The cymothoid isopod *Nerocila phaiopleura* parasitic on gnomefish, *Scombrops boops*, in coastal Pacific waters of central Japan, with an updated list of the hosts reported from Japan

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■ Abstract

Nerocila phaiopleura Bleeker, 1857 was collected from the body surface of gnomefish, *Scombrops boops* (Houttuyn, 1782) (Perciformes: Scombropidae), in the Kowaura Fishing Port, part of Kowaura Bay facing the western North Pacific Ocean, Mie Prefecture, central Japan. This represents a new host record for *N. phaiopleura*. The collected specimens of *N. phaiopleura*, consisting of 10 ovigerous females, 3 transitional-stage individuals, and 5 juveniles, are briefly described. The gnomefish examined were young fish, which are considered to have become infected by *N. phaiopleura* during their stay in coastal waters of the bay. Skin wounds caused by *N. phaiopleura* were found at some attachment sites. This paper also provides an updated list of the Japanese hosts of *N. phaiopleura*, including 11 nominal species of fishes in three clupeiform families (Clupeidae, 3 spp.; Dussumieriidae, 1 sp.; Engraulidae, 1 sp.) and four perciform families (Carangidae, 1 sp.; Scombridae, 3 spp.; Scombropidae, 1 sp.; Sphyraenidae, 1 sp.).

■ Introduction

The cymothoid isopod *Nerocila phaiopleura* Bleeker, 1857 is a skin parasite of actinopterygian fishes in the Indo-West Pacific region, including South Africa, Kuwait, Pakistan, India, Thailand, Indonesia, Australia, China, and Japan (see Nagasawa and Isozaki, 2017). In Japan, *N. phaiopleura* was first reported in 1982 (Mitani, 1982) and since has been studied for its host range, juvenile morphology, geographical distribution, and impact on the host fish (Bruce and Harrison-Nelson, 1988; Hiramoto, 1996; Saito and Hayase, 2000; Nunomura, 2011; Nagasawa and Tensha, 2016; Hata et al., 2017; Nagasawa and Isozaki, 2017; Nagasawa and Nakao, 2017; Nagasawa and Kawai, 2018; Saito and Ogawa, 2019; Nagasawa, 2019; Nagasawa et al., 2019, 2020). The species is kown to parasitize cultured Pacific bluefin tuna, *Thunnus orientalis* (Temminck and Schlegel, 1844), as well (Shirakashi, 2013; Nagasawa and Shirakashi, 2017).

Recently, specimens of *N. phaiopleura* were collected from gnomefish, *Scombrops boops* (Houttuyn, 1782), in coastal Pacific waters of Mie Prefecture, central Japan. This paper reports on this collection as a new host record for *N. phaiopleura*. The information on the Japanese hosts of this parasite was previously compiled by Nagasawa and Isozaki (2017) but, using the recent literature (Nagasawa and Kawai, 2018; Nagasawa et al., 2019, 2020; this paper), an updated list of those hosts is also given in this paper (Table 1).

■ Materials and Methods

The isopod-infected gnomefish were found among individuals of the same species caught using rod and line in mid-June 2017 in the Kowaura Fishing Port at Kowaura (34°15′15″N, 136°27′41″E), Minami-Ise, Mie Prefecture, central Japan. The port is located in the innermost part of Kowaura Bay, which faces the western North Pacific Ocean. After the infected fish were photographed, isopods were removed and frozen with sea water. Later, at the Aquaparasitology Laboratory, Shizuoka Prefecture, the isopods were thawed, examined for their morphological features using an Olympus SZX10 stereo microscope, and identified as *N. phaiopleura*. They were measured for body length (BL, from the anterior end of the cephalon to the posterior end of

