Redescription of *Dactylogyrus petruschewskyi* Gussev, 1955 (Monogenea: Dactylogyridae), a Newly Recorded Alien Monogenean from an Alien Cyprinid, *Megalobrama amblycephala* Yih, 1955 (Cypriniformes: Cyprinidae), in Ibaraki Prefecture, Central Japan

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*Dactylogyrus petruschewskyi* Gussev, 1955 (Monogenea: Dactylogyridae) was found infecting the gills of *Megalobrama amblycephala* Yih, 1955 (Cypriniformes: Cyprinidae) that was sampled from the Ono River flowing into Lake Kasumigaura in Ibaraki Prefecture, central Japan. This is the first record of this monogenean from Japan, and this parasite was most likely introduced and established along with *M. amblycephala* from China into Japan. The 28S rDNA sequence of *D. petruschewskyi* is available in the database but not based on a published study. We analyzed molecular data based on newly collected specimens, and the obtained sequence corresponded to the available sequence.

**Key Words:** Monogenea, fish parasite, alien species, 28S rDNA sequence, Lake Kasumigaura, Tone River system.

**Introduction**

*Megalobrama amblycephala* Yih, 1955, a cyprinid fish belonging to the subfamily Cultrinae, is natively distributed throughout lakes in the middle reaches of the Yangtze River, China (Wu *et al.* 1979). Recently, this cyprinid was collected from Lake Kasumigaura in Ibaraki Prefecture, central Japan, as an alien fish (Hagiwara 2017). Over 30 species of alien freshwater fishes have been reported from the Tone River system, which includes Lake Kasumigaura (*e.g.*, Hagiwara and Kumagai 2007; Yanai *et al.* 2008; Sekine 2009; Nemoto *et al.* 2011; Arayama *et al.* 2012; Hagiwara 2017), and some alien parasites have been co-introduced and have established with them (Nitta and Nagasawa 2015, 2020). In this study, we examined *M. amblycephala* collected from the Ono River, which flows into Lake Kasumigaura, and collected some specimens of a dactylogyrid monogenean, *Dactylogyrus petruschewskyi* Gussev, 1955. This dactylogyrid was originally described from *Parabramis pekinensis* (Basiléwsky, 1855) (Cyprinidae: Cultrinae) in Lake Hanka at Astrakhanka, Primorsky Krai, Far East Russia (Gussev 1955), then reported from China (see Long 2000). However, to date, no morphological character other than the sclerotized parts of this species has been described. This study presents the first record of this monogenean as an alien species in Japan, along with its redescriptions and molecular information.

The 28S rDNA sequence of *D. petruschewskyi* is available in the database (AY548927) but not based on a published study. Nevertheless, this data has been used for molecular phylogenetic studies (*e.g.*, Šimková *et al.* 2006). Since the phylogenetic relationships of species are important information that is referred to when constructing a taxonomy, we covered all studies that performed phylogenetic estimation based on this unpublished sequence data. Furthermore, based on the newly obtained sequence in this study, we confirmed the correctness of this registered sequence.

**Materials and Methods**

Two *M. amblycephala* specimens were collected by seines from the Ono River (35°58′12.1″N, 140°21′09.0″E) flowing into Lake Kasumigaura (the Tone River system), at Horinouchi, Inashiki City, Ibaraki Prefecture, central Japan on 10 March and 28 September 2019. The first specimen (standard length, SL: 36.3 mm) was fixed in 99% ethanol in the field, and the second one (SL: 338.0 mm) was kept in a freezer before the examination for gill parasites. Gills were removed from each fish, and monogeneans were collected using needles by observing under a dissecting microscope. Two monogenean specimens collected from a host fixed in ethanol were stained in alum carmine. Bodies of two other specimens were cut from their haptors using needles and preserved in 99% ethanol for molecular analysis. The rest of the haptors and the other specimens were flattened under...
coverslips and fixed in modified picrocarnoic glycerin (Nitta and Nagasawa 2018). All such specimens used for morphological analysis were dehydrated using a series of graded ethanol, cleared in xylene, and mounted in Canada balsam.

Drawings were made with the aid of a drawing tube fitted on an Olympus BX60 light microscope. Sclerotized parts were measured following the methods reported by Nitta and Nagasawa (2016). All measurements are in micrometers and given as the range followed by the mean and the number (n) of specimens examined in parentheses. The scientific names of fishes used in this paper follow Froese and Pauly (2019). Prevalence and intensity of infection are as defined by Bush et al. (1997). Voucher specimens of dactylogyrids were deposited in the Platyhelminthes collection of the National Museum of Nature and Science (NSMT-PI 6451, 6452), Tsukuba City, Ibaraki Prefecture, Japan.

