Mothocya parvostis (Isopoda: Cymothoidae) parasitic on Japanese halfbeak, *Hyporhamphus sajori*, in the central Seto Inland Sea, Japan, with a brief summary of the hosts, geographical distribution, and pathogenic effects of the isopod

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Abstract

Two females and two males of the cymothoid isopod *Mothocya parvostis* Bruce, 1986 were found on two of three individuals of Japanese halfbeak, *Hyporhamphus sajori* (Temminck and Schlegel, 1846), from the central Seto Inland Sea off Ikunoshima Island, Hiroshima Prefecture, Japan. Each infected fish hosted a female and a male of *M. parvostis* in the right and left branchial cavities, respectively. The female and the male of *M. parvostis* collected are briefly described. To date, *M. parvostis* has been reported only from Japan, where the species occurs in the eastern East China Sea, the southern Sea of Japan, the Seto Inland Sea, the western North Pacific Ocean, and the southern Sea of Okhotsk. Five species of wild fishes, which belong to five families in two orders, are known as hosts of the isopod, and Japanese halfbeak is considered the most important host in terms of high prevalence and many records of the isopod from this fish species. There used to be an outbreak of the isopod in cage-cultured fingerling Japanese amberjack, *Seriola quinqueradiata* Temminck and Schlegel, 1845, in western Japan, but no such case has been reported recently. The isopod is harmful to its hosts. It negatively affected the body condition of wild Japanese halfbeak and also retarded the growth of tank-reared juvenile Mejina, *Girella punctata* Gray, 1835. It is necessary to conduct a taxonomic study of *M. parvostis* and its closely related species, *Mothocya sajori* Bruce, 1986, which is also found in branchial cavity of Japanese halfbeak.

Introduction

Japanese halfbeak, *Hyporhamphus sajori* (Temminck and Schlegel, 1846), is an epipelagic schooling fish in Far East Asia (Nakabo, 2018), being commercially caught in coastal fisheries of Japan (Sadakata et al., 1998; Tsuji and Sadakata, 2000). The male and female of the species grow up to 26–29 and 31–36 cm in total length, respectively, and their life span is two years (Nakabo, 2018).

Since the 1930's, a cymothoid infection has been recorded from Japanese halfbeak in Japan. The cymothoid isopod from the fish had been identified as *Irona melanosticta* (Schioedte and Meinert, 1884) (Hiraiwa, 1934; Inouye, 1941; Shiino, 1951, 1965; Ogawa, 1952; Hattori and Seki, 1956; Nunomura, 1981: 55) or *Irona* sp. (Nunomura, 1981: 55–56). However, based on a revisional study of the cymothoid genus *Mothocya*, Bruce (1986) reported *I. melanosticta* as a parasite of flyingfishes and described two new species, *Mothocya parvostis* Bruce, 1986 and *Mothocya sajori* Bruce, 1986, from three Japanese marine fishes (including Japanese halfbeak, see below) and Japanese halfbeak, respectively. He regarded *I. melanosticta* reported by Hiraiwa (1934), Inouye (1941), Shiino (1951, 1965), Hattori and Seki (1956), and Nunomura (1981) as *M. sajori* and did *Irona* sp. reported by Nunomura (1981) as *M. parvostis*. *Mothocya parvostis* was also collected from Japanese amberjack, *Seriola quinqueradiata* Temminck and Schlegel, 1845, and Mejina, *Girella punctata* Gray, 1835 (Bruce, 1986). Since Bruce's (1986) work, no substantial research has been done on these two species of *Mothocya* in Japan, except for a work of *M. parvostis* by Kawanishi et al. (2016). An immature isopod from Japanese halfbeak from Otsuchi, northern Japan, was reported as *Mothocya* sp. (Nunomura, 1987) but later as *M. sajori* (Saito et al., 2000; Nunomura, 2011). Both *M. parvostis* and

