



Complementary Description and Range Extension of an Unusual Caligid Copepod *Anchicaligus nautili* (Willey, 1896) (Copepoda: Siphonostomatoida) Parasitizing the Endangered Deep-sea Cephalopod *Nautilus pompilius* Linnaeus, 1758 from the Indian Ocean

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Abstract

The present study reports an unusual caligid copepod, *Anchicaligus nautili* (Willey, 1896) infesting the deep-water chambered nautilus *Nautilus pompilius* Linnaeus, 1758 from the Indian Ocean. Both male and female are redescribed and illustrated based on the materials recovered from the museum collection of the Department of Aquatic Biology & Fisheries, University of Kerala, collected in March, 1985 from the Andaman region of the Indian Ocean as a trawl bycatch. The species is characterised by the presence of a pair of large lenses (conspicillae) in the median eyes, postanal-protrusions and the displacement of the caudal rami. It appears to be the first record of the species from Indian waters.

Keywords Parasitic copepods · *Nautilus* · Re-description · Caligidae · Indian ocean

Introduction

The siphonostomatoid copepod family Caligidae Burmeister (1835), the most diverse family of parasitic copepods, currently includes more than 500 species under 30 valid genera (see Walter and Boxshall 2020). While the great majority of the caligid copepods utilize marine fishes as their hosts, *Anchicaligus nautili* (Willey 1896) is the only species infesting an invertebrate host (Ho 1980). The genus *Caligus* Müller (1785) is the most speciose with 270 valid species, followed by *Lepeophtheirus* von Nordmann (1832) having 125 valid species and other 10

genera are monotypic (Walter and Boxshall 2020). The family Caligidae is relatively well known, from India represented by approximately 15% of the global species, (more than 70 species). However, *Anchicaligus nautili* (Willey 1896) has not been reported from the Indian waters, so far.

The fish-infesting families such as Bomolochidae, Caligidae, Eargasilidae, Lernaeopodidae, Lernanthropidae, Pandaridae, Pennellidae and Taeniacanthidae are well documented from Indian waters (Gnanamuthu 1953; Rangnekar 1960; Sebastian 1967; Pillai 1985; Aneesh et al. 2018, 2021). Very recently from our laboratory, we have described two new species of the little known Indian family Chondracanthidae (see Aneesh et al. 2020). On the other hand, very little information is available on parasitic copepod infesting the invertebrates.

The discovery of *Anchicaligus nautili* (Willey 1896) was first reported as *Caligus nautili* by Wiley (1896) based on the specimens collected from nautili collected from New Britain (South Pacific). Later, Stebbing (1900) provided the full description of the same species and erected a monotypic genus *Anchicaligus* Stebbing (1900) for this unusual caligid, this is the only valid redescription,

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based on the original syntypic specimens. According to Ho (1980), the type specimens of *A. nautili* remain unknown, and he redescribed the species based on the specimens from *Nautilus pompilius* collected at Ngemoulis Reef, Palau (Ho 1980). In the present study, we are reporting the occurrence of the caligid copepod, *A. nautili*, from the museum specimen of *N. pompilius* collected from the Andaman region of the Indian Ocean. It appears to be the first report of this species from Indian ocean and Indian Exclusive Economic Zone (EEZ).

Materials and Methods

Specimens (78 females and 16 males) of *Anchicaligus nautili* (Willey 1896) were recovered from a single host individual of *Nautilus pompilius* Linnaeus, 1758 (size: 243 mm L, 161 mm W; 68 mm T) stored in the museum collection of the Department of Aquatic Biology & Fisheries, University of Kerala, collected in March, 1985 from the Andaman & Nicobar Islands as a trawl bycatch. The recovered specimens are further stored 75% ethanol and taxonomically identified (Stebbing 1900; Ho 1980). The identification of *Anchicaligus* is mainly based on Stebbing (1900), Ho and Lin (2004) and Dojiri and Ho (2013). Methods for dissection, mounting, and drawings of appendages followed Aneesh et al. (2020). The specimen was stained using lactophenol cotton

Fig. 2 *Anchicaligus nautili* (Willey 1896) from *Nautilus pompilius* Linnaeus, ovigerous female (ZSI/WGRC/IR./ INV./14617), **a** dorsal view, **b** cephalothorax ventral view, **c** abdomen ventral view, **d** leg 3, **e** abdomen posterolateral angle with remanence of leg 5 (arrow) gc: genital complex; es: egg string; A1: antennule; A2: antenna; mx1. maxilla; mx2: maxillule; Mxd: maxilliped; L1–L4: leg 1–4; o: oviduct; ab: abdomen; cr: caudal ramus.

blue for 3–5 min. Drawings were digital inked using Adobe Illustrator and WACOM CTL-472/K0-c drawing pad. The specimens were microphotographed using multi-focusing dissection microscope Leica-M205A and image capturing software (Leica Application Suit). Voucher specimens were deposited in the National Zoological Collections of Zoological Survey of India, Kozhikode (NZC-ZSIK). The terminology used according to Dojiri and Ho (2013).

Results

Systematics

Order: Siphonostomatoida Burmeister (1835)

Family: Caligidae Burmeister (1835)

Genus: *Anchicaligus* Stebbing (1900)

***Anchicaligus nautili* (Willey 1896)**

(Figs. 1–6).