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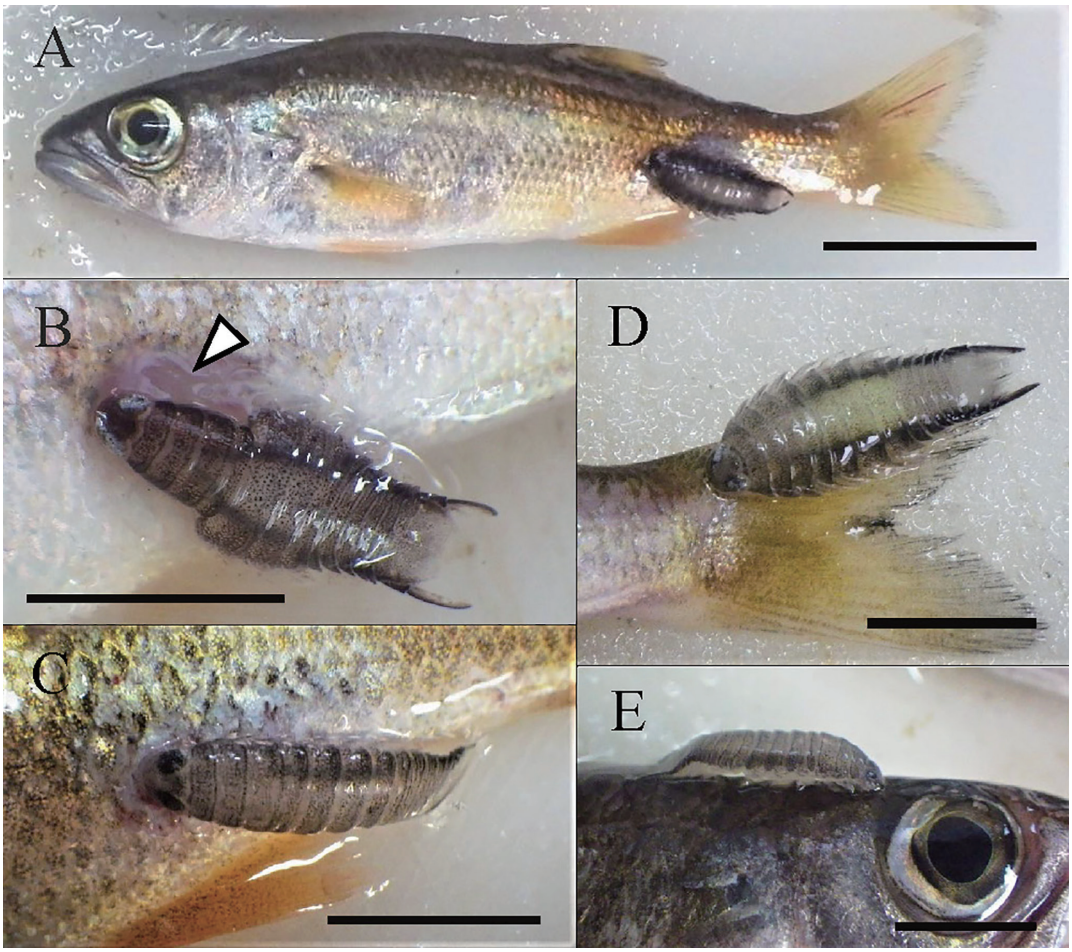

Fig. 1. Gnomefish, *Scombrops boops*, infected by *N. phaiopleura* on the posterior lateral body surface above the anal fin (A–C), the posteriormost lateral caudal penduncle (D), and the dorsal surface of the head (E), lateral views, fresh specimens. An arrowhead in Fig. 1B shows a skin wound caused by *N. phaiopleura*. Scale bars: A, 30 mm; B–E, 10 mm.

the pleotelson) and body width (BW, across the widest pereonite excluding coxae).

The specimens preserved in 70% ethanol of *N. phaiopleura* are retained by the first author (KN) of this paper for a taxonomic study of cymothoid isopods from Japanese fishes but will be deposited in the Crustacea collection of the National Museum of Nature and Science, Tsukuba, Ibaraki Prefecture, Japan. The scientific and common names of fishes mentioned in this paper follow Froese and Pauly (2019), except for Japanese sardine, *Sardinops melanostictus* (Temminck and Schlegel, 1846), which follows Nakabo (2013).

■ Results

In total, 18 specimens of *N. phaiopleura*, consisting of 10 ovigerous females, 3 transitional-stage individuals, and 5 juveniles, were collected from over 100 young gnomefish examined [105–140 (mean: 119) mm fork length (FL), n = 7]. Of these specimens, 16 (9 ovigerous females, 3 transitional-stage individuals, and 4 juveniles) were attached on the posterior lateral body surface above the anal fin of the host fish (Fig. 1A–C), while 1 ovigerous female and 1 juvenile were found, respectively, on the posteriormost lateral caudal peduncle (Fig. 1D) and the dorsal surface of the head (Fig. 1E) of the host fish. Skin wounds were found at some attachment sites (Fig. 1B). Due to limited time, no data on prevalence were taken.

