New records of a freshwater fish parasite Argulus japonicus (Branchiura: Argulidae) from northern Honshu, Japan, with a note on its occurrence in a brackish water lake

New records of a freshwater fish parasite Argulus japonicus (Branchiura: Argulidae) from northern Honshu, Japan, with a note on its occurrence in a brackish water lake

Kazuya Nagasawa, Masato Nitta, Nobuyuki Azuma

Abstract. One and two specimens of *Argulus japonicus* Thiele, 1900 were collected from the body surface of big-scaled redfin *Pseudaspius hakonensis* (Günther, 1877) (Cypriniformes: Leuciscidae) in the Babame River, Akita Prefecture, and Lake Jusan, Aomori Prefecture, northern Honshu, Japan, respectively. This is two new prefecture records in Japan and a new host record for A. japonicus. Lake Jusan is the northernmost collection locality of this parasite in Japan recorded from wild fishes. As Lake Jusan is a brackish water lake and big-scaled redfin is known to migrate from fresh to salt waters, and since *A. japonicus* completes its life cycle in fresh waters, we infer that the two individuals of *A. japonicus* parasitized the big-scaled redfin in an inflowing river, then this fish was collected along with the surviving argulid individuals after migrating to the lake. The collection of *A. japonicus* in Lake Jusan represents the second record for the species from brackish water lakes in Japan.

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Key words: parasitic crustacean, fish louse, new locality record, new host record, northern Honshu, big-scaled redfin

■ Introduction

Argulus japonicus Thiele is an ectoparasite of freshwater fishes (Yamaguti, 1963; Neethling & Avenant-Oldewage, 2016) distributed in East/Southeast Asia (Poly, 2008). This species was originally described by Thiele (1900) from a female specimen collected in Japan, where it has since been studied for various aspects of its biology (Nagasawa, 2009, 2011). In Japan, it is known to occur on all of the four major islands (Hokkaido, Honshu, Shikoku, and Kyushu) (e.g., Nagasawa *et al*., 1989, 2010, 2012, 2018, 2021, 2023c; Nagasawa & Sato, 2014; Nagasawa, 2017, 2018, 2019, 2021, 2023a, b), but much remains poorly studied on its distribution in the northern region of Honshu. Although there are six prefectures (Aomori, Iwate, Miyagi, Akita, Yamagata, and Fukushima) in this region, *A. japonicus* has been reported only from Miyagi Prefecture (Nagasawa *et al*., 2022, 2023b). During a parasitological survey of freshwater fishes in northern Honshu, we collected specimens of *A. japonicus* from big-scaled

redfin *Pseudaspius hakonensis* (Günther, 1877) (Cypriniformes: Leuciscidae) from Akita and Aomori prefectures. This represents two new prefecture records in Japan and a new host record for *A. japonicus*.

■ Materials and Methods

Ten individuals of big-scaled redfin were caught with a scoop net in the middle-reaches of the Babame River (39°56′36″N, 140°07′53″E) at Takasaki-Hirogano in Gojome, Akita Prefecture, on 30 July 2015 (Fig. 1, locality 2). These fish were transported frozen to the laboratory of Hiroshima University, where they were thawed, measured for their standard length (SL, mm), and examined for metazoan parasites. Seven individuals of big-scaled redfin were also caught with a small fixed net installed in coastal waters of a brackish water lake, Lake Jusan (41°00′17″N, 140°21′32″E), at Jusan in Goshogawara, Aomori Prefecture, on 26 September 2016 (Fig. 1, locality 1). They were transported alive to the laboratory of Hirosaki University and similarly examined for their SL and metazoan parasites. When crustacean parasites were found at both laboratories, they were carefully taken from the hosts using forceps and preserved in 70% ethanol. Later, these specimens were observed under an Olympus SZX10 stereo microscope and an Olympus BX51 phase-contrast compound microscope at the Aquaparasitology Laboratory. Identification was made using the wooden slide procedure recommended by Humes & Gooding (1964) and Benz & Otting (1996). The specimens were soaked in lactophenol for two hours before observation under the compound microscope, and drawings were made with the aid of a drawing tube attached to this microscope. After the specimens were identified, they were recorded for their sex and total length (TL, from the anterior tip of the carapace to the posterior tip of the abdomen). They have been deposited in the Crustacea (Cr) collection of the National Museum of Nature and Science, Tsukuba, Ibaraki Prefecture (NSMT-Cr 31502, one specimen from the Babame River; NSMT-Cr 31503, two specimens from Lake Jusan). The scientific and common names of fishes mentioned in this paper follow Hosoya (2015), except for those of *P. hakonensis* and the common names of Carassius cuvieri Temminck & Schlegel, 1846 and *Cyprinus carpio* Linnaeus, 1758, which are based on Froese & Pauly (2023).

