

Caligid copepods parasitic on yellowfin tuna, *Thunnus albacares*, and bigeye tuna, *Thunnus obesus*, in the western North Pacific Ocean off central Japan, with a list of parasitic copepods of tunas (*Auxis* spp., *Euthynnus affinis*, *Katsuwonus pelamis*, and *Thunnus* spp.) in Japan (1894–2018)

Kazuya Nagasawa^{1,2,3}, Hiroshi Ashida³ and Takuya Sato³

¹Graduate School of Biosphere Science, Hiroshima University, 1–4–4 Kagamiyama, Higashi-Hiroshima, Hiroshima 739–8523, Japan

²Aquaparasitology Laboratory, 365–61 Kusanagi, Shizuoka 424–0886, Japan

³National Research Institute of Far Seas Fisheries, Japan Fisheries Research and Education Agency, 5–7–1 Orido, Shimizu, Shizuoka 424–8633, Japan

■ **Abstract**

A sample of yellowfin tuna, *Thunnus albacares* (Bonnaterre, 1788), and bigeye tuna, *Thunnus obesus* (Lowe, 1839), caught in the western North Pacific Ocean near the Izu Islands off central Japan, was examined for parasitic copepods. Three species of caligid copepods were collected: *Euryphorus brachypterus* (Gerstaecker, 1853) from the inner surface of the operculum of both tuna species, and *Caligus bonito* Wilson, 1905 and *Caligus coryphaenae* Steenstrup and Lütken, 1861 from the gills of bigeye tuna. These copepods are known to parasitize ocean-migrating pelagic fishes, and the present collection includes the first record of *C. bonito* from bigeye tuna in Japan. Based on the literature published between the years 1894 and 2018, a list of the parasitic copepods of tunas (the tribe Thunnini) from Japan is given: 13 nominal species (3 spp. in *Unicolax* [Bomolochidae]; 6 spp. in *Caligus*; 2 spp. in *Euryphorus* [Caligidae]; 1 sp. in *Brachiella* [Lernaeopodidae]; and 1 sp. in *Pseudocycnus* [Pseudocycnidae]) and three or four unidentified species (*Caligus* sp./spp., *Parapelatus* sp.? [Caligidae], and *Pennella* sp. [Pennellidae]) have so far been reported from the Japanese tunas.

■ **Introduction**

Nine species of tunas (the tribe Thunnini) in four scombrid genera are known to occur in Japanese waters: bullet tuna, *Auxis rochei* (Risso, 1810); frigate tuna, *Auxis thazard* (Lacepède, 1800); kawakawa, *Euthynnus affinis* (Cantor, 1849); skipjack tuna, *Katsuwonus pelamis* (Linnaeus, 1758); albacore, *Thunnus alalunga* (Bonnaterre, 1788); yellowfin tuna, *Thunnus albacares* (Bonnaterre, 1788); bigeye tuna, *Thunnus obesus* (Lowe, 1839); Pacific bluefin tuna, *Thunnus orientalis* (Temminck and Schlegel, 1844); and longtail tuna, *Thunnus tonggol* (Bleeker, 1851). These species are commercially important and caught in various fisheries around Japan. *Thunnus orientalis* is also cultured in coastal waters of western Japan.

Recently, we had an opportunity to examine a small sample of *T. albacares* and *T. obesus* caught off central Japan for parasitic copepods, and the results of this examination are herein reported.

The parasitic copepods of tunas (the tribe Thunnini) from Japan have been reported since 1894, when the first paper on parasitic copepod from a Japanese tuna was published by Goto (1894), who found “a copepod, probably of the genus *Parapelatus*” on *T. albacares* or *Auxis* sp. from Misaki. Subsequently, two scientists, Dr. Satyu Yamaguti and Dr. Sueo M. Shiino, greatly contributed to clarifying the parasitic copepod fauna of Japanese tunas (Yamaguti, 1936a,b; Shiino, 1952, 1954a–c, 1957, 1959a,b,d, 1960). In this note, based on their and some other papers published for 125 years between 1894 and 2018, a list of the parasitic copepods of Japanese tunas is also provided (Table 1).

