

Trebius benzi n. sp. (Siphonostomatoida: Trebiidae) infecting *Squalus acutipinnis* Regan off South Africa

Susan M. Dippenaar 

Received: 28 April 2016 / Accepted: 24 September 2016
© Springer Science+Business Media Dordrecht 2016

Abstract *Trebius* Krøyer, 1838 currently consists of 15 accepted species all infecting elasmobranchs. Apart from two species, i.e. *T. caudatus* Krøyer, 1838 and *T. latifurcatus* Wilson, 1921, that have been reported from ten and eight host species, respectively, the other 13 species have each been reported from only one or two host species. *Trebius benzi* n. sp., collected from *Squalus acutipinnis* Regan, is described and illustrated after examination through stereo- and compound microscopes. This species can be distinguished from the other known species by a combination of characters including an abdomen that is shorter than the genital complex, a maxillule with an endite that consists of a single-tined dentiform process, sternal furca tines that are blunt and as long as the base, and the innermost spine of the last exopodal segment of leg 1 the shortest.

Introduction

Representatives of the family Trebiidae C.B. Wilson, 1905 differ from the members of the Caligidae Burmeister, 1835 in the presence of free third and fourth pedigerous somites between the cephalothorax

and genital complex (Kabata, 1979) and a biramous fourth leg (similar to *Avitocaligus* Boxshall & Justine, 2005 and *Euryphorus* Milne Edwards H., 1840 in Caligidae) (Boxshall & Halsey, 2004; Boxshall & Justine, 2005). Even though there is great morphological similarity between the members of the two families they differ vastly in their life cycles (Trebiidae lacking a chalimus phase vs Caligidae with four chalimus stages) and reproductive behaviour [copulation in Trebiidae taking place in copepodid III and/or IV females (according to Izawa's interpretation), but only in the adult females in Caligidae] (Izawa, 2013).

Trebiidae currently consists of *Kabataia ostorhynchi* Kazachenko, Korotaeva & Kurochkin, 1972 described from a teleost [probably *Oplegnathus woodwardi* Waite (see Froese & Pauly, 2016)] and 15 accepted species of *Trebius* all described from elasmobranchs (Kabata, 1979; Deets & Dojiri, 1989; Nagasawa et al., 1998). No records could be found on the validity of *T. cyclopteri* (Beneden, 1870) and *T. soleae* (Beneden, 1861) (see Walter & Boxshall, 2015). *Trebius caudatus* Krøyer, 1838 seems to be the most generalist species being reported from both rays (eight species) and sharks (two species) followed by *T. latifurcatus* Wilson, 1921 reported from eight species of rays while other species seem to be specialists being reported from only one or two host species (Boxshall & Halsey, 2004). Species of *Trebius* are mostly ectoparasites on the body surface or inside the brachial chambers of their hosts (see Nagasawa

S. M. Dippenaar (✉)
Department of Biodiversity, University of Limpopo,
Private Bag X1106, Sovenga 0727, South Africa
e-mail: susan.dippenaar@ul.ac.za

et al., 1998) while *T. shiinoi* Nagasawa, Tanaka & Benz, 1998 was reported as an endoparasite inside the uteri and on the body surface of embryos (Nagasawa et al., 1998) as well as an ectoparasite on the body surface, brachial lamellae, and buccobranchial cavity of *Squatina japonica* Bleeker (see Izawa, 2013). The only report of a *Trebius* species from a host species of *Squalus*, is *T. caudatus* from *S. acanthias* Linnaeus (Boxshall & Halsey, 2004).

