

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/263040860>

# Two new genera of pennellids (Copepoda, Siphonostomatoida): Propeniculus and Pseudopeniculus, each with a new combination, Propeniculus trichiuri (Gnanamuthu, 1951) and Pseudopenic...

Article in *Crustaceana* · June 2014

DOI: 10.1163/15685403-00003304

CITATIONS

6

READS

203

1 author:



Raul Castro

University of Antofagasta

56 PUBLICATIONS 362 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



Lenaepodidae on Chilean fishes [View project](#)



Pennellidae on Chilean fishes [View project](#)



TWO NEW GENERA OF PENNELLIDS (COPEPODA,  
SIPHONOSTOMATOIDA): *PROPENICULUS* AND *PSEUDOPENICULUS*,  
EACH WITH A NEW COMBINATION, *PROPENICULUS TRICHIURI*  
(GNANAMUTHU, 1951) AND *PSEUDOPENICULUS ASINUS*  
(KABATA & WILKES, 1977)

BY

RAUL CASTRO ROMERO<sup>1</sup>)

Universidad de Antofagasta, Depto. de Ciencias Acuáticas y ambientales,  
Facultad de Ciencias del Mar y Recursos Biológicos, Casilla 170, Antofagasta, Chile

ABSTRACT

A new genus, *Propeniculus* (Copepoda, Pennellidae), is established here to accommodate a pennellid originally described as *Peniculus trichiuri* Gnanamuthu, 1951, in the new combination, *Propeniculus trichiuri* (Gnanamuthu, 1951). Four other species of *Peniculus* (*P. sciaenae* Gnanamuthu, 1951; *P. scomberi* Gnanamuthu, 1951; *P. stromatei* Gnanamuthu, 1951; and *P. theraponi* Gnanamuthu, 1951) are considered junior synonyms of *Propeniculus trichiuri*. The habitus of the new genus is generally similar to that of *Peniculus*. It differs from that genus in that it has a prominent ventral swelling on its cephalothorax, a minute buccal cone, and in the absence of a proboscis. The labral plate is simple (whereas it is complex in *Peniculus*), and the posterior surface of the labium bears two groups of spinules (two pairs of scale-like plates are found in *Peniculus*). Sclerotized skeletal bars are present in the neck of the new genus, and these also occur in *Metapeniculus* but not in *Peniculus*. *P. trichiuri* lives on the fins of its hosts, which are marine fishes in the Indian Ocean (type locality), in Taiwanese as well as in Indonesian waters.

*Pseudopeniculus* is erected to accommodate *Peniculus asinus* Kabata & Wilkes, 1977 as a new combination in *Pseudopeniculus asinus* (Kabata & Wilkes, 1977). In this case, the presence of two pairs of holdfasts on the cephalothorax, the type of labrum (simple), and the probable absence of labial armature, together with the type of intrabuccal stylet, bearing plumose setae, make *P. asinus* completely different from all other species of *Peniculus*. *P. asinus* also lives attached to the fins of its host, parasitizing *Sebastes* in North America (Oregon and Canada).

A key is included for the identification of the genera.

RESUMEN

Un género nuevo *Propeniculus* (Copepoda, Pennellidae) es creado para acomodar un penélido originalmente descrito como *Peniculus trichiuri* Gnanamuthu, 1951. Cuatro especies de *Peniculus*

<sup>1</sup>) e-mail: raul.castro@uantof.cl

(*P. sciaenae* Gnanamuthu, 1951, *P. scomberi* Gnanamuthu, 1951; *P. stromatei* Gnanamuthu, 1951 y *P. theraponi* Gnanamuthu, 1951) son considerados sinónimo de *P. trichiuri*. El hábito del nuevo género es similar al de *Peniculus*, difiere de este último en poseer una prominencia ventral en su cefalotorax, un cono bucal diminuto y por la ausencia de una proboscis. El labro es una placa simple. La superficie posterior del labio lleva dos grupos de espínulas (dos pares de escamas en *Peniculus*). Barras esqueléticas esclerotizadas están presentes en el cuello del nuevo género, las que también ocurren en *Metapeniculus*, pero no en *Peniculus*. *Propeniculus trichiuri* parasita a peces marinos en el área de Taiwán, así como en el océano Índico (localidad tipo) y en aguas de Indonesia.

Se erige además, *Pseudopeniculus* nuevo género, para acomodar la antigua especie *Peniculus asinus*, (Kabata & Wilkes, 1977), la cual se caracteriza por la presencia de dos pares de cuernos (no presentes *Peniculus*), y por cuanto su labro es del tipo simple (complejo en *Peniculus*), además del estilete intrabucal con seta plumosa (simple en *Peniculus*). En conjunto estos caracteres permiten diferenciarlo de *Peniculus*. *Pseudopeniculus* parasita a *Sebastes* en Oregon y Canada, viviendo sobre las aletas.

Se anexa una clave de identificación para géneros de la familia Pennellidae.

## INTRODUCTION

Pennellidae (Copepoda, Siphonostomatoida) contain 20 genera currently recognized as valid (Boxshall & Halsey, 2004; Boxshall & Walter, 2013). They are characterized by extensive morphological variability. Thus, although genera such as *Peniculus* Von Nordmann, 1832; *Peniculisa* Wilson, 1917; *Exopenna* Boxshall, 1986; and *Metapeniculus* Castro Romero & Baeza Kuroki, 1985, have straight trunks and a simple cephalosome, others, including *Lernaeenicus* Le Sueur, 1924; *Cardiodectes* Wilson, 1917; *Peroderma* Heller, 1865; and *Sarcotretes* Jungersen, 1911, have distinctly developed holdfasts. *Pennella* Oken, 1816 has a straight trunk and a characteristic abdominal brush, and a similar condition is present in *Parinia* Kazatchenko & Avdeev, 1977 and *Lernaeolophus* Heller, 1865. These genera last-mentioned also bear abdominal brushes, but their cephalosome does have a developed holdfast. Some genera also have sigmoid trunks, as well as developed holdfasts, including *Lernaeocera* de Blainville, 1822; *Haemobaphes* Steenstrup & Lütken, 1861; *Trifur* Wilson, 1917; and *Allotrifur* Yamaguti, 1963.

The simplest habitus is represented by *Peniculus*, a genus with a simple subcylindrical trunk and without cephalothoracic processes (with the exception of *P. asinus* Kabata & Wilkes, 1977, which is a focus of this study). *Peniculus* currently includes 15 valid species (cf. Boxshall & Halsey, 2004; Venmathi Maran et al., 2012), which are found in various parts of the world's oceans. Some of these nominal species are of doubtful identity (e.g., *P. calamus* Von Nordmann, 1864) because their descriptions are based on gross morphology only. Moreover, the interspecific uniformity of their appendages (e.g., the legs) prevents their use as specific discriminants. Generally recognized features of *Peniculus* include a short, oblong cephalothorax; a buccal area with a short cone ending in a buccal tube; and a short neck bearing three pairs of legs. The fourth thoracic somite with the fourth

pair of legs is marked by a constriction separating it from a subcylindrical trunk, which is wider posteriorly and ends in the abdomen. These features differ among species in the degree of development. Interspecific differences within the genus have been based principally on the ratio of trunk length to its width, the ratio of the length of the fourth somite to trunk width, and neck length.