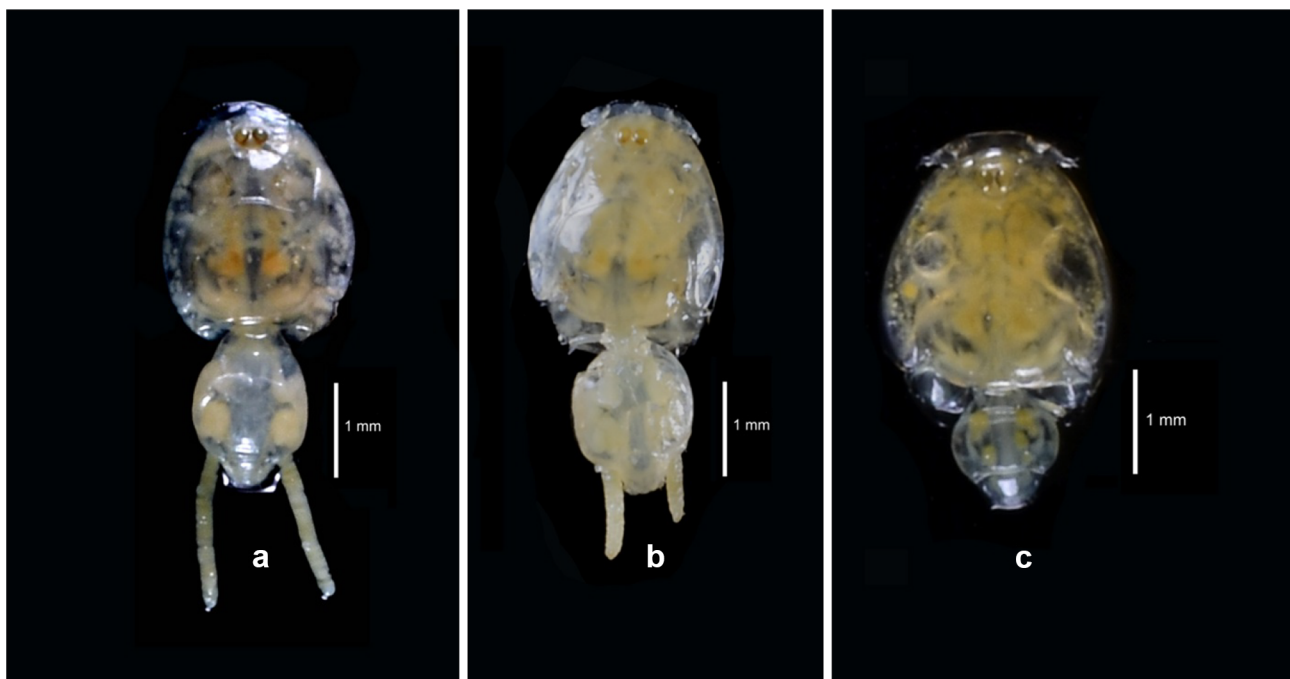
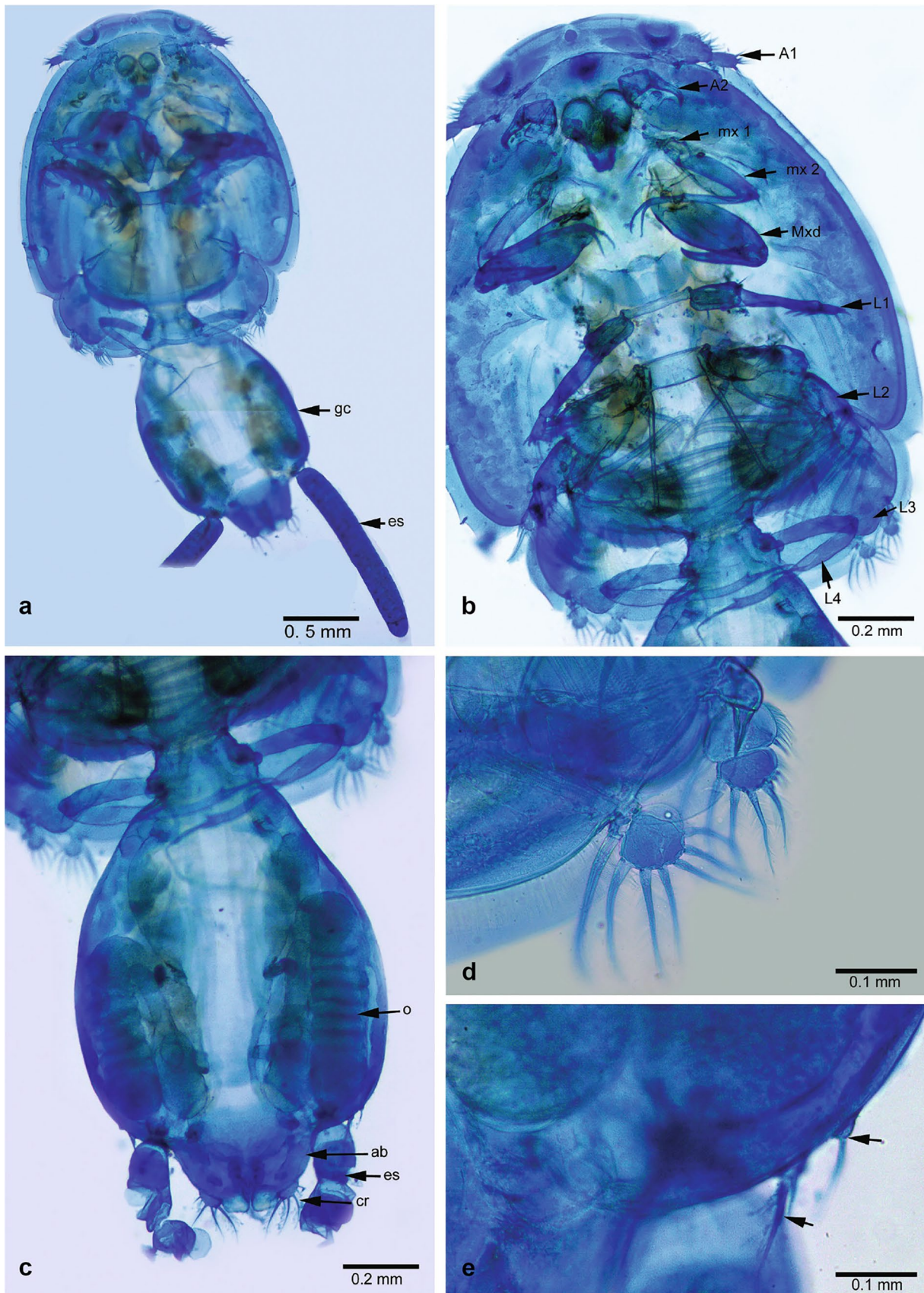
