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Schistobrachia kabata sp. nov. (Siphonostomatoida: Lernaeopodidae) from rajiform hosts off South Africa

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Abstract

The genus *Schistobrachia* Kabata, 1964 (Lernaeopodidae: Siphonostomatoida) currently accommodates five species of which two infect holocephalans and three utilize elasmobranchs. Kensley & Grindley (1973) reported three females from "*Dipturus batis"* (Linnaeus, 1758) collected in Table Bay, South Africa, which they assigned to *S. ramosa* (Krøyer, 1863), a species previously known only from the North Atlantic. Re-examination of these specimens (labelled *Charopinus ramosus* Krøyer, 1863 and deposited in the Iziko South African Museum) and additional *Schistobrachia* material newly collected from the gills of various Rajiformes off the South African west and south coasts, showed that Kensley & Grindley's (1973) earlier record of *S. ramosa* was misidentified and in reality represents a distinct species, *S. kabata* **sp. nov.** Both sexes of the new species are described using light and/or scanning electron microscopy.

Key words: Copepoda, Rajidae, ectoparasites, elasmobranchs

Introduction

The genus *Schistobrachia* Kabata, 1964 (Lernaeopodidae: Siphonostomatoida) currently consists of five species (Dippenaar *et al.* 2004). Two of these were reported from holocephalans, namely *S. chimaerae* (Yamaguti, 1939) from *Hydrolagus ogilbyi* (Waite, 1898) and *S. pilgrimi* Kabata, 1988 from the Pacific longnose chimaera, *Harriotta raleighana* Goode & Bean, 1895 (Yamaguti 1939; Kabata 1988). The other three infect elasmobranchs of the orders Rajiformes, Torpediniformes and Myliobatiformes. *Schistobrachia ramosa* (Krøyer, 1863) was reported from hosts belonging to the Rajidae (*Amblyraja radiata* (Donovan, 1808), *A. hyperborea* (Collett, 1879), *Leucoraja fullonica* (Linnaeus, 1758) and *Raja clavata* (Linnaeus, 1758) and Narcinidae (*Narcine maculata* (Shaw, 1804)) (Kabata 1979; Rokicki *et al.* 2001), while *S. tertia* Kabata, 1970 was reported from *Raja rhina* Jordan & Gilbert, 1880 and *R. binoculata* Girard, 1855 (Kabata 1970) and *S. jordaanae* Dippenaar, Olivier & Benz, 2004 infects *Gymnura natalensis* (Gilchrist & Thompson, 1911) (Gymnuridae) (Dippenaar *et al.* 2004).

Kensley & Grindley (1973) reported three ovigerous *Schistobrachia* females from *Dipturus batis* (Linnaeus, 1758) (as *Raia* [*sic*] *batis*) (Rajidae: Rajiformes) in Table Bay, South Africa which they assigned to *S. ramosa*. An illustration of the habitus of one female was given together with a statement that the total body length was approximately 9 mm and the maxillae were "distally fused, and each split into 2 slender fingers" (Kensley & Grindley 1973: 114–115, fig. 31). However, Kabata (1979) noted that the habitus of Kensley & Grindley's (1973) *S. ramosa* differed considerably from those of specimens collected in the North Atlantic (see Kabata 1964: fig. 67; Kabata 1979: fig. 1598). The most notable differences include the shape of the tips of the maxillae and the length of the posterior processes (Dippenaar *et al.* 2004). Kabata (1979) also considered the host identification to be unusual since *D. batis* is restricted to the eastern Atlantic, the western Mediterranean and the western part of the Baltic (Froese & Pauly 2014). He suggested that the specific identity of the South African specimens should be considered doubtful until a full description of the appendages is completed.

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Material and methods

The three ovigerous specimens (A 13015), reported by Kensley & Grindley (1973) as *S. ramosa*, that were deposited by M.L. Pritchard in the Iziko South African Museum, Cape Town, South Africa during January 1962 as *Charopinus ramosus* Krøyer, 1863 from *Raja batis* Linnaeus, 1758, were re-examined and permission was obtained to dissect one of them. The latter was stained in 70% EtOH with a small amount of dissolved lignin pink and drawn with a stereo-microscope using a drawing tube. The specimen was subsequently transferred to a lactic acid and lignin pink solution before the cephalothorax (excluding the maxillae) was cut off and the appendages removed and dissected. These were drawn with a light microscope equipped with a drawing tube, using the wooden slide technique (Humes & Gooding 1964). Measurements were done with a stage micrometer.