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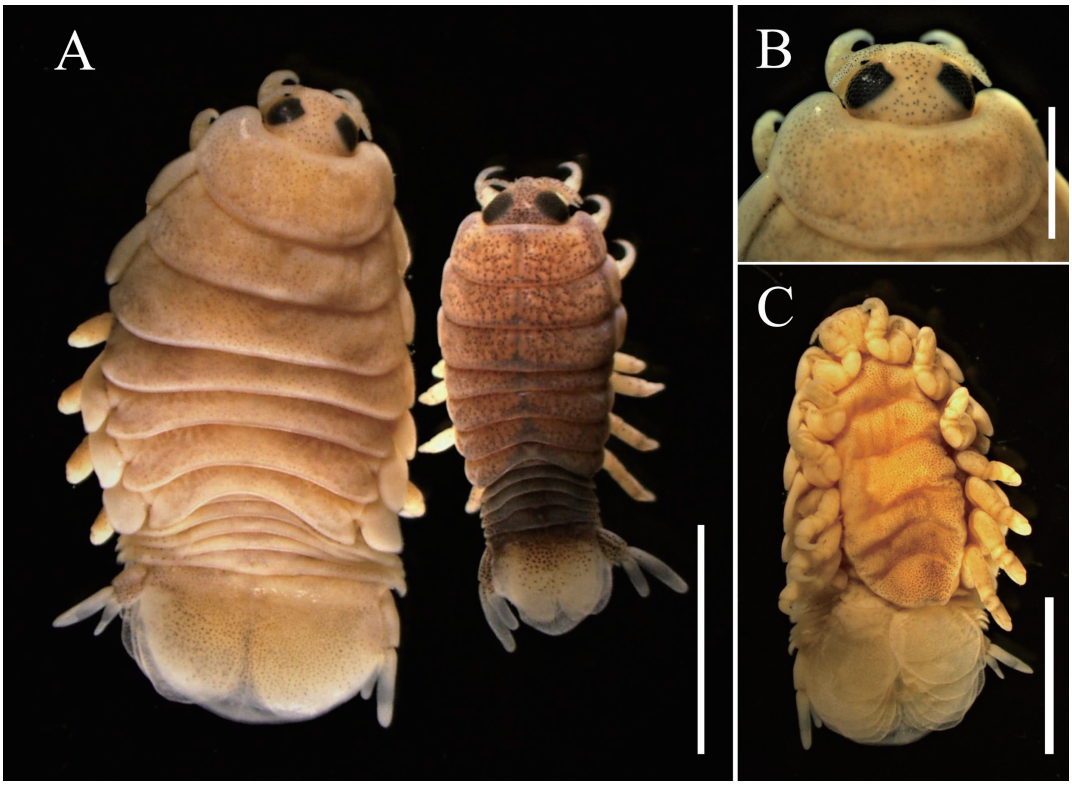

Fig. 1. *Mothocya parvostis*, female (14.0 mm BL) and male (9.9 mm BL), NSMT-Cr 27517, respectively, from the right and left branchial chambers of a Japanese halfbeak, *Hyporhamphus sajori* (230 mm TL), from the central Seto Inland Sea off Ikunoshima Island, Hiroshima Prefecture, Japan. Ethanol-preserved specimens. A, female (left) and male (right), habitus, dorsal view; B, female, cephalon and pereonite 1, dorsal view; C, female, habitus, ventral view. Scale bars: A and C, 5 mm; B, 2 mm.

M. sajori have been listed in Nunomura (1995), Saito et al. (2000), and Yamauchi (2016).

I collected specimens of *M. parvostis* from Japanese halfbeak in the central Seto Inland Sea, Japan, and briefly describe them in this paper. I also herein summarize the information published in Japan on the hosts, geographical distribution, and pathogenic effects of *M. parvostis* because this parasite was usually reported in Japanese in local journals and books, and it is almost impossible for scientists in other countries to get such information on the species.

Materials and Methods

Three individuals of Japanese halfbeak were collected using hook and line on 2 November 2006 in the central Seto Inland Sea off the northern coast of Ikunoshima Island, Hiroshima Prefecture, Japan. The fish were kept on ice in a container and transported to the laboratory of Hiroshima University, Higashi-Hiroshima, where they were measured for total length (TL, mm) and examined for metazoan parasites on the same day. When parasitic isopods were found, they were carefully removed using forceps from attachment sites and fixed in 70% ethanol. Later, at the Aquaparasitology Laboratory, Shizuoka Prefecture, they were examined using an Olympus SZX10 stereo microscope. Isopod specimens were measured for body length (BL, mm, from the anterior margin of the cephalon to the posterior margin of the pleotelson) and for body width (BW, mm, across the widest pereonite). Voucher specimens (two females and two males) of the isopod preserved in 70% ethanol 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 fishes mentioned in this paper follow Froese and Pauly (2019).