Materials and methods

Copepods were collected from the gill filaments of *Squalus acutipinnis* Regan taken as bycatch in demersal trawls conducted during commercial hake and sole fishing off Mossel Bay, Western Cape, South Africa. The heads of caught sharks were cut off and frozen and later defrosted and examined for infection by copepods. Collected copepods were preserved in 70% ethanol, cleared, and stained in lactic acid with a small amount of dissolved lignin pink before being dissected. They were studied using both stereo- and light microscopes with the wooden slide technique (Humes & Gooding, 1964) and drawn with the aid of a drawing tube. Measurements were done using a stage micrometer. Anatomical terminology used conforms mostly to that of Huys & Boxshall (1991) and Kabata (1979) while host nomenclature is according to Ebert & Van Hees (2015).

Family Trebiidae Wilson C.B., 1905 Genus *Trebius* Krøyer, 1837

Trebius benzi n. sp.

Type-host: *Squalus acutipinnis* Regan (Chondrichthyes: Squaliformes: Squalidae).

Type-locality: Off Mossel Bay, Western Cape, South Africa.

Site in host: Gill filaments.

Material studied: Three adult females (somewhat contracted and shrivelled) from three different hosts on the 3rd of April 2013.

Type-material: One adult female (holotype) (SAMC-A085806) deposited in the Iziko South African Museum, Cape Town, South Africa. Remaining females (1 dissected) have been retained in the personal collection of the author.

Etymology: The species epithet, *benzi*, is in honour of Dr George Benz in recognition of his major contribution to our knowledge and understanding of siphonotomatoids infecting elasmobranchs.

Description (Figs. 1, 2)

Adult female

Cephalothorax (Figs. 1A, B) wider than long with well-developed frontal plates; tips of antennules not extending beyond lateral margins of cephalothorax bearing thin marginal membranes; posterior sinuses conspicuous, fringed by marginal membranes. Third pedigerous somite (Fig. 1A) wider than long, slightly shorter than posterior lobe of cephalothorax. Fourth pedigerous somite (Fig. 1A) narrowed anteriorly, posteriorly about half width of third pedigerous somite. Genital complex (Fig. 1A) elongated, about as long as cephalothorax (no spinules or spinulated processes observed posterolaterally, maybe due to contraction?). Abdomen (Fig. 1A) 3-segmented, about two thirds length of genital complex; first somite almost twice length of each of second and third somites. Caudal rami (Fig. 2G) about twice as long as wide, posterior margin pointed, medial margin with setules, distally bearing 6 pinnate setae; 3 long setae terminally; 2 shorter, unequal setae distolaterally; 1 small ventral seta distomedially. (No measurements taken due to contracted state of specimens, but female about 3.7 mm including caudal rami).

Antennule (Fig. 1C) 2-segmented (3rd segment, see, Izawa, 2013, not observed); first segment with numerous (probably 27) pinnate setae; second segment seemingly 2-segmented, much narrower than first with one seta halfway along length, distally with cluster of setae of varying lengths (none with branched tips observed) and at least one aesthetasc. Antenna (Fig. 2A) subchelate, unciform claw, 4-segmented; first segment broad with 3 small processes; second segment slightly narrower with conspicuous indent on distolateral margin, third segment with large corrugated process laterally; claw with proximal naked seta and another about mid-length on inner margin. Postantennal process (Fig. 2A) an inflated base with finger-like projection longer than base. Mandible (Fig. 1D) stylet with 12 small teeth distomedially. Maxillule (Fig. 1E) bilobed; palp (anterior lobe) papillate, bearing 3 naked seta, 1 long (extending to about mid-length of endite) and 2 very short; endite