Additional *Schistobrachia* specimens were collected from by-catch hosts during hake assessment demersal cruises off the south and west coasts of South Africa on board the Department of Agriculture, Forestry and Fishery (DAFF) research vessel (*Africana*). These specimens were collected from the gill filaments of three hosts belonging to the Rajidae (Rajiformes) namely *Leucoraja wallacei* (Hulley, 1970), *Raja straeleni* Poll, 1951 and *Rostroraja alba* (Lacepède, 1803). Collected specimens were fixed and preserved in 70% EtOH and studied as indicated above. Selected specimens were prepared for scanning electron microscopy by dehydrating them through a graded ethanol series (70, 80, 90, 96, 100%) followed by critical point drying and sputter-coating with gold-palladium alloy.

Descriptive terminology conforms to Huys & Boxshall (1991) and detail about appendages to Kabata (1979) while host nomenclature is according to FishBase (Froese & Pauly 2014).

Results

Order Siphonostomatida Burmeister, 1835

Family Lernaeopodidae Milne Edwards, 1840

Genus *Schistobrachia* Kabata, 1964

Schistobrachia kabata sp. nov.
(Figs. 1–4)

Schistobrachia ramosa (Krøyer, 1863) *sensu* Kensley & Grindley (1973: 114).

Type material. Originally identified as *Charopinus ramosus* and deposited in the Iziko South African Museum by M.L. Pritchard. Holotype ♀ (ovigerous) (SAM A74035) with 1 ♂ attached (allotype SAM A74036) from *R. straeleni* caught off the west coast during January 2008. Paratypes include 3 ovigerous ♀♀ (1 dissected) (A 13015) and 2 ovigerous ♀♀ from *R. alba* (SAM A74037) caught off the south coast during April 2007; 1 ♀ (non-ovigerous) (SAM A74038) from *R. straeleni* caught off the west coast during January 2008.

Other material examined. 3 ♀♀ from one *R. alba* and 8 ♀♀ from four *R. straeleni* caught off the south coast during April 2007; 11 ♀♀ and 2 ♂♂ from six *R. straeleni* caught off the west coast during January 2008; and 1 ♀ from one *R. alba*, 7 ♀♀ from four *R. straeleni* and 1 ♀ from one *L. wallacei* caught off the south coast during April 2008.

Description of adult female. Body length of adult female from tip of cephalothorax to tip of abdomen (excluding posterior processes) varying, 5.7–9.7 mm. Tip of cephalothorax, including maxillipeds, ventrally inclined to trunk (Figs. 1A, 2A, F, G, I), with proximal portions of maxillae at an almost 90° angle to trunk, conforming to Kabata's (1979) "Type A" structural plan. Distance between maxillipeds and origin of maxillae approximately 8–15% of body length. Dorsal shield of cephalothorax indistinct, region between maxillipeds and base of maxillae cylindrical, expanding slightly posteriorly to form cylindrically shaped trunk. Small abdomen situated posteriorly on trunk (Figs. 1B, 2B). Posterior processes oblong with slightly pointed tips (Figs. 1A, B, 2A, B, F, G, I), 0.9–3.2 mm (approximately 16–33% of body length). Egg sacs (Figs. 1A, 2F, G) multiseriate.

Antennule (Figs. 1C, 2C) 3-segmented. Basal segment with lateral whip; second segment with solus; apical segment with three short and three long elements, conforming to Kabata's (1979) Type A antennule structure, but with element nr 5 not observed in one specimen. Antenna (Fig. 1D) biramous, rami almost equal in length; exopod 1-segmented, covered mostly by denticles, with two short, naked setae near tip; endopod 2-segmented, first segment with medial denticles, second segment (Figs. 1E, 3D) with flexed hook (1), naked seta (2), denticulated process (4) and truncated seta (5), element 3 not observed (element notation according to Kabata (1979)). Mouth cone (Fig. 3C) similar to other lernaeopodids with labrum and labium fringed with setules; mandible (Figs. 1F, 2D) with dental formula P1, S1, P1, S1, P1, S1, B4. Maxillule (Figs. 1G, 3E) biramous; exopod/palp with two apical naked setae; endopod/endite proximally with lateral denticulated patch, apically bearing three terminal papillae with apical setae. Maxillae (Figs. 1A, 2A, F, G) approximately 60% of body length and mostly equal in diameter, distally inflated, united only at vestigial bulla (Fig. 2E). Tip of each maxilla leading to two processes of holdfast organ (Figs. 1A, H, I, 2A, F, G, I), processes of mostly equal length and width, especially in young female (Fig. 2I); adult females with ventral processes sometimes slightly thinner (Fig. 2F). One of the ventral processes of a specimen collected from *R. alba* with bifurcating tip (Fig. 2H). Maxilliped (Fig. 1J) robust, consisting of long narrow corpus and long subchela; myxal area (Figs. 1K, 3A) inflated with a short, slender seta on inflated base and additional digitiform process; small denticulated process surrounded by tiny denticles (Figs. 1L, 3F) distomedially on corpus; subchela (Figs. 1J, M, 3B) with small seta on proximal half, inner distal margin with few small denticles, small protruding papilla at base of small naked seta next to claw; claw (Figs. 1M, 3B) curved, tapering with small secondary tooth on proximal half of inner margin.