Results

Mothocya parvostis Bruce, 1986
(New Japanese name: Sayori-no-ojama-mushi)
(Figs. 1–2)

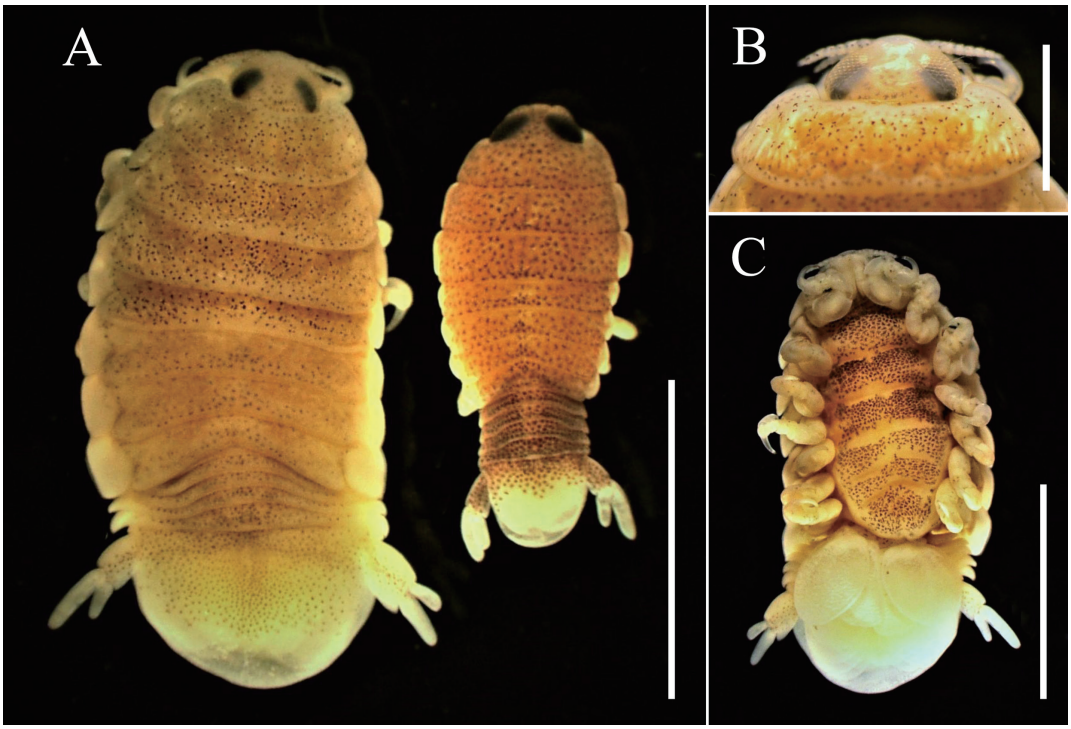

Fig. 2. *Mothocya parvostis*, female (10.3 mm BL) and male (7.1 mm BL), NSMT-Cr 27517, respectively, from the right and left branchial chambers of a Japanese halfbeak, *Hyporhamphus sajori* (215 mm TL), from the central Seto Inland Sea off Ikunoshima Island, Hiroshima Prefecture, Japan. Ethanol-preserved specimens. A, female (left) and male (right), habitus, dorsal view; B, female, cephalon and pereonite 1, dorsal view; C, female, habitus, ventral view. Scale bars: A and C, 5 mm; B, 2 mm.