Ovigerous female (Fig. 2A): Body elliptical, 2.3–2.7 (mean: 2.5, n = 10) times as long as wide, measuring 18.0–21.5 (19.7, n = 10) mm BL and 6.8–9.5 (7.8, n = 10) mm BW (Fig. 3). Cephalon with broad anterior margin. Eyes large. Pereonite 1 with concaved anterior margin. Pereonites 5–6 longest and widest. Coxae of

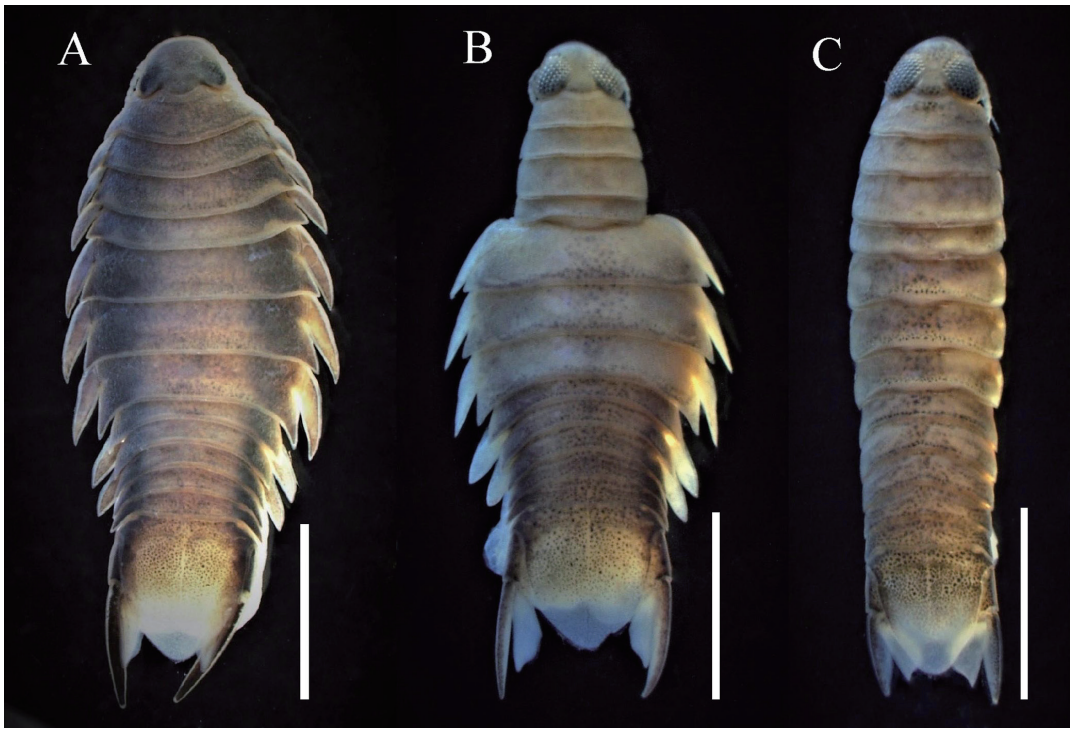

Fig. 2. *Nerocila phaiopleura*. A, an ovigerous female (18.1 mm BL); B, a transitional-stage individual (16.8 mm BL); C, a juvenile (17.0 mm BL), dorsal views, ethanol-preserved specimens. Scale bars: A–C, 5 mm.

pereonites 5–7 developed. Pleonites 1 and 2 with lateral processes slightly produced. Pleotelson nearly triangular with lateral margins smoothly curved. Uropod rami straight and slender; exopods longer than endopods. Black stripes on lateral portions of pereon, pleon, and pleotelson and uropod exopods.

Transitional-stage individuals (Fig. 2B): Body separated into two (anterior and posterior) portions, 2.6–2.8 (mean: 2.7, n = 3) times as long as wide, measuring 15.8–16.8 (16.3, n = 3) mm BL and 5.9–6.5 (6.2, n = 3)

Table 1. Hosts of *Nerocila phaiopleura* reported from Japan. The orders of fishes are arranged based on their systematics. Fish species in each family are shown in alphabetical order.