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✉ KN: e-mail: ornatus@hiroshima-u.ac.jp

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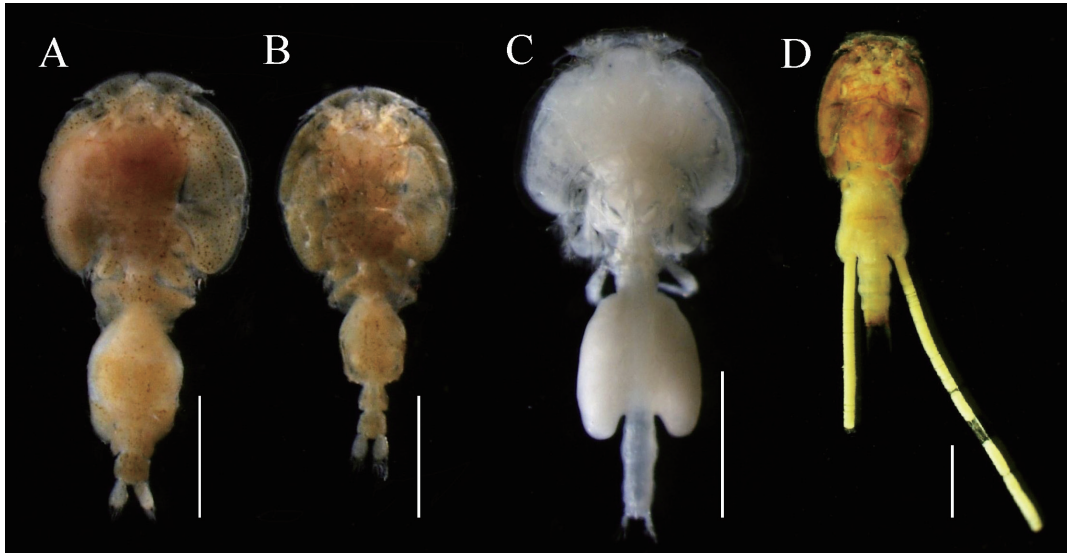


Fig. 1. *Euryphorus brachypterus*, female (A, dorsal view) and male (B, dorsal view), NSMT-Cr 25877, from *Thunnus albacares*; *Caligus bonito*, female (C, dorsal view), NSMT-Cr 25878, and *Caligus coryphaenae*, female (D, dorsal view), NSMT-Cr 25879, from *Thunnus obesus*. Scale bars: 2 mm in A–D.

■ Materials and Methods

In total, 10 individuals of *T. albacares* (n=5) and *T. obesus* (n=5) from the western North Pacific Ocean near the Izu Islands south of central Japan were examined for parasitic copepods. These fishes were caught with pole-and-line gear by two fishing vessels (*Sagamyojin maru No. 11* and *Jin-ichi maru*) at two close locations (31°50'N, 140°20'E; 31°50'N, 140°00'E) on 24 and 30 June 2018, respectively, and immediately stored in cold waters in the tanks of the vessels. The vessels returned to their mother port in Katsu-ura, Chiba Prefecture in one or two days after fishing, and the fishes were soon transported in fresh conditions to the National Research Institute of Far Seas Fisheries, Shizuoka, Shizuoka Prefecture, and on their arrival at the institute, they were measured for fork length (FL) and examined for parasitic copepods parasitic in the head region (surface, gills, walls of gill and oral cavities). Copepods found were fixed and preserved in 70% ethanol and then identified. They were sexed and measured for body length (excluding setae on the caudal rami). Voucher specimens of copepods have been deposited in the Crustacea collection of the National Museum of Nature and Science, Tsukuba, Ibaraki Prefecture, Japan (NSMT-Cr). The scientific and common names of tunas mentioned in this paper are those recommended in FishBase (Froese and Pauly, 2018).

■ Results

Three species of caligid copepods were collected: *Euryphorus brachypterus* (Gerstaecker, 1853) (Fig. 1A–B, NSMT-Cr 25877) from the inner surface of the operculum of both yellowfin and bigeye tunas, and *Caligus bonito* Wilson, 1905 (Fig. 1C, NSMT-Cr 25878) and *Caligus coryphaenae* Steenstrup and Lütken, 1861 (Fig. 1D, NSMT-Cr 25879) from the gills of bigeye tuna. Of the five individuals of yellowfin tuna examined, three (47.2, 46.0, and 48.3 cm FL) were infected each by one, two, and four *E. brachypterus*: these consisted of three females (7.0–7.1 mm long) and four males (6.0–6.1 mm long). Similarly, of the five individuals of bigeye tuna examined, three (54.6, 54.8, and 54.6 cm FL) were parasitized each by one, three, and three *E. brachypterus*: these were all females (5.6–7.6 mm long). A female of *Caligus bonito* (6.6 mm long) and an ovigerous female of *C. coryphaenae* (7.6 mm long) were found each on two individuals (54.2 and 53.6 cm FL) of bigeye tuna.

