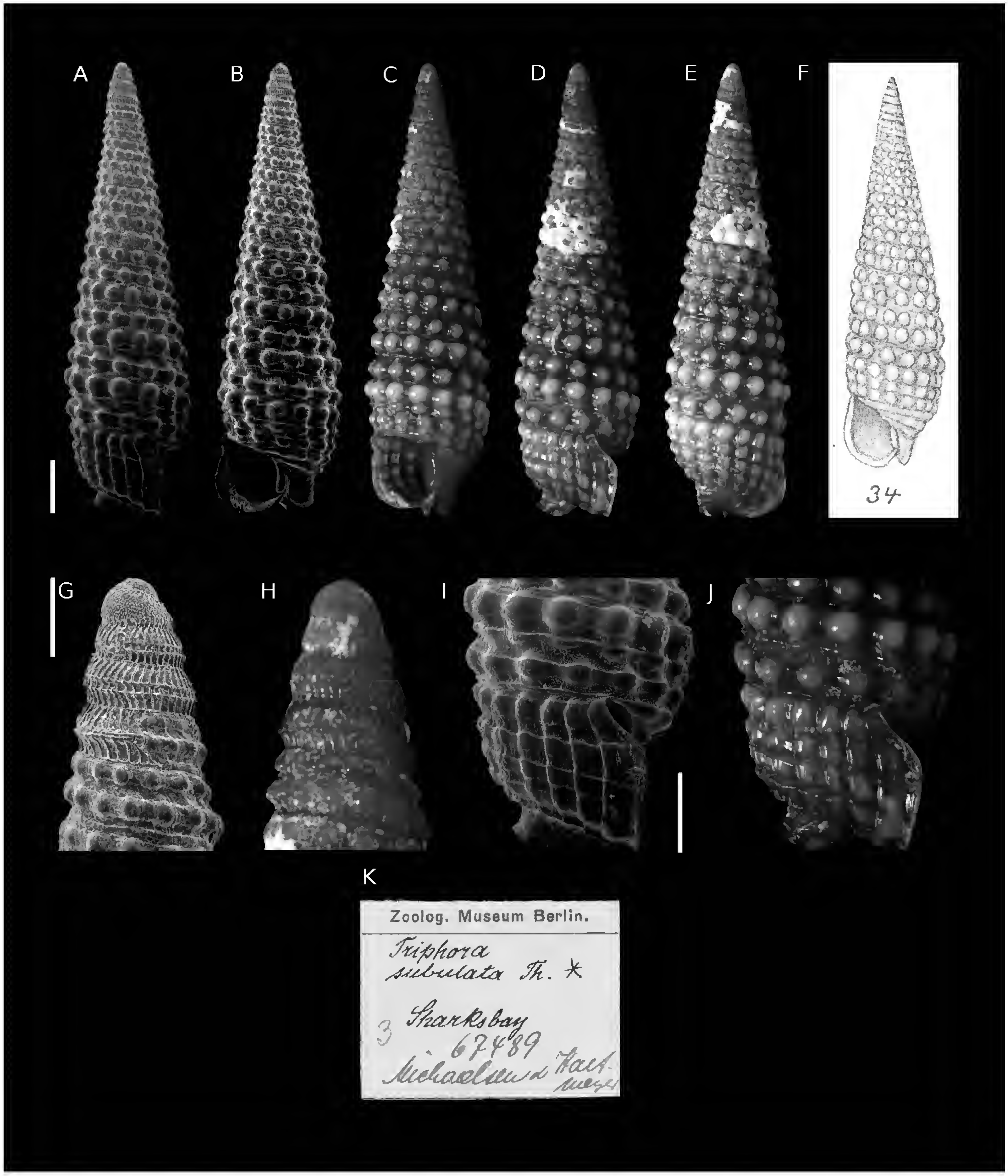


Figure 26. *Triforis sceptrum* Thiele, 1925, Station 242 (6°34.8'S, 39°35.5'E, 404 m depth, off Dar es Salaam). **A-C**, **H-K**. Lectotype, ZMB/Moll no. 109275a: front (**A**), left side (**B**), back (**C**), protoconch (**H-I**), peristome (**J-K**). **D-F**. Paralectotype A, ZMB/Moll no. 109275b: front (**D**), left side (**E**), back (**F**). **G**. Original figure in Thiele 1925. **L**. Original label. Scale bar: **A-F**: 2 mm, **H-I**: 0.3 mm, **J-K**: 0.6 mm.



Zoolog. Museum Berlin.
Triphora
subulata Th. *
3 Sharksbay
. 67489
Michaelsen u. Hartmeyer

Figure 27. *Triphora subulata* Thiele, 1930, Stations 1, 3, 9, 12, 14, 16 and 20 (Shark Bay). **A-E, G-J**. Lectotype, ZMB/Moll no. 67489a: left side (**A, D**), front (**B-C**), back (**E**), protoconch (**G-H**), peristome (**I-J**). **F**. Original figure in Thiele 1930. **K**. Original label. Scale bar: **A-E**: 0.5 mm, **G-H**: 0.2 mm, **I-J**: 0.4 mm.

fine suprasutural cord is present, but barely visible. The last whorl has a fourth tubercled spiral cord, and the base has a single smooth cord. The peristome has a posterior siphonal canal. The protoconch is composed of five whorls: the first two whorls have granules and tiny axial threads near the suture, the other whorls have two spiral keels and axial riblets. Colour brown with grey granules.

Remarks. No specimens of 6.5 mm height were found, notwithstanding it is stated that the illustrated specimen is this size. The only specimen of comparable size is a subadult (hence not the illustrated specimen) (here selected as paralectotype B), while the lectotype and the other adult specimens range around 4 mm.

Triforis tricincta Dunker, 1882

(new name for *Triforis cingulata* Dunker, 1860)
Figure 28
Triforis cingulata Dunker, 1860: 236; figured in Dunker 1861: 10, tab. 2, figure 1.
Triforis tricincta Dunker, 1882: 109.

Type specimens. Holotype SMF no. 304813 (designated by Janssen, 1993).

Type locality. Japan.

Original description. *T. testa turrita, unicolore fusca, anfractibus planis 14 (usque ad 16?) costulis duabus crassioribus et una tenuiore intermedia cinctis, interstitiis clathratis; basi planata; peristomate subquadrato; rostro brevi. – Alt. 9, lat. 2½ mill.*

Diese Art ist durch ihre Skulptur ausgezeichnet. Die Windungen sind von zwei stumpfen glatten Kielen oder Rippchen umgeben, in dem Zwischenraum aber befinden sich zarte erhabene Längsstrichelchen, die von einer feinen Querlinie durchschnitten werden, wodurch eine gegitterte Oberfläche entsteht. Die Naht ist deutlich.

Translation. Slender shell, of brown uniform colour. Fourteen flat whorls (to 16?) with two large cords and a fine further cord in the middle, space between cords with a cancellate sculpture. Flat base [but it refers to a subadult specimen, illustrated in 1861], subquadrate peristome [again may be due to the description of a subadult specimen], short siphonal canal. Height 9, width 2.5 mm.

This species is characterized by its sculpture. The whorls bear two blunt smooth cords, between them there are longitudinal riblets, which are intersected by a fine thread, creating a cancellate sculpture. A clear suture is visible.

Diagnosis. Large and slender shell, the illustrated specimen (Fig. 28 A-C) is 11.6 mm. Teleoconch of 15 whorls, which have three smooth spiral cords; the second is thinner than the other two. A fine suprasutural smooth cord is also present. The last whorl has a fourth smooth cord, the base has a fifth smooth cord. On the peristome, an additional spiral cord develops between the second and the third. A large posterior notch is present. The apex is not present in the holotype (Janssen 1993) nor in the Japanese specimens preserved in Berlin. The specimen from Dutch Bay (Sri Lanka) has a worn apex, but it can be recognized to have several whorls (multispiral protoconch), probably with two spiral keels and axial riblets. Colour brown.

Remarks. This species was first described by Dunker in 1860 as *T. cingulata*. In 1882, Dunker introduced the new name *T. tricincta*; although he did not specify the reason, *T. cingulata* was indeed a preoccupied name by *Triphoris cingulatus* A. Adams, 1854. The holotype preserved in the Senckenberg Museum is a worn subadult specimen, lacking apex and with a very worn sculpture (Janssen 1993).

The collection in Berlin hosts four lots labelled as *T. cingulata* or *T. tricincta*: three coming from Japan (Enosima, Sakura) and one from Dutch Bay (Sri Lanka). All Japanese specimens are in poor condition, but the specimens from Dutch Bay are quite nice and deserved illustration to better depict the diagnostic characters of this species.

Triphora tubifera Thiele, 1925

Figure 29
Triphora tubifera Thiele, 1925: 132 (98), plate XXII (X), figures 28 and 28a.

Type specimens. Lectotype: ZMB/Moll no. 109266, here designated.

Type locality. "Station 193 (0°30,2' nördl. Br., 97°59,7' östl. L., 132 m Tiefe, im Nias-Süd-Kanal)" [West Sumatra, Indonesia].

Original description. *Zwei Schalen von Station 193 (0°30,2' nördl. Br., 97°59,7' östl. L., 132 m Tiefe, im Nias-Süd-Kanal), von denen die eine nicht ganz ausgewachsen, die andere etwas abgerollt und ohne Spitze ist, gehören zu einer Art mit einem Rohr, das von der Rückseite der letzten Windung abgeht (*Iniforis *Jousseaume); die Art dürfte noch nicht bekannt sein. Die entfärbte Schale ist schlank getürmt, die spitze bräunliche Embryonalschale besteht aus etwa 5 Windungen die mit 2 ziemlich dicht zusammenliegenden Kielen und herablaufenden Fäden skulptiert sind. Die folgenden 12 Windungen zeigen 2 Reihen von Knoten, deren obere unter der undeutlichen Naht gelegene schwächer ist als die untere, sie sind durch Spiralreifen und schräge Falten verbunden, so daß die oberen über den Zwischenräumen der unteren liegen, zu den Rinne zwischen beiden Reihen verläuft ein feiner Spiralfaden. Die letzte Windung bildet unten eine starke durch eine Knotenreihe bezeichnete Kante, unter der am Grunde des unteren schrägen Rohres ein Reifen vorhanden ist; unter dem mäßig langen und ziemlich starken Rohr der Rückseite biegt die mittlere Knotenreihe herum und nähert sich dann dem Oberrande, während eine schwächere sie auf der Mitte fortsetzt. Mündung klein und rundlich, gegen den Kanal ganz geschlossen. Höhe (mit embryonalschale ohne unteren Fortsatz) etwa 4,5 mm, Durchmesser 1 mm.*

Translation. Two shells from station 193 (0°30.2' N, 97°59.7'E, 132 m depth, in the canal south of Nias Island, Sumatra), of which one is not fully grown, the other one very worn and lacks the apex; they belong to a species with a tube protruding from the back of the last whorl (*Iniforis* Jousseaume); this species seems not to be known yet. The faded shell lacks colour and is slender, the brown pointed protoconch has 5 whorls and is sculptured with two spiral keels and axial riblets. The following 12 whorls have two rows of tubercles, of which the upper one is weaker than the lower one, they are connected by spiral

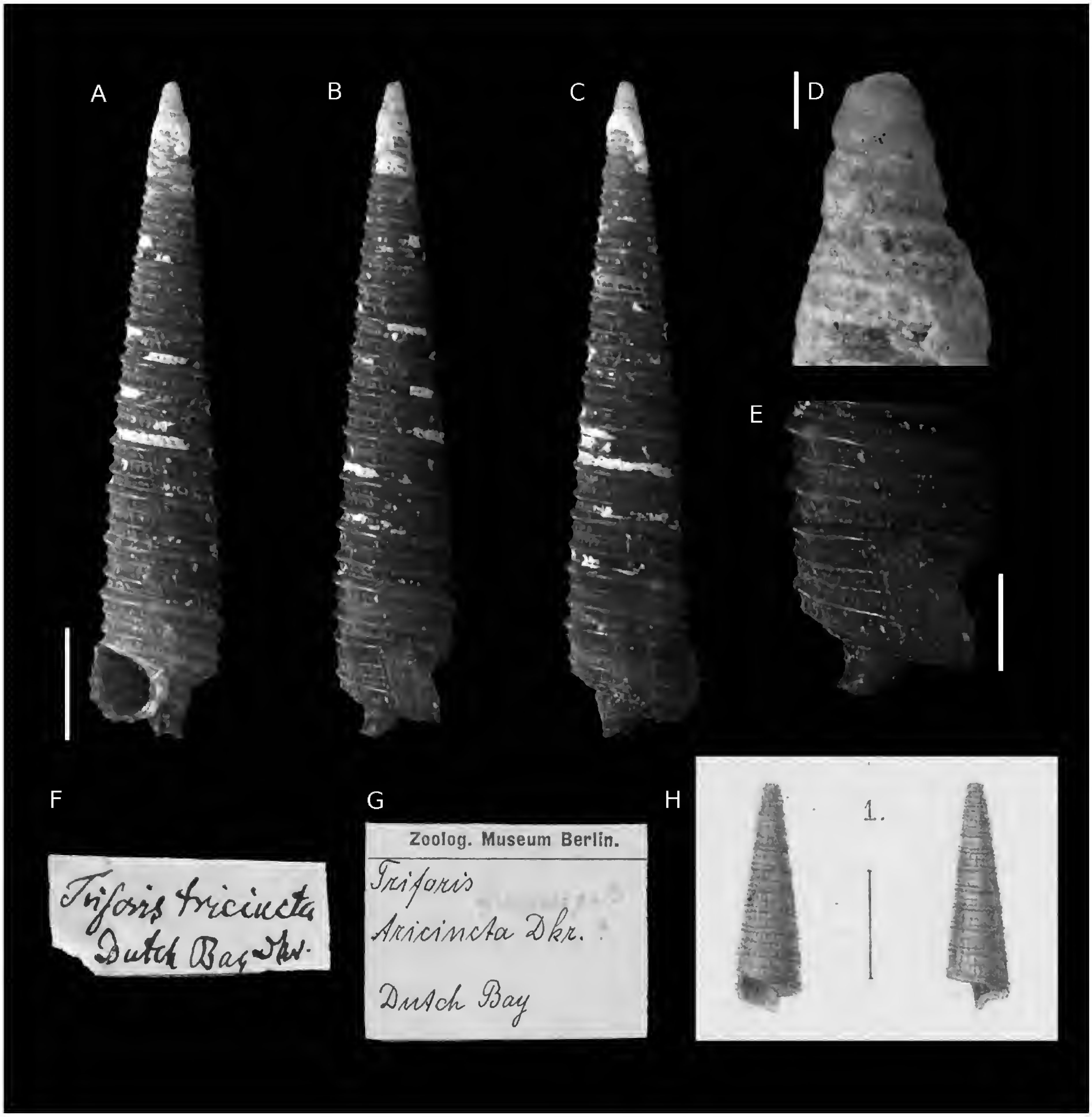


Figure 28. *Triforis tricincta* Dunker, 1882 (= *T. cingulata* Dunker, 1861). **A-E**. Dutch Bay [Sri Lanka]. ZMB/Moll no. 33066: front (**A**), side (**B**), back (**C**), protoconch (**D**), peristome (**E**). **F-G**. Original labels of *Triforis tricincta*. **H**. Original figure of *Triforis tricincta*, as *Triforis cingulata* in Dunker, 1861. Scale bar: **A-C**: 2 mm, **D**: 0.2 mm, **E**: 1 mm.

threads and diagonal folds, in this way the tubercles of the upper row lies above the interspaces of the lower row, a fine spiral thread is present in the groove between the two rows of tubercles. The last whorl has a strong spiral cord with tubercles which forms an angle at the periphery, on the lower part of the last whorl and under the tube another spiral thread is visible; underneath the long and strong tube on the last whorl, the lower row of tubercles is bended around the tube and then approaches the upper edge of the whorl, in the middle of the peristome a further weak spiral cord is present. The aperture is small and rounded, the siphonal canal is closed. Height (with the protoconch whorls but without the missing lower part) about 4.5 mm, diameter 1 mm."

Diagnosis. Lectotype height 4.1 mm, but lacks the protoconch. Shell conical, with rather flat sides. Teleoconch of ca. 11 whorls, which have two strong tubercled spiral cords; the first cord is weaker than the second. A fine suprasutural smooth cord may be present. The last whorl has a third spiral cord, probably weakly tubercled, but lectotype conditions are too poor to better define this character. The base seems smooth. A strong tubular posterior siphonal canal is present. The peristome seems to host an

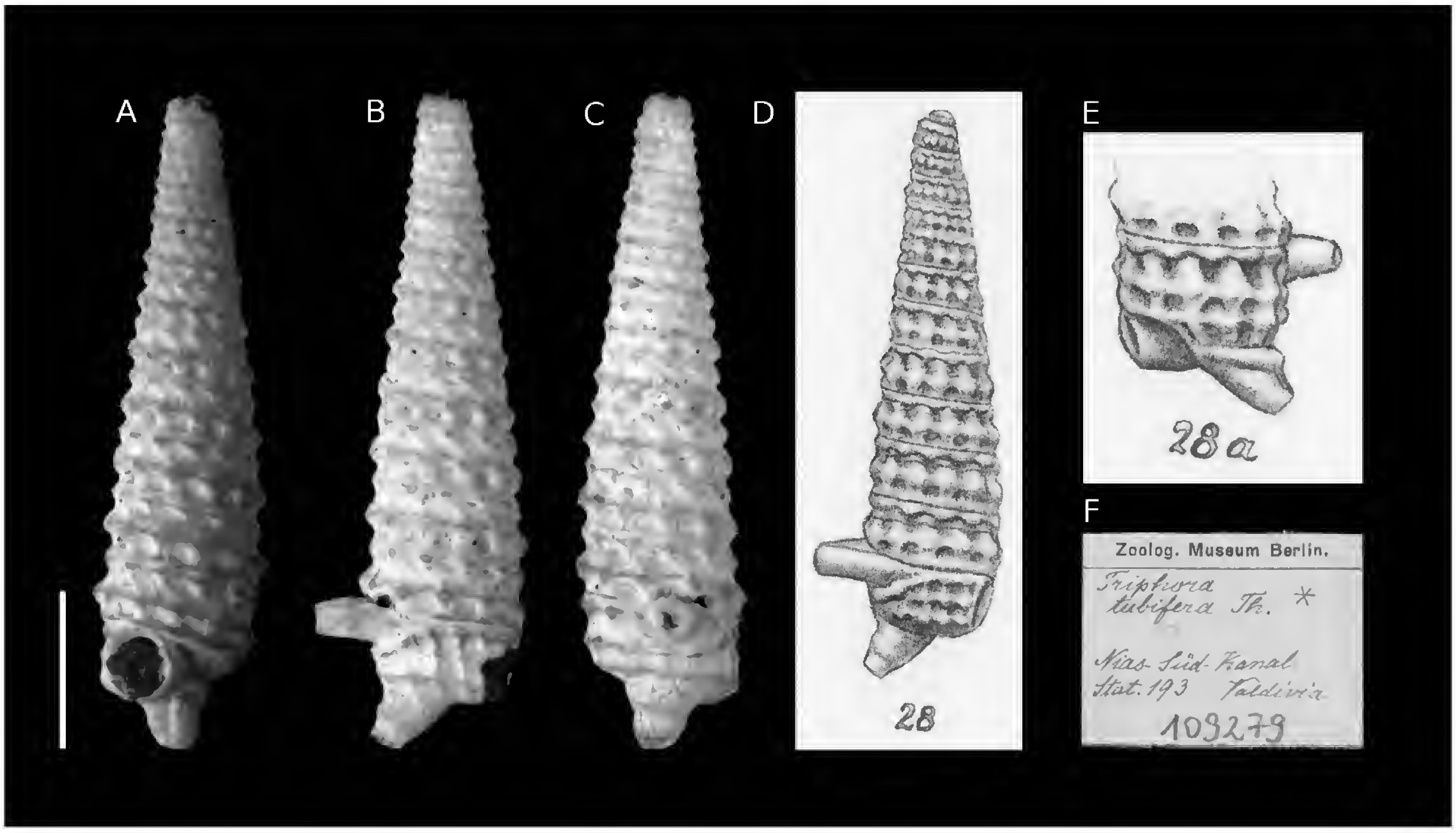


Figure 29. *Triforis tubifera* Thiele, 1925, station 193 (0°30.2' N, 97°59.7'E, 132 m depth, in the canal south of Nias Island, Sumatra, Indonesia). **A**-**C**. Holotype, ZMB/Moll no. 109279: front (**A**), left side (**B**), back (**C**). **D**-**E**. Original figures in Thiele 1925. **F**. Original label. Scale bar: **A**-**C**: 2 mm.

additional cord between the two main ones. According to the original description, the protoconch has five whorls which bear two spiral keels and axial riblets. The colour cannot be described on the basis of the lectotype; the protoconch is described as brown.

Remarks. The juvenile specimen cited in the original description and which probably had a complete protoconch was not found in the Berlin collection. The specimen found is clearly the specimen illustrated by Thiele.

Triphora virginalis Thiele, 1925

Figure 30
Triphora virginalis Thiele, 1925: 304 (270), plate XXII (X), figure 29.

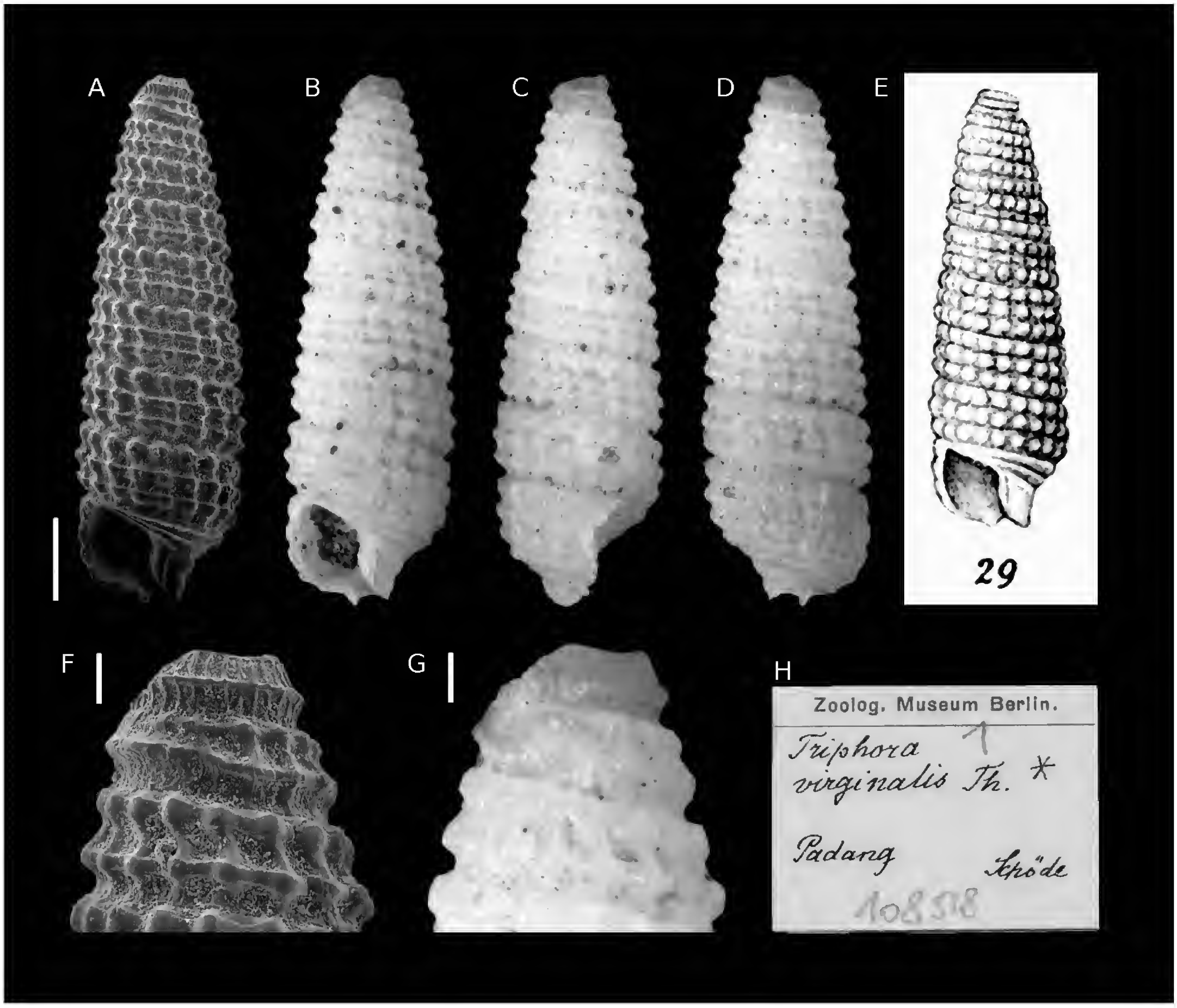
Type specimens. Holotype: ZMB/Moll no. 108518, fixed by monotypy.

Type locality. Padang (Sumatra) [Indonesia].

Original description. *Die einzige weiße Schale scheint zu keiner bekannten Art zu gehören, leider fehlt die Spitze; ein Rest der bräunlichen Embryonalschale zeigt, daß die Windungen einen Mittelkiel und herablaufende Fäden haben. Die folgenden 8 Windungen haben zuerst 2 Knotenreihen, zwischen denen sich dann eine dritte ausbildet, die Knötchen sind rundlich, erhoben, senkrecht übereinander gelegen. Die letzte Windung hat untern 2 deutliche und einen schwächeren Reifen. Spindelfortsatz ziemlich kurz und breit. Die Form der Schal ist walzig kegelförmig, die Windungen bedeutend breiter als hoch, zuletzt kaum zunehmend. Höhe etwa 3,5 mm, Durchmesser 1 mm.*

Translation. The single white shell does not seem to belong to any described species, unfortunately it lacks the top; only a small part of the brown protoconch is visible, the whorl has a single keel and axial riblets. The following 8 whorls have on the upper whorls two rows of tubercles and between them a third appears; the tubercles are rounded, raised, located vertically one above the other. The last whorl has on the underside two conspicuous spiral cords and an obsolete one. Siphonal canal short and wide. The shell has a more or less conical shape, the whorls are considerably wider than high, the last whorl is barely larger in size than the previous one. Height about 3.5 mm, diameter 1 mm.

Diagnosis. Holotype height 3.2 mm. Shell conical with flat sides. Teleoconch of seven whorls, which have three tubercled spiral cords. The first two are well visible since the first teleoconch whorl, while a third appears later between the two main cords: it is initially a fine thread on the third whorl, and is fully developed on fifth whorl. The last whorl has a fourth weakly tubercled spiral cord, and the base has two further smooth cords. Only the last whorl of the protoconch is present in the holotype, but it is clearly multispiral and bears a single spiral keel and several axial riblets. Colour white, the visible protoconch whorl is light brown.



Zoolog. Museum Berlin.
Triphora 1
virginalis Th. *
Padang Schröde
108518

Figure 30. *Triforis virginalis* Thiele, 1930, Padang (Sumatra). **A-D**, **F-G**. Holotype, ZMB/Moll no. 108518: front (**A-B**), left side (**C**), back (**D**), protoconch (**F-G**). **E**. Original figure in Thiele 1930. **H**. Original label. Scale bar: **A-D**: 0.5 mm, **F-G**: 0.1 mm.

Antarctic species

Triforis delicatula Thiele, 1912

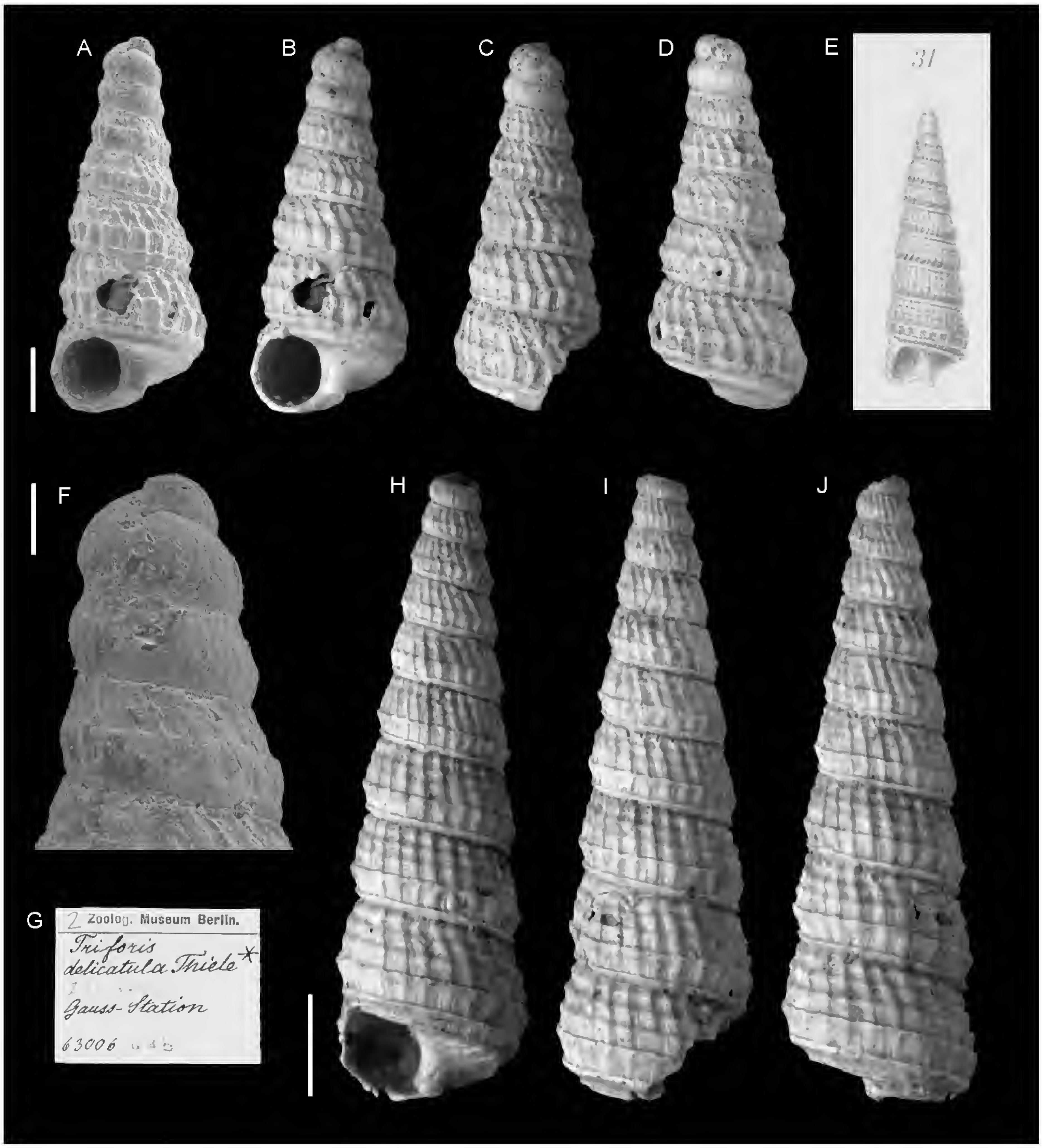
Figure 31
Triforis delicatula Thiele, 1912: 205-206, plate 12, figure 30.

Type specimens. Two specimens are present in the ZMB/Moll (no. 63006), but do not correspond to the original description and figure. We refrain at this stage from selecting any lectotypes.

Type locality. Antarctica, Gauss Station [Davis Sea, 66°02’09”S - 89°38’05”E, -385 m; fide Engl (2012)].

Original description. *Die einzige Schale von der Gauss-Station (Fig. 30) ist 4,5 mm hoch und 1,25 mm breit, aus 11 Windungen gebildet, die ziemlich schwach gewölbt sind und eine flache Naht zeigen. Sie sind mit schmalen, etwas schrägen Fältchen skulptiert und zeigen etwas unter der Mitte einen Kiel, der besonders auf den unteren Windungen nach oben steiler abfällt, als nach unten; darüber weisen die unteren Windungen noch drei erhabene Spirallinien auf, durch welche die Längsfältchen knotig erscheinen. Unmittelbar über der Naht ist noch eine einfache, nicht knotige Spirallinie sichtbar und an der Unterseite der letzten Windung noch eine ähnliche. Der Spindelfortsatz ist kurz und deutlich gedreht, an dem Exemplar ebenso wie der Unterrand der Mündung etwas beschädigt.*

Translation. The only shell comes from the Gauss Station and is 4.5 mm high and 1.25 mm broad. It has 11 whorls, weakly rounded and shows a flat suture. They are sculptured by thin axial ribs and have a keel on the lower part of the whorl, which is especially prominent on the lower whorls. Moreover, the lower whorls have further three spiral cords, which show tubercles at the intersection with axial ribs. Immediately above the suture a simple smooth cord is visible. Also the base has another smooth cord. The columella is short and clearly curved, but damaged like the lower part of the aperture.



2 Zoolog. Museum Berlin.
Triforis
delicatula Thiele*
I
Gauss-Station
63006

Figure 31. *Triforis delicatula* Thiele, 1912, Antarctica, Gauss Station. **A-D**, **F**. ZMB/Moll no. 63006a: front (**A-B**), left side (**C**), back (**D**), protoconch (**F**). **E**. Original figure in Thiele 1912. **G**. Original label. **H-J**. ZMB/Moll no. 63006b: front (**H**), left side (**I**), back (**J**). Scale bar: **A-D**: 0.5 mm, **F**: 0.2 mm, **H-J**: 1 mm.

Diagnosis. Teleoconch up to eight whorls and 6.1 mm, but possibly slightly more, because the largest available specimen has a complete base but not a complete peristome. A strong adapical spiral cord is present since the early teleoconch whorls and further threads later appear. The sculpture on the lower whorls is composed by four spiral cords and prosocline axial ribs which form tubercles at the intersections; a fifth smooth suprasutural cord is also present. The base has a sixth smooth cord. The paucispiral protoconch, composed by 2.5 whorls, suggests lecitotrophic development. The first whorl appears smooth, and the last whorl has axial riblets and a single spiral keel. However, the condition of the specimen with protoconch is very poor, and finer sculpture, if present, cannot be described. Colour ivory, but both specimens are worn and it is difficult to judge which the original colour was.

Remarks. A single specimen is cited in the original description. However, the lot in the ZMB is composed by two specimens which are different in size (height: 2.9 and

6.1 mm, respectively) than the specimen cited by Thiele (4.5 mm), as already noted by Engl (2012). Also the figure in plate 12 (in Thiele 1912) shows that the available specimens are not the same that Thiele studied: the illustrated specimen has a complete apex and eight whorls, while the smaller specimen in the Museum has a complete protoconch, but just four whorls, while the larger has eight whorls, but no protoconch. Due to these circumstances, these two specimens cannot be considered syntypes, because there is no evidence they were part of the type series that brought to the description of this species.

Acknowledgements

The Synthesys project (project DE-TAF-3510) funded PGA's visit to the Museum für Naturkunde in Berlin. Matthias Glaubrecht and Christine Zorn supported PGA during the work on the malacological collection. Bernhard Schurian hosted PGA in his room, allowed the use of the photographic equipment under his responsibility and gave suggestions to improve results. Anke Sänger helped with SEM imaging. David Herbert provided important literature. Martin Zuschin kindly hosted PAJB during his stay at the Department of Palaeontology of the University of Vienna. Bruno Sabelli inspired this work and advised continuously. Philippe Bouchet advised on the interpretation of the ICZN code. Winfried Engl provided useful information on *T. delicatula*. Frank Köhler and Emilio Rolán provided useful comments during the review process. The Museum für Naturkunde supported the open access publication of this paper.

References

Albano PG, Sabelli B, Bouchet P (2011) The challenge of small and rare species in marine biodiversity surveys: microgastropod diversity in a complex tropical coastal environment. Biodiversity and Conservation 20(13): 3223–3237. doi: 10.1007/s10531-011-0117-x

Bieler R, Petit RE (2012) Molluscan taxa in the publications of the Museum Godeffroy of Hamburg, with a discussion of the Godeffroy Sales Catalogs (1864-1884), the Journal des Museum Godeffroy (1873-1910), and a history of the museum. Zootaxa 3511: 1–80.

Bouchet P, Strong EE (2010) Historical name-bearing types in marine molluscs: An impediment to biodiversity studies? In: Polaszek A (Ed.) Systema naturae 250. CRC Press, London, 63–74. doi: 10.1201/ebk1420095012-c6

Bouchet P, Lozouet P, Maestrati P, Héros V (2002) Assessing the magnitude of species richness in tropical marine environments: exceptionally high numbers of molluscs at a New Caledonia site. Biological Journal of the Linnean Society 75: 421–436. doi: 10.1046/j.1095-8312.2002.00052.x

Dance SP (1966) Shell collecting. An illustrated history. University of California Press, London, 344 pp.

Dunker WR (1860) Neue Japanische Mollusken. Malakozoologische Blatter 6: 221–240.

Dunker WR (1861) Mollusca Japonica descripta et tabulis tribus iconum illustrata. E. Schweizerbart, Stuttgart, 36 pp.

Dunker WR (1882) Index molluscorum maris Japonici. Conscriptus et tabulis iconum XVI ilustratus. Cassellis Cattorum. Sumptibus Theodori Fischer, 1882, 390 pp.

Engl W (2012) Shells of Antarctica. Hackenheim, Conchbooks, 402 pp.

Higo S, Callomon P, Goto Y (1999) Catalogue and bibliography of the marine Shellbearing Mollusca of Japan. Isahaya, Elle Scientific Publications, 750 pp.

Janssen R (1993) Die Typen und Typoide des Natur-Museums Senckenberg, 81. Die Typen der von Dunker 1860/1871 beschriebenen japanischen Meeresmollusken. Archive für Molluskenkunde 122: 403–435.

Jay M (2007) Triphoridae (Mollusca: Gastropoda) of Reunion Island (Indian Ocean): types revisited. Novapex 8(2): 31–42.

Kilburn RN (1996) Notes on the benthic stations sampled by the Deutsche Tiefsee-Expedition (1898-1899) in Southern African waters. South African Journal of Marine Science 17: 325–328. doi: 10.2989/025776196784158491

Kükenthal W (1919) Gorgonaria. In: Chun C (Ed.) Wissenschaftliche Ergebnisse der deutschen Tiefsee Expedition auf dem Dampfer "Valdivia" 1898-1899. 13(2): 1–646.

Lebour MV (1937) The eggs and larvae of the British prosobranchs with special reference to those living in the plankton. Journal of the Marine Biological Association of the United Kingdom 22: 105–166. doi: 10.1017/S0025315400011917

Marshall BA (1983) A revision of the recent Triphoridae of Southern Australia. Records of the Australian Museum Suppl. 2: 1–119. doi: 10.3853/j.0812-7387.2.1983.102

Marshall BA (1994) Results of the Rumphius Biohistorical Expedition to Ambon (1990). Part 2. An unusual triphorid (Mollusca: Gastropoda) from the Moluccas, Indonesia. Zoologische Mededelingen 68: 39–43.

Michaelsen W, Hartmeyer R (1907) Reisebericht. In: Michaelsen W, Hartmeyer R (Eds) Die Fauna Südwest-Australiens Ergebnisse der Hamburger Südwest-australischen Forschungsreise 1905 1(1): 1–116.

Pfeiffer L (1840) Uebersicht der im Januar, Februar und März 1839 auf Cuba gesammelten Mollusken. Archiv für Naturgeschichte 6(1): 250–261.

Poppe GT (Ed.) (2009) Philippine marine mollusks, vol 1. Conchbooks, Hackenheim, 769 pp.

Rolán E, Fernández-Garcés R (2008) New data on the Caribbean Triphoridae (Caenogastropoda, Triphoroidea) with the description of 26 new species. Iberus 26(1): 81–170.

Thiele J (1912) Die Antarktischen Schnecken und Muscheln. Deutsche Südpolar-Expedition 1901-1903. Wissenschaftliche Ergebnisse. 13, Zoologie 5: 185–285.

Thiele J (1925) Gastropoda der DeutschenTiefsee-Expedition. II. Teil. Wissenschaftliche Ergebnisse Deutschen Tiefsee-Expedition auf dem Dampfer "Valdivia" 1898–1899. 17: 1(35)–348(382), pls. 1(13)–34(46).

Thiele J (1930) Die Fauna Südwest-Australiens. Ergebnisse der Hamburger südwest-australischen Forschungsreise 1905. Gastropoda und Bivalvia. Gustav Fischer Verlag (Jena) 5(8): 561–596.

von Martens E (1880) Beitrage zur Meeresfauna der Insel Mauritius und der Seychellen. Mollusken. William Healey Dall, 194 pp.

Zoosyst. Evol. 91 (1) 2016, 79–102 | DOI 10.3897/zse.91.7616

PENSOFT.

museum für naturkunde

Four new species of the genus *Orobdella* from Shikoku and Awajishima island, Japan (Hirudinida, Arhynchobdellida, Orobdellidae)

Takafumi Nakano[1,2]

1 *Department of Science Education, Graduate School of Education, Hiroshima University, 1-1-1 Kagamiyama, Higashihiroshima 739-8524, Japan*
2 *Department of Zoology, Graduate School of Science, Kyoto University, Kitashirakawa-oiwakecho, Sakyo-ku, Kyoto 606-8502, Japan*

http://zoobank.org/04BCA088-96F0-4202-A36F-56FFF1DF2298

Corresponding author: *Takafumi Nakano* (tnakano@hiroshima-u.ac.jp)

Received 24 December 2015
Accepted 22 February 2016
Published 17 March 2016

Academic editor:
Michael Ohl

Key Words

Hirudinea
Orobdella
new species
gastroporous
molecular phylogeny
Japan

Abstract

Four new species of the genus *Orobdella* Oka, 1895 from the mountainous regions of Shikoku and Awajishima island, Japan are described. These new species consist of one quadrannulate, two sexannulate and one octannulate species. The quadrannulate *Orobdella brachyepididymis* **sp. n.** is a small species with a body length reaching only ca. 5 cm. The sexannulate *Orobdella okanoi* **sp. n.** was collected from Shikoku, and the other sexannulate species, *Orobdella yamaneae* **sp. n.**, inhabits Awajishima island. The octannulate *Orobdella nakahamai* **sp. n.** is a large species with a body length greater than 20 cm and is only the second large octannulate species known within this genus. Phylogenetic analyses using nuclear 18S rRNA and histone H3, as well as mitochondrial cytochrome *c* oxidase subunit I, $\mathrm{tRNA^{Cys}}$, $\mathrm{tRNA^{Met}}$, 12S rRNA, $\mathrm{tRNA^{Val}}$, 16S rRNA, $\mathrm{tRNA^{Leu}}$ and NADH dehydrogenase subunit 1 markers, indicated that *O. brachyepididymis* is a sister species of the quadrannulate *O. naraharaetmagarum* Nakano, 2016, while the other three new species formed a clade closely related to *O. masaakikuroiwai* Nakano, 2014 and *O. whitmani* Oka, 1895. The ranges of the distant phylogenetic lineage groups of *Orobdella* overlap in Shikoku and adjacent islets.

Introduction

The genus *Orobdella* Oka, 1895 is a terrestrial macrophagous leech taxon that inhabits the Japanese Archipelago, Korean Peninsula and Taiwan (Nakano and Lai 2012, Nakano and Seo 2014, Sawyer 1986). The latest taxonomic study on this genus showed that *Orobdella* contains 13 species (Nakano 2016) split into three groups based on their mid-body somite annulation: eight species in the quadrannulate (four annuli per one somite) group and four species in the sexannulate (six annuli) group. The other species *O. octonaria* Oka, 1895 is an octannulate (eight annuli) taxon.

Additionally, these 13 species can be also split into another three types based on the body lengths of mature leeches (Nakano 2016): three quadrannulate species belong to the small-type (of which the body lengths of mature leeches are shorter than 5 cm); the other five quadrannulate and all sexannulate species are designated the middle-type (reaching ca. 10 cm); and the octannulate species is assigned to the large-type. The body length of the octannulate *O. octonaria* has been described as being greater than 20 cm (Nakano 2012c, Richardson 1971). Molecular phylogenetic analyses of the *Orobdella* species clearly showed that these morphological groups or forms do not reflect phylogenetic relationships (e.g. Nakano 2016): the sexannulate mid-body somite annulation and the small-type body length have evolved in parallel in the genus.

Additional *Orobdella* leeches were collected from Shikoku and Awajishima island, Japan. The specimens collected from Shikoku comprised three morphological units: a quadrannulate small-type, a sexannulate middle-type and an octannulate large-type. Meanwhile, *Orobdella* leeches on Awajishima island belonged to the sexannulate middle-type. Each of these four units is described here as a new species. In addition, the phylogenetic positions of these new species were estimated using nuclear 18S rRNA and histone H3, as well as mitochondrial cytochrome *c* oxidase subunit I, tRNA^{Cys}, tRNA^{Met}, 12S rRNA, tRNA^{Val}, 16S rRNA, tRNA^{Leu}, and NADH dehydrogenase subunit 1 sequence data.

Materials and methods

Sampling and morphological examination

Leeches were collected from five localities in Shikoku, and one locality on Awajishima island, Japan (Fig. 1). When possible, elevation and geographical coordinates for localities were obtained using a Garmin eTrex® GPS unit.

Almost all of the specimens were relaxed by the gradual addition of absolute ethanol to freshwater. For DNA extraction, botryoidal tissue was removed from the posterior part of the body around the caudal sucker of every specimen, and then preserved in absolute ethanol. The remainder of the body was fixed in 10% formalin and preserved in 70% ethanol. Four measurements were taken: body length (BL) from the anterior margin of the oral sucker to the posterior margin of the caudal sucker, maximum body width (BW), caudal sucker length (CL) from the anterior to the posterior margin of the sucker and caudal sucker width (CW) from the right to the left margin of the sucker. Examination, dissection, and drawing of the specimens were conducted using a stereoscopic microscope with a drawing tube (Leica M125). Specimens used in this study have been deposited in the Zoological Collection of Kyoto University (KUZ).

The numbering convention is based on Moore (1927): body somites are denoted by Roman numerals, and the annuli in each somite are given alphanumeric designations.

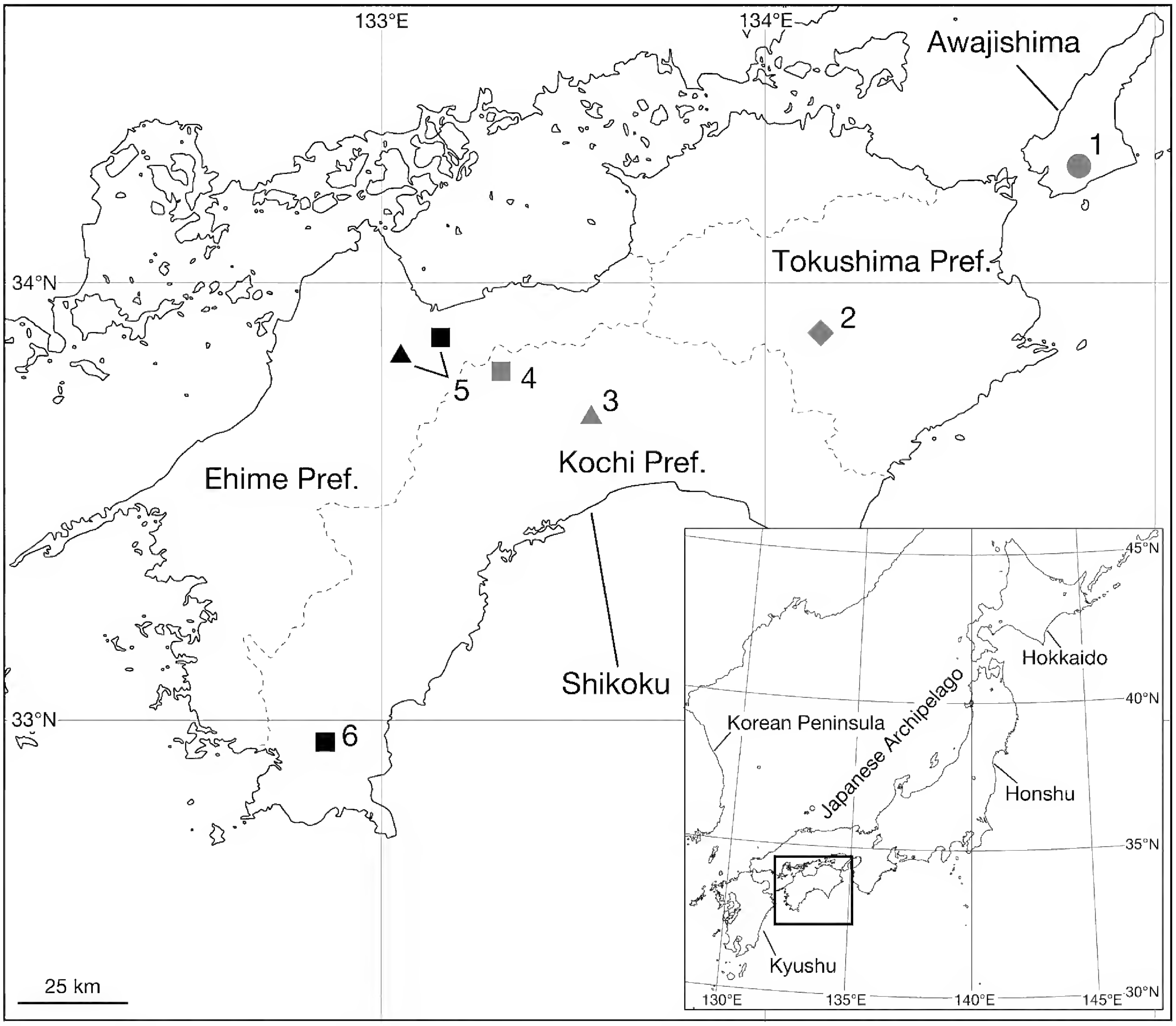


Figure 1. Map showing the collection localities of the specimens examined in this study. The closed diamond (2) denotes the locality of *Orobdella brachyepididymis* sp. n., closed squares (4–6) show the localities of *Orobdella nakahamai* sp. n., closed triangles (3, 5) designate the localities of *Orobdella okanoi* sp. n., and the closed circle (1) specifies the locality of *Orobdella yamaneae* sp. n. Symbols in red indicate the type locality of each of the new species.

The following morphological abbreviations are used in the figures: **ac**—atrial cornu; **af**—annular furrow; **an**—anus; **at**—atrium; **cl**—clitellum; **cod**—common oviduct; **cp**—crop; **ed**—ejaculatory duct; **ep**—epididymis; **fg**—female gonopore; **gd**—gastroporal duct; **gp**—gastropore; **mg**—male gonopore; **np**—nephridiopore; **od**—oviduct; **ov**—ovisac; **ph**—pharynx; **ts**—testisac.