Order	Family	Species	Common Name	Reference
Clueiformes	Clupeidae	*Konosirus punctatus*	dotted gizzard shad	Mitani (1982), Hiramoto (1996)
		Sardinella zunasi	Japanese sardinella	Mitani (1982), Hiramoto (1996)
		*Sardinops melanostictus**	Japanese sardine	Mitani (1982), Bruce and Harrison-Nelson (1988), Hiramoto (1996), Saito and Hayase (2000), Nunomura (2011), Hata et al. (2017), Nagasawa et al. (2020)
	Dussumieriidae	*Etrumeus micropus*	round herring	Nagasawa and Isozaki (2017)
	Engraulidae	*Engraulis japonicus*	Japanese anchovy	Mitani (1982), Williams and Bunkley-Williams (1986: 654)**, Bruce and Harrison-Nelson (1988), Hiramoto (1996)
Perciformes	Carangidae	*Trachurus japonicus*	Japanese jack mackerel	Nagasawa and Isozaki (2017)
	Scombridae	*Scomber japonicus*	chub mackerel	Nagasawa and Nakao (2017), Nagasawa and Kawai (2018), Nagasawa et al. (2019)
		Scomberomorus niphonius	Japanese Spanish mackerel	Nagasawa and Tensha (2016), Hata et al. (2017)
		Thunnus orientalis	Pacific bluefin tuna	Shirakashi (2013, as *Nerocila* sp.?), Nagasawa and Shirakashi (2017)
	Scombropidae	*Scombrops boops*	gnomefish	This paper
	Sphyraenidae	*Sphyraena japonica*	Japanese barracuda	Nagasawa and Isozaki (2017)

*The generic name of this species was incorrectly reported as *Sardinopsis* by Nagasawa and his coauthors (Nagasawa and Tensha, 2016; Nagasawa and Shirakashi, 2017; Nagasawa and Isozaki, 2017). *Sardinops* is the correct generic name of Japanese sardine (see Nagasawa et al., 2020).

**Nagasawa and Isozaki (2017: table 1) mistakenly cited this paper and reported that *N. phaiopleura* was found from *Sardinops melanostictus*. However, the isopod was actually found from *Engraulis japonicus*.

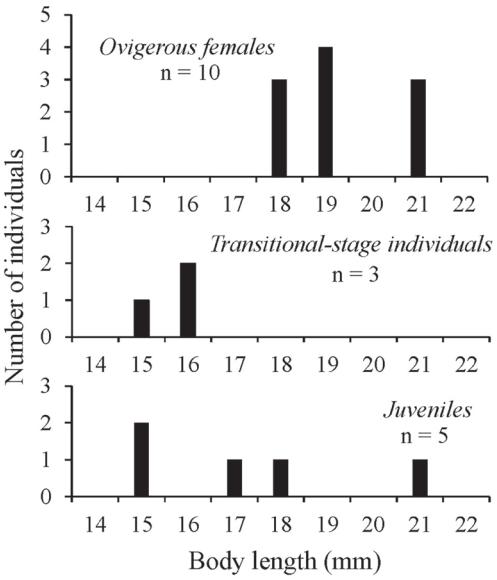

Fig. 3. Body length distributions of ovigerous females (top), transitional-stage individuals (middle), and juveniles (bottom) of *Nerocila phaiopleura* from gnomefish, *Scombrops boops*, caught in mid-June 2017 in the Kowaura Fishing Port, part of Kowaura Bay, Mie Prefecture, central Japan.

mm BW (Fig. 3). Anterior portion consists of cephalon with large eyes and pereonites 1–4, while posterior portion of pereonites 5–7, pleon, pleotelson, and uropods. Pereonite 6 longest and widest. Coxae of pereonites 5–7 developed. Pleonites 1 and 2 with lateral processes posteriorly produced. Pleotelson nearly triangular. Uropods extending beyond posterior end of pleotelson; exopods longer than endopods. Dark spots scattered on dorsal surface of pereonites 5–7, pleon, and pleotelson.

Juvenile (Fig. 2C): Body elongate, 3.9–4.2 (mean: 4.1, n = 5) times as long as wide, measuring 15.6–21.2 (17.5, n = 5) mm BL and 3.8–5.1 (4.3, n = 5) mm BW (Fig. 3). Cephalon with anterior margin rounded. Eyes prominent and ovate. Pereonites almost equal in length; pereonites 5–6 slightly wider than others. Pleon slightly narrower than pereon; pleonite 1 longest. Pleotelson shield-shaped. Uropods similar to those of transitional-stage individual.