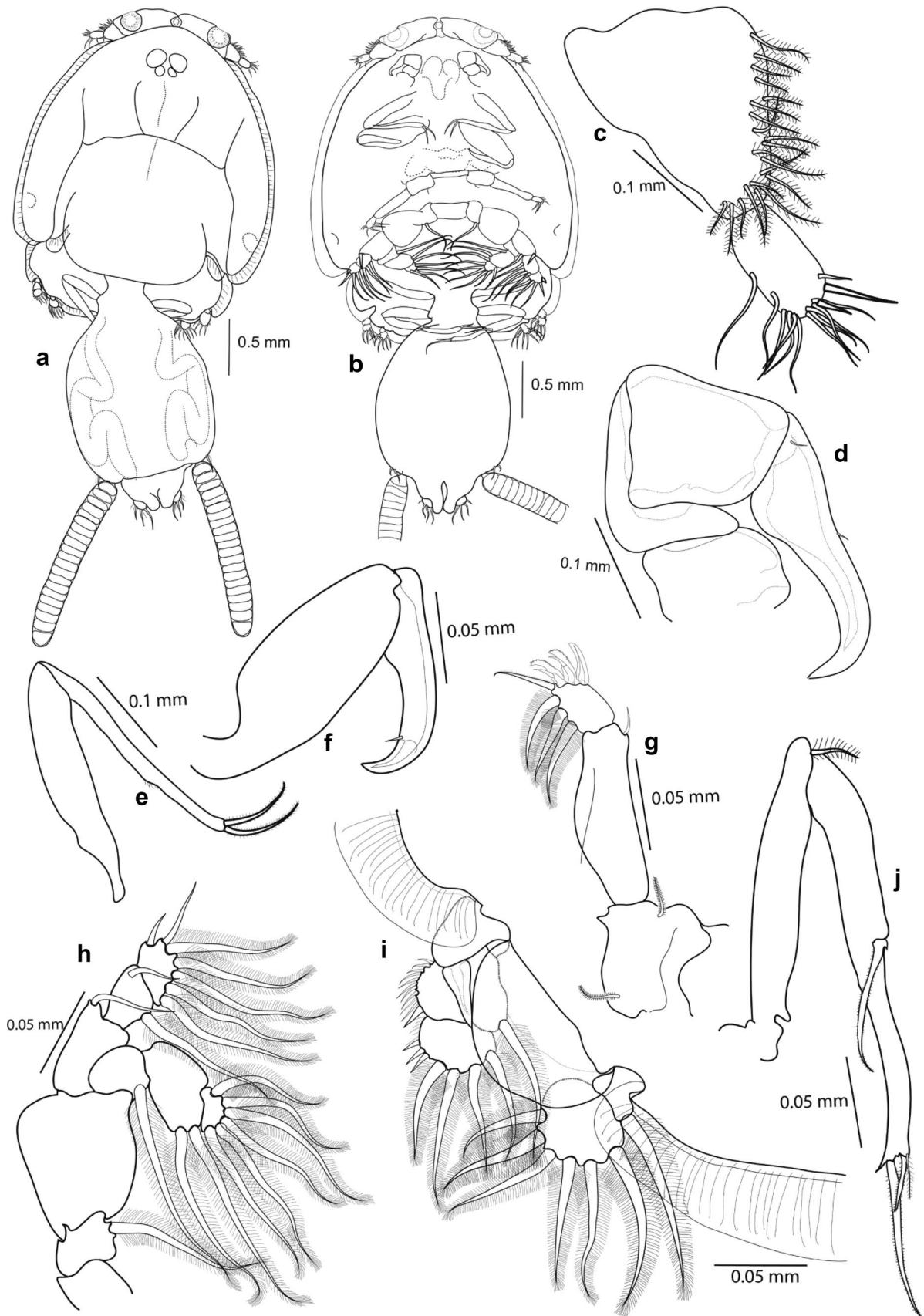