Mothocya parvostis Bruce, 1986: 1105–1108, figs. 6–7 (off Nagasaki, Kyushu, Japan, ca. 33º10′N, 129º 40′E [type locality]; Horioka, Shinminanto [as Sinminato], Toyama Prefecture; vicinity of Nagasaki, Kyushu); Nunomura 1987: 2 (Kamaishi, Iwate Prefecture); Nunomura 1995: 222, fig. 21-201J (mention); Lester and Roubal 1995: 550–561 (mention); Yamauchi et al. 2004: 4–5 (mention); Hatai 2006: 162 (mention); Hatai et al. 2007: 128–130, figs. 10–42, 10–43 (mention); Yamauchi and Nunomura 2010: 73 (Toyama Bay: off mouth of Hayatsuki River, Uozu-Namerikawa, Toyama Prefecture; fish market of Uozu, Uozu, Toyama Prefecture; mouth of Kado River, Uozu, Toyama Prefecture); Nunomura 2011: 29 (list of museum specimens from off Shari, Hokkaido; Kamaishi, Iwate Prefecture; off mouth of Hayatsuki River, Namerikawa City, Toyoma Prefecture; mouth of Kado River, Uozu City, Toyama Prefecture; Uozu City, Toyama Prefecture; Horioka, Shinminato, Toyama Prefecture; off Mizuhashi, Toyama, Toyama Prefecture; off Nagasaki, Nagasaki Prefecture; off Nomozaki, Nagasaki Prefecture; vicinity of Nagasaki, Nagasaki Prefecture); Yamauchi 2016: 115, table 2 (list); Kawanishi et al. 2016: 13–19 (Seto Inland Sea [Onomichi, Mitsuhama, Ushimado]; southern Sea of Japan [Yoshimi]); Hata et al. 2017: 105, table 1 (Ehime); Yamauchi and Kashio 2018: 56–57, fig. 1 (Kishiwada, Osaka Prefecture; unknown locality, Japan; coast of Ozaki, Hannan, Osaka Prefecture; coast of Oishi, Yura, Sumoto, Hyogo Prefecture).

Irona melanosticta: Hatai and Yasumoto 1980: 87–96, figs. 1–10 (Fish farms at Osaki, Sasebo, and Oshima, Nishisonogi, Nagasaki Prefecture; Hatai and Yasumoto 1981: 77–81 (East China Sea off west coast of Nagasaki Prefecture; fish farm at Obama, Minamitakaki, Nagasaki Prefecture; Nomo Cove near Nagasaki Prefectural Institute of Fisheries, Nomozaki, Nagasaki Prefecture); Hatai and Yasumoto 1982a: 75–79 (Nomo Cove near Nagasaki Prefectural Institute of Fisheries, Nomozaki, Nagasaki Prefecture; East China Sea off Cape Nomo and Ikeshima Island); Hatai and Yasumoto 1982b: 147–150 (Nomo Cove near Nagasaki Prefectural Institute of Fisheries, Nomozaki, Nagasaki Prefecture); Hatai 1989: 22 (mention).

Irona sp.: Nunomura 1981 (southern Sea of Japan [off Tassya, Aikawa, Niigata Prefecture])

Material examined. Two females (14.0 and 10.3

mm BL; 6.9 and 4.9 mm BW), two males (9.9 and 7.1 mm BL; 4.0 and 2.9 mm BW), the central Seto Inland Sea (34°17′56″N, 132°54′59″E) off the northern coast of Ikunoshima Island, Hiroshima Prefecture, Japan, from branchial cavity of Japanese halfbeak, *Hyporhamphus sajori*, 2 November 2006, coll. Kazuya Nagasawa (NSMT-Cr 27517).

Female. Body weakly twisted, 2.0–2.1 times as long as greatest width, widest at pereonite 4, lateral margin slightly convex. Cephalon with rounded frontal margin, 0.5–0.6 times longer than wide. Eyes oval, well visible, moderately large, 0.4 times width of cephalon, 0.6–0.8 times length of cephalon. Pereonite 1 smooth, anterior border idented to surround posterior region of cephalon, anterolateral angle beyond posterior end of eye. Pereonites 2–6 posterior margins smooth and slightly curved laterally; 7 with slightly recessed posterior margin. Coxae lateral margins nearly straight or slightly convex; 2–3 narrow; 4–7 with posteroventral angles mostly rounded; 6–7 slightly extending past pereonite margin. Pereonite 1 longest; 2–7 decreasing in length; 1–4 increasing in width; 5–7 decreasing in width. Pleon with pleonite 1 largely concealed by pereonite 7, slightly visible in dorsal view; pleonite 2 partially overlapped by pereonite 7; pleonites posterior margin smooth; pleonite 5 widest, posterior margin straight. Pleotelson 0.6–0.7 times as long as anterior width, dorsal surface smooth, lateral margins indented immediately posterior to pleonite 5 and weakly convex, posterior margin rounded. Uropod more than half length of pleotelson, peduncle 0.6–0.7 times longer than rami, peduncle lateral margin without setae, rami extending around posterior margin of pleotelson. Exopod 1.6–2.0 times longer than endopod, both apically rounded, terminating without setae.