The author had the opportunity to examine several specimens of pennellids that are parasites of various species of fish in Taiwan. At first sight, these copepods appeared to resemble species of *Peniculus* as described by Gnanamuthu (1951a, b) from the Indian Ocean. Closer scrutiny of the specimens and of Gnanamuthu's descriptions convinced the author that all five species of *Peniculus* described by Gnanamuthu are conspecific with *Peniculus trichiuri* (this species name was chosen because of its page priority in Gnanamuthu's (1951a) paper).

Castro Romero & Baeza Kuroki (1989b) stressed the importance of the labial armature as a generic discriminant for pennellid genera and used this characteristic to establish differences among *Peniculus* and *Metapeniculus*. Comparison of Gnanamuthu's (1951a, b) species with other species of *Peniculus* revealed comparable differences between these two groups of species. In addition, the structure of the labrum sets them apart. These differences prompted the author to establish a new genus, *Propeniculus* n. gen., the type species of which is to be *Propeniculus trichiuri* (Gnanamuthu, 1951), a designation that also encompasses relegating the other four nominal species described by Gnanamuthu (1951a, b) to its junior synonyms. Another species, *P. asinus* Kabata & Wilkes, 1977, shows notable differences from all other species of its hitherto ascribed genus by bearing two pairs of holdfasts and having a simple labrum, characteristics that make its status not congeneric with the remaining species described in *Peniculus*. This last-mentioned species is herein reclassified in *Pseudopeniculus* n. gen. and hence renamed as a new combination, *Pseudopeniculus asinus* (Kabata & Wilkes, 1977).

Also, a key for the identification of the genera discussed has been composed and is included below.

#### MATERIAL AND METHODS

Specimens of "*Peniculus*" were collected from Taiwanese fishes by Drs. Chin Long Lin (Taiwan) and Ju-Shey Ho (U.S.A.). *Peniculus asinus* was received as a loan from Dr. Z. Kabata (Pacific Biological Station, Nanaimo, B.C., Canada). Specimens were fixed in 70% ethanol and studied under both dissection and compound microscopes. Some specimens were examined under a scanning electron microscope (SEM) as described by Castro Romero & Baeza Kuroki (1989a). Measurements, in  $\mu\text{m}$ , were made with the aid of a reticulated eyepiece. A camera

lucida was used to make the line drawings. Some specimens were cleared in lactic acid to permit detailed examination of fine morphological details, especially involving the buccal cone. The terminology of Kabata (1979) was adopted, except for the maxillule, for which the terminology of Huys & Boxshall (1991) has been used.

## RESULTS

### **Propeniculus** new genus

Generic diagnosis.— In adult female pennellids, the cephalothorax does not have a holdfast, but it has subconical process on its posterolateral surface. Buccal proboscis absent, buccal cone and tube often retracted in cavity anterior to subconical process (swelling). Labrum plate-like and simple. Labium at base of buccal cone and armed on ventral surface with groups of spinules. Mandibular dentition ill-defined. Inner lobe of maxillule with two setae, outer lobe papilliform with a single seta. Maxilla short, with spiniform process on basal segment (lacertus) and with claw shorter than brachium. Cephalothorax and neck of subequal length, and neck armed with chitinous skeletal ribs. Constriction present between fourth thoracic somite and trunk. Trunk elongated and longer than wide. General number of legs and their armature yet to be verified when more species of this genus will be found: no legs observed in present material. Abdomen short with rounded posterior margin. Eggs sacs of variable size, and uniseriate.

Etymology.— The generic name is composed of “Pro” = pre (anterior to *Peniculus*; some characteristics allegedly are more primitive than those present in species of the existing genus *Peniculus*) + “Peniculus” = *Propeniculus*. The gender of the new name is masculine.

Type species.— *Peniculus trichiuri* Gnanamuthu, 1951.

### **Propeniculus trichiuri** (Gnanamuthu, 1951) n. comb.

(figs. 1-17)

Synonymy.—

*Peniculus trichiuri* Gnanamuthu, 1951a: 77-80.

*Peniculus theraponi* Gnanamuthu, 1951a: 80-82.

*Peniculus sciaenae* Gnanamuthu, 1951a: 82-84.

*Peniculus scomberi* Gnanamuthu, 1951b: 224-226.

*Peniculus stromatei* Gnanamuthu, 1951b: 221-224.

Material examined.— Ten specimens from *Atrobuca nibe* (Jordan & Thompson, 1911), six specimens from *Johnius sina* (Cuvier, 1830), three specimens from *Liza macrolepis* (Smith, 1846), five specimens from *Pampus argenteus* (Euphrasen, 1788), two specimens from *Pomadasys kaakan* (Cuvier, 1830), one specimen from *Scatophagus argus* (Linnaeus, 1766), five specimens from *Scomberomorus koreanus* (Kishinouye, 1915), one specimen from *Sillago sihama* (Forsskål, 1775),

one specimen from *Terapon jarbua* (Forsskål, 1755), and 10 specimens from *Trichiurus lepturus* (Linnaeus, 1758). These specimens are all females recovered from hosts captured in Taiwanese waters.

The specimens examined here are kept in the author's collection, Universidad de Antofagasta, Chile.

Host.— Type host: *Trichiurus lepturus* (Linnaeus, 1758) (Teleostei, Trichiuridae); type locality: Indian Ocean (Madras to South Africa). Site of attachment: rays of caudal fins.

New locality.— Taiwan.

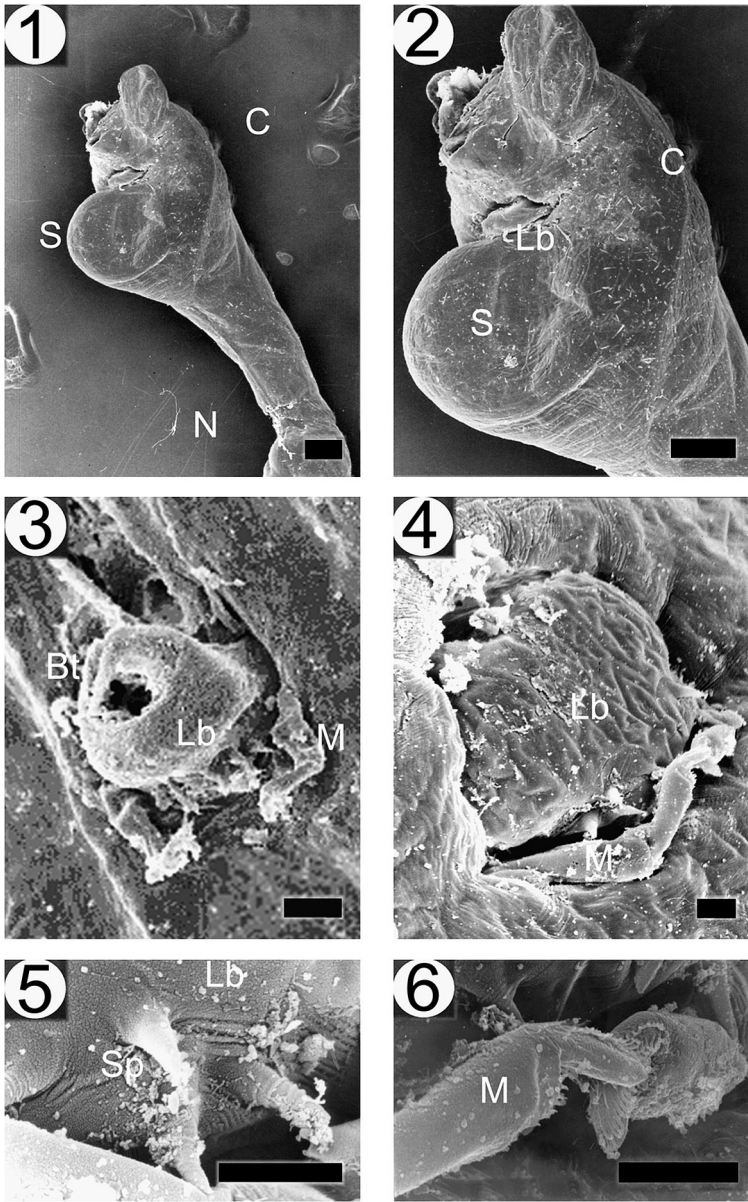
Type-specimen(s) lodged in the Indian Museum, Calcutta. No registration number was indicated.

