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Neoalbionella izawai n. sp. from the smallfin gulper shark *Centrophorus moluccensis* Bleeker and additional host records for *N. etmopteri* (Yamaguti, 1939) off South Africa

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Abstract *Neoalbionella* Özdikmen, 2008 comprises 10 accepted species, which all infect sharks of Squaliformes and Carcharhiniformes. Adult females belonging to species of *Neoalbionella*, based on the maxillule palp armed with three setae and the maxilliped subchela claw with only one secondary denticle, were collected from sharks off the coast of South Africa. *Neoalbionella izawai* n. sp. collected from the anterodorsal part of the spiracle opening of *Centrophorus moluccensis* Bleeker differs from its congeners by having maxillae that are separated except at the tapering tips where they are fused and that are longer than the trunk, uropods originating from the pointed posterior margin of the trunk and that are well developed, and maxillipeds without an additional spine at the base of the subchela barb. *Neoalbionella etmopteri* (Yamaguti, 1939) is herein reported from two new hosts (*Etmopterus* spp.) off South Africa.

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Introduction

Neoalbionella Özdikmen, 2008 (Lernaeopodidae Milne Edwards, 1840) comprises 10 species: *N. globosa* (Leigh-Sharpe, 1918); *N. centroscyllii* (Hansen, 1923); *N. longicaudata* (Hansen, 1923); *N. etmopteri* (Yamaguti, 1939); *N. oviformis* (Shiino, 1956); *N. tenuis* (Castro-Romero & Baeza-Kuroki, 1986); *N. fabricii* (Rubec & Hogans, 1988); *N. kabatai* (Benz & Izawa, 1990); *N. benzipirata* Ruiz & Bullard in Ruiz, Driggers & Bullard, 2019 and *N. dannytangi* Ruiz & Bullard, 2019 (see Ruiz & Bullard, 2019; Ruiz et al., 2019; Dippenaar, 2020). Three innominate species exist according to Ruiz et al. (2019). These lernaeopodids infect sharks of Carcharhiniformes (Pentanchidae, Scyliorhinidae and Triakidae) and Squaliformes (Centrophoridae, Etmopteridae and Squalidae) (Castro-Romero & Baeza-Kuroki, 1986; Ruiz et al., 2019).

Females of species of *Neoalbionella* resemble those of *Lernaeopoda* von Nordmann, 1832 (see Kabata, 1979) but can be distinguished based upon the morphology of the maxillule palp (armed with 3 setae in *Neoalbionella* spp. *vs* 2 in *Lernaeopoda* spp.) and the number of secondary denticles on the maxilliped subchela claw (1 in *Neoalbionella* spp. *vs* 2 or more in *Lernaeopoda* spp.) (see Ruiz et al., 2019). Males are more readily distinguishable (Kabata, 1979), but are seldom reportedly collected along with females and few have been described (Hansen, 1923; Kabata,

1964, 1979; Rubec & Hogans, 1988; Benz, 1991a; Ruiz & Bullard, 2019; Ruiz et al., 2019).

The only species of *Neoalbionella* previously reported from South African waters is *N. etmopteri* from *Etmopterus* sp. caught off Cape Point (Atlantic Ocean) (Kensley & Grindley, 1973) and also from a congeneric shark from the Indian Ocean (Benz, 1991a).

The examination of sharks caught off the coast of South Africa for copepod infection revealed the presence of two species of *Neoalbionella*. The present paper describes the female of a new species of *Neoalbionella* and reports new hosts for *N. etmopteri*.

Materials and methods

The copepod specimens were collected from *Etmopterus* spp. caught as by-catch during hake assessment demersal cruises off the south and west coasts of South Africa on board the Department of Agriculture, Forestry and Fisheries (DAFF) research vessel *R/V* (*Africana*) during April 2008, January 2012 and March 2013 as well as from a single host of *Centrophorus moluccensis* Bleeker that was caught by a fisherman off Durban (KZN) on the 25th of April 2009. This shark was identified by staff of the KZN Sharksboard. Collected specimens were fixed and preserved in 70% ethanol. One adult female copepod collected from *C. moluccensis* was cleared and stained in lactic acid containing a pinch of dissolved lignin pink. The specimen was dissected and studied under both stereo- and light microscopes using the wooden slide technique (Humes & Gooding, 1964). Drawings were made with the aid of a drawing tube. Names of previously reported hosts of species of *Neoalbionella* were verified using Froese & Pauly (2019) and morphological nomenclature mostly follows Kabata (1979).