RCP and DNA sequencing

The extraction of genomic DNA from botryoidal tissues preserved in absolute ethanol followed Nakano (2012b). Primer sets for the PCR and cycle sequencing (CS) reactions used in this study were as follows: for 18S rRNA, A and L (PCR and CS), C and Y (PCR and CS), as well as O and B (PCR and CS) (Apakupakul et al. 1999); for histone H3 (H3), H3aF and H3bR (PCR and CS) (Colgan et al. 1998); for cytochrome *c* oxidase subunit I (COI), LCO1490 (PCR and CS) and HCO2198 (CS) (Folmer et al. 1994), and LCO-in (CS) and HCO-out (PCR and CS) (Nakano 2012b) or HCO-outout (PCR and CS) (Nakano 2012a); for tRNA^{Cys}, tRNA^{Met}, 12S rRNA, tRNA^{Val} and 16S rRNA (tRNA^{Cys}–16S), 12SA-out and 12SB-in (PCR and CS), and 12SA-in and 12SB-out (PCR and CS) (Nakano 2012b); for tRNA^{Leu} and NADH dehydrogenase subunit 1 (ND1) (tRNA^{Leu}–ND1), LND3000 and HND1932 (PCR and CS) (Light and Siddall 1999). The PCR reactions and DNA sequencing were performed using the modified method mentioned in Nakano (2012a). The PCR reactions were performed using a GeneAmp PCR System 2700 and 9700 (Applied Biosystems) as well as a T100 Thermal Cycler (Bio-Rad). The PCR mixtures were heated to 94°C for 5 min, followed by 35 cycles at 94°C (10 s each), 52°C for 18S and H3, 50°C for the anterior and posterior parts of tRNA^{Cys}–16S, 48°C for COI or 42°C for tRNA^{Leu}–ND1 (20 s), and 72°C (1 min 12 s for COI, 24 s for H3 or 42 s for the other markers), and a final extension at 72°C for 6 min. The sequencing mixtures were heated 96°C for 2 min, followed by 40 cycles at 96°C (10 s each), 50°C (5 s each) and 60°C (42 s each). The obtained sequences were edited using DNA BASER (Heracle Biosoft S.R.L.). The DNA sequences listed in Table 1 were newly obtained in this study and were deposited with the International Nucleotide Sequence Database Collaboration (INSDC) through the DNA Data Bank of Japan (DDBJ). The GenSeq nomenclature proposed by Chakrabarty et al. (2013) was followed in Table 1 to show the reliability of the obtained DNA sequences.

Molecular phylogenetic and genetic distance analyses

Eighty-five published sequences were obtained from the INSDC for use in molecular phylogenetic analyses (Table 1). In addition to 13 known *Orobdella* species, the following four erpobdelliform species were used as outgroup taxa: *Erpobdella japonica* Pawłowski, 1962 (Erpobdellidae), *Gastrostomobdella monticola* Moore, 1929 (Gastrostomobdellidae), *Mimobdella japonica* Blanchard, 1897, and *Odontobdella blanchardi* (Oka, 1910a) (both Salifidae).

The phylogenetic relationships of the newly identified *Orobdella* species within the genus was estimated based on 18S, H3, COI, tRNA^{Cys}–16S and tRNA^{Leu}–ND1 sequences. The alignments of H3 and COI were trivial, as no indels were observed. 18S, tRNA^{Cys}–16S, and tRNA^{Leu}–ND1 were aligned using MAFFT v. 7.266 L-INS-I (Katoh and Standley 2013). The lengths of the 18S, H3, COI, tRNA^{Cys}–16S, and tRNA^{Leu}–ND1 sequences were 1,844, 328, 1,267, 1,135, and 635 bp, respectively. The concatenated sequences thus yielded 5,209 bp of aligned positions.

Phylogenetic trees were constructed using maximum likelihood (ML) and Bayesian inference (BI). ML phylogenies were constructed using RAxML v. 8.1.5 (Stamatakis 2014) with the substitution model set as GTRCAT, immediately after nonparametric bootstrapping (Felsenstein 1985) conducted with 1,000 replicates. The best-fit partitioning scheme for the ML analyses was identified with the Akaike information criterion (Akaike 1974) using PartitionFinder v. 1.1.1 (Lanfear et al. 2012) with the "greedy" algorithm: 18S/the 1st and 2nd positions of H3/the 3rd position of H3/the 1st position of COI/the 2nd position of COI/the 3rd positions of COI and ND1/the 1st position of ND1/the 2nd position of ND1/12S/16S/tRNA^{Cys}, tRNA^{Met}, tRNA^{Val} and tRNA^{Leu}.

BI and Bayesian posterior probabilities (BPPs) were estimated using MrBayes v. 3.2.5 (Ronquist et al. 2012). The best-fit partition scheme and models for each partition were selected based on the Bayesian information criterion (Schwarz 1978) using PartitionFinder with the "greedy" algorithm: for 18S and the 1st position of H3, K80+I; for the 2nd position of H3, JC69; for the 3rd position of H3, HKY85+G; for the 1st position of COI, GTR+G; for the 2nd positions of COI and ND1, HKY85+I+G; for the 3rd positions of COI and ND1 plus 16S, HKY85+I+G; for the 1st position of ND1, 12S, tRNA^{Cys}, tRNA^{Met}, tRNA^{Val} and tRNA^{Leu}, GTR+I+G. Two independent runs of four Markov chains were conducted 12 million generations, and the tree was sampled every 100 generations. The parameter estimates and convergence were checked using Tracer v. 1.6.0 (Rambaut and Drummond 2009) and the first 40,001 trees were discarded based on the results.

Nodes with bootstrap support (BS) values higher than 70% were considered sufficiently resolved (Hillis and Bull 1993). Nodes with BPPs higher than 0.95 were considered statistically significant (Leaché and Reeder 2002).

Pairwise comparisons of uncorrected *p*-distances for nine COI sequences (1,267 bp) obtained from specimens of the new species in this study and sequences from *Orobdella masaakikuroiwai* Nakano, 2014 and *Orobdella naraharaetmagarum* Nakano, 2016 were calculated using MEGA6.06 (Tamura et al. 2013) in accordance with the results of the molecular phylogenetic analyses.

Table 1. Samples used for the phylogenetic analyses. The information on the vouchers is accompanied by the collection locality numbers for the new species of *Orobdella* described in this study (see Fig. 1) and the INSDC accession numbers. Sequences marked with am asterisk were obtained for the first time in the present study. Acronyms: KUZ, the Zoological Collection of Kyoto University; UNIMAS, the Universiti Malaysia Sarawak.

Species	**Voucher (locality number)**	**INSDC #**					**GenSeq Nomenclature**
		18S	**Histone H3**	**COI**	**tRNA^{Cys}–16S**	**tRNA^{Leu}–ND1**	
Orobdella brachyepididymis sp. n.	KUZ Z1673 Holotype (2)	LC106319*	LC106321*	LC106320*	LC106318*	LC106322*	genseq-1 18S, H3, COI, tRNA^{Cys}, tRNA^{Met}, 12S, tRNA^{Val}, 16S, tRNA^{Leu}, ND1
Orobdella brachyepididymis sp. n.	KUZ Z1674 Paratype (2)			LC106324*	LC106323*	LC106325*	genseq-2 COI, tRNA^{Cys}, tRNA^{Met}, 12S, tRNA^{Val}, 16S, tRNA^{Leu}, ND1
Orobdella nakahamai sp. n.	KUZ Z1352 Paratype (5)			LC106327*	LC106326*	LC106328*	genseq-2 COI, tRNA^{Cys}, tRNA^{Met}, 12S, tRNA^{Val}, 16S, tRNA^{Leu}, ND1
Orobdella nakahamai sp. n.	KUZ Z1672 Holotype (4)	LC106330*	LC106332*	LC106331*	LC106329*	LC106333*	genseq-1 18S, H3, COI, tRNA^{Cys}, tRNA^{Met}, 12S, tRNA^{Val}, 16S, tRNA^{Leu}, ND1
Orobdella nakahamai sp. n.	KUZ Z1680 (6)			LC106335*	LC106334*	LC106336*	genseq-3 COI, tRNA^{Cys}, tRNA^{Met}, 12S, tRNA^{Val}, 16S, tRNA^{Leu}, ND1
Orobdella okanoi sp. n.	KUZ Z1491 (5)			LC106338*	LC106337*	LC106339*	genseq-3 COI, tRNA^{Cys}, tRNA^{Met}, 12S, tRNA^{Val}, 16S, tRNA^{Leu}, ND1
Orobdella okanoi sp. n.	KUZ Z1671 Holotype (3)	LC106341*	LC106343*	LC106342*	LC106340*	LC106344*	genseq-1 18S, H3, COI, tRNA^{Cys}, tRNA^{Met}, 12S, tRNA^{Val}, 16S, tRNA^{Leu}, ND1
Orobdella yamaneae sp. n.	KUZ Z1358 Paratype (1)			LC106346*	LC106345*	LC106347*	genseq-2 COI, tRNA^{Cys}, tRNA^{Met}, 12S, tRNA^{Val}, 16S, tRNA^{Leu}, ND1
Orobdella yamaneae sp. n.	KUZ Z1678 Holotype (1)	LC106349*	LC106351*	LC106350*	LC106348*	LC106352*	genseq-1 18S, H3, COI, tRNA^{Cys}, tRNA^{Met}, 12S, tRNA^{Val}, 16S, tRNA^{Leu}, ND1
Orobdella dolichopharynx Nakano, 2011b	KUZ Z120 Holotype	AB663665	AB698876	AB679680	AB679681	AB828558	
Orobdella esulacata Nakano, 2010	KUZ Z29 Holotype	AB663655	AB698873	AB679664	AB679665	AB828555	
Orobdella ijimai Oka, 1895	KUZ Z110 Topotype	AB663659	AB698877	AB679672	AB679673	AB828559	
Orobdella kawakatsuorum Richardson, 1975	KUZ Z167 Topotype	AB663661	AB698878	AB679704	AB679705	AB828561	
Orobdella ketagalan Nakano & Lai, 2012	KUZ Z208 Holotype	AB704785	AB704786	AB704787	AB828582	AB828563	
Orobdella koikei Nakano, 2012b	KUZ Z156 Holotype	AB698883	AB698882	AB679688	AB679689	AB828560	
Orobdella masaakikuroiwai Nakano, 2014	KUZ Z694 Holotype	AB938003	AB938013	AB938006	AB937997	AB938016	
Orobdella mononoke Nakano, 2012a	KUZ Z224 Holotype	AB698868	AB698869	AB698866	AB698867	AB828564	
Orobdella naraharaetmagarum Nakano, 2016	KUZ Z1652 Holotype	LC087143	LC087145	LC087144	LC087142	LC087146	
Orobdella octonaria Oka, 1895	KUZ Z181 Topotype	AB698870	AB698871	AB679708	AB679709	AB828562	
Orobdella shimadae Nakano, 2011b	KUZ Z128 Holotype	AB663663	AB698875	AB679676	AB679677	AB828557	
Orobdella tsushimensis Nakano, 2011a	KUZ Z134 Holotype	AB663653	AB698872	AB679662	AB679663	AB828554	
Orobdella whitmani Oka, 1895	KUZ Z45 Topotype	AB663657	AB698874	AB679668	AB679669	AB828556	
Erpobdella japonica Pawłowski, 1962	KUZ Z178	AB663648	AB698879	AB679654	AB679655	AB828542	
Gastrostomobdella monticola Moore, 1929	UNIMAS/ A3/ BH01/10	AB663649	AB698880	AB679656	AB679657	AB828543	
Mimobdella japonica Blanchard, 1897	KUZ Z179	AB663650	AB698881	AB679658	AB679659	AB828544	
Odontobdella blanchardi (Oka, 1910a)	KUZ Z180	AB663651	AB938012	AB938004	AB937995	AB938014	

Results

Taxonomy

Family Orobdellidae Nakano et al., 2012

Genus *Orobdella* Oka, 1895

Orobdella Oka, 1895: 278–280; Oka 1910b: 177; Soós 1966: 377, 381, 382; Richardson 1975: 42; Lukin 1976: 463, 464; Sawyer 1986: 680; Nakano 2010: 881; Nakano 2011b: 3.

Kumabdella Richardson 1971: 590, 591 (type species, *Orobdella octonaria* Oka, 1895 by original designation).

Type species. *Orobdella whitmani* Oka, 1895 by subsequent designation of Soós (1966).

Diagnosis. Body firm and muscular, elongate, with constant width in caudal direction, dorsoventrally compressed. Somite I completely merged with prostomium. Somite II uniannulate, not separated from I. Mid-body somite annulation variable, complete quadr-, sex- or octannulate. Post-anal annulus absent. Male gonopore in posterior part of XI. Female gonopore in anterior part of XIII. Pappilae numerous, minute, hardly visible, one row on every annulus. Pharynx agnathous, euthylaematous. Crop tubular, acaecate. Gastropore, when present, in anterior part of XIII. Gastroporal duct generally lying on female organ. Intestine tubular, acaecate. Rectum tubular, thin-walled, straight. Testisacs multiple. Ejaculatory bulbs absent. Male median reproductive system in posterior part of XI, without penis or penis sheath. Ovisacs globular. Oviducts thin-walled. Common oviduct thin-walled, short. Female median reproductive system essentially lacking.

Orobdella brachyepididymis sp. n.

http://zoobank.org/2A527AE0-4B23-4D87-B4EB-83C5A2F00520

Figs 2–5

Type materials. Holotype: KUZ Z1673, dissected, collected from under a rock along a road (33.87151°N, 134.12016°E; Elev. ca. 990 m; locality #2, see Fig. 1) at Mt. Ichinomori, Mima, Tokushima Prefecture, Japan, by TN on 7 July 2015. Paratype: KUZ Z1674, dissected, collected from under a rock along a road (33.87119°N, 134.12233°E; Elev. ca. 1014 m) at the type locality, by TN on 7 July 2015.

Figure 2. *Orobdella brachyepididymis* sp. n., holotype, KUZ Z1673. **A** dorsal, **B** ventral views. Scale bar: 5 mm.

Type locality. Japan, Tokushima Prefecture: Mima, Mt. Ichinomori (Shikoku).

Diagnosis. Body length of mature individual reaching to ca. 5 cm. Somite IV uniannulate, somites VIII–XXV quadrannulate. Clitellum in XI b5 to XIII a2. Male gonopore in middle of XI b6, female gonopore in anterior margin of or slightly anterior to middle of XIII a1, behind gastropore, gonopores separated by 1/2 + 4 [+ (< 1/2)] annuli. Pharynx reaching to XIV a1–a1/a2. Gastropore conspicuous, in anterior margin of or slightly anterior to middle of XIII a1. Gastroporal duct tubular, slightly bulbous at junction with gastropore. Paired epididymides in XX to XXI, occupying four annuli (one somite). Atrial cornua small ovate.

Description of holotype. BL 51.6 mm, BW 5.2 mm (Fig. 2). Caudal sucker ventral, elliptic, CL 3.0 mm, CW 3.4 mm (Figs 2B, 3D).

Somites III, IV uniannulate; IV with slight dorsal furrow (Fig. 3A). Somite V biannulate, (a1 + a2) = a3; a3 forming posterior margin of oral sucker (Fig. 3A, B). Somites VI and VII triannulate; VI, a1 < a2 > a3, a2 with slight dorsal furrow; VII, a1 = a2 = a3 (Fig. 3A, B). Somites VIII–XXV quadrannulate, a1 = a2 = b5 = b6 (Fig. 3A–E). Somite XXVI triannulate; dorsally a1 > a2 < a3, a3 with slight furrow; ventrally a1 > a2 = a3; a3 being ventrally last complete annulus (Fig. 3C, D). Somite XXVII uniannulate with slight dorso-lateral furrows (Fig. 3C). Anus behind somite XXVII (Fig. 3C).

X b5 and XIII a2, respectively, being first and last annuli of clitellum (Fig. 3E).

Male gonopore in middle of XI b6 (Fig. 3E). Female gonopore in anterior margin of XIII a1, inconspicuous, located posterior to gastropore (Fig. 3E, F). Gonopores separated by 1/2 + 4 annuli (Fig. 3E).

Anterior ganglionic mass in VI a2 and a3. Ganglion VII in a2. Ganglion VIII in a2 and b5. Ganglia IX and X, of each somite, in a2. Ganglion XI in a2 and b5 (Fig. 4A). Ganglia XII–XVI, of each somite, in a2 (Fig. 4A). Ganglia XVII–XX, of each somite, in a1 and a2 (Fig. 4A). Ganglia XXI (Fig. 4A) and XXII, of each somite, in a2. Ganglion XXIII in a2 and b5. Ganglia XXIV and XXV, of each somite, in a1 and a2. Ganglion XXVI in XXV b6 and XXVI a1. Posterior ganglionic mass in XXVI a2 and a3.

Eyes in three pairs, first pair dorsally on posterior margin of II, second and third pairs dorsolaterally on posterior margin of V (a1 + a2) (Fig. 3A).

Nephridiopores in 17 pairs, one each situated ventrally at posterior margin of a1 of each somite in VIII–XXIV (Fig. 3B, D, E).

Pharynx reaching to XIV a1 (Fig. 3G). Crop reaching to XIX b5/b6. Gastropore conspicuous, ventral, in anterior margin of XIII a1 (Fig. 3E, F). Gastroporal duct tubular, but slightly bulbous and winding at junction with gastropore, joining with crop in XIV a1 (Fig. 3G). Intestine reaching to XXIV/XXV.

Testisacs (Fig. 4A); on right side, in XXI b6 to XXV b5, in total approx. 27 testisacs, 2 in XXI, 7 in XXII, 6 in

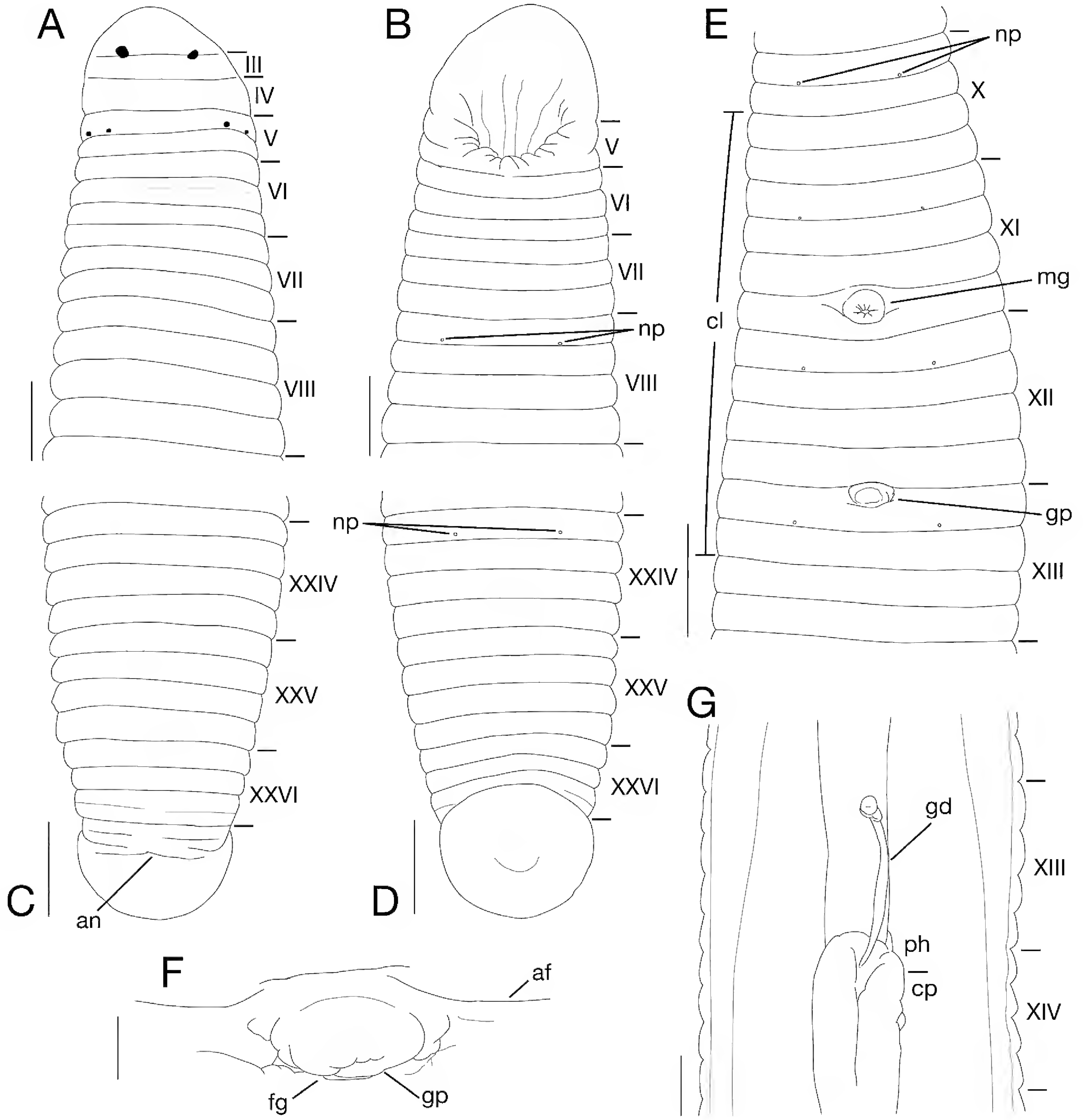


Figure 3. *Orobdella brachyepididymis* sp. n., holotype, KUZ Z1673. **A** dorsal, **B** ventral views of somites I–VIII; **C** dorsal, **D** ventral views of somites XXIV–XXVII and caudal sucker; **E** ventral view of somites X–XIII; **F** ventral view of gastropore and female gonopore; **G** ventral view of gastroporal duct. Scale bars: **A, B, G** = 1 mm; **C–E** = 2 mm; **F** = 0.25 mm.

XXIII, 7 in XXIV, 5 in XXV; on left side, in XXI b6 to XXV b6, in total approx. 25 testisacs, 2 in XXI, 5 in XXII, 7 in XXIII, 5 in XXIV, 6 in XXV. Paired epididymides; right epididymis in XX b5/b6 to XXI b5/b6, occupying 4 annuli; left epididymis in XX b6 to XXI b5/b6, occupying 4 annuli (Fig. 4A). Paired ejaculatory ducts, thick; right duct in XI b5 to XX b5/b6; left duct in XI b5 to XX b6; loosely coiled in position posterior to ovisacs; each widening from respective junction with epididymis, narrowing at junction with atrial cornua, then turning gradually inward toward atrial cornua without pre-atrial loop (Fig. 4A–D). Pair of muscular atrial cornua small ovate, in XI b5 and b6 (Fig. 4A–D). Atrium short, muscular, globular in XI b5 and b6 (Fig. 4A–D).

Paired ovisacs in XIII a2 and b5 (Fig. 4A, E). Oviducts; right oviduct crossing ventrally beneath nerve cord; both oviducts converging into common oviduct in XIII a1 (Fig. 4A, E). Common oviduct directly descending to female gonopore (Fig. 4E).

Variation. BL 36.3 mm, BW 3.5 mm, CL 1.8 mm, CW 2.2 mm. Somite IV uniannulate Somite VI triannulate, a1 = a2 = a3. Male gonopore in middle of XI b6, female gonopore in slightly anterior to middle of XIII a1, go-

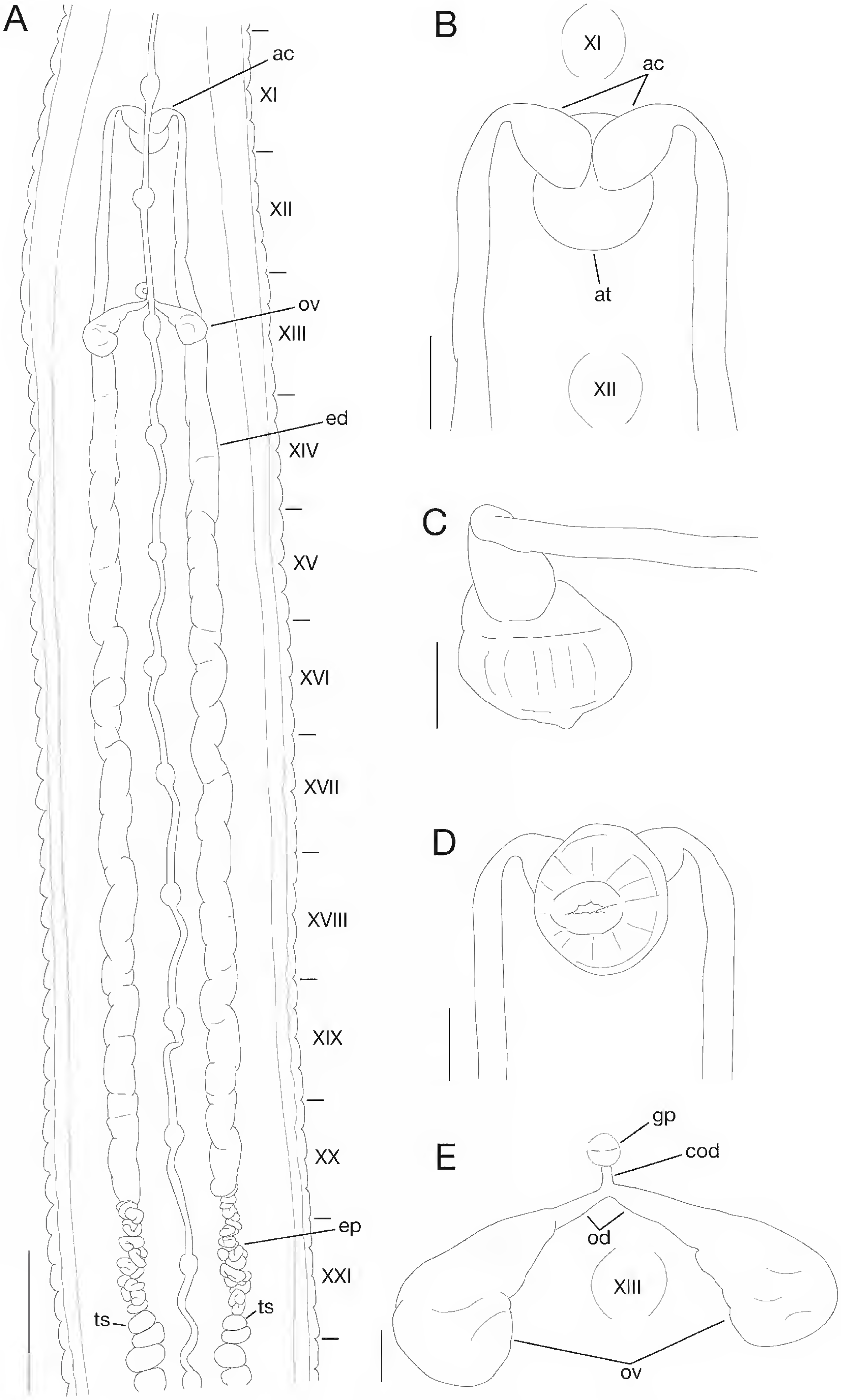


Figure 4. *Orobdella brachyepididymis* sp. n., holotype, KUZ Z1673. **A** dorsal view of reproductive system including ventral nervous system; **B** dorsal (including positions of ganglia XI and XII), **C** lateral, **D** ventral views of male atrium; **E** dorsal view of female reproductive system including position of ganglion XIII. Scale bars: **A** = 3 mm; **B–D** = 0.5 mm; **E** = 0.25 mm.

Table 2. Comparisons of morphological characters between *Orobdella brachyepididymis* sp. n. and eight quadrannulate congeneric species.

Character	Body length	Somite IV	Somite XXV	Gastroporal duct	Annuli between gonopores	Epididymides	Atrial cornua
Orobdella brachyepididymis sp. n.	less than or reaching to ca. 5 cm	uniannulate	quadrannulate	tubular	1/2 + 4 [+ (< 1/2)]	XX to XXI	small, ovate
Orobdella esulcata	reaching to ca. 10 cm	uniannulate	quadrannulate	tubular, but bulbous at junction with gastropore	2/3 + 4 + 1/3	XVI to XX	developed, ovate
Orobdella kawakatsuorum	reaching to ca. 10 cm	biannulate	quadrannulate	simple tubular	6	XVI to XVII	undeveloped
Orobdella ketagalan	reaching to ca. 10 cm	uniannulate	quadrannulate	simple tubular	1/2 + 4 + 1/2	absent	undeveloped
Orobdella koikei	less than 4 cm	uniannulate	triannulate	bulbous	1/2 + 4 + 1/2	XV to XX	developed, ovate
Orobdella masaakikuroiwai	less than 4 cm	uniannulate	quadrannulate	bulbous	1/2 + 4 + 1/2	XVI to XVIII	developed, ovate
Orobdella naraharaetmagarum	less than 5 cm	uniannulate	quadrannulate	bulbous	1/2 + 4 + 1/2	XV to XX	developed, ellipsoid or ovate
Orobdella tsushimensis	reaching to ca. 10 cm	uniannulate	quadrannulate	bulbous	1/2 + 5	XVII to XIX	developed, ovate
Orobdella whitmani	reaching to ca. 10 cm	uni- or biannulate	quadrannulate	bulbous	1/2 + 4 + 1/2	XVI to XVIII	developed, ovate

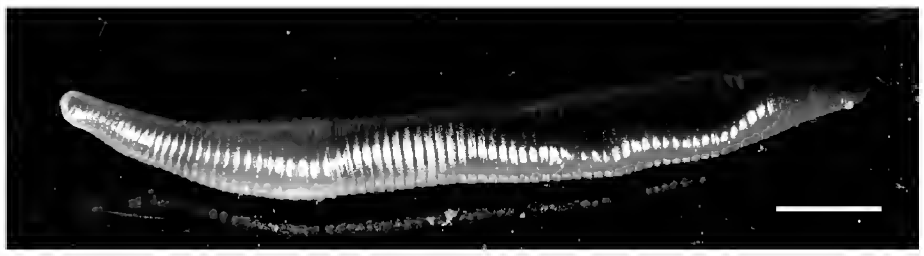


Figure 5. *Orobdella brachyepididymis* sp. n., holotype, KUZ Z1673. Dorsal view of live animal. Scale bar: 5 mm.

nopores thus separated by 1/2 + 4 + (< 1/2) annuli. Pharynx reaching to XIV a1/a2. Crop reaching to XX a1/a2. Gastropore in slightly anterior to middle of XIII a1. Gastroporal duct tubular, but slightly bulbous at junction with gastropore, joining with crop in XIV a2/b5. Intestine reaching to XXIV a1/b5. Testisacs undetectable. Paired epididymides; right epididymis in XX b5 to XXI a2/b5; left epididymis in XX a2/b5 to XXI a2; each occupying four annuli. Atrium in XI b6. Left oviduct crossing ventrally beneath nerve cord.

Colouration. In life, dorsal surface grayish (Fig. 5); ventral surface whitish red; clitellum, when obvious, whitish grayish pale ochre (Fig. 5). Color faded in preservative.

Etymology. The specific name is a compound noun in apposition derived from the Greek words transliterated into Latin, brachys (short) and epididymis (epididymis), referring to the fact that the epididymides of this species occupy only four annuli.

Distribution. This species was found only from its type locality.

Natural history. This species was found curled up under rocks in moist mountainous habitats. As oligochaete worms were observed in the digestive tract of a dissected specimen, KUZ Z1674, this species is an earthworm-eater, as are the other known *Orobdella* species.

A mature leech, KUZ Z1673, was collected on 7 July. Therefore, *Orobdella brachyepididymis* is considered to enter its reproductive season before early July.

Remarks. The specimens were small (up to 52 mm), but the holotype was determined to be mature because it possessed an obvious clitellum and developed testisacs.

According to taxonomic studies (Nakano 2010, 2012b, 2014, 2016, Nakano and Gongalsky 2014, Nakano and Lai 2012, Nakano and Seo 2014), the new species is distinguished from the eight quadrannulate species (i.e. *O. esulcata* Nakano, 2010, *O. kawakatsuorum* Richardson, 1975, *O. ketagalan* Nakano & Lai, 2012, *O. koikei* Nakano, 2012b, *O. masaakikuroiwai*, *O. naraharaetmagarum*, *O. tsushimensis* Nakano, 2011a and *O. whitmani*) by the following combination of characteristics (Table 2): body length less than or reaching ca. 5 cm, IV uniannulate, XXV quadrannulate, gonopores separated by 1/2 + 4 [+ (< 1/2)] annuli, gastroporal duct tubular, epididymides in XX to XXI and atrial cornua small ovate.

Orobdella nakahamai sp. n.

http://zoobank.org/47B528A0-16E3-40D6-BAA8-E7035C167A56

Figs 6–9

Type materials. Holotype: KUZ Z1672, dissected, collected from under rocks of a small mountain stream at Mt. Takanosuyama (33.788°N, 133.271°E; Elev. ca. 1500 m; locality #4), Ino, Kochi Prefecture, Japan, by Ryosuke Okano on 4 July 2015. Paratype: KUZ Z1352, dissected, collected from under rocks of a small mountain stream at Mt. Iwagurosan

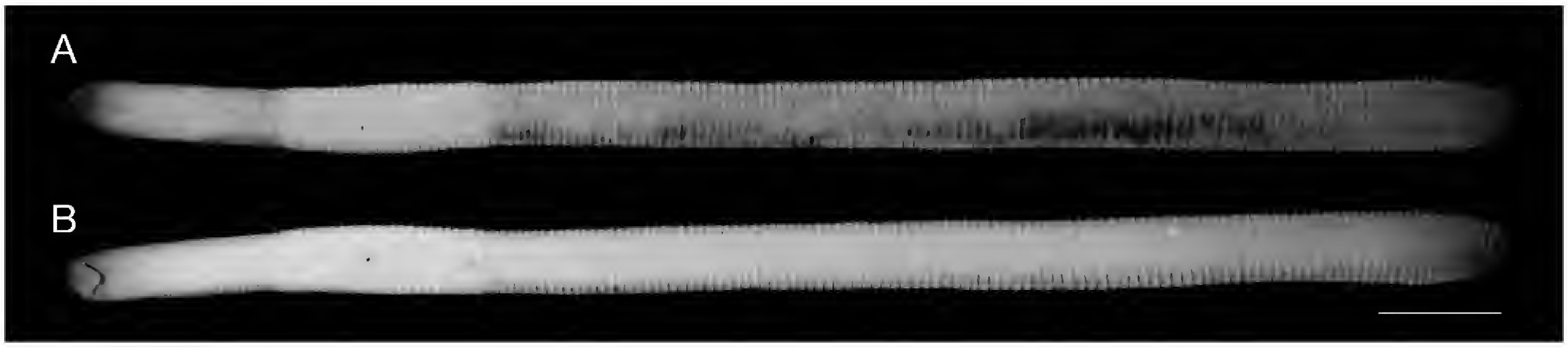


Figure 6. *Orobdella nakahamai* sp. n., holotype, KUZ Z1672. **A** dorsal, **B** ventral views. Scale bar: 2 cm.

(33.7516°N, 133.1533°E; Elev. ca. 1600 m; locality #5), Kumakogen, Ehime Prefecture, Japan, by Naoyuki Nakahama on 10 August 2010. For locality numbers, see Fig. 1.

Additional material. KUZ Z1680, collected from Kaminodoi (32.942714°N, 132.841350°E; Elev. ca 140 m; locality #6, see Fig. 1), Shimanto, Kochi Prefecture, Japan, by Ryosuke Okano on 2 November 2015.

Type locality. Japan, Kochi Prefecture: Ino, Ishizuchi Mountains, Mt. Takanosuyama (Shikoku).

Diagnosis. Body length of mature individual greater than 15 cm. Somites IX–XXV octannulate. Clitellum in X c9 to XIII b4. Male gonopore in slightly posterior to middle of XI c11 or XI c10/c11, female gonopore in XIII b2/b3, behind gastropore, gonopores separated by 1/2 + 11 or 12 annuli. Pharynx reaching to XIV b1–b3/b4. Gastropore conspicuous, in XIII b2/b3. Gastroporal duct bulbous, slightly winding at junction with gastropore. Paired epididymides in XV to XVII, occupying 12 or 13 annuli (one and half somites). Atrial cornua ovate or ellipsoid.

Description of holotype. BL 237.7 mm, BW 11.3 mm (Fig. 6). Caudal sucker ventral, elliptic, CL 3.9 mm, CW 6.5 mm (Figs 6B, 7D).

Somites III–V biannulate; III and V, (a1 + a2) = a3; IV, (a1 + a2) > a3; V a3 forming posterior margin of oral sucker (Fig. 7A, B). Somite VI dorsally quinquannulate, b1 = b2 < a2 > b5 < b6; ventrally quadrannulate, a1 = a2 > b5 < b6 (Fig. 7A, B). Somite VII quiquannulate, a1 > b3 = b4 = b5 = b6, a1 with slight lateral furrow on each side (Fig. 7A, B). Somite VIII dorsally septannulate, a1 (with obvious secondary furrow, b1 = b2) > b3 = b4 = c9 = c10 = c11 = c12; ventrally octannulate, b1 = b2 = b3 = b4 = c9 = c10 = c11 = c12 (Fig. 7A, B). Somite IX octannulate, b1 = b2 = b3 < b4 = c9 = c10 = c11 = c12. Somites X–XXV octannulate, b1 = b2 = b3 = b4 = c9 = c10 = c11 = c12 (Fig. 7C–E). Somite XXVI octannulate, b1 = b2 = b3 = b4 = c9 = c10 = c11 > c12. Somite XXVII comprises three annuli, second and third annuli, respectively, with slight dorsal furrow; first annulus being ventrally last complete annulus (Fig. 7C, D). Anus behind somite XXVII (Fig. 7C).

X c9 and XIII b4, respectively, being first and last annuli of clitellum (Fig. 7E).

Male gonopore in slightly posterior to middle of XI c11 (Fig. 7E). Female gonopore in XIII b2/b3, inconspicuous, located posterior to gastropore (Fig. 7E, F). Gonopores separated by 1/2 + 11 annuli (Fig. 7E).

Anterior ganglionic mass in VI b5 and b6. Ganglion VII in a1. Ganglia VIII–X, of each somite, in b3 and b4. Ganglion XI in b4 (Fig. 8B). Ganglion XII in b3 and b4 (Fig. 8B). Ganglion XIII in b4 (Fig. 8B). Ganglia XIV–XVI, of each somite, in b3 and b4 (Fig. 8B). Ganglion XVII in b3 (Fig. 8B). Ganglion XVIII in b3 and b4. Ganglion XIX in b3. Ganglia XX and XXI, of each somite, in b3 and b4. Ganglia XXII–XXV, of each somite, in b3. Ganglion XXVI in b2. Posterior ganglionic mass in XXVI c10–c12.

Eyes undetectable.

Nephridiopores in 17 pairs, one each situated ventrally at posterior margin of b2 of each somite in VIII–XXIV (Fig. 7B, D, E).

Pharynx reaching to XIV b1 (Fig. 8A). Crop reaching to XXII c9. Gastropore conspicuous, ventral, in XIII b2/b3 (Fig. 7E, F). Gastroporal duct bulbous, slightly winding at junction with gastropore, joining with crop in XIII c12 (Fig. 8A). Intestine reaching to XXV/XXVI.

Testisacs (Fig. 8B); on right side, in XVII c9 to XXV c11, in total approx. 164 testisacs, 7 in XVII, 18 in XVIII, 24 in XIX, 21 in XX, 21 in XXI, 20 in XXII, 23 in XXIII, 16 in XXIV, 14 in XXV; on left side, in XVII b4 to XXV c12, in total approx. 160 testisacs, 6 in XVII, 15 in XVIII, 24 in XIX, 20 in XX, 22 in XXI, 18 in XXII, 18 in XXIII, 21 in XXIV, 16 in XXV. Paired epididymides in XV c9 to XVI/XVII, occupying 12 annuli (Fig. 8B). Paired ejaculatory ducts in XI c9 to XV c9; coiled in position posterior to ovisacs; each duct crossing ventrally beneath each ovisac, then running straight in position anterior to ovisacs; each widening from respective junction with epididymis, narrowing at junction with atrial cornua, then turning sharply inward toward atrial cornua without pre-atrial loop (Fig. 8B–E). Pair of muscular atrial cornua ovate, in XI c9–c11 (Fig. 8B–E). Atrium short, muscular, globular in XI c10 and c11 (Fig. 8B–E).

Paired ovisacs in XIII b3 and b4 (Fig. 8B, F). Oviducts; right oviduct crossing ventrally beneath nerve cord; both oviducts converging into common oviduct in XIII b3/b4 (Fig. 8B, F). Common oviduct directly descending to female gonopore (Fig. 8B, F).

Variations. BL 162.3–180.4 mm, BW 7.6–98 mm, CL 3.3–4.3 mm, CW 5.6 mm. Somite VI quadrannulate, a1

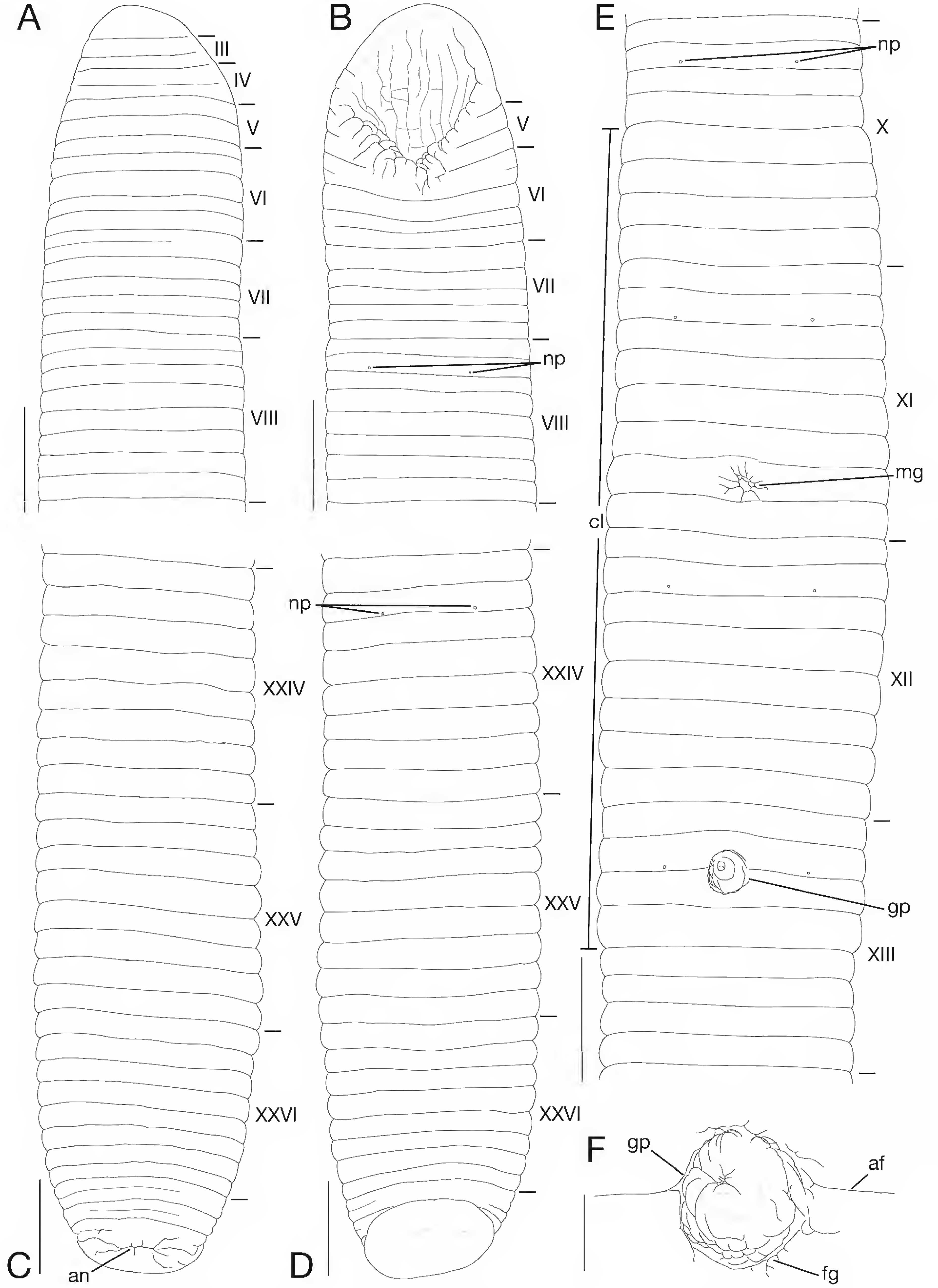


Figure 7. *Orobdella nakahamai* sp. n., holotype, KUZ Z1672. **A** dorsal, **B** ventral views of somites I–VIII; **C** dorsal, **D** ventral views of somites XXIV–XXVII and caudal sucker; **E** ventral view of somites X–XIII; **F** ventral view of gastropore and female gonopore. Scale bars: **A–E** = 5 mm; **F** = 1 mm.

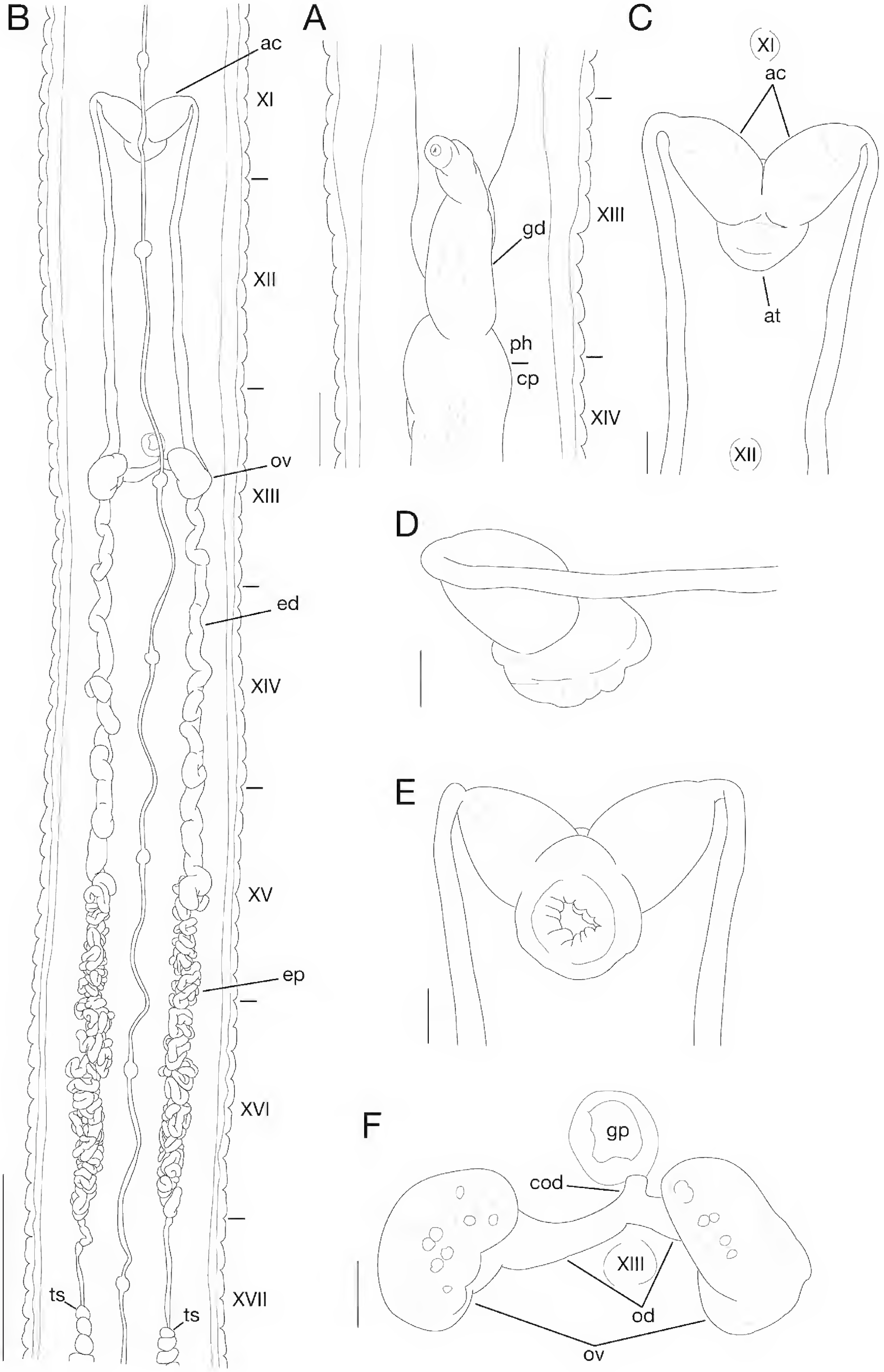


Figure 8. *Orobdella nakahamai* sp. n., holotype, KUZ Z1672. **A** ventral view of gastroporal duct; **B** dorsal view of reproductive system including ventral nervous system; **C** dorsal (including positions of ganglia XI and XII), **D** lateral, **E** ventral views of male atrium; **F** dorsal view of female reproductive system including position of ganglion XIII. Scale bars: **A** = 3 mm; **B** = 1 cm; **C–F** = 1 mm.

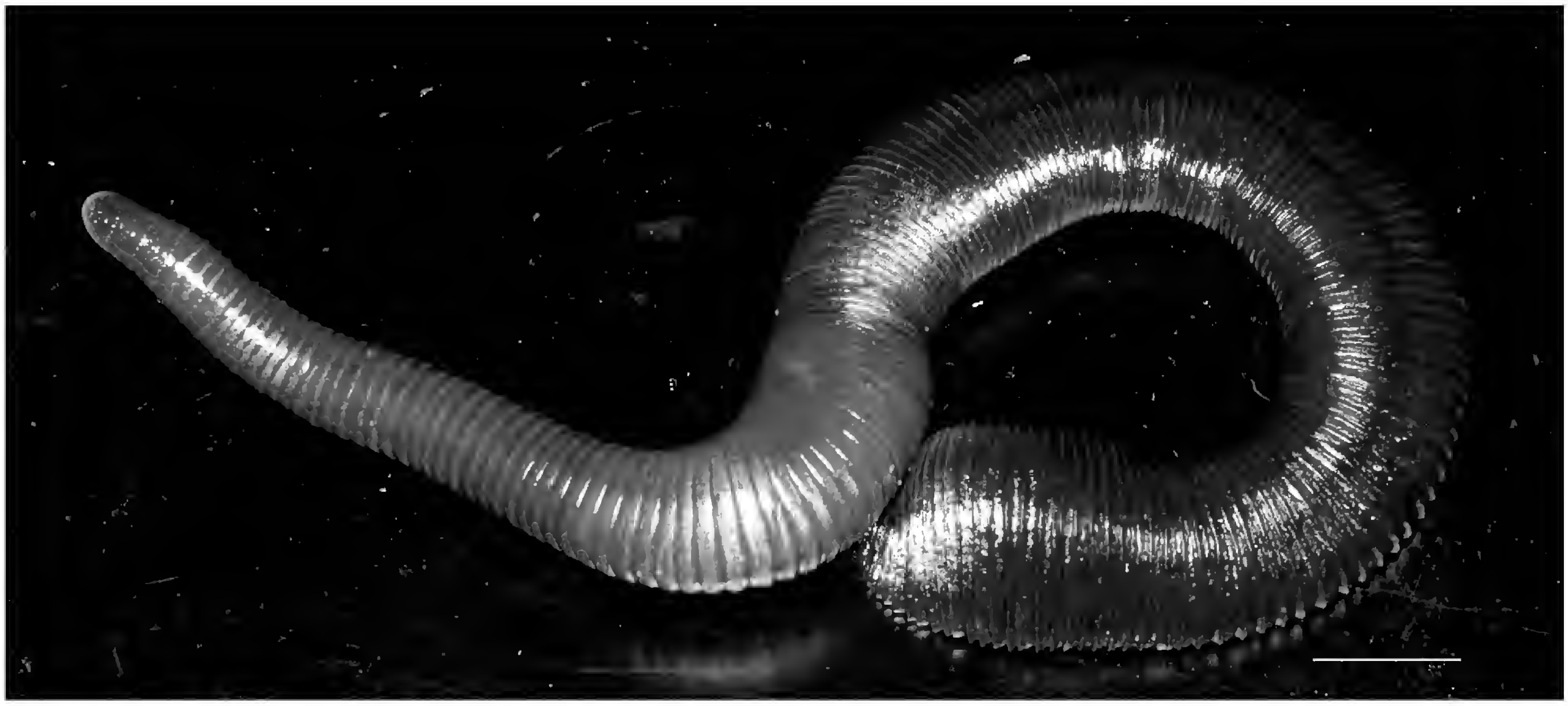


Figure 9. *Orobdella nakahamai* sp. n., holotype, KUZ Z1672. Dorsal view of live animal. Scale bar: 1 cm.