Description of female.— Measurements ( $n = 17$ ): average length and width of cephalothorax 733  $\mu\text{m}$  (range 552-973  $\mu\text{m}$ ) and 378  $\mu\text{m}$  (range 289-426  $\mu\text{m}$ ), respectively; average neck length and width 509  $\mu\text{m}$  (368-710  $\mu\text{m}$ ) and 213  $\mu\text{m}$  (154-263  $\mu\text{m}$ ), respectively; average length and width of first free thoracic somite 259  $\mu\text{m}$  (210-289  $\mu\text{m}$ ) and 345  $\mu\text{m}$  (263-395  $\mu\text{m}$ ), respectively; average trunk length and width 11 506  $\mu\text{m}$  (8500-14 000  $\mu\text{m}$ ) and 1215  $\mu\text{m}$  (1052-1447  $\mu\text{m}$ ), respectively; average total length 12 956  $\mu\text{m}$  (10 209-15 262  $\mu\text{m}$ ).

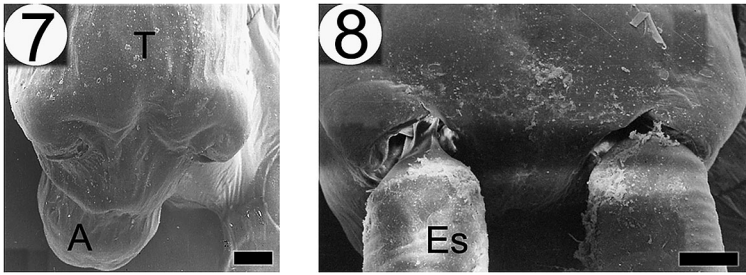
Cephalothorax (figs. 1, 2, 3, 10, 11) elongate, subrectangular in dorsal view. Anterior margin with pair of elongated lobular projections with vestiges of antennae in-between. Anterior part of ventral surface flat, posterior part with prominent swelling (figs. 2, 10, 11). Neck (figs. 1, 10, 11) with skeletal ribs, as described by Gnanamuthu (1951a, b), slightly different in specimens from different hosts. Fourth thoracic somite rounded. Trunk subcylindrical and wider posteriorly. Abdomen short with rounded posterior margin (figs. 7, 8). Egg sacs straight and uniserial (fig. 8). No antennule observed. Antennae covered by anterior processes of cephalothorax, a coating of mucus, and probably also by cement-like substances that attach the copepod to the fin rays of its host.

Buccal area anterior to ventral swelling (figs. 1, 2, 3, 4, 10, 11) usually with buccal cone and tube oriented ventrally, not forming proboscis. Buccal cone composed of fused labrum and labium, topped by buccal tube of approx. 33  $\mu\text{m}$  long by 63  $\mu\text{m}$  in diameter; armed with three chitinous rings (fig. 12).

When retracted, buccal cone and buccal tube positioned anteriorly, only labium with smooth surface visible (length ca. 94  $\mu\text{m}$ ; fig. 4). When completely compressed, labium appearing as a flat plate (figs. 1, 2). When not completely compressed, labium showing turgid (i.e., swollen, inflated) appearance, leaving some part of its armature visible at its base (fig. 4) as well as at base of maxilla. In both cases with differing degrees of labral compression, buccal tube being completely occluded inside specific cavity of cephalothorax. Labial armature (figs. 4, 5, 16) comprising four pairs of spinules in two rows.



Figs. 1-6. *Propeniculus trichiuri* (Gnanamuthu, 1951) adult female, scanning electron micrographs (SEM). 1, Cephalothorax, lateral view, with buccal tube completely inside buccal cavity; 2, cephalothorax, lateral view, different specimen, showing plate-like labium; 3, do., ventral view, other specimen, showing buccal cone extended; 4, cephalothorax, frontal view, other specimen, showing position of labium, and buccal tube occluded inside buccal cavity; 5, armature on labium; 6, maxilla, distal claw. Abbreviations: Bt, buccal tube; C, cephalothorax; Lb, labium; M, maxilla; N, neck; Sp, spines; S, swelling. Scale bars: for 1 = 100  $\mu\text{m}$ ; 2 = 100  $\mu\text{m}$ ; 3 = 20  $\mu\text{m}$ ; 4 = 10  $\mu\text{m}$ ; 5 = 10  $\mu\text{m}$ ; 6 = 10  $\mu\text{m}$ .



Figs. 7-8. *Propeniculus trichiuri* (Gnanamuthu, 1951), by SEM. 7, Distal end of trunk and abdomen; 8, egg sac attachment. Abbreviations: A, abdomen; Es, egg sac; T, trunk. Scale bars: for 7 and 8 = 100  $\mu\text{m}$ .

Labrum (figs. 14, 15) a small, simple, subrectangular plate narrowing and curving distally and bearing pair of intrabuccal stylets distoventrally. Stylets consisting of suboval base bearing a longer, slender segment carrying short apical setae. Inside buccal tube (figs. 12, 13) a well-defined plate (intrabuccal armature or hypopharynx) arising from body wall. This plate being concave in lateral view and bearing two blunt projections laterally.

Mandible with dentition was not well defined; located medial to base of maxillule and entering buccal tube through opening under labrum (fig. 12). Maxillule (figs. 16, 17) very small, consisting of inner lobe with two long setae (as long as maxillular base) and outer lobe with a single seta. Maxilla (figs. 3, 4, 6) situated posterolateral to labium and clearly exposed during retraction of buccal area; length of maxilla ca. 84  $\mu\text{m}$ ; lacertus bearing short spiniform process at midlength of lateral margin, short brachium with setules on distomedial margin, claw bearing two rows of short setae (fig. 6).