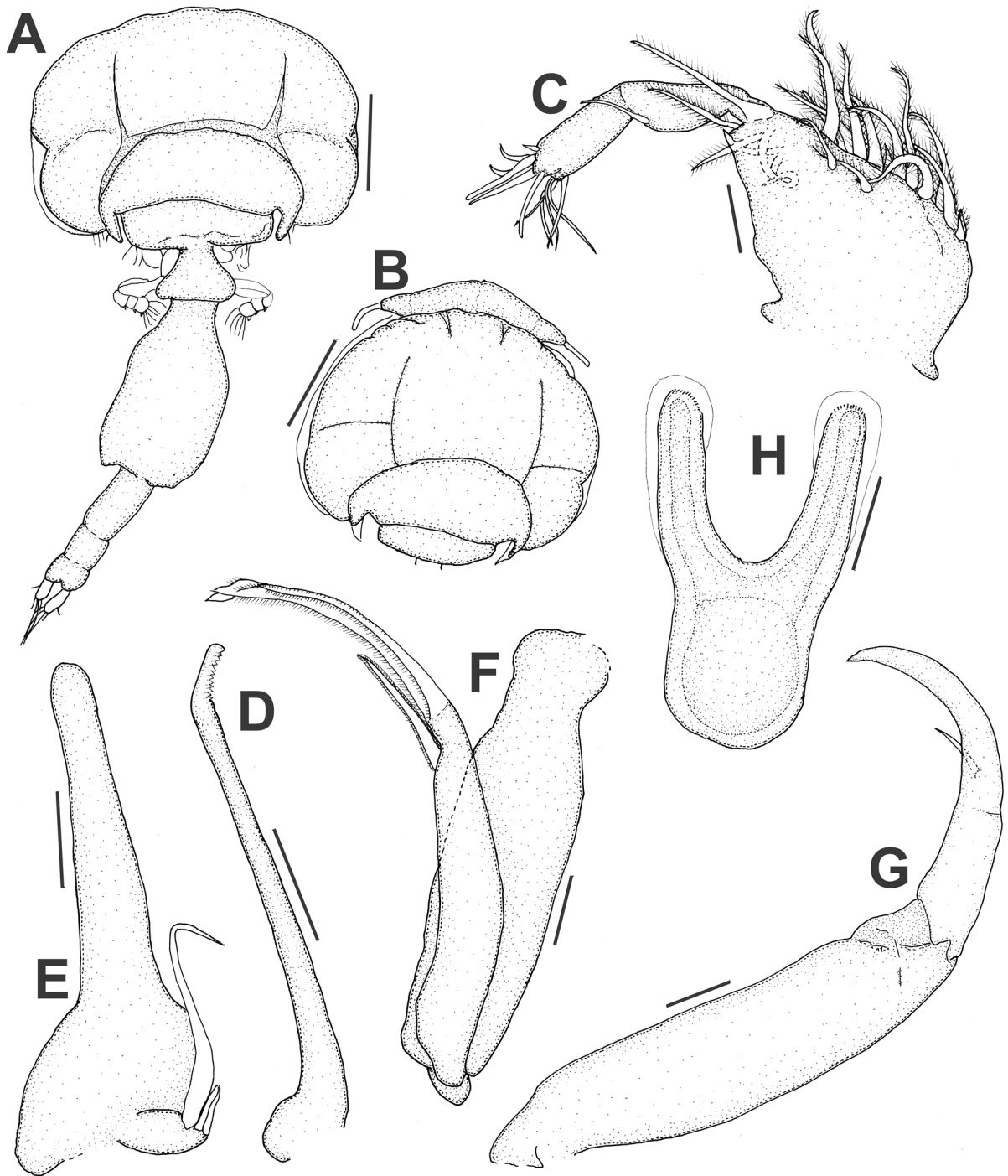


Fig. 1 *Trebius benzi* n. sp. ex *Squalus acutipinnis* Regan. Adult female. A, Habitus, dorsal view of contracted specimen with frontal plates and antennules curled ventrally; B, Cephalothorax with frontal plates and antennules, dorsal view; C, Antennule; D, Mandible; E, Maxillule; F, Maxilla; G, Maxilliped; H, Sternal furca. Scale-bars: A, B, 0.5 mm; C–H, 50 μ m