Remarks: The specimens of *Euryphorus brachypterus* collected in this study are in accordance with the descriptions of the species by Yamaguti (1936, reported as *Elytrophora brachyptera*) and Shiino (1954a, as *Elytrophora brachyptera*) from Japan; Ho et al. (2008) from Taiwan; Lewis (1967, as *Elytrophora brachyptera*) from the Hawaiian Islands; Kabata (1979) from the U.K.; and Dojiri and Ho (2013) from the Mediterranean Sea. The species is a common

parasite of large scombrids (Dojiri and Ho, 2013) and has been recorded from Croatia, Turkey, South Africa, the Indian Ocean, Australia, New Zealand, and various oceans as well (see Nagasawa and Shirakashi, 2018 for the literature). Markevich (1956: 233) also collected the species (reported as *Elytrophora brachyptera*) from the Sea of Japan and off the Kurile Islands. In Japan, *E. brachypterus* has been reported from four species of tunas (Pacific bluefin tuna, albacore, yellowfin tuna, and bigeye tuna) and also from farmed Pacific bluefin tuna (Table 1). There are also records of juvenile *E. brachypterus* (reported as *Dysgamus sagamiensis* Shiino, 1958) from non-scombrid fishes in Japanese waters (Shiino, 1958; Kabata and Gusev, 1966).

The female specimen of *C. bonito* collected in this study corresponds to the morphology of the species reported by Yamaguti (1936a) and Shiino (1959a, reported as *Caligus kuroshio*) from Japan; Lin and Ho (2002) from Taiwan; Lewis (1967) from the Hawaiian Islands; Wilson (1905) from the western North Atlantic; and Kabata (1979) from the U.K. The species is known to parasitize primarily scombrids (see Margolis et al., 1975; Cressey and Cressey, 1980; Lin and Ho, 2002; Ho and Lin, 2004 for the host names and literature). According to Cressey et al. (1983), *C. bonito* is more common on scombrids of the tribe Sardini than those of the tribe Thunnini and has a circumglobal distribution in tropical, subtropical, and temperate waters. The collection of *C. bonito* in this study represents its first record from bigeye tuna in Japan. Based on the previous and present studies, three species of tunas (skipjack tuna, Pacific bluefin tuna, and bigeye tuna) are the known hosts of *C. bonito* in Japan (Table 1). *Caligus kuroshio*, which was originally described by Shiino (1959a) from skipjack tuna and Pacific bluefin tuna from off central Japan, has been regarded as a junior synonym of *C. bonito* (Pillai, 1969). Recently, *C. bonito* was reported from skipjack tuna caught in the East China Sea off the west coast of Kyushu, Japan (Nagasawa et al., 2018).

The morphology of the ovigerous specimen of *C. coryphaenae* collected in this study is identical with that of the species described by Shiino (1952 [reported as *Caligus tesserafer*]) from Japan; Shiino (1959b) from Japan, the eastern Pacific, and the Indian Ocean; Lin and Ho (2002) from Taiwan; Lewis (1967) from the Hawaiian Islands; and Kabata (1979) from the U.K. The species is a common parasite of dolphinfishes of the coryphaenid genus *Coryphaena* as well as tunas and some other pelagic fishes (see Margolis et al., 1975; Cressey and Cressey, 1980; Ho and Lin, 2004

for the host names and literature) and, like *C. bonito*, the geographical distribution of *C. coryphaenae* is circumglobal in the tropical and subtropical waters (Cressey et al., 1983). In Japan, *C. coryphaenae* has been found from four species of tunas (kawakawa, skipjack tuna, Pacific bluefin tuna, and bigeye tuna) (Table 1), common dolphinfish, *Coryphaena hippurus* Linnaeus, 1758 (Shiino, 1959b, 1960), and blue shark, *Prionace glauca* (Linnaeus, 1758) (reported as *Isurus glaucus*) (Shiino, 1959d). Ho and Lin (2004: 160) listed yellow bobo, *Polydactylus opercularis* (Gill, 1863), as one of the Japanese hosts of *C. coryphaenae*, which, however, is wrong because *P. opercularis* does not occur in Japanese waters (Froese and Pauly, 2018): Shiino (1959c) found juvenile *C. coryphaenae* on *P. opercularis* in the eastern Pacific. The copepod identified as “*Caligus coryphaenae*” by Yamaguti (1936a) from common dolphinfish in Japan has been regarded as *Caligus quadratus* Shiino, 1954 (Shiino, 1959b). Further, *C. tesserafer* originally described by Shiino (1952) from Japanese skipjack tuna was relegated by Shiino (1959b) to a junior synonym of *C. coryphaenae*. Recently, the species was found in the plankton samples taken off southern Kyushu, Japan (Venmathi Maran and Ohtsuka, 2008).