Pale yellow in ethanol, black chromatophores well visible on dorsal surface of body and ventral surface of brood pouch.

Male. Body not twisted, 2.4–2.5 times as long as greatest width, widest at pereonite 3. Pleotelson shield-shaped with rounded posterior margin. Uropod extending past posterior margin of pleotelson. Exopod 1.3–1.6 times longer than endopod, both apically bluntly rounded.

Dark brown or yellow in ethanol, many black chromatophores visible on dorsal surface of body.

Occurrence on host. Two (230 and 215 mm TL) of the three fish examined were each infected by two (female and male) isopods. A female and a male of isopod were found in the right and left branchial cavities of each infected fish, respectively.

Remarks. Bruce (1986) described *M. parvostis* using female and male specimens from Japanese halfbeak, Japanese amberjack (type host), and Mejina collected in Japan. Two papers have since been published on the species (Nunomura, 1987; Kawanishi et al., 2016) but no observation was made on the morphology of the species. The measurements and morphological features of the specimens collected in this study correspond to those of *M. parvostis* described by Bruce (1986), and the specimens are herein identified as the species. Following Kawanishi et al.'s (2016) paper, the present report represents the second record of the species from the Seto Inland Sea.

As pointed out by Bruce (1986), *M. parvostis* closely resembles a congeneric species, *Mothocya sajori*, which was also described by Bruce (1986) based on specimens from Japanese halfbeak in Japan. Interestingly, *M. sajori* was reported from Japanese halfbeak from the Seto Inland Sea near our collection locality (Hiraiwa, 1934; Inouye, 1941), which indicates that two morphologically similar species, *M. parvostis* and *M. sajori*, occur in the same area and parasitize the same fish species. According to Bruce (1986), the body sizes of adults of both species do not overlap: the ovigerous females of *M. parvostis* from three host species including Japanese halfbeak were smaller (11.0–15.0 mm BL) than those of *M. sajori* from Japanese halfbeak (20.5–27.5 mm BL). The BL/BW ratios were also different between females of the two species: 1.97–2.15 and 2.08–2.16 in *M. parvostis* and *M. sajori*, respectively (Bruce, 1986). Moreover, the female specimens collected in this study (10.3–14.0 mm BL; 2.02–2.10 in BL/BW ratio) match these criteria for *M. parvostis*. However, Kawanishi et al. (2016) found that some of their specimens of *M. parvostis* from Japanese halfbeak did not match such criteria, being larger than *M. parvostis* and smaller than *M. sajori*. The authors also showed that the body size of *M. parvostis* increased with an increase in body length of Japanese halfbeak. These results suggest that the body sizes of adults are not be useful to differentiate *M. parvostis* from *M. sajori*, and it is, thus, highly necessary to evaluate usefulness of the adult body size for identifying the two *Mothocya* species. Furthermore, since the shape of the body, coxae, and posterior margin of pereonite 7 and the eye size have been regarded as useful characters to differentiate both species from each other (Bruce, 1986), it is important to examine variations in these characters using many specimens covering a wide range of body size.

As stated below, Pacific saury, *Cololabis saira*

(Brevoort, 1856), is one of the wild hosts of *M. parvostis* (Nunomura, 2011). *Mothocya* sp. (reported as *Iroha* [sic] *melanosticta japonensis*) has been described from this fish from the Sea of Japan (Avdeev and Avdeev, 1974; see Hadfield et al., 2015 for its nomenclature), and a re-examination of the specimens of *Mothocya* sp. from Pacific saury is desired in relation to identification of *M. parvostis* and its relates species. An isopod infection was also recorded from Pacific saury in the early 1980's in Japan (Wada, 1982), where the isopod was reported as *I. melanosticta* (Nagasawa, 1984). No taxonomic work has so far been done on this isopod, but it has been listed as *M. sajori* (Saito et al., 2000) or *M. parvostis* (Nunomura, 2011).