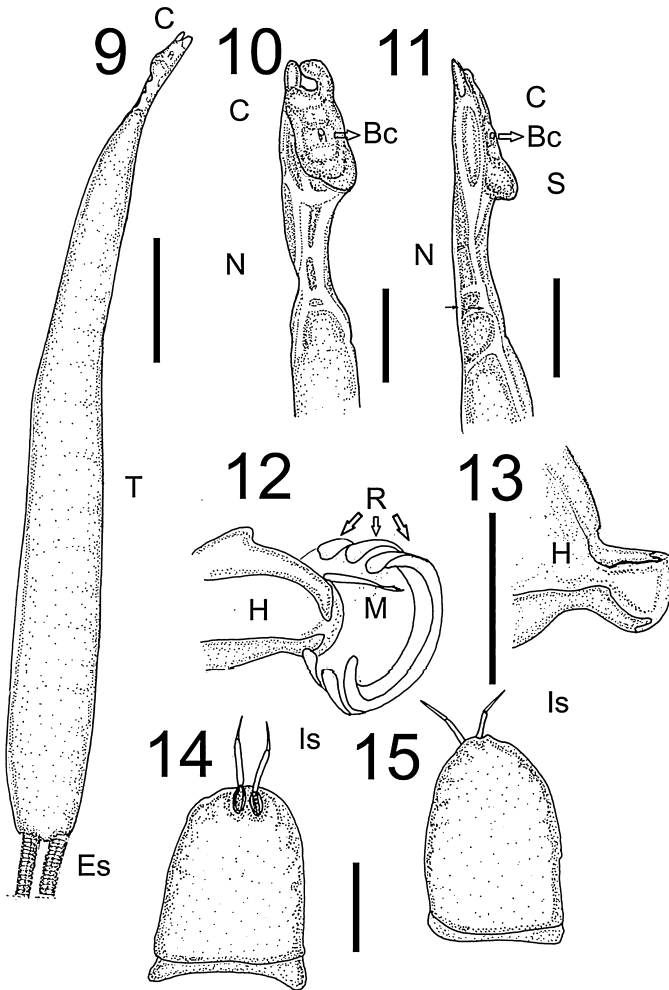
Legs not detected; these may have been lost in detaching copepod from its host.

Egg sac attachment (fig. 8) with genital opening equipped with several flanges allowing insertion or just securing of egg sac. In outline of outer edge of genital opening, a winding flange of which medial stretch articulating with other flange in half-upright position. Upper end of egg sac in direct contact with a flange running from outer margin of hole inwards. A final flange present on innermost edge of hole, but this one not well observed or defined.

### **Pseudopeniculus** new genus

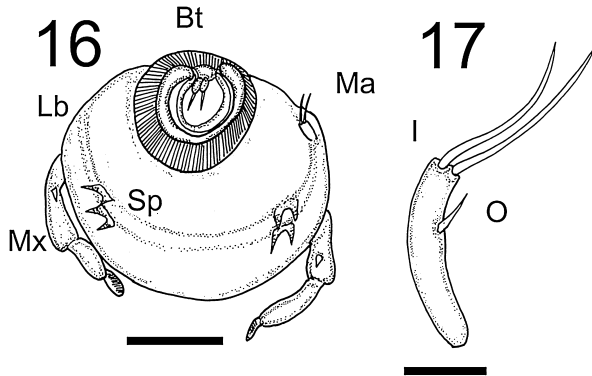
Generic diagnosis.— Shape of trunk *Peniculus*-like, cephalothorax subquadrangular, with pair of anterior and pair of posterior holdfasts. Buccal area supported by short, extension-like proboscis. Labrum short, simple, approximately subquadrangular and slightly projecting anteriorly. Mandible dentate. Maxillule as usual





Figs. 9-15. *Propeniculus trichiuri* (Gnanamuthu, 1951). 9, Adult female, lateral view; 10, adult female, cephalothorax and neck, ventral view, showing chitinous skeletal structure and position of buccal cone; 11, adult female, cephalothorax and neck, lateral view, showing chitinous skeletal rib: two small arrows, to left of neck as well as in the middle, indicating the skeletal ribs; 12, rings of buccal tube and hypopharynx, as seen through transparent body (treated with lactic acid); 13, hypopharynx, alternative view; 14, labrum, ventral view and intrabuccal position of stylet; 15, labrum, dorsal view. Abbreviations: Bc, buccal cone (position); C, cephalothorax; H, intrabuccal armature = hypopharynx; Is, intrabuccal stylet; La, labrum; M, mandible; N, neck; R, rings; S, swelling; T, trunk. Scale bars: for 9 = 2000  $\mu\text{m}$ ; 10-11 = 500  $\mu\text{m}$ ; 12 = 50  $\mu\text{m}$ ; 13 = 50  $\mu\text{m}$ ; 14-15 = 25  $\mu\text{m}$ .

with inner lobe with wide base and two long terminal setae; outer lobe short segment, approximately cylindrical, with short seta. Maxilla located rather laterally, to side of ventral surface of cephalothorax and at some distance from maxillule;



Figs. 16-17. *Propeniculus trichiuri* (Gnanamuthu, 1951). 16, Buccal cone and maxilla; 17, maxillule. Abbreviations: Bt, buccal tube; Lb, labium; Ma, maxillule; Mx, maxilla; Sp, spines; I, inner lobe; O, outer lobe. Scale bars: for 16 = 50  $\mu$ m; 17 = 15  $\mu$ m.

lacertus armed with one strong spiniform process; brachium unarmed; claw short, shorter than lacertus. Neck long and without cuticular skeleton. Trunk uniform and without posterior process. Four pairs of legs present. Egg sacs straight.

Location on host.— *Pseudopeniculus* is a parasite on the fins of its host.

Etymology.— The name *Pseudopeniculus* composed from “pseudo” = false, plus the existing generic name *Peniculus*. The addition “false” refers to the presence of holdfasts, which are not present in species of *Peniculus*. The gender of the new name is masculine.

Type species.— *Peniculus asinus* Kabata & Wilkes, 1977.

***Pseudopeniculus asinus* (Kabata & Wilkes, 1977), new combination**  
(figs. 18-26)

Synonymy.—

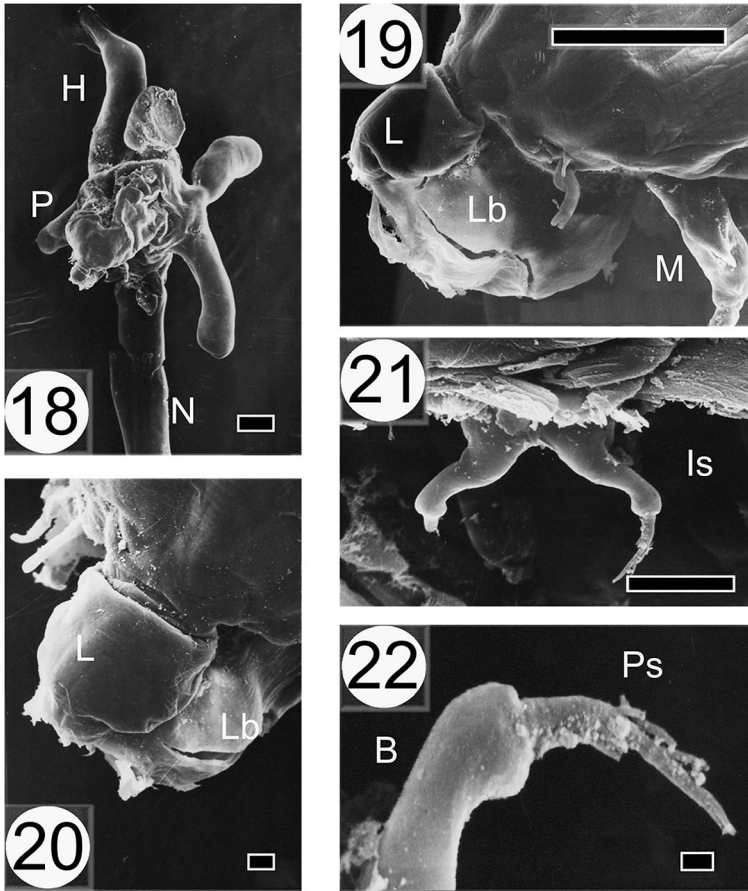
*Peniculus asinus* Kabata & Wilkes, 1977: 1988-1991, figs. 1-7.