Fig. 1 *Anchicaligus nautili* (Willey 1896) from *Nautilus pompilius* Linnaeus, **a** female (ZSI/WGRC/IR/INV/15357), **b** female (ZSI/WGRC/IR/INV/14616) **c** male (ZSI/WGRC/IR/INV/15358)





◀**Fig. 3** *Anchicaligus nautili* (Willey 1896) from *Nautilus pompilius* Linnaeus, ovigerous female (ZSI/WGRC/IR./INV./14617), **a** dorsal view; **b** ventral view; **c** antennule; **d** antenna; **e** maxilla; **f** maxilliped; **g–j** leg 1–leg 4

Anchicaligus nautili Willey (1896): 145; Stebbing (1900): 668; Monod and Dollfus (1932): 175; Capart (1941): 177; Yamaguti (1963): 47; Haven (1972): 78; Ho (1980): 157; Dojiri (1983): 103; Dojiri and Ho (2013): 95–104.

Caligulina ocularis Heegaard (1972): 304; Kabata (1979): 164; Ho (1980): 164.

Material examined: 78 females and 16 males from mantle chamber of *Nautilus pompilius* (243 × 161 × 68 mm) collected from Andaman region of Indian Ocean, in March, 1985. **Voucher specimens**—all material recovered from *Nautilus pompilius* Linnaeus, 1758 (n = 1) sampled from Andaman region of Indian Ocean. 1 ♀ (4.2 mm) (ZSI/WGRC/IR./INV./14616); 1 ♀ (3.8 mm) (ZSI/WGRC/IR./INV./14617); 1 ♀ (4.5 mm) (ZSI/WGRC/IR./INV./15355); 1 ♀ (4.0 mm) (ZSI/WGRC/IR./INV./15356); 1 ♀ (4.3 mm) (ZSI/WGRC/IR./INV./15357); 1 ♂ (3.0 mm) (ZSI/WGRC/IR./INV./15358); 1 ♂ (3.6 mm) (ZSI/WGRC/IR./INV./15359); 1 ♂ (3.4 mm) (ZSI/WGRC/IR./INV./15360).

Colour: White.

Distribution: New Britain (South Pacific) (Willey 1896); Philippines (Haven 1972); Ngemoulis Reef, Palau (Ho 1980); Andaman region of Indian Ocean (present study).

Host: *Nautilus pompilius* Linnaeus, 1758.

Site of attachment: Mantle chamber.

Redescription

Adult Female (Figs. 1a, 2 and 3a, b): Body slender, total body length, 3.8–4.5 (excluding egg strings and included the length of setae on caudal rami) 3.8–4.5 (4.2 mm) (n = 5). Cephalothorax, anteriorly narrower, with subcircular carapace, with sensory pit on posterolateral corner, and shallow posterior sinuses (Fig. 2b). Frontal region with paired, lunules at ventral side (Figs. 2b and 3b). Pair of prominent eyes (Figs. 1a, 2a and 3a), located in mid-anterior to cephalosome; each eye with large oval lens (conspicillae), much prominent above the carapace surface. Free margin of thoracic zone extending beyond posterior end of lateral zone. Carapace lateral margin fringed with narrow hyaline membrane. Fourth pedigerous somite 0.5 times