Yamauchi (2016) may have a different opinion about the taxonomy of Japanese *Mothocya* spp. from those of Bruce (1986), Saito et al. (2000), and Nunomura (2011). In a list of Japanese cymothoids, he treated each of the isopods reported from Japanese halfbeak (Inouye, 1941; Hattori and Seki, 1956; Nunomura, 1987), Pacific saury (Wada, 1982; Nagasawa, 1984; Nunomura, 2011), and chub mackerel, *Scomber japonicus* Houttuyn, 1782 (Hatai and Yasumoto, 1982a) as *Mothocya* sp. Since he did not mention any reason for this treatment, his opinion is not adopted herein.

Summary of the hosts, geographical distribution, and pathogenic effects of *Mothocya parvostis*

Mothocya parvostis does not show a strict host specificity: it has been recorded from wild and cage-cultured fishes. The known wild fish hosts include five species which belong to five families in two orders: Japanese amberjack, *S. quinqueradiata* (type host) (Perciformes: Carangidae) (Hatai and Yasumoto, 1980, 1981, 1982a; Bruce, 1986; Nunomura, 2011); Mejina, *G. punctata* (Perciformes: Girellidae) (Hatai and Yasumoto, 1981, 1982a, b; Nunomura, 2011); chub mackerel, *S. japonicus* (Perciformes: Scombridae) (Hatai and Yasumoto, 1982a); Japanese halfbeak, *H. sajori* (Beloniformes: Hemiramphidae) (Nunomura, 1981, 1987; Bruce, 1986; Yamauchi and Nunomura, 2010; Kawanishi et al., 2016; Hata et al., 2017; Yamauchi and Kashio, 2018; this paper); and Pacific saury, *C. saira* (Beloniformes: Scomberesocidae) (Nunomura, 2011). Among these wild fish hosts, Japanese halfbeak is considered the most important because the fish was frequently (41.6–74.4%) infected by *M. parvostis* (Kawanishi et al., 2016) and, to date, eight papers have recorded the isopod from the species (see above).

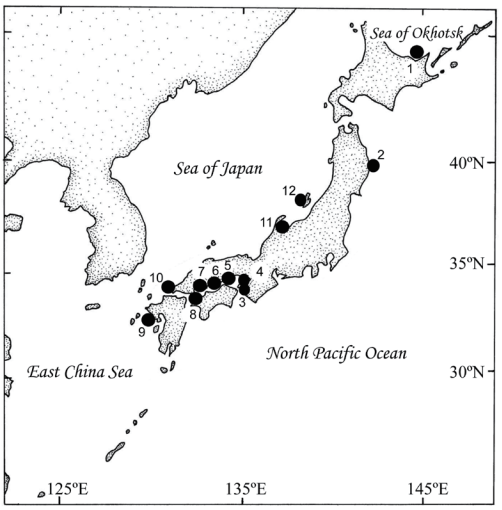

Fig. 3. Map of the Japanese Archipelago, showing the collection localities of *Mothocya parvostis* in the previous and present studies. 1, off Shari, Hokkaido (Nunomura, 2011); 2. Kamaishi, Iwate Prefecture (Nunomura, 1987, 2011); 3, Kishiwada and Hannan, Osaka Prefecture (Yamauchi and Kashio, 2018); 4, Sumoto, Hyogo Prefecture (Yamauchi and Kashio, 2018); 5, Ushimado, Okayama Prefecture (Kawanishi et al., 2016); 6, Onomichi, Hiroshima Prefecture (Kawanishi et al., 2016); 7, Ikunoshima Island, Hiroshima Prefecture (this paper); 8, Mitsuhama, Ehime Prefecture (Kawanishi et al., 2016; Hata et al., 2017); 9, East China Sea off Nagasaki and off Cape Nomo and Ikeshima Island, Nomo Cove, and fish farms, Nagasaki Prefecture (Hatai and Yasumoto, 1980, 1981, 1982a, b; Bruce, 1986); 10, Yoshimi, Yamaguchi Prefecture (Kawanishi et al., 2016); 11, Toyama Bay including Shinminato, Toyama Prefecture (Bruce, 1986; Yamauchi and Nunomura, 2010); 12, Aikawa, Niigata Prefecture (Nunomura, 1981). See the synonym list of *M. parvostis* in this paper for detailed information on the collection localities.