Description of adult male. Cephalothorax (Fig. 4A) more than half body length, comprising two indistinctly separated parts; anterior part ventrally inclined towards posterior part and trunk, anteriorly with large mouth tube, antennules, antennae and buccal appendages; posteriorly with prominent maxillae and maxillipeds on bifid mediative process. Trunk (Fig. 4B) more slender than cephalothorax, indistinctly 3-segmented with 1 pair of vestigial legs laterally on first segment, posterior part with caudal rami.

Antennule (Fig. 4C) similar to female with solus not observed but all six elements of apical segment present. Antenna (Fig. 4D), mandible (Fig. 4E) and maxillule (Fig. 4F) resembling those of female. Maxillae (Fig. 4G) subchelate, broad and stout, bigger than maxillipeds, linked by tympanum; corpus broad, myxal area with prominent tubercle with rounded protrusions on distal margin; subchela tapering into strongly curved claw with small secondary tooth proximally on inner margin. Maxillipeds (Fig. 4H) subchelate, linked, robust, squat, situated on mediative process (Fig. 4I); corpus broad, myxa elevated to receive tip of claw; subchela (Fig. 4J) short, indistinctly delimitated from claw, one seta midway on lateral margin and one distomedially; claw short, tapered, curved. Vestigial leg (Fig. 4K) papilliform armed with single naked seta. Caudal ramus (Fig. 4L) setiform, with three short setae on lateral margin (one caudal ramus deformed (Fig. 4B)).

Attachment site. On gill filaments with holdfast organ inserted in host tissue.

Etymology. This species is named in honour of the late Dr Zbigniew Kabata for his extraordinary contribution to the taxonomy and systematics of symbiotic copepods. The species name is a noun in apposition.

Remarks. Comparison of these specimens with the re-description of *S. ramosa* given by Kabata (1979) reveals many differences. The general habitus of the South African females (Figs. 1A, 2A, F, G) differs from that of North Atlantic *S. ramosa* in the shape of the trunk, the length and diameter of the maxillae compared to the length of the trunk, and most notably the length of the posterior processes which are twice as long in the current species compared to *S. ramosa* (*cf.* Markewitch 1956). The antennae (Figs. 1E, 3D) differ in the absence of element 3 on the endopod, but also in the structure of element 4 and the size of the denticles on it (*cf.* Kabata 1979; Fig. 1602). The maxillae of our specimens (Figs. 1A, 2A, F, G) equal about 60% of the body length while those of *S. ramosa* are about 90% of the body length (*cf.* Markewitch 1956). The diameter of the maxillae seems to be larger in *S. kabata* **sp. nov.** compared to the body length than that of *S. ramosa* (*cf.* Figs. 1A, 2A, F, G and Kabata 1979: Fig. 1598), but the structure of the holdfast organ is similar. The maxillipeds of *S. kabata* **sp. nov.** (Fig. 1J) differ from those of *S. ramosa* (*cf.* Kabata 1979: Fig. 1606) in the structure of the myxal area (*cf.* Kabata 1979: Fig. 1607) displaying a digitiform process in the new species (Figs. 1K, 3A) rather than a small distally pointing conical process as in *S. ramosa*. In addition, the protruding papilla at the base of the naked seta on the inner side of the claw and the naked seta (Figs. 1M, 3B) are both shorter compared to the length of the claw than those of *S. ramosa* (*cf.* Kabata 1979; Fig. 1608).