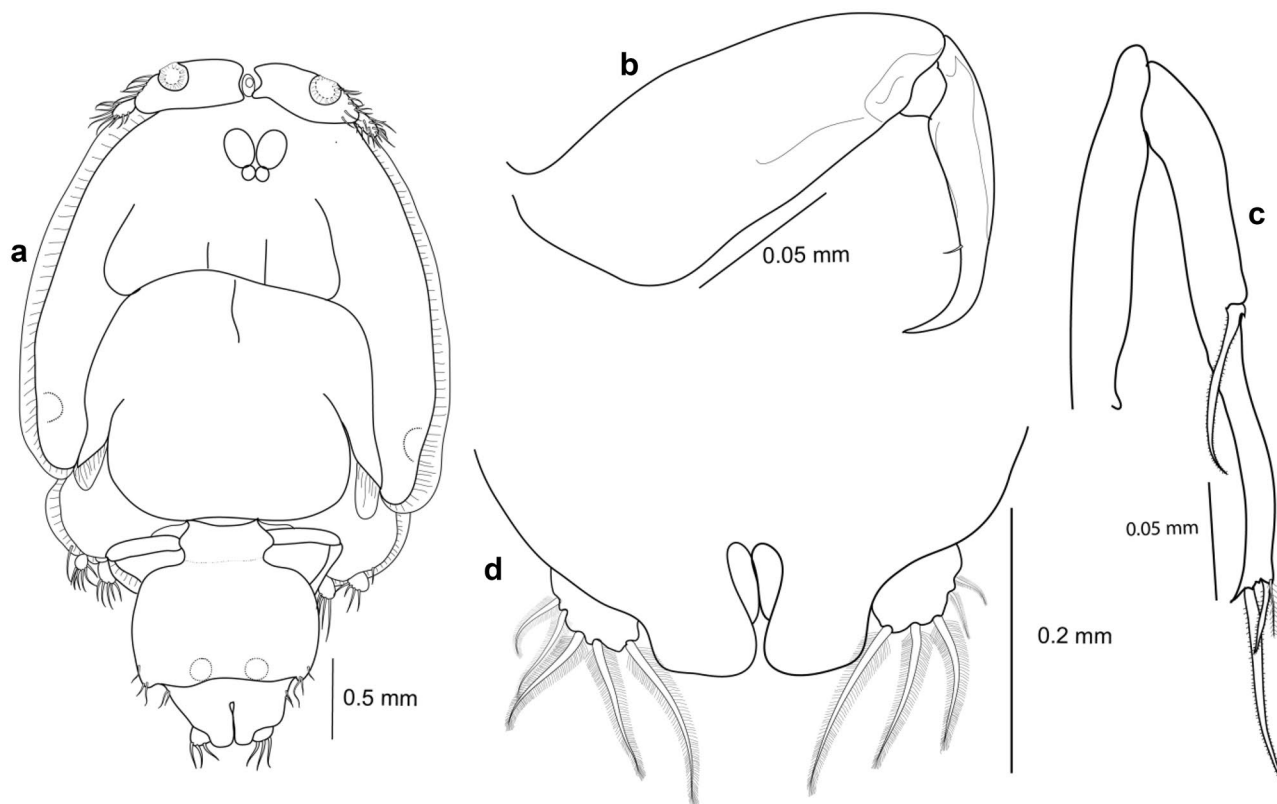


Fig. 4 *Anchicaligus nautili* (Willey 1896) from *Nautilus pompilius* Linnaeus, male (ZSI/WGRC/IR./INV./15359), **a** dorsal view, **b** maxilliped, **c** leg 4, **d** genital complex