■ Results

Argulus japonicus was collected from one (122 mm SL) of the 10 big-scaled redfin [86–122 (mean = 97) mm SL] in the Babame River, Akita Prefecture, and from two (216 and 230 mm SL) of the seven big-scaled redfin [190–230 (215) mm SL] in Lake Jusan, Aomori Prefecture. The number

of *A. japonicus* per infected fish was one in both localities, and the species was found on the host's operculum (in the Babame River) and body surface (in Lake Jusan).

The collected specimens of A. japonicus (Fig. 2) are all females, being 3.1 (from the Babame River), 3.9, and 6.0 mm TL (from Lake Jusan). They are morphologically characterized by a dorsoventrally flattened body; a nearly circular carapace, covering the first to third pairs of legs; compound eyes visible in the frontal region of the carapace; a naupliar eye present dorsally along midline of the carapace; the ventral surface of the frontal and lateral regions of the carapace ornamented with numerous, small sharply pointed spines; posterolateral lobes of the carapace separated by a sinus, ending each in a rounded margin; paired respiratory areas, each comprising a small anterior area and a large posterior area; the thorax consisting of four segments, each bearing a pair of legs; a bilobed abdomen ending in a rounded tip; the first and second antennae found beneath the frontal region of the carapace; the preoral sheath and stylet located along the midline posterior to the second antennae; the mouth tube longer than wide, becoming wider posteriorly; the first maxillae forming cup-like suckers; the second maxillae each with a robust first segment bearing three large projections; the first to fourth pairs of legs biramous, each comprising the coxa, basis, exopod, and endopod; and the fourth pair of legs each with the coxa forming a natatory lobe. In addition, the number of plumose setae on the posterior margin of the coxa in each of the first legs is constantly one (Fig. 3). The number of supporting rods per first maxilla ranges from 45 to 54 (52 and 54 in a specimen from the Babame River; 46 and 46, and 45 and 49, in two specimens from Lake Jusan, respectively).

The body of the frozen-thawed specimen is nearly transparent and its respiratory areas are pale brown (Fig. 2A, B), whereas the body of the ethanol-preserved specimen is white and its carapace and thorax have dark brown dorsal spots (Fig. 2C, D).

Remarks

The morphological characters of the specimens collected in this study are almost identical to those of female *A. japonicus* reported by Tokioka (1936a), Yamaguti (1937), and Nagasawa (2021), and the specimens are herein identified as this species.

In Japan, three species of the genus *Argulus*, *i.e.*, *A. japonicus*, *A. coregoni* Thorell, 1864, and *A. mongolianus* Tokioka, 1939, have been reported from wild freshwater fishes (Nagasawa *et al.*, 2022). Of these species, *A. japonicus* and *A. coregoni* bear a morphological resemblance to each other (Tokioka, 1936a; Yamaguti, 1937) and show no strict host specificity (Nagasawa, 2011, 2021), and the latter species also occurs in northern Honshu (Nagasawa & Ishikawa, 2015; Nagasawa *et al.*,

2019, 2020, 2023a). Thus, it is necessary to distinguish *A. japonicus* from *A. coregoni* using reliable morphological characters. As reported above, the specimens collected in this study have the first pair of legs each with a single plumose seta on the posterior margin of the coxa (Fig. 3), which can be used as is one of the features to differentiate *A. japonicus* from *A. coregoni* (Nagasawa, 2021; Nagasawa *et al.*, 2022, 2023b): the latter species has more than four plumose setae on the same posterior margin (4–7 in Yamaguti, 1937; 4–9 in Hoshina, 1950; 6 in Nagasawa & Taniguchi, 2021). Moreover, the present specimens have 45–54 supporting rods per first maxilla. This number is almost similar to those reported from *A. japonicus* (*ca*. 50 in Tokioka, 1936a; 40–50 in Yamaguti, 1937; 50 and 52 in Nagasawa, 2021; 46–51 in Nagasawa *et al.*, 2023b; 47 and 48 in Nagasawa *et al.*, 2023c). In contrast to this, *A. coregoni* has usually more than 60 supporting rods (*ca*. 60 in Tokioka, 1936a; 60–70 in Yamaguti, 1937; 54–73 in Hoshina, 1950; 67 and 72 in Nagasawa & Taniguchi, 2021).