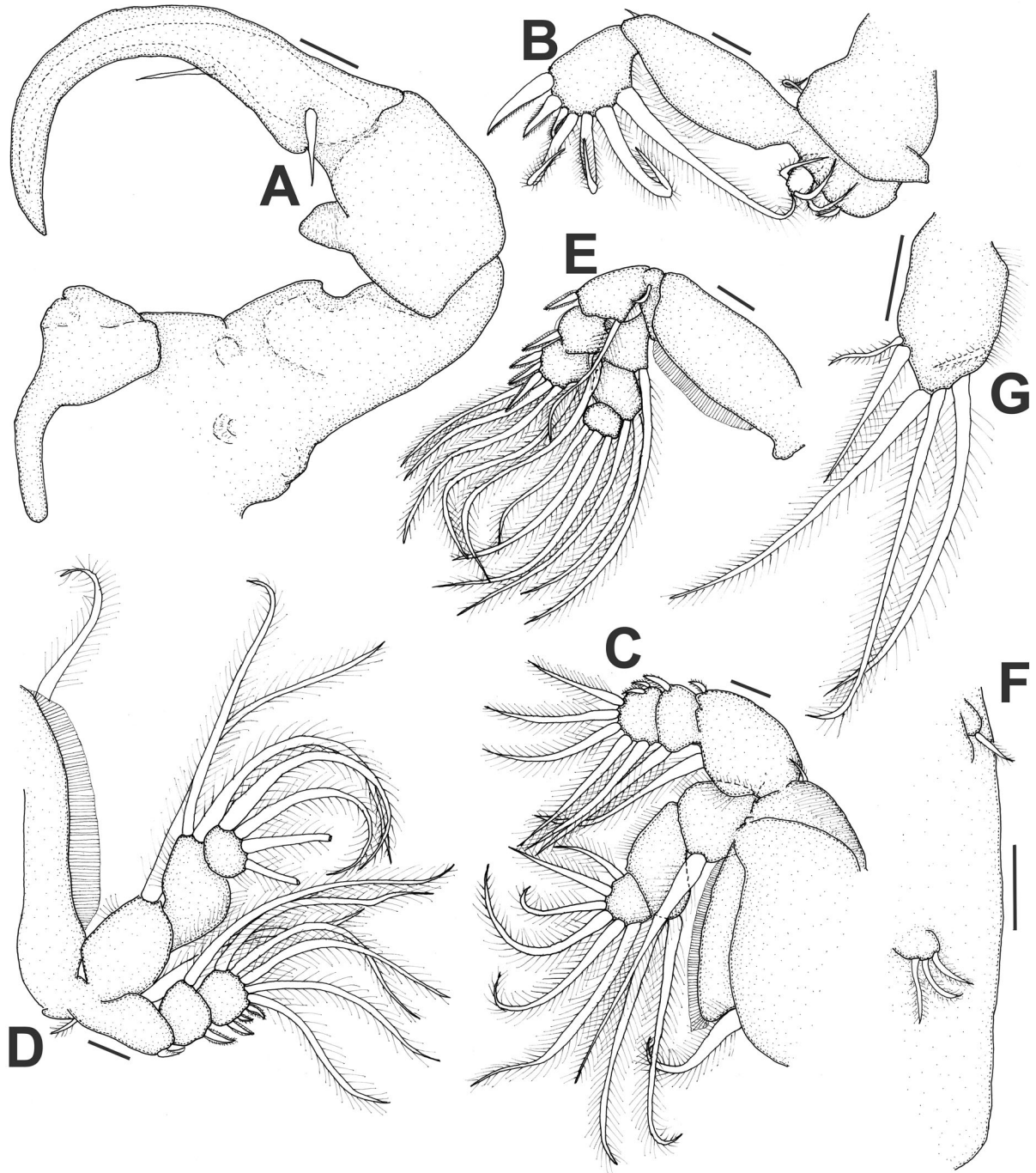


Fig. 2 *Trebius benzi* n. sp. ex *Squalus acutipinnis* Regan. Adult female. A, Antenna and postantennal process; B, Leg 1; C, Leg 2; D, Leg 3; E, Leg 4; F, Leg 5, ventral on genital complex; G, Caudal ramus. Scale-bars: 50 μ m

(posterior lobe) dentiform process. Maxilla (Fig. 1F) brachiform; lacertus unarmed; brachium with calamus and canna both fringed by serrated membranes.