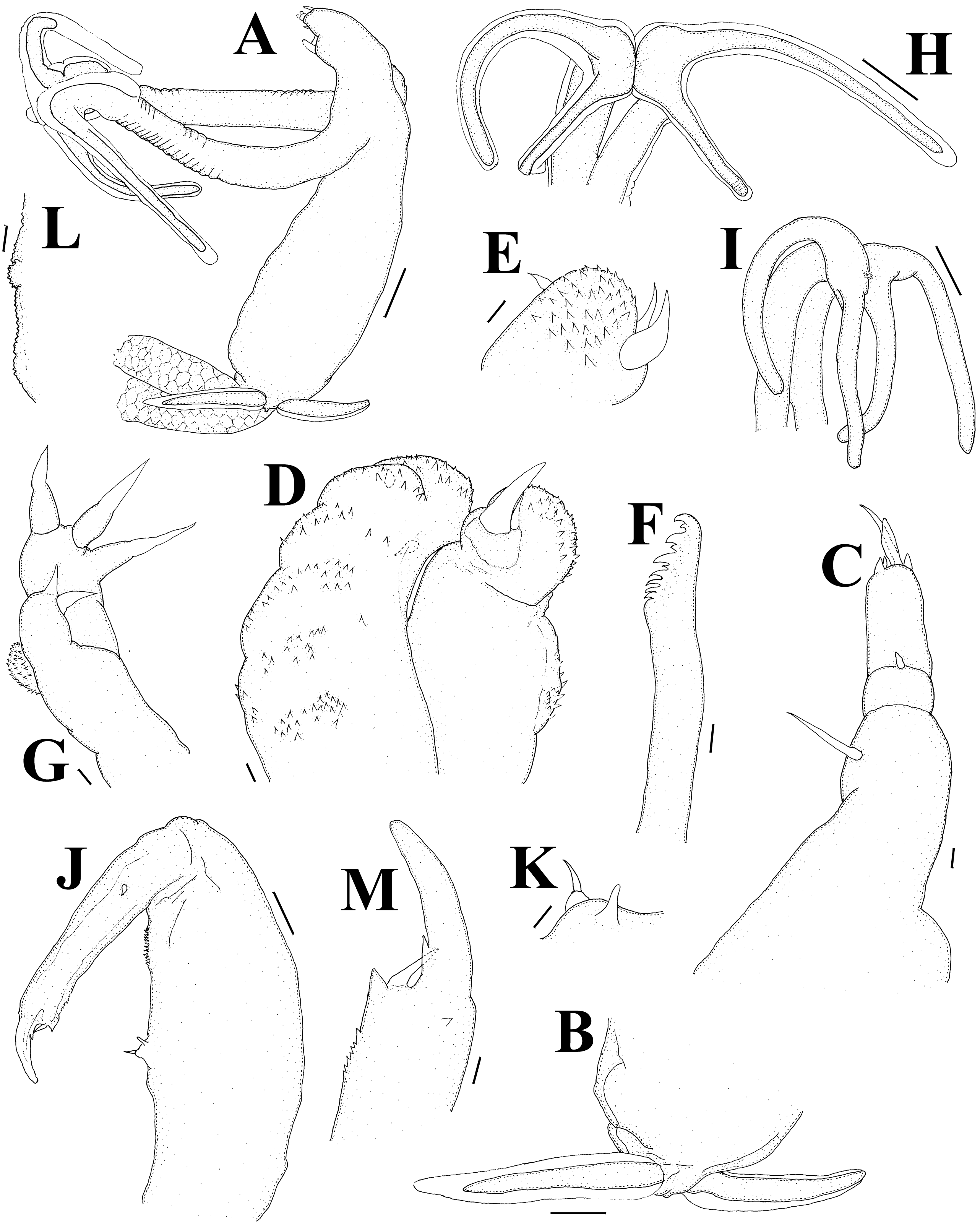

FIGURE 1. *Schistobrachia kabata* **sp. nov.** (adult female from "*Dipturus batis*" *sensu* Kensley & Grindley (1973)). A, general habitus; B, posterior of trunk and abdomen, dorsal view; C, antennule; D, antenna; E, second segment of antennary endopod; F, mandible; G, maxillule; H, holdfast organ formed by distal portions of maxillae; I, holdfast organ, more lateral view; J, maxilliped; K, maxillipedal myxal area; L, inner distal margin of maxillipedal corpus; M, distal part of maxillipedal subchela and claw. Scale bars: A, H, I = 1 mm; B = 0.5 mm; J = 50 µm; C–G, K–M = 10 µm.