There are records of *M. parvostis* from cage-cultured Japanese amberjack (Hatai and Yasumoto, 1980, 1981; Bruce, 1986). An outbreak of *M. parvostis* occurred in 1979 in fingerling Japanese amberjack cultured in coastal waters of the East China Sea, Nagasaki Prefecture, and prevalence of the isopod ranged from 3.1 to 52.0% at five fish farms surveyed (Hatai and Yasumoto, 1980). In 1980, however, the isopod was found at only one of the six fish farms sampled with a prevalence of 4.7% (Hatai and Yasumoto, 1981). No similar outbreak since has been reported. In Japan, juvenile Japanese amberjack are caught at sea and used for farming, and those juveniles caught in the eastern East China Sea off Nagasaki Prefecture harbored *M. parvostis* with its prevalence being 2.8 and 2.79% in 1980 and 1981, respectively (Hatai and Yasumoto, 1981, 1982a). While Bruce (1986) mentions that *M. parvostis* was collected from "cage-cultured" Mejina

(as fingerling *Girella punctata*), this fish was not commercially cultured during the early 1980's in Japan. Actually, Hatai and Yasumoto (1981, 1982a, b) found the isopod on wild Mejina fingerlings in coastal waters near their institute and reared wild-caught Mejina in concrete tanks to evaluate the impact of the isopod on the fish and to test a chemical for treatment.

In addition to the above wild and reared fishes, fingelings of barred knifejaw, *Oplegnathus fasciatus* (Temminck and Schlegel, 1844) (Perciformes: Oplegnathidae) and blackhead seabream, *Acanthopagurus schlegelii* (Bleeker, 1854) (Perciformes: Sparidae), can get infected in tanks by cohabitation of Japanese amberjack fingerlings harboring *M. parvostis* (Hatai and Yasumoto, 1980).

Mothocya parvostis has so far been reported only from Japan, where it was collected in the eastern East China Sea (Hatai and Yasumoto, 1980, 1981, 1982a, b; Bruce, 1986; Nunomura, 2011), the southern Sea of Japan (Nunomura, 1981, 2011; Bruce, 1986; Yamauchi and Nunomura, 2011; Kawanishi et al., 2016), the Seto Inland Sea (Kawanishi et al., 2016; Hata et al., 2017; Yamauchi and Kashio, 2018; this paper), the western North Pacific Ocean (Nunomura, 1987, 2011), and the southern Sea of Okhotsk (Nunomura, 2011) (Fig. 3). Information on detailed collection localities is found in the above synonym list. Hata et al. (2017) collected *M. parvostis* at "Ehime", which is most probably Mitsuhama because their research group (Kawanishi et al., 2016) collected the sample of the species at that site in Ehime Prefecture. Since Japanese halfbeak is widely distributed in coastal waters of Japan ranging from Hokkaido in the north to Kyushu in the south (Tsuji and Sadakata, 2000; Nakabo, 2018) and, as stated above, is frequently infected by *M. parvostis* (Kawanishi et al., 2016), it is desirable to examine this fish species from various localities to clarify the geographical distribution of *M. parvostis* in Japanese waters.

The branchial cavity has been reported as the site of infection by *M. parvostis* (Hatai and Yasumoto, 1980 [as the gill chamber], 1982b; Kawanishi et al., 2016 [as the gill cavity]; this paper). Exceptionally, Nunomura (1981) collected three females of the species from the body surface of a Japanese halfbeak. This may have resulted from movement of the females after the host fish was dead.

Mothocya parvostis is harmful to its hosts. The species retarded the growth of juvenile Mejina reared in the tanks (Hatai and Yasumoto, 1981, 1982a; see also Lester and Roubal, 1995: 558, fig.13.38B). The body condition of wild Japanese halfbeak from western Japan was reduced by *M. parvostis* (Kawanishi et al., 2016).

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