Maxilliped (Fig. 1G) 2-segmented, subchelate; corpus maxillipedis slender, unarmed with few denticles distomedially; subchela slightly shorter than corpus,

tapering with naked seta near base of claw. Sternal furca (Fig. 1H) with divergent, blunt tines (longer than box) fringed by narrow flanges.

Legs 1–4 (Figs. 2B, C, D, E) biramous; rami 2-segmented in leg 1; 3-segmented in legs 2–4. Leg 1 (Fig. 2B) sympod with small outer and inner pinnate setae; exopod first segment elongated with medial fringe of setules and small distolateral spine; second segment armed with medial setules followed by 4 pinnate setae (decreasing in length from medial to distal), 1 spiniform seta with serrated lateral margins, 1 larger spiniform seta with serrated lateral margins, and 1 large spiniform seta with serrated medial margin; endopod first segment small, unarmed; second segment armed with three pinnate setae distally. Leg 2 (Fig. 2C) sympod with pinnate outer and inner setae and medial membrane; exopod first segment with medial setules, distomedial pinnate seta and distolateral spiniform seta with serrated margins; second segment with distomedial pinnate seta and distolateral spiniform seta with serrated margins; third segment with 5 pinnate setae (decreasing in length from medial to distal) and 2 small lateral spiniform setae with serrated margins; endopod first segment with lateral setules and pinnate seta distomedially; second segment with lateral setules and 2 distomedial pinnate setae; third segment bearing 6 pinnate setae (decreasing in length from medial to lateral). Leg 3 (Fig. 2D) sympod with small pinnate outer seta, large pinnate inner seta and medial membrane; exopod first segment with medial setules, distomedial pinnate seta and distolateral spiniform seta with serrated margins; second segment with distomedial pinnate seta and distolateral spiniform seta with serrated margins; third segment with 5 pinnate setae (slightly decreasing in length from medial to distal) and 3 lateral spiniform setae with serrated margins (middle one smallest); endopod first segment with lateral setules and pinnate seta distomedially; second segment with lateral setules and 2 distomedial pinnate setae; third segment bearing 4 pinnate setae distally. Leg 4 (Fig. 2E) sympod with small pinnate outer seta and medial membrane; exopod first segment with medial setules, distomedial pinnate seta and distolateral spiniform seta with serrated margins; second segment with distomedial pinnate seta and distolateral spiniform seta with serrated margins; third segment with 4 pinnate setae (slightly decreasing in length from medial to distal) and 3 lateral spiniform setae with serrated margins;

endopod first segment with lateral setules and pinnate seta distomedially; second segment with lateral setules and 2 distomedial pinnate setae; third segment bearing 3 pinnate setae distally. Leg 5 (Fig. 2F) vestigial, consisting of 2 setiferous papillae with 1 and 3 small pinnate setae, respectively.