■ The known parasitic copepod fauna of tunas in Japan

Based on the literature published between the years 1894 and 2018, the parasitic copepods reported from tunas (the tribe Thunnini) in Japan are listed in Table 1. To date, 13 nominal species (3 spp. in *Unicolax* [Bomolochidae]; 6 spp. in *Caligus*; 2 spp. in *Euryphorus* [Caligidae]; 1 sp. in *Brachiella* [Lernaeopodidae]; and 1 sp. in *Pseudocycnus* [Pseudocycnidae]) and three or four unidentified species (*Caligus* sp./spp., *Parapelatus* sp.? [Caligidae], and *Pennella* sp. [Pennellidae]) have been reported from the Japanese tunas. Recently, our knowledge has been increasing of the parasitic copepods of farmed Pacific bluefin tuna (Nagasawa, 2011a,b, 2015, 2017; Nagasawa and Shirakashi, 2018).

Of the 13 nominal species reported, *Caligus mebachii* Marukawa, 1927 is most poorly known because Marukawa (1927) briefly described the species from bigeye tuna in an encyclopedia of Japanese animals but there is no subsequent report on it. We need to collect caligid specimens from bigeye tuna for determining whether *C. mebachii* is a valid taxon or not. Further, *Pennella* sp. was reported only once more than 100 years ago from juvenile Pacific bluefin tuna in the North Pacific Ocean off Chiba Prefecture (Ishii, 1916), and recently, based on Ishii's paper, Nagasawa

Table 1. Parasitic copepods reported from tunas (*Auxis* spp., *Euthynnus affinis*, *Katsuwonus pelamis*, and *Thunnus* spp.) in Japan during a period from 1894–2018. The scientific names of the tunas are adopted from FishBase (Froese and Pauly, 2018).