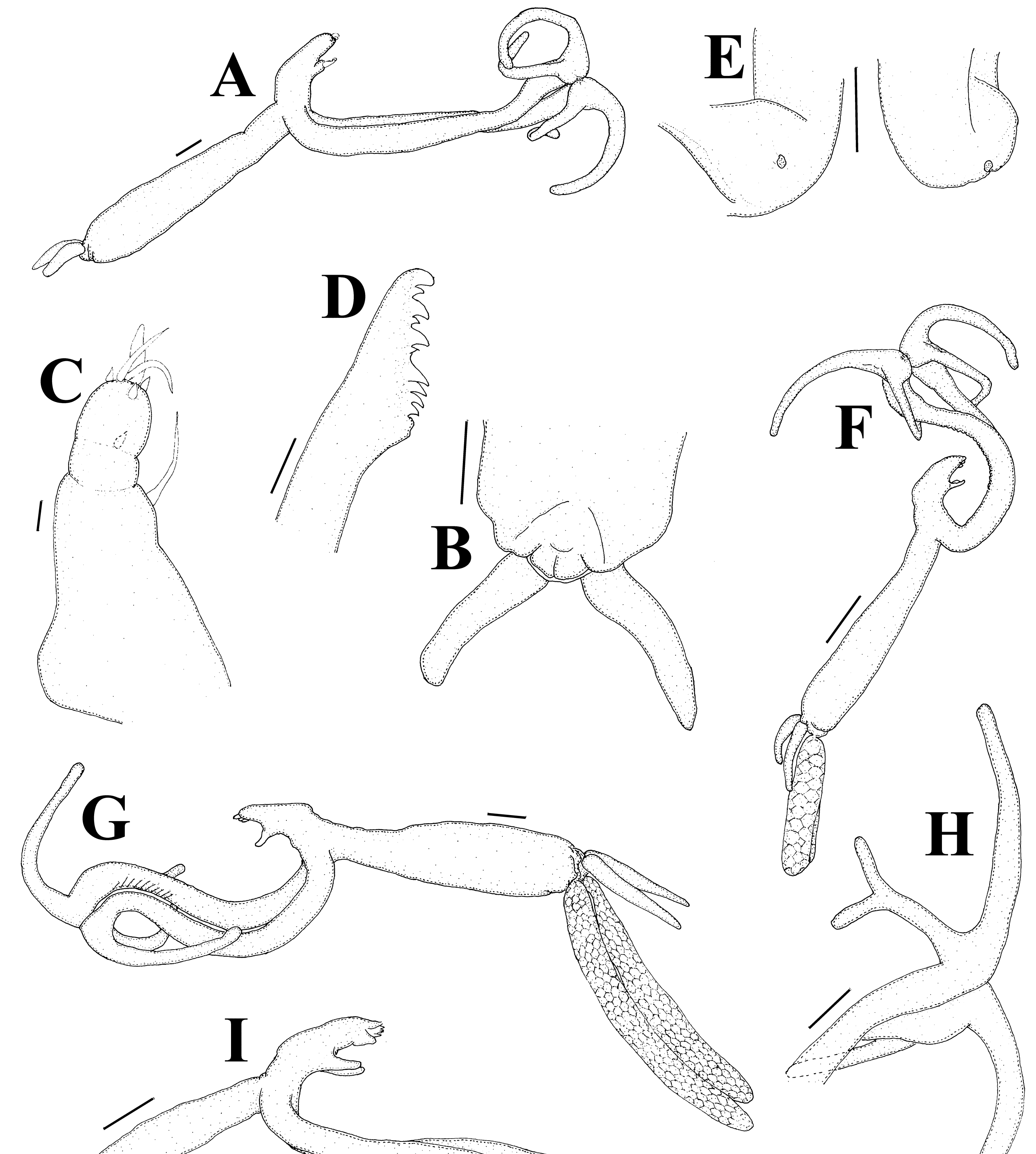

FIGURE 2. *Schistobrachia kabata* **sp. nov.** (females from *Raja straeleni* (A–E), *Leucoraja wallacei* (F) and *Rostroraja alba* (G–I)). A, general habitus of non-ovigerous female; B, posterior of trunk and abdomen, ventral view; C, antennule; D, mandible; E, two tips of maxillae with half of vestigial bulla in each; F, general habitus of adult female; G, general habitus of adult female; H, holdfast organ with one bifurcating tip; I, immature female. Scale bars: A, B, E = 0.5 mm; C–D = 10 µm; F–I = 1 mm.