(dorsally b1 = b2) = a2 (dorsally b3 = b4) > b5 < b6, or dorsally quinquannulate, b1 = b2 < a2 > b5 < b6. Somite VII quinquannulate, a1 (dorsally b1 = b2 in KUZ Z1680) > b3 = b4 = b5 = b6. Somite VIII octannulate, b1 = b2 < b3 < b4 = c9 = c10 = c11 = c12, or ventrally septannulate, a1 (b1 = b2) > b2 = b3 = b4 = c9 = c10 = c11 = c12. Somite IX octannulate, b1 = b2 = b3 = b4 = c9 = c10 = c11 = c12. Somite XXVI dorsally octannulate, b1 = b2 = b3 = b4 > c9 = c10 = c11 = c12, ventrally septannulate, b1 = b2 = b3 = b4 > c9 = c10 < b6, or sexannulate, b1 = b2 = b3 = b4 = b5 < b6 (c11 = c12). Somite XXVII comprises two annuli, first annulus with slight three dorsal furrows, or comprises four annuli. Eyes in one pair, dorsally on posterior margin of II (KUZ Z1352). Pharynx reaching to XIV b3/b4. Crop reaching to XXII b1/b2. Gastroporal duct joining with crop in XIV b3. Intestine reaching to XXV b4. Male gonopore in XI c10/c11 (KUZ Z1680), thus gonopores separated by 12 annuli. Testisacs in XVII c10 to XXV c11; on right side, in total approx. 122 testisacs, 5 in XVII, 18 in XVIII, 17 in XIX, 18 in XX, 16 in XXI, 15 in XXII, 14 in XXIII, 10 in XXIV, 9 in XXV; on left side, in total approx. 126 testisacs, 4 in XVII, 16 in XVIII, 19 in XIX, 21 in XX, 17 in XXI, 13 in XXII, 13 in XXIII 11 in XXIV, 12 in XXV. Paired epididymides in XV c10/c11 to XVII b3/b4, occupying 13 annuli. Pair of muscular atrial cornua ellipsoid. Left oviduct crossing ventrally beneath nerve cord; both oviducts converging into common oviduct in XIII b3.

Colouration. In life, dorsal surface bluish gray (Fig. 9); ventral surface bluish white; clitellum, when obvious, paler than other body parts (Fig. 9). Color faded in preservative.

Etymology. The specific name is a noun in the genitive case formed directly from the name of Mr Naoyuki Nakahama, who collected a specimen of this new species.

Distribution. This species was collected from the Ishizuchi Mountains and south-western part of Kochi Prefecture. The lowest elevation among the localities was ca. 140 m, and the highest was ca. 1600 m. The locality data for this species suggested that it is distributed in mountainous regions in the western part of Shikoku, Japan. Its distribution may not be restricted by habitat elevation.

Natural history. Mature leeches with an obvious clitellum, KUZ Z1352 and Z1672, were collected on 4 July and 10 August, respectively, in the Ishizuchi Mountains. Therefore, the reproductive season of *O. nakahamai* in the mountains begins before or during July, and then continues at least to early August.

Remarks. *Orobdella nakahamai* is only the second octannulate large-type species known within the genus. According to Nakano (2012c), this species can be distinguished from another octannulate species *O. octonaria* by the following combination of characteristics (Table 3): female gonopore in XIII b2/b3, gonopores separated by 1/2 + 11 or 12 annuli and epididymides in XV to XVII. *Orobdella nakahamai* is clearly distinguishable from the quadrannulate and sexannulate species of this genus because it possesses octannulate mid-body somites.

Orobdella okanoi sp. n.

http://zoobank.org/28E2B152-07C6-4E03-8A92-5F91E7353881

Figs 10–13

Type material. Holotype: KUZ Z1671, dissected, collected from under a rock along a mountain trail at Mt. Kuishiyama (33.67636°N, 133.51556°E; Elev. ca. 910 m; locality #3, see Fig. 1), Kochi, Kochi Prefecture, Japan, by Yoshiko Yamane on 5 July 2015.

Table 3. Comparisons of morphological characters between octannulate *Orobdella nakahamai* sp. n. and *Orobdella octonaria*.

Character	Female gonopore	Annuli between gonopores	Epididymides
Orobdella nakahamai sp. n.	XIII b2/b3	1/2 + 11 or 12	XV to XVII
Orobdella octonaria	middle of XIII b2	1/2 + 10 + 1/2	XVII to XIX

Additional material. KUZ Z1491, dissected, collected from in soil along a road at Mt. Iwagurosan (33.755278°N, 133.148333°E; Elev. ca 1510 m; locality #5, see Fig. 1), Saijyo, Ehime Prefecture, Japan, by Yoshiko Yamane on 22 August 2013.

Type locality. Japan, Kochi Prefecture: Kochi, Tosayamatakakawa, Mt. Kuishiyama (Shikoku).

Diagnosis. Dorsal surface reddish. Somite VII quinquannulate. Somite VIII–XXVI sexannulate. Male gonopore in slightly posterior to middle of XI c11/c12, female gonopore in middle of XIII b2, behind gastropore, gonopores separated by 8 + 1/2 annuli. Pharynx reaching to XIV b1–b2/a2. Gastropore conspicuous, in middle of XIII b2. Gastroporal duct bulbous, slightly winding at junction with gastropore. Paired epididymides in XV to XVII, occupying 8–11 annuli (one and half to almost two somites). Pre-atrial loop absent. Atrial cornua ellipsoid.

Description of holotype. BL 95.2 mm, BW 5.8 mm (Fig. 10). Caudal sucker ventral, elliptic, CL 2.3 mm, CW 3.7 mm (Figs 10B, 11D).

Somite III uniannulate (Fig. 11A). Somites IV and V biannulate; IV, (a1 + a2) > a3 (Fig. 11A); V, (a1 + a2) = a3; V a3 forming posterior margin of oral sucker (Fig. 11A, B). Somite VI triannulate, a1 (dorsally b1 = b2) > a2 = a3 (Fig. 11A, B). Somite VII quinquannulate, b1 = b2 = a2 = b5 = b6 (Fig. 11A, B). Somites VIII–XXVI sexannulate, b1 = b2 = a2 = b5 = c11 = c12 (Fig. 11A–E). Somite XXVII comprises two annuli; first annulus being ventrally last complete annulus (Fig. 11C, D). Anus behind somite XXVII (Fig. 11C).

Male gonopore in XI c11/c12 (Fig. 11E). Female gonopore in slight posterior to middle of XIII b2, inconspicuous, located posterior to gastropore (Fig. 11E, F). Gonopores separated by 8 + 1/2 annuli (Fig. 11E).

Anterior ganglionic mass in VI a1 and VII b1. Ganglion VII in b2 and a2. Ganglion VIII in a2. Ganglion IX in a2 and b5. Ganglion X in a2. Ganglion XI in a2 and b5 (Fig. 12A). Ganglion XII in a2 (Fig. 12A). Ganglion XIII in a2 and b5 (Fig. 12A). Ganglia XIV and XV, of each somite, in a2 (Fig. 12A). Ganglion XVI in b2 and a2 (Fig. 12A). Ganglia XVII (Fig. 12A) and XVIII, of each somite, in a2. Ganglion XIX in b2 and a2. Ganglia XX–XXII, of each somite, in a2. Ganglia XXIII–XXV, of each somite, in b2 and a2. Ganglion XXVI in b1 and b2. Posterior ganglionic mass in XXVI b5–c12.

Eyes in three pairs, first pair dorsally on posterior margin of II, second and third pairs dorsolaterally on posterior margin of V (a1 + a2) (Fig. 11A).

Nephridiopore in 17 pairs, one each situated ventrally at posterior margin of b2 of each somite in VIII–XXIV (Fig. 11B, D, E).

Pharynx reaching to XIV b1 (Fig. 11G). Crop reaching to XXII b1. Gastropore conspicuous, ventral, in slightly posterior to middle of XIII b2 (Fig. 11E, F). Gastroporal duct bulbous, slightly winding at junction with gastropore, joining with crop in XIV b1 (Fig. 11G). Intestine reaching to XXV b5/c11.

Testisacs (Fig. 12A); on right side, in XVII b5 to XXV c12, in total approx. 94 testisacs, 5 in XVII, 13 in XVIII, 12 in XIX, 13 in XX, 11 in XXI, 12 in XXII, 10 in XXIII, 10 in XXIV, 8 in XXV; on left side, in XVII c11 to XXIV c12, in total approx. 86 testisacs, 3 in XVII, 15 in XVIII, 11 in XIX, 13 in XX, 13 in XXI, 10 in XXII, 11 in XXIII, 10 in XXIV. Paired epididymides; right epididymis in XV c11/c12 to XVII b2, occupying 9 annuli; left epididymis in XV c11/c12 to XVII b1/b2, occupying 8 annuli (Fig. 12A). Paired ejaculatory ducts in XI b5 to XV c11/c12; slightly coiled in position posterior to ovisacs; each duct crossing ventrally beneath each ovisac, then loosely curved in position anterior to ovisacs; each widening from respective junction with epididymis, narrowing at junction with atrial cornua, then turning sharply inward toward atrial cornua without pre-atrial loop (Fig. 12A–D). Pair of muscular atrial cornua ellipsoid, in XI b5–c12 (Fig. 12A–D). Atrium short, muscular, globular in XI c11 and c12 (Fig. 12A–D).

Paired ovisacs; right ovisac in XIII a2 and b5; left ovisac in XIII a2–c11 (Fig. 12A, E). Oviducts; left oviduct

Figure 10. *Orobdella okanoi* sp. n., holotype, KUZ Z1671. **A** dorsal, **B** ventral views. Scale bar: 1 cm.

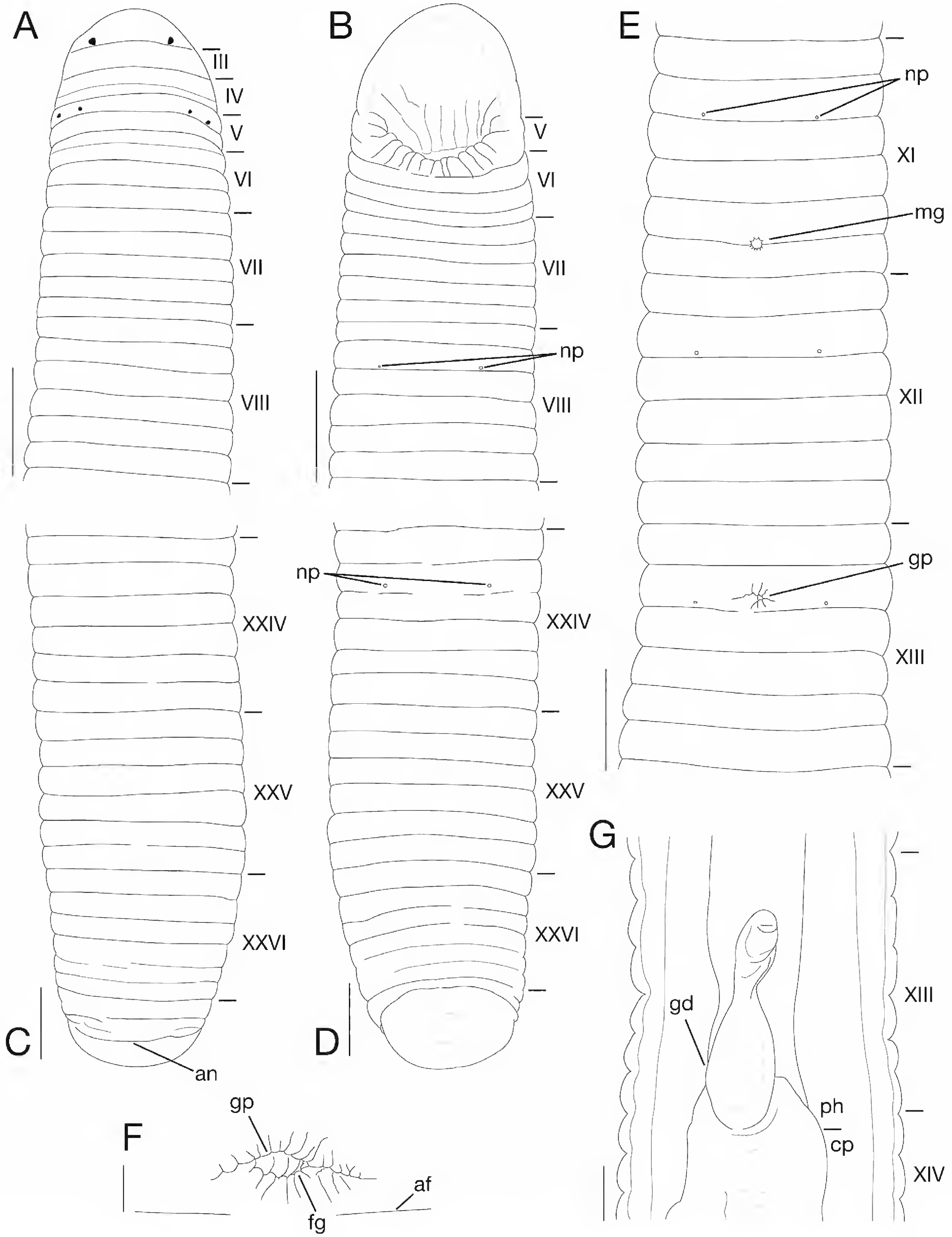


Figure 11. *Orobdella okanoi* sp. n., holotype, KUZ Z1671. **A** dorsal, **B** ventral views of somites I–VIII; **C** dorsal, **D** ventral views of somites XXIV–XXVII and caudal sucker; **E** ventral view of somites XI–XIII; **F** ventral view of gastropore and female gonopore; **G** ventral view of gastroporal duct. Scale bars: **A–E** = 2 mm; **F** = 0.25 mm; **G** = 1 mm.

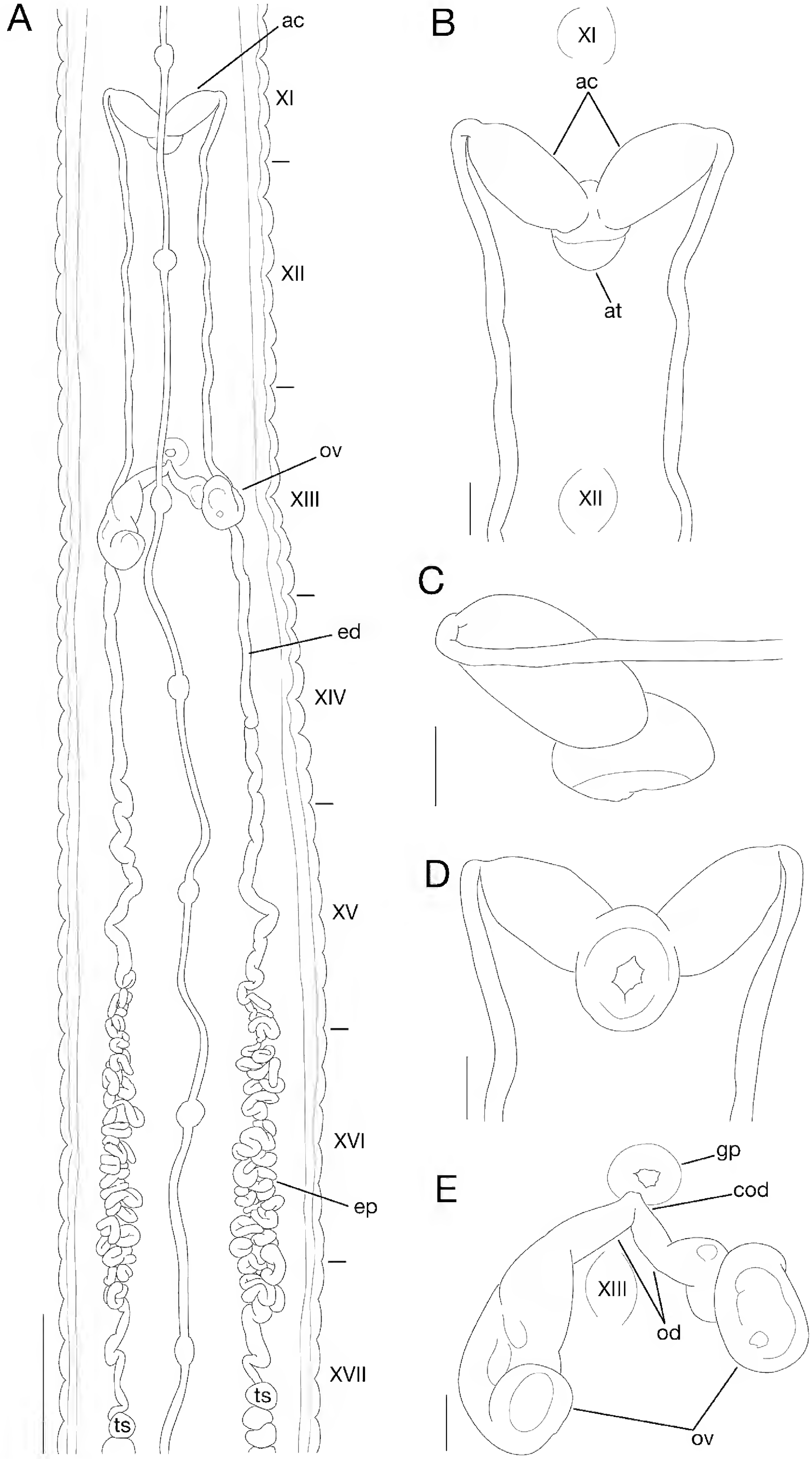


Figure 12. *Orobdella okanoi* sp. n., holotype, KUZ Z1671. **A** dorsal view of reproductive system including ventral nervous system; **B** dorsal (including positions of ganglia XI and XII), **C** lateral, **D** ventral views of male atrium; **E** dorsal view of female reproductive system including position of ganglion XIII. Scale bars: **A** = 3 mm; **B–E** = 0.5 mm.

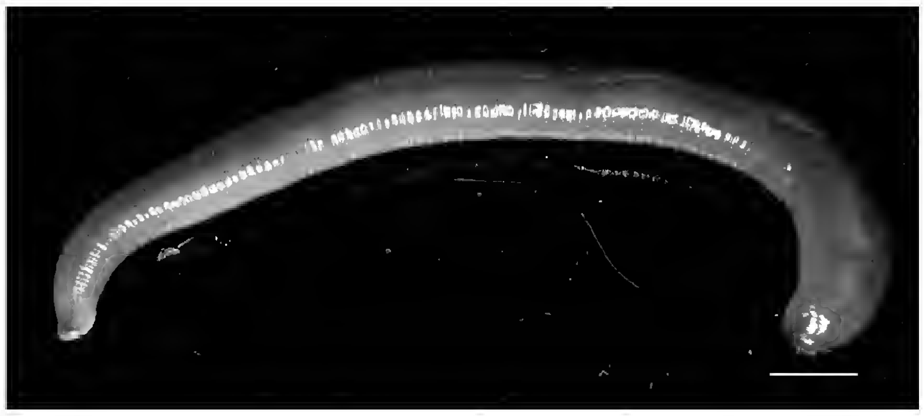


Figure 13. *Orobdella okanoi* sp. n., holotype, KUZ Z1671. Dorsal view of live animal. Scale bar: 5 mm.

crossing ventrally beneath nerve cord; both oviducts converging into common oviduct in XIII a2 (Fig. 12A, E). Common oviduct directly descending to female gonopore (Fig. 12E).

Variation. BL 143.2 mm, BW 7.6 mm, CL 3.1 mm, CW 4.0 mm. Somite III uniannulate with slight dorsal furrow. Somite XXVII comprises two annuli, each annulus with slight dorsal furrow. Male gonopore in posterior margin of XI c11. Female gonopore in middle of XIII b2. Eyes in three pairs, firs pair dorsally on anterior margin of III. Pharynx reaching to XIV b2/a2. Crop reaching to XXII a2. Gastropore in middle of XIII b2. Gastroporal duct joining with crop in XIV b2. Intestine reaching to XXIV c12. Testisacs; on right side, in XVII b2 to XXI b5, in total approx. 64 testisacs, 8 in XVII 13 in XVIII, 18 in XIX, 17 in XX, 8 in XXI; on left side, in XVII b2 to XXIV c11, in total approx. 99 testisacs, 7 in XVII, 10 in XVIII, 17 in XIX 17 in XX, 15 in XXI, 13 in XXII, 11 in XXIII, 9 in XXIV. Paired epididymides; right epididymis in XV a2 to XVI/XVII, occupying 10 annuli; left epididymis in XV a2 to XVII b1, occupying 11 annuli. Paired ejaculatory ducts curved in position anterior to ovisacs. Paired atrial cornua; right cornu in XI c12 and XII b1; left cornu in XI b5 and c11. Paired ovisacs in XIII a2 and b5.

Colouration. In life, dorsal surface red-purple (Fig. 13) or pinkish gray; ventral surface grayish red-purple or whitish red. Color faded in preservative; dark line present from VI a1 (b2) to XIV b5 in KUZ Z1491.

Etymology. The specific name is a noun in the genitive case formed directly from the name of Mr Ryosuke Okano, who collected valuable specimens of *Orobdella* leeches.

Distribution. The type locality of this species is located in the central region of Shikoku, Japan. In addition, this species was collected from the Ishizuchi Mountains. According to the collection localities, this species is considered to inhabit the central mountainous region of Shikoku.

Natural history. This species was found curled up under a rock or in soil in moist mountainous habitats. Oligochaete worms were found in the digestive tract of the holotype, and thus this species is an earthworm-eater. The reproductive season of *O. okanoi* remains unclear because no individuals of this species with a clitellum have been collected.

Remarks. According to taxonomic studies on sexannulate *Orobdella* species (Nakano 2011b, 2012a), *Orobdella okanoi* differs from the four known sexannulate species, *O. dolichopharynx* Nakano, 2011b, *O. ijimai* Oka, 1895, *O. mononoke* Nakano, 2012a and *O. shimadae* Nakano, 2011b, as well as the new sexannulate species described below in having the following characteristics (Table 4): dorsal surface reddish, somite VII quinquannulate, somite VIII sexannulate, 8 + 1/2 annuli between gonopores, pharynx reaching to XIV, gastroporal duct bulbous, epididymides in XV to XVII, pre-atrial loop absent and atrial cornua ellipsoid. *Orobdella okanoi* is clearly distinguished from quadrannulate and octannulate species in having sexannulate mid-body somites.

The right atrial cornu of one specimen, KUZ Z1491, is caudad. Because its right side testisacs only reach somite XXI, the right side of its male genital organ may be a result of abnormal development.

Orobdella yamaneae sp. n.

http://zoobank.org/CCAC9A26-3497-4325-9B2C-5E2EB2A3BDD3
Figs 14–18

Type materials. Holotype: KUZ Z1678, dissected, collected from under fallen leaves along a forest road, "Yuzuruha Forest Road" (34.24741°N, 134.80791°E; Elev. ca. 195 m; locality #1, see Fig. 1), at Mt. Yuzuruhasan, Awajishima island, Japan, by Yoshiko Yamane on 8 July 2015. Paratypes: six specimens collected from the type locality; KUZ Z1358 (34.245889°N, 134.811861°E; Elev. ca. 210 m), and Z1359 (34.246000°N, 134.812000°E; Elev. ca. 210 m), from under a rock along the forest road, by TN on 17 June 2011; KUZ Z1675–Z1677 (34.24743°N, 134.80777°E; Elev. ca. 195 m), and Z1679 (34.24711°N, 134.80884°E; Elev. ca. 195 m), from under fallen leaves along a forest road, by Yoshiko Yamane on 8 July 2015; three specimens, KUZ Z1358, Z1676 and Z1679, dissected.

Additional material. KUZ Z1488, collected from under fallen leaves along the forest road (34.247222°N, 134.808611°E; Elev. ca. 215 m) at the type locality, by Yoshiko Yamane on 20 August 2013.

Type locality. Japan, Hyogo Prefecture: Minamiawaji, Mt. Yuzuruhasan (Awajishima island).

Diagnosis. Dorsal surface purplish. Somite VII quinquannulate. Somite VIII–XXVI sexannulate, b1 = b2 = a2 = c9 = c10 = b6. Male gonopore in middle of XI b6, female gonopore in slightly posterior to middle of XIII

Table 4. Comparisons of morphological characters between *Orobdella okanoi* sp. n., *Orobdella yamaneae* sp. n. and four sexannulate congeneric species.

Character	Dorsal colour	Somite VII	Somite VIII	Annuli between gonopores	Pharynx	Gastroporal duct	Epididymides	Pre-atrial loop	Atrial cornua
Orobdella okanoi sp. n.	reddish	quinquannulate	sexannulate	8 + 1/2	reaching to XIV	bulbous	XV to XVII	absent	ellipsoid
Orobdella yamaneae sp. n.	purplish	quinquannulate	sexannulate	1/2 + 7 + 1/2	reaching to XIV	bulbous	XVI to XVIII	extending to anterior of XI c9	ovate
Orobdella dolichopharynx	yellowish green	quadrannulate	quinquannulate	8	reaching to XVI	tubular, reaching to XVI	absent	extending to ganglion XI	absent
Orobdella ijimai	yellowish green	quadrannulate	sexannulate	1/2 + 7 + 1/2	reaching to XIV	bulbous	XVI to XIX	absent	ellipsoid
Orobdella mononoke	anterior and posterior parts grayish purple, mid-body amber	quadrannulate	sexannulate	8 + 1/2	reaching to XIV	tubular, but bulbous at junction with crop	XV to XIX	absent	ovate
Orobdella shimadae	yellowish green	triannulate	quinquannulate	9	reaching to XVI	tubular, reaching to XV	absent	extending to ganglion XI	absent

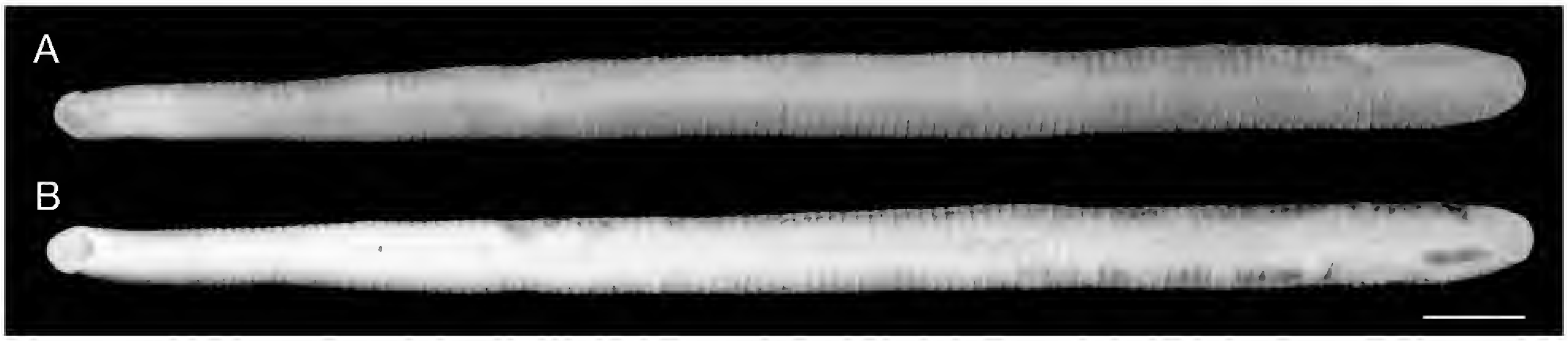


Figure 14. *Orobdella yamaneae* sp. n., holotype, KUZ Z1678. **A** dorsal, **B** ventral views. Scale bar: 1 cm.

b2, behind gastropore, gonopores separated by 1/2 + 7 + 1/2 annuli. Pharynx reaching to XIV a2/c9–c9. Gastropore conspicuous, in slightly posterior to middle of XIII b2. Gastroporal duct bulbous, slightly winding at junction with gastropore. Paired epididymides in XVI to XVIII, occupying 8–11 annuli (one and half to almost two somites). Pre-atrial loop present. Atrial cornua ovate.

Description of holotype. BL 142.2 mm, BW 8.1 mm (Fig. 14). Caudal sucker ventral, elliptic, CL 3.0 mm, CW 5.1 mm (Figs 14B, 15D).

Somites III–V biannulate; III and IV, (a1 + a2) > a3; V, (a1 + a2) = a3; V a3 forming posterior margin of oral sucker (Fig. 15A, B). Somite VI triannulate, a1 (dorsally b1 = b2) > a2 > a3 (Fig. 15A, B). Somite VII quinquannulate, a1 = a2 = c9 = c10 = b6 (Fig. 15A, B). Somites VIII–XXV sexannulate, b1 = b2 = a2 = c9 = c10 = b6 (Fig. 15A–E). Somite XXVI sexannulate dorsally, b1 = b2 = a2 > c9 = c10 = b6, quinquannulate ventrally, b1 = b2 = a2 < b5 (c9 = c10) > b6 (Fig. 15C, D). Somite XXVII comprises two annuli, first annulus with slight dorsal furrow; first annulus being ventrally last complete annulus (Fig. 15C, D). Anus behind somite XXVII (Fig. 15C).

X c9 and XIII a2, respectively, being first and last annuli of clitellum (Fig. 15E).

Male gonopore in middle of XI b6 (Fig. 15E). Female gonopore in slightly posterior to middle of XIII b2, inconspicuous, located posterior to gastropore (Fig. 15E, F). Gonopores separated by 1/2 + 7 + 1/2 annuli (Fig. 15E).

Anterior ganglionic mass in VI a2 and a3. Ganglion VII in a2. Ganglia VIII and IX, of each somite, in b2 and a2. Ganglia X–XII, of each somite, in a2 (Fig. 16A). Ganglion XIII in a2 and c9 (Fig. 16A). Ganglia XIV–XVIII, of each somite, in a2 (Fig. 16A). Ganglion XIX in b2 and a2. Ganglia XX–XXIV, of each somite, in a2. Ganglion XXV in b2 and a2. Ganglion XXVI in b1 and b2. Posterior ganglionic mass in XXVI c9–b6.

Eyes in three pairs, first pair dorsally on II/III, second and third pairs dorsolaterally on posterior margin of V (a1 + a2) (Fig. 15A).

Nephridiopores in 17 pairs, one each situated ventrally at posterior margin of b2 of each somite in VIII–XXIV (Fig. 15B, D, E).

Pharynx reaching to XIV a2/c9 (Fig. 15G). Crop reaching to XXI b6. Gastropore conspicuous, ventral, in slightly posterior to middle of XIII b2 (Fig. 15E, F). Gastroporal duct bulbous, slightly winding at junction with gastropore, joining with crop in XIV a2/c9 (Fig. 15G). Intestine reaching to XXIV c9/c10.

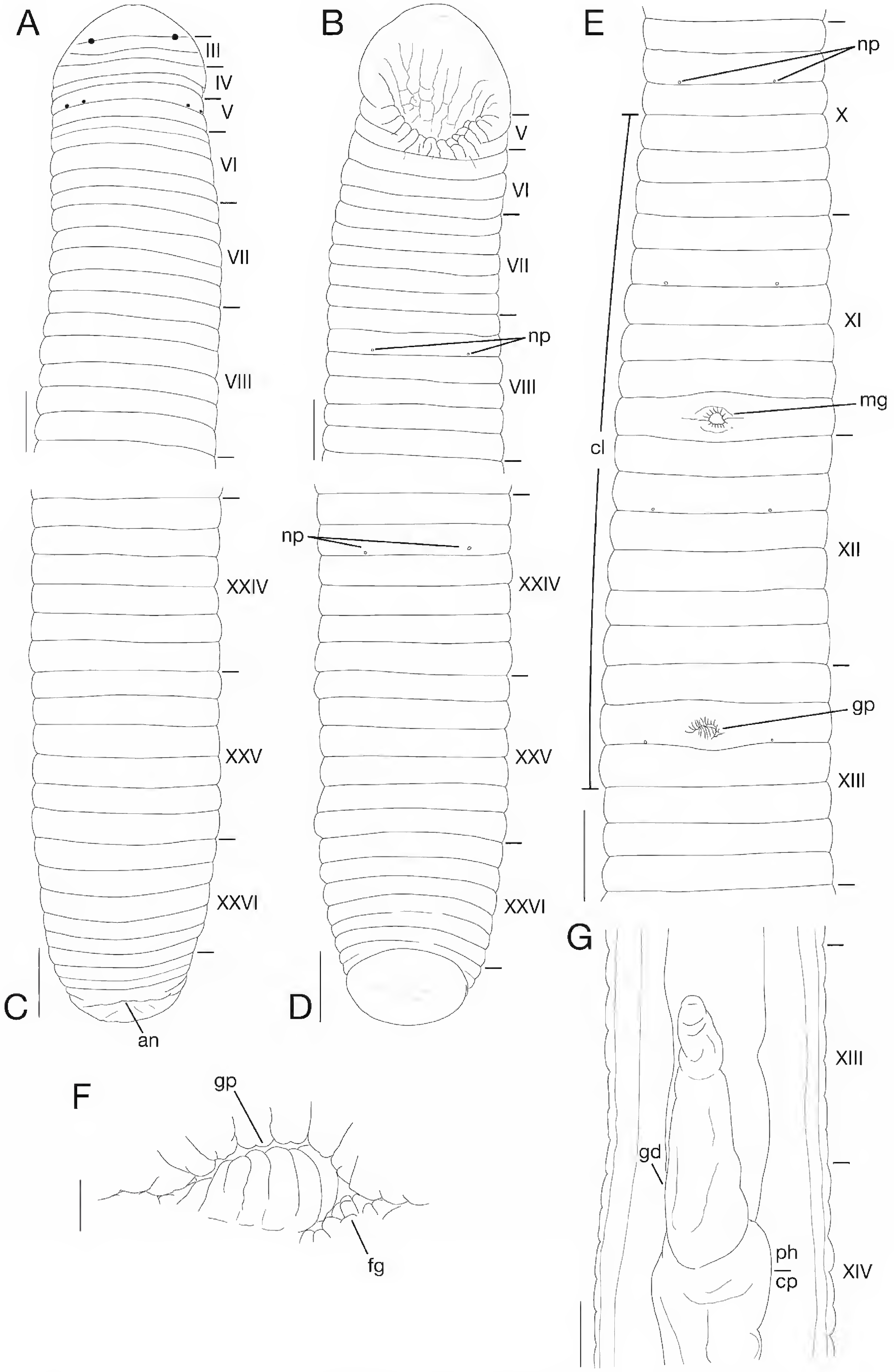


Figure 15. *Orobdella yamaneae* sp. n., holotype, KUZ Z1678. **A** dorsal, **B** ventral views of somites I–VIII; **C** dorsal, **D** ventral views of somites XXIV–XXVII and caudal sucker; **E** ventral view of somites X–XIII; **F** ventral view of gastropore and female gonopore; **G** ventral view of gastroporal duct. Scale bars: **A, B, G** = 2 mm; **C–E** = 3 mm; **F** = 0.25 mm.

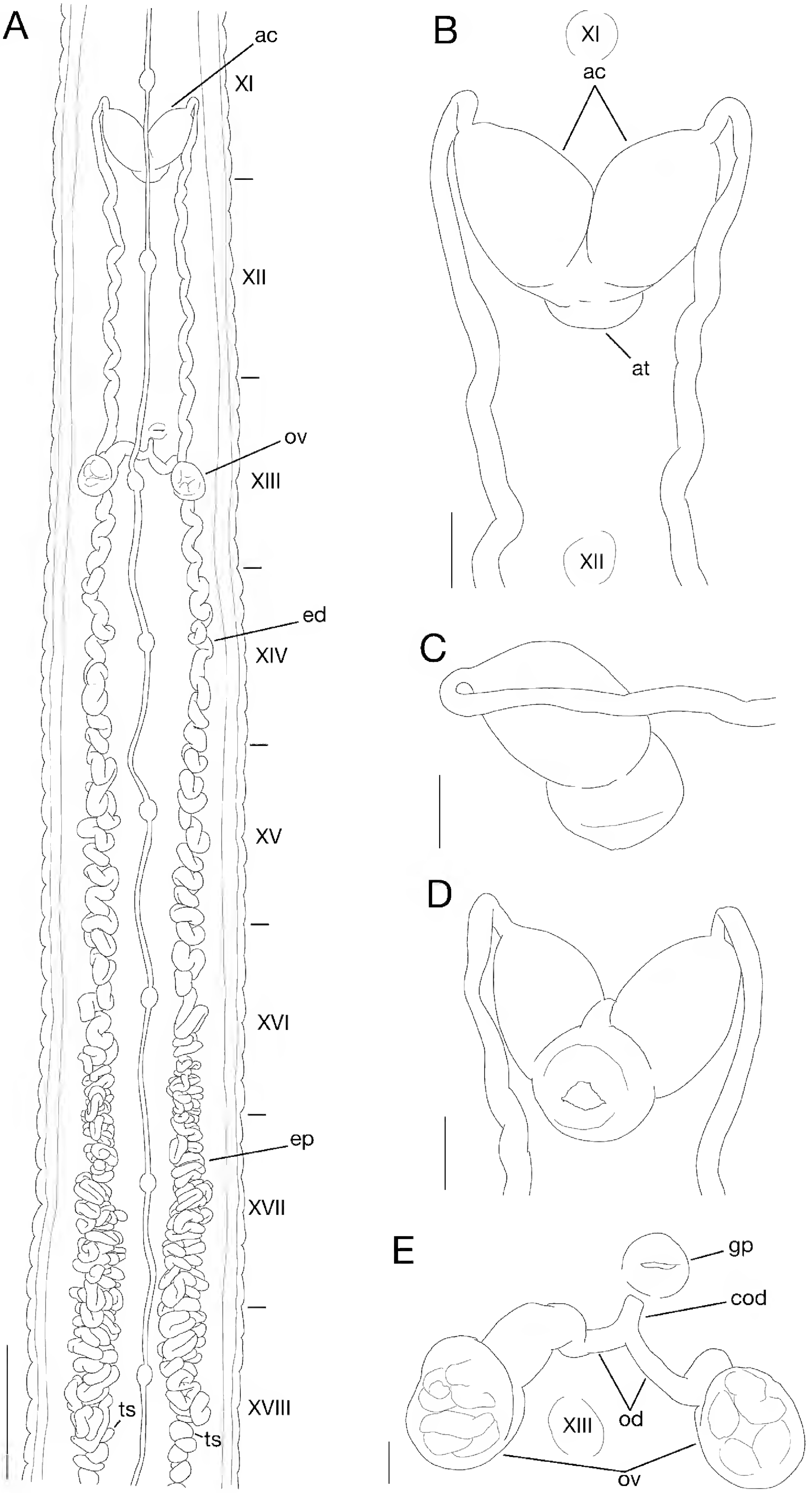


Figure 16. *Orobdella yamaneae* sp. n., holotype, KUZ Z1678. **A** dorsal view of reproductive system including ventral nervous system; **B** dorsal (including positions of ganglia XI and XII), **C** lateral, **D** ventral views of male atrium; **E** dorsal view of female reproductive system including position of ganglion XIII. Scale bars: **A** = 5 mm; **B–D** = 1 mm; **E** = 0.5 mm.

Testisacs in XVIII c9 to XXVI b1 (Fig. 16A): on right side, in total approx. 107 testisacs, 7 in XVIII, 13 in XIX, 16 in XX, 17 in XXI, 14 in XXII, 14 in XXIII, 14 in XXIV, 11 in XXV, 1 in XXVI; on left side, in total approx. 108 testisacs, 5 in XVIII, 12 in XIX, 19 in XX, 15 in XXI, 15 in XXII, 13 in XXIII, 14 in XXIV, 14 in XXV, 1 in XXVI. Paired epididymides; right epididymis in XVI c9 to XVIII c9, occupying 13 annuli; left epididymis in XVI c9/c10 to XVIII c9, occupying 12 annuli (Fig. 16A). Paired ejaculatory ducts; right duct in XI c9 to XVI c9; left duct in XI c9 to XVI c9/c10; coiled in position posterior to ovisacs; each duct crossing ventrally beneath each ovisac, then curved in position anterior to ovisacs; each widening from respective junction with epididymis, narrowing at junction with atrial cornua, then turning sharply inward toward atrial cornua with atrial loop extending to anterior of XI c9 (Fig. 16A–D). Pair of muscular atrial cornua ovate, in XI c9–b6 (Fig. 16A–D). Atrium short, muscular, globular in XI c10 and b6 (Fig. 16A–D).

Paired ovisacs in XIII a2 and c9 (Fig. 16A, E). Oviducts; left oviduct crossing ventrally beneath nerve cord; both oviducts converging into common oviduct in XIII a2 (Fig. 16A, E). Common oviduct directly descending to female gonopore (Fig. 16A, E).

Variations. BL 62.4–97.6 mm, BW 4.0–6.5 mm, CL 1.6–2.8 mm, CW 2.5–3.6 mm. Somite III uniannulate with slight dorsal furrow, [(a1 + a2) > a3]. Somite IV uniannulate with slight dorsal furrow, [(a1 + a2) > a3] in KUZ Z1359 (Fig. 17A). Somite VII quadrannulate in KUZ Z1359, a1 = a2 < b5 (ventrally c9 = c10) > b6 (Fig. 17A, B). Somite VIII quinquannulate in KUZ Z1359, b1 = b2 = a2 < b5 (c9 = c10) > b6 (Fig. 17A, B). Somite XXVI generally sexannulate, b1 = b2 = a2 = c9 = c10 = b6, or b1 = b2 = a2 = c9 > c10 = b6; KUZ Z1359, quinquannulate, b1 = b2 = a2 < b5 > b6. Somite XXVII comprises 2–4 annuli. XXVI b6, or first annulus of XXVII being ventrally last complete annulus. Female gonopore rarely in posterior margin of XIII b2, gonopores thus rarely separated by 1/2 + 8 annuli. First pair of eyes generally dorsally on posterior margin of II. Pharynx reaching to XIV a2/c9–c9. Crop reaching to XXI c9–XXII c9/c10. Gastroporal duct often tubular, slightly bulbous at junction with gastropore, joining with crop in XIV b1/b2–b2/a2. Intestine reaching to XXIV/XXV–XXV a2/c9. Testisacs hardly detected. Paired epididymides: right epididymis in XVI b2–b2/a2 to XVII c9–XVIII b1, occupying 8–11 annuli; left epididymis in XIV b1/b2–XVI b2/a2 to XVII c9–XVIII b1, occupying 9–11 annuli. Paired ejaculatory ducts running straight, or nearly straight in position anterior to ovisacs; pre-atrial loop reaching to XI a2/c9–c9. Pair of muscular atrial cornua fusiform or ellipsoid, often in XI c10 and b6. Paired ovisacs generally in XIII a2 and c9; KUZ Z1358, in XIII c9. Right or left oviduct crossing ventrally beneath nerve cord.

Colouration. In life, dorsal surface grayish purple or red-purple (Fig. 18); ventral surface whitish blue or grayish purple; clitellum, when obvious, paler than other body parts (Fig. 18). Color faded in preservative.

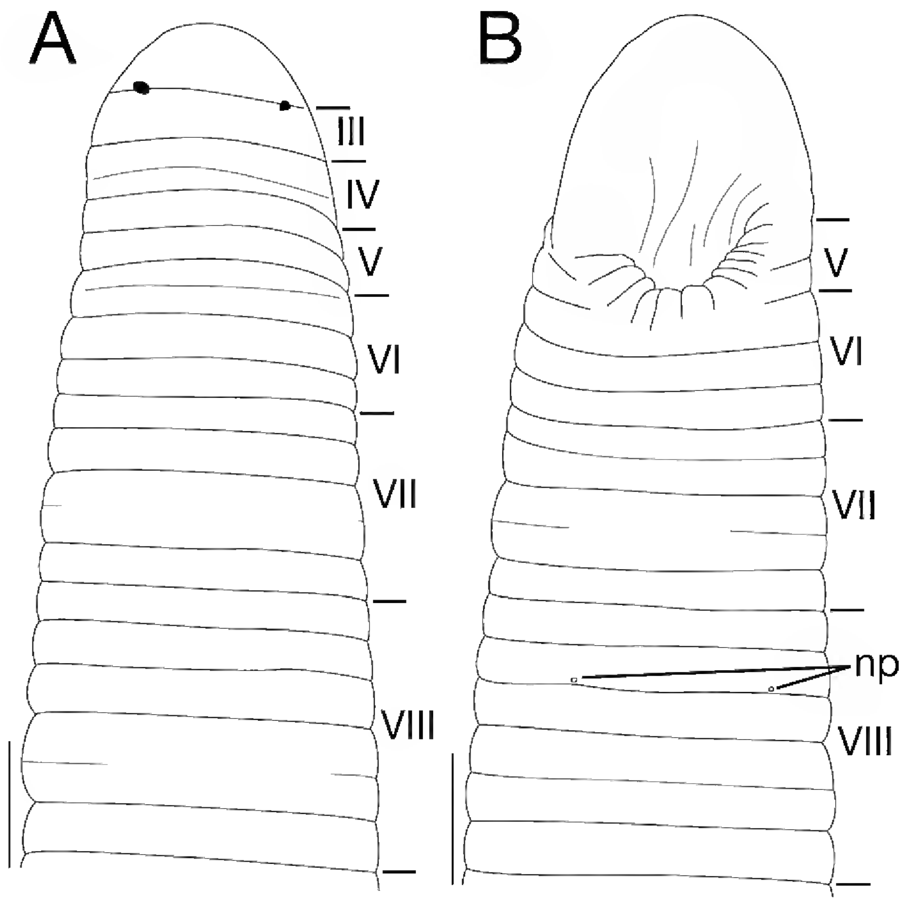


Figure 17. *Orobdella yamaneae* sp. n., paratype, KUZ Z1359. **A** dorsal, **B** ventral views of somites I–VIII. Scale bars: **A, B** = 1 mm.

Etymology. The specific name is a noun in the genitive case formed directly from the name of Ms Yoshiko Yamane, who collected specimens of this new species.

Distribution. This species was collected only from its type locality.

Natural history. This species was found curled up under fallen leaves in moist mountainous habitats. A mature leech, KUZ Z1678, was collected on 8 July. Therefore, *Orobdella yamaneae* is considered to enter its reproductive season before early July.

Remarks. The mid-body somite annulation of the known sexannulate *Orobdella* species was described as being composed of b1, b2, a2, b5, c11 and c12 (Nakano 2011b, 2012a). However, the annulation of somites VII [a1 = a2 < b5 (ventrally c9 = c10) > b6] and VIII [b1 = b2 = a2 < b5 (c9 = c10) > b6] of one specimen, KUZ Z1359, clearly suggests that b5 is divided into c9 and c10, and b6 remains undivided in *O. yamaneae*. The sexannulation of this species is thus b1 = b2 = a2 = c9 = c10 = b6.

In addition to its unique sexannulation, *O. yamaneae* is distinguishable from the four known sexannulate species and *O. okanoi* by the following characteristics (Table 4): dorsal surface purplish, somite VII quinquannulate, somite VIII sexannulate, 1/2 + 7 + 1/2 annuli between gonopores, pharynx reaching to XIV, gastroporal duct bulbous, epididymides in XVI to XVIII, pre-atrial loop present and atrial cornua ovate. *Orobdella yamaneae* obviously differs from quadrannulate and octannulate species of this genus in its mid-body somite annulation.

Except for the holotype, all dissected individuals possess the following characteristics of the male genital or-

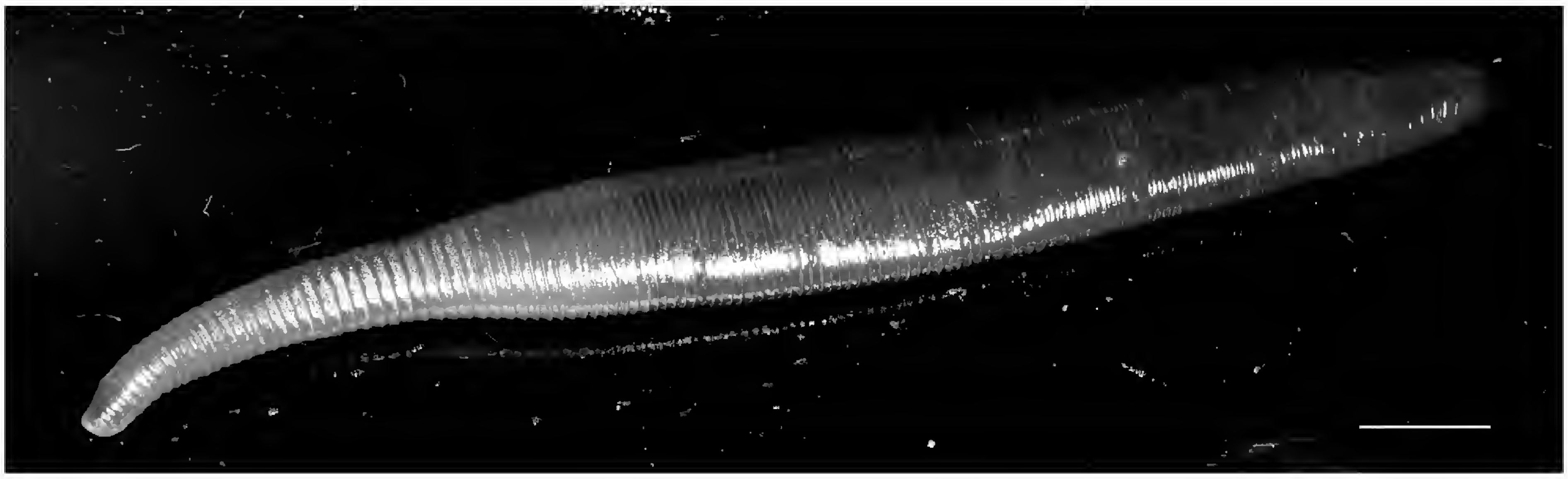


Figure 18. *Orobdella yamaneae* sp. n., holotype, KUZ Z1678. Dorsal view of live animal. Scale bar: 1 cm.

gan: ejaculatory ducts in position anterior to ovisacs running straight and male atrial cornua ellipsoid or fusiform. However, they seem to be immature leeches because all of them have undeveloped and undetectable testisacs. Therefore, straight ejaculatory ducts and ellipsoid or fusiform testisacs are considered to be immature characteristics of *O. yamaneae*.

Molecular phylogenies and genetic distances

The obtained BI tree (Fig. 19) had an almost identical topology to that of the ML tree (ln $L = -27703.79$; not shown). In the ML phylogeny, *Orobdella tsushimensis* formed a monophyletic lineage with the clade containing *O. dolichopharynx*, *O. esulcata*, *O. ketagalan*, *O. mononoke*, *O. naraharaetmagarum*, *O. shimadae* and *O. brachyepididymis* (BS = 41%).

Orobdella brachyepididymis formed a monophyletic clade with *O. naraharaetmagarum* (BS = 100%, BPP = 1.0). This clade is a sister lineage to *O. esulcata* (BS = 100%, BPP = 1.0). The monophyly of the two specimens identified as *O. brachyepididymis* was fully supported (BS = 100%, BPP = 1.0). The other three new species, *O. nakahamai*, *O. okanoi* and *O. yamaneae* formed a monophyletic clade (BS = 100%, BPP = 1.0). The monophyly of this clade and *O. masaakikuroiwai* was revealed, but this relationship was not strongly supported in the BI tree (BS = 87%, BPP = 0.90). Within the three new species, *O. okanoi* and *O. yamaneae* formed a monophyletic lineage (BS = 78%, BPP = 0.94). The monophyly of the specimens of the three new species was fully recovered (*O. nakahamai*, BS = 98%, BPP = 1.0; *O. okanoi*, and *O. yamaneae*, respectively, BS = 100%, BPP = 1.0).