Material examined.— Two specimens from the collection of Z. Kabata; region of origin, off British Columbia, Canada; one specimen here examined is now kept in the author’s collection, Universidad de Antofagasta, Chile.

Host.— Species of the fish genus *Sebastes* (Teleostei, Scorpaenidae), attached to the host’s fins; occurring in Oregon, U.S.A. and British Columbia, Canada.

Type specimen.— An ovigerous female deposited in the national Museum of Natural Science, Ottawa, Reg. No. 21584.

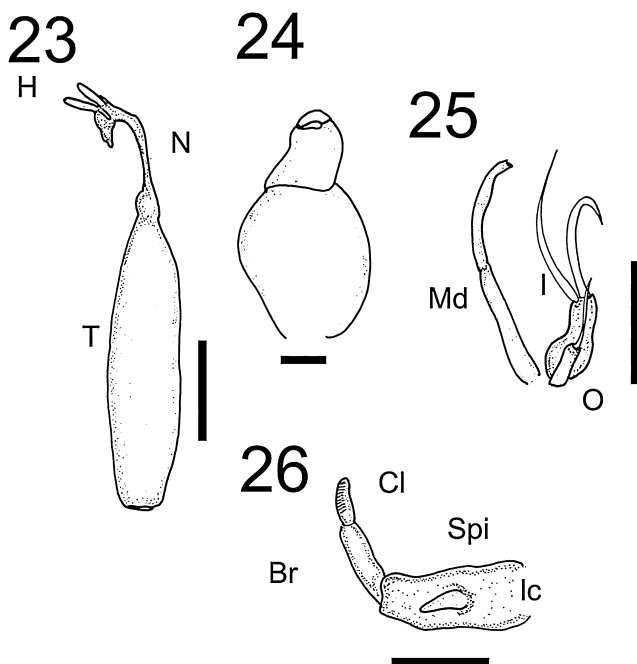
Description of female.— Cephalothorax (fig. 18) short, subquadrangular, with one anterior pair and one posterior pair of holdfasts. Apex of cephalothorax situated between anteriormost holdfast and second antenna. Base of antenna (fig. 24) longer than wide; second segment subrectangular, with short claw.



Figs. 18-22. *Pseudopeniculus asinus* (Kabata & Wilkes, 1977), by SEM. 18, Adult female cephalothorax and neck, ventral view; 19, buccal cone, lateral view; 20, buccal cone, dorsal view; 21, intrabuccal stylet inside buccal tube; 22, intrabuccal stylet, detail. Abbreviations: B, base; H, hold-fast; La, labrum; Lb, labium; M, maxilla; N, neck; Is, intrabuccal stylet; P, proboscis; Ps, plumose seta. Scale bars: for 18 = 200  $\mu\text{m}$ ; 19 = 100  $\mu\text{m}$ ; 20 = 50  $\mu\text{m}$ ; 21 = 100  $\mu\text{m}$ ; 22 = 5  $\mu\text{m}$ .

Neck (fig. 23) about two times as long as cephalosome (including proboscis-like extension). Ventral surface of cephalothorax forming short, proboscis-like extension, bearing buccal area.

Labrum appearing as simple plate with rounded lateral margins, and about straight basally (figs. 19, 20). No armature observed on labium, which is, however, to be confirmed in more extensive material (fig. 19). Buccal tube with intrabuccal stylet (figs. 21, 22), with both rami fused at base and curved distally; distal setae armed with setules; no hypopharynx observed. Mandible bisegmented and toothed (fig. 25). Maxillule (fig. 25) with inner lobe, as long basal segment with two long setae of equal length, about two times as long as segment; outer lobe a very short



Figs. 23-26. *Pseudopeniculus asinus* (Kabata & Wilkes, 1977). 23, Entire female, lateral view (redrawn from Kabata & Wilkes, 1977); 24, antenna; 25, mandible and maxillule; 26, maxilla. Abbreviations: Br, brachium; Cl, claw; H, holdfast; I, inner lobe; lc, lacertus; Md, mandible; N, neck; O, outer lobe; Spi, spiniform process; T, trunk. Scale bars: for 23 = 2 mm; 24 = 50  $\mu$ m; 25 = 50  $\mu$ m; 26 = 50  $\mu$ m.

segment (not papilliform) with simple seta. Maxilla (fig. 26) with lacertus longer than brachium (more than twice as long); brachium with no apparent armature on distal inner surface and no flaps; claw shorter than brachium and armed distally with two rows of setae; also with strong spiniform process on outer surface.

Four pairs of legs present: first two pairs situated closely together, third and fourth pairs at greater distance (cf. Kabata & Wilkes, 1977). Trunk with morphology usual for species of *Peniculus*, although in *Peniculus* it is rather narrower anteriorly and more widening posteriorly. Abdomen not developed.

#### DISCUSSION

The habitus of *Propeniculus* closely resembles that of *Peniculus*, but the morphology of the new genus is sufficiently distinct from that of *Peniculus* to separate it at the generic level. In particular the morphology of cephalothorax, with its characteristic posteroventral prominence, as well as the position of the structures of the buccal area, and also the structure of the buccal cone and buccal tube are unique.

The buccal structure is the most simple, and thus allegedly the most primitive, among Pennellidae found parasitic on fish fins (*Peniculus*, *Peniculisa*, *Metapeniculus*). In most species of these genera, and also in *Propeniculus*, the buccal apparatus does not form a proboscis, as it does in some species of *Peniculus* and *Metapeniculus* (short in *P. fistula* Von Nordmann, 1832; longer in *P. elongatus* Boxshall, 1986; and very long in *Metapeniculus antofagastensis* Castro Romero & Baeza Kuroki, 1985). In *Propeniculus trichiuri*, when fully extended the buccal cone and buccal tube project in ventral or anterior direction (perpendicular to the surface of the cephalothorax), but when compressed, i.e., withdrawn, the buccal cone and tube remain inside their cephalothoracic cavity. In such condition, the labium appears like a plate, and the buccal tube is not visible. Alternatively, when the buccal cone and tube are partially retracted, the labium appears more turgid but still occludes the buccal tube, residing inside the cephalothoracic cavity. In this case, some armature was observed on the labium and also the maxilla was completely visible. This situation is never observed for any species of *Peniculus* (cf. *P. fistula*; pers. obs.) in which the buccal area always remains visible, even if, as in *Peniculus clavatus* (O. F. Müller, 1779) (pers. obs.), some kind of cavity can be observed into which the buccal area can be partially retracted. The present specimens of *Propeniculus trichiuri* have spines at each side of the base of the labium, in two rows, which is different from the situation found in *Peniculus* (cf. Castro Romero & Baeza Kuroki, 1989b), which is armed with two pairs of scale-like plates located in two lines; in *Lernaeenicus sprattae* (Sowerby, 1806) (cf. Schram, 1979; Kabata, 1988), which is armed with several rows of spines; in *L. longiventris* Wilson, 1917 (R. Castro Romero & J. C. Joyeux, pers. obs.), which has four scale-like plates in one line; and in *Trifur* Wilson, 1917 (cf. Castro Romero & Baeza Kuroki, 1989a), which is armed with several rows of short, scale-like plates.