Discussion

According to Deets & Dojiri (1989) eight of the *Trebius* species possess a maxillule in which the endite consists of a single-tined dentiform process (also see Nagasawa et al., 1998; Izawa, 2013) and seven species have an endite with a bifid dentiform process. Four of the eight species (*T. exilis* Wilson, 1906; *T. javanicus* Hameed & Pillai, 1973; *T. kirtii* Hameed & Pillai, 1973 and *T. sepheni* Hameed & Pillai, 1973) with a single-tined dentiform process were reported from rays from the Indian Ocean (Pillai, 1985). However, all four have similar sternal furca with a large base and short, pointed tines (see figure 68A in Pillai, 1985) whereas in *T. benzi* n. sp. the base and the rounded tines are about equal in length (see Fig. 1H). Additionally, three other single-tined dentiform species (*T. elongatus* Capart, 1953; *T. minutus* Capart, 1959; *T. nunesi* Capart, 1959) have more pointed tines (cf. Deets & Dojiri, 1989) while all three also have abdomens that are equal to or longer than the genital complex (Capart, 1959; Deets & Dojiri, 1989) while that of *T. benzi* n. sp. is shorter (see Fig. 1A). The last species with a single-tined dentiform process, i.e. *T. shiinoi*, has an abdomen that is much longer than the genital complex, the tine of the dentiform process has an additional small protuberance about two thirds along the medial margin as well as additional secondary tines on the sternal furca (Nagasawa et al., 1998; Izawa, 2013). Thus, *T. benzi* n. sp. can be distinguished from all the other species by the combination of an abdomen that is shorter than the genital complex (Fig. 1A), a maxillule with an endite that consists of a single-tined dentiform process (Fig. 1E), sternal furca tines that are blunt and as long as the base (Fig. 1H) and with the innermost spine of the last exopodal segment of leg 1 the shortest (Fig. 2B) (see Deets & Dojiri, 1989).

Acknowledgements This work is based upon research supported by the National Research Foundation (NRF). However, any opinion, findings, and conclusions or recommendations expressed

in this manuscript are those of the author and therefore the NRF does not accept any liability in regard thereto. I thank Oceans Research (Mossel Bay) and the University of Limpopo (UL) for field and laboratory assistance. I also thank Ms MC Lebepe and Ms RA Molele who assisted with examination of hosts for infection. Also at UL, I thank the Research Development and Administration for financial support and Ms BP Jordaan for continued field assistance.

Compliance with ethical standards

Conflict of interest The author declares that she has no conflict of interest.

Ethical approval All applicable institutional, national and international guidelines for the care and use of animals were followed.

References

- Boxshall, G. A., & Halsey, S. H. (2004). *An introduction to copepod diversity*. London: The Ray Society.
- Boxshall, G. A., & Justine, J.-L. (2005). A new genus of parasitic copepod (Siphonostomatoida: Caligidae) from the razorback scabbardfish, *Assurger anzac* (Trichiuridae) off New Caledonia. *Folia Parasitologica*, 52, 349–358.
- Capart, A. (1959). Copépodes Parasites. *Résultats Scientifiques. Expédition Océanographique Belge dans les Eaux Côtières Africaines de L'Atlantique Sud (1948-1949)*, 3, 55–126.
- Deets, G. B., & Dojiri, M. (1989). Three species of *Trebius* Krøyer, 1838 (Copepoda: Siphonostomatoida) parasitic on Pacific elasmobranchs. *Systematic Parasitology*, 13, 81–101.
- Ebert, D. A., & Van Hees, K. E. (2015). Corrigendum. *African Journal of Marine Science*, 37, 435–435.
- Froese, R., & Pauly, D. (2016). FishBase. World Wide Web electronic publication. <http://www.fishbase.org>, version (10/2015). Accessed on 17 March 2016.
- Humes, A. G., & Gooding, R. U. (1964). A method for studying the external anatomy of copepods. *Crustaceana*, 6, 238–240.
- Huys, R., & Boxshall, G. A. (1991). *Copepod evolution*. London: The Ray Society.
- Izawa, K. (2013). Redescription of adults and description of developmental stages of *Trebius shiinoi* Nagasawa, Tanaka & Benz, 1998 (Copepoda, Siphonostomatoida, Trebiidae) from the Japanese angelshark, *Squatina japonica* Bleeker, 1858. *Crustaceana*, 86, 739–766.
- Kabata, Z. (1979). *Parasitic copepods of British fishes*. London: The Ray Society.
- Nagasawa, K., Tanaka, S., & Benz, G. W. (1998). *Trebius shiinoi* n. sp. (Trebiidae: Siphonostomatoida: Copepoda) from uteri and embryos of the Japanese angelshark (*Squatina japonica*) and the Clouded angelshark (*Squatina nebulosa*), and redescription of *Trebius longicaudatus*. *Journal of Parasitology*, 84, 1218–1230.
- Pillai, N. K. (1985). *The fauna of India. Copepod parasites of marine fishes*. Calcutta: Director, Zoological Survey of India.
- Walter, T. C., & Boxshall, G. (2015). *Trebius* Krøyer, 1837. In: Walter, T. C., & Boxshall, G. (2015). World of Copepods database. <http://www.marinespecies.org/copepoda/aphia.php?p=taxdetails&id=135661>. Accessed on 28 April 2016.