The pairwise COI uncorrected *p*-distances within each of the new species were as follows: in *O. brachyepididymis*, 0.5%; *O. nakahamai*, 2.1–4.6% (mean = 3.7%); *O. okanoi*, 2.4%; and *O. yamaneae*, 3.9% (Table 5). The genetic divergence between *O. brachyepididymis* and *O. naraharaetmagarum* was 4.7%. The genetic distances among the three new species were as follows: *O. nakahamai* and *O. okanoi*, 5.6–6.2% (mean = 5.8%); *O. nakahamai* and *O. yamaneae*, 5.6–5.8% (mean = 5.7%); and *O. okanoi* and *O. yamaneae*, 5.8–6.0% (mean = 5.9%) (Table 5). Those between *O. masaakikuroiwai* and each of the three new species were as follows: *O. nakahamai*, 5.9–7.2% (mean = 6.8%); *O. okanoi*, 7.1–7.3% (mean = 7.2%); and *O. yamaneae*, 6.6–6.8% (mean = 6.7%).

Discussion

According to the morphological characteristics of the four new species, each of them can be well defined and distinguished from each other and from the previously known species of *Orobdella*. However, the genetic divergences of the COI sequences showed small interspecific divergences. The genetic distance between *Orobdella brachyepididymis* and its sister species *O. naraharaetmagarum* (4.7%) was equivalent to the largest intraspecific COI divergence of the latter species indicated by Nakano (2016). Although no clear genetic distance gap exists between *O. brachyepididymis* and *O. naraharaetmagarum*, the new species is clearly distinguished from *O. naraharaetmagarum* by the following combination of morphological characters (Table 2): morphology of the gastroporal duct, number of annuli between gonopores, lengths of epididymides and morphology of the male atrial cornua. Clearly, *O. brachyepididymis* is a distinctive new species within the genus *Orobdella*.

Calculated interspecific COI distances among the three other new species, *O. nakahamai*, *O. okanoi* and *O. yamaneae*, each of which is well defined by morphological characteristics, were also small. These values and the obtained phylogenetic trees indicated that these three species are closely related to each other. *Orobdella nakahamai* is sympatric with *O. okanoi* on Mt. Iwagurosan in the Ishizuchi Mountains (locality #5, see Fig. 1). Moreover, specimens of each new species collected from Mt. Iwagurosan belonged to its respective clade. The present genetic analyses clearly support that *O. nakahamai* and *O. okanoi* are well-defined species. The COI divergences between *O. yamaneae* and *O. okanoi* (mean = 5.9%), and those between *O. yamaneae* and *O. nakahamai* (mean = 5.7%), were almost equal to those between *O. nakahamai* and *O. okanoi* (mean = 5.8%). Therefore, these distance values confirmed the distinctiveness of *O. yamaneae*.

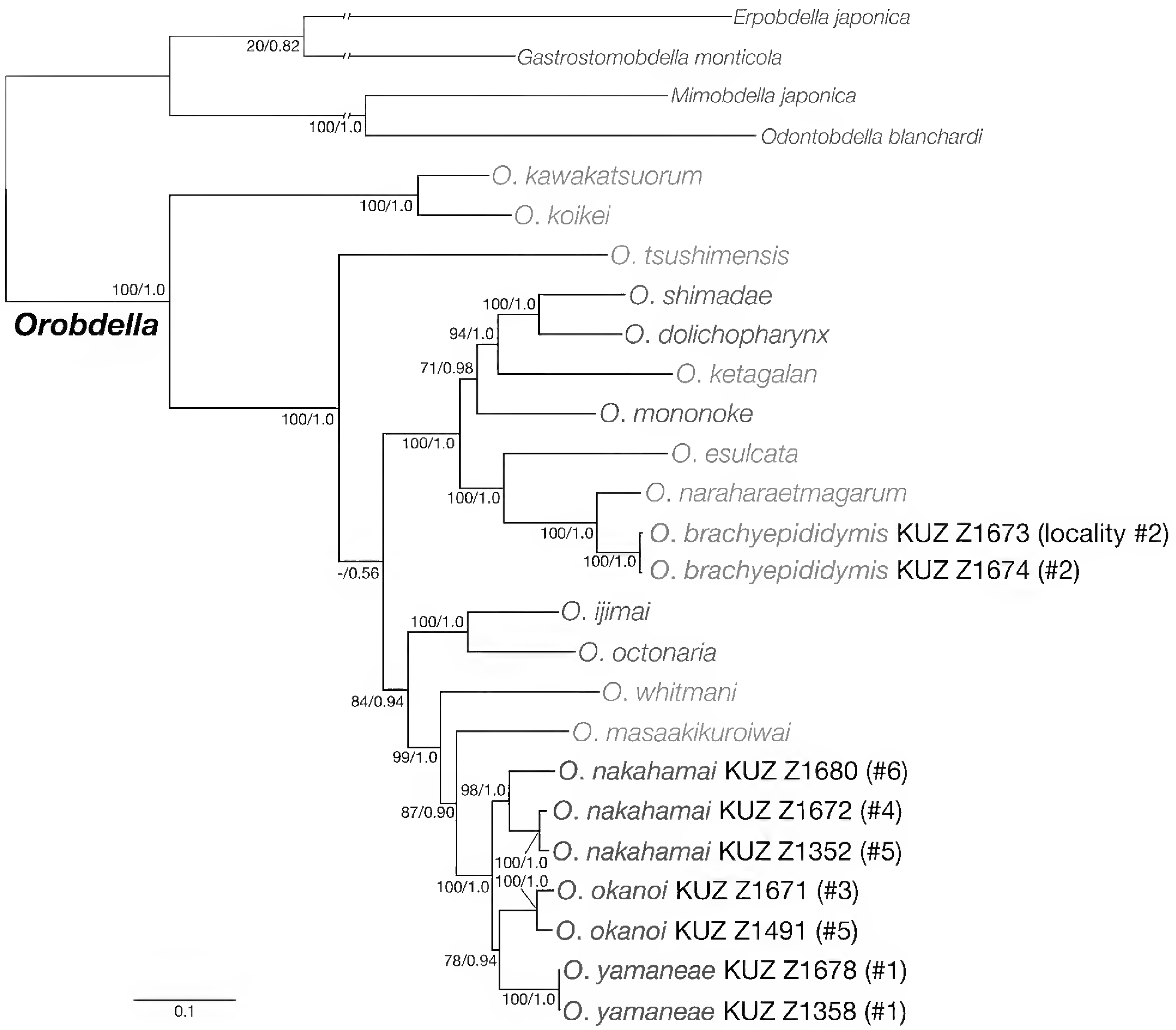


Figure 19. Bayesian inference tree for 5,209 bp of nuclear 18S rRNA and histone H3 and mitochondrial COI, tRNA^{Cys}, tRNA^{Met}, 12S rRNA, tRNA^{Val}, 16S rRNA, tRNA^{Leu} and ND1 markers. Numbers on nodes represent bootstrap values for maximum likelihood and Bayesian posterior probabilities. A species name of *Orobdella* in red indicates a quadrannulate species; green, a sexannulate; and blue, an octannulate species. Locality numbers are shown in Fig. 1.

According to the obtained molecular phylogenies, mid-body somite annulation and body size of mature leeches within *Orobdella* clearly evolved in parallel. Nakano (2012b) stated that sexannulate mid-body somite annulation had evolved in parallel within this genus. The present finding of the second octannulate species, *O. nakahamai*, and its phylogenetic position indicate that octannulate mid-body somite annulation also evolved in parallel within *Orobdella*. Note that both of the octannulate species formed a clade with the sexannulate species. These phylogenetic relationships shed light on a possible evolutionary correlation between sexannulation and octannulation in *Orobdella* leeches. Richardson (1971) erected the genus *Kumabdella* Richardson, 1971, which has been considered subjective junior synonym of *Orobdella*, only for *O. octonaria*, based principally on its octannulate mid-body somite annulation. In the redescription of *O. octonaria*, Nakano (2012c) briefly reviewed the taxonomic history of *Kumabdella* and concluded that *Kumabdella* should retain its status as a junior synonym of *Orobdella*. The presence of the second octannulate species within this genus, and the fact that these two octannulate species are phylogenetically distant, fully support the present taxonomic treatment for the genus *Kumabdella*.

The sexannulation of *O. yamaneae* and the fact that this species is genetically quite close to *O. okanoi* imply the possibility that the sexannulation of *O. okanoi* also follows b1 = b2 = a2 = c9 = c10 = b6, and not the b1 = b2 = a2 = b5 = c11 = c12 observed in the other known sexannulate species of *Orobdella*. The annulation pattern of *O. yamaneae* suggests that annular formulae can vary among *Orobdella* species possessing the same annulation. The quadrannulate somite of *Orobdella* obviously consists of a1, a2, b5 and b6, according to the positions of paired

Table 5. Uncorrected *p*-distances for the 1267 bp for the COI sequences of specimens of *Orobdella nakahamai* sp. n., *Orobdella okanoi* sp. n. and *Orobdella yamaneae* sp. n., with associated collection locality numbers (see Fig. 1).

Species	Specimen (locality #)	1	2	3	4	5	6
Orobdella nakahamai sp. n.	1: KUZ Z1352 (5)						
	2: KUZ Z1672 (4)	0.021					
	3: KUZ Z1680 (6)	0.043	0.046				
Orobdella okanoi sp. n.	4: KUZ Z1491 (5)	0.058	0.056	0.056			
	5: KUZ Z1671 (3)	0.062	0.058	0.058	0.024		
Orobdella yamaneae sp. n.	6: KUZ Z1358 (1)	0.056	0.057	0.058	0.059	0.059	
	7: KUZ Z1678 (1)	0.057	0.056	0.058	0.058	0.060	0.004

nephridiopores and the ventral ganglion in each somite. However, the annulation pattern of sexannulate and octannulate *Orobdella* species should be determined based on several specimens, including immature individuals.

Nakano (2014, 2016) stated that the small-type body length also evolved in parallel within *Orobdella*. In addition to small size, the present phylogenies indicated that the large-type body length evolved in parallel within this genus. The close relation of the small- and large-types to mid-body somite annulation in *Orobdella* leeches is highly possible. According to current knowledge on *Orobdella* species, the small-type only occurs in the quadrannulate species, i.e. *O. brachyepididymis*, *O. koikei*, *O. masaakikuroiwai* and *O. naraharaetmagarum*, while the large-type species consist of octannulate species, *O. nakahamai* and *O. octonaria*. Future phylogenetic studies, including an ancestral state reconstruction, will elucidate the character state evolution of *Orobdella* leeches.

The present phylogenetic tree showed that 17 *Orobdella* species consist of four main lineages: a Hokkaido lineage containing two species, *O. kawakatsuorum* and *O. koikei*; an *Orobdella tsushimensis* lineage; a western lineage comprising four species inhabiting the Ryukyu Islands and Taiwan, along with *O. esulcata* distributed in Kyushu, *O. naraharaetmagarum* in the Chugoku district, western Honshu, as well as the new species *O. brachyepididymis* from Shikoku; and an eastern lineage comprising four species known from the eastern to central parts of Honshu, along with the other three new species, *O. nakahamai* and *O. okanoi* collected from Shikoku and *O. yamaneae* from Awajishima island. Therefore, the range of the western lineage group overlaps that of the eastern lineage group in Shikoku and adjacent islets. Because species belonging to both lineage groups are distributed in Shikoku, the species diversity of *Orobdella* in this region may be quite high compared to other regions. The new *Orobdella* species inhabiting Shikoku and Awajishima island would offer a suitable opportunity to reveal speciation events, as well as species coexistence mechanisms in the genus *Orobdella*.

Acknowledgements

The author is grateful to Naoyuki Nakahama (Kyoto University; KU), Ryosuke Okano (Ehime University), and Yoshiko Yamane (KU) for providing specimens of the new species, to Professor Hidetoshi Nagamasu (The Kyoto University Museum) for his helpful advice on a specific name of the new species. The author expresses his sincere thanks to Dr Yi-Te Lai (National Taiwan University) and Dr Michael Ohl (Museum für Naturkunde) for their constructive comments on this manuscript. A part of this study was financially supported by Grants for Biodiversity and Evolutionary Research of Global COE (A06) and for Excellent Graduate Schools, both from MEXT, Japan, to KU, and JSPS Grants-in-Aid for JSPS Fellows (#15J00720) and Young Scientists (B) (#26840127) to the author. The open access publication of this manuscript was supported by the Museum für Naturkunde.

References

Akaike H (1974) A new look at the statistical model identification. IEEE Transactions on Automatic Control 19(6): 716–723. doi: 10.1109/TAC.1974.1100705

Apakupakul K, Siddall ME, Burreson EM (1999) Higher level relationships of leeches (Annelida: Clitellata: Euhirudinea) based on morphology and gene sequences. Molecular Phylogenetics and Evolution 12(3): 350–359. doi: 10.1006/mpev.1999.0639

Blanchard R (1897) Hirudinées du Musée de Leyde. Notes from the Leyden Museum 19(1–2): 73–113.

Chakrabarty P, Warren M, Page L, Baldwin C (2013) GenSeq: An updated nomenclature and ranking for genetic sequences from type and non-type sources. ZooKeys 346: 29–41. doi: 10.3897/zookeys.346.5753

Colgan DJ, McLauchlan A, Wilson GDF, Livingston SP, Edgecombe GD, Macaranas J, Cassis G, Gray MR (1998) Histone H3 and U2 snRNA DNA sequences and arthropod molecular evolution. Australian Journal of Zoology 46(5): 419–437. doi: 10.1071/ZO98048

Felsenstein J (1985) Confidence limits on phylogenies: an approach using the bootstrap. Evolution 39(4): 783–791. doi: 10.2307/2408678

Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3(5): 294–299. doi:

Hillis DM, Bull JJ (1993) An empirical test of bootstrapping as a method for assessing confidence in phylogenetic analysis. Systematic Biology 42(2): 182–192. doi: 10.1093/sysbio/42.2.182

Katoh K, Standley DM (2013) MAFFT multiple sequence alignment software version 7: improvements in performance and usability.

Molecular Biology and Evolution 30(4): 772–780. doi: 10.1093/molbev/mst010

Lanfear R, Calcott B, Ho SYW, Guindon S (2012) PartitionFinder: Combined selection of partitioning schemes and substitution models for phylogenetic analyses. Molecular Biology and Evolution 29(6): 1695–1701. doi: 10.1093/molbev/mss020

Leaché AD, Reeder TW (2002) Molecular systematics of the eastern fence lizard (*Sceloporus undulatus*): a comparison of parsimony, likelihood, and Bayesian approaches. Systematic Biology 51(1): 44–68. doi: 10.1080/10635150252753475871

Light JE, Siddall ME (1999) Phylogeny of the leech family Glossiphoniidae based on mitochondrial gene sequences and morphological data. The Journal of Parasitology 85(5): 815–823. doi: 10.2307/3285816

Lukin EI (1976) Fauna USSR. Leeches. Nauka, Leningrad, 484 pp.

Moore JP (1927) The segmentation (metamerism and annulation) of the Hirudinea. In: Harding WA, Moore JP. The Fauna of British India, including Ceylon and Burma. Hirudinea. Taylor & Francis, London, 1–12.

Moore JP (1929) Leeches from Borneo with descriptions of new species. Proceedings of the Academy of Natural Sciences of Philadelphia 81: 267–295.

Nakano T (2010) A new species of the genus *Orobdella* (Hirudinida: Arhynchobdellida: Gastrostomobdellidae) from Kumamoto, Japan, and a redescription of *O. whitmani* with the designation of the lectotype. Zoological Science 27(11): 880–887. doi: 10.2108/zsj.27.880

Nakano T (2011a) A new species of *Orobdella* (Hirudinida: Arhynchobdellida: Gastrostomobdellidae) from Tsushima Island, Japan. Species Diversity 16(1–2): 39–47.

Nakano T (2011b) Redescription of *Orobdella ijimai* (Hirudinida: Arhynchobdellida: Gastrostomobdellidae), and two new species of *Orobdella* from the Ryukyu Archipelago, Japan. Zootaxa 2998: 1–15.

Nakano T (2012a) A new sexannulate species of *Orobdella* (Hirudinida, Arhynchobdellida, Orobdellidae) from Yakushima Island, Japan. ZooKeys 181: 79–93. doi: 10.3897/zookeys.181.2932

Nakano T (2012b) A new species of *Orobdella* (Hirudinida, Arhynchobdellida, Gastrostomobdellidae) and redescription of *O. kawakatsuorum* from Hokkaido, Japan with the phylogenetic position of the new species. ZooKeys 169: 9–30. doi: 10.3897/zookeys.169.2425

Nakano T (2012c) Redescription of *Orobdella octonaria* (Hirudinida: Arhynchobdellida: Orobdellidae) with designation of a lectotype. Species Diversity 17(2): 227–233. doi: 10.12782/sd.17.2.227

Nakano T (2014) A new quadrannulate species of *Orobdella* (Hirudinida, Arhynchobdellida, Orobdellidae) from central Honshu, Japan. ZooKeys 445: 57–76. doi: 10.3897/zookeys.445.7999

Nakano T (2016) A new quadrannulate species of *Orobdella* (Hirudinida, Arhynchobdellida, Orobdellidae) from western Honshu, Japan. ZooKeys 553: 33–51. doi: 10.3897/zookeys.553.6723

Nakano T, Gongalsky KB (2014) First record of *Orobdella kawakatsuorum* (Hirudinida: Arhynchobdellida: Erpobdelliformes) from Kunashir Island, Kuril Islands. Biodiversity Data Journal 2: e1058. doi: 10.3897/BDJ.2.e1058

Nakano T, Lai Y-T (2012) A new species of *Orobdella* (Hirudinida, Arhynchobdellida, Orobdellidae) from Taipei, Taiwan. ZooKeys 207: 49–63. doi: 10.3897/zookeys.207.3334

Nakano T, Ramlah Z, Hikida T (2012) Phylogenetic position of gastrostomobdellid leeches (Hirudinida, Arhynchobdellida, Erpobdelliformes) and a new family for the genus *Orobdella*. Zoologica Scripta 41(2): 177–185. doi: 10.1111/j.1463-6409.2011.00506.x

Nakano T, Seo H-Y (2014) First record of *Orobdella tsushimensis* (Hirudinida: Arhynchobdellida: Gastrostomobdellidae) from the Korean Peninsula and molecular phylogenetic relationships of the specimens. Animal Systematics, Evolution and Diversity 30(2): 87–94. doi: 10.5635/ASED.2014.30.2.087

Oka A (1895) On some new Japanese land leeches. (*Orobdella* nov. gen.). The Journal of the College of Science, Imperial University, Japan 8(2): 275–306.

Oka A (1910a) Key to Japanese leeches. Dobutsugaku Zasshi 22(256): 56–64.

Oka A (1910b) Synopsis der japanischen Hirudineen, mit Diagnosen der neuen Species. Annotationes Zoologicae Japonenses 7(3): 165–183.

Pawłowski LK (1962) O występowaniu pijawki *Erpobdella octoculata* (L.) w Japonii. Zeszyty Naukowe Uniwersytetu Łódzkiego Seria II Nauki Matematyczno-przyrodnicze 12: 127–136.

Rambaut A, Drummond AJ (2013) Tracer v. 1.6. http://tree.bio.ed.ac.uk/software/tracer/

Richardson LR (1971) Gastrostomobdellidae f. nov. and a new genus for the gastroporous *Orobdella octonaria* Oka, 1895, of Japan (Hirudinoidea: Arhynchobdellae). Bulletin of the National Science Museum (Tokyo) 14(4): 585–602.

Richardson LR (1975) A new species of terricolous leeches in Japan (Gastrostomobdellidae, *Orobdella*). Bulletin of the National Science Museum Series A (Zoology) 1(1): 39–56.

Ronquist F, Teslenko M, van der Mark P, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP (2012) MrBayes 3.2: Efficient Bayesian phylogenetic inference and model choice across a large model space. Systematic Biology 61(3): 539–542. doi: 10.1093/sysbio/sys029

Sawyer RT (1986) Leech Biology and Behaviour. Clarendon Press, Oxford, 1065 pp.

Schwarz G (1978) Estimating the dimension of a model. The Annals of Statistics 6(2): 461–464. doi: 10.1214/aos/1176344136

Soós Á (1966) Identification key to the leech (Hirudinoidea) genera of the world, with a catalogue of the species. III. Family: Erpobdellidae. Acta Zoologica Academiae Scientiarum Hungaricae 12(3–4): 371–407.

Stamatakis A (2014) RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. Bioinformatics 30(9): 1312–1313. doi: 10.1093/bioinformatics/btu033

Tamura K, Stecher G, Peterson D, Filipski A, Kumar S (2013) MEGA6: Molecular Evolutionary Genetics Analysis version 6.0. Molecular Biology and Evolution 30(12): 2725–2729. doi: 10.1093/molbev/mst197

Zoosyst. Evol. 92 (1) 2016, 103–110 | DOI 10.3897/zse.92.7469

museum für naturkunde

Remarks on the taxonomy and nomenclature of the genus *Hypsilurus* Peters, 1867 (Reptilia, Agamidae, Amphibolurinae)

Wolfgang Denzer[1], Ulrich Manthey[2]

1 *Society for Southeast Asian Herpetology, Calle Rio Segura 26, 30600 Archena, Murcia, Spain*
2 *Society for Southeast Asian Herpetology, Kindelbergweg 15, 12249 Berlin, Germany*

http://zoobank.org/90C6EFC7-16E9-4FC8-AF34-C6B45DD1910D

Corresponding author: *Wolfgang Denzer* (wolfdenoxford@yahoo.co.uk)

Received 9 December 2015
Accepted 3 March 2016
Published 17 March 2016

Academic editor:
Johannes Penner

Abstract

Specimens of *Hypsilurus* spp. corresponding to sequences deposited on GenBank were re-examined. The voucher specimens relating to GenBank sequences were tracked down and their species status confirmed. Sequences reported in earlier publication as *H.* "*bruijnii*" and *H.* "*nigrigularis*" turned out to be those of *H. magnus* and *H. schultzewestrumi* instead. Further confusion surrounded specimens of *H. modestus*, *H. dilophus* and *H. papuensis.* Based on these results a new phylogenetic tree was constructed and the genus name *Lophosaurus* Fitzinger, 1843 was resurrected.

Key Words

Hypsilurus
resurrection of *Lophosaurus*
Lophosaurus dilophus comb. n.
Lophosaurus boydii comb. n.
Lophosaurus spinipes comb. n.

Introduction

The Melanesian-Australian agamid genus *Hypsilurus* currently contains 20 species of which the majority (14 species) occurs on the main island of New Guinea (Manthey and Denzer 2006; Kraus and Myers 2012). Two species are endemic to Australia and several species inhabit the Bismarck Archipelago, Solomon Islands and d'Entrecasteaux Archipelago to the East, Aru Islands to the Southwest and Palau Islands to the North of New Guinea as well as most New Guinean offshore islands. The species with the widest distribution – and most probably the commonest species – is *H. modestus* which occurs on most of the before mentioned islands apart from the Solomons and Palau. *Hypsilurus dilophus* shows a similarly wide distribution and appears to be common in places where it occurs (Manthey and Denzer 2006).

The phylogeny of the genus *Hypsilurus* has been investigated within molecular studies concerned with agamid lizards in general by for example Macey et al. (2000a, b), Schulte et al. (2003), Hugall et al. (2008) and Pyron et al. (2013). The phylogenetic studies of both Schulte et al. (2003) and Pyron et al. (2013) result in two clades for *Hypsilurus* rendering the genus paraphyletic. None of the studies compared the resulting phylogenetic trees to morphology-based taxonomy and consequently did not name individual clades for nomenclatural purposes.

Manthey and Denzer (2006) published a revision of the genus based on morphological characters. They proposed four species groups which can each be identified by a set of characters:

1) *godeffroyi* group: *Hypsilurus godeffroyi* Peters, 1867, *H. binotatus* Meyer, 1874, *H. bruijnii* Peters & Doria, 1878, *H. hikidanus* Manthey & Denzer, 2006, *H. longii* (Macleay, 1877), *H. macrolepis* Peters, 1872, *H. magnus* Manthey & Denzer, 2006, *H. ornatus* Manthey & Denzer, 2006, *H. papuensis* (Macleay, 1877), *H. schoedei* (Vogt, 1932), *H. schultzewestrumi* (Urban, 1999) and *H. tenuicephalus* Manthey &

Denzer, 2006. This group also includes the recently described *H. capreolatus* Kraus & Myers, 2012.

2) *dilophus* group comprising *Hypsilurus dilophus* (Duméril & Bibron, 1837), *H. boydii* (Macleay, 1884) and *H. spinipes* (A. Duméril in Duméril & Duméril, 1851)
3) *nigrigularis* group *Hypsilurus nigrigularis* Meyer, 1874, *H. geelvinkianus* (Peters & Doria, 1878), and *H. auritus* Meyer, 1874.
4) *Hypsilurus modestus* Meyer, 1874 was considered as the sole representative of the *modestus* group.

Currently GenBank (gb, http://www.ncbi.nlm.nih.gov/genbank/) holds sequences for eight species. However, some specimen identifications and assignments of museum vouchers to their respective sequence have been questioned by Manthey and Denzer (2006) as several of the biomolecular studies preceded the revision of the genus and the material was prone to misidentification. Although our analysis does not include *Hypsilurus godeffroyi* – there are only two short 12S and 16S rRNA available – we note that the species identification of the specimen and corresponding sequence (gb AB031984; KUZ 45215, Kyoto University, Dept. of Zoology, collected in Irian Jaya, New Guinea) is most probably wrong as *H. godeffroyi* does not occur on New Guinea. Up to now the species is only known from two museum specimens of unreliable provenance and some bone fragments from Palau Island where the species may be extinct (Crombie and Pregill 1999, Bauer and Watkins-Colwell 2001, Manthey and Denzer 2006). With respect to the species investigated in this paper in particular the determination of *Hypsilurus nigrigularis* (gb AY133016 and HQ662413; TNHC 52009) and *Hypsilurus bruijnii* (gb AY133014; AMS R122474) were considered doubtful as both species are presumably only represented by very few specimens in museum collections and earlier descriptions were misleading (Boulenger 1914; de Rooij 1922). Currently *H. nigrigularis* is known only from its type locality (Rubi, Geelvink Bay) [nowadays Cenderawasih Bay or Teluk Sarera]. *H. bruijnii* specimens are only known from a few specimens near the type locality in the Arfak Mountains.

In this paper we present the results of our investigation into the correct determination of the museum material and assignment of the corresponding GenBank sequences, followed by a phylogenetic analysis of the identified species and a comparison with our earlier morphological study. Finally, we will briefly discuss nomenclatural consequences of the results.

Material and methods

For specimen identification we compared photographs of preserved specimens with material, figures and descriptions given in Manthey and Denzer (2006). Additionally, curators and collection managers were asked to verify the identification of specimens housed in their museum. Abbreviations for museum collections are as follows: ABTC – Australian Biological Tissue Collection, AMS – Australian Museum Herpetological Collection; ANWC – Australian National Wildlife Collection; BPBM – Bernice Pauahi Bishop Museum, QM – Queensland Museum; SAM – South Australian Museum and TNHC – Texas Natural History Collections. Localities and geographical data for *Hypsilurus* species were sourced online from OZCAM (Online Zoological Collections of Australian Museums, http://ozcam.ala.org.au) and VertNet (http://vertnet.org).

Gene sequences that have been used in the earlier studies by Pyron et al. (2013), Macey et al. (2000a, b) and Schulte et al. (2003) were retrieved from the Nucleotide database (GenBank) of the National Centre for Biotechnology Information (www.ncbi.nlm.nih.gov/nuccore). GenBank accession numbers are listed in Appendix 1. Museum voucher specimens of *Hypsilurus* spp. corresponding to GenBank sequences are specified in Table 1. The sequence lengths were typically about 1700 bases (shortest sequence 1696, longest 1720 bases) and comprised the mitochondrial genesND1 (partial CDS), tRNA-Gln, tRNA-Ile, and tRNA-Met (complete sequence), ND2 (complete CDS) tRNA-Trp, tRNA-Ala, tRNA-Asx, tRNA-Cys, and tRNA-Tyr (complete sequence) as well as COI (partial CDS) (see Macey et al. 2000a for further information). In our phylogenetic analysis of 19 amphibolurine species the sequence alignment there were 1292 complete sites, of which 753 were variable and 583 were phylogenetically informative (45.1% of complete sites). We employed SeaView 4.5.4 (Gouy et al. 2010) to evaluate the phylogenetic relationships between Australian amphibolurine lizards and species of the genus *Hypsilurus*. This program package uses Clustal Omega (Sievers et al. 2011) for the alignment procedure as well as PHYLIP 3.696 / dnapars (Felsenstein 1989) and PhyML 3.1 (Guindon et al. 2010) to calculate most parsimonious (MP) and maximum likelihood (ML) phylogenetic trees, respectively. For non parametric bootstrap analysis of the best tree the number of bootstrap replicates was set to 1000. In PhyML the best tree was found by enabling both nearest neighbour interchange (NNI) and subtree pruning and regrafting (SPR).

Results

Initially material used in earlier studies (Macey et al. 2000a, b; Schulte et al. 2003; Hugall et al. 2008) and studied within this paper was re-determined in accordance with the key provided in Manthey and Denzer (2006). Two species turned out to have been misidentified. The corresponding voucher specimens are depicted in Figure 1. The specimen identified in earlier publications as *H.* "*bruijnii*" (gb AY133014; AMS R122474) could be determined as *H. magnus* (see also Kraus and Myers 2012). The voucher specimen clearly shows characters distinguishing it from *H. bruijnii*. There are 4 rows of small scales between the infralabialia and enlarged submandib-

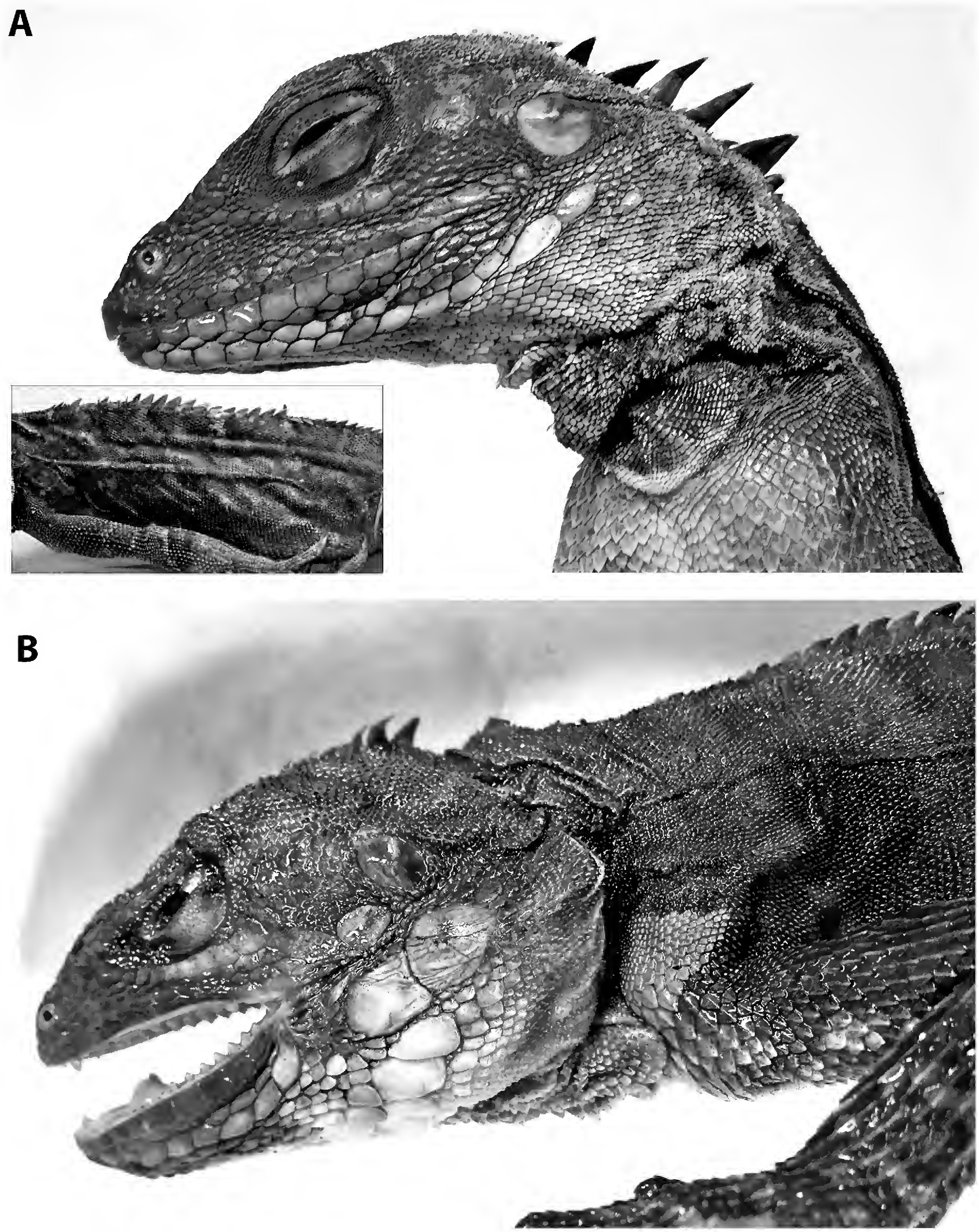


Figure 1. Photographs of re-determined specimens. **A**: *Hypsilurus magnus* (AMS R122474, previously identified as *H. bruijnii*). Please note the number of small scale rows (n=4) between infralabialia and enlarged submandibular scales. Insert: Lateral view of the dorsum showing crossbands. Photos: Cecilie Beatson. **B**: *Hypsilurus schultzewestrumi* (TNHC 52009, previously identified as *H. nigrigularis*). Please note the large gular plates that characterize this species. Photo: Travis LaDuc

ular scales (3 rows in *H. bruijnii*) plus it possesses several dorsal crossbands (no crossbands in *H. bruijnii*). The *H.* "*nigrigularis*" specimen (gb AY133016; TNHC 52009) could be identified as *Hypsilurus schultzewestrumi*. The gular region and the sides of the head of the voucher specimen are covered with large plates as it is typical for *H. schultzewestrumi* (gular scales small in *H. nigrigularis*).

Some of the confusion surrounding the identification (or rather misidentification) of *Hypsilurus nigrigularis* specimens in museum collections most probably result-

Table 1. Museum and GenBank collection / accession numbers and collection data of *Hypsilurus* species used in this study. Where the currently accepted nomenclature differs from the species name provided on GenBank this is indicated below the gb accession number.

Species	Catalog No.	Genbank No.	Locality	Coordinates
Hypsilurus boydii	QM J60630	AY133013	Mt. Boolbun, South Queensland, Australia	15°55'S, 145°9'E
Hypsilurus dilophus	AMS R122449	AF128466	Namosado, Southern Highlands, Papua New Guinea	6°15'S, 142°47'E
Hypsilurus magnus	AMS R122474	AY133014 *H. bruijnii*	Fogamayiu [=Fogomaiu on Google Maps], Southern Highlands, Papua New Guinea	6°31'S, 143°05'E
Hypsilurus modestus	AMS R115478	AY133015	Yuro, Chimbu District, Papua New Guinea	6°32'S, 144°51'E
Hypsilurus papuensis	BPBM 24102	AY133017	Wau, Morobe Province, Papua New Guinea	7°20'S, 146°43'E
Hypsilurus schultzewestrumi	TNHC 52009	AY133016 *H. nigrigularis*	Kaironk Village, ~10 km NW Simbai, Papua New Guinea	5°16'S, 144°32'E
Hypsilurus spinipes	ANWC R05324	AY133018	Nana Creek Area, N(orth) of Coffs Harbour, New South Wales, Australia	30°12'S, 152°57'E

ed from two earlier published figures, both of which did not depict "*Gonyocephalus nigrigularis*" [= *H. nigrigularis*] as written in the figure captions. In fact Boulenger (1914: pl.XXVIII, fig. 4) shows *H. magnus* and AMNH (1972:92) shows a photograph of *H. schultzewestrumi* instead. To our knowledge the only published figure of a true *H. nigrigularis* is the photograph of the type specimen in Manthey and Denzer (2006: 9, fig. 6).

The specimen of *H. dilophus* (gb AF128466; AMS R122449) is currently catalogued as *H. magnus* (OZCAM). This specimen is also erroneously (pers. comm. F. Kraus) listed in Kraus (2010) as AMS R12249 (sic! =R122449) and identified as *H. magnus* but citing a differing locality, namely Fogamaiyu instead of Namosado (Southern Highlands District) as given on OZCAM, GenBank and in earlier publications (Hugall et al. 2008, ABTC 46027; Schulte et al. 2003; Macey et al. 2000a). A re-examination of the specimen corroborated its original identification as *H. dilophus* and the collection locality as Namosado.

Additionally there were inconsistencies with respect to the GenBank sequence of *Hypsilurus papuensis* (gb AY133017) and its corresponding voucher specimen. In an earlier publication (Schulte et al. 2003; Appendix) the source is given a SAMA tissue sample 12965 (South Australian Museum) referring to a voucher specimen CCA 12965 (s. GenBank record). The abbreviation CCA typically refers to collection numbers by C. Austin (Louisiana State University) according to whom this number is too high for collections he made on New Guinea (pers. comm. C. Austin). Enquiries with the Australian Biological Tissue Collection (ABTC) revealed that the number should actually read AA12965 and that this represents a collection number by A. Allison (BPBM). The most recent and correct number for the tissue sample is ABTC 49747 and the corresponding voucher specimen is deposited under BPBM 24102.

Finally there also exists some confusion around *Hypsilurus modestus* on the OZCAM online database. Schulte et al. (2003) and we used the sequence gb AY133015 (voucher specimen AMS R115478). This specimen is still registered under its old name „*Gonocephalus modestus*". A different sequence (gb AF128464; AMS R122434) was used by Hugall et al. (l.c.) and correctly identified as *H. modestus*. The online database (OZCAM) however, erroneously (pers. comm. G. Shea) assigns this number to a specimen of *H. magnus*.

Based on these findings we conducted a phylogenetic analysis the results of which are depicted in Figure 2. Both cladograms (MP and ML) are nearly identical and recover previously published phylogenetic relationships. Our analysis corroborates the rejection of the monotypic genus *Caimanops* and classification of *Caimanops amphiboluroides* (Lucas & Frost, 1902) as *Diporiphora* (Hugall et al. 2008) as well as the classification of *Rankinia adelaidensis* (Gray, 1841) as *Ctenophorus* (Melville et al. 2001, Hugall et al. 2008).

With respect to species of the genus *Hypsilurus* both trees clearly support different clades. Our maximum likelihood analysis yields a clade containing the two Australian species *Hypsilurus spinipes* and *H. boydii* as well as the wide ranging *H. dilophus* as a sister group to the other studied Australian Amphibolurinae. The remaining four Melanesian species are well supported in an apparently monophyletic clade but still with well supported branches differentiating between *H. modestus* and *H. magnus*, *H. papuensis*, *H. schultzewestrumi*. In our parsimony analysis a clade containing *Hypsilurus spinipes*, *H. boydii* and *H. dilophus* is formed that also contains the closely related species *Moloch horridus* and *Chelosania brunnea* as a sister group. This clade is nested between the Melanesian species of *Hypsilurus* and the remaining Australian amphibolurine lizards. The branch supports in our maximum likelihood and parsimony analyses for the *Moloch* / *Chelosania* clade are comparatively weak. None of the resulting topologies is sufficiently supported to present a clear case for either phylogenetic position of these two genera. Again, our parsimony analysis produces a node separating the branch containing only *H. modestus* (100% bootstrap support) from the branch comprising the other Melanesian species of *Hypsilurus*. In summary the two resulting *Hypsilurus* clades are well supported by molecular genetics and well-defined by morphology (see Manthey and Denzer 2006) such that their separation into two genera is justified.

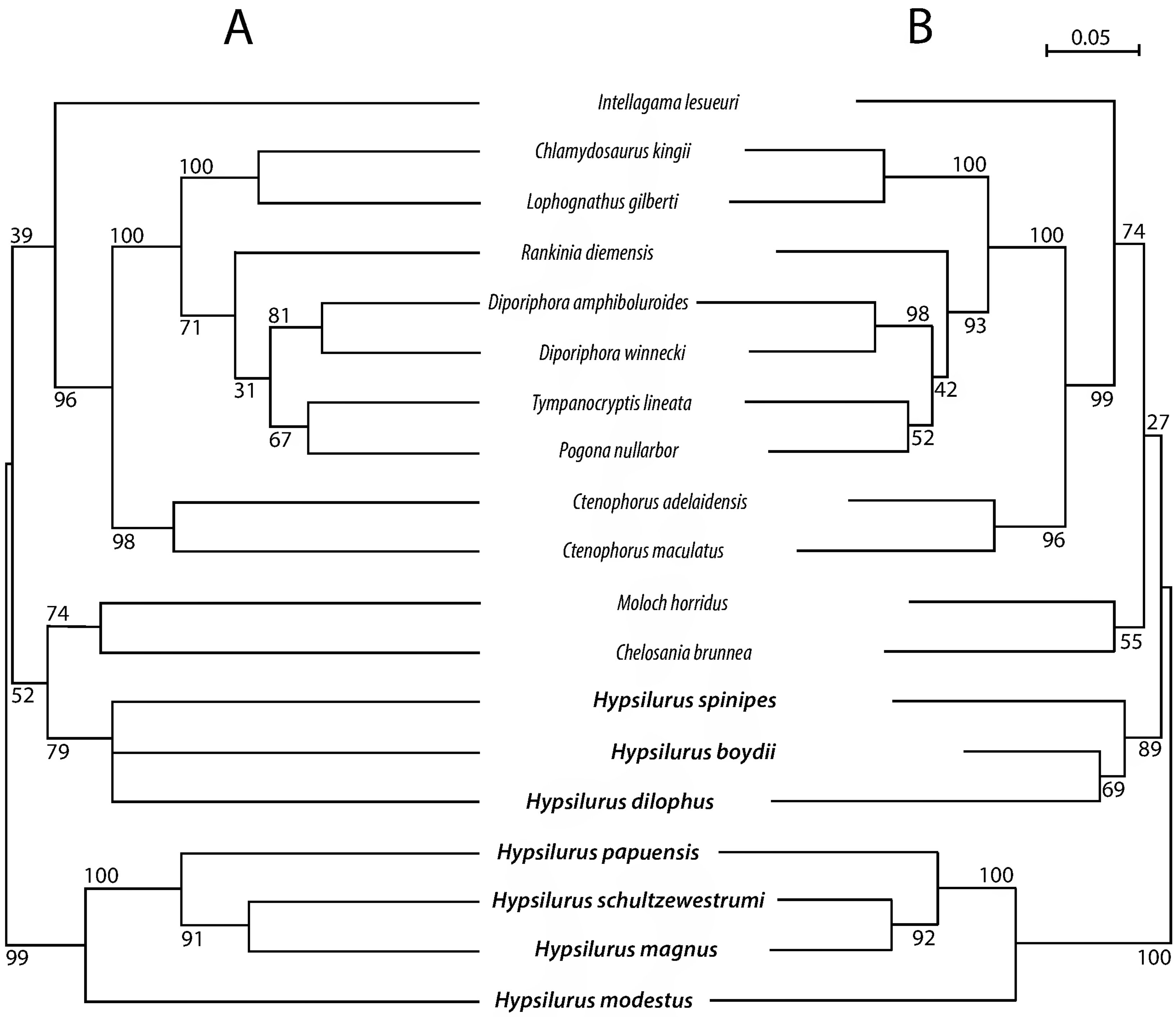


Figure 2. Phylogenetic analysis of *Hypsilurus* spp. and some Australian agamid lizards belonging to the subfamily Amphibolurinae. **A**: Most parsimonious tree (PHYLIP/Dnapars); **B**: Maximum likelihood tree (PhyML). Branch length scale represents number of substitutions/site. Branch support values are given above or next to the branch. Both trees clearly show that *Hypsilurus* is paraphyletic and forms two distinct clades.

Discussion

First, we would like to note that, if sequences are retrieved from databases or databases are consulted for identifying museum material, it may be necessary and appropriate to re-determine the voucher specimens. Great care has to be taken to ensure correct species identification or otherwise misleading phylogenies are published that do not reflect the true intra- and intergeneric relationships between species in accordance with their morphology based taxonomy. For an in-depth discussion on issues related to GenBank see Federhen (2014).

With respect to *Hypsilurus* species our analysis corroborates the results of earlier published phylogenetic studies by Schulte et al. 2003, Hugall et al. 2008 and Pyron et al. 2013, where the Australian species (*H. boydii* and *H. spinipes*) cluster with *H. dilophus*, while the Melanesian species *H.* "*bruijnii*" (= *magnus*, see results) and *H.* "*nigrigularis*" (=*schultzewestrumi*, see results) are closely related and form a second clade including *H. papuensis*; *H. modestus* is the basal taxon and a sister group to the remaining Melanesian *Hypsilurus* species. Macey et al. (2000a, b) even considered *H. modestus* sufficiently genetically different from other *Hypsilurus* species that they used *Arua* Doria, 1874 as the genus name. The study by Hugall et al. (2008, included species: *H. modestus*, *H.* "*bruijnii*" (= *magnus*, see results), *H. spinipes*, *H. boydii*, *H. dilophus*) recovered a clade containing *Chelosania* and *Moloch* as well as *Hypsilurus* spp. that was considered to be the sister taxon to all remaining Australian amphibolurine taxa, Townsend et al. (2011, only *Hypsilurus boydii* included) found that *Chelosania* and *Moloch* constitute a sister taxon to a clade containing all Australian amphibolurine taxa and *Hypsilurus*. Hugall et al. (l.c.) report two clades with respect to *Hypsilurus* species; one comprising the *H. boydii*, *H. spinipes* and *H. dilophus*, the other clade contains *H.* "*bruijnii*" (= *magnus*, see results) and *H. modestus*. Morphologically they also found support for this split in the dentition of the species. While *H. boydii*, *H. spinipes* and *H. dilophus* possess "numerous (15–17) small marginal teeth and tiny anterior pleurodont teeth", *H.* "*bruijnii*" (= *magnus*, see results) and *H. modestus* possess "larger marginal teeth and enlarged 'caniniform' pleurodont teeth" (Hugall et al. 2008: 354).

Already in the original description of *Gonyocephalus* (*Arua*) *inornatus* [= *H. modestus* fide Boulenger 1885 and Manthey and Denzer 2006] Doria (1874) noted morphological differences between the subgenus *Hypsilurus* and the subgenus *Arua* proposed by him. Doria (l.c.) stated that *Arua* can easily be distinguish from *Hypsilurus*: "per la mancanza di grossi scudetti agli angoli della bocca, per un sacco golare poco amplio, per la cresta dorsale inconspicua…" [by missing large scales at the angle of the mouth, by a small gular sac, by an inconspicuous dorsal crest...]. The genus *Arua* was resurrected by Moody (1980) but unfortunately never published formally. Denzer et al. (1997: 323) treated *Arua* as a subgenus ad *Hypsilurus*. Macey et al. (2000) removed *H. modestus* from its synonymy with *Hypsilurus* species and placed the species in the genus *Arua*. It has to be noted that Peters and Doria (1878) and Moody (1980) also considered *Hypsilurus geelvinkianus* and *H. auritus* as members of *Arua*. While *H. geelvinkianus* is superficially similar to *H. modestus*, *H. auritus* is not. Both species have several morphological features in common with *H. nigrigularis* and were combined in a *nigrigularis* group by Manthey and Denzer (2006). For lack of material these species have not yet been investigated by molecular biological techniques and it may well turn out that species considered by us as belonging to *Hypsilurus* are more closely related to *Arua*, should the latter genus be resurrected in future.

The clade containing *H. magnus*, *H. papuensis* and *H. schultzewestrumi* is supported by morphological data and these species are members of the *godeffroyi* group as defined by Manthey and Denzer (2006). Common characters are enlarged scales or plates at the angle of the mouth or below the tympanum, a row of enlarged submandibular scales (called submaxillaries by Manthey and Denzer [2006]), a homogeneous dorsal scalation and anterior gular pouch scales larger than posterior gular pouch scales.

The clade containing the species *Hypsilurus spinipes*, *H. boydii* and *H. dilophus* was recognised as a species group by Manthey and Denzer (2006). The group can be characterised morphologically by a heterogeneous dorsal scalation and their short tail length (TL/SVL <2.3 in most cases smaller than 2). In their originals description *H. boydii* were placed in the genus *Tiaris* Duméril & Bibron, 1837 and *H. dilophus* in the genus *Lophyrus* Duméril, 1805. *Tiaris* is preoccupied and hence not available (*Tiaris* Swainson, 1827, Aves: Passeriformes); the same is true for *Lophyrus* which is preoccupied by *Lophyrus* Poli, 1791 (Mollusca). Manthey and Denzer (l.c.) showed that *Lophosaurus* Fitzinger, 1843 is a nomen oblitum preceding *Hypsilurus* Peters, 1867 and available if *H. dilophus* is removed from its synonymy with *Hypsilurus*. Therefore the only name available for nomenclatural purposes for this group of lizards is *Lophosaurus* Fitzinger, 1843 with *H. dilophus* as the type species.

Conclusion

We currently consider the clade containing *Hypsilurus modestus* and all Melanesian species of *Hypsilurus* (apart from *H. dilophus*) as monophyletic. We suggest to leave these species in *Hypsilurus* sensu lato until additional material becomes available and further biomolecular studies can be conducted that include additional species of *Hypsilurus* s.l. Morphologically *Hypsilurus* s.l. can be divided into a *godeffroyi* species group, a *nigrigularis* species group and the monotypic *modestus* species group (s. Manthey and Denzer 2006 for definitions). All three groups may turn out to be genera in their own right, in particular further analysis may warrant the resurrection of the genus *Arua* Doria, 1874 for *Hypsilurus modestus*. We also consider the clade containing the Australian species *Hypsilurus boydii* and *H. spinipes* as well as the Melanesian *H. dilophus* as monophyletic and propose to resurrect the genus name *Lophosaurus* Fitzinger, 1843 for this group of agamid lizards. The name is masculine gender and therefore the species epithets remain the same.

Lophosaurus Fitzinger, 1843

Type species. *Lophyrus dilophus* Duméril & Bibron, 1837.

Nomenclature of the type species. On p. 419 Duméril and Bibron (1837) introduce the new species *Lophyrus dilophus*. A line further down they refer to a drawing of this species on plate 46 under the genus name of *Tiaris*. This discrepancy is explained on p. 421 where the authors state that it was originally intended to erect a new genus *Tiaris* for this species and that they decided against it at a later stage. We assume that the plates containing the name *Tiaris* had already been printed and subsequent changes would have been difficult to realize. On the same page the authors remark that the Leiden Museum holds specimens of this species under the name *Calotes megapogon*. This name has never been published in conjunction with a description and therefore constitutes a nomen nudum.

Diagnosis. Medium to large sized, arboreal amphibolurine lizard without femoral or precloacal pores (present in all Australian agamid lizards apart from *Chelosania* and *Moloch*); no spines on the body (present in *Moloch*), no frill around the neck (present in *Chlamydosaurus*); a transverse gular fold (absent in *Chelosania*), dorsal scales heterogeneous in size (homogeneous in all *Hypsilurus* s. l.); TL/HBL < 2.3, typically < 2; lacrimal bone present (absent in all Australian Amphibolurinae apart from *Intellagama* and *Chelosania*)

Content

Lophosaurus dilophus (Duméril & Bibron, 1837)
Distribution: New Guinea and adjacent islands

Lophosaurus boydii (Macleay, 1884)
Distribution: Australia (Northeastern Queensland)

Lophosaurus spinipes (Duméril & Bibron, 1851)
Distribution: Australia (Southeastern Queensland, northeastern New South Wales)

Key to the species

1a	Median line of gular pouch without lanceolate scales	*L. spinipes*
1b	Median line of gular pouch with lanceolate scales	2
2a	Diameter of conical scales below tympanum > ½ diameter of the tympanum	*L. boydii*
2b	Diameter of conical scales below tympanum << ½ diameter of the tympanum	*L. dilophus*

Acknowledgements

We are grateful to Travis LaDuc and David Cannatella (both TNHC), Cecilie Beatson and Ross Sadlier (AMS) as well as Molly Hagemann (BPBM) for providing photographic records of specimens held in their collections. Leanne Wheaton (SAM) tracked down the tissue specimen for *H. papuensis* and provided vital information regarding the voucher specimen. Chris Austin (Louisiana State University) shared his view on the collection number of *H. papuensis*; Allen Allison and Molly Hagemann (both BPBM) confirmed the identity and collection data of the voucher specimen. Fred Kraus (University of Michigan) shared his knowledge on *H. magnus* specimens in the collection of the Australian Museum and confirmed their identification. Glenn Shea (University of Sydney) helped to identify the voucher specimen for *H. dilophus* and checked the identities of *H. modestus* specimens held in the Australian Museum. We very much appreciate their help in solving the “mysteries” surrounding some of the specimens used in this study.