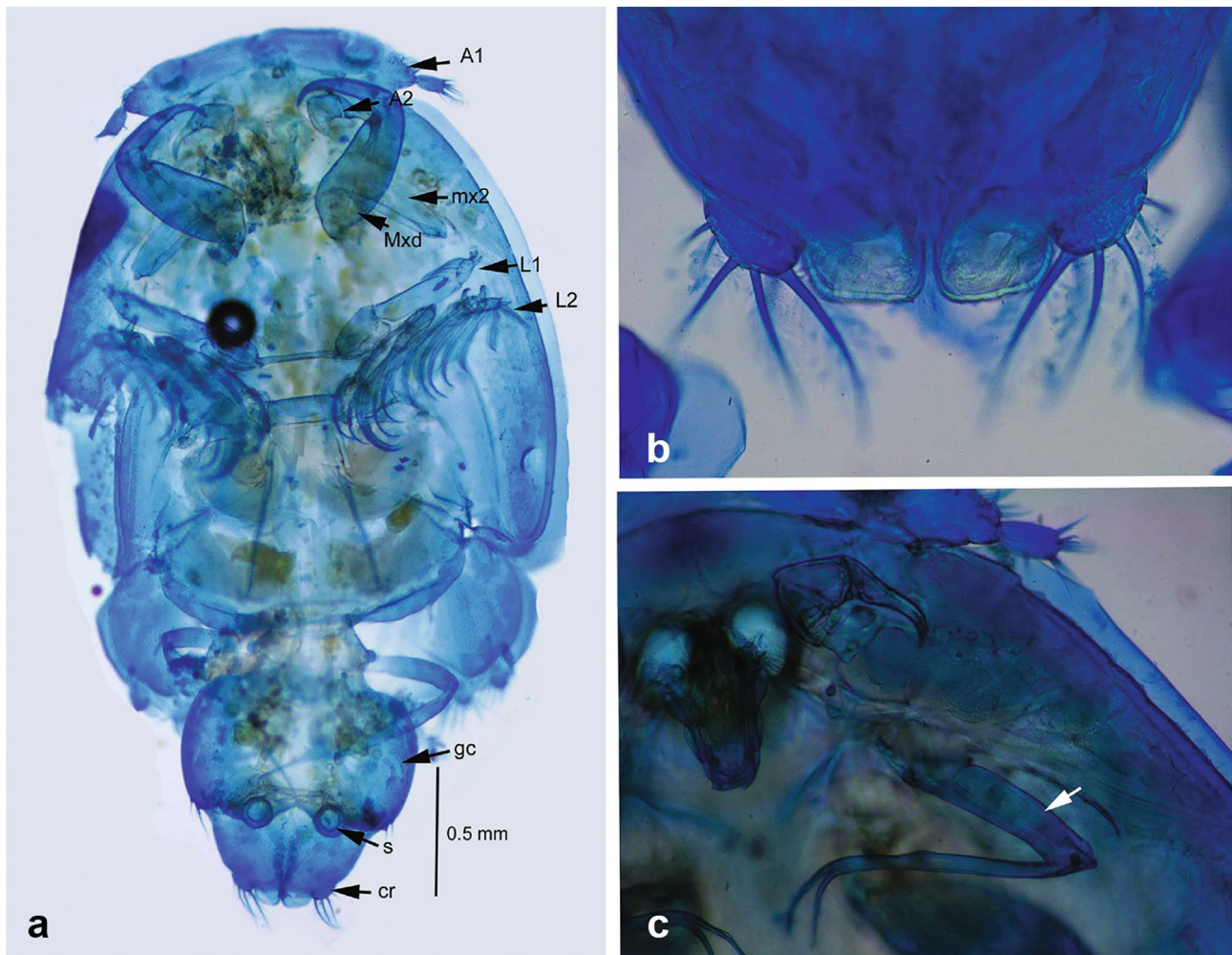


Fig. 5 *Anchicaligus nautili* (Willey 1896) from *Nautilus pompilius* Linnaeus, male (ZSI/WGRC/ IR/INV/15360, **a** ventral view, **b** genital complex, **c** maxilla. gc: genital complex; A1: antennule; A2:

antenna; mx2: maxillule; Mxd: maxilliped; L1–L2: leg 1–2; s: spermatophore; cr: caudal ramus

as long as wide, distinct from the broad cephalothorax; with small lateral protrusions to which the fourth legs are attached. Genital complex globose, 1.1 times as wide as long. Abdomen (Fig. 2c) with 1 free somite, 1.4 times as wide as long; with pair of postanal protrusions at posterior surface, extending beyond distal limit of caudal ramus. Caudal ramus 2.2 times wider than long, slightly displaced with 6 plumose setae (Fig. 2c). Egg strings (Figs. 1a, 2a and 3a, b) longer than abdomen; eggs uniseriate. Number of eggs per string ranged from 28 to 34, dependent on length of the string.

Antennule (Fig. 2c) 2-segmented, not extending beyond lateral limit of cephalothorax. Proximal segment with 26 marginal plumose setae, distal segment with 13 setae and 1 aesthetasc. Antenna (Fig. 2d) 4-segmented, basal segment, short 1.9 times wider than long; second segment largest, unarmed, 2 times longer than basal segment; the terminal

segment modified into a claw, with two small setae. Postantennal process small with a pair of setules. Mouth tube, with both strigil and intrabuccal stylet. Mandible with 12 blades at apex. Maxillule with 3 setae. Maxilla, 2-segmented with two subequal terminal processes; flabellum located near midpoint of brachium. Both calamus and canna with serrated membranes; canna slightly narrower than calamus; subequal in length. Maxilliped (Fig. 3f), corpus robust; terminal segment claw-like. Small rounded knob and naked seta present near distal end of shaft. Shaft and claw combined. Sternal area (Fig. 6a) with cuticular folds and pair of posteriorly directed, sclerotized protrusions at the ventral side, just above the leg 1.

Leg 1 (Fig. 3g) vestigial endopod lobate, exopod 2-segmented, proximal segment longest, bearing short setules along free posterior margin plus a short spine at outer distal corner, distal segment with three plumose setae on free posterior margin, a long seta and three spines; spine