The labrum of the specimens of *Propeniculus trichiuri* examined, appeared as a simple plate, short and subrectangular, in contrast to those of *Peniculus* spp. The labrum of species of *Peniculus* has proximolateral slits, as observed in Chilean specimens of *Peniculus* by Castro Romero & Baeza Kuroki (1989a) and in *P. fistula* (pers. obs.). The labrum of *Propeniculus* is also different from the labrum of all pennellids of which the labrum has been described, e.g., *Lernaeocera branchialis* (Linnaeus, 1767) as described by Castro Romero & Baeza Kuroki (1989a) and Huys & Boxshall (1991), and *Trifur* (cf. Castro Romero & Baeza Kuroki, 1989a).

The structure of the intrabuccal stylet of *Propeniculus* was found to be substantially different from that of *Peniculus* and *Metapeniculus* (cf. Castro Romero & Baeza Kuroki, 1989a, b), mainly because of the fact that the stylet base has the simplest configuration possible. The intrabuccal armature (cf., e.g., Castro Romero & Baeza Kuroki, 1991) arises from the body wall at the base of the buccal tube.

This armature is reminiscent of that observed in *Peniculus* spp. from Chilean waters (Castro Romero & Baeza Kuroki, 1989b), but differs in the length of the lateral extension. In general, this armature, which also occurs in other pennellids, shows differences in both shape and length. In *Metapeniculus* (cf. Castro Romero & Baeza Kuroki, 1989a), the plate has a more complex lateral projection.

The maxilla of *Propeniculus* is relatively smaller than that of *Peniculus* species of comparable size and the relative length of the claw (less than a third of length of brachium) was also shorter than that in *Peniculus*.

The neck of the new genus, *Propeniculus*, is reinforced by a chitinous skeleton, connecting it to the cephalothoracic area. Similar structures are present in *Metapeniculus antofagastensis* Castro Romero & Baeza Kuroki, 1985 but not in species of *Peniculus*. In this last-mentioned genus, the exception is *P. communis* (as figured by Leigh-Sharpe, 1934, his fig. 33). Because of that similar skeleton of the neck, this species must be re-examined, especially because it also shares the shape of the cephalothorax with *Propeniculus*.

A comparison of the characteristics observed in the pennellids from Taiwan with those from South Africa described by Gnanamuthu (1951a, b) casts considerable doubt on the validity of including these specimens in *Peniculus*. The characteristics at issue are: (a) the posteroventral protrusion of the cephalothorax and, as a consequence, differences in the position of the buccal area, (b) the type of labrum, (c) the armature of the labium, and (d) the complete absence of a proboscis. Taken together, these are considered by the present author to provide sufficient evidence to establish a new genus for the species described by Gnanamuthu (1951a, b). As a result, the proposed name for this genus is *Propeniculus*, with *P. trichiuri* (Gnanamuthu, 1951a) comb. nov., as its type species. Also, as indicated above, four of those species have herein been relegated to the synonymy of the fifth species, i.e., *Propeniculus trichiuri*.

All specimens observed lacked legs (probably because these became detachment from the specimens when removing them from the host), and thus new studies are necessary, especially of younger specimens that have just attached to their host, to determine the exact number of legs present as well as the condition of their rami. Gnanamuthu (1951a) described *P. trichiuri* as having four pairs of legs (first pair, uniramous; second to fourth, biramous), *P. sciaenae* as having only three pairs, and *P. theraponi*, with a fourth pair of legs that would be uniramous. Usually, pennellids have four pairs of legs, the first two of which are biramous and the last two of which are uniramous (e.g., *Trifur tortuosus* Wilson, 1917 as described by Kabata, 1979; Castro Romero & Baeza Kuroki, 1986; Etchegoin et al., 2009; species of *Peniculus* Von Nordmann, 1932 as described by Shiino, 1966; *Peniculus elongatus* as described by Boxshall, 1986; *Peniculisa shiinoi* Izawa, 1965;

*Phrioxcephalus cincinnatus* Wilson, 1908, as described by Kabata, 1969; *Ophiolernaea* Shiino, 1958; and *Exopenna crimmeni* Boxshall, 1986). In other genera, with three pairs of legs, the first two are biramous and the third pair is uniramous, as in *Metapeniculus antofagastensis* (cf. Castro Romero & Baeza Kuroki, 1985, 1986), *Cardiodectes boxshalli* (Belwood, 1981), *Pennella* sp. (reported by Castro Romero & Baeza Kuroki, 1986), and *Peroderma cylindricum* (as described by Ben Hassine et al., 1990). Gnanamuthu (1951b), when describing *P. stromatei* and *P. scomberi*, was unable to find the rami of the legs but, as this is an important characteristic, further studies have to be made in order to enable a comparison of the actual numbers of legs in the various species of Pennellidae.

Some consideration must be given regarding the buccal appendages, especially in view of the conditions found in *Propeniculus trichiuri*. Gnanamuthu (1951a), when describing the maxillule (as first maxilla) and maxilla (as second maxilla), was correct in his terminology, but in a subsequent paper (Gnanamuthu, 1951b) he referred to these same appendages as first maxilliped and second maxilliped, respectively. This confusion arose, because in a later description that author described other structures in the buccal area also (but incorrectly) as appendages, and thereby indicated a first maxilla and second maxilla as well, but these structures actually correspond to the intrabuccal stylet. The mandible was then described (Gnanamuthu, 1951b) as having a bifid structure at its tip, but that part presumably corresponds to the apex of the intrabuccal armature (cf. Castro Romero & Baeza Kuroki, 1989a).

The egg sac is attached to the genital pore by means of flanges (visible externally around the genital orifice), which hold the egg sac and may participate in its release when all larvae (nauplii) have hatched. That distal configuration has not been observed for species of *Peniculus* or other pennellids. Only Schram (2001) has reported the presence of an inner hook apparatus that attaches the eggs to the body, i.e., the genital pores, in species of Pennellidae (including *Haemobaphes*, *Lernaeocera*, *Lernaeenicus*, *Sarcotretes*, and *Pennella*). In contrast, Schram (2000a, b) described the inner apparatus of *Hatschekia hippoglossi* (Cuvier, 1830), showing differences with that of *Lepeophtheirus salmonis* (Krøyer, 1837), especially in the suspension of the hooks and the impression of the hook in the proximal end of the egg string.

Another case of a species originally included in *Peniculus* is *P. asinus* Kabata & Wilkes, 1977, but its principal feature, the presence of two pairs of holdfasts, is not present in any of the other species of *Peniculus* (characteristics noted by Kabata & Wilkes, 1977). In addition, this species has a simple labrum (versus complex in *Peniculus*), and any armature on the labium is absent (two pairs of scale-like structures are observed in *Peniculus*, cf. Castro Romero & Baeza Kuroki, 1989a, b; Schram, 1991). The above-mentioned reasons suggest that *P. asinus* does not

belong in that genus nor in any other known genus, whence it seemed necessary to erect a new genus for this species. The new generic name is derived from *Peniculus* that accommodated the species until now, and as such the present author has propose above to use the name *Pseudopeniculus asinus* (Kabata & Wilkes, 1977) henceforth.

Another distinguishing characteristic of Kabata & Wilkes' (1977) species is the presence of an intrabuccal stylet with plumose setae, which are simple in the case of *Peniculus* (cf. Castro Romero & Baeza Kuroki, 1989a).