While there are some records of diseasecausing argulid branchiurans or fish lice in northern Honshu, their identification has not been made based on morphological and/or molecular features (Nagasawa *et al.*, 2023b). In this region, *A. japonicus* is known to occur only in two small lakes (Lake Izunuma and Lake Uchinuma), Miyagi Prefecture (Nagasawa *et al.*, 2022, 2023b), and the present collection of the species extends its distribution range from Miyagi Prefecture northward to Akita and Aomori prefectures (Fig. 1). Furthermore, *A. japonicus* was reported from common carp *Cyprinus carpio* from Hokkaido Island north of Honshu (Nagasawa *et al.*, 1989; Nagasawa, 1994, 2018) but there is no record of this parasite from wild freshwater fishes of the island. Thus, Lake Jusan represents the northernmost collection locality in Japan for *A. japonicus* recorded from wild fishes.

Big-scaled redfin, from which we collected the specimens of *A. japonicus*, is distributed in East Asia surrounding the Sea of Japan, including the Japanese Archipelago, the eastern Korean Peninsula, Primorsky Kray, and Sakhalin Island (Russia) (Sakai *et al.*, 2002; Watanabe *et al*., 2018). To date, *A. japonicus* has not been reported from this fish species in Japan (Nagasawa & Katahira, 2013) and the above adjacent regions (*e.g*., Smirnova, 1971; Sokolov *et al.*, 2012). Here, big-scaled redfin is regarded as a new host of *A. japonicus*.

■ Discussion

Since *A. japonicus* completes its life cycle in fresh waters (Tokioka, 1936b), it is interesting to

note that this parasite was collected in Lake Jusan, which is connected to the Sea of Japan and its salinity often exceeds 20 psu in coastal waters near the mouth of the Iwaki River, one of the rivers flowing into the lake (Umeda *et al.*, 2008). A similar occurrence in both freshwater and salt waters has been reported in three other *Argulus* species: *A. dartevellei* Braian, 1940 in Congo (Fryer, 1960), *A. kosus* Avenant-Oldewage, 1994 in South Africa (Van As *et al.*, 1999), and *A. flavescens* Wilson, 1916 in North America (Causey, 1960; Cressey, 1972; Suárez-Morales *et al.*, 1998). In Japan, *A. japonicus* was previously collected in droughtinduced brackish waters in Lake Shinji, and Nagasawa (2019) has suggested that this parasite could survive in those lake waters for a certain period along with its euryhaline host, Japanese white crucian carp *Carassius cuvieri* (Cypriniformes: Cyprinidae). This fish usually occurs in fresh waters but can stay even in brackish waters (Suzuki & Kimura, 1977, 1978). As big-scaled redfin is also a euryhaline species and some individuals migrate from fresh to salt waters for feeding and growth (Nakamura, 1969; Sakai, 1995), *A. japonicus* may be able to survive in brackish waters of Lake Jusan when this parasite is attached on such lake-migrating big-scaled redfin.

Based on the above consideration, Lake Jusan is not regarded as the habitat constantly utilized by *A. japonicus*, and this parasite is very likely to maintain its populations in the rivers flowing into the lake. The Iwaki River is the largest among those rivers, and at least 20 species of freshwater fishes are found in its middle-reaches, where big-scaled redfin is the most abundant, followed by fat minnow *Phoxinus lagowskii steindachneri* Sauvage, 1883, pale chub *Opsariichthys platypus* (Temminck & Schlegel, 1846), and ayu *Plecoglossus altivelis altivelis* (Temminck & Schlegel, 1846) (Izumi *et al.*, 2006). It is thus reasonable to infer that big-scaled redfin serves as a host for *A. japonicus* in the Iwaki River and some of its infected individuals migrate to Lake Jusan. In addition, pale chub has been reported as a host of *A. japonicus* in other localities of Japan (Nagasawa & Sato, 2014; Nagasawa, 2017; Nagasawa *et al*., 2023c) and this fish may also harbor the parasite in the Iwaki River.

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Addresses

(KN and MN) Graduate School of Integrated Sciences for Life, Hiroshima University, 1–4–4 Kagamiyama, Higashi-Hiroshima, Hiroshima 739–8528, Japan

(KN's present address) Aquaparasitology Laboratory, 365–61 Kusanagi, Shizuoka 424–0886, Japan

(MN's present address) Pathology Division, Nansei Field Station, Fisheries Technology Institute,

Japan Fisheries Research and Education Agency, Minami-Ise, Watarai, Mie 516–0193, Japan
(NA) Faculty of Agricultural and Life Sciences, Hirosaki University, 3 Bunkyo, Hirosaki, Aomori 036–8561, Japan
Email address of the corresponding author
(KN) ornatus@hiroshima-u.ac.jp