References

AMNH (1972) The American Museum of Natural History. An Introduction. The American Museum of Natural History, New York, 160 pp.

Bauer AM, Watkins-Colwell GJ (2001) On the origin of the types of *Hypsilurus godeffroyi* (Reptilia: Squamata: Agamidae) and early German contributors to the herpetology of Palau. Micronesica 34(1): 73–84.

Boulenger GA (1914) An annotated list of the batrachians and reptiles collected by the British Ornithologists’Union Expedition and the Wollaston Expedition in Dutch New Guinea. Transactions of the Zoological Society of London, Vol. XX: 247–275. doi: 10.1111/j.1469-7998.1912.tb07833.x

Crombie RI, Pregill GK (1999) A checklist of the herpetofauna of the Palau Islands (Republic of Belau). Oceania. Herpetological Monographs 13: 29–80. doi: 10.2307/1467060

Denzer W, Günther R, Manthey U (1997) Kommentierter Typenkatalog der Agamen (Reptilia: Squamata: Agamidae) des Museums für Naturkunde der Humboldt-Universität zu Berlin (ehemals Zoologisches Museum Berlin). Mitteilungen des Zoologischen Museums Berlin 73(2): 309–332. doi: 10.1002/mmnz.19970730209

Doria G (1874) Enumerazione dei rettili raccolti da Dr. O. Beccari in Amboina, alle Isole Aru ed alle Isole Kei durannte gli anni 1872–73. Annali del Museo Civico di Storia Naturale di Genova, ser. 1 vol. 6: 325–357.

Duméril AMC (1805) Zoologie analytique, ou méthode naturelle de classification des animaux, rendue plus facile à l’aide de tableaux synoptiques. Allais, Paris, “1806”: i–xxxii + 1–344.

Duméril AMC, Bibron G (1837) Erpétologie générale ou Histoire Naturelle complète des Reptiles. Librarié Encyclopedique de Roret, Paris, ii+572 pp.

Duméril MC, Duméril MA (1851) Catalogue méthodique de la collection des reptiles du Museum d’Histoire Naturelle de Paris. Gide et Baudry, Paris, vi + 224 pp.

Federhen S (2014) Type material in the NCBI taxonomy database. Nucleic Acid Research 43(Database issue): D1086–D1098.

Felsenstein J (1989) PhYLIP – Phylogeny Inference Package (Version 3.2). Cladistics 5: 164–166.

Fitzinger LJ (1843) Systema Reptilium. Fasciculus Primus. Amblyglossae. Braumüller & Seidel Bibliopolas, Wien, 106 pp.

Gouy M, Guindon S, Gascuel O (2010) SeaView version 4: a multiplatform graphical user interface for sequence alignment and phylogenetic tree building. Molecular Biology and Evolution 27(2): 221–224. doi: 10.1093/molbev/msp259

Guindon S, Dufayard JF, Lefort V, Anisimova M, Hordijk W, Gascuel O (2010) New algorithms and methods to estimate maximum-likelihood phylogenies: Assessing the performance of PhyML 3.0. Systematic Biology 59(3): 307–321. doi: 10.1093/sysbio/syq010

Hugall AF, Foster R, Hutchinson M, Lee MS (2008) Phylogeny of Australasian agamid lizards based on nuclear and mitochondrial genes: implications for morphological evolution and biogeography. Biological Journal of the Linnean Society 93: 343–358. doi: 10.1111/j.1095-8312.2007.00911.x

Kraus F (2010) More range extensions for Papuan reptiles and amphibians. Herpetological Review 41(2): 246–248.

Kraus F, Myers S (2012) New species of *Hypsilurus* (Agamidae) from Papua New Guinea. Journal of Herpetology 43(3): 396–401. doi: 10.1670/11-159

Macey JR, Schulte II JA, Larson A, Ananjeva NB, Wang Y, Pethiyagoda R, Rastegar-Pouyani N, Papenfuss TJ (2000a) Evaluating Trans-Tethys migration: An example using acrodont lizard phylogenetics. Systematic Biology 49(2): 233–256. doi: 10.1093/sysbio/49.2.233

Macey JR, Schulte II JA, Larson A (2000b) Evolution and phylogenetic information content of mitochondrial genomic structural features illustrated with acrodont lizards. Systematic Biology 49(2): 257–277. doi: 10.1093/sysbio/49.2.257

Macleay W (1877) The lizards of the Chevert Expedition. Proceedings of the Linnean Society New South Wales 2: 97–104.

Macleay W (1884) Notes on some reptiles from the Herbert River, Queensland. Proceedings of the Linnean Society New South Wales 8: 432–436. doi: 10.5962/bhl.part.28670

Manthey U, Denzer W (2006) A revision of the Melanesian-Australian Angle Head lizards of the genus Hypsilurus (Sauria: Agamidae: Amphibolurinae), with description of four new species and one new subspecies. Hamadryad 30(1&2): 1–40.

Melville J, Ritchie EG, Chapple SN, Glor RE, Schulte II JA (2011) Evolutionary origins and diversification of dragon lizards in Australia's tropical savannas. Molecular Phylogenetics and Evolution 58: 257–270. doi: 10.1016/j.ympev.2010.11.025

Melville J, Schulte II JA, Larson A (2001) A molecular phylogenetic study of ecological diversification in the Australianlizard genus *Ctenophorus*. Journal of Experimental Zoology: Molecular and Developmental Evolution 291(4): 339–353. doi: 10.1002/jez.1133

Meyer AB (1874) Eine Mitteilung von Hrn. Dr. Adolf Bernhard Meyer über die von ihm auf Neu-Guinea und den Inseln Jobi, Mysore und Mafoor im Jahre 1873 gesammelten Amphibien. Monatsberichte der Königlichen Akademie der Wissenschaften zu Berlin, 128–140.

Moody SM (1980) Phylogenetic and historical biogeographical relationship of the genera in the family Agamidae (Reptilia: Lacertilia). Ph.D. Thesis, University of Michigan, 373 pp.

Peters W (1867) Sitzung der physikalisch-mathematischen Klasse. Über Flederthiere (*Pteropus Gouldii*, *Rhinolopus Deckenii*, *Vespertilio lobipes*, *Vesperugo Temminckii*) und Amphibien (*Hysilurus Godeffroyi*, *Lygosoma scutatum*, *Stenostoma narirostre*, *Onychocephalus unguirostris*, *Ahaetulla polylepis*, *Pseudechis scutellatus*, *Hoplobatrachus Reinhardtii*, *Hyla coriacea.*). Monatsberichte der Königlichen Akademie der Wissenschaften zu Berlin, 703–724.

Peters W (1872) Über neue oder weniger bekannte Saurier. Monatsberichte der Königlichen Akademie der Wissenschaften zu Berlin, 774–776.

Peters W, Doria G (1878) Catalogo dei rettili e dei Batraci raccolti da O. Beccari, L.M. D'Albertis e A.A. Bruijn nella sotto-regione Austro-Malese. Annali del Museo Civico di Storia Naturale di Genova, Genova ser. 1(13): 323–450, Pls. 1–7.

Pyron RA, Burbrink FT, Wiens JJ (2013) A phylogeny and revised classification of Squamata, including 4161 species of lizards and snakes. BMC Evolutionary Biology 13: 93. doi: 10.1186/1471-2148-13-93

Rooij N de (1922) Reptiles (Lacertilia, Chelonia and Emydosauria). Resultat de L'Expedition Scientifique Neerlandaise a la Nouvelle Guinee en 1912 et 1913 sous les auspices de A. Franssen Herderschee, Vol. XIII (Zoologie, Livr. I): 133–153.

Schulte II JA, Melville J, Larson A (2003) Molecular phylogenetic evidence for ancientdivergence of lizard taxa on either side of the Wallace's Line. Proceedings of the Royal Society of London B 270: 597–603. doi: 10.1098/rspb.2002.2272

Sievers F, Wilm A, Dineen D, Gibson TJ, Karplus K, Li W, Lopez R, McWilliam H, Remmert M, Soeding J, Thompson JD, Higgins DG (2011) Fast, scalable generation of high-quality protein multiple sequence alignments using Clustal Omega. Molecular Systems Biology 7, 539. doi: 10.1038/msb.2011.75

Townsend TM, Mulcahy DG, Noonan BP, Sites Jr JW, Kuczynski CA, Wiens JJ, Reeder TW (2011) Phylogeny of iguanian lizards inferred from 29 nuclear loci, and a comparison of concatenated and species-tree approaches for an ancient, rapid radiation. Molecular Phylogenetics and Evolution 61: 363–380. doi: 10.1016/j.ympev.2011.07.008

Urban H (1999) Eine neue Agamenart der Gattung *Gonocephalus* aus Papua-Neu Guinea (Squamata: Sauria: Agamidae). Herpetozoa 11(3/4): 185–188.

Vogt T (1932) Beitrag zur Reptilienfauna der ehemaligen Kolonie Deutsch-Neuguinea. Sitzungsberichte der Gesellschaft Naturforschender Freunde zu Berlin (5–7): 281–294.

Appendix 1

Genbank Accession Numbers and corresponding museum specimen data (for *Hypsilurus* specimens only): *Caimanops* (=*Diporiphora*) *amphiboluroides* (AF128472), *Chelosania brunnea* (AF128465), *Chlamydosaurus kingii* (EF090421), *Ctenophorus adelaidensis* (AF128471), *Ctenophorus maculatus* (AF375628), *Diporiphora winneckei* (AY133012), *Lophognathus gilberti* (AY133019), *Moloch horridus* (AF128467), *Physignathus* (=*Intellagama*) *lesueurii* (AF128463), *Pogona nullarbor* (AY133025), *Rankinia diemensis* (KF791202), *Tympanocryptis lineata* (AF128475).

Zoosyst. Evol. 92 (1) 2016, 111–118 | DOI 10.3897/zse.92.7629

PENSOFT.

museum für naturkunde

Description of a striking new *Mantophryne* species (Amphibia, Anura, Microhylidae) from Woodlark Island, Papua New Guinea

Rainer Günther[1], Stephen Richards[2]

1 *Museum für Naturkunde Berlin, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Invalidenstr. 43, 10115 Berlin, Germany*
2 *Herpetology Department, South Australian Museum, North Terrace, Adelaide, South Australia 5000, Australia*

http://zoobank.org/E134B166-6A06-41F7-B1C6-ACC8A503C2C2

Corresponding author: *Rainer Günther* (rainer.guenther@mfn-berlin.de)

Received 26 December 2015
Accepted 7 April 2016
Published 11 May 2016

Academic editor:
Johannes Penner

Key Words

Frog
new species
taxonomy
bioacoustics
New Guinea

Abstract

We describe a striking new species of the microhylid frog genus *Mantophryne* from Woodlark Island in Milne Bay Province, Papua New Guinea. It is most similar to *M. lateralis* but is distinguished from that species by its more slender body, longer shanks, larger discs on the toes, and unique advertisement call. Most known specimens had, in life, a striking golden tan mid-dorsum bordered by broad blackish dorsolateral bands. The new species is currently known only from the rainforests of Woodlark Island, where males call from elevated perches up to 4 m above the ground from climbing *Freycinetia* plants, from crevices and hollows in elevated limestone outcrops, and from tree buttresses and on top of fallen logs on the forest floor. It is the most arboreal member of this predominantly terrestrial genus discovered to date.

Introduction

The genus name *Mantophryne* was coined by Boulenger (1897) to accommodate a single frog species (*lateralis*), “similar to *Xenorhina* but with large eyes and ranoid habit”, from the east of New Guinea. The name *Mantophryne lateralis* was retained by Méhely (1901) and Vogt (1911) but treated as a synonym of *Hylophorbus rufescens* Macleay, 1878, by Fry (1913) and Van Kampen (1923). Parker (1934) stated that the five type specimens of *Mantophryne lateralis* were not all conspecific and that the name bearing syntype must be allocated to *Asterophrys rufescens* Parker, 1934 (he treated *Hylophorbus* as a synonym of *Asterophrys* Tschudi, 1838). In his revision of the subfamily Asterophryinae Günther, 1858, Zweifel (1972) included *lateralis* in the genus *Phrynomantis* Peters, 1867, described a similar species as *Phrynomantis infulata*, and also allocated *Asterophrys louisiadensis* Parker, 1934 to this genus. However the genus name *Phrynomantis* was subsequently shown by Dubois (1988) to be preoccupied by an African taxon and it was therefore replaced by *Callulops* Boulenger, 1888. Zweifel (1972) had also resurrected the genus name *Hylophorbus* mainly because members of that genus have an eleutherognathine jaw, in contrast to a symphygnathine jaw in members of the genus *Phrynomantis* (*Callulops*). On the basis of osteological and myological studies Burton (1986) then resurrected the name *Mantophryne* where he accommodated the symphygnathine species *infulata*, *lateralis* and *louisiadensis*. These three species were later complemented by *M. axanthogaster* Kraus & Allison, 2009.

In a recent paper Oliver et al. (2013) studied phylogenetic relationships between the closely related genera *Mantophryne, Hylophorbus* and *Pherohapsis* Zweifel, 1972. They used three mitochondrial and three nuclear genes and confirmed *M. lateralis, M. louisiadensis* and *M. axanthogaster* as congeneric; the monotypic *Pherohapsis menziesi* Zweifel, 1972 is also nested within *Mantophryne* and was transferred to that genus; *M. infulata* is

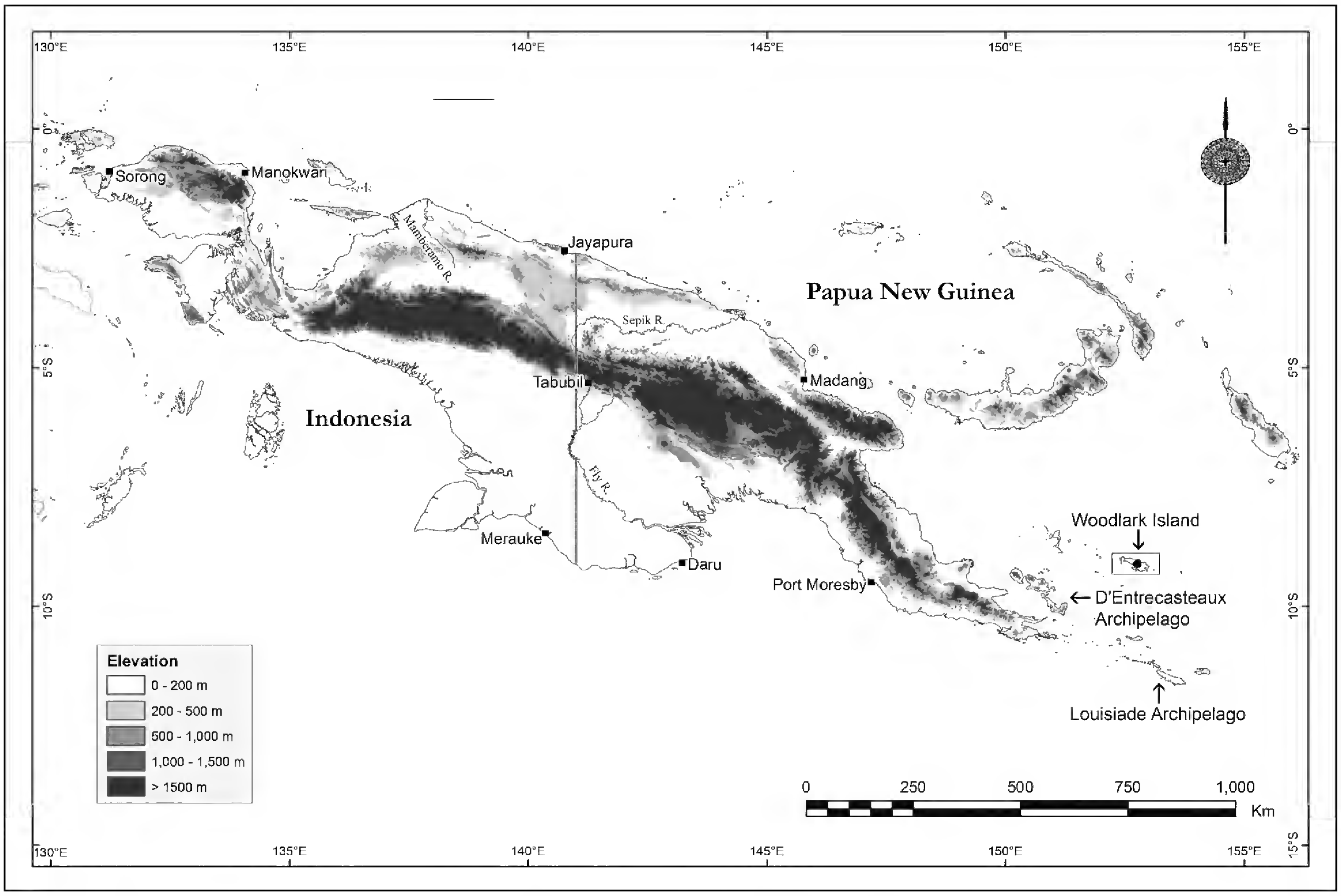


Figure 1. Map of New Guinea showing location of Woodlark Island, type locality of *Mantophryne insignis*.

nested within *Hylophorbus* and was included in that genus as *H. infulatus*. Accordingly *Mantophryne* at present contains four species and quite a number of undescribed forms (Oliver et al. 2013, Frost 2015).

During field work on Woodlark Island, Papua New Guinea (Fig. 1) in April 2011 three strikingly coloured male frogs were encountered that, on the basis of their overall morphology and the symphygnathine condition of the maxillary bones belong to the genus *Mantophryne* but cannot be assigned to any of the known species. We describe and illustrate the new species here.

Material and methods

Frogs were located at night by tracking their advertisement calls, and all specimens were photographed in life prior to preservation. Tissue probes from liver were taken from two of the three collected specimens and stored in about 96% ethanol to enable DNA sequencing. All specimens were fixed in 10% formalin and later transferred to 75% ethanol for permanent storage. Measurements were taken with a digital calliper (> 10 mm) or with a binocular dissecting microscope fitted with an ocular micrometer (< 10 mm) to the nearest 0.1 mm.

SUL	snout-urostyle length: from tip of snout to distal tip of urostyle-bone; SUL is subject to lower measurement error than the traditionally used snout-vent length (SVL) (R. Günther, pers. obs.) so we have used it here. However both measurements are very similar. We therefore directly compare SUL measurements reported here with SVL measurements of congeners presented in the literature;
TL	tibia length: external distance between knee and ankle;
TaL	length of tarsus: external distance between tarsal and ankle joints held at a right angle;
T4L	length of fourth toe: from tip of toe to proximal end of inner metatarsal tubercle;
T4D	transverse diameter of disc of fourth toe;
F3L	length of third finger from tip to proximal margin of central palmar tubercle;
F3D	transverse diameter of disc of third finger;
F1D	transverse diameter of disc of first finger;
T1D	transverse diameter of disc of first toe;
HL	head length: from tip of snout to posterior margin of tympanum;
HW	head width, taken in the widest point;
SL	snout length: from an imaginary line that connects the centres of eyes to tip of snout;
END	distance from anterior corner of orbital opening to centre of naris;
IND	internarial distance between centres of external nares;
ED	eye diameter: from anterior to posterior corner of orbital opening;
TyD	horizontal diameter of tympanum.

Advertisement calls were recorded with a Marantz PMD-660 digital recorder and a Sennheiser ME66 shotgun microphone and analysed with Avisoft-SAS Lab Pro software.

Specimens are stored in the collection of the South Australian Museum, Adelaide (SAMA), the Museum für Naturkunde Berlin (ZMB) and prospectively the Papua New Guinea National Museum (PNGNM), Port Moresby.

Our information concerning features of *Mantophryne* species was taken from original descriptions (Boulenger 1897; Parker 1934; Zweifel 1972; Kraus and Allison 2009), recompiled treatises (Parker 1934; Zweifel 1972; Burton 1986, Menzies 2006; Oliver et al. 2013) and our own observations including direct examination of eight *Mantophryne lateralis* (SAMA R69327–34) specimens from mainland New Guinea.

Results

Mantophryne insignis sp. n.

http://zoobank.org/A66147A7-C0C9-443E-85B0-9A1589D415B8

Holotype. SAMA R69237 (field number = FN SJR 13920); adult male, collected on the slopes of Talpos Mountain, Woodlark Island (Fig 1), Milne Bay Province, Papua New Guinea (9°09.364'S, 152°46.495'E, 180 m a.s.l.) on 15.IV.2011 by S.J. Richards.

Paratypes. ZMB 83181 (FN SJR 13923), same data as for holotype, and FN SJR 13932 (to be deposited in the PNG National Museum), Upper Muniai Creek, Woodlark Island, Milne Bay Province, Papua New Guinea (9°07.502'S, 152°44.902'E, 30 m a.s.l.).

Diagnosis. The new species is assigned to the genus *Mantophryne* on the basis of the following characters: body slender, circum-marginal grooves on all finger and toe discs, those on the toes wider than those of fingers; symphygnathine condition of the maxillary bones (anterior processes of the maxillary bones not fused but almost in contact and joined by a ligament); and two protuberances on chin. It differs from all hitherto known congeners by its 1) relatively long legs (TL/SUL 0.55–0.57 vs. <0.51 in males of all congeners; Menzies 2006, Kraus and Allison 2009), 2) more expanded terminal discs on the toes, 3) smooth dorsum, 4) advertisement calls consisting of 38–52 notes and lasting 4.6–6.5 s, and 5) distinct colouration normally comprising a uniformly golden tan dorsum, broad blackish dorsolateral bands edged below with a narrow, slightly undulating white stripe and large, distinct dark brown blotches each encircled by a white border, on the abdomen.

Description of the holotype. In life mid-dorsal band and dorsal surfaces of thighs uniform golden tan, dorsal surfaces of shanks yellow, posterior of thighs, extending partly to dorsal surfaces, orange-red; supra-canthal stripe, extending onto upper eyelids, yellowish; dorsolateral band blackish, ventral boundary of this band delineated by narrow white stripe; axillary region yellowish and inguinal region orange-red. Lateral surfaces

Figure 2. Holotype of *Mantophryne insignis* sp. n., dorsolateral view in life.

Figure 3. Holotype of *Mantophryne insignis* sp. n., ventral view in life.

of shanks and dorsal surfaces of tarsi dark brown, their ventral parts mottled with dark brown. Iris silvery with a few irregular dark lines; anterior and posterior portions of iris more strongly pigmented by dark lines and with an orange hue (Fig. 2). Ground colour of all ventral surfaces whitish. Throat and chest covered by variably intense brown pigmentation and scattered large dark-brown spots especially along the chin and on the bases of the forelegs. Abdomen and lower areas of flanks are covered by a pattern of very conspicuous dark-brown blotches, each encircled by a narrow white line; areas between the spots are less densely pigmented than the throat and chest; brown spots on inferior thighs are smaller than on abdomen and not encircled by white lines (Fig. 3).

Colouration of the preserved holotype: Dorsal surfaces of head, shanks and mid-dorsum uniform light grey; dorsal surfaces of thighs with faint brown mottling; those of upper arm more strongly mottled with brown; anterior of lower arm and dorsal surfaces of hands, tarsi and metatarsi irregularly brown; conspicuous large dark brown spots edged with a white line extend to posterior of lower arm and anterior tarsus and metatarsus; a relatively wide whitish supra-canthal stripe extends from snout tip to middle of eyelid. The broad dorsolateral bands begin at the posterior edge of the orbital opening, are widest on middle of flanks, and end with a small tip at cloacal opening. Ground colour of all ventral surfaces is off-white. Mottling is same colour as in life.

Measurements of the holotype are listed in Table 1. There is a longitudinal incision in the abdomen. Head longer than broad (HL/HW 1.06). Snout truncate, with only a slight narrowing at the tip in dorsal view and protruding in lateral view. Canthus rostralis rounded, straight anterior to eyes before bending laterally above the nares; loreal region flat, nares directed laterally, close to end of snout and not visible from above; distance between nares greater than distance between eye and naris (END/IND 0.86). Supratympanic skin fold scarcely pronounced, tympanic annulus clearly visible; horizontal diameter of tympanum more than half that of eye (TyD/ED 0.55). Pupil horizontally oval. Tongue very broad, long and free laterally and posteriorly, its posterior margin not notched. Anterior prepharyngeal ridge with three lobes and posterior ridge with ten denticles. Vocal slits small and near angle of jaws. No webbing between fingers; one well developed subarticular tubercle on finger I and II and two well developed tubercles on fingers III and IV; three less prominent metacarpal tubercles; no other palmar tubercles; all fingers bear small but distinct, grooved discs; disc of third finger clearly smaller than that of fourth toe (F3D/T4D 0.63); relative length of fingers III>IV>II>I (Fig. 4). Legs long and slender (TL/SUL 0.57). Toe discs clearly broader than those of fingers and all with distinct circum-marginal grooves; no webbing between toes; one well-developed subarticular tubercle on toe I and toe II, two prominent subarticular tubercles on toes III, V and three on toe IV; clearly expressed inner

Figure 4. Ventral view of the left hand of the holotype of *Mantophryne insignis* sp. n. in life.

metatarsal tubercle, no outer one; relative length of toes IV>III>V>II>I (Fig. 5). All dorsal and ventral surfaces of legs, body and head smooth except two inconspicuous)(-shaped longitudinal ridges beginning between eyes and reaching to occiput. Two small chin protuberances, clearly visible in the living specimen, disappeared in preservative. There are 3 faint, whitish tubercles on the upper edge of the eyelid.

Variation in the type series. Body size (SUL) of three adult males (including the holotype) varied only slightly, from 35.0 mm to 36.2 mm, mean 35.5 mm, SD (standard deviation) 0.61. Measurements of all types are listed in Table 1. Deviations in colouration of the paratypes from the holotype are insignificant; all share the striking colour pattern of a golden tan dorsum with broad, blackish dorsolateral bands and a heavily spotted venter.

Additional variation. Three additional adult male specimens of this species (BPBM 40135–7) collected on Woodlark Island by F. Kraus are 34.1–35.3 mm SUL and agree closely with the description of the type series in all features except that the dorsal colouration of one of the three specimens (BPBM 40135), including the mid-dorsal band, is creamy tan rather than golden tan.

Vocalisation. The advertisement call of *Mantophryne insignis* sp. n., recorded at an air temperature of 25 °C, is a rattle of several seconds duration (Fig. 6).

Figure 5. Ventral view of the left foot of the holotype of *Mantophryne insignis* sp. n. in life.

Two complete calls of the holotype and two calls of SJR 13932 were analysed. Call duration varied from 4.6 to 6.5 s, mean 5.9 s. Number of notes per call was 38–52, mean 47.5. Note repetition rate was from 8.0 to 8.3/s, mean 8.1 notes/s. Mean note duration of two calls from the holotype was 53.1 ms, SD 15.4, range 30–78 ms, n=104; mean internote interval duration was 72.9 ms, SD 12.7, range 41–153 ms, n=102. For technical reasons note and internote length from the calls of the second specimen could not be measured exactly and therefore are not considered here. Note and internote interval length and amplitude of notes clearly increased during the course of the call (compare Figs 7 and 8).

In three of the four calls the last internote interval is clearly the longest and in one call the last but one interval was the longest. All notes are composed of pulses, and these mostly cluster into pulse-groups. The first pulse of almost all notes is clearly separated from the following (clustered) pulses. Frequencies scatter mainly from 1.0 to 3.5 kHz with dominant frequency at 2.0 kHz (Fig. 9). There are no harmonics evident and no modulation of frequencies.

Table 1. Body measurements and body ratios of the type series of *Mantophryne insignis* sp. n. Reg-No=registration numbers; FN are the field numbers of Stephen Richards (SJR). SAMA R69237 is the holotype, all three specimens are adult males. All measurements are in mm; SD=standard deviation; all other abbreviations are explained in "Materials and methods".

Reg-No	SAMA R69237	ZMB 83181	PNGNM	Mean±SD
FN	SJR 13920	SJR 13923	SJR 13932	
SUL	36.2	35.0	35.4	35.5±0.61
TL	20.7	19.8	19.5	
TaL	12.2	12.0	11.5	
T4L	20.1	19.1	18.3	
T4D	1.6	1.5	1.5	
F3L	10.7	9.2	9.1	
F3D	1.0	1.0	1.0	
T1D	1.1	1.0	1.0	
F1D	0.8	0.7	0.7	
HL	12.5	12.2	12.3	
HW	11.8	11.5	11.6	
END	3.0	2.9	3.1	
IND	3.5	3.2	3.4	
ED	3.8	4.1	4.0	
TyD	2.1	2.5	2.3	
SL	5.5	6.0	5.6	
TL/SUL	0.57	0.57	0.55	0.56±0.01
TaL/SUL	0.33	0.34	0.32	0.33±0.01
T4L/SUL	0.56	0.55	0.52	0.54±0.02
T4D/SUL	0.044	0.043	0.042	0.043±0.001
F3L/SUL	0.30	0.26	0.26	0.27±0.02
F3D/SUL	0.022	0.029	0.028	0.026±0.004
T4D/F3D	1.60	1.50	1.50	1.53±0.06
F1D/SUL	0.022	0.020	0.020	0.021±0.001
T1D/F1D	1.38	1.43	1.43	1.41±0.03
HL/SUL	0.35	0.35	0.35	0.35±0.00
HW/SUL	0.33	0.33	0.33	0.33±0.00
HL/HW	1.06	1.06	1.06	1.06±0.00
END/IND	0.86	0.91	0.91	0.89±0.03
ED/SUL	0.105	0.117	0.113	0.112±0.006
TyD/SUL	0.058	0.071	0.065	0.065±0.007
TyD/ED	0.55	0.61	0.58	0.58±0.03
SL/SUL	0.152	0.171	0.158	0.160±0.009

Distribution and ecological remarks. The three type specimens of *M. insignis* were detected by their calls, which were uttered at night from hidden perches 50–80 cm high in a limestone block, a tree buttress and a fallen log, all in lowland rainforest (30–180 m asl) in south-central Woodlark Island. However two of three additional specimens found calling on Woodlark Island by F. Kraus (pers. comm.) were approximately 4 m above the ground, in climbing pandanus (*Freycinetia* sp.) plants. The third specimen was calling from under a leaf on the forest floor. The slender body form, long legs and expanded toe discs (relative to congeners) reflect the unusually arboreal habits of this *Mantophryne* species. Given the uniformity of habitat across the island, and the lack of major topographic relief, it is likely that the species is widespread in lowland rainforest on Woodlark Island. This species has not been reported from any other islands in the region and may be endemic to Woodlark.

Etymology. The name *insignis* is derived from the Latin 'insignis' meaning remarkable or conspicuous, and refers to the species' distinctive colour pattern and unusual (for the genus) ecology.

Comparison with other species. *Mantophryne lateralis*, which is mainly distributed throughout the lowlands of eastern New Guinea (Oliver et al. 2013), is most similar to the new species in having black lateral bands and distinct spotting on the abdomen. Some specimens of this species also have extremely smooth skin, approaching the state in the new species. However it is larger than the new species (males more than 40 mm SUL vs. less than 40 mm SUL in *M. insignis*), has shorter legs (SUL/TL <0.51 vs. 0.55–0.57), smaller toe discs (T4D/SUL <0.034–0.042 vs. 0.042–0.044), lacks the conspicuous golden tan dorsum, and has very long advertisement calls (up to 30 s) at 22–24 °C with a note duration of about 200 ms vs. calls of about 6 s and a mean note length of about 50 ms in the new species (Zweifel 1972, Menzies 2006).

With a snout-vent length up to 82 mm *Mantophryne louisiadensis* is substantially larger than the new species; it also has a broader head, a more robust habitus, lacks dark lateral bands and does not exhibit the striking golden tan middorsal area or clearly delimited brown spots on the abdomen (Zweifel 1972, Kraus and Allison 2009).

Mantophryne axanthogaster male is also larger (> 40 mm SVL) than *M. insignis* and further differs from the new species by its flecked (vs. uniform golden tan) dorsum, lack of dark lateral bands, and uniform grey venter (vs. strongly spotted). Moreover, its advertisement call contains 13–18 notes (vs. 38–52 notes) with a mean note duration of 126 ms (vs. about 50 ms) and a mean note repetition rate of 1.8 notes/s (vs. 8.1 notes/s) at 26.5 °C (Kraus and Allison 2009).

With a snout-vent length of 25–31 mm *Mantophryne menziesi* is smaller than the new species, lacks dark lateral bands and a blotched venter, and has a grey- brown (vs. golden tan) dorsum. Its advertisement call is also different, with notes having a length of about 200 ms (temperature not available) (vs. 50 ms). Moreover in *M. menziesi* the squamosal and frontoparietal bones meet to form an arch over the prootic region, a character which is unique for asterophryine microhylid frogs.

Hylophorbus infulatus (until recently *Mantophryne infulata*) is similar to *M. insignis* sp. n. in many body proportions. The species differ, however, in their internarial spacing. The ratio END/IND of 20 specimens of *H. infulatus* ranges from 0.73–0.84 (Zweifel 1972) whereas three specimens of the new species have values of 0.86–0.91. Moreover, the species differ in their colouration. *H. infulatus* has an inconspicuous brown mid-dorsum with some darker markings (vs. uniform golden tan mid-dorsum in most *M. insignis*), the upper margin of its blackish dorsolateral band is poorly defined (vs. well defined

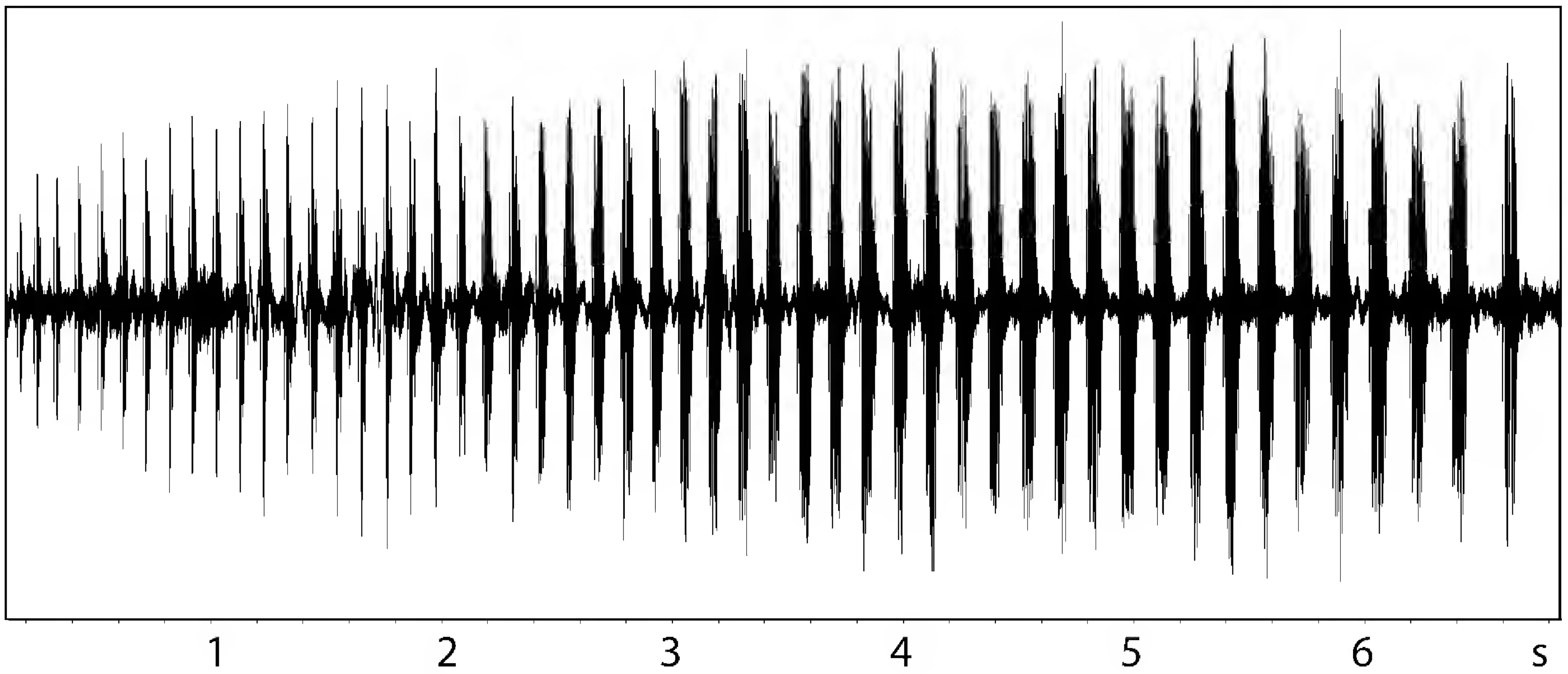


Figure 6. Wave form of a complete advertisement call of the holotype of *Mantophryne insignis* sp. n. with 52 notes.

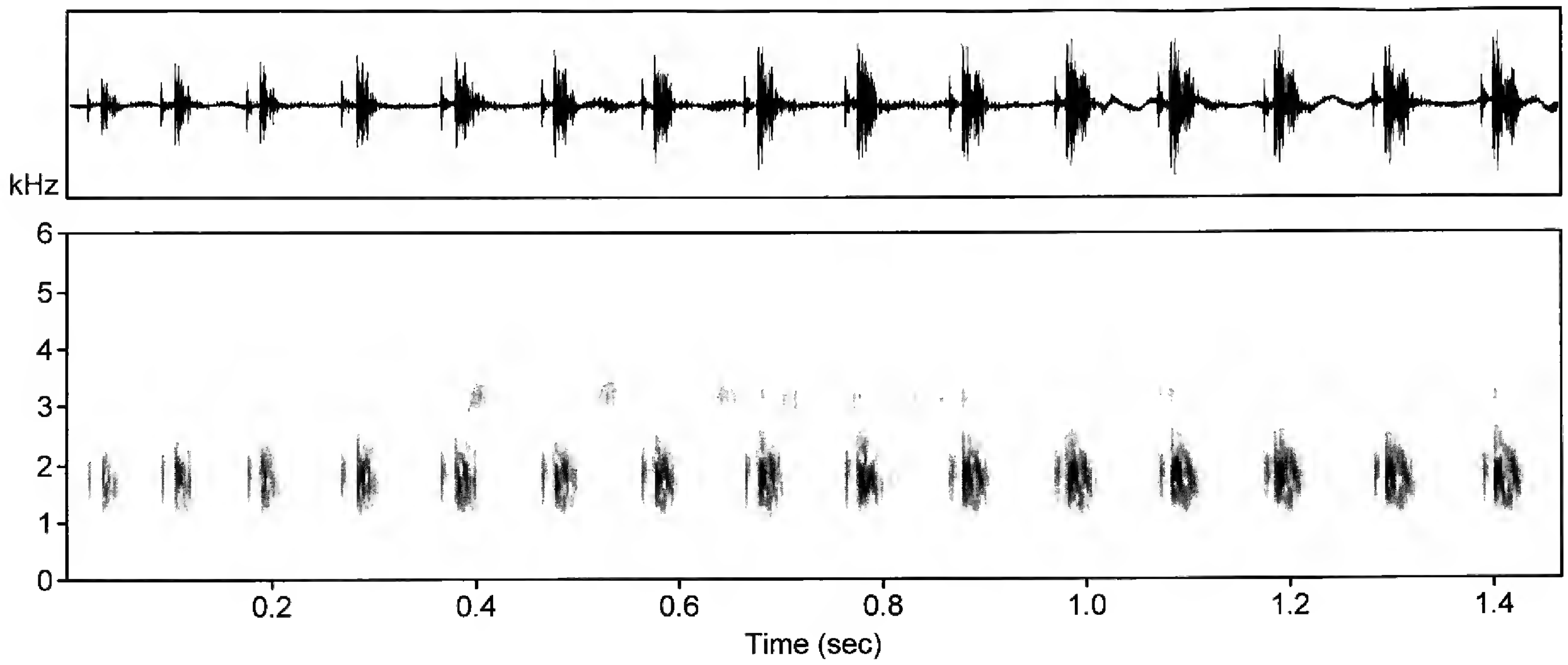


Figure 7. Wave form (above) and spectrogram (below) of a sequence of 15 notes from the first part of an advertisement call of the holotype of *Mantophryne insignis* sp. n.

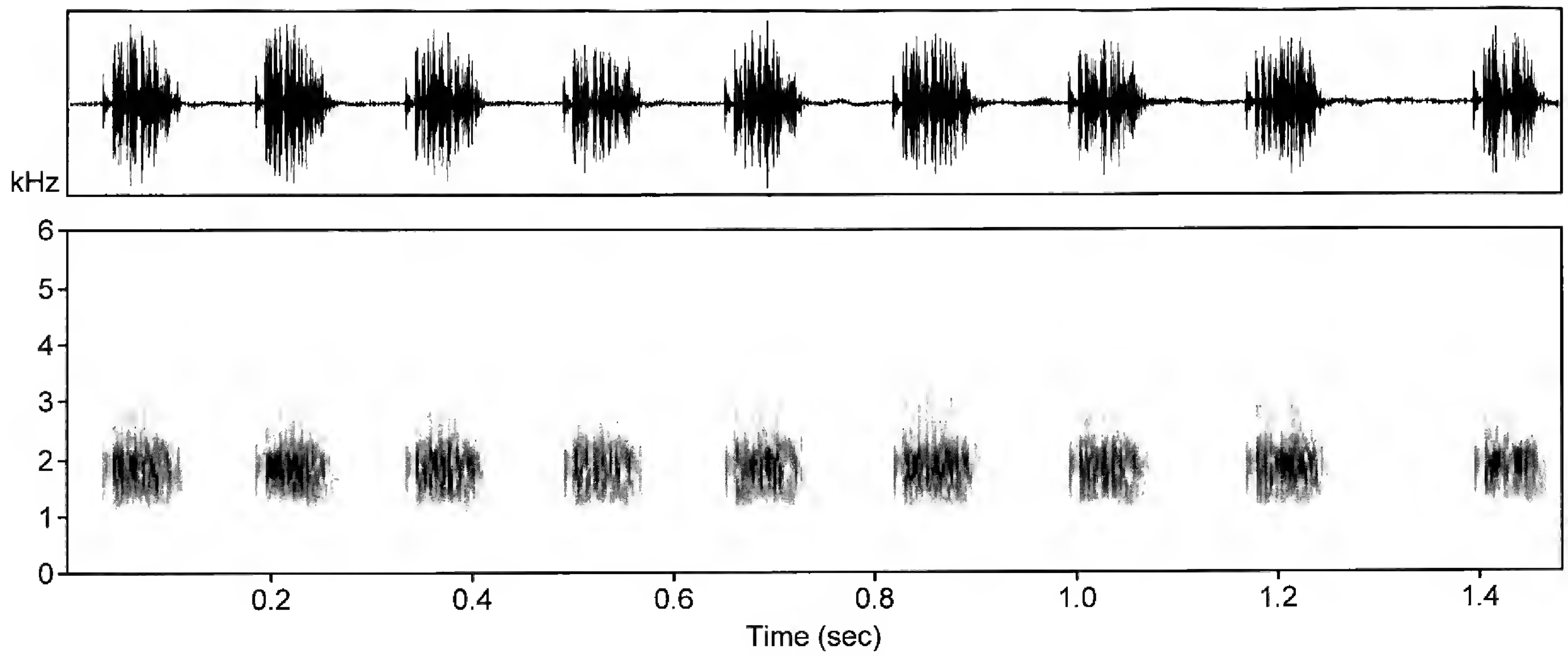


Figure 8. Wave form (above) and spectrogram (below) of a sequence of 9 notes from the last part of an advertisement call of the holotype of *Mantophryne insignis* sp. n.

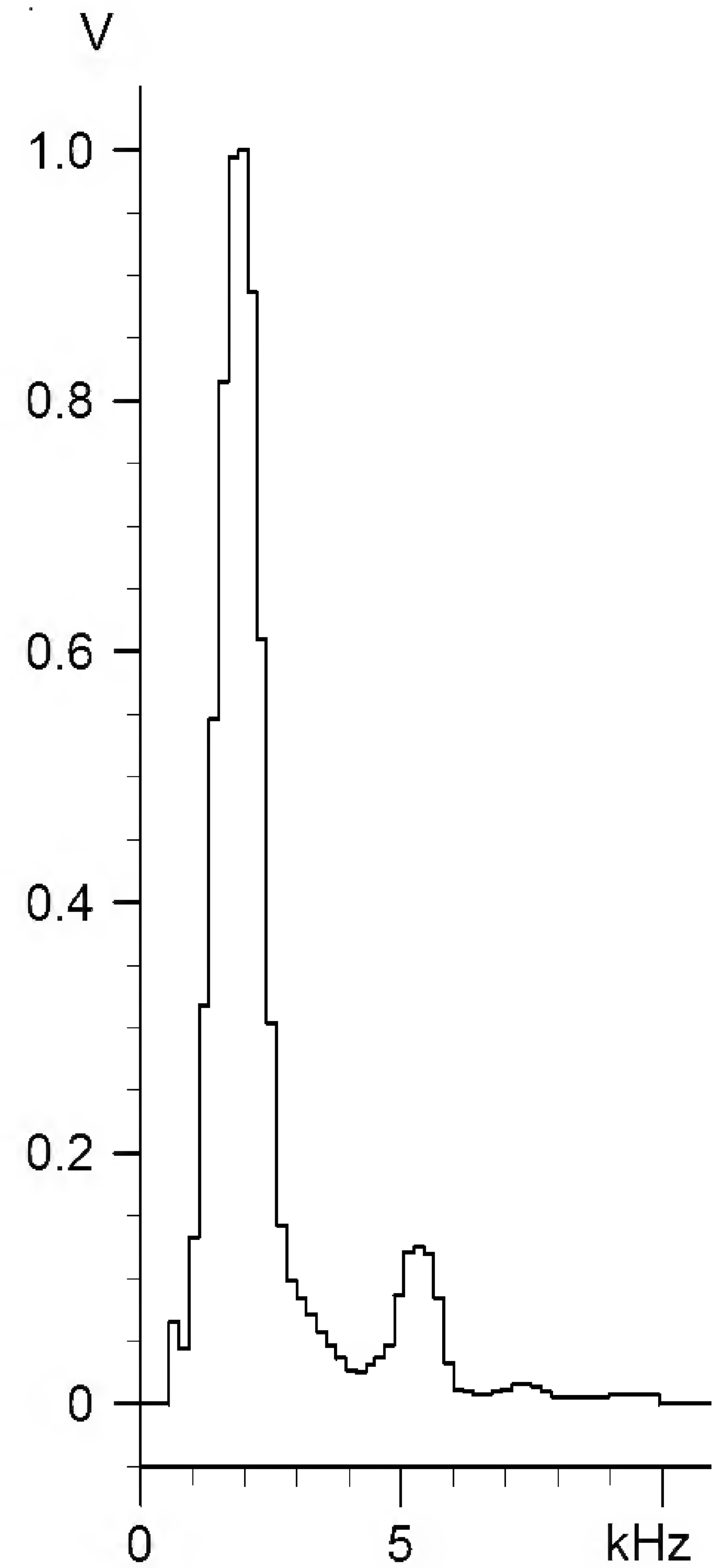


Figure 9. Power spectrum of an advertisement call of *Mantophryne insignis* sp. n.

in *M. insignis*) and its ventral surfaces are mottled with diffuse flecks (vs. covered with well-defined dark brown blotches) (Zweifel 1972).

Acknowledgements

Field work on Woodlark Island was supported by Woodlark Mining Limited and SJR is particularly grateful to George and Eleanor Clapp of WML's Environment Department for their assistance and support. Francis Crome and Daniel Moriarty also assisted the second author's work in various ways. The PNG National Research Institute and Department of Environment and Conservation approved the second author's research visa, and the export of specimens respectively. Carolyn Kovach and Mark Hutchinson provided assistance at the South Australian Museum, and Lisa Capon produced the map. Fred Kraus (University of Michigan) kindly provided field observations on the new species' habitat use, and a photograph of an additional specimen from Woodlark Island and we are also grateful to Allen Allison (Bishop Museum) who provided some measurements of this material.

References

Boulenger GA (1897) Descriptions of new lizards and frogs from Mount Victoria, Owen Stanley Range, New Guinea, collected by Mr. A. S. Anthony. The Annals and Magazine of Natural History 19: 6–13. doi: 10.1080/00222939708680502

Burton TC (1986) A reassessment of the Papuan subfamily Asterophryinae (Anura: Microhylidae). Records of the South Australian Museum 19: 405–450.

Dubois A (1988) Miscellanea nomenclatorica batrachologica (XVII). Alytes 7: 1–5.

Frost DR (2015) Amphibian Species of the World: an online reference, version 6.0 (11/05/2015). American Museum of Natural History, New York. Available from: http://research.amnh.org/herpetology/amphibia/index.php

Fry DB (1913) A re-examination of Macleay's New Guinea and Queensland frog types. Memoirs of the Queensland Museum 2: 46–50.

Kraus F, Allison A (2009) New species of frogs from Papua New Guinea. Bishop Museum Occasional Papers 104: 1–36.

Méhely L v (1901) Beiträge zur Kenntnis der Engystomatiden von Neu-Guinea. Természetrajzi Füzetek 24: 169–271.

Menzies J (2006) The frogs of New Guinea and the Solomon Islands. Pensoft, Sofia-Moscow, 345 pp.

Oliver LA, Rittmeyer EN, Kraus F, Richards SJ, Austin CC (2013) Phylogeny and phylogeography of *Mantophryne* (Anura: Microhylidae) reveals cryptic diversity in New Guinea. Molecular Phylogenetics and Evolution 67: 600–607. doi: 10.1016/j.ympev.2013.02.023

Parker HW (1934) A monograph of the frogs of the family Microhylidae. British Museum (Natural History), London, 208 pp. [figs 1–67, 2 maps]

Van Kampen PN (1923) Amphibia of the Indo-Australian Archipelago. E. J. Brill, Leiden, The Netherlands, 304 pp.

Vogt T (1911) Reptilien und Amphibien aus Kaiser-Wilhelmsland. Sitzungsberichte der Gesellschaft naturforschender Freunde Berlin 9: 420–432.

Zweifel RG (1972) Results of the Archbold expeditions. No. 97. A revision of the frogs of the subfamily Asterophryinae Family Microhylidae. Bulletin of the American Museum of Natural History 148: 413–546.