The maxilla in *Pseudopeniculus asinus* is short, located at some distance from the ventral surface of the head, and near the maxillule, presumably because of the growth of the proboscis. In *Metapeniculus* (cf. *Metapeniculus antofagastensis* as described by Castro Romero & Baeza Kuroki, 1985), the maxilla remains in its normal position, i.e., near the ventral surface of the head, but rather far away from the buccal tube and the maxillule. In contrast, in *Sarcotretes*, which shows a similar development of the proboscis (cf. *Sarcotretes umitake* Uyeno, Wakabayashi & Nagasawa, 2012, as described by Uyeno et al., 2012), the maxilla is displaced with respect to the buccal tube and the maxillule. In those *Peniculus* species that have developed a short proboscis, the maxilla is displaced far away from the ventral surface of the head, too, as occurs in *P. clavatus* (cf. Wilson, 1917; Kabata, 1988) and *P. elongatus* (cf. Boxshall, 1986). In these two cases, the position of the maxilla, i.e., its displacement, is similar to that observed in *Pseudopeniculus asinus*.

With the introduction of two new genera, the Pennellidae now include: *Allotri-fur*, *Cardiodectes*, *Creopelates*, *Exopenna*, *Haemobaphes*, *Impexus*, *Lernaeenicus*, *Lernaeocera*, *Lernaeolophus*, *Metapeniculus*, *Ophiolernaea*, *Parinia*, *Peniculisa*, *Peniculus*, *Pennella*, *Peroderma*, *Phrixocephalus*, *Propeniculus*, *Pseudopeniculus*, *Sarcotretes*, *Serpentisaccus*, and *Trifur*.

As consequence of the erection of *Propeniculus*, with a single species, *Propeniculus trichiuri* (Gnanamuthu, 1951), which is synonymous with all (four) other species described by Gnanamuthu (1951a, b) in *Peniculus*, and the description of *Pseudopeniculus*, with the new combination *P. asinus* (Kabata & Wilkes, 1971), only nine species remain in *Peniculus*. They are: *P. calamus* Von Nordmann, 1864; *P. clavatus* (O. F. Müller, 1799); *P. communis* Leigh-Sharpe, 1934; *P. elegans* Leigh-Sharpe, 1934; *P. elongatus* Boxshall, 1986; *P. fistula* Von Nordmann, 1832; *P. minuticaudae* Shiino, 1956; *P. ostraciontis* Yamaguti, 1939; and *P. truncatus* Shiino, 1956. Yet, the validity of some of these nominal species is not altogether certain: the genus *Peniculus* is definitely in need of revision. Also, future descriptions should consider the possibility of studying specimens under the scanning electron microscope in order to observe all possible (minute) characteristics, especially those on the buccal cone, the buccal tube, the labrum,



the labium, especially its armature, the intrabuccal stylet, the intrabuccal armature, etc., etc.

*Propeniculus* lives on fishes in the Indian Ocean (the type locality of the type-species) (cf. Gnanamuthu, 1951a, b), in Taiwanese waters (present report), and also in Indonesian waters (Yuniar et al., 2007), as well as on *Rastrelliger kanagurta* (Cuvier, 1816) in the Bay of Bengal (Madhavi & Triveni, 2011). *Pseudopeniculus* is found in the North Atlantic, in waters off Canada and the U.S.A. (Kabata & Wilkes, 1979).

### KEY TO THE GENERA OF PENNELLIDAE BURMEISTER, 1834

- Body straight . . . . . Group I  
 Body with sigmoid trunk . . . . . Group II  
 Body ovoid, neck at angle with trunk . . . . . Group III

#### Group I

1. Neck simple, in line with trunk . . . . . 2  
 – Neck with annexed structure . . . . . 6
2. Cephalothorax subcircular, buccal area with a median-sized, highly muscular proboscis, three pairs of legs, labrum simple, labium armed with only one pair of scale-like plates . . . . .  
 . . . . . *Metapeniculus* Castro Romero & Baeza Kuroki, 1985  
 – Cephalothorax elongate, longitudinally extended . . . . . 3
3. Trunk with two posterior projections, buccal area not forming a proboscis . . . . .  
 . . . . . *Peniculisa* Wilson, 1917  
 – Trunk without posterior projection . . . . . 4
4. Buccal area forming a proboscis . . . . . 5  
 – Buccal area not forming a proboscis, with a prominent ventral swelling, labium armed with spines, labrum simple . . . . . *Propeniculus* new genus
5. Proboscis short or more developed, with four pairs of legs, labium armed with two pairs of scale-like structures, labrum complex (with slits) . . . . . *Peniculus* Von Nordmann, 1832  
 – Proboscis extremely long, longer than body . . . . . *Ophiolernaea* Shiino, 1958
6. Cephalothorax with annexed structure . . . . . 7  
 – Cephalothorax simple, antenna with expanded base, neck long . . . *Exopenna* Boxshall, 1986
7. Body with branching processes . . . . . 12  
 – Body with holdfast or other attachment devices . . . . . 8
8. Cephalothorax with brushes and/or holdfast . . . . . 9  
 – Cephalothorax with holdfast only . . . . . 10
9. Cephalothorax with ventral brushes, holdfast, abdomen with plumose projections . . . . .  
 . . . . . *Pennella* Oken, 1816  
 – Cephalothorax with ventral brushes, not bearing a horned holdfast, abdomen with plumose projection . . . . . *Parinia* Kazatchenko & Avdeev, 1977
10. Cephalothorax subquadrangular, with two pairs of holdfasts (one directed anteriorly, the other posteriorly), with buccal area forming a short proboscis, labrum simple . . . . .  
 . . . . . *Pseudopeniculus* new genus

- Cephalothorax elongate or more compact ..... 11
- 11. Cephalothorax with a pair of holdfasts directed laterally (or posterolaterally), buccal area forming a medium sized proboscis, labium surface with a pair of pad-like structures ..... *Sarcotretes* Jungersen, 1911
- Cephalothorax with three simple holdfasts (rarely ramified, e.g., in *L. ramosus* Kirtisinghe, 1956), buccal area not forming a proboscis, labium surface bearing a row of spines or row of scale-like plates (pers. obs., MS in prep.) ..... *Lernaenicus* Le Sueur, 1824
- 12. With only ramified processes on cephalothorax ..... *Phrixocephalus* Wilson, 1908
- With branched processes and lobes ..... 13
- 13. Neck in line with trunk ..... *Cardiodectes* Wilson, 1917
- Neck at an angle with trunk ..... 14
- 14. Cephalothorax with two pairs of lobes ..... *Creopelates* Shiino, 1958
- Cephalothorax with three pairs of lobes ..... *Peroderma* Heller, 1865

## Group II

- 1. Body trunk sigmoid, neck simple ..... 2
- Body trunk sigmoid, neck with annexed structure ..... 4
- 2. Trunk without any outgrowth ..... 3
- Trunk bearing brush-like outgrowth ..... *Lernaevolophus* Heller, 1864
- 3. With three simple holdfasts, not forming a proboscis, labium armed with row of small scale-like plates, four pairs of legs (two pairs biramous and two pairs uniramous) ..... *Trifur* Wilson, 1917 (all uniramous legs in *Allotrifur* Yamaguti, 1963; the condition for this last nominal genus must be verified, cf. Kabata, 1979; Etchegoin et al., 2009)
- With ramified holdfast, trunk without any outgrowth ..... *Lernaocera* Blainville, 1822
- 4. Neck with lateral, simple outgrowth ..... *Haemobaphes* Steenstrup & Lütken, 1861

## Group III

- 1. Cephalothorax with two posterolateral processes and branched anterior processes ..... *Impexus* Kabata, 1972
- Cephalothorax with anterior tubiform processes (simple or bifurcate), egg sac tightly coiled ..... *Serpentisaccus* Blasiola, 1979

### ACKNOWLEDGEMENTS

Special thanks are due to Dr. Ching-Long Lin (Taiwan) and Dr. Ju-Shey Ho (U.S.A.) for providing specimens of pennellid parasites from several Taiwanese fishes to the author, and to Dr. Z. Kabata (Canada) for sending the author specimens of *Peniculus asinus* and for his various comments on the first draft of this paper, as well as to Martin M. Montes for edition of the figures.