Copepod	Host	Site of infection	Collection locality of host	Reference	
Cyclopoida: Poecilostomatoida					
Bomolochidae					
<i>Unicolax collateralis</i> Cressey and Cressey, 1980	<i>Auxis</i> sp.*	Nasal sinus	Japan	Cressey and Cressey (1980)	
	<i>Euthynnus affinis</i>	Nasal sinus	Okinawa; Tokyo	Cressey and Cressey (1980)	
<i>Unicolax mycterobius</i> (Vervoort, 1965)	<i>Auxis</i> sp.*	Nasal sinus	Tokyo	Cressey and Cressey (1980)	
	<i>Euthynnus affinis</i>	Nasal sinus	Tokyo; Kagoshima	Cressey and Cressey (1980)	
<i>Unicolax reductus</i> Cressey and Cressey, 1980	<i>Katsuwonus pelamis</i>	Nasal sinus	Japan	Cressey and Cressey (1980)	
Siphonostomatoida					
Caligidae					
<i>Caligus bonito</i> Wilson, 1905	<i>Katsuwonus pelamis</i> (as <i>Euthynnus pelamys</i>)	Gills	Yaizu (as Yaidu) in Shizuoka (as Siduoka)***	Yamaguti (1936a)	
	<i>Katsuwonus pelamis</i>	Body surface	western North Pacific off Hamajima, Mie Prefecture	Shiino (1959a, as <i>Caligus kuroshio</i>)	
	<i>Katsuwonus pelamis</i>	—**	Choshi in Chiba***; Misaki in Kanagawa***; Ito in Shizuoka***; neritic waters of Japan	Kuwabara (1959)	
	<i>Katsuwonus pelamis</i>	Gills, oral cavity	—	Kihara (1960)	
	<i>Katsuwonus pelamis</i>	Inner surface of the operculum	East China Sea off the Goto Islands, Nagasaki	Nagasawa et al. (2018)	
	<i>Thunnus orientalis</i> (as <i>T. thynnus</i>)	Body surface	western North Pacific off Hamajima, Mie Prefecture	Shiino (1959a, as <i>Caligus kuroshio</i>)	
	<i>Thunnus obesus</i>	Gills	western North Pacific near the Izu Islands	This paper	
	<i>Caligus coryphaena</i> Steenstrup and Lütken, 1861	<i>Euthynnus affinis</i> (as <i>E. yaito</i>)	Body surface	Hamajima in Mie***	Shiino (1959d)
	<i>Katsuwonus pelamis</i> (as <i>Katsuwonus vagans</i>)	—	Unknown locality of Izu Peninsula in Shizuoka***	Shiino (1952, as <i>Caligus tesseriifer</i>)	
	<i>Katsuwonus pelamis</i>	—	Hamajima in Mie***	Shiino (1959b)	
<i>Katsuwonus pelamis</i>	—	Coast of Izu Peninsula in Shizuoka***	Shiino (1959b)		
<i>Katsuwonus pelamis</i>	Body surface	Hamajima in Mie***	Shiino (1960)		
<i>Thunnus orientalis</i> (as <i>T. thynnus</i>)	Body surface	Hamajima in Mie***	Shiino (1959d)		
<i>Thunnus obesus</i>	Gills	western North Pacific near the Izu Islands	This paper		
<i>Caligus macarovi</i> Gusev, 1951	<i>Thunnus orientalis</i>	Body surface	Fish farm in Mie	Nagasawa (2011a, b)	
<i>Caligus mebachi</i> Marukawa, 1927	<i>Thunnus obesus</i> (as "mebachi" in Japanese)	Body surface	Neritic waters of Japan	Marukawa (1927)	
<i>Caligus productus</i> Dana, 1854	<i>Katsuwonus pelamis</i> (as <i>Euthynnus pelamys</i>)	Gills	North Pacific	Yamaguti (1936a, as <i>Caligus katuwo</i>)	
	<i>Katsuwonus pelamis</i> (as <i>Euthynnus pelamys</i>)	Inner surface of the operculum, oral cavity	western North Pacific off Hamajima, Mie	Shiino (1954c, as <i>Caligus katuwo</i>)	
	<i>Katsuwonus pelamis</i>	Body surface	Hamajima in Mie***	Shiino (1959b)	
	<i>Katsuwonus pelamis</i>	Body surface	Fish market in Tsu, Mie***	Shiino (1959d)	
	<i>Katsuwonus pelamis</i>	—	Misaki in Kanagawa***; Choshi in Chiba***; neritic waters of Japan	Kuwabara (1959, as <i>Caligus katuwo</i>)	
	<i>Katsuwonus pelamis</i>	Gills, oral cavity	—	Kihara (1960, as <i>Caligus katuwo</i>)	
	<i>Katsuwonus pelamis</i>	Body surface	Hamajima in Mie***	Shiino (1960)	
	<i>Thunnus albacares</i> (as <i>Neothunnus albacora</i>)	Inner surface of the operculum	Owase and Hamajima in Mie***	Shiino (1959d)	
	<i>Thunnus orientalis</i> (as <i>T. thynnus</i>)	Inner surface of the operculum	Hamajima in Mie***	Shiino (1959d)	
	<i>Thunnus orientalis</i> (as <i>T. thynnus</i>)	—	Japan	Cressey and Cressey (1980)	
<i>Caligus quadratus</i> Shiino, 1954	<i>Katsuwonus pelamis</i>	Inner surface of the operculum	Fish market in Tsu, Mie***	Shiino (1959d)	
	<i>Thunnus albacares</i> (as <i>Neothunnus macropterus</i>)	Inner surface of the operculum	Fish market in Shimakatsu (as Shimakatu), Mie***	Shiino (1954b)	
	<i>Thunnus albacares</i> (as <i>Neothunnus albacora</i>)	Inner surface of the operculum	Shimakatsu in Mie	Shiino (1959b)	
	<i>Auxis rochei</i> (as "marusoda" in Japanese, and <i>Auxis tapeinosoma</i>)	Gills	Sagami Bay	Kato et al. (1963)	
<i>Caligus</i> sp.	<i>Thunnus orientalis</i>	Body surface	Fish farms	Shirakashi (2013)	
<i>Euryphorus brachypterus</i> (Gerstaecker, 1853)	<i>Thunnus orientalis</i> (as <i>Thynnus thynnus</i>)	Inner surface of the operculum	North Pacific	Yamaguti (1936b, as <i>Elytrophora brachyptera</i>)	
	<i>Thunnus orientalis</i>	Inner surface of the operculum	Choshi (as Tyōsi) Market in Chiba***; Owase Market in Mie***	Shiino (1954a, as <i>Elytrophora brachyptera</i>)	
	<i>Thunnus orientalis</i> (as <i>Thynnus thynnus</i>)	Inner surface of the operculum	western North Pacific	Shiino (1957, as <i>Elytrophora brachyptera</i>)	
	<i>Thunnus orientalis</i> (as <i>Thynnus thynnus</i>)	Inner surface of the operculum	Owase and Hamajima in Mie***	Shiino (1959d, as <i>Elytrophora hemiptera</i>)	
	<i>Thunnus orientalis</i>	Inner surface of the gill operculum	Tsugaru Strait	Kanaiwa et al. (2016)	
<i>Thunnus orientalis</i>	—	Fish farms	Bali et al. (2016, as <i>Euryphorus</i> spp., see Nagasawa and Shirakashi, 2018)		