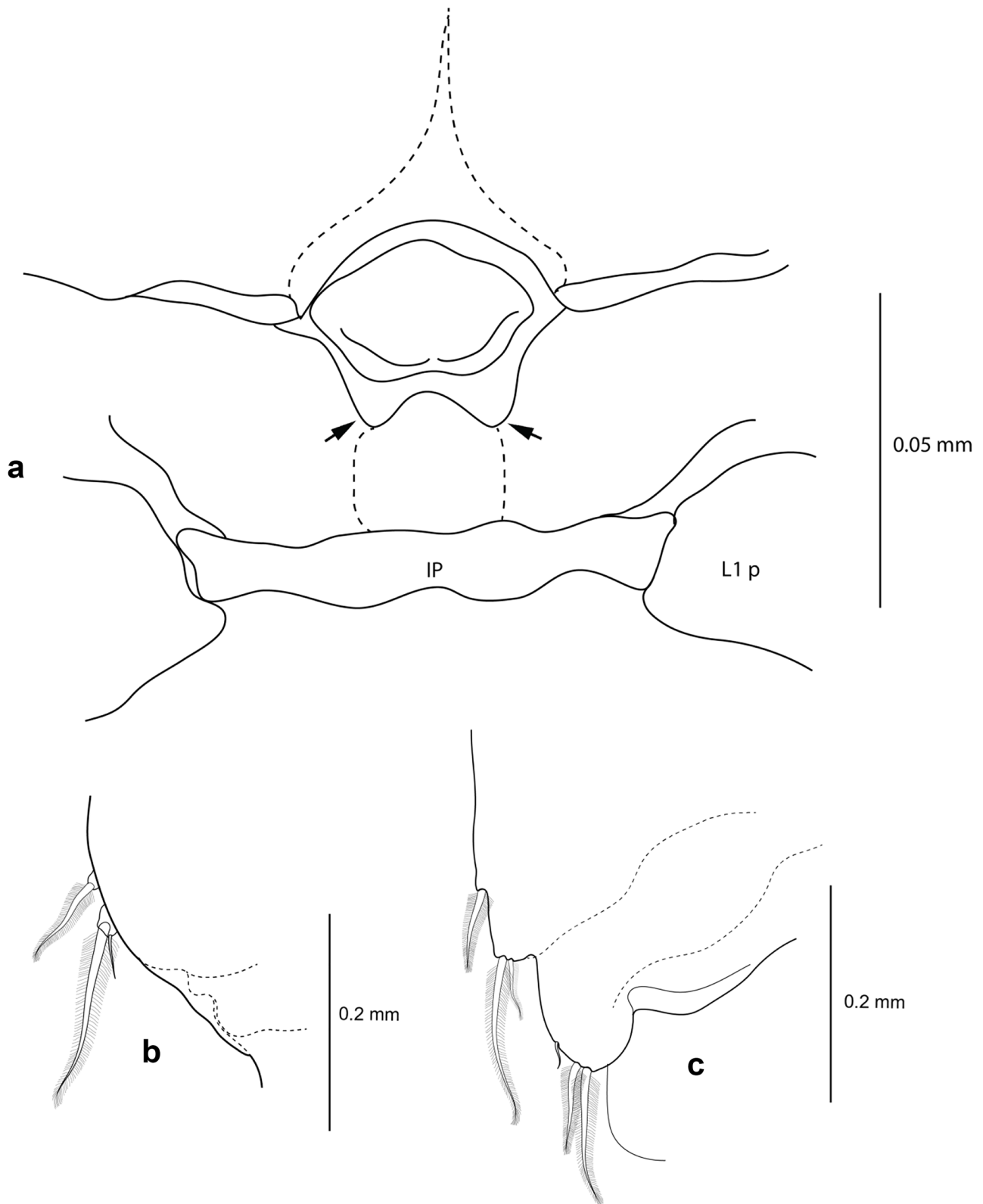


Fig. 6 *Anchicaligus nautili* (Willey 1896) from *Nautilus pompilius* Linnaeus, **a** female (ZSI/WGRC/IR./ INV./14617), sternal area, showing posteriorly directed, sclerotized protrusions (arrows), **(b–c)**

ventral of genital area, showing legs 5 and 6, **b** leg 5 of female (ZSI/WGRC/IR./ INV./14617), **c** leg 5 and 6 of male (ZSI/WGRC/ IR/ INV/15360). IP. intercoxal plate, L1p. protopods of leg 1