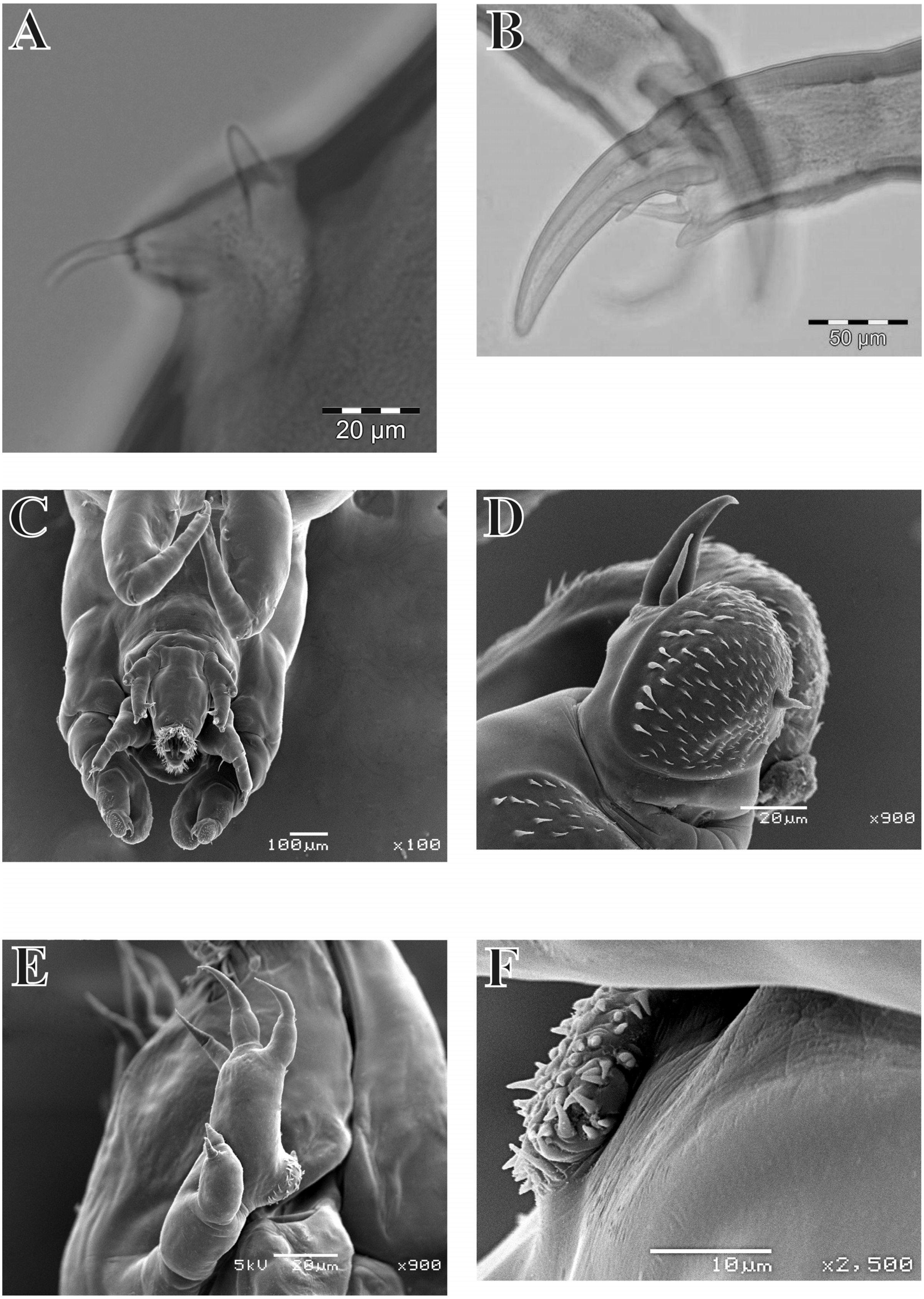

FIGURE 3. *Schistobrachia kabata* **sp. nov.** (adult females from "*Dipturus batis*" *sensu* Kensley & Grindley (1973) (A–B) and *Rostroraja alba* (C–F; SEM micrographs)). A, maxillipedal myxal area; B, distal part of maxillipedal subchela and claw; C, distal part of cephalothorax; D, second segment of antennary endopod; E, maxillule; F, inner distal margin of maxillipeda; corpus. Scale bars: A, D, E = 20 µm; B = 50 µm; C = 100 µm; F = 10 µm.