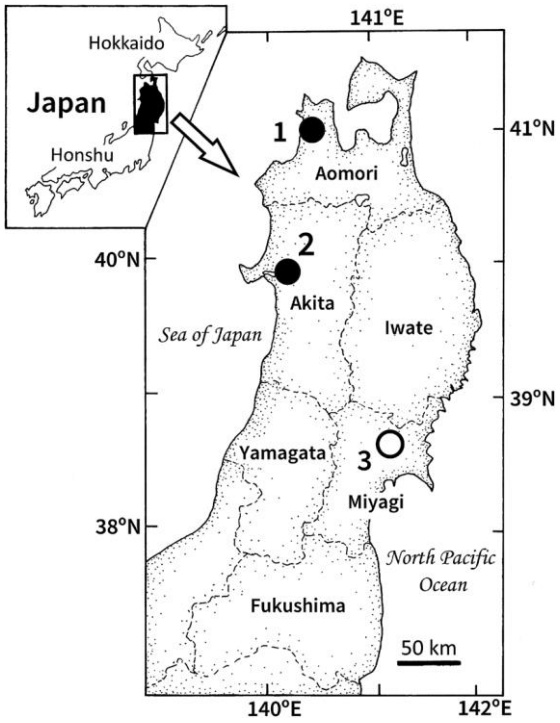

Fig. 1. Map of northern Honshu, Japan, showing the collection localities of *Argulus japonicus* in the previous (open circle) and present (closed circles) studies. 1, Lake Jusan, Aomori Prefecture (this paper); 2, Babame River, Akita Prefecture (this paper); 3. Lake Izunuma and Lake Uchinuma, Miyagi Prefecture (Nagasawa *et al.*, 2022, 2023b).

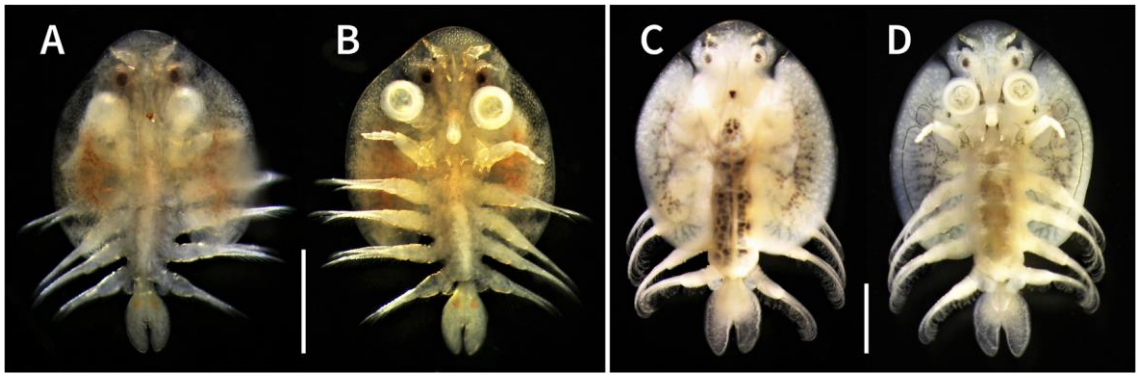

Fig. 2. *Argulus japonicus* from the body surface of big-scaled redfin *Pseudaspius hakonensis* in northern Honshu. A and B, female, 3.1 mm total length, NSMT-Cr 31502, from the Babame River, Akita Prefecture; C and D, female, 6.0 mm total length, NSMT-Cr 31503, from Lake Jusan, Aomori Prefecture. The frozen-thawed (A and B) and ethanol-preserved specimens (C and D) of *A. japonicus* were photographed. A and C, habitus, dorsal view; B and D, habitus, ventral view. Scale bars: A and B, 1 mm; C and D, 1 mm.

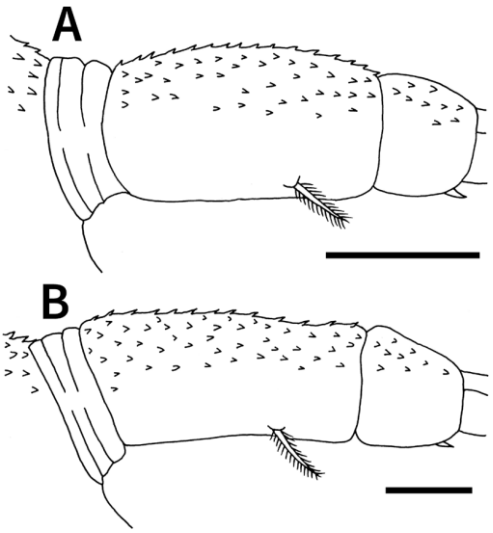

Fig. 3. Coxa (with a plumose seta) and basis of the first leg in *Argulus japonicus* from the body surface of big-scaled redfin *Pseudaspius hakonensis* in northern Honshu, ventral view. A, female, 3.1 mm total length, NSMT-Cr 31502, from the Babame River, Akita Prefecture; B, female, 6.0 mm total length, NSMT-Cr 31503, from Lake Jusan, Aomori Prefecture. Scale bars: A and B, 0.2 mm.