## REFERENCES

- BEN HASSINE, O. K., A. RAIBAUT, J. BEN SOUISSI & V. ROUSSET, 1990. Morphologie de *Peroderma cylindricum* Heller, 1865, copepode parasite de la sardine: *Sardina pilchardus* (Walbaum, 1792) et quelques aspects de son écologie dans les eaux côtières tunisiennes. Ann. Sci. Nat. Zool., Paris, (13) **11**: 9-16.
- BOXSHALL, G. A., 1986. A new genus and two new species of Pennellidae (Copepoda: Siphonostomatoida) and an analysis of evolution within the family. Syst. Parasitol., **8**(3): 215-225, figs. 1-5, tab. 1.
- BOXSHALL, G. A. & S. H. HALSEY, 2004. An introduction to copepod diversity, **166**: 1-1966. (Ray Society, London).
- BOXSHALL, G. A. & T. C. WALTER, 2013. Pennellidae. In: T. C. WALTER & G. A. BOXSHALL (eds.), World of copepods database, available online at <http://www.marinespecies.org/copepoda/>.
- CASTRO ROMERO, R. & H. BAEZA KUROKI, 1985. *Metapeniculus antofagastensis* gen. et sp. nov. (Copepoda, Pennellidae) parasitic on two inshore fishes of Antofagasta, Chile, south Pacific. Crustaceana, **19**(1): 22-29.
- & —, 1986. Premetamorphosis stages of two Pennellidae (Copepoda, Siphonostomatoida) from their definitive host. Crustaceana, **50**(2): 166-175.
- & —, 1989a. Characters for the Pennellidae taxonomy based on *Peniculus*, *Metapeniculus*, *Trifur*, *Lernaeenicus* and *Lernaeocera* specimens study with SEM. Est. Oceanol., **8**: 21-45.
- & —, 1989b. Lamelliform structures in the proboscis of *Peniculus* and *Metapeniculus*. Proc. Biol. Soc. Wash., **102**: 912-915.
- & —, 1991. A scanning electron microscope study of the buccal complex of *Metapeniculus antofagastensis* (Copepoda, Pennellidae). Proc. Biol. Soc. Wash., **104**(3): 613-619.
- ETCHEGOING, J. A., A. L. LANFRANCHI & J. T. TIMI, 2009. The mesoparasitic copepod *Trifur tortuosus* Wilson, 1917 (Pennellidae). Redescription with notes on its congeners. Acta Parasitol., **54**(1): 57-63.
- GNANAMUTHU, C. P., 1951a. Copepods parasitic on south Indian fishes. Ann. Mag. Nat. Hist., **12**(4): 77-86.
- , 1951b. Two new species of copepods of the genus *Peniculus* parasitic on Madras fishes. Rec. Indian Mus., **49**(2): 221-226.
- HUYS, R. & G. A. BOXSHALL, 1991. Copepod evolution, **159**: 1-468. (Ray Society, London).
- KABATA, Z., 1969. *Phrixecephalus cincinnatus* Wilson, 1915 (Copepoda, Lernaeoceridae) morphology, metamorphosis, and host parasite-relationship. J. Fish. Res. Bd Can., **26**: 921-934.
- , 1979. Parasitic Copepoda of British fishes, **152**: 1-468. (The Ray Society, London).
- , 1988. Copepoda and Branchiura. In: L. MARGOLIS & Z. KABATA (eds.), Guide to the parasites of fishes of Canada, III, Crustacea. Can. Spec. Publ. Fish. Aquat. Sci., **101**: 3-127.
- KABATA, Z. & S. N. WILKES, 1977. *Peniculus asinus* (Copepoda: Pennellidae), a new species of copepod parasitic on fishes of the genus *Sebastes* along the west coast of North America. Can. J. Zool., **55**(12): 1988-1991.
- LEIGH-SHARPE, W. H., 1934. The Copepoda of the Siboga Expedition. Part II. Commensal and parasitic Copepoda. Siboga Exp. Mon., **29b**: 1-43.
- MADHAVI, E. & T. TRIVENI LAKSHMI, 2001. Metazoan parasites of the Indian mackerel, *Rastrelliger kanagurta* (Scombridae) of Visakhapatnam coast, Bay of Bengal. J. Paras. Dis., **35**: 66-74.
- SCHRAM, T. A., 1979. The life history of the eye-maggot of the sprat, *Lernaeenicus sprattae* (Sowerby) (Copepoda, Lernaeoceridae). Sarsia, **64**: 279-316.
- , 1991. The mackerel (*Scomber scombrus* L.), a new host for the parasitic copepod *Peniculus* sp., (Pennellidae). Sarsia, **75**: 327-333.

- —, 2000a. The egg string attachment mechanism in *Hatschekia hippoglossi* (Guérin-Méneville, 1837) (Copepoda, Hatschekiidae). *Sarsia*, **85**: 151-156.
- —, 2000b. The egg string attachment mechanism in salmon lice *Lepeophtheirus salmonis* (Copepoda: Caligidae). *Contrib. Zool.*, **69**: 21-29.
- —, 2001. The egg string attachment mechanism of selected pennellid copepods. *J. Mar. Biol. Ass. U.K.*, **81**: 23-32.
- SHIINO, S., 1966. Copepods parasitic on Japanese fishes, 7. *Peniculus* and *Peniculisa*. *Jpn. J. Zool.*, **11**(V): 593-608.
- UYENO, D., K. WAKABAYASHI & K. NAGASAWA, 2012. A new species of parasitic copepod, *Sarcotretes umitakae* sp. n. (Siphonostomatoida, Pennellidae), on the rattail (Actinopterygii, Macrouridae) from the East China Sea, Japan. *ZooKeys*, **246**: 1-10.
- VENMATHI MARAN, B. A., S. Y. MOON, S.-Y. OH, Y. S. HO & J.-G. MYOUNG, 2012. Redescription of two pennellids (Copepoda, Siphonostomatoida) from Korea with a key to species of *Peniculus* Von Nordmann, 1832. *ZooKeys*, **243**: 1-14.
- WILSON, C. B., 1917. North American parasitic copepods belonging to the Lernaecidae with a revision of the entire family. *Proc. U.S. Nat. Mus.*, **2194**(53): 1-150, pls. 1-21.
- YUNIAR, A. T., Y. H. PALM & T. WALTER, 2007. Crustacean fish parasites from Segara Anakan Lagoon, Java, Indonesia. *Parasitol. Res.*, **100**: 1193-1204.