■ Discussion

The present collection of *N. phaiopleura* from gnomefish in the Kowaura Fishing Port (Kowaura Bay) represents the second record of the cymothoid from the bay and its new host record (see Nagasawa and Isozaki, 2017). In the bay, *N. phaiopleura* was previously found parasitizing three other fish species, i.e., round herring, *Etrumeus micropus* (Temminck and Schlegel, 1846), Japanese jack mackerel, *Trachurus japonicus* (Temminck and Schlegel, 1844), and Japanese barracuda, *Sphyraena japonica* Bloch and Schneider, 1801.

Based on the previous and present papers, *N. phaiopleura* has been reported from 11 nominal species of coastal actinopterygian fishes in Japan (Table 1). Those fishes belong to three families of the order Clupeiformes (Clupeidae, 3 spp.; Dussumieriidae, 1 sp.; Engraulidae, 1 sp.) and four families of the order Perciformes (Carangidae, 1 sp.; Scombridae, 3 spp.; Scombropidae, 1 sp.; Sphyraenidae, 1 sp.). Of these fishes, both Japanese sardine, *S. melanostictus*, and Japanese anchovy, *Engraulis japonicus* Temminck and Schlegel, 1846 have been reported most often as the hosts of *N. phaiopleura*, followed by chub mackerel, *Scomber japonicus* Houttuyn, 1782 (Table 1).

As compared with adults of *N. phaiopleura*, our knowledge of both transitional and juvenile stages of the species is still limited. As far as we know, Barnard (1936) reported an transitional-stage individual of the species from the Bay of Bengal (Indian Ocean). The juveniles of *N. phaiopleura* have been reported as the aegathoid stage from Australia (Bruce, 1987) and Japan [Saito and Hayase, 2000; Saito et al., 2014 (as *Nerocila* sp.); Saito and Ogawa, 2019].

Gnomefish are known to change their habitats during their life in Japanese waters (Mochizuki, 1997). In the western North Pacific near our sampling site in Mie Prefecture, the species spawns in November to February (Yamada et al., 2007) and juveniles and young fish stay in coastal waters but move to deeper waters with their growth (Kimura et al., 1982). Based on the age-fork length relationship of the species (Yamada et al., 2007), the fish collected in this study (105–140 mm FL) are regarded as age-0 individuals. Thus, those young fish are considered to have become infected by *N. phaiopleura* during their stay around our sampling site, which is coastal waters of Kowaura Bay. A recent review of the geographical distribution of *N. phaiopleura* in Japanese waters has shown that Kowaura Bay and other coastal Pacific waters affected by a warm current, the Kuroshio, are one of the major distribution areas of the species (Nagasawa et al., 2020).

Nerocila phaiopleura was almost exclusively attached on the posterior lateral body surface of fishes (Fig. 1A–C). This is consistent, irrespective of taxonomic positions of the host fishes in Hong Kong (Morton, 1974) and Japan (Mitani, 1982; Saito and Hayase, 2000; Nagasawa and Tensha, 2016; Nagasawa and Shirakashi, 2017; Nagasawa and Isozaki, 2017; Nagasawa and Nakao, 2017; Nagasawa and Kawai, 2018;

Nagasawa et al., 2020). In India, however, the species has been reported to most frequently occur on the body surface near the base of the pectoral fin of engraulids (Aneesh et al., 2013).

In this study, skin wounds were found on some attachment sites of *N. phaiopleura* (Fig. 1B). Similar wounds have been recorded from other fish species infected by *N. phaiopleura* in the same locality (Nagasawa and Isozaki, 2017), Kaneda Bay (Mitani, 1982), Omaezaki Harbor (Saito and Hayase, 2000: fig. 5), the Seto Inland Sea (Nagasawa and Tensha, 2016; Nagasawa and Kawai, 2018), and at Shirahama (Nagasawa and Shirakashi, 2017) in Japan. The wounds have been suggested to be caused by deep insertion of the pereopod dactyli of *N. phaiopleura* into and feeding of the species on the host skin (Nagasawa and Isozaki, 2017; Nagasawa and Kawai, 2018).

In Kowaura Bay, two other species of cymothoid isopods have been reported: *Ceratothoa verrucosa* (Schioedte and Meinert, 1883) from crimson seabream, *Evynnis tumifrons* (Temminck and Schlegel, 1843) (Perciformes: Sparidae) (Nagasawa and Isozaki, 2016) and *Nerocila trichiura* (Miers, 1877) from Hoso-tobiuo, *Cypselurus hiraii* Abe, 1953 (Beloniformes: Exocoetidae) (Nagasawa and Isozaki, 2019).

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