PENSOFT. museum für naturkunde

A new species of *Arenosetella* Wilson, 1932 from Turkey with notes on the genus (Copepoda, Harpacticoida, Ectinosomatidae)

Serdar Sönmez[1], Serdar Sak[2], Süphan Karaytuğ[3]

1 *Department of Biology, Faculty of Science and Letters, Adıyaman University, 02040, Adıyaman, Turkey*
2 *Department of Biology, Faculty of Arts and Science, Balıkesir University, Çağış Campus, 10145, Balıkesir, Turkey*
3 *Department of Biology, Faculty of Arts and Science, Mersin University, Çiftlikköy Campus, 33343, Mersin, Turkey*

http://zoobank.org/AABEE82F-5908-48E4-85B5-42A9ED0F9CC1

Corresponding author: *Serdar Sönmez* (sonmezserdar@gmail.com)

Received 29 October 2015
Accepted 17 May 2016
Published 20 May 2016

Academic editor:
Michael Ohl

Key Words

Taxonomy
Mediterranean Sea
interstitial
intertidal
meiofauna

Abstract

A new species of the genus *Arenosetella* CB Wilson, 1932 is described from specimens that were collected from the Mediterranean coast of Turkey. The new species is closely related to *A. fimbricaudata* McLachlan & Moore, 1978, *A. germanica* Kunz, 1937 and *A. kaiseri* Lang, 1965 within the 21 species/subspecies of the genus by having five setae at the exopod of the first and the second swimming leg, six setae at the terminal exopod segment of the fourth swimming leg, four setae at the terminal segment of the endopod of the first to fourth swimming legs and four marginal and one surface seta at the exopod of the fifth swimming leg of female. It can be differentiated from all of the species above by the loss of the inner seta at the first segment of the exopod of the second and the third swimming legs. As the diagnosis of the genus was not up to date and did not cover all of the species, a revised and extended diagnosis is provided. The antenna of *A. bassantae* Mitwally and Montagna 2001 was re-examined from the holotype, as the given armature in the original description was unusual for the basic pattern of the family, an amended description and drawing are presented herein.

Introduction

In the course of a survey conducted along the mediolittoral zone of the Mediterranean coast of Turkey between 2007–2008, a new species of the genus *Arenosetella* was encountered in the interstitial samples and is described herein.

The genus *Arenosetella* CB Wilson, 1932 is one of the 21 genera of the family Ectinosomatidae (Wells 2007, Kihara and Huys 2009) and currently has 21 valid species / subspecies (Wells 2007). They are all marine and interstitial, and can easily be differentiated from other ectinosomatids by their vermiform body, well-developed maxilla and the dorsal ornamentation of the anal somite.

The genus was established by Wilson (1932) to accommodate the new species *A. spinicauda* CB Wilson, 1932 and *A. fissilis* CB Wilson, 1932 from Woods Hole, USA. In Wilson's original diagnosis female antennule was described as five- or six-segmented but Lang (1965) revised the diagnosis according to the eight species known by that time and amended the female antennule as six-segmented. As the new species does not fit with Lang's (1965) diagnosis and 13 species have been described after Lang (1965), a revised and extended diagnosis of the genus is given.

The antenna of *A. bassantae* Mitwally and Montagna 2001 is redrawn and redescribed from the holotype [BM(NH) 1999.1236] as its armature was unusual for the pattern described for the family.

Material and methods

Samples were collected from 42 interstitial habitats along the mediolittoral (intertidal) zone of the Mediterranean Coast of Turkey (Fig. 1 and Table 1) by Karaman-Chappuis method (Delamare Deboutteville 1954). Illustrations of the habitus of the holotype and the paratype were

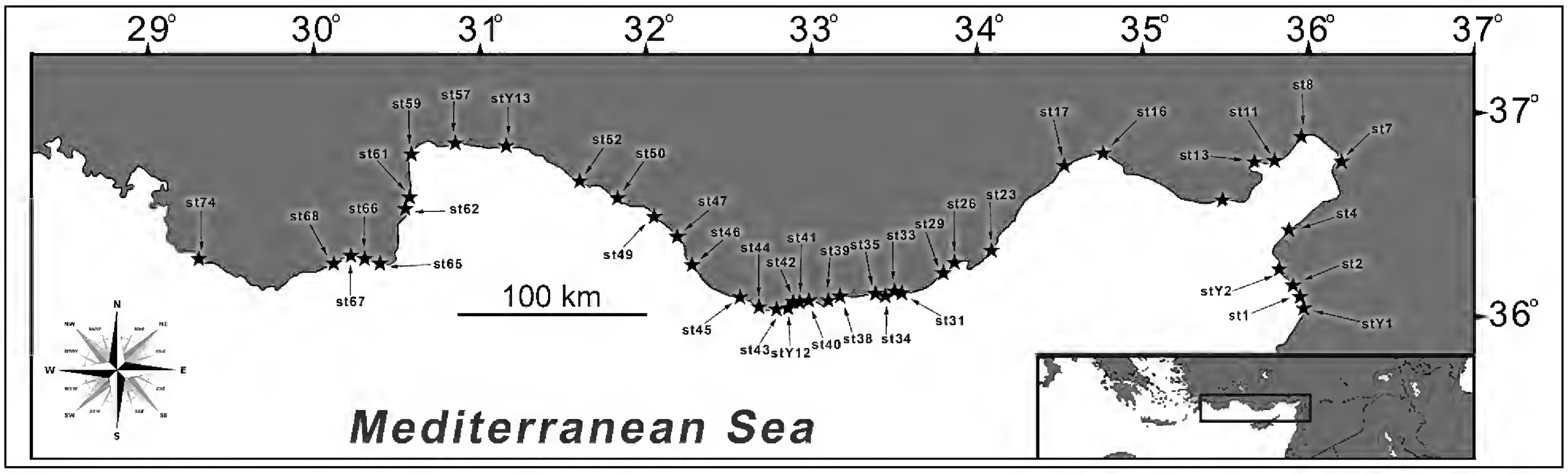


Figure 1. Map of sampling localities

Table 1. Sampling localities and dates.

St.	Sampling Dates				Localities	Coordinates
	1.	2.	3.	4.		
Y1	-	25.07.07	24.11.07	-	100 m south of Asi River, /Hatay	N36°02.774’; E35°57.753’
1	07.04.07	25.07.07	24.11.07		Samandağ beach, Mağaracık / Hatay	N36°05.783’; E35°56.182’
2	07.04.07	25.07.07	24.11.07		North of Mağaracık / Hatay	N36°08.315’; E35°54.598’
Y2	-	25.07.07	24.11.07		North of Samandağ beach / Hatay	N36°15.344’; E35°49.028’
4	07.04.07	25.07.07	24.11.07		Arsuz beach / Hatay	N36°24.808’; E35°53.202’
7	07.04.07	24.07.07	24.11.07		Payas beach / Hatay	N36°45.604’; E36°11.834’
8	08.04.07	24.07.07	25.11.07	13.09.08	Kurtpınar beach / Hatay	N36°53.409’; E35°56.775’
11	08.04.07	24.07.07	25.11.07		West beach of Yumurtalık /Adana	N36°46.133’; E35°46.553’
13	08.04.07	24.07.07	25.11.07	13.09.08	Deveciuşağı village / Adana	N36°44.809’; E35°37.699’
16	09.04.07	26.07.07	26.11.07		Kazanlı beach / Mersin	N36°48.617’; E34°45.442’
17	09.04.07	26.07.07	26.11.07		Viranşehir beach / Mersin	N36°44.357’; E34°32.478’
23	10.04.07	27.07.07	27.11.07	14.09.08	Arkum beach / Mersin	N36°21.519’; E34°04.762’
26	10.04.07	27.07.07	27.11.07	14.09.08	Akçakıl camping area-Taşucu/Mersin	N36°17.829’; E33°50.863’
29	10.04.07	27.07.07	27.11.07		Vadi/Mersin	N36°15.129’; E33°48.489’
31	11.04.07	28.07.07	28.11.07	-	West of Yeşilovacık/Mersin	N36°11.297’; E33°37.723’
33	11.04.07	28.07.07	28.11.07	-	Ahi beach, (East side)	N36°08.990’; E33°29.961’
34	11.04.07	28.07.07	28.11.07	-	Ağaçlı beach / Mersin	N36°09.382’; E33°28.917’
35	11.04.07	28.07.07	28.11.07	-	Eskur-2 beach / Mersin	N36°09.315’; E33°26.548’
38	11.04.07	28.07.07	28.11.07	15.09.08	Tekeli beach / Mersin	N36°08.281’; E33°09.728’
39	11.04.07	-	-	-	Gözsüzce beach / Mersin	N36°08.934’; E33°07.734’
40	11.04.07	28.07.07	28.11.07	-	Bozyazı beach / Mersin	N36°06.023’; E32°58.201’
41	11.04.07	28.07.07	29.11.07	15.09.08	Mamure castle beach / Mersin	N36°05.167’; E32°54.354’
42	12.04.07	29.07.07	29.11.07	-	Anamur beach / Mersin	N36°04.319’; E32°52.271’
Y12	-	29.07.07	29.11.07	-	Dragon kamping beach, / Mersin	N36°04.806’; E32°53.480’
43	12.04.07	29.07.07	29.11.07	-	2 km east of Anamuryum / Mersin	N36°01.959’; E32°48.749’
44	12.04.07	29.07.07	29.11.07	-	Melleç beach / Mersin	N36°02.582’; E32°41.029’
45	12.04.07	29.07.07	29.11.07	-	Kaledran beach / Mersin	N36°05.932’; E32°34.066’
46	12.04.07	29.07.07	29.11.07	-	Gazipaşa marina / Antalya	N36°16.137’; E32°16.783’
47	12.04.07	29.07.07	29.11.07	-	East of Demirtaş /Antalya	N36°22.930’; E32°11.374’
49	12.04.07	29.07.07	29.11.07	-	Alanya Krizantem hotel beach / Antalya	N36°32.066’; E32°02.028’
50	12.04.07	29.07.07	29.11.07	-	Payallar beach / Antalya	N36°35.549’; E31°50.348’
52	12.04.07	29.07.07	29.11.07	-	10 km east of İncekum / Antalya	N36°40.720’; E31°37.163’
Y13	-	30.07.07	30.11.07	-	Boğazkent beach / Antalya	N36°49.866’; E31°09.394’
57	13.04.07	30.07.07	30.11.07	-	Lara beach / Antalya	N36°51.031’; E30°50.966’
59	13.04.07	30.07.07	01.12.07	-	Küçükçaltıcak beach, Kemer / Antalya	N36°47.710’; E30°34.490’
61	13.04.07	31.07.07	01.12.07	-	East of Kemer / Antalya	N36°37.291’; E30°33.399’
62	13.04.07	31.07.07	01.12.07	16.09.08	Phaselis beach / Antalya	N36°31.624’; E30°33.087’
65	13.04.07	31.07.07	01.12.07	-	Karaöz beach / Antalya	N36°16.467’; E30°24.543’
66	13.04.07	31.07.07	01.12.07	-	Mavikent beach / Antalya	N36°17.269’; E30°20.491’
67	14.04.07	31.07.07	01.12.07	16.09.08	Hasyurt intersection / Antalya	N36°18.913’; E30°11.915’
68	14.04.07	31.07.07	-	-	3 km east of Finike, Sahilkent / Antalya	N36°18.491’; E30°09.857’
74	14.04.07	01.08.07	01.12.07	-	Patara beach / Antalya	N36°15.162’; E29°18.720’

drawn from whole specimens; the specimens were then dissected, and the dissected parts were mounted in lactophenol under an Olympus SZX-12 stereomicroscope. Broken coverslip pieces were placed between the slide and the coverslip in order to avoid compression of the specimen and to assist rotation and manipulation. Afterwards, preparations were sealed with Entellan (Merck) for permanent preservation. All drawings were made using a U-DA drawing tube which was attached to an Olympus BX-51 differential interference contrast microscope. Measurements were made with an ocular micrometre.

Scanning electron microscopy (SEM) examinations were made with a Zeiss SUPRA 55VP (FESEM) microscope in Mersin University Advanced Technology Education, Research and Application Centre (MEITAM). Specimens for SEM observation were prepared as described in Kaymak and Karaytuğ (2014). The descriptive terminology is adopted from Huys et al. (1996). Abbreviations used in the text are: ae, aesthetasc; P1–P6, for swimming legs 1–6; exp (enp)-1 (-2, -3) to refer to the proximal (middle, distal) segment of a ramus. Material was deposited in the Zoology Museum of Adıyaman University (ZMADYU) and in the collection of Balıkesir University Zoology Museum (BUZM).

Results

Phylum Arthropoda
Subphylum Crustacea Brünnich, 1772
Superclass Multicrustacea Regier et al., 2010
Subclass Copepoda Milne-Edwards, 1840
Order Harpacticoida GO Sars, 1903
Family Ectinosomatidae GO Sars, 1903

Genus *Arenosetella* CB Wilson, 1932

Amended diagnosis. Ectinosomatidae. Body cylindrical, slightly compressed laterally, without definite demarcation between urosome and prosome. All somites except the penultimate somite with hyaline frills. Genital double somite without any trace of subdivision. Penultimate somite with a parabolic shaped pseudo-operculum. Anal somite ornamented with cuticular projections. Antennule 5 or 6 segmented in female, first segment with a long plumose seta; 6 or 7 segmented in male. Antenna basis distinct, with two segmented endopod and three segmented exopod, first segment of exopod naked or with a seta at inner distal corner, second segment with a seta at inner distal corner, last segment bears a short and a relatively long seta apically. Maxillae well developed, syncoxa slightly longer than wide, with three endites, basis elongated, about two times as long as syncoxa, slightly tapers to the tip, endopod uni-segmented, very short and curved on the anterior margin of the basis. Maxilliped stenopodial. P1-P4 with three segmented rami. Endopod longer than exopod. Setal formula of the swimming legs:

	Exopod			**Endopod**		
	1	**2**	**3**	**1**	**2**	**3**
P1	0	0-1	(0-1)22	1	0-1-2*	(0-1-2)2(0-1-2)
P2	0-1	0-1	(0-1-2)22	1	2*	(1-2)2(0-1)
P3	0-1	0-1	(1-2)22	1	1-2*	(1-2)2(0-1)
P4	0-1	0-1	(0-1-2)2(1-2)	1	1-2*	(1-2)2(0-1-2)

*in case of two setae, one of them is a hyaline seta which originates from the posterior surface.

Arenosetella bassantae Mitwally & Montagna, 2001

Fig. 3C, D

Material examined. Holotype ♀ [BM(NH) 1999.1236]

Amended description. Antenna (Fig. 3C) with a distinct basis. Exopod (Fig. 3D) three segmented; first segment slightly longer than wide, bears a short unipinnate seta at distal corner; second segment short and squarish, armed with a unipinnate seta distally; third segment longest, about four times as long as wide, armed with two unipinnate setae at tip. Endopod two-segmented, second segment slightly shorter than the first, bears two unipinnate setae on inner edge and six setae apically.

Arenosetella lanceorostrata sp. n

http://zoobank.org/E5456DB7-064E-47CB-AD8C-16755D2596CF
Figs 2, 3, 4, 5, 6, 7

Diagnosis. Differs from all other members of the genus by the unique shape of the anal somite dorsal ornamentation which is a strongly chitinised symmetric projection, resembling three strong spines with a common base on dorsal surface.

Type- locality. Kazanlı beach/Mersin (st16), 09.04.2007, 36°48.614’N - 34°45.434’E. Leg. Süphan Karaytuğ, Serdar Sak, Alp Alper, Serdar Sönmez.

Type-specimen. Holotype ♀ (ZMADYU2015/01) and paratype ♂ (ZMADYU2015/02) dissected in 8 slides, 13 ♀♀ and 11♂♂ in ethanol (BUZM).

Additional material. *1. Sampling* st1 (3♀♀, 1♂), st13 (2♀), st17 (9♀♀, 7♂♂), st23 (13♀♀, 4♂♂), st29 (11♀♀), st33 (11♀♀, 1♂), st34 (8♀♀, 4♂♂), st39 (3♀♀), st40 (15♀♀), st41 (3♀♀, 3♂♂), st42 (4♂♂), st44 (1♀), st45 (16♀♀, 4♂♂), st52 (4♀♀, 6♂♂), st65 (2♀♀, 3♂♂), st66 (11♀♀, 11♂♂), st68 (1♀), st74 (2♀♀, 1♂); *2. Sampling* st1 (2♀♀), st2 (20♀♀, 4♂♂), st7 (2♂♂), st8 (14♀♀, 20♂♂), st11 (13♀♀, 4♂♂), st23 (12♀♀, 3♂♂), st29 (2♀♀), st31 (1♀), st32 (4♀♀), st35 (4♀♀), st40 (3♀♀), st45 (3♀♀, 1♂), st46 (5♀♀, 4♂♂), st47 (26♀♀, 2♂♂), st50 (2♀♀, 3♂♂), st57 (5♀♀), st59 (1♀), st61 (1♀), st62 (1♀), st65 (11♀♀, 3♂♂), st66 (1♀), st67 (4♀♀, 3♂♂), stY1 (14♀♀), stY12 (1♀), stY13 (8♀♀, 10♂♂); *3. Sampling* st1 (5♂♂), st4 (1♀, 2♂♂), st8 (9♀♀, 3♂♂), st11 (8♀♀, 1♂), st16 (2♀♀, 1♂), st17 (11♀♀, 9 ♂♂),

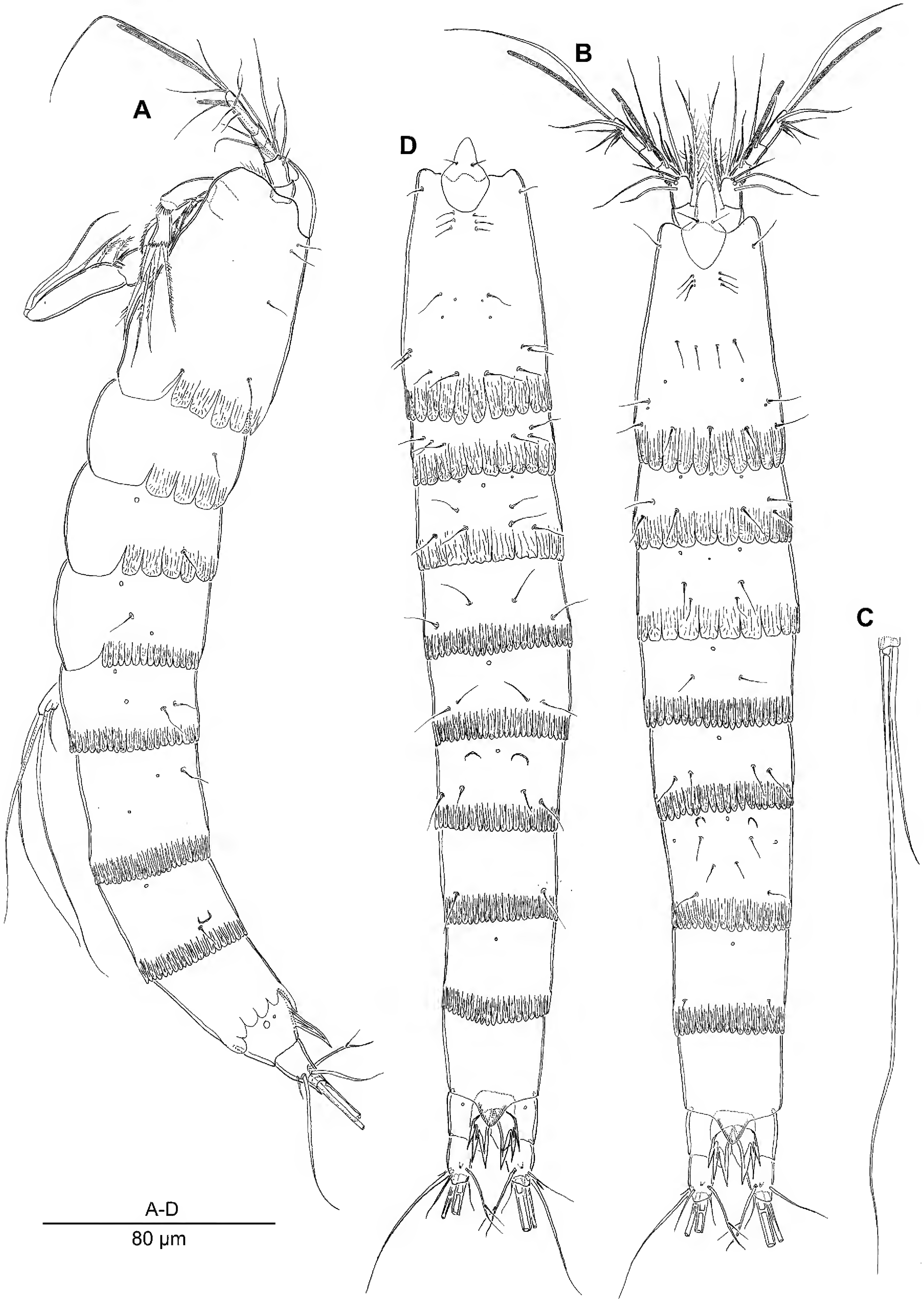


Figure 2. *Arenosetella lanceorostrata* sp. n., Habitus, **A** ♀, lateral view **B** ♀, dorsal view **C** Terminal setae of right caudal ramus **D** ♂ dorsal view.

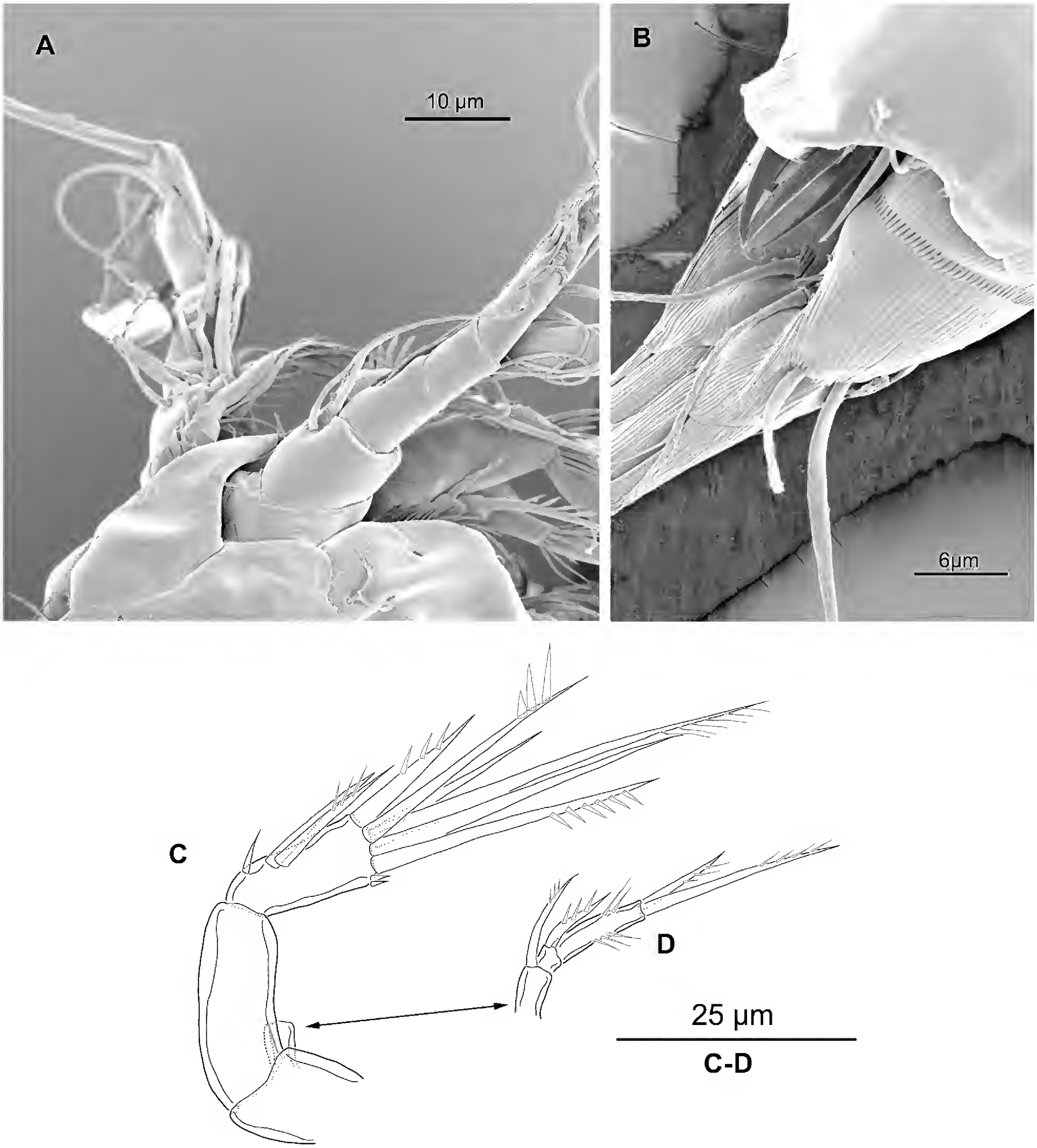


Figure 3. A, B SEM micrographs of *Arenosetella lanceorostrata* sp. n., ♀, **A** Rostrum and antennule **B** Anal somite and caudal ramus **C** Antenna of *A. bassantae*, ♀ Holotype

st23 (5♀♀, 1♂), st26 (2♀♀), st29 (15♀♀, 2♂♂), st34 (2♂♂), st35 (29♀♀, 1♂), st38 (1♀), st40 (46♀♀, 4♂♂), st42 (3♀♀), st43 (1♀), st45 (12 ♀), st47 (3♀♀, 1♂), st49 (1♀), st52 (36♀♀, 1♂), st57 (5♀♀, 3♂♂), st65 (14♀♀, 3♂♂), st66 (13♀♀, 6♂♂), stY1 (16♀♀, 10♂♂); *4. Sampling* st23 (7♀♀), st26 (3♀♀) (BUZM).

Description of female. Total body length from tip of rostrum to the posterior margin of the caudal rami 353 µm (267 - 412 µm, mean = 348 µm, n = 10). Body (Fig. 2A–C) cylindrical, urosome and prosome demarcation not distinct, slightly compressed laterally. All somites except the penultimate somite with hyaline frills as figured (Fig. 2A, B). Antenna, mouthparts and swimming legs partially covered with the lateral extensions of the urosomites. Penultimate somite with a parabolic shaped pseudo-operculum on posterior margin dorsally. Anal somite (Fig. 4A) armed with a strongly chitinised symmetric projection, resembling three strong spines with a common base on dorsal surface, bears a pair of pores and

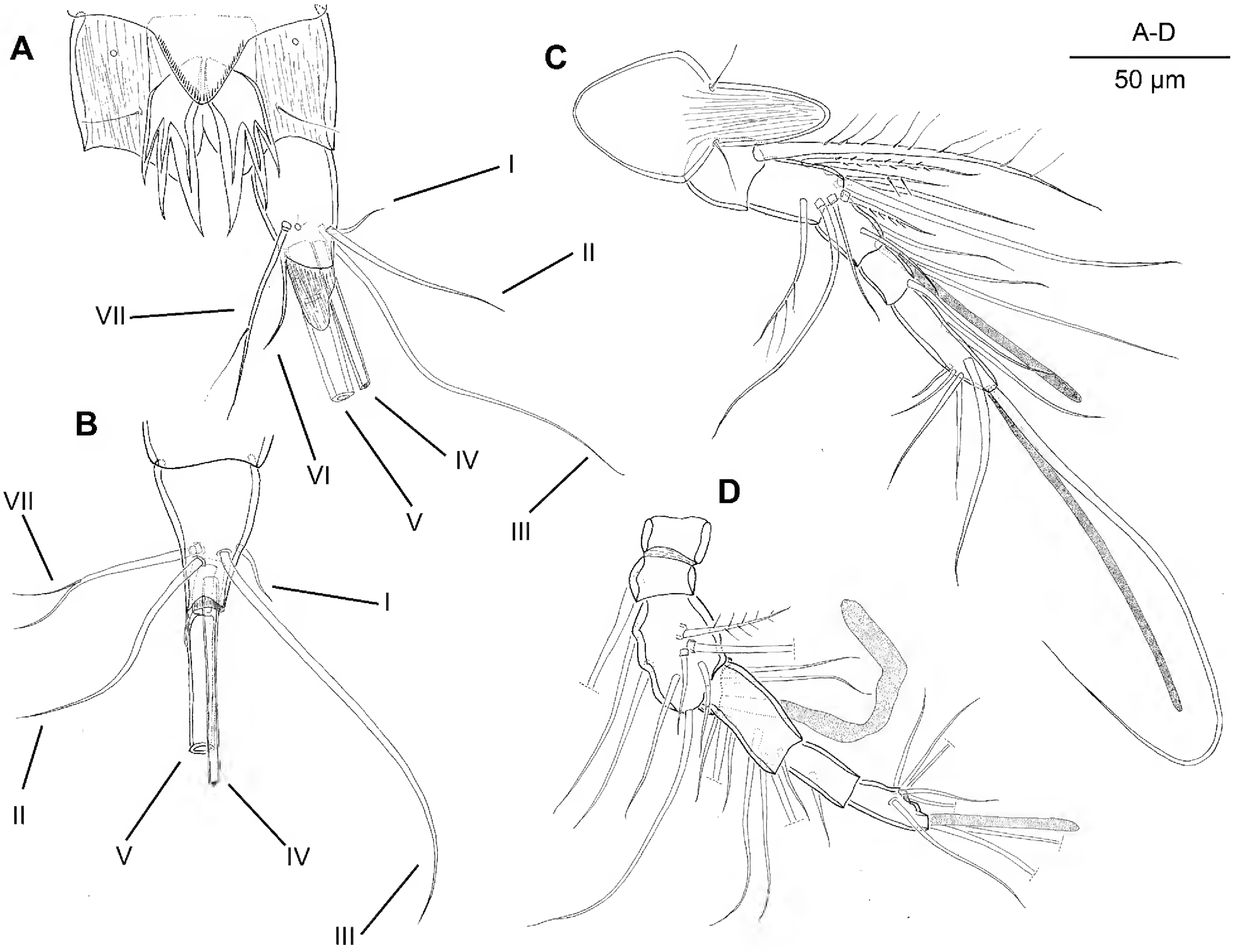


Figure 4. *Arenosetella lanceorostrata* sp. n. **A** ♀, Anal somite and caudal rami, dorsal view **B** ♀, caudal rami, ventral view **C** ♀, Rostrum and antennule, dorsal view **D** ♂, antennule.

a pair of sensillae dorsally and a pair of tube pores on ventral surface. Surface cuticle of anal somite and caudal rami wrinkled (Figs 3B, 4A).

Caudal rami (Figs 3B, 4A, B) longer than wide, posterior margin prolonged as a hyaline membrane that covers the bases of seta IV and V, bears seven setae and a tube pore near the base of seta VII; seta I short and naked, seta II long and naked, seta III naked, longer than seta II, seta IV and V located at the terminal of the caudal rami, seta V about three times longer than seta IV, with a fracture plane basally (Fig. 2C), seta VI naked, located at the inner distal corner of the caudal rami, seta VII located at the dorsal surface, tri-articulated at base.

Rostrum (Figs 3A, 4C) distinct at base, spearhead shaped, cuticle of anterior surface wrinkled, bears two sensillae, curved to ventral at tip.

Antennule (Figs 3A, 4C) short, five segmented. First segment squarish, second segment is longer than wide, third segment slightly longer than wide, bears an aesthetasc which originates from the inner distal corner of the ventral surface, fourth segment short, slightly longer than wide, fifth segment long and narrow, about four times longer than wide, bears an apical acrothek consisting of a long aesthetasc fused basally to one very long and one short bare setae. Setal formula as follows: 1- [1 plumose], 2-[4+3 spinulose +1 plumose], 3- [3+(1+ae)], 4- [1], 5 [6+acrothek].

Antenna (Fig. 6E) with a short and naked coxa. Basis slightly longer than wide, clearly distinct from endopod. Exopod three segmented; first segment slightly longer than wide, bears a short unipinnate seta at distal corner; second segment short and squarish, armed with a unipinnate seta distally; third segment longest, about three times as long as wide, armed with a transverse row of spinules near apical margin, with two unipinnate setae at tip. Endopod two segmented, first segment about three times longer than wide, ornamented with a transverse row of spinules apically; second segment shorter than the first, about two times as long as wide ornamented with short spinules along apical margin, bears two short unipinnate setae on inner edge and six spinulose and one plumose setae apically.

Mandible (Fig. 5A, B). Gnathobase well developed, armed with 8 teeth that fused to cutting edge. Basis longer than wide, clearly narrower at base, bears one plumose and two bipinnate setae. Exopod reduced to a short and

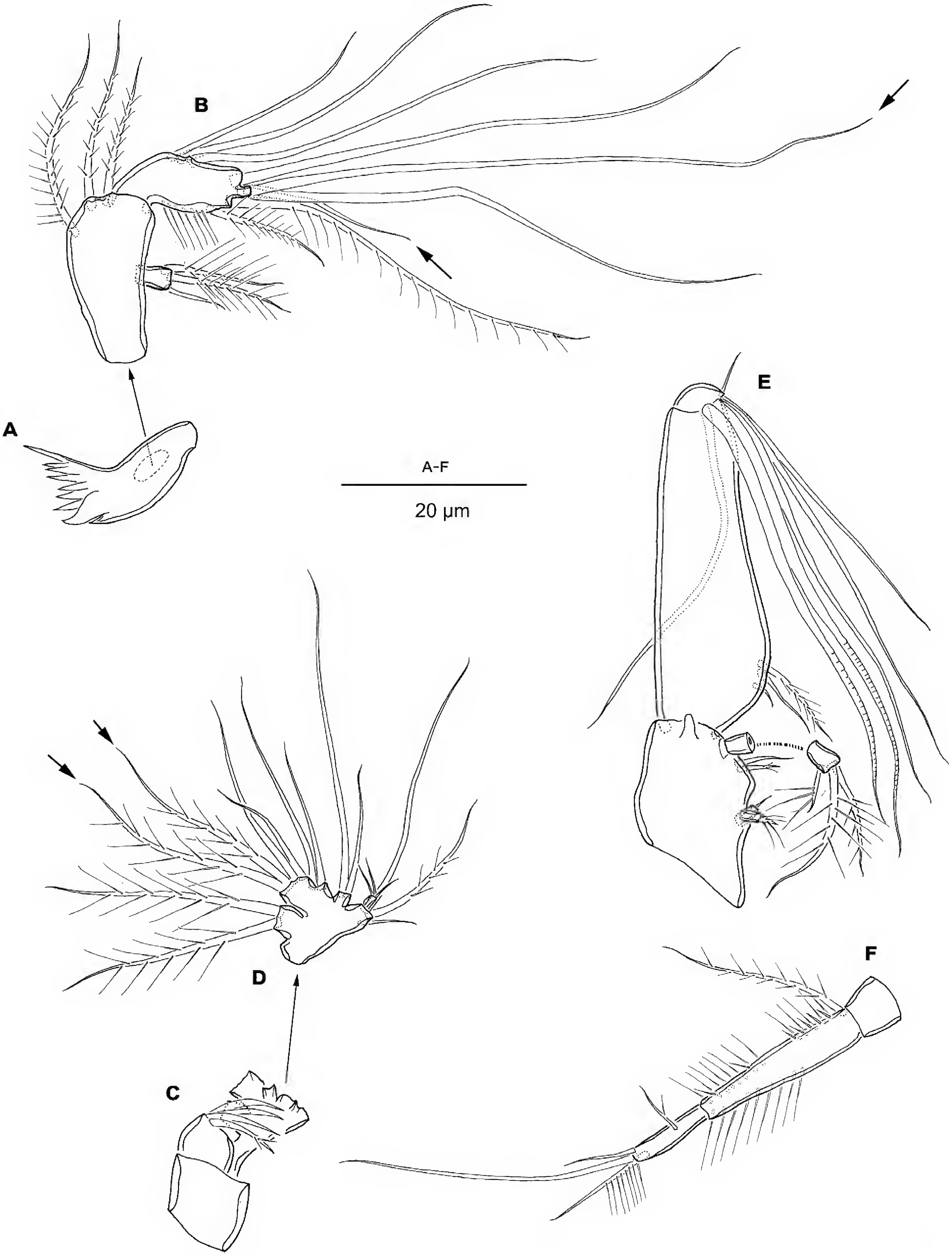


Figure 5. *Arenosetella lanceorostrata* sp. n. ♀, mouthparts, **A** Mandibular gnathobase **B** Mandibular palp **C, D** Maxillule **E** Maxilla **F** Maxilliped.

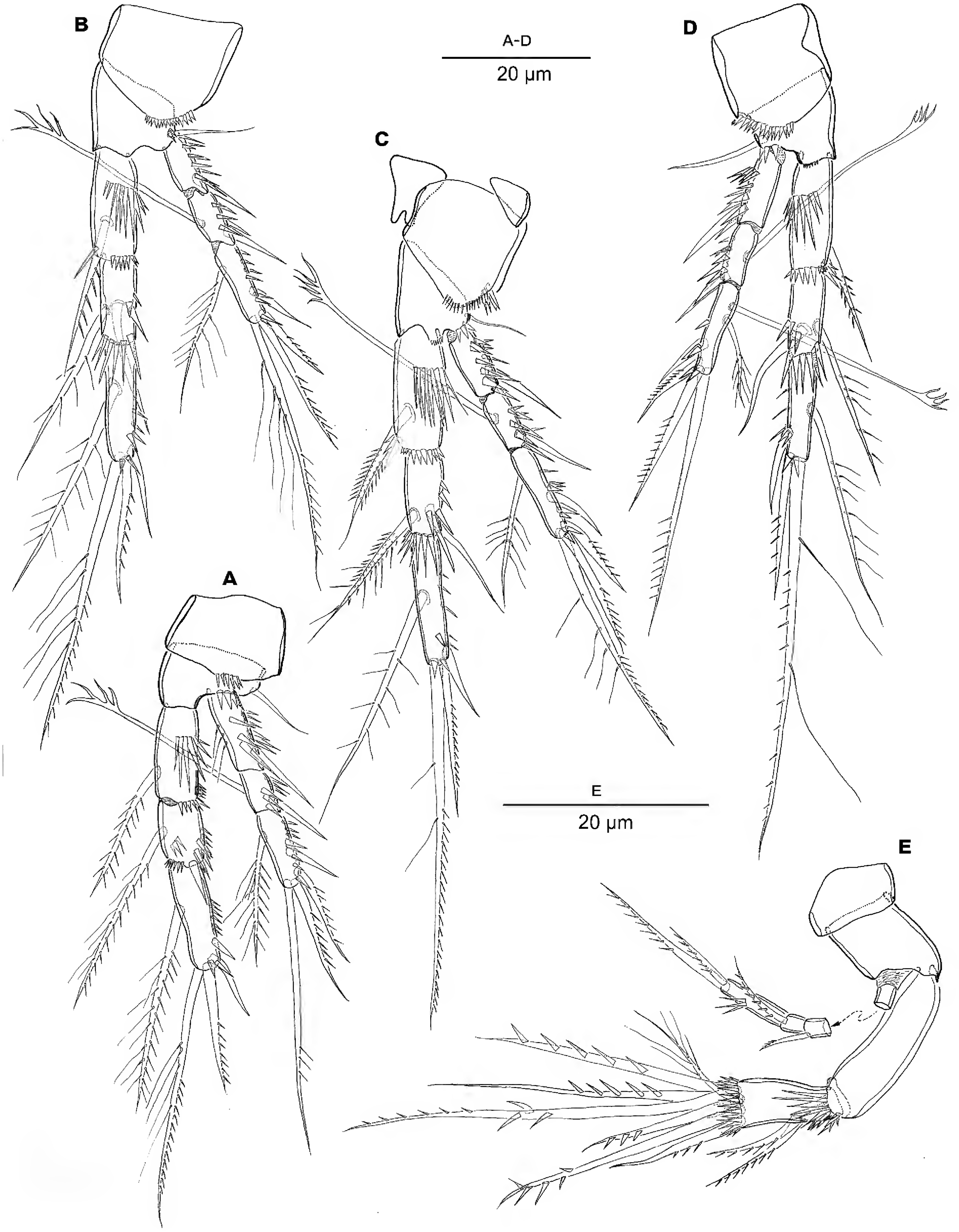


Figure 6. *Arenosetella lanceorostrata* sp. n. ♀ **A** P1 **B** P2 **C** P3 **D** P4 **E** Antenna.

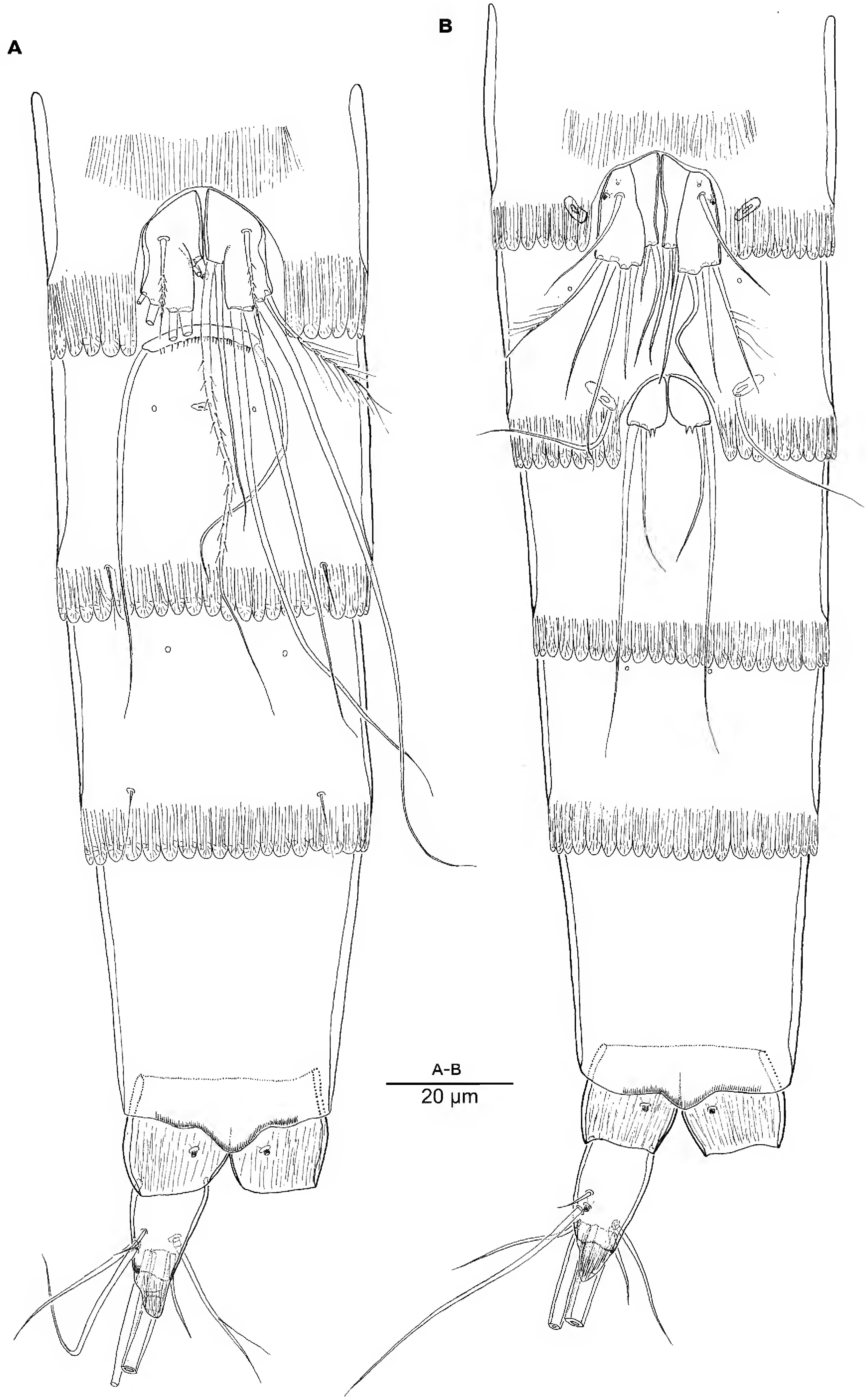


Figure 7. *Arenosetella lanceorostrata* sp. n., urosome, ventral view **A** ♀, **B** ♂.

squarish segment, armed with one short bare and two relatively longer plumose setae. Endopod uni-segmented, rectangular, ornamented with fine spinules at outer margin, bears three long bare setae at inner margin, one short plumose seta at outer distal corner, one long plumose and four bare setae apically which of two fused at base (arrowed in Fig. 5B)

Maxillule (Fig. 5C, D). Pre-coxal arthrite with four setae. Coxa, basis and endopod fused, armed with five plumose setae which of two fused at base (arrowed in Fig. 5D) and eight bare setae. Exopod reduced to a very short segment, bears three minute bare setae.

Maxillae (Fig. 5E) Syncoxa slightly longer than wide, armed with two short seta near distal corner, bears a short cuticular projection near anterior margin, with three endites. First and second endite very short and narrow, located close to each other; first endite with one very short plumose and thick seta, second endite with one minute bare seta; third endite well developed, located near distal corner, bears one short and plumose seta at distal corner and two relatively long and plumose setae apically. Basis elongated, about two times as long as syncoxa, slightly tapers to the tip, armed with one plumose and two bare setae at inner margin. Endopod uni-segmented, very short, curved on the anterior margin of basis, bears seven setae which of two geniculate.

Maxilliped (Fig. 5F) stenopodial. Coxa squarish and naked. Basis elongated, about 4 times as long as basis and two times as long as endopod, bears a long plumose seta located at proximal corner, ornamented with fine spinules on both margins. Endopod long and narrow, armed with one plumose seta medially, bears one plumose and two bare setae apically.

P1-P4 (Fig. 6A–D) coxa well developed, armed with a row of tiny spinules on distal edge. Basis bears a bare seta at outer edge, with three segmented rami. Exopod shorter than endopod, first segment bears well developed spinules and a bare spiniform seta at outer edge, inner edge naked (P2-P4) or ornamented with fine spinules (P1); second segment with well-developed spinules and a bare spiniform seta at outer edge, bears a very long seta directed obliquely upwards, with a fringed tip; third segment ornamented with well-developed spinules, bears one bare and one unipinnate spiniform seta at outer edge, two setae apically, one (P1-P3) or two setae (P4, one of them directed obliquely upwards with a fringed tip) at inner margin. First endopod segment ornamented with a transverse row of spinules on anterior surface and distal margin, outer margin naked, bears a long bipinnate seta at inner margin; second segment ornamented with well-developed spinules along the outer and distal margins, bears a long plumose seta at inner margin and a hyaline seta located at the posterior surface (except P1); third segment with a short bare seta at outer distal corner, one short unipinnate and one relatively long unipinnate and plumose setae apically and a long plumose seta at inner margin. Setal formula of the swimming legs as follows:

	Exopod	Endopod
P1	0.1.122	1.1.121
P2	0.1.122	1.2.121
P3	0.1.122	1.2.121
P4	0.1.222	1.2.121

P5 (Fig. 7A) baseo-endopod and exopod fused, baseo-endopod bears one long and plumose and one bare setae terminally. Exopod bears one relatively short and plumose and three very long and bare setae terminally and one short and bipinnate surface seta located near the proximal part of the exopodal lobe.

P6 (Fig. 7A) pairs fused and formed a short and broad plate, posterior margin of the plate ornamented with fine spinules, each side bears a very long, bare seta.

Description of male. Antennule, P5 and P6 are sexually dimorphic. Total body length from tip of rostrum to the posterior margin of the caudal rami 364 μm (253-364 μm, mean = 322 μm, n = 6). Body ornamentation (Fig. 2D) generally as in female.

Antennule (Fig. 4D) seven segmented. First and second segment short and broad, third segment widest, fourth segment very short, located at the posterior of the fifth segment, bears an aesthetasc, fifth segment longest, sixth segment with a naked seta, seventh segment with an acrothek at tip, consisting of one short aesthetasc and two bare setae fused at base. Setal formula: 1-[0], 2-[1], 3-[7+1 plumose], 4-[2 + ae], 5-[7], 6-[1], 7-[6+acrothek].

P5 (Fig. 7B) baseo-endopod and exopod distinction clear. Baseo-endopod armed with two bare setae terminally. Exopod armed with one bare surface seta and three bare and one plumose terminal setae, bears two tube pores.

P6 (Fig. 7B) baseo-endopod and exopod fused forming a triangular plate, armed with two bare setae and two minute mucroniform projections. P6 bearing somite with a long bare seta at each side of the P6 originated from a button like structure.

Etymology. The specific name "*lanceorostrata*" refers to the spearhead shaped rostrum.

Discussion

In the original description of *A. bassantae* the exopod of the antenna was described as "3-segmented and longer than first endopod segment. First segment with two setae on distal corner. Second segment with two setae on distal corner and one on proximal corner. The 3rd segment with two terminal setae." (Mitwally and Montagna 2001). As this situation does not fit with the general pattern found in the Ectinosomatidae (Seifreid 2003), the holotype was re-examined. This examination revealed that the illustration and the description of the holotype were inaccurate so they are redrawn and described.

The new species is closely related to the *A. fimbricaudata* McLachlan & Moore, 1978, *A. germanica germanica*

Kunz, 1937, *A. germanica galapagosensis* Mielke, 1979, *A. kaiseri* Lang, 1965 within the 21 species / sub species of the *Arenosetella* by having five setae at P1-P2 exp-3, six setae at P4 exp-3, four setae at P1-P4 enp-3 and four marginal and one surface seta at P5 of female. However, it can be differentiated from all of the species above by the loss of the inner seta at the first segment of P2-P3 exopods and the unique shape of the anal somite dorsal ornamentation. Additionally the new species is very similar to *A. kaiseri* Lang, 1965 with its anal somite dorsal ornamentation but differs from this species by having a 5 segmented female antennule and not having an inner seta at P2 - P4 exp-1.

The first record of the genus from Turkish marine waters was provided by Karaytuğ and Sak (2006) from Sarımsaklı beach (Edremit Bay, Aegean coast of Turkey) with *A. germanica*, which was subsequently reported by Sönmez et al. (2012) from the Mediterranean coasts of Turkey. Therefore the new species described herein is the second representative of the genus in the Turkish marine waters.

Acknowledgments

This study was funded by TÜBITAK (The Scientific and Technological Research Council of Turkey) under project number 106T590. We also would like to thank Dr A. Alper for his help in collecting the material.

References

Delamare Deboutteville C (1954) La faune des eaux souterraines littorales en Alge´rie. Vie Milieu 4: 470–504

Huys R, Gee JM, Moore CG, Hamond R (1996) Marine and brackish water harpacticoid copepods. Linnean Society of London, Synopses of the British Fauna (New Series) no. 51. Linnean Society of London, London, 352 pp.

Karaytuğ S, Sak S (2006) A contribution to the marine harpacticoid (Crustacea, Copepoda) fauna of Turkey. Ege University Journal of Fisheries and Aquatic Sciences 23: 403–405.

Kaymak N, Karaytuğ S (2014) Systematics of the genus *Heterolaophonte* (Crustacea, Copepoda, Harpacticoida) with redescription of *H. uncinata* and *H. curvata*. Zootaxa 3780(3): 503–533. doi: 10.11646/zootaxa.3780.3.4

Kihara T, Huys R (2009) A new genus of Ectinosomatidae (Copepoda, Harpacticoida) from sublittoral sediments in Ubatuba, São Paulo State, Brazil, including an updated key to genera and notes on *Noodtiella* Wells, 1965. ZooKeys 17: 57–88. doi: 10.3897/zookeys.17.202

Lang K (1965) Copepoda Harpacticoidea from the Californian Pacific Coast. Kungliga Svenska vetenskapsakademiens handlingar 10: 1–566.

Mitwally H, Montagna PA (2001) Egyptian interstitial Copepoda Harpacticoida with the description of two new species and one new subspecies. Crustaceana 64: 513–544 doi: 10.1163/156854001300228825

Seifried S (2003) Phylogeny of Harpacticoida (Copepoda): Revision of "Maxillipedasphalea" and Exanechentera. Cuvillier Verlag, Göttingen, Sweden, 259 pp.

Sönmez S, Sak S, Karaytuğ S (2012) Meiobenthic ectinosomatids (Crustacea: Copepoda: Harpacticoida) of the Mediterranean sea coasts of Turkey. Journal of Anatolian Natural Sciences 3: 1–14.