Family Lernaeopodidae Milne Edwards, 1840
Genus Neoalbionella Özdikmen, 2008

Neoalbionella izawai n. sp.

Type-host: *Centrophorus moluccensis* Bleeker (Chondrichthyes: Squaliformes: Centrophoridae).
Type-locality: Off Durban, Kwa-Zulu Natal, South Africa.
Type-material: One adult female (holotype) (SAMC-A091411) is 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.
Material studied: Three adult females from one host caught on the 25th of April 2009.
Site on host: Anterodorsal part of spiracle opening.
ZooBank registration: To comply with the regulations set out in Article 8.5 of the amended 2012 version of the *International Code of Zoological Nomenclature* (ICZN, 2012), details of the new species have been submitted to ZooBank. The Life Science Identifier (LSID) for *Neoalbionella izawai* n. sp. is urn:lsid:-zoobank.org:act:D7D6C7B0-1A0B-43B4-B25E-1C06A0C1B5E1.
Etymology: The specific epithet *izawai* honours Dr Kunihiko Izawa (Izawa Marine Biologiocal Laboratory, Japan) for his contributions to our knowledge of elasmobranch siphonostomatoids.

Description

Adult female [Based on 3 specimens; Figs. 1, 2.] Body length from tip of cephalosome to tip of abdomen (excluding uropods) about 8.1 mm. Cephalosome well delimited from trunk, less than third length of trunk, at right angle to main axis of trunk (Fig. 1A); dorsal shield of cephalosome indistinct. Trunk pyriform, decreasing in width posteriorly, anteriorly with 2 transverse constrictions, posterolateral margins rounded, posterior margin pointed (Fig. 1B), median anal slit on slightly pointed posterior margin. Uropods fusiform (Figs. 1A, B), about half length of trunk, 3.3 mm long. Egg-sacs multiseriate, *c.*3.6 mm long.

Antennule (Fig. 1C) 4-segmented; basal segment inflated; second segment with long whip; third segment with small solus; distal segment with only 4 setae observed (Fig. 1D). Antenna (Fig. 1E) with 1-segmented, bulbous exopod, lateral and apical margins with scattered small denticles and two papillae; endopod, smaller than exopod, 2-segmented (Fig. 1F), proximal segment medial margin with raised patch covered with denticles, distal segment armed with hook 1, spiniform seta 2, shorter seta (tubercle) 3, inflated distomedial margin with very small denticles (process 4, according to Kabata (1979), but 5 according to Kabata (1964)) and naked seta 4 (according to Kabata (1979) but 5 according to

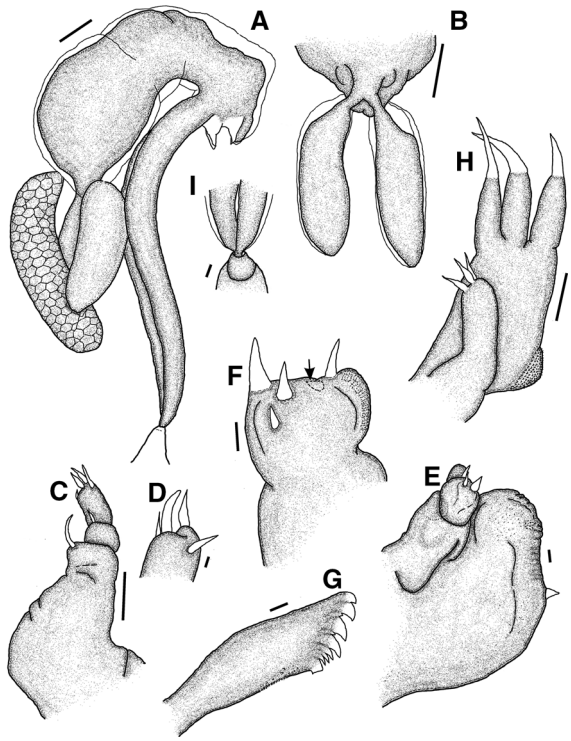

Fig. 1 *Neoalbionella izawai* n. sp., adult female. A, General habitus, lateral view; B, Posterior part of trunk, dorsal view; C, Antennule; D, Tip of antennule; E, Antenna; F, Endopod of antenna (additional small seta arrowed); G, Mandible; H, Maxillule, I, Tips of maxillae with bulla. *Scale-bars*: A, B, 1 mm; I, 0.1 mm; C, H, 0.05 µm; D–G, 0.01 µm