Terms and Conditions

Springer Nature journal content, brought to you courtesy of Springer Nature Customer Service Center GmbH (“Springer Nature”). Springer Nature supports a reasonable amount of sharing of research papers by authors, subscribers and authorised users (“Users”), for small-scale personal, non-commercial use provided that all copyright, trade and service marks and other proprietary notices are maintained. By accessing, sharing, receiving or otherwise using the Springer Nature journal content you agree to these terms of use (“Terms”). For these purposes, Springer Nature considers academic use (by researchers and students) to be non-commercial.

These Terms are supplementary and will apply in addition to any applicable website terms and conditions, a relevant site licence or a personal subscription. These Terms will prevail over any conflict or ambiguity with regards to the relevant terms, a site licence or a personal subscription (to the extent of the conflict or ambiguity only). For Creative Commons-licensed articles, the terms of the Creative Commons license used will apply.

We collect and use personal data to provide access to the Springer Nature journal content. We may also use these personal data internally within ResearchGate and Springer Nature and as agreed share it, in an anonymised way, for purposes of tracking, analysis and reporting. We will not otherwise disclose your personal data outside the ResearchGate or the Springer Nature group of companies unless we have your permission as detailed in the Privacy Policy.

While Users may use the Springer Nature journal content for small scale, personal non-commercial use, it is important to note that Users may not:

1. use such content for the purpose of providing other users with access on a regular or large scale basis or as a means to circumvent access control;
2. use such content where to do so would be considered a criminal or statutory offence in any jurisdiction, or gives rise to civil liability, or is otherwise unlawful;
3. falsely or misleadingly imply or suggest endorsement, approval, sponsorship, or association unless explicitly agreed to by Springer Nature in writing;
4. use bots or other automated methods to access the content or redirect messages
5. override any security feature or exclusionary protocol; or
6. share the content in order to create substitute for Springer Nature products or services or a systematic database of Springer Nature journal content.

In line with the restriction against commercial use, Springer Nature does not permit the creation of a product or service that creates revenue, royalties, rent or income from our content or its inclusion as part of a paid for service or for other commercial gain. Springer Nature journal content cannot be used for inter-library loans and librarians may not upload Springer Nature journal content on a large scale into their, or any other, institutional repository.

These terms of use are reviewed regularly and may be amended at any time. Springer Nature is not obligated to publish any information or content on this website and may remove it or features or functionality at our sole discretion, at any time with or without notice. Springer Nature may revoke this licence to you at any time and remove access to any copies of the Springer Nature journal content which have been saved.

To the fullest extent permitted by law, Springer Nature makes no warranties, representations or guarantees to Users, either express or implied with respect to the Springer nature journal content and all parties disclaim and waive any implied warranties or warranties imposed by law, including merchantability or fitness for any particular purpose.

Please note that these rights do not automatically extend to content, data or other material published by Springer Nature that may be licensed from third parties.

If you would like to use or distribute our Springer Nature journal content to a wider audience or on a regular basis or in any other manner not expressly permitted by these Terms, please contact Springer Nature at

onlineservice@springernature.com