Wells JBJ (2007) An annotated checklist and keys to the species of Copepoda Harpacticoida (Crustacea). Magnolia Press, Auckland. New Zealand, 872 pp.

Wilson CB (1932) Copepods of the Woods Hole region, Massachusetts. United States Government Printing Office, Washington, 635 pp. doi: 10.5479/si.03629236.158.i

Zoosyst. Evol. 92 (1) 2016, 131–152 | DOI 10.3897/zse.92.8107

PENSOFT. museum für naturkunde

Annotated type catalogue of lymnaeid snails (Mollusca, Gastropoda) in the collection of the Natural History Museum, Berlin

Maxim V. Vinarski[1,2]

1 *Laboratory of Macroecology and Biogeography of Invertebrates, Saint-Petersburg State University, 7-9 Universitetskaya Emb., Saint-Petersburg, Russian Federation, 199034*

2 *Museum of Siberian Aquatic Molluscs, Omsk State Pedagogical University, 14 Tukhachevskogo Emb., Omsk, Russian Federation, 644099*

http://zoobank.org/2589CECE-F1F5-4D0F-AC4E-F032A70FB03F

Corresponding author: *Maxim V. Vinarski* (radix.vinarski@gmail.com)

Received 11 February 2016
Accepted 18 May 2016
Published 27 May 2016

Academic editor:
Matthias Glaubrecht

Abstract

The article deals with examination of the type materials of sixty-one species and variety of lymnaeid snails (Mollusca: Gastropoda: Lymnaeidae) housed in molluscan collection of the Natural History Museum Berlin, Germany (ZMB). Each taxon is discussed following the same scheme, including synomymy, information on the type materials, current taxonomic allocation, taxonomic and nomenclatorial remarks.

Key Words

Pond snails
taxonomy
nomenclature
type series
history of malacology

Introduction

The malacological collection of the Berlin Natural History Museum, Germany (ZMB hereafter) is among the richest molluscan repositories of the World. A brief information on the origin of the collection and its founders and former curators may be found in Glaubrecht and Zorn (2012) that allows me to omit it here. From the nomenclatorial point of view, the most valuable part of ZMB collection is that including the type materials of species described either by ZMB employes and associates (von Martens, Simroth, Thiele) or by scientists from other scientific institutions and / or countries. The systematic description of the type collection and publication of annotated catalogues of the type materials of molluscan species has started in 1960s (Kilias 1961, 1967) and is continuing now. In total, more than ten papers devoted to examination of the ZMB type materials have appeared in the last two decades. Most of them deal with terrestrial snails and slugs of various families (Köhler 2007; Glaubrecht and Zorn 2012; Breure 2013), others are devoted to cephalopods (Glaubrecht and Salcedo-Vargas 2000), freshwater snails (Köhler and Glaubrecht 2006), and brakishwater bivalves (Glaubrecht et al. 2007).

In this article, I present the results of my examination of the type series of species belonging to the family Lymnaeidae Rafinesque, 1815 housed in ZMB. This diverse family of aquatic pulmonates includes, according to different authorities, from 40 (Hubendick 1951) to several hundreds (Kruglov 2005) living species, most of which are characterized by substantial variation in shell traits. High phenotypical plasticity demonstrated by lymnaeids is the main cause that systematics of this family has been overloaded by synonyms. Hubendick (1951) listed more than 1000 names of the species group introduced by malacologists in their attempts to arrange the lymnaeid diversity, and it is by no means the exhaustive list. Though the vast majority of these names have been thrown out to the limbo of synonyms, many of them are still available for nomenclatorial acts. A relatively recent example of the resurrection of a long-forgotten lymnaeid name is Falkner et al. (2002) proposition to replace the species name *Radix peregra* (O.F. Müller, 1774) with almost ignored one, *R. labiatus* (Rossmässler, 1835), which was not in use since the middle of the 19th century. The current advances in molecular taxonomic studies also may create a situation when a long neglected name should be resurrected out of the limbo as being the oldest available label for a designation of a certain cryptic species not recognized by earlier, morphology-based, taxonomy. It makes both examination of the type specimens and publication of their images a challenging business, rather than a sort of activity once thought to be the destiny of old-fashioned museum curators and amateur conchologists.

Material and methods

This study is a part of my recent project devoted to identification and publication of the Lymnaeidae types from European repositories. I worked with ZMB collection in April of 2015 searching for type materials of lymnaeid species described by Franz Hermann Troschel, Wilhelm Dunker, Eduard von Martens, Frank C. Baker and other, less prominent, malacologists of the 19th – first half of the 20th century. Some of these type series were identified earlier by Kilias (1961, 1967), who listed them and published illustrations of type specimens of a few of these species. However, the closer examination has shown Kilias overlooked nearly 30 type series kept in ZMB. In two his papers, the type materials of 31 lymnaeid taxa of species and below species rank were characterized, whereas in 2015 I managed to identify and examine as many as sixty one type series represented by dried shells exclusively. All these sixty one type series are presented below with images of syntypes (or lectotypes), shell dimensions, brief synonymies and various remarks concerning taxonomy, nomenclature and distribution of the taxa. The taxa accounts are arranged in the alphabetic order. The generic and suprageneric taxonomy used here follows my previously published system (Vinarski 2013). The structure of the article as well as the taxa accounts is based on the recently published catalogues of ZMB collection. As the nearest example to mimic I chose Köhler's (2007) article. The scheme of measurements of a turbospiral shell corresponds to shemes used in recent taxonomic monographs (Glöer 2002; Kruglov 2005).

Abbreviations of shell dimensions are as follows. SH – shell height, SW – shell width, SpH – spire height, BWH – body whorl height, AH – aperture height, AW – aperture width, WN – whorls number. All dimensions in the taxa accounts are given in millimeters.

Abbreviations of the malacological repositories

BMNH – British Museum (Natural History), London, UK; MNHN – National Museum of Natural History, Paris, France; NHMV – Natural History Museum in Vienna, Austria; NMG – Natural History Museum in Gothenburg, Sweden; ZIN – Zoological Institute, the Russian Academy of Sciences, Saint-Petersburg, Russia; ZMB – Berlin Natural History Museum, Germany.

Systematic list of species and varieties arranged in alphabetical order

alfredi Suter, 1890

Fig. 1

Limnaea alfredi Suter 1890: 229, pl. 15, figs. 17, 17a.
Limnaea tenisoni var. β *Alfredi* Suter 1893: 230.
Lymnoëa alfredi Suter 1913: 604, pl. 24, fig. 10.
Limnaea alfredi Dell 1956: 74, figs. 8, 9, 11, 12.
Limnaea alfredi Kilias 1967: 337.
Lymnaea truncatula Climo and Pullan 1972: 6, figs. 2C–E, 3D.

Type material. The lectotype is housed in the Museum of New Zealand (Te Papa Tongarewa) under accession number M 125077 (see Dell 1956, fig. 8; Climo and Pullan 1972, fig. 2 E). ZMB collection possesses two paralectotypes kept under accession number 47038. The largest of the two is 7,2 mm height.

Type locality. New Zealand, Southern Island, Governors Bush, Hooker Valley, Mount Cook Hermitage (fide Kilias 1967). leg. H. Suter.

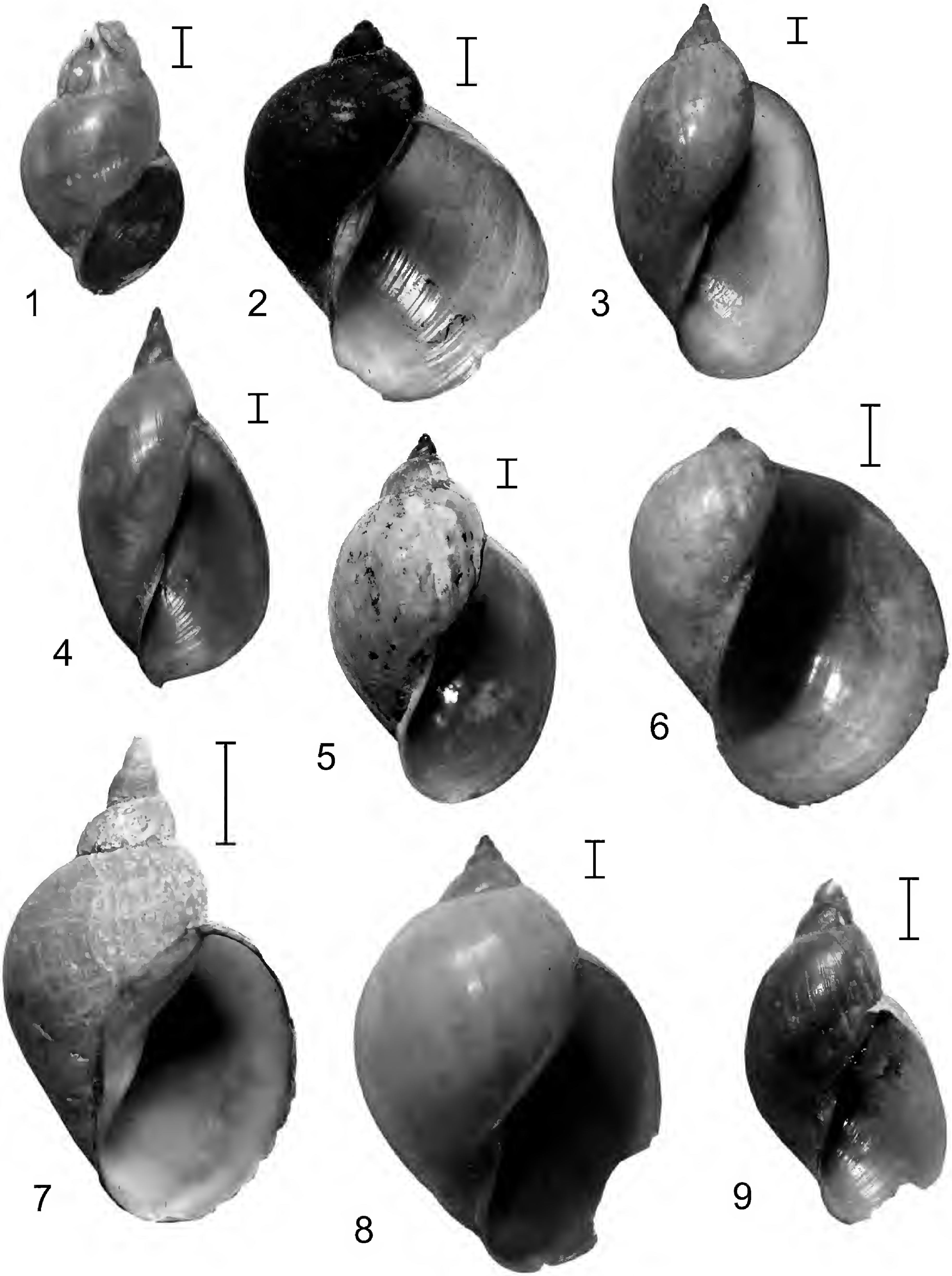
Current taxonomic allocation. Climo and Pullan (1972) considered it to be a synonym of *Galba* (*Galba*) *truncatula* (O.F. Müller, 1774) introduced to New Zealand after advent of Europeans, however Dell (1956: 74) noted some slight conchological differences between *L. alfredi* and *G. truncatula* and stated that *L. alfredi* "has had a history in New Zealand that pre-dates European influence" and that "it is a truly indigenous form". Hubendick (1951) synonymized *L. alfredi* with *Limnaea tenella* Hutton, 1885, but Dell (1956) was able to show that the latter species name was based on juvenile shells of the introduced from Europe *Lymnaea stagnalis* (L., 1758).

amnicola Westerlund, 1890

Fig. 2

Limnaea (*Gulnaria*) *ovata* var. *amnicola* Westerlund 1890: 147.
Limnaea ovata var. *amnicola* Kilias 1967: 337.

Type material. It is known that Westerlund often distributed parts of the type series of taxa described by him among several European museums (Vinarski et al. 2013), therefore in many cases the syntypes of the same species or variety are kept now in more than one repository. I



Figures 1–9. Type specimens of Lymnaeidae (ZMB). **1** – *Limnaea alfredi* Suter, 1890, a paralectotype. **2** – *Limnaea ovata* var. *amnicola* Westerlund, 1890, a syntype. **3, 4** – *Limnaeus amygdalum* Troschel, 1837, two syntypes. **5** – *Limnaea javanica* var. *angustior* von Martens, 1881, a syntype. **6** – *Limnaea brevispira* von Martens, 1897, the holotype. **7** – *Limnaea stagnalis* var. *baltica* Lindström, 1869, a syntype. **8** – *Limnaeus cerasum* Troschel, 1837, a syntype. **9** – *Limnaea columella* var. *championi* von Martens, 1899, a syntype. Scale bars: 1 mm (**1**), 2 mm (**2–6, 8–9**), 5 mm (**7**).

managed to find syntypes of *L. ovata* var. *amnicola* in NMG (accession number 3727), ZIN (accession number 1) and ZMB (three syntypes kept under No. 49530). The lectotype was not designated.

Type locality. Ronneby and Kristianstad, Sweden (Westerlund 1890).

Current taxonomic allocation. An obvious junior synonym of *Radix* (*Peregriana*) *balthica* (L., 1758).

amygdalum Troschel, 1837

Figs 3, 4

Limnaeus amygdalum Troschel 1837: 168.
Limnaeus amygdalum Küster 1862: 35, pl. 6, figs 15, 16.
Limnaea acuminata var. *amygdalum* von Martens, 1881: 76, pl. 14, figs 7, 8.
Limnaea acuminata var. *amygdalum* Preston 1915: 107.
Limnaea acuminata f. *typica* Annandale and Rao 1925: 180.
Lymnaea auricularia race *rufescens* Hubendick 1951: 157, fig. 344.
Lymnaea (*Pseudosuccinea*) *acuminata* Subba Rao 1989: 126, figs 254–265, 272.

Type material. Two samples of *L. amygdalum* from the Ganges River in ZMB (Nos. 72991 and 109767) contain, in total, 12 syntypes. The largest syntype is 30.0 mm height. The syntypes are visibly different in their proportions (compare figs 3 and 4).

Type locality. India, the Ganges River.

Current taxonomic allocation. *Radix* (*Radix*) *rufescens* (Gray, 1822).

angustior von Martens, 1881

Fig. 5

Limnaea javanica var. *angustior* von Martens, 1881: 88, pl. 16, fig. 8.
Limnaea javanica var. *angustior* von Martens, 1897a: 4.
Limnaea javanica var. *angustior* Kilias, 1961: 162.

Type material. 49 syntypes collected in Makassar (Celebes Island, Indonesia) and kept under No. 8136. The largest of these shells reaches 26.2 mm height. Kilias (1961) reported that he intended one of these shells to become the lectotype of *Limnaea javanica* var. *angustior* and separated it under accession number 8136a, however I was not able to find this specimen in ZMB collection. Probably, it is still placed among other syntypes under No. 8136.

Type locality. Indonesia: Java Island (Batavia and Tjisurupan), Celebes Island (Makassar). leg. von Martens.

Current taxonomic allocation. *Cerasina luteola* (Lamarck, 1822). Hubendick (1951) synonymized *L. javanica* var. *angustior* with the race *rubiginosa* of *Radix auricularia* (L., 1758).

baltica Lindström, 1868

Fig. 7

Limnaea stagnalis var. *baltica* Lindström 1868: 22.
Limnaea stagnalis var. *baltica* Westerlund 1885: 29.
Limnaea stagnalis f. *baltica* Kilias 1961: 162.

Type material. ZMB collection contains six specimens (presumably syntypes) of this variety from Westerlund's collection. The largest of them is 24.2 mm height (Lindström [1868] reported the maximum shell height for this variety equal to 30 mm). The current location of other shells from the type series is unknown.

Type locality. Baltic Sea, east shores of the Gotland Island (Östergarn, Legraf, Haugröne and Fårosund).

Current taxonomic allocation. *Lymnaea* (*Lymnaea*) *stagnalis*. This variety represents a dwarf morph of the great pond snail inhabiting the Baltic Sea (Westerlund 1885).

brevispira von Martens, 1897

Fig. 6

Limnaea brevispira von Martens 1897a: 2, pl. 1, figs 1, 2; pl. 13, figs 1, 3.
Lymnaea brevispira Hubendick 1951: 165, fig. 356.
Lymnaea brevispira Kilias 1961: 163.

Type material. A single specimen is kept in ZMB under accession number 101157. The original description of the species was based on this single specimen (von Martens 1897a) and thus this specimen must be regarded as the holotype by monotypy.

Holotype dimensions. WN 2.50; SH 10.9; SW 9.5; SpH 1.2; BWH 10.4; AH 9.6; SW 6.8.

Type locality. Indonesia, Sumatra Island, Manindjau Lake.

Current taxonomic allocation. This is valid species with unclear generic position. It may belong to either genus *Austropeplea* Cotton, 1942 or to the genus *Bullastra* Bergh, 1901.

cerasum Troschel, 1837

Fig. 8

Limnaeus cerasum Troschel 1837: 170.
Limnaea acuminata var. *cerasum* Preston 1915: 108.
Lymnaea luteola Hubendick 1951: 161, fig. 349.

Type material. There are three samples of *L. cerasum* from the Ganges River in ZMB kept under accession numbers 8650 (six syntypes), 72989 (a single syntype), and 109766 (two syntypes). The largest syntype's shell is 23.3 mm height.

Type locality. India, the Ganges River.

Current taxonomic allocation. A junior synonym of *Cerasina luteola*.

championi von Martens, 1899

Fig. 9

Limnaea columella var. *championi* von Martens 1890-1901: 378, pl. XIX, fig. 12.
Limnaea columella var. *championi* Kilias 1961: 162.

Type material. Two syntypes collected in Bugaba (South Panama) by Champion and kept in ZMB collection under No. 51244. The largest of these shells reaches 12.4 mm height. Kilias (1961) reported that he intended one of these shells to become the lectotype of *Limnaea columella* var. *championi* and separated it under accession number 51244a, however I was not able to find this specimen in ZMB collection. Probably, it is still placed among other syntypes under No. 51244. Both type specimens represent subadult shells.

Type locality. Panama (southern), Bugaba.

Current taxonomic allocation. *Pseudosuccinea columella* (Say, 1817).

coreana von Martens, 1886

Fig. 10

Limnaea auricularia var. *coreana* von Martens 1886: 80.
Lymnaea auricularia var. *coreana* Kilias 1967: 338, fig. 2.
Lymnaea (*Radix*) *coreana* Bogatov and Zatravkin 1990: 112, fig. 28 в.
Lymnaea (*Radix*) *coreana* Kruglov and Starobogatov 1993a: 92, fig. 14 C.
Lymnaea (*Radix*) *coreana* Starobogatov et al. 2004: 316, pl. 132, fig. 2.

Type material. 11 syntypes in two samples: No. 38440 (seven syntypes) and No. 55594 (4 syntypes), leg. Gottsche (without date).

Type locality. Korea, “Changjin, Prov. Hangyöngdo”.

Current taxonomic allocation. *Radix* (*Radix*) *coreana*.

Syntypes dimensions. See Table 1.

Remarks. Hubendick (1951) considered *L. auricularia* var. *coreana* as a synonym of *R. auricularia*, whereas the Russian authors (Bogatov and Zatravkin 1990; Kruglov and Starobogatov 1993; Kantor et al. 2010) accept its validity. Kilias (1967) stated he separated one of the syntypes under the museum number 38440a – to become the lectotype of this taxon. However, I failed to find this specimen in the collection. Currently none of the syntypes either is labelled as the syntype or is placed in a separate container with number 38440a.

costulata von Martens, 1874

Fig. 11

Limnaea lagotis var. *costulata* von Martens 1874: 26, pl. II, fig. 24.
Limnaea lagotis var. *costulata* Nevill 1878: 8.
Limnaea lagotis f. *costulata* Annandale & Rao 1925: 153, fig. 7.
Limnaea auricularia var. *lagotis* f. *costulata* Zhadin 1933: 95.
Lymnaea costulata Hubendick 1951: 72, fig. 154.
Radix lagotis var. *costulata* Zhadin 1952: 170, fig. 67.

Type material. I could not recognize the syntype(s) of this variety in ZMB collection. However, there are several specimens (subadult shells) labelled as *L. lagotis* var. *costulata* and collected in Charik-Kul’ Lake (Uzbekistan, in vicinities of Katta-Kurgan Town) by Fedchenko (see Fig. 11). Martens (1874: 27) discussed shells from this locality in his monograph under the name *L. lagotis* but did not assign them to a certain variety of this species. It is unclear who and when identified shells from Charik-Kul’ as *L. lagotis* var. *costulata*.

Type locality. Uzbekistan, Tashkent City, leg. A.P. Fedchenko.

Current taxonomic allocation. *Radix* (*Peregriana*) *lagotis* (Schrank, 1803) or *Radix* (*Radix*) sp.

Remark. In 1897, von Martens (1897a) described a new variety *Limnaea javanica* var. *costulata* from Indonesia (Java Island). I was not able to find the type series of it in ZMB collection.

cubensis Pfeiffer, 1839

Fig. 12

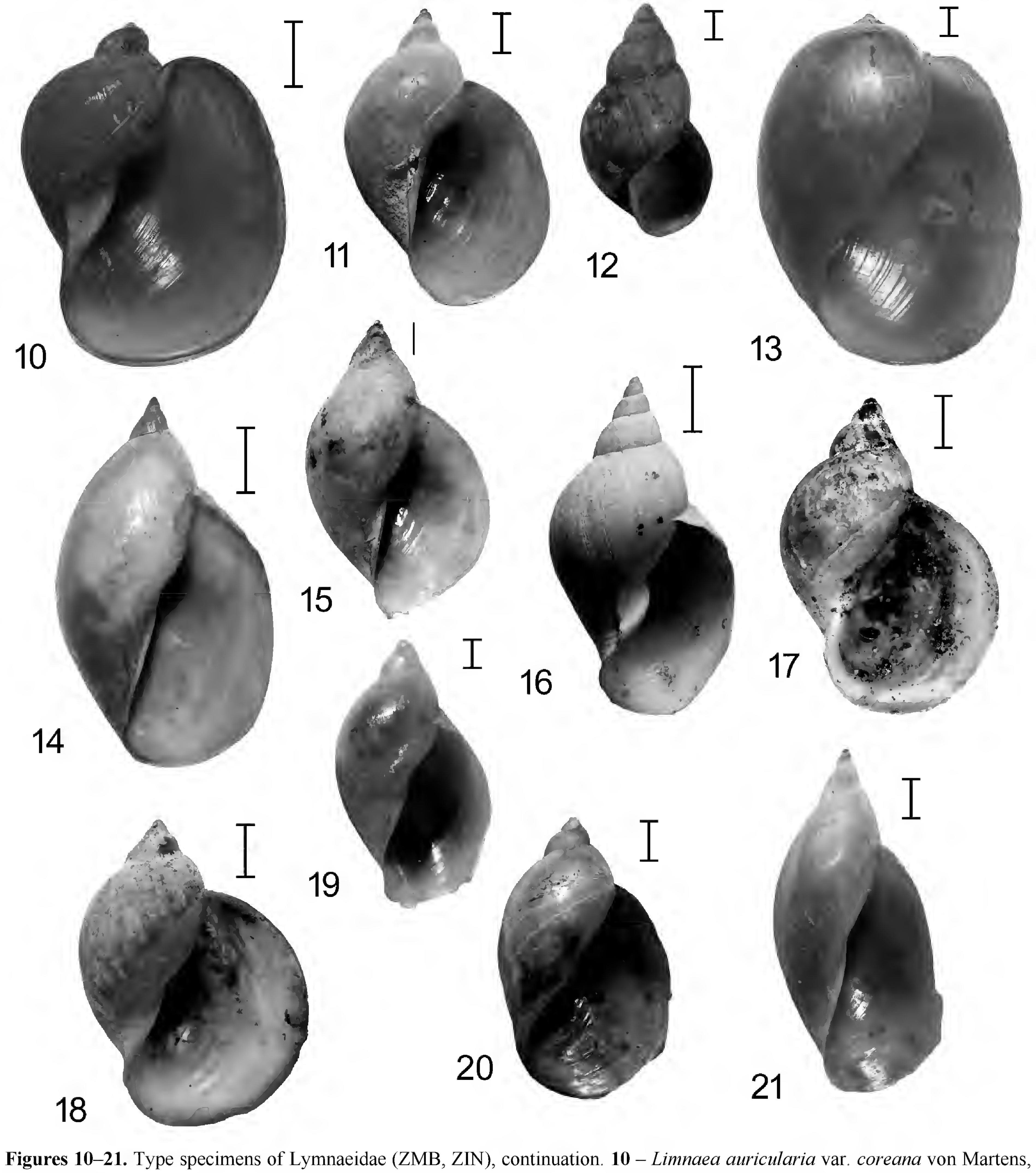
Limnaeus cubensis Pfeiffer 1839: 354.
Limnaeus cubensis Küster 1862: 32, pl. 6, figs 6–8.
Limnaea cubensis von Martens 1899: 378.
Galba (*Galba*) *cubensis* Baker 1911: 204, pl. 27, figs 9–16.
Lymnaea cubensis Hubendick 1951: 128, fig. 310.
Limnaeus cubensis Kilias 1961: 163.
Fossaria (*Bakerilymnaea*) *cubensis* Burch 1989: 174, fig. 587.
Fossaria cubensis Pointier et al. 2005: 38, textfigs

Type material. Two syntypes kept under No. 101522. leg. Pfeiffer.

Type locality. “Cuba”, without precise location.

Syntypes dimensions. (1) WN 5.25; SH 8.1; SW 4.4; SpH 4.5; BWH 5.9; AH 3.8; SW 3.1; (2) WN 5.25; SH 7.6; SW 4.1; SpH 4.1; BWH 5.2; AH 3.6; SW 2.7.

Current taxonomic allocation. *Galba* (*Bakerilymnaea*) *cubensis*. Some authors place this species into the genus *Fossaria* Westerlund, 1885.



Figures 10–21. Type specimens of Lymnaeidae (ZMB, ZIN), continuation. **10** – *Limnaea auricularia* var. *coreana* von Martens, 1886, a syntype. **11** – *Limnaea lagotis* var. *costulata*. **12** – *Limnaea cubensis* Pfeiffer, 1839, a syntype. **13** – *Amphipeplea cumingiana* Pfeiffer, 1845, a probable syntype (ZMB No. 109771). **14** – *Limnaea amygdalum* var. *cycacea* Troschel, 1837, a syntype. **15** – *Limnaea elmeteitensis* Smith, 1894, a syntype. **16** – *Stagnicola elrodi* Baker & Henderson, 1933, a syntype. **17** – *Limnaea ovata* var. *eversa* von Martens, 1882, the lectotype. **18** – *Limnaea ovata* var. *eversa* von Martens, 1882, a paralectotype. **19** – *Limnaeus natalensis* var. *exsertus* von Martens, 1966, the syntype. **20** – *Amphipeplea ampulla* var. *globosa* Suter, 1891, a syntype. **21** – *Limnaea acuminata* var. *gracilior* von Martens, 1881, the syntype. Scale bars: 1 mm (12, 19), 2 mm (**11, 13, 15–18, 20, 21**), 5 mm (**10, 14**). All shells are from ZMB collection, except of 17 (ZIN).

cumingiana (*cumingi*) Pfeiffer, 1845

Fig. 13

Amphipeplea cumingiana Pfeiffer 1845: 68.
Amphipeplea cumingi Pfeiffer 1854–1860: 5, pl. II, figs 3-4.
Lymnaea cumingiana Hubendick 1951: 162, fig. 355.

Type material. Two probable syntypes from Luzon Island kept under No. 109771. leg. Dunker ex coll. Pfeiffer. Another probable syntype from the same island is under No. 109772. The largest of these specimens is 26.1 mm height. The labels bear no information about the nomenclatorial status of the shells, and their identification as probable syntypes may be questioned. The species name on the labels is spelled as "*Amphipeplea cumingi*" (see Remark below).

Type locality. Philippines, island of Luzon, Naga, province of South Camerines. leg. Cuming.

Current taxonomic allocation. *Bullastra cumingiana*.

Remark. Originally, Pfeiffer (1845) described this species as *Amphipeplea cumingiana* but later he re-named it *A. cumingi*.

cycacea Troschel, 1837

Fig. 14

Limnaea amygdalum var. *cycacea* Troschel 1837: 170.
Lymnaea auricularia race *rufescens* Hubendick 1951: 157, fig. 344.

Type material. Five syntypes kept under No. 109768.

Type locality. India, the Ganges River.

Current taxonomic allocation. *Radix* (*Radix*) *rufescens* (Gray, 1822).

elmeteitensis Smith, 1894

Fig. 15

Limnaea elmeteitensis Smith 1894: 167, fig. 5.
Lymnaea elmeteitensis Hubendick 1951: 59, fig. 74.
Limnaea elmeteitensis Kilias 1961: 163.
Lymnaea natalensis Brown 1994: 166, fig. 76 a, b; 79a.

Type material. Three syntypes of *L. elmeteitensis* kept under No. 47554. The largest of them is 21.2 mm height. The rest of the type series is, probably, in BMNH.

Type locality. Kenya, lakes Baringo and Elmeteita.

Current taxonomic allocation. *Radix* (*Radix*) *natalensis* (Krauss, 1848).

elrodi Baker & Henderson, 1933

Fig. 16

Stagnicola elrodi Baker and Henderson 1933: 30.

Type material. ZMB collection possesses two syntypes kept under No. 90525. Other syntypes are in the University of Illinois Museum of Natural History (No. Z33780) and the University of Colorado Museum (No. 19134) [fide Baker and Henderson 1933].

Type locality. USA, Montana, west shore Flathead Lake, 13 1/2 miles north of Poison.

The largest ZMB syntype dimensions. WN 5.25; SH 16.3; SW 8.6; SpH 7.6; BWH 13.2; AH 10.2; SW 5.8.

Current taxonomic allocation. Hubendick (1951) identified *S. elrodi* with *Lymnaea emarginata* (Say, 1821). It should be noted, however, the ZMB syntypes resemble closely a subadult shell of the Holarctic *L. stagnalis*.

eversa von Martens, 1882

Figs 17, 18

Limnaea ovata var. *eversa* von Martens 1882: 35, pl. 4, fig. 7.
Limnaea auricularia var. *eversa* Zhadin 1933: 96, fig. 39.
Lymnaea eversa Starobogatov & Streletzkaya 1967: 231, fig. 18.

Type material. The lectotype of *L. ovata* var. *eversa* (see Fig. 17) was designated by Starobogatov and Streletzkaya (1967). It is housed in ZIN (No. 2 in systematic catalogue). ZIN collection contains also 25 paralectotypes (No. 1 in systematic catalogue). Other 19 paralectotypes (adult and juvenile shells) are in ZMB (accession number 34822).

Type locality. Northern Mongolia, Eter River near Dzha-Dzassyk Monastery. leg. Potanin, 1877.

Current taxonomic allocation. *Radix* (*Peregriana*) *balthica* (L., 1758). Most of the syntypes correspond to the species *Lymnaea* (*Peregriana*) *intermedia* Lamarck, 1822 sensu Kruglov 2005 = *R. balthica* s. lato.

ZMB paralectotypes dimensions. See Table 1.

exsertus von Martens, 1866

Fig. 19

Limnaeus natalensis var. *exsertus* von Martens 1866: 101, pl. 3, figs 8, 9.
Limnaeus natalensis var. *exsertus* Clessin 1886: 400.
Limnaea exserta von Martens 1897b: 136, pl. 6, fig. 7.
Lymnaea natalensis Hubendick 1951: 158, figs 345–347.
Lymnaea natalensis Brown 1994: 166, fig. 76 a, b; 79a.

Type material. A single shell (the syntype) is kept under No. 8586. This shell has 9.4 mm height.

Type locality. Ethiopia (Abyssinia), Aiz Zaba spring near Zasaga.

Current taxonomic allocation. *Radix* (*Radix*) *natalensis* (Krauss, 1848).

globosa Suter, 1891

Fig. 20

Amphipeplea ampulla var. *globosa* Suter 1891: 93, pl. 18, figs 12a–c.
Amphipeplea ampulla var. *globosa* Suter 1893: 231.
Amphipeplea ampulla var. *globosa* Suter 1913: 608.
Simlimnaea tomentosa Dell 1956: 76, figs 33–48.
Amphipeplea ampulla var. *globosa* Kilias 1967: 339.
Lymnaea tomentosa tomentosa Climo and Pullan 1972: 8, fig. 1, C–I.

Type material. There are three syntypes in ZMB kept under No. 47040. The largest of them is 11.6 height. Another syntype is housed in the Museum of New Zealand (Te Papa Tongarewa) under accession number M 125108. leg. Suter.

Type locality. New Zealand, Southern Island, Governors Bush, Hooker Valley.

Current taxonomic allocation. *Austropeplea tomentosa* (Pfeiffer, 1855) [fide Climo and Pullan 1972].

gracilior von Martens, 1881

Fig. 21

Limnaea acuminata var. *gracilior* von Martens 1881: 77.
Limnaea acuminata var. *gracilior* Preston 1915: 109.
Lymnaea auricularia race *rufescens* Hubendick 1951: 157, fig. 344.
Lymnaea (*Pseudosuccinea*) *acuminata* Subba Rao 1989: 126, figs 254–265, 272.

Type material. There is a single specimen (the syntype) of *L. acuminata* var. *gracilior* in ZMB (accession number 9362). Its shell height is equal to 22.5 mm (von Martens reported SH = 24.0 mm).

Type locality. India, Bengal (without precise location).

Current taxonomic allocation. *Radix* (*Radix*) *rufescens*.

gutta Villa & Villa, 1871

Fig. 22

Limnaea gutta Villa and Villa 1871: 92 (nomen nudum).
Limnaea gutta Kilias, 1967: 339.

Type material. There is a single specimen (syntype) of *L. gutta* in ZMB (accession number 17739). Its shell height is equal to 6.6 mm.

Type locality. Italy, Lombardy (from the Villa and Villa's work title).

Current taxonomic allocation. The syntype of *L. gutta* may be identified as a juvenile *R.* (*Peregriana*) sp. Possibly, this shell belongs to *R. balthica* or *R. ampla* (Hartmann, 1821).

Remark. Villa and Villa (1871) published this species name without diagnosis or other information that would make it available under article 12 of the International Codex of Zoological Nomenclature.

humerosa von Martens, 1897

Fig. 23

Limnaea humerosa von Martens 1897b: 135, pl. 6, fig. 1.
Lymnaea natalensis Hubendick 1951: 158, figs 345–347.
Limnaea humerosa Kilias 1961: 163.
Lymnaea natalensis Brown 1994: 166, figs 76 a, b; 79a.

Type material. The lectotype (ZMB No. 101518) and six paralectotypes (No. 101519) in ZMB collection. The lectotype was designated by Kilias (1961), its shell height is 23.4 mm.

Type locality. Uganda, Mengo, in an artificial pond leg. Stuhlmann (05.01.1891) – locality of the lectotype. von Martens (1897b) mentioned more locations of this species in Uganda and other regions of East Africa.

Current taxonomic allocation. *Radix* (*Radix*) *natalensis*.

impedita Baker, 1934

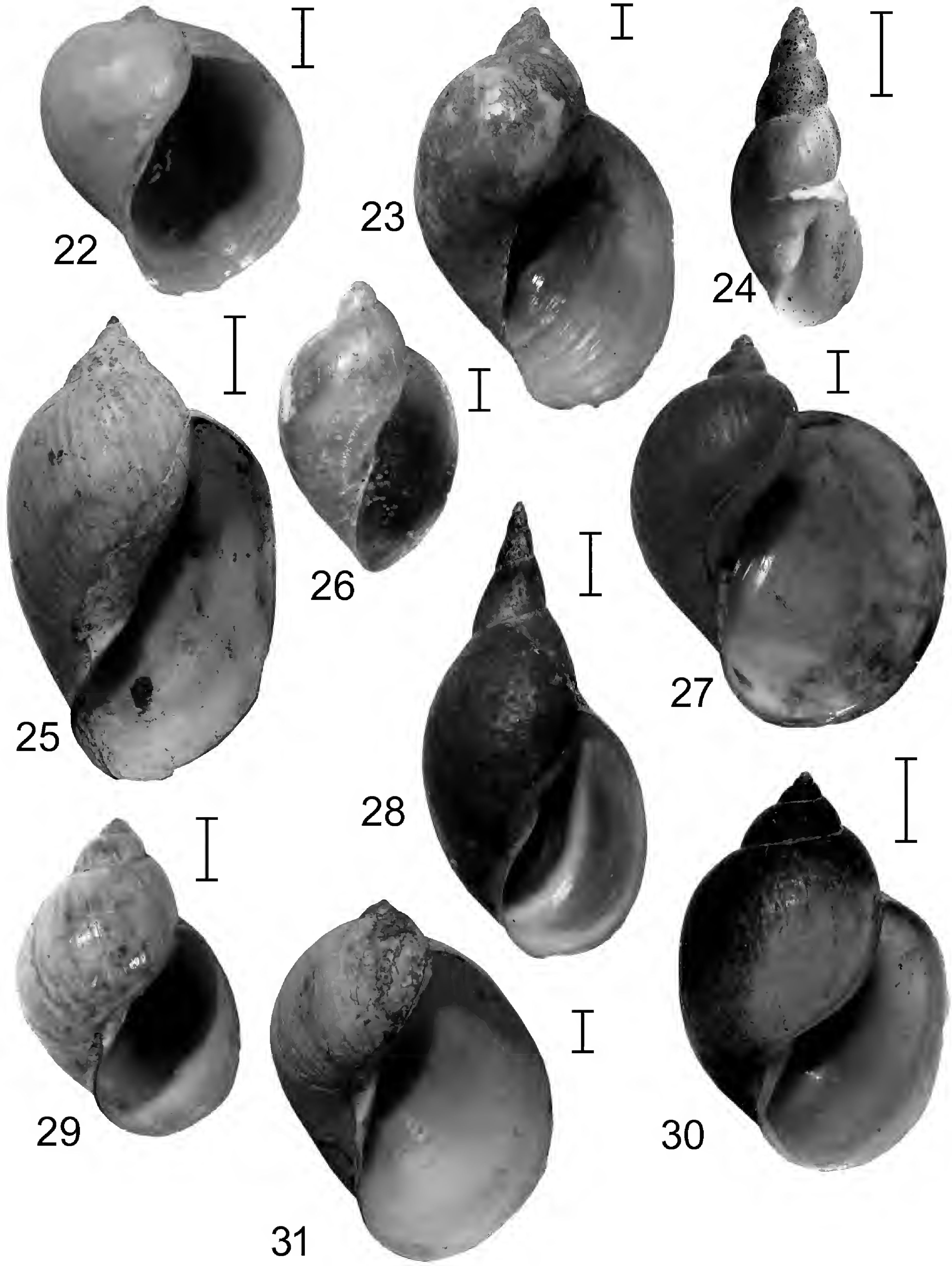
Fig. 24

Stagnicola impedita Baker 1934: 20.
Stagnicola impedita Kilias 1961: 163.

Type material. Originally, the type series consisted of four specimens (the holotype and three paratypes) housed in the Geological Department of the Stanford University under accession number 5776 (Baker 1934). Later, two of the paratypes were given to ZMB and are kept now under No. 90524. Their label contains an indication that the shells origin "from type lot". The larger of two shells is 12.8 mm height that a little less than size reported by Baker (1934).

Type locality. USA, Utah, near Logan, Cash Co.

Current taxonomic allocation. Hubendick (1951) believe *S. impedita* to be a synonym of *Lymnaea palustris* (O.F. Müller, 1774), but it is incredible since this Palearctic species does not live in North America (Burch 1989; Johnson et al. 2013).



Figures 22–31. Type specimens of Lymnaeidae (ZMB), continuation. **22** – *Limnaea gutta* Villa & Villa, 1871, the syntype. **23** – *Limnaea humerosa* von Martens, 1897, the lectotype. **24** – *Stagnicola impedita* Baker, 1934, a paratype. **25** – *Limnaeus javanicus* var. *intumescens* von Martens, 1867, a syntype. **26** – *Limnaea kempi* Preston, 1911, the syntype. **27** – *Limnaea limosa* var. *ovata* f. *margaritacea* Westerlund, 1865, a syntype. **28** – *Limnaea stagnalis* var. *westerlundi* f. *nereni* Westerlund, 1894, a syntype. **29** – *Limnaea nitidella* von Martens, 1885, the lectotype. **30** – *Limnaeus nucleus* Troschel, 1837, a syntype. **31** – *Limnaea nyansae* von Martens, 1892, a syntype. Scale bars: 1 mm (**22, 26, 29**), 2 mm (**23, 24, 27, 31**), 5 mm (**25, 28, 30**).

intumescens von Martens, 1867

Fig. 25

Limnaeus javanicus var. *intumescens* von Martens 1867: 223.
Limnaea javanica var. *intumescens* von Martens 1881: 88, pl. 16, figs 2, 3.
Limnaea javanica var. *intumescens* von Martens 1897a: 3.
Limnaea javanica var. *intumescens* Kilias 1961: 163.

Type material. Three shells of syntypes collected in Surabaya (Java Island, Indonesia) and kept under No. 8140. The largest of these shells reaches 26.6 mm height. Kilias (1961) reported that he intended one of these shells to become the lectotype of *Limnaeus javanicus* var. *intumescens* and separated it under accession number 8140a, however I was not able to find this specimen in ZMB collection. Probably, it is still placed among other syntypes under No. 8140.

Type locality. Indonesia: Java Island (Surabaya, Passuruan, Rogodjampi). leg. von Martens and Zollinger.

Current taxonomic allocation. *Cerasina luteola*. Hubendick (1951) synonymized *L. javanica* var. *intumescens* with the race *rubiginosa* of *Radix auricularia*.

kempi Preston, 1912

Fig. 26

Limnaea kempi Preston 1912: 190, pl. 32, fig. 1.
Lymnaea natalensis Hubendick 1951: 158, figs 345–347.
Limnaea kempi Kilias 1961: 163.
Lymnaea natalensis Brown 1994: 166, figs 76 a, b; 79a.

Type material. A single (subadult) specimen, the syntype, is kept in ZMB under accession number 62382. Its shell height is 7.4 mm.

Type locality. East Africa, Victoria Lake.

Current taxonomic allocation. *Radix* (*Radix*) *natalensis*.

margaritacea Westerlund, 1865

Fig. 27

Limnaea limosa var. *ovata* f. *margaritacea* Westerlund 1865: 91.
Limnaea lagotis var. *margaritacea* Westerlund 1873: 334.
Limnaea lagotis var. *margaritacea* Westerlund 1885: 34.
Limnaea lagotis var. *margaritacea* Kilias 1961: 164.

Type material. Two syntypes are kept in ZMB under accession number 49531. The largest of them is 18.5 height. The other syntypes are in ZIN (No. 1 in systematic catalogue) and NMG (accession number 3690).

Type locality. Ronneby, Sweden.

Current taxonomic allocation. Most probably, *Radix* (*R.*) *auricularia*.

nereni Westerlund, 1894

Fig. 28

Limnaea stagnalis var. *westerlundi* f. *nereni* Westerlund 1894: 196.
Lymnaea stagnalis Hubendick 1951: 118, figs 299–300.
Limnaea stagnalis var. *westerlundi* f. *nereni* Kilias 1967: 339.
Lymnaea stagnalis Glöer 2002: 222, fig. 250.

Type material. Two syntypes are kept in ZMB under accession number 49527. The largest of them is nearly 40 mm of height (the shell apex is broken). The four other syntypes are in ZIN (No. 1 in systematic catalogue). Possibly, some syntypes will be found in NMG.

Type locality. Skeninge, Sweden.

Current taxonomic allocation. *Lymnaea* (*Lymnaea*) *stagnalis*.

nitidella von Martens, 1885

Fig. 29

Limnaea nitidella von Martens 1885: 178, pl. 35, figs 16, 17.
Limnaea nitidella Kilias 1961: 164.

Type material. The lectotype (designated by Kilias 1961) and 18 paralectotypes (ZMB No. 35593).

Type locality. Ecuador, region of Chorrera de Agoyan (von Martens 1885).

Lectotype dimensions. WN 3.75; SH 7.8; SW 5.1; SpH 2.9; BWH 6.5; AH 5.0; SW 3.3.

Current taxonomic allocation. Uncertain. Hubendick (1951) treated it as a species of unclear identity (possibly no lymnaeid). In my opinion, *L. nitidella* is similar to another lymnaeid species described from Ecuador, *L. cousini* (Jousseaume, 1887) [see conchological characterization of this species in Paraense 1995; Pointier et al. 2004] and may represent its senior objective synonym.

nucleus Troschel, 1837

Fig. 30

Limnaeus nucleus Troschel 1837: 171.
Limnaea acuminata var. *nucleus* von Martens 1881: 82, pl. 15, figs 8, 9.
Limnaeus nucleus Clessin 1886: 378, pl. 50, fig. 6.
Limnaea acuminata var. *nucleus* Preston 1915: 109.
Limnaea luteola f. *ovalis* Annandale and Rao 1925: 184, fig. IV (2)

Type material. Ten syntypes are kept in ZMB under accession number 8051. The largest syntype's shell is 23.0 mm height.

Type locality. India, the Ganges River.

Current taxonomic allocation. A junior synonym of *Cerasina luteola*.

nyansae von Martens, 1892

Fig. 31

Limnaea nyansae von Martens 1892: 16.
Lymnaea nyansae Hubendick 1951: 60, fig. 76.
Limnaea nyansae Kilias 1961: 164.
Lymnaea natalensis Brown 1994: 166, figs 76 a, b; 79a.

Type material. 16 shells (syntypes) from the type locality are kept in ZMB under accession number 101521. Kilias (1961) reported that he intended one of these shells to be the lectotype of *Limnaea nyansae* and separated it under No. 101521a, however I was not able to find this specimen in ZMB collection. Probably, it is still placed among other syntypes under No. 101521. The largest shell in this sample reaches 15.3 mm height.

Type locality. The western shore of the Victoria Lake, near Bukoba and Towalio.

Current taxonomic allocation. *Radix* (*Radix*) *natalensis*.

obesus von Martens, 1867

Fig. 32

Limnaeus javanicus var. *obesus* von Martens 1867: 223.
Limnaea javanica var. *obesa* von Martens 1881: 87, pl. 16, fig. 1.
Limnaeus javanicus var. *obesus* Kilias, 1961: 164, fig. 5.

Type material. 14 shells of syntypes collected in Indonesia and kept under No. 8124. The largest of these shells reaches 27.0 mm height. Kilias (1961) reported that he intended one of these shells to be the lectotype of *Limnaeus javanicus* var. *obesus* and separated it under accession number 8124a, however I was not able to find this specimen in ZMB collection. Probably, it is still placed among other syntypes under No. 8124.

Type locality. Indonesia: Java Island (Telaga, Patengan). leg. Baron von Richthofen.

Current taxonomic allocation. *Cerasina luteola*. Hubendick (1951) synonymized *L. javanica* var. *obesus* with the race *rubiginosa* of *Radix auricularia*.

obliquatus von Martens, 1864

Fig. 33

Limnaeus obliquatus von Martens 1864b: 116, pl. 3, figs 9–10.
Limnaea auricularia var. *obliquata* Zhadin 1933: 96, fig. 38.
Radix auricularia var. *obliquata* Zhadin 1952: 168, figs 65, 66.
Lymnaea (*Radix*) *obliquata* Kruglov and Starobogatov 1993: 88, fig. 13B.

Type material. Two syntypes (ZMB no. 7164). leg. Semenov.

Type locality. "Im Landsee Issyk-Kul am Nordabhang des Thienschan, 4691′ Pariser Fuss über der Meere, 43° N.B" = Kyrgyzstan, nothern shore of the Issyk-Kul' Lake.

Current taxonomic allocation. *Radix* (*Radix*) *obliquata*.

Syntypes dimensions. (1) WN 3.75; SH 27.1; SW 25.2; SpH 7.3; BWH 26.3; AH 23.3; SW 16.8; (2) WN 4.12; SH 28.8; SW 25.8; SpH 6.8; BWH 27.4; AH 22.4; SW 17.6.

Remarks. The type series has been overlooked by Kilias (1961, 1967). Hubendick (1951) considered *L. obliquata* as a junior synonym of *R. auricularia*, whereas the Russian authors (Kruglov and Starobogatov 1993; Kantor et al. 2010) accept its validity.

patulus Troschel, 1837

Fig. 34

Limnaeus patulus Troschel 1837: 167.
Limnaeus patulus Clessin 1886: 378, pl. 50, fig. 3.
Limnaea acuminata var. *patula* Preston 1915: 107.
Limnaea acuminata var. *patula* Annandale and Rao 1925: 181, fig. III (9).
Lymnaea auricularia race *rufescens* Hubendick 1951: 157, fig. 344.
Lymnaea acuminata f. *patula* Subba Rao 1989: 127, figs 256, 257.

Type material. The syntypes of *L. patulus* in ZMB are placed in two samples: No. 8044 (25 syntypes) and 72990 (a single syntype). leg. Lamare Piquot.

Type locality. India, the Ganges River.

Current taxonomic allocation. *Radix* (*Radix*) *rufescens*.

Syntypes dimensions. See Table 1.

pervius von Martens, 1867

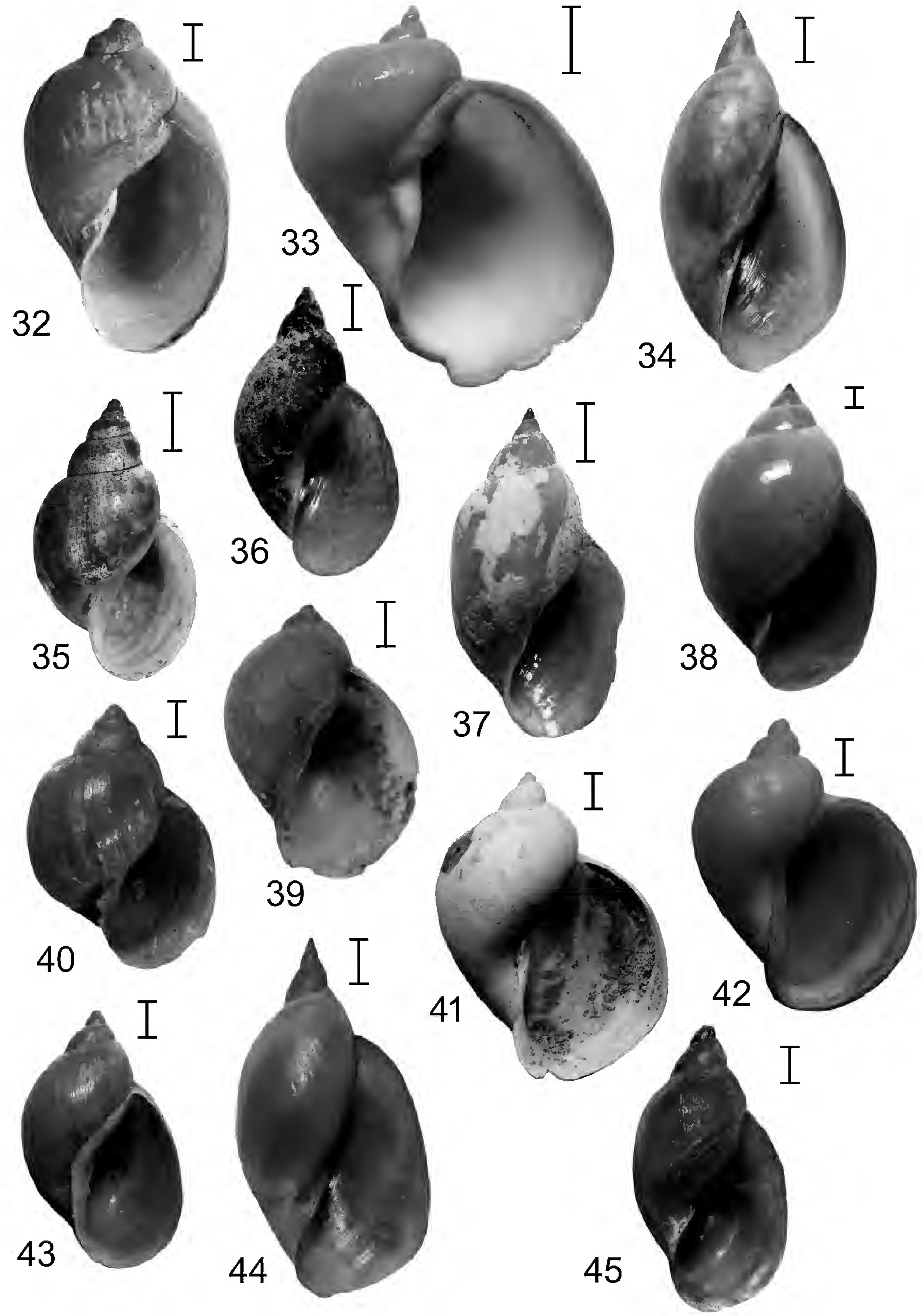
Fig. 35

Limnaeus pervius von Martens 1867: 221.
Limnaea pervia von Martens 1882: 40, pl. 4, fig. 11.
Limnaeus pervia Clessin 1886: 388, pl. 53, fig. 6.
Lymnaea pervia Hubendick 1951: 94, figs 234-235, 248-250.
Galba pervia Zhadin 1952: 176, fig. 77.
Limnaeus pervius Kilias 1961: 164.