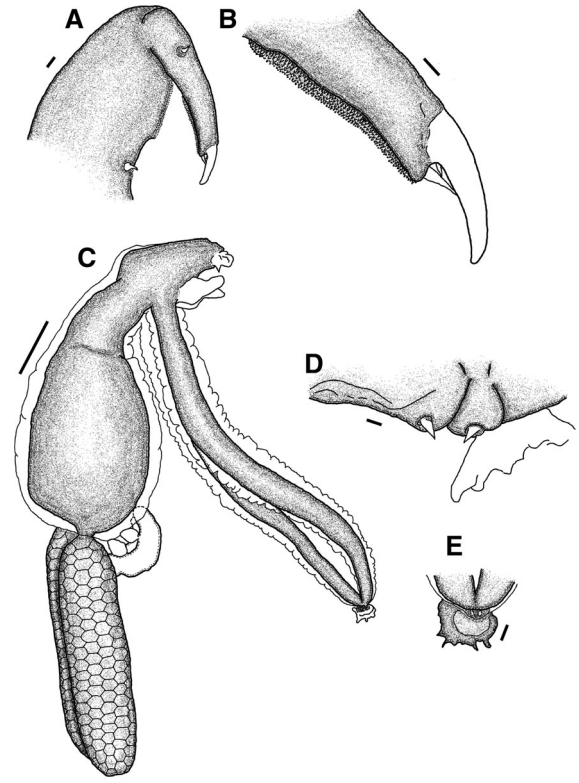

Fig. 2 A, B, *Neoalbionella izawai* n. sp., adult female. A, Maxilliped; B, Maxilliped claw; C–E, *Neoalbionella etmopteri* (Yamaguti, 1939). C, Adult female with attached male, lateral view; D, Posterior part of trunk, ventral view; E, Tips of maxillae with bulla. *Scale-bars*: A, 0.02 µm; B, 0.01 µm; C, 1 mm; D, E, 0.1 mm

Kabata (1964)), as well as another small seta at base of naked seta 4 (arrowed). Mandible (Fig. 1G) with dental formula P1, P1, S1, P1, S1, B4 and some scattered denticles proximal to basal teeth. Maxillule (Fig. 1H) bilobate; palp bearing three short apical naked setae; endite with dorsal denticulated raised pad, distally with three papillae, each bearing a naked seta. Maxillae (Fig. 1A), *c*.8.8 mm long, longer than total body length (excluding uropods), cylindrical and slightly decreasing in diameter towards tips, not expanded at tips, each maxilla separate, united only at small bulla, with short manubrium and plano-convex anchor (Fig. 1I). Maxilliped (Fig. 2A) with robust corpus and long, slender subchela; myxal area with short seta flanked posteriorly by denticulated pad, another denticulated pad at base of subchela; subchela with proximal small naked seta and denticulated pad distally on inner margin; barb tapering, shorter than half length of claw; latter slightly curved, tapering with blunt tip, one secondary denticle at level of barb (Fig. 2B).

Remarks

Of the 10 described species of *Neoalbionella*, two (*N. longicaudata* and *N. benzipirata*) are quite distinct due to the fused maxillae (Ruiz et al., 2019) whereas *Neoalbionella izawai* n. sp. and the remaining eight species all have maxillae that are separate from its opposite except at the tips (excluding *N. oviformis*). The maxillae tips of three species (*N. globosa*, *N. tenuis*, *N. dannytangi*) are swollen (Kabata, 1979; Castro-Romero & Baeza-Kuroki, 1986; Ruiz & Bullard, 2019) whereas those of *N. izawai* n. sp. and the remaining five species taper distally.

Furthermore, two species (*N. kabatai* and *N. etmopteri*) have reduced uropods (Benz & Izawa, 1990;

Benz, 1991a; Hogans & Marques, 1994) while those of *N. izawai* n. sp. and the remaining three species are well developed. *Neoalbionella oviformis* differs from *N. izawai* n. sp., *N. centroscyllii* and *N. fabricii* by having maxillae that are slightly longer than the body, separated along the entire length (Benz, 1991b) whereas the maxillae of *N. izawai* n. sp., *N. centroscyllii* and *N. fabricii* unite at the tips proximal to the bulla (see Fig. 1I; Kabata, 1964; Rubec & Hogans, 1988).