Table 1. Continued.

Copepod	Host	Site of infection	Collection locality of host	Reference
	<i>Thunnus orientalis</i>	Gills	Fish farm in Wakayama	Nagasawa and Shirakashi (2018)
	<i>Thunnus alalunga</i> (as <i>Thynnus alalunga</i>)	Inner surface of the operculum	North Pacific	Yamaguti (1936b, as <i>Elytrophora brachyptera</i>)
	<i>Thunnus albacares</i> (as <i>Neothunnus albacora</i>)	Inner surface of the operculum	western North Pacific	Shiino (1957, as <i>Elytrophora brachyptera</i>)
	<i>Thunnus albacares</i> (as <i>Neothunnus albacora</i>)	Inner surface of the operculum	Owase in Mie***	Shiino (1959d, as <i>Elytrophora hemiptera</i>)
	<i>Thunnus albacares</i>	Inner surface of the operculum	western North Pacific near the Izu Islands	This paper
	<i>Thunnus obesus</i> (as <i>Parathynnus sibi</i>)	Inner surface of the operculum	western North Pacific off Irozaki (as Irozaki) point in Shizuoka (as Sizuoka)	Shiino (1954a, as <i>Elytrophora brachyptera</i>)
	<i>Thunnus obesus</i> (as <i>Parathynnus obesus</i>)	Inner surface of the operculum	western North Pacific	Shiino (1957, as <i>Elytrophora brachyptera</i>)
	<i>Thunnus obesus</i>	Inner surface of the operculum	western North Pacific near the Izu Islands	This paper
<i>Euryphorus nordmanii</i> Milne Edwards, 1840	<i>Thunnus albacares</i> (as <i>Neothunnus macropterus</i>)	Inner surface of the operculum	western North Pacific off Shimakatsu (as Simakatu) in Mie	Shiino (1954a, <i>Euryphorus nympha</i>)
<i>Parapelatus</i> sp. ?	<i>Thunnus albacares</i> (as <i>Thynnus albacora</i>) or <i>Auxis</i> sp. (as "Sōdagatsuwō" in Japanese)	Gills	Misaki in Kanagawa***	Goto (1894)
Lernaeopodidae				
<i>Brachiella thynni</i> Cuvier, 1830	<i>Thunnus orientalis</i>	Near the base of the pectoral fin	Fish farm in Miyazaki	Nagasawa (2015)
Pennellidae				
<i>Pennella</i> sp.****	<i>Thunnus orientalis</i>	Anterior body in the host's abdominal cavity, with posterior body protruding externally	western North Pacific off Boso (as Boshu) in Chiba	Ishii (1916)
Pseudocycnidae				
<i>Pseudocycnus appendiculatus</i> Heller, 1865*****	<i>Thunnus orientalis</i>	Gills	Fish farm in Miyazaki	Nagasawa (2017)

* Cressey and Cressey (1980) did not refer to the specific name of *Auxis*.

** Not reported.

*** The fish examined were landed or purchased at these localities.

**** Nagasawa and Uyeno (2014) treated this species as *Pennella instructa*.

***** Shiino (1965: 499) listed this species in an encyclopedia of Japanese animals, but no original record of the species from Japan was reported by him.

and Uyeno (2014) treated this unidentified species as *Pennella instructa* (Wilson, 1917). Nevertheless, it is highly desirable to collect and identify new material of copepod of *Pennella* from Pacific bluefin tuna in Japanese waters.

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