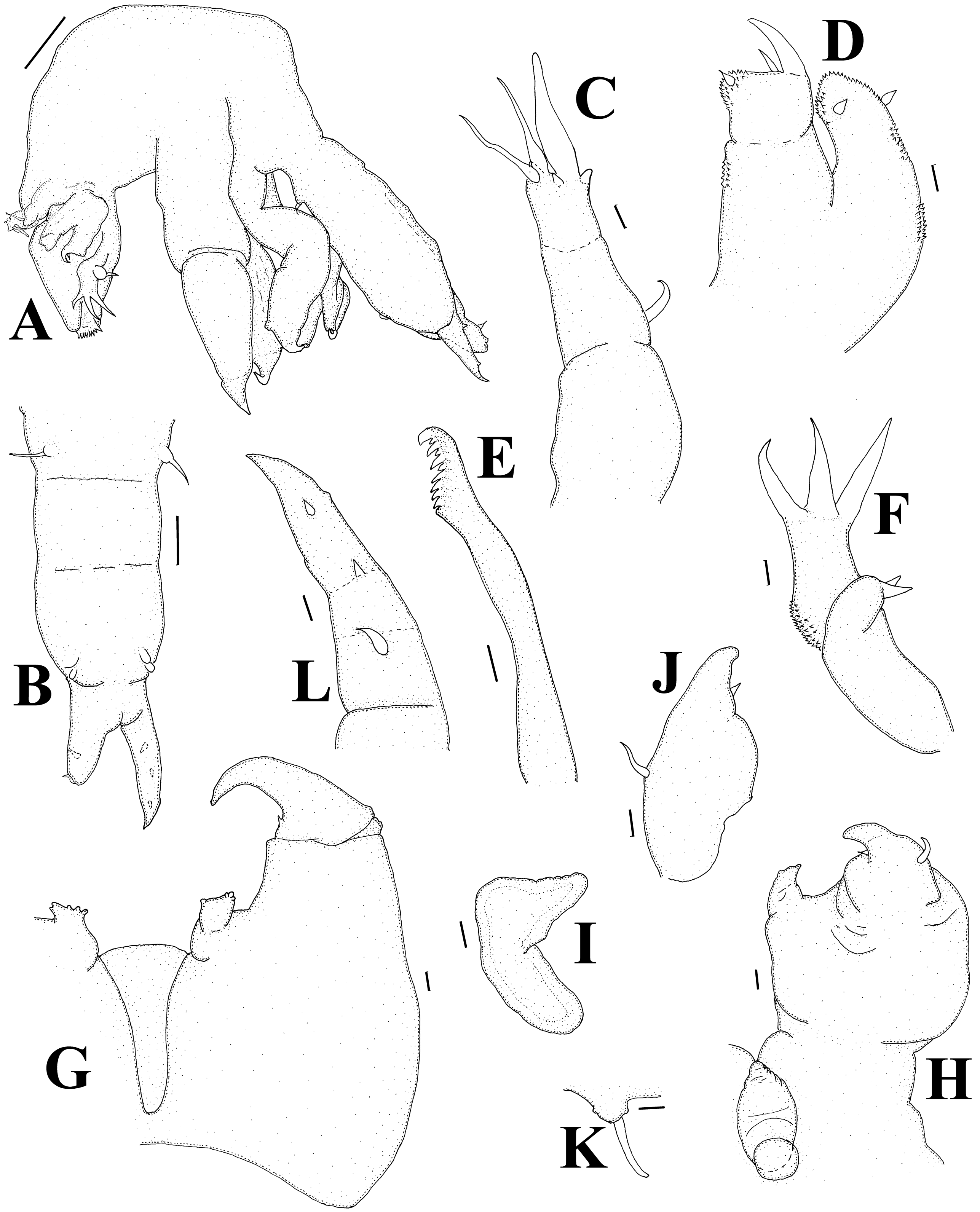

FIGURE 4. *Schistobrachia kabata* **sp. nov.** (male from *Raja straeleni*). A, general habitus, lateral view; B, trunk with caudal rami; C, antennule; D, antenna; E, mandible; F, maxillule; G, maxillae linked by tympanum; H, maxillipeds on mediative process; I, mediative process, lateral view; (J) maxillipedal subchela and claw; K, vestigial leg; L, caudal ramus. Scale bars: A = 100 µm; B = 50 µm; C–L = 10 µm.