Neoalbionella fabricii has two separate swellings from which the uropods originate at the posterior margin of the trunk (see figure 2 in Rubec & Hogans, 1988), maxillae that are twice the trunk length, an apparently 3-segmented antennule with the distal segment armed with 6 setae and the antenna endopod distal segment armed with all 5 elements (according to Kabata, 1979); however, no mention is made of the denticulated medial margin (nr 4) by Rubec & Hogans (1988) whereas an 'additional seta' is referred to as nr 4 (see figure 4b in Rubec & Hogans, 1988), and a mandible with dental formula P2, S1, P1, S1, B5 (Rubec & Hogans, 1988). The posterior margin of the trunk of *N. centroscyllii* is not swollen at the uropods' origin (see figure 1B in Kabata 1964), the maxillae are approximately as long as the trunk, the antennule is 4-segmented (distal segment armed with 7 setae), the antenna endopod distal segment is armed with all 5 elements (it should be noted that 4 and 5 is transposed compared to those in Kabata, 1979), the mandible with a dental formula P1, S1, P1, S1, P1, S1, B5 and the maxilliped has an additional spine at the base of the barb next to the subchela claw (see figure 2K in Kabata, 1964).

Neoalbionella izawai n. sp. has uropods originating from the pointed posterior margin of the trunk (see Fig. 1B), the maxillae are longer than the trunk (see Fig. 1A), the antennule is 4-segmented and the distal segment with only 4 observed setae (see Fig. 1D), the antenna endopod distal segment is armed with all 5 elements (according to Kabata, 1979) but with an additional seta similarly located to "nr 4" in *N. fabricii* (see Fig. 1F (arrowed) and figure 4b in Rubec & Hogans, 1988), the mandible has a dental formula of P2, S1, P1, S1, B4 (see Fig. 1G), and the maxilliped is without an additional spine at the base of the barb.

***Neoalbionella etmopteri* (Yamaguti, 1939)**

Hosts: *Etmopterus baxteri* Garrick, *E. compagnoi* Fricke & Koch, *Etmopterus* sp.
Locality: Off the west coast (Atlantic Ocean), South Africa (*E. baxteri*); off the south coast (Indian Ocean), South Africa (*E. compagnoi* and *Etmopterus* sp.)
Voucher material: One adult female (SAMC-A091413) is deposited in the Iziko South African Museum, Cape Town, South Africa. Remaining specimens have been retained in the personal collection of the author.
Material examined: One female with an attached male of *N. etmopteri* was collected from *E. baxteri* Garrick caught on 21.iv.2008 off the west coast of South Africa (Atlantic Ocean) (Figs. 2C, D, E), one female from *E. compagnoi* Fricke & Koch caught on 31.i.2012 off the south coast and two females from *Etmopterus* sp. caught on 11.iii.2013 off the south coast of South Africa (Indian Ocean).

Remarks

Neoalbionella etmopteri and *N. kabatai* are most similar with regard to the reduced uropods. They can be differentiated based upon the three small spines and one long apical seta on the uropod of *N. etmopteri* whereas that of *N. kabatai* has two short and one long apical setae. Additionally, the number of setae on the distal antennule segment differs between these species: 9 setae in *N. etmopteri vs* 7 setae in *N. kabatai*. Furthermore, the maxillae of *N. etmopteri* are about as long as the body while those of *N. kabatai* are slightly longer than the body (Benz, 1991a; Benz & Izawa, 1990).

Discussion

Including *N. izawai* n. sp. there are now 11 accepted/nominal species of *Neoalbionella*, two of which have been reported off the coast of South Africa. Since these copepods infect mostly "deepwater" sharks that are rarely caught (Ruiz et al., 2019) and seldom examined for parasites, it is possible that several innominate lernaeopodids await discovery. *Centrophorus moluccensis*, *E. baxteri* and *E. compagnoi* all are new hosts for species of *Neoalbionella*.

The morphology of the males helps to distinguish between species of *Lernaeopoda* and species of *Neoalbionella* (see Kabata, 1979). Unfortunately, males are not always collected attached to the female. To date, the males of seven of the *Neoalbionella* species are described or partly described (i.e. *N. globosa*, *N. centroscyllii*, *N. longicaudata*, *N. etmopteri*, *N. fabricii*, *N. benzipirata* and *N. dannytangi*) (Hansen, 1923; Kabata, 1964, 1979; Rubec & Hogans, 1988; Benz, 1991a; Ruiz & Bullard, 2019; Ruiz et al., 2019) while those of *N. oviformis*, *N. tenuis*, *N. kabatai* and *N. izawai* n. sp. are still unknown.

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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.

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