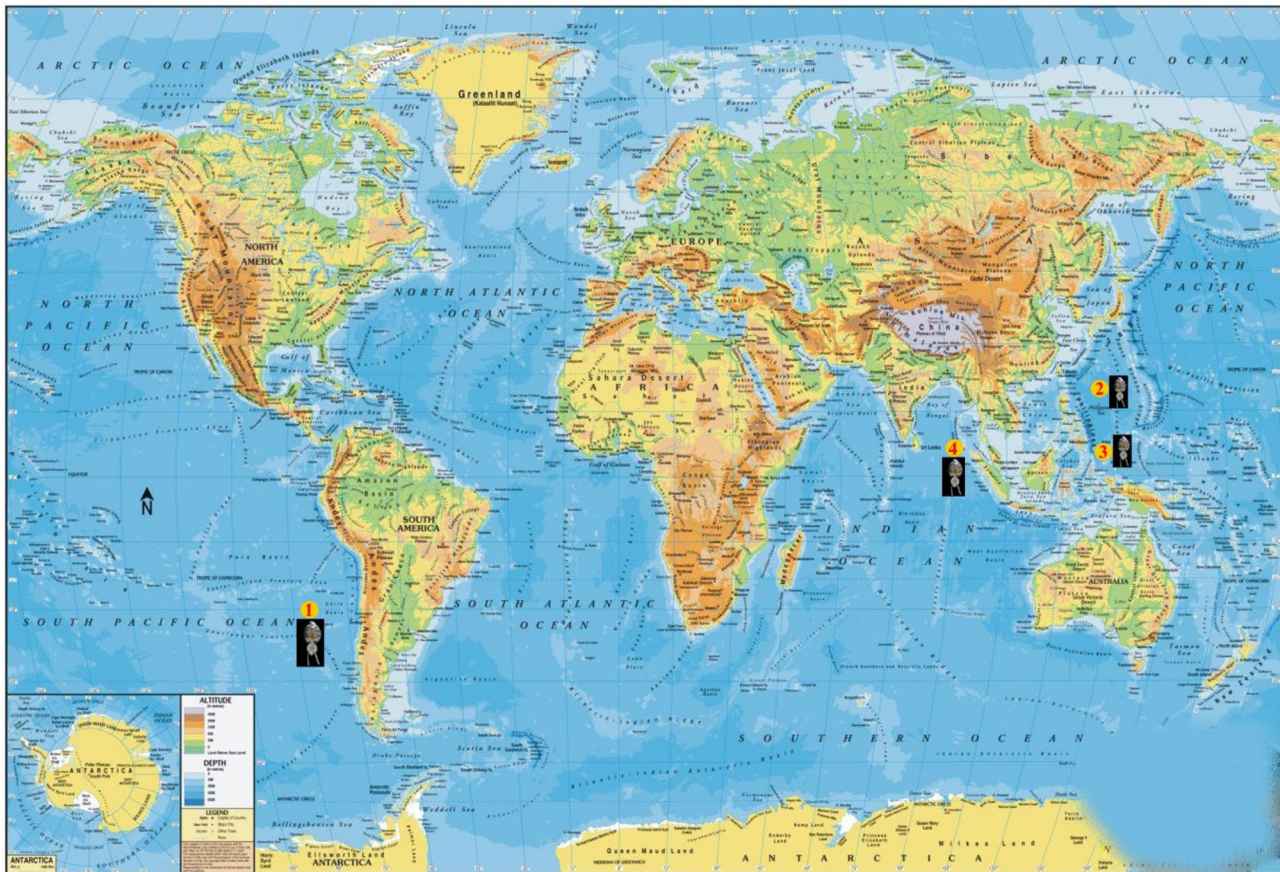


Fig. 7 Map of the distribution of *Anchicaligus nautili* (Willey 1896), (1) New Britain (South Pacific), (2), the Philippines (3), Ngemoulis Reef, Palau, (4), Andaman region of Indian Ocean (source: <https://www.google.co.in/maps>)

one and two with serrated outer borders and accessory processes. Leg 2 (Fig. 3h) typical caligid type, coxa with large plumose seta at posterior corner; basis without seta; endopod 3-segmented, first segment inner margin with one, second segment with two and third segments with 6 plumose setae; exopod 3-segmented, first segment with long outer spine directed obliquely across surface of second segment, second segment with relatively short outer spine and one inner plumose setae, third segment with two reduced outer spines, and 5 plumose setae increasing in size. Leg 3 (Fig. 3i) without dorsal adhesion pad, endopod 2-segmented, proximal segment small, with 1 long plumose seta; second segment expanded along outer margin with 6 plumose seta; exopod 3-segmented proximal segment small, with slightly curved outer spine, second segment with 1 inner plumose and 11 outer naked seta, third segment with 8 spiniform setae and 4 inner plumose seta. Leg 4 (Fig. 3j) slender, with 2-segmented exopod; terminal spines decreasing in length from inner to outer margin. Exopod much longer than sympod. A minute spine located on lateral side of the outermost spine of

exopod second segment. Leg 5 rudimentary, represented with 2 papillae. One with 1 plumose seta; other with 1 large plumose seta and 1 smaller naked seta on posteroventral corner of the genital complex (Fig. 2e and 6b). Leg 6, absent.

Adult Male (Figs. 1b, 4a and 5a): Total body length 3.0–3.6 mm (3.3 mm) ($n=4$). Cephalothorax 1.1 times as wide as long, slightly smaller than female. Fourth pedigerous somite 2 times wider than long. Genital complex 1.5 times wider than long, with spermatophores (Figs. 4a and 5a). Abdomen, caudal ramus as in female. Antennule similar to that in female. Antenna 3-segmented, proximal segment large, distal approximately same size, terminal portion with 2 setae and bifid claw. Mandible, maxillule, and maxilla, maxilliped as in female. Legs 1–4 as in female. Leg 5 triangular with two papillae; the first papilla with 1 plumose seta and the second with 1 large and 1 small plumose setae (Fig. 6c). Leg 6 with two papillae; the first papilla with 1 laterally directed seta and the second with two unequal plumose setae (Fig. 6c).

Remarks

The monotypic genus *Anchicaligus*, the only caligid copepod preferring invertebrate host, can be distinguished from other caligid genera by the following characteristic features: presence of a pair of prominent lenses (conspicillae) in the median eyes and postanal-protrusions, and the displacement of the caudal rami. *Anchicaligus nautili* (Willey 1896) is previously known from New Britain (South Pacific), the Philippines, Ngemoulis Reef, Palau (Willey 1896; Haven 1972; Ho 1980) and this report based on the materials from Indian EEZ appears to be the first report of this species from the Indian Ocean. The host cephalopod, *Nautilus pompilius* Linnaeus, 1758 is found throughout the Indo-West Pacific, the Philippines, Papua New Guinea to Fiji and northeastern and north-western Australia.

After the original description by Willey in 1896, and the subsequent redescription and generic replacement by Stebbing (1900) the species was further redescribed based on non-type materials by Ho (1980). Recently Dojiri and Ho (2013) synonymized *Caligulina ocularis* Heegaard (1972) with *Anchicaligus nautili*, based on the re-examination of the holotype male of *C. ocularis* available at Zoologisk Museum, Copenhagen, Denmark along with five females and 1 male of *Anchicaligus nautili* from the mantle cavity of *Nautilus pompilius* collected at Palau (see the Fig. 7 for distribution map of *A. nautili*).

Conclusions

In conclusion, the present study reports *Anchicaligus nautili* from *Nautilus pompilius*. It seems to be the first report of this species from the Indian Ocean.

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Author Contributions PTA is the main worker on the topic, identified, worked on illustrations and pictures and prepared the draft of the manuscript. PTA, AKH, and AB conceived and designed research, critically reviewed for improving the quality of the manuscript. MPP and RR identified the host mollusc. All authors read and approved the final manuscript.

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Data Availability All the specimens herein studied were deposited at the National Zoological Collections of Zoological Survey of India, Kozhikode (NZC-ZSIK) and accession numbers for material are provided.

Declarations

Consent to Participate In no case human participants whose consent to participate was needed were involved.

Consent for Publication In this study, human participants whose consent for publication was needed were not involved.

Declaration of Competing Interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Conflict of Interest The authors declare that they have no competing interests.

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