Type material. The lectotype (designated by Kilias 1961) and 175 paratypes are kept in ZMB under accession numbers 8143a (the lectotype) and 8143b. The height of the lectotype shell is 11.4 mm.

Type locality. Northern China, Chi-foo (= Tschifu). leg. Schottmüller.

Current taxonomic allocation. *Orientogalba hookeri* (Reeve, 1850).



Figures 32–45. Type specimens of Lymnaeidae (ZMB), continuation. **32** – *Limnaeus javanicus* var. *obesus* von Martens, 1867, a syntype. **33** – *Limnaeus obliquatus* von Martens, 1864, a syntype. **34** – *Limnaeus patulus* Troschel, 1837, a syntype. **35** – *Limnaeus pervius* von Martens, 1867, the lectotype. **36** – *Limnaea pettiti* Jones & Preston, 1904, a syntype. **37** – *Limnaea javanica* var. *porrecta* von Martens, 1881, a syntype. **38** – *Limnaeus prunum* Troschel, 1837, a syntype. **39** – *Limnaea ovata* var. *sericina* Westerlund, 1890, a syntype. **40** – *Limnaea shantungensis* Jones & Preston, 1904, a syntype. **41** – *Limnaea ovata* var. *solidior* von Martens, 1882, a syntype. **42** – *Limnaea lagotis* var. *solidissima* Kobelt, 1872, a syntype. **43** – *Limnaea solidulus* Villa & Villa, 1871, a syntype. **44** – *Limnaea amygdalum* var. *straminea* Troschel, 1837, a syntype. **45** – *Limnaea javanica* var. *subteres* von Martens, 1881. Scale bars – 1 mm (**40**), 2 mm (**32, 35, 36, 38, 39, 42–43, 45**), 5 mm (**33, 34, 37, 44**).

Table 1. Measurements of shells of syntypes of some lymnaeid species described by von Martens (ZMB). Above lines – limits of variation, below the lines – means ± standard deviations.

Character / index	***Limnaea auricularia* var. *coreana***		***Limnaea eversa* No. 34822 (n = 10)**	***Limnaeus patulus* No. 8044 (n = 25)**
	No. 38440 (n = 7)	**No. 55594 (n = 4)**		
Whorls number	3.5 – 3.75 3.62 ± 0.11	3.50 ± 0.00	3.87 – 4.50 4.08 ± 0.21	5.00 – 5.50 5.20 ± 0.13
SH, mm	24.8 – 29.4 27.9 ± 1.5	27.5 – 31.8 28.9 ± 2.0	14.4 – 17.3 15.7 ± 1.0	34.6 – 44.4 39.0 ± 2.9
SW, mm	18.2 – 23.6 21.3 ± 1.7	22.1 – 26.5 23.7 ± 2.0	10.4 – 12.3 11.2 ± 0.6	16.2 – 24.6 18.9 ± 2.3
SpH, mm	3.4 – 5.4 4.4 ± 0.7	3.3 – 7.1 4.7 ± 1.7	4.3 – 5.9 4.9 ± 0.5	9.8 – 16.6 13.0 ± 1.7
BWH, mm	22.8 – 27.3 25.6 ± 1.5	22.1 – 29.9 25.4 ± 3.5	12.8 – 15.2 13.7 ± 0.8	29.4 – 39.3 33.7 ± 2.8
AH, mm	20.2 – 27.4 24.5 ± 2.4	24.8 – 26.7 25.9 ± 0.8	11.2 – 13.4 12.2 ± 0.8	24.8 – 33.8 28.2 ± 2.6
AW, mm	14.6 – 19.8 17.8 ± 1.6	18.2 – 19.2 18.8 ± 0.4	8.2 – 10.0 8.9 ± 0.8	11.8 – 19.1 14.5 ± 2.2
SW/SH	0.73 – 0.80 0.76 ± 0.03	0.79 – 0.85 0.82 ± 0.03	0.68 – 0.77 0.72 ± 0.02	0.42 – 0.55 0.48 ± 0.03
SpH/SH	0.14 – 0.20 0.16 ± 0.02	0.12 – 0.22 0.16 ± 0.04	0.27 – 0.35 0.31 ± 0.02	0.24 – 0.39 0.48 ± 0.04
BWH/SH	0.90 – 0.93 0.92 ± 0.01	0.79 – 0.94 0.88 ± 0.07	0.84 – 0.89 0.87 ± 0.02	0.82 – 0.89 0.86 ± 0.02
AH/SH	0.80 – 0.95 0.89 ± 0.05	0.84 – 0.93 0.90 ± 0.04	0.73 – 0.81 0.78 ± 0.03	0.66 – 0.80 0.72 ± 0.03
AW/AH	0.70 – 0.79 0.73 ± 0.03	0.70 – 0.76 0.73 ± 0.02	0.64 – 0.78 0.74 ± 0.05	0.49 – 0.64 0.51 ± 0.04

pettiti Jones & Preston, 1904

Fig. 36

Limnaea (*Gulnaria*) *pettiti* Jones and Preston 1904: 142, fig. 3.
Lymnaea pettiti Hubendick 1951: pl. IV, fig. 12.
Limnaea pettiti Kilias 1961: 164.

Type material. ZMB collection contains a single syntype (accession number 59228), its shell height is 13.4 mm. Hubendick (1951, pl. IV, fig. 12) illustrated the “type” (? syntype) of this species (BMNH collection).

Type locality. East China, “near Chefoo, Shantung” (= Shandong Province).

Current taxonomic allocation. Possibly, a synonym of *Radix* (*Radix*) *plicatula* (Benson, 1842).

porrecta von Martens, 1881

Fig. 37

Limnaea javanica var. *porrecta* von Martens 1881: 89, figs 9, 10.
Limnaea javanica var. *porrecta* von Martens 1897a: 5.
Limnaea javanica var. *porrecta* Kilias 1961: 165.

Type material. There are 14 shells of this variety collected from the type locality in ZMB (No. 8135). The largest syntype is 28.7 mm height. Kilias (1961) reported that he intended one of these shells to be the lectotype of *Limnaeus javanicus* var. *porrecta* and separated it under accession number 8135a, however I was not able to find this specimen in ZMB collection.

Type locality. Timor Island, Kupang. leg. E. von Martens, December 1862.

Current taxonomic allocation. *Cerasina luteola* (Lamarck, 1822).

prunum Troschel, 1837

Fig. 38

Limnaeus prunum Troschel 1837: 170.
Limnaea acuminata var. *prunum* Preston 1915: 108.
Limnaeus prunum Kilias 1961: 165.

Type material. 12 syntypes of *L. prunum* in ZMB are kept in two samples: No. 101523 (11 syntypes) and 72998 (a single syntype), leg. Lamare Piquot. The shell height of the largest syntype is 27.4 mm.

Type locality. India, the Ganges River (Troschel 1837). The label of the syntypes is “Ganges, Bengalien”.

Current taxonomic allocation. *Cerasina luteola* (Lamarck, 1822).

sericina Westerlund, 1890

Fig. 39

Limnaea (*Gulnaria*) *ovata* var. *sericina* Westerlund 1890: 147.
Limnaea ovata var. *sericina* Kilias 1967: 340.

Type material. Five syntypes are kept in ZMB under accession number 49529. The largest of them is 13.2 height. The other syntypes are in NMG (accession number 3726).

Type locality. Ronneby, Sweden.

Current taxonomic allocation. Most probably, *Radix* (*P.*) *balthica*.

Remark. The syntypes (ZMB No. 49529) are labelled as "*Limnaea ovata* var. *sericea*", not *sericina* as in Westerlund (1890).

shantungensis Jones & Preston, 1904

Fig. 40

Limnaea (*Gulnaria*) *shantungensis* Jones and Preston 1904: 142, fig. 4.
Lymnaea shantungensis Hubendick 1951: pl. IV, fig. 10.
Limnaea shantungensis Kilias 1961: 165.

Type material. ZMB collection contains a single syntype (accession number 59227), its shell height is 8.1 mm. Hubendick (1951, pl. IV, fig. 10) illustrated the "type" (? syntype) of this species (BMNH collection). Another syntype is kept in NHMV (accession number 40698).

Type locality. East China, "Shantung, Wei Hai Wei" (= Shandong Province).

Current taxonomic allocation. *Orientogalba viridis* (Quoy & Gaimard, 1834).

solidior von Martens, 1882

Fig. 41

Limnaea ovata var. *solidior* von Martens 1882: 34, pl. 4, fig. 6.

Type material. ZMB collection contains seven syntypes (accession number 34817). The size of the syntypes is very different; the largest shell of this sample is 16.8 height.

Type locality. Northwestern China, Dzungaria, Ulungur River. leg. A. Regel, 1879.

Current taxonomic allocation. Possibly, *Radix* (*Peregriana*) *lagotis*.

solidissima Kobelt, 1872

Fig. 42

Limnaea lagotis var. *solidissima* Kobelt 1872: 77, pl. 2, figs 7, 8.
Limnaea lagotis var. *solidissima* Kobelt 1877: 38, pl. 118, fig. 1242.
Limnaea lagotis var. *solidissima* Annandale and Rao 1925: 154, fig. I (3, 5).

Type material. ZMB collection contains a single syntype (accession number 20416).

Type locality. East India, Himalaya Mts. (without precise location).

Syntype dimensions. WN 4.00; SH 17.4; SW 13.2; SpH 6.6; BWH 15.3; AH 12.9; SW 8.8.

Current taxonomic allocation. *Radix* (*Peregriana*) *lagotis*.

solidulus Villa & Villa, 1871

Fig. 43

Limnaea solidulus Villa and Villa 1871: 92 (nomen nudum).
Limnaea solidulus Kilias, 1967: 340.

Type material. There is a single specimen (syntype) of *L. solidulus* in ZMB (accession number 8192). Its shell height is equal to 14.1 mm.

Type locality. Italy, Brescia (from the syntype label).

Current taxonomic allocation. The syntype of *L. solidulus* may be identified as a juvenile *R.* (*Peregriana*) *balthica* = *Lymnaea intermedia* Lamarck, 1822 sensu Kruglov 2005.

Remark. Villa and Villa (1871) published this species name without diagnosis or other information that would make it available under article 12 of the International Codex of Zoological Nomenclature.

straminea Troschel, 1837

Fig. 44

Limnaea amygdalum var. *straminea* Troschel 1837: 169.
Lymnaea auricularia race *rufescens* Hubendick 1951: 157, fig. 344.

Type material. 31 syntypes kept in ZMB under No. 8047. The largest of them is of 35.4 mm height. There is another sample of this variety collected from the type locality in ZMB (without accession number). It contains two probable syntypes.

Type locality. India, the Ganges River.

Current taxonomic allocation. *Radix* (*Radix*) *rufescens* (Gray, 1822).

subulatus Dunker in Küster, 1862

Fig. 46

Limnaeus subulatus Küster 1862: 24, pl. 4, fig. 24.
Limnaeus subulatus Clessin 1886: 395, pl. 16, figs 1, 2.

Type material. 11 shells from the type locality in three samples: no. 4613 and two without numbers. One of these shells (see fig. 45) is separated and marked as belonging to the type collection (a syntype). The rest of specimens are not formally labeled as syntypes but probably also origin from the type series.

Type locality. Mexico, in Zimapan and Lake of Mexico (Küster 1862). leg. Albers, Dunker.

Current taxonomic allocation. *Ladislavella* (*Walterlymnaea*) *elodes* (Say, 1821).

Syntype dimensions. WN 7.75; SH 32.2; SW 9.6; SpH 22.1; BWH 18.3; AH 11.8; SW 6.6.

Remarks. Not discussed by Kilias (1961, 1967). Hubendick (1951) considered it to be a synonym of *Stagnicola palustris* that is apparently wrong since the latter species does not live in North America (Burch 1989; Johnson et al. 2013). Baker (1911) synonymized *L. subulatus* with *Stagnicola attenuata* (Say, 1829) that seems to be more reliable. Currently, *S. attenuata* is treated as identical with *Stagnicola elodes* (Say, 1821), placed by Vinarski (2012) into the subgenus *Walterlymnaea* Starobogatov & Budnikova, 1976 of the genus *Ladislavella* B. Dybowski, 1913.

subteres von Martens, 1881

Fig. 45

Limnaea javanica var. *subteres* von Martens 1881: 88, figs 6, 7.
Limnaea javanica var. *subteres* von Martens 1897a: 4.
Limnaea javanica var. *subteres* Kilias 1961: 165.

Type material. There is a single shell of this variety in ZMB (kept under No. 101520). Kilias (1961) regarded it as the holotype (by monotypy). Its shell height is 17.1 mm.

Type locality. Indonesia, Sumatra Island, Palembang. leg. E. von Martens.

Current taxonomic allocation. Possibly, a synonym of *Radix* (*Radix*) *rubiginosa* (see Hubendick 1951).

sulcatulus Troschel, 1837

Fig. 47

Limnaeus sulcatulus Troschel 1837: 167.
Limnaea acuminata var. *sulcatula* Preston 1915: 107.
Lymnaea auricularia race *rufescens* Hubendick 1951: 157, fig. 344.

Type material. Three samples in ZMB collection contain the syntypes of *L. sulcatulus*: No. 8046 (eight syntypes), No. 109764 (one syntype), and No. 109765 (one syntype). The largest's syntype shell heiht is 41.1 mm.

Type locality. India, the Ganges River.

Current taxonomic allocation. *Radix* (*Radix*) *rufescens*.

tigrinus Dohrn, 1858

Fig. 48

Limnaea tigrina Dohrn 1858: 134.
Limnaea luteola f. *ovalis* Annandale and Rao 1925: 184, fig. IV (1).
Lymnaea luteola Hubendick 1951: 161, fig. 349.

Type material. A single shell (syntype) is housed in ZMB under accession number 13865. Its shell height is equal to 24.7 mm.

Type locality. Ceylon (without precise location).

Current taxonomic allocation. *Cerasina luteola* (Lamarck, 1822).

undussumae von Martens, 1897

Fig. 49

Limnaea undussumae von Martens 1897: 135, pl. I, fig. 18; pl. VI, figs 2, 5.
Lymnaea undusumae (sic!) Hubendick 1951: 59, fig. 73.
Lymnaea natalensis Brown 1994: 166, figs 76 a, b; 79a.

Type material. The lectotype (designated by Kilias 1967) and 22 paratypes are kept in ZMB under accession numbers 54301a and 54301 b. The lectotype' shell height is 19.8 mm.

Type locality. Undussuma, in a brook beyond the Tamaro. leg. Stuhlmann, 1891.

Current taxonomic allocation. *Radix* (*Radix*) *natalensis*.

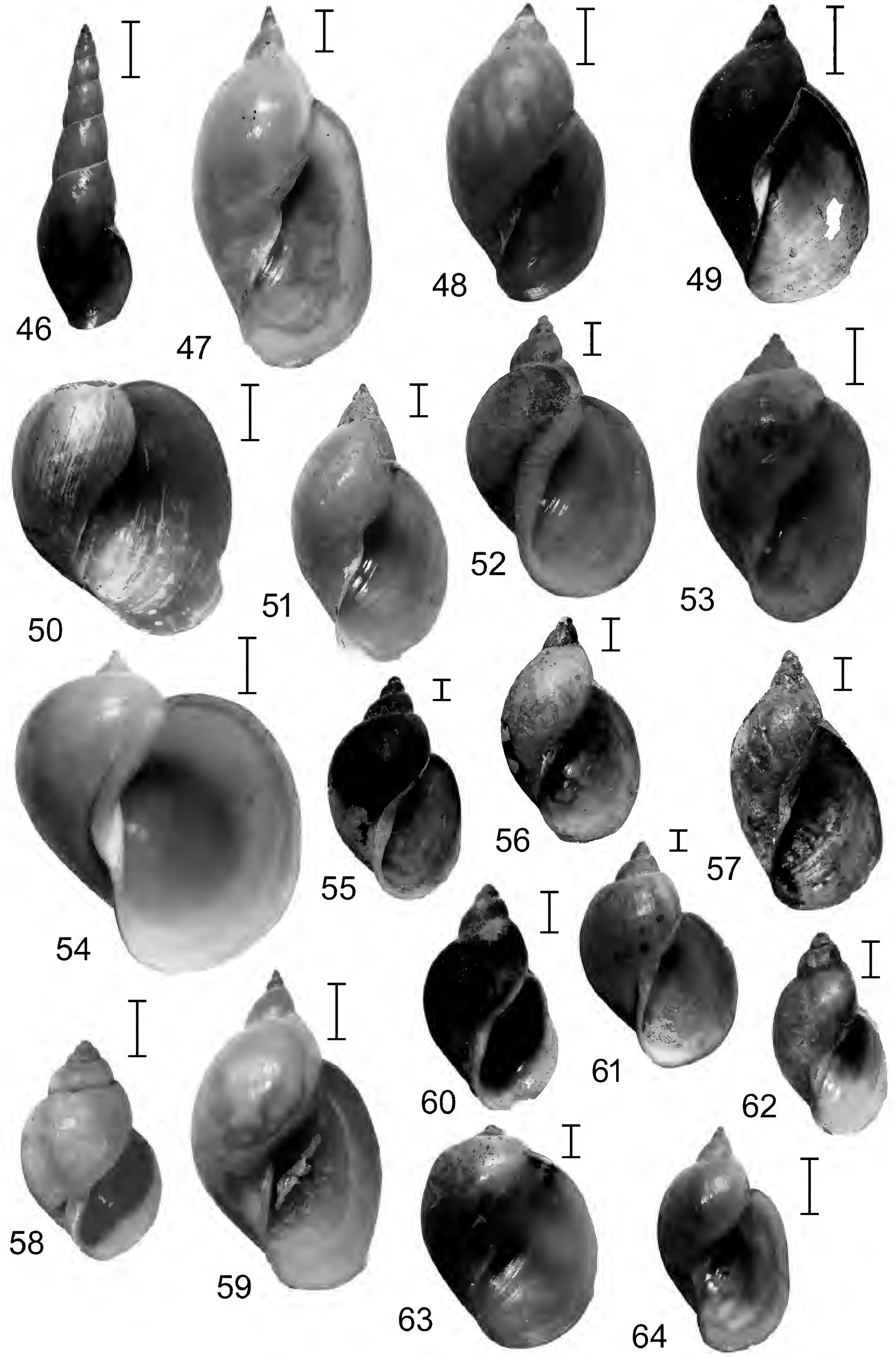
velutinoides Bergh, 1901

Fig. 50

Bullastra velutinoides Bergh 1901: 254, pl. 20, figs 22–34.
Lymnaea cumingiana Hubendick 1951: 162, fig. 355.

Type material. The only shell (syntype) is kept in ZMB under accession number 22485. Its apex is corroded; shell height is 18.6 mm. Bergh (1901) reported there was two syntypes of this species in the Berlin Museum.

Type locality. Bergh (1901) stated it as "M[are] philippin.", i.e. as the Philippine Sea. Possibly, the author sug-



Figures 46–64. Type specimens of Lymnaeidae (ZMB), continuation. **46** – *Limnaeus subulatus* Dunker in Küster, 1862, a syntype. **47** – *Limnaeus sulcatulus* Troschel, 1837, a syntype. **48** – *Limnaea tigrina* Dohrn, 1858, the syntype. **49** – *Limnaea undussumae* von Martens, 1897, the lectotype. **50** – *Bullastra velutinoides* Bergh, 1901, a syntype. **51** – *Limnaea whartoni* Jones & Preston, 1904, a syntype. **52** – *Limnaea lagotis* var. *yarkandensis* Nevill, 1878, a syntype. **53** – *Limnaeus coarctatus* Dunker. **54** – *Limnaeus compactus* "Ziegler". **55** – *Limnaea cornea* "Ziegler". **56** – *Limnaea elgonensis* Preston. **57** – *Limnaea fernanensis* Preston. **58** – *Limnaeus nebulosus* Dunker. **59** – *Limnaea acuminata* var. *nevilli* von Martens. **60** – *Limnaeus nigricans* "Ziegler". **61** – *Limnaeus nitens* "Ziegler". **62** – *Limnaeus opacus* "Ziegler". **63** – *Amphipeplea pfefferiana* Dunker. **64** – *Limnaea splendens* Dunker. Scale bars: 2 mm (**51, 52, 55–58, 60–63**), 5 mm (**46–50, 53, 54, 59, 64**).

gested it may be a marine species. According to Kilias (1967), the syntype was collected in Manila by Salmin.

Current taxonomic allocation. *Bullastra cumingiana*.

whartoni Jones & Preston, 1904

Fig. 51

Limnaea (*Gulnaria*) *whartoni* Jones and Preston 1904: 142, fig. 1.
Lymnaea whartoni Hubendick 1951: 72, fig. 152; pl. IV, fig. 14.
Limnaea whartoni Kilias 1961: 165.

Type material. ZMB collection contains a single syntype (accession number 59226), its shell height is 16.3 mm. Hubendick (1951, pl. IV, fig. 14) illustrated the "type" (? syntype) of this species (BMNH collection). A single shell collected from the type locality and labelled as "M. Preston No. 49" is kept in MNHN (without accession number).

Type locality. East China, "Liu Shi Tao, north-east promontory of Shantung".

Current taxonomic allocation. Possibly, *Radix plicatula*.

yarkandensis Nevill, 1878

Fig. 52

Limnaea lagotis var. *yarkandensis* Nevill 1878: 8.

Type material. Nevill (1878) reported he was able to examine more than 70 shells (syntypes) of this variety collected in Northern India. Ten of these specimens are kept now in ZMB (No. 27487). The largest of these shells is 18.0 height. The rest of syntypes may be placed in the Zoological Survey of India (where other type materials of Nevill are kept; see Subba Rao 1989).

Type locality. From near Sásak Taka (Nevill 1878: 9).

Current taxonomic allocation. *Radix* (*Peregriana*) *lagotis*.

Supplement

ZMB collection includes several type series belonging to lymnaeid species not mentioned in the taxonomic literature, including the most comprehensive catalogues (Küster 1862; Clessin 1886; Hubendick 1951), and their original descriptions remain unknown to me. Possibly, most of these "types" belong to the so-called "manuscript names" never published formally by their authors as it was not rare in the 19th century. Kilias (1967) listed three such doubtful names but closer examination of ZMB collection revealed as many as 12 lymnaeid species and varieties of unclear status. These are characterized below.

coarctatus Dunker

Fig. 53

Limnaeus coarctatus Dunker (? in MS).

Material. ZMB collection contains two specimens collected in Sumatra (Indonesia) and marked as 'types'. The largest of two shells is 17.6 mm height.

Current taxonomic allocation. *Cerasina luteola*.

Remark. The species has not been mentioned in the most inclusive handbooks on lymnaeid taxonomy (Küster 1862; Clessin 1886; Hubendick 1951) as well as in special works devoted to continental malacofauna of the Ost-Indian region (von Martens 1897a).

compactus "Ziegler"

Fig. 54

Limnaeus compactus "Ziegler" (? in MS).

Material. Two shells collected in the Danube River in Austria are housed in ZMB under accession number 109748. The largest of two shells is 24.8 mm height.

Current taxonomic allocation. An obvious synonym of *R. auricularia*.

Remark. The species has not been mentioned in the most inclusive handbooks on lymnaeid taxonomy (Küster 1862; Clessin 1886; Hubendick 1951) as well as in special works devoted to the Central and Eastern Europe continental malacofauna, where other species attributed to Ziegler were listed (Rossmässler 1835; Beck 1837; Kobelt 1877; Westerlund 1885; Clessin 1887-1890). I have to add that the very attribution of this species to Ziegler is conventional. As Welter-Schultes (2013) explains, Ziegler was not a scientist. He was a shell dealer in Vienna and "sent labelled shells with new names to researchers, who then described the new species and attributed the names to the dealers. At the end they had many hundreds of names. After 1905 the malacologists agreed that shell dealers should not be regarded as authors of names because they had in most cases not done any scientific work" (Welter-Schultes 2013: 96).

cornea "Ziegler"

Fig. 55

Limnaea cornea "Ziegler" (? in MS).

Material. Three shells collected in Carniolia (= Kraina, a historical region of Slovenia) and kept in ZMB under accession number 109754 (ex Dunker collection). The largest of the three shells is 13.1 mm height.

Current taxonomic allocation. *Radix peregra* = *R. labiata* sensu Falkner et al. 2002.

Remark. *L. cornea* is absent in most taxonomic works devoted to overview of the European continental malacofauna, including those dealing with the species names attributed to Ziegler (Rossmässler 1835; Beck 1837; Küster 1862; Kobelt 1877; Clessin 1887; Hubendick 1951). Dupuy (1851: 473) as well as Westerlund (1885) listed *Limnaea cornea* Zgl. among synonyms of *L. peregra*, but I could not find any evidence that this species was ever described formally.

elgonensis Preston

Fig. 56

Limnaea elgonensis Preston (? in MS).

Material. A single specimen kept under No. 62871. Its shell height is 12.0 mm.

Type locality. Uganda, Mt. Elgon. leg. Preston.

Current taxonomic allocation. Probably, a junior synonym of *Radix natalensis*.

Remark. I could not find the original description of this species in Preston's works devoted to new taxa of African land and freshwater mollusks (Preston 1910a, b, 1911, 1912, 1913). Preston introduced several tens of species names, including those with the species epithet "*elgonensis*" (for instance, *Ledoulxia elgonensis* Preston, 1914, family Urocyclidae Simroth, 1899), however among lymnaeid taxa described by him the species name *Lymnaea* (or *Limnaea*) *elgonensis* is absent. Both Hubendick (1951) and Brown (1994), in their comprehensive works dealing with the African Lymnaeidae, do not mention such a species. I am not sure Preston ever described it formally.

fernanensis Preston

Fig. 57

Limnaea fernanensis Preston (? in MS).

Material. A single shell is kept under No. 63775. This shell has 19.2 mm height.

Type locality. «British East Africa» (probably Kenya), Fort Fernan.

Current taxonomic allocation. *Radix* (*Radix*) *natalensis*.

Remark. See remark for *L. elgonensis* above.

nebulosus Dunker

Fig. 58

Limnaeus nebulosus Dunker (? in MS).

Material. Two shells (labelled as 'types') collected in the Antilles (without precise locality) and kept in ZMB under accession number 9364. The largest of them is of 8.5 mm height.

Current taxonomic allocation. Most probably, a synonym of *Galba cubensis*.

Remark. This species name is absent in subsequent comprehensive works devoted to overview the New World lymnaeid fauna (Küster 1862; Clessin 1886; von Martens 1890–1901; Hubendick 1951), and it remains unclear if *L. nebulosus* has been ever formally described.

nevilli von Martens

Fig. 59

Limnaea acuminata var. *nevilli* von Martens (? in MS).

Material. A single shell (SH = 32.3 mm) collected in Bengal (without precise location) by Lamare Piquot is kept in ZMB collection. Its label bears no accession number.

Current taxonomic allocation. *Radix* (*Radix*) *rufescens*.

Remark. I could not find this variety name in von Martens publications devoted to Indian freshwater snails (von Martens 1881, 1885) as well as in subsequent works on the subject (Preston 1915; Annandale and Rao 1925; Hubendick 1951; Subba Rao 1989).

nigricans "Ziegler"

Fig. 60

Limnaeus nigricans "Ziegler" (? in MS).

Material. A single shell, 10.8 mm shell height, collected in Neuwaldegg, Austria, is kept in ZMB under accession number 109749.

Current taxonomic allocation. An obvious synonym of *Radix* (*Peregriana*) *peregra* (O.F. Müller, 1774) auct. = *Radix labiata* (Rossmässler, 1835) sensu Falkner et al., 2002.

Remark. See comment to *Limnaeus compactus* "Ziegler" above.

nitens "Ziegler"

Fig. 61

Limnaeus nitens "Ziegler" (? in MS).

Material. Two shells collected in Vienna, Austria, are kept in ZMB under accession number 109747. The largest of them has 12.8 mm shell height.

Current taxonomic allocation. Possibly, a synonym of *Radix* (*Peregriana*) *balthica*.

Remark. See comment to *Limnaeus compactus* "Ziegler" above.

opacus "Ziegler"

Fig. 62

Limnaea opaca Dupuy 1851: 473.
Limnaeus pereger var. *opacus* von Gallenstein 1852: 43.
Limnaea peregra var. *opaca* Moquin-Tandon 1855: 468.

Material. Two shells collected in Carniolia and kept in ZMB under accession number 109755. The largest of two shells is 10.0 mm height.

Current taxonomic allocation. Possibly a synonym of *Radix* (*Peregriana*) *peregra* auct. = *Radix labiata* sensu Falkner et al. 2002.

Remark. Though a few authors of the 19th century used this taxon name (Dupuy 1851; von Gallenstein 1852; Moquin-Tandon 1855), I could not trace the source where it was described originally. Perhaps, it should be considered as one of those numerous "manuscript names" attributed to the authorship of Ziegler (see also comment to *Limnaeus compactus* above).

pfeifferiana Dunker

Fig. 63

Amphipeplea pfeifferiana Dunker (? in MS).

Material. Five shells collected somewhere in New Holland (= mainland Australia) are kept in ZMB under accession number 109770. The largest of them is 14.1 mm height.

Current taxonomic allocation. Possibly, a synonym of *Austropeplea lessoni* (Deshayes, 1830) .

Remark. Like other species names attributed to Dunker and listed in this supplement, *L. pfeifferiana* seems to be a member of the group of so-called "manuscript names", whose original descriptions have been not found in the literature.

splendens Dunker

Fig. 64

Limnaeus splendens Dunker (? in MS).

Material. Six shells from China (without precise location) kept under accession number 109769. The largest of them is 19.2 mm height.

Current taxonomic allocation. Possibly, a synonym of *Radix plicatula*.

Remark. See remark to *Amphipeplea pfeifferiana* above.

Acknowledgements

I wish to express my sincerest thanks to Dr. Matthias Glaubrecht (Hamburg, Centrum für Naturkunde) and Christine Zorn (Berlin, ZMB) for their indispensable help in organization of my work with ZMB malacological collection. Also I thank Anton Loginov (Komische Oper Berlin) and his family for their hospitality during my stay in Berlin. This study was supported by grants from the Russian Ministry of Education and Science (project no. 6.1957.2014/K) and the Russian Foundation for Basic Research (no. 14-04-01236). The Museum für Naturkunde supported the open access publication of this paper.

References

Annandale N, Rao HS (1925) Materials for a revision of the recent Indian Limnaeidae (Mollusca Pulmonata). Records of the Indian Museum 27: 137–189. http://faunaofindia.nic.in/PDFVolumes/records/027/03/0137-0189.pdf

Baker FC (1911) The Lymnaeidae of North and Middle America. Special publication of the Chicago Academy of Sciences, volume 3, 539 pp. doi: 10.5962/bhl.title.10622

Baker FC (1934) New Lymnaeidae from the United States and Canada. I. California, Oregon and other western states. The Nautilus 48: 17–20. http://biodiversitylibrary.org/page/8520848

Baker FC, Henderson J (1933) A new *Stagnicola* from Montana. The Nautilus 47: 30–32. http://biodiversitylibrary.org/page/8522599

Beck H (1837) Index molluscorum praesentis aevi musei principis augustissimi Christiani Frederici. Hafniae, 124 pp. doi: 10.5962/bhl.title.77331

Bergh R (1901) Bullacea. In: Semper von DrC (Ed.) Reisen in Archipel der Philippinen. Kreidel, Wiesbaden, 7, 4, 209–256. http://biodiversitylibrary.org/page/14454288

Bogatov VV, Zatravkin MN (1990) Gastropod molluscs of fresh and brackish waters of the Far East of the USSR – A guide. Far Eastern branch of the Soviet Academy of Sciences, Vladivostok, 169 pp.

Breure ASH (2013) Annotated type catalogue of the Orthalicoidea (Mollusca, Gastropoda) in the Museum für Naturkunde, Berlin. ZooKeys 279: 1–101. doi: 10.3897/zookeys.279.4701

Brown DS (1994) Freshwater snails of Africa and their medical importance. Taylor & Francis, London, 607 pp.

Burch JB (1989) North American freshwater snails. Malacological publications, Hamburg (Michigan), 366 pp.

Clessin S (1886) Die Familie der Limnaeiden enthaltend die Genera *Planorbis*, *Limnaeus*, *Physa* und *Amphipeplea*. Systematisches Conchylien-Cabinet von Martini und Chemnitz. Bauer und Raspe, Nürnberg, 1, 17, 29–34, 35a–36a, 63–430. http://biodiversitylibrary.org/page/32776441

Clessin S (1887–1890) Die Mollusken-Fauna Österreich-Ungarns und der Schweiz. Bauer & Raspe, Nürnberg, 858 pp. doi: 10.5962/bhl.title.60371

Climo FM, Pullan NB (1972) A taxonomic review of the family Lymnaeidae (Mollusca: Gastropoda) in New Zealand. Journal of the Royal Society of New Zealand 2: 5–13. doi: 10.1080/03036758.1972.10423300

Dell RK (1956) The freshwater Mollusca of New Zealand. Parts II and III. Part II. – The species previously assigned to the genera *Limnaea* and *Myxas*. Transactions of the Royal Society of New Zealand 84: 71–90. http://rsnz.natlib.govt.nz/volume/rsnz_84/rsnz_84_01_000740.pdf

Dohrn H (1858) Descriptions of new species of land- and freshwater shells collected in Ceylon, from the collection of H. Cuming, Esq. Proceedings of the Zoological Society of London 26: 134–135. http://biodiversitylibrary.org/page/32271631

Dupuy D (1851) Histoire naturelle des mollusques terrestres et d'eau douce qui vivent en France. V. Masson, Paris, 5: 459–594. http://biodiversitylibrary.org/page/32249746

Falkner G, Ripken TEJ, Falkner M (2002) Mollusques continentaux de France. Liste de référence annotée et bibliographie. Collection Patrimoines Naturels 52: 1–350.

Gallenstein M von (1852) Kärntern's Land- und Süßwasser-Conchylien. Klagenfurt, 78 pp. doi: 10.5962/bhl.title.10673

Glaubrecht M, Fehér Z, Köhler F (2007) Inventorizing an invader: annotated type catalogue of Corbiculidae Gray, 1847 (Bivalvia, Heterodonta, Veneroidea), including Old World limnic *Corbicula* in the Natural History Museum Berlin. Malacologia 49: 243–272. doi: 10.4002/0076-2997-49.2.243

Glaubrecht M, Salcedo-Vargas MA (2000) Annotated type catalogue of the Cephalopoda (Mollusca) in the Museum für Naturkunde, Humboldt University of Berlin. Mitteilungen aus dem Museum für Naturkunde Berlin, Zoologische Reihe 76: 269–282. doi: 10.1002/mmnz.20000760209

Glaubrecht M, Zorn C (2012) More slug(-ish) science: another annotated catalogue on types of tropical pulmonate slugs (Mollusca: Gastropoda) in the collection of the Natural History Museum Berlin. Zoosystematics and Evolution 88: 33–51. doi: 10.1002/zoos.201200005

Glöer P (2002) Die Süßwassergastropoden Nord- und Mitteleuropas: Bestimmungschlussel, Lebenweise, Verbreitung. Conchbooks, Hackenheim, 327 pp.

Hubendick B (1951) Recent Lymnaeidae. Their variation, morphology, taxonomy, nomenclature and distribution. Kungliga Svenska Vetenskapsakademiens Handlingar. Fjärde Serien 3(1): 1–223.

Johnson PD, Bogan AE, Brown KM, Burkhead NM, Cordeiro JR, Garner JT, Hartfield PD, Lepitzki DAW, Mackie GL, Pip E, Tarpley TA, Tiemann JS, Whelan NV, Strong EE (2013) Conservation status of freshwater gastropods of Canada and the United States. Fisheries 38: 247–282. doi: 10.1080/03632415.2013.785396

Jones KH, Preston HB (1904) List of Mollusca collected during the commission of H.M.S. "Waterwitch" in the China seas, 1901-1903, with description of new species. Proceedings of the Malacological Society of London 6: 138–151. http://biodiversitylibrary.org/page/15176094

Kantor YI, Vinarski MV, Shileyko AA, Sysoev AV (2010) Catalogue of the continental mollusks of Russia and adjacent territories. Version 2.3.1 (issued 02.03.2010). http://www.ruthenica.com/categorie-8.html

Kilias R (1961) Die Typen and Typoide der Mollusken-Sammlung des Zoologischen Museums in Berlin. Mitteilungen aus dem Zoologischen Museum in Berlin 37: 159–167. doi: 10.1002/mmnz.19610370106

Kilias R (1967) Die Typen and Typoide der Mollusken-Sammlung des Zoologischen Museums in Berlin. Nachtrag und alphabetisches Register zu I. Euthyneura (Pulmonata), Basommatophora. Mitteilungen aus dem Zoologischen Museum in Berlin 43: 337–343. doi: 10.1002/mmnz.19670430217

Kobelt W (1872) Eine Limnäe aus dem Himalaya. Malakozoologische Blätter 19: 76–77. http://biodiversitylibrary.org/page/15647992

Kobelt W (1877) Rossmässler's Iconographie der Land- und Süsswasser-Mollusken mit vorzüglicher Berücksichtigung der Europäischen noch nicht abgebildeten Arten. C.W. Kreidel's Verlag, Wiesbaden 5: 1–129. http://biodiversitylibrary.org/page/16288283

Köhler F (2007) Annotated type catalogue of the Bulimulinae (Pulmonata, Orthalicoidea, Bulimulidae) in the Museum für Naturkunde Berlin. Mitteilungen aus dem Museum für Naturkunde Berlin, Zoologische Reihe 83: 125–159. doi: 10.1002/mmnz.200700004

Köhler F, Glaubrecht M (2006) The types of Ampullariidae Gray, 1824 (Mollusca, Gastropoda) in the Malacological Collection of the Natural History Museum, Berlin: an annotated catalogue with lectotype designations. Mitteilungen aus dem Museum für Naturkunde Berlin, Zoologische Reihe 82: 201–218. doi: 10.1002/mmnz.200600006

Kruglov ND (2005) Molluscs of the family Lymnaeidae (Gastropoda Pulmonata) in Europe and northern Asia. SGPU Publishing, Smolensk, 507 pp. [In Russian]

Kruglov ND, Starobogatov YI (1993) Annotated and illustrated catalogue of species of the family Lymnaeidae (Gastropoda Pulmonata Lymnaeiformes) of Palaearctic and adjacent river drainage areas. Part I. Ruthenica 3: 65–92.

Küster HC (1862) Die Gattungen *Limnaeus*, *Amphipeplea*, *Chilina*, *Isidora* und *Physopsis*. Systematisches Conchylien-Cabinet von Martini und Chemnitz. Bauer und Raspe, Nürnberg, 1, 17b, 1–48. http://biodiversitylibrary.org/page/32776995

Lindström G (1868) Om Gotlands nutida mollusker. Th. Norby, Wisby, 48 pp.

Martens E von (1864a) Drei centralasiatische Schnecken. Malakozoologische Blätter 11: 114–119. http://biodiversitylibrary.org/page/16079909

Martens E von (1864b) Fossile Süsswasser-Conchylien aus Sibirien. Zeitschrift der Deutschen Geologischen Gesellschaft 16: 345–351. http://biodiversitylibrary.org/page/43812140

Martens E von (1866) Einige afrikanische Binnenconchylien. Malakozoologische Blätter 13: 91–110. http://biodiversitylibrary.org/page/15855655

Martens E von (1867) Ueber die ostasiatischen Limnaeaceen. Malakozoologische Blätter 14: 211–227. http://biodiversitylibrary.org/page/15856012

Martens E von (1874) Slugs (Mollusca). A.P. Fedchenko's Travel to Turkestan. Vol. II. Zoogeographic studies. Saint-Pétersbourg-Moscow, 1, 1–66. [In Russian]

Martens E von (1881) Conchologische Mittheilungen als Fortsetzung der Novitates Conchologicae. Th. Fischer, Cassel, 1, 1–101. http://biodiversitylibrary.org/page/15865773

Martens E von (1882) Ueber centralasiatische Mollusken. Mémoires de l'Académie Impériale des Sciences de Saint-Pétersbourg, series 7(30) 11: 1–65. http://biodiversitylibrary.org/page/46871759

Martens E von (1885) Conchologische Mittheilungen als Fortsetzung der Novitates Conchologicae. Th. Fischer, Cassel, 2, 103–213. http://biodiversitylibrary.org/page/15865850

Martens E von (1886) Einige der von Dr. Gottsche in Japan und Korea gesammelten Land- und Süsswasser-Mollusken. Sitzungsberichte der Gesellschaft der naturforschenden Freude zu Berlin. Jahrband 1886: 74–80. http://biodiversitylibrary.org/page/7794138

Martens E von (1890–1901) Land and freshwater Mollusca. Biologia Centrali-Americana, or Contributions to the knowledge of the fauna and flora of Mexico and Central America. RH Porter, London, 706 pp. http://biodiversitylibrary.org/page/573268

Martens E von (1892) Ueber einige neue Arten von Land- und Süsswasser-Mollusken aus Uganda und dem Victoria-Nyansa. Sitzungsberichte der Gesellschaft der naturforschenden Freude zu Berlin. Jahrband 2: 15–19. http://biodiversitylibrary.org/page/8790481

Martens E von (1897a) Süss- und brackwasser-mollusken des Indischen Archipels. Zoologische Ergebnisse einer Reisen in Niederländisch Ost-Indien. E.J. Brill, Leiden, 4, 1–331. http://biodiversitylibrary.org/page/36298713

Martens E von (1897b) Beschalte Weichthiere Deutsch Ost-Afrikas. D. Reimer, Berlin, 308 pp. doi: 10.5962/bhl.title.12943

Moquin-Tandon A (1855) Histoire naturelle des mollusques terrestres et fluviatiles de France contenant des études générales sur leur anatomie et leur physiologie et la description particulière des genres, les espèces et des variétés. J.-B. Baillière, Paris, 2, 646 pp. doi: 10.5962/bhl.title.13098

Nevill G (1878) Mollusca from Eastern Turkestan and Lada'k. Scientific results of the second Yarkand mission. Office of the superintendent of Gouvernment printing, Calcutta, 1–21. http://biodiversitylibrary.org/page/19502434

Paraense WL (1995) *Lymnaea cousini* Jousseaume, 1887, from Ecuador (Gastropoda: Lymnaeidae). Memorias do Instituto Oswaldo Cruz 90: 605–609. doi: 10.1590/S0074-02761995000500011

Pfeiffer L (1839) Bericht über die Ergebnisse meiner Reise nach Cuba im Winter 1838-1839. Archiv für Naturgeschichte 5: 346–358. http://biodiversitylibrary.org/page/24904257

Pfeiffer L (1845) Description of a new species of *Amphipeplea*. Transactions of the Zoological Society of London, 13, 68. http://biodiversitylibrary.org/page/12862564

Pfeiffer L (1854-1860) Novitates conchologicae. Series prima. Mollusca extramarina. Beschreibung und Abbildung neuer oder kritischer Land- und Süsswasser-Mollusken. Th. Fischer, Cassel, 1, 138 pp. doi: 10.5962/bhl.title.10371

Pointier JP, Noya O, Amarista M, Théron A (2004) *Lymnaea cousini* Jousseaume, 1887 (Gastropoda: Lymnaeidae): first record for Venezuela. Memorias do Instituto Oswaldo Cruz 99: 567–569. doi: 10.1590/S0074-02762004000600005

Pointier JP, Yong M, Gutiérrez A (2005) Guide to the freshwater molluscs of Cuba. Hackenheim, Conchbooks, 120 pp.

Preston HB (1910a) Further additions to the molluscan fauna of Central Africa. Annals and Magazine of Natural History (8th series) 6: 58–64. http://biodiversitylibrary.org/page/18619299

Preston HB (1910b) Additions to the non-marine molluscan fauna of British and German East Africa and Lake Albert Edward. Annals and Magazine of Natural History (8th series) 6: 526–536. http://biodiversitylibrary.org/page/15629297

Preston HB (1911) Descriptions of thirty-six new species of land and freshwater shells from British East Africa, chiefly from Mount Kenia and the neighbouring district. Annals and Magazine of Natural History (8th series) 7: 463–476. http://biodiversitylibrary.org/page/22098424

Preston HB (1912) Diagnoses of new species of terrestrial and fluviatile shells from British and German East Africa, with the description of a new genus (*Eussoia*) from the Eusso Nyiro River, B.E. Africa. Proceedings of the Zoological Society of London 1: 183–193. http://biodiversitylibrary.org/page/31854892

Preston HB (1913) New species and varieties of terrestrial and fluviatile shells from Equatorial Africa. Revue Zoologique Africaine 3: 47–62. http://biodiversitylibrary.org/page/32991295

Preston HB (1915) Mollusca (Freshwater Gastropoda & Pelecypoda). The Fauna of British India, including Ceylon and Burma. Taylor & Francis, London, 244 pp. doi: 10.5962/bhl.title.13091

Rossmässler EA (1835) Iconographie der Land- und Süsswasser-Mollusken mit vorzüglicher Berücksichtigung der Europäischen noch nicht abgebildeten Arten. Arnoldische Buchhandlung, Dresden und Leipzig, 1, 1–132. http://biodiversitylibrary.org/page/24986222

Smith JA (1894) A list of the land and fresh-water Mollusca collected by Dr. J.W. Gregory in East Africa during his expedition to Mount Kenia, with description of a few new species. Proceedings of the Malacological Society of London 1: 163–168. http://biodiversitylibrary.org/page/15167466

Starobogatov YI, Prozorova LA, Bogatov VV, Saenko EM (2004) Molluscs. In: Tsalolikhin SY (Ed.) Key to freshwater invertebrates of Russia and adjacent lands. Vol. 6. Molluscs, polychaetes, nemerteans. Nauka, Sankt-Petersburg, 9–492. [In Russian]

Starobogatov YI, Streletzkaya EA (1967) Composition and zoogeographical characteristics of freshwater malacofauna of the East Siberia and northern part of the Far East. Mollusks and their role in biocoenoses and formation of faunas = Trudy Zoologicheskogo Instituta AN SSSR 42: 221–268. [In Russian]

Subba Rao NV (1989) Freshwater Molluscs of India: Handbook. Zoological Survey of India, Calcutta, 289 pp.

Suter H (1890) Descriptions of new species of New Zealand land and fresh-water shells. Transactions and Proceedings of the New Zealand Institute 22: 221–229. http://biodiversitylibrary.org/page/3288734

Suter H (1891) Descriptions of new species of New Zealand land and fresh-water shells. Transactions and Proceedings of the New Zealand Institute 23: 84–93. http://biodiversitylibrary.org/page/9777645

Suter H (1893) Liste synonymique et bibliographique des Mollusques terrestres et fluviatiles de la Nouvelle-Zélande. Journal de Conchyliologie 41: 220–293. http://biodiversitylibrary.org/page/9777645

Suter H (1913) Manual of the New Zealand Mollusca (With an Atlas of quarto plates). J. Mackay, Wellington, 1120 pp. doi: 10.5962/bhl.title.1716

Troschel FH (1837) Neue Süßwasser-Conchylien aus dem Ganges. Archiv für Naturgeschichte 3: 166–182. http://biodiversitylibrary.org/page/13477892

Villa A, Villa GB (1871) Specie e varietà di Molluschi della Lombardia, Catalogo sinonimico. Bullettino Malacologico Italiano 4: 81–96. http://biodiversitylibrary.org/page/39452753

Vinarski MV (2012) The lymnaeid genus *Catascopia* Meier-Brook et Bargues, 2002 (Mollusca: Gastropoda: Lymnaeidae), its synonymy and species composition. Invertebrate Zoology 9: 91–104. http://kmkjournals.com/upload/PDF/IZ/IZ%20Vol%2009/invert9_2%20091_104%20Vinarski.pdf

Vinarski MV (2013) One, two, or several? How many lymnaeid genera are there? Ruthenica 23: 41–58. http://www.biotaxa.org/Ruthenica/article/download/1020/1669

Vinarski MV, Nekhaev IO, Glöer P, von Proschwitz T (2013) Type materials of freshwater gastropod species described by C.A. Westerlund and accepted in current malacological taxonomy: a taxonomic and nomenclatorial study. Ruthenica 23: 79–108. http://www.biotaxa.org/Ruthenica/article/view/3366/4996

Welter-Schultes FW (2013) Guidelines for the capture and management of digital zoological names information. Version 1.1 released on March 2013. Global Biodiversity Information Facility, Copenhagen, 126 pp. http://www.gbif.org/system/files_force/gbif_resource/resource-80625/gbif_Management_Zoological_Names_en_v1.1.pdf?download=1

Westerlund CA (1865) Sveriges land- och sötvatten-mollusker. C.W.K. Gleerups, Lund, 142 pp. doi: 10.5962/bhl.title.13137

Westerlund CA (1873) Fauna molluscorum terrestrium et fluviatilium Sueciae, Norvegiae et Daniae. 2. Sötvatten Mollusker. O.W. Backmann, Stockholm, 297–651. http://biodiversitylibrary.org/page/13189205

Westerlund CA (1885) Fauna der in der Paläarktischen Region (Europa, Kaukasien, Sibirien, Turan, Persien, Kurdistan, Armenien, Mesopotamien, Kleinasien, Syrien, Arabien, Egypten, Tripolis, Tunisien, Algerien und Marocco) lebenden Binnenconchylien. V. Fam. Succineidae, Auriculidae, Limnaeidae, Cyclostomidae und Hydrocenidae. H. Ohlsson, Lund, 135 pp. doi: 10.5962/bhl.title.10301

Westerlund CA (1890) Fauna der in der Paläarktischen Region (Europa, Kaukasien, Sibirien, Turan, Persien, Kurdistan, Armenien, Mesopotamien, Kleinasien, Syrien, Arabien, Egypten, Tripolis, Tunisien, Algerien und Marocco) lebenden Binnenconchylien. I Supplement. E.G. Johansson, Karlshamn, 179 pp.

Westerlund CA (1894) Specilegium malacologicum. Nachrichtsblatt der Deutschen Malakozoologischen Gesellschaft 26: 190–205. http://biodiversitylibrary.org/page/15601404

Zhadin VI (1933) The freshwater molluscs of the USSR. Lensnabtehizdat, Leningrad, 232 pp. [In Russian]

Zhadin VI (1952) Fresh- and brakishwater mollusks of the USSR. Sovetskaya Nauka, Moscow, 346 pp. [In Russian]

Zoosystematics and Evolution

92 (**1**) 2016

http://zse.pensoft.net