Schistobrachia kabata **sp. nov.** is thus different from *S. ramosa* in a number of features including the general habitus and the morphology of several appendages. Comparing it with the other known congeners, it differs in general appearance from *S. tertia* but also in the size of the posterior processes that are about 50% of the body length in *S. tertia* (Kabata 1970) compared to only about 16–33% of the body length in *S. kabata* **sp. nov.** There are also clear differences in the structure of the holdfast organ which has three pairs of "tines" at the tips of the maxillae in *S. tertia* (Kabata 1970: Fig. 5) compared to the two pairs of much longer branches in *S. kabata* **sp. nov.** (Figs. 1H, I, 2A, F, G). The myxal area of the maxillipeds of *S. tertia* (Kabata 1970: Fig. 15) is without the digitiform processes clearly visible in *S. kabata* **sp. nov.** (Figs. 1K, 3A). The general appearance of the new species is also completely different from that of *S. jordaanae*, with additional differences observed in the structure of the appendages (Dippenaar *et al.* 2004). The same is true when comparing *S. kabata* **sp. nov.** with *S. pilgrimi* (Kabata 1988) and *S. chimaerae* (Yamaguti 1939). Even though the holdfast organs appear to be mostly similar in structure, the general habitus (see Kabata 1988: Fig. 1 and Yamaguti 1939: Fig. 122) with the position of the maxillae on the cephalothorax (very close to maxillipeds) and the length of the maxillae compared to the body length (equal or longer) as well as the length of the posterior processes (very short) are clearly different. In addition there are also obvious differences in the structure of the appendages. The fact that one of the specimens of *S. kabata* **sp. nov.** has one of the four processes of the holdfast organ bifurcating (Fig. 2H) raises the question whether this may have happened during the development of the process when it could have been opposed by the gill arch.

Kabata (1979) provided a very short description of the male of *S. ramosa* with no illustrations of the appendages and stated that antennae and buccal appendages are similar to those of the female while the maxillae and maxillipeds resemble those of the male of *Charopinus dubius* T. Scott, 1901. Differences in the structure of the appendages between *S. kabata* **sp. nov.** and *S. ramosa* females have been highlighted above; in addition there are clear differences in the structure of most of the appendages (except antennule and maxillule) between the males of *S. kabata* **sp. nov.** and those of *C. dubius* (see Kabata 1979: Figs 1587–1597).

Discussion and conclusions

Including *S. kabata* **sp. nov.** there are now six species in the genus *Schistobrachia* of which two infect holocephalans and four elasmobranchs (orders Rajiformes, Torpediniformes and Myliobatiformes). The occurrence of one specimen of *S. kabata* **sp. nov.** displaying a bifurcating holdfast process is likely to be interpreted as individual variation possibly caused by an obstruction during the formation of the process. The bifurcation of one process is the primary distinguishing feature between *S. pilgrimi* and *S. chimaerae* (both infecting holocephalans). If the presence/absence of this bifurcation is indeed influenced by aberrations during development it would raise concern about the validity of the two species. However, Kabata (1988) observed the bifurcation in all four specimens he examined and concluded that this could not be dismissed as individual variation due to attachment site. This matter will only be resolved with certainty once more specimens of both *S. pilgrimi* and *S. chimaerae* are collected and studied, especially since *S. chimaerae* was described from a single female with no other reports since.

The variation in body size observed in *S. kabata* **sp. nov.** specimens has not been reported for other *Schistobrachia* species. Apart from *S. ramosa* (reported from five host species) and *S. kabata* **sp. nov.** (reported from four host species) all other species seem to be relatively host specific. The four hosts utilized by *S. kabata* **sp. nov.** are quite variable in size with *D. batis* (which constitutes a doubtful host identification) reaching a total length of 285 cm and *R. alba* reaching total lengths of 200–230 cm while *L. wallacei* (100 cm) and *R. straeleni* (70 cm) are much smaller (Froese & Pauly 2014). Whether the observed variation in body size is related to the total length of the host can only be confirmed by a thorough study of more specimens of *S. kabata* **sp. nov.** and measurement of the total lengths of their individual hosts, including the size of the infected gills. *Schistobrachia kabata* **sp. nov.** exhibits the highest prevalence on *R. alba* (14.3%) and *R. straeleni* (12.4%) with only 1.9% prevalence on *L. wallacei*. The fact that only one *L. wallacei* out of 54 examined hosts was infected raises concern about the correct identification of the host. The mean intensity values are also mostly low with 3, 2 and 1 individuals per infected host on *R. alba*, *R. straeleni* and *L. wallacei*, respectively.

Key to the adult females of *Schistobrachia*

1. Posterior processes very short . . . 2
- Posterior processes medium to long . . . 4
2. Maxillae originate at about same position as maxillipeds . . . 3
- Maxillae originate posterior to maxillipeds . . . *S. ramosa*
3. Holdfast processes not bifurcate . . . *S. chimaerae*
- Holdfast with one bifurcate process . . . *S. pilgrimi*
4. Posterior processes less than half of trunk length . . . *S. kabata* **sp. nov.**
- Posterior processes about half length of trunk . . . 5
5. Holdfast processes bifurcating into secondary, tertiary and quaternary branches . . . *S. jordaanae*
- Holdfast with three pairs of tines, dorsal pair short, blunt and conical; distal to this pair both tips constrict abruptly, each expanding into two processes . . . *S. tertia*

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