DNA was extracted from bodies using a DNeasy Blood and Tissue Kit (Qiagen, Hilden, Germany). The DNA was amplified by polymerase chain reaction (PCR) using the primer pairs C1 primer (5′-ACC CGC TGA ATT TAA GCA T3′) and D2 primer (5-TGG TCC GTG TTT CAA GAC-3′) to amplify partial 28S rDNA (Mollaret et al. 1997). PCR was performed in a total volume of 20 µl, containing 0.1 µl Takara Ex Taq DNA polymerase (TaKaRa, Kusatsu, Japan), 2.0 µl PCR buffer (TaKaRa), 1.6 µl dNTP mixture (2.5 mM each of dATP, dCTP, dGTP, and dTTP) (TaKaRa), 0.6 µl of each 10 µM primer, 1.6 µl of extracted DNA, and 13.5 µl of distilled water. The cycling conditions included initial denaturation at 94°C for 5 min followed by 30 cycles at 94°C for 30 s, 54°C for 30 s, and 72°C for 45 s, and a final extension. Amplified PCR products were purified using the NucleoSpin Gel and PCR Clean-up kit (Macherey-Nagel, Düren, Germany). The DNA was sequenced using the PCR primers. Sequence data and electropherograms were inspected and edited manually using MEGA7 (Kumar et al. 2016), then the partial 28S rDNA (796 bp) sequence obtained was submitted to the DNA Data Bank of Japan Centre (DDBJ: accession number LC538183) and was compared with the available sequences for dactylogyrid species in GenBank using BLAST (http://www.ncbi.nlm.nih.gov/BLAST/) software on 11 April 2020.

Dactylogyrus petruschewskyi Gussev, 1955
[New Japanese Name: Dantōbō-yubigata-mushi] (Figs 1, 2)

Dactylogyrus petruschewskyi Gussev, 1955: 242–243, fig. 24–4; Bykhovskaya-Pavlovskaya et al. 1962: 334, fig. 663; Strelkov 1971: 72; Anonymous 1973: 132–134, figs 111–114; Chen 1981: 151; Long and Tao 1981: 546; Gussev 1985: 161, fig. 223; Wu et al. 1991: 18, 111–112, fig. 105; Li and Zhang, 1992: 90; Jin et al. 1993a: 326, 327, fig. 95; Jin et al. 1993c: 411; Gibson et al. 1996: 25; Wang et al. 1997: 91, 116, 117; Wu et al. 2000: 24; Long 2000: 196–197, fig. 145; Ding and Liao 2004: 629, 630, 631; Ding and Liao 2005: 246; Šimková et al. 2006: 44, 47; Gussev et al. 2010: 231, fig. 278; Singh and Chaudhary 2010: 123, 124, 125, 126; Wang et al. 2012: 45; Rajvanshi and Agrawal 2013: 580, 582; Tan 2013: 71, 133, 159, 160, 161, 192; Mendoza-Palmero et al. 2015: 4, 6; Nitta and Nagasawa 2016: 485, 486; Mendoza-Palmero et al. 2017: 154, 159; Nitta and Nagasawa 2017: 2; Šimková et al. 2017: 5, 7; Chiarle and Singh 2019: 143; Dahghif Roohi et al. 2020: 1056, 1057; Nitta and Nagasawa 2020: 64.

Description. Body elongate, total length of body including haptor 278–291 (285, n=2), maximum width 69–97 (83, n=2) in mid-body. Cephalic region with well-developed medial and bilateral cephalic lobes. Three pairs of head organs. Head gland cells on both sides of body at level of posterior pharynx. Two pairs of eye-spots. Pharynx subspherical, 20–24 (22, n=2) long, 21–26 (24, n=2) wide; esophagus short; intestinal ceca bifurcate with caeca confluent posterior to testis.

Haptor 57–61 (59, n=2) long, 67–88 (78, n=2) wide. A pair of dorsal hamulus, 35–45 (41, n=10) long; shaft slightly expanded before bent and tapering to point; length to notch 26–33 (31, n=9) long; outer root slightly tapering distally, 3–5 (4, n=9) long; inner root elongate trapezoid, 13–16 (15, n=9); point 12–15 (14, n=9) long. Dorsal bar broadly W-shaped, total length 24–30 (28, n=9), total width 7–9 (8, n=9), median width 4–5 (4, n=9). Ventral bar T-shaped, total length 20–22 (21, n=8), total width 11–14 (12, n=8); base of each side of the vertical deeply concave (n=6, Fig. 2: VB), or concavity becoming circular holes (n=2, Fig. 2: VBc). Marginal hooks in 7 pairs; hook length: pair I 23–27 (25, n=8); pair II 28–37 (32, n=8); pair III 30–41 (36, n=8); pair IV 28–35 (32, n=8); pair V 25–29 (27, n=8), pair VI 24–31 (28, n=8); pair VII 27–35 (32, n=8). Pair of needles 8–9 (8, n=7) long, located near the tip of fifth marginal hooks.

Gonads intercelal. Testis pyriform, posterodorsal to germarium, 32–45 (39, n=2) long, 22–23 (23, n=2) wide. Vas deferens arising from anterior margin of testis, extending from intercaecal portion, looping around left intestinal ceca onto ventral, extending seminal vesicle lying left to base of male copulatory organ, entering base of penis. Two prostatic reservoirs saccate, rounded, posterior to male copulatory organ. Male copulatory organ consisting of penis and accessory piece, 29–33 (31, n=7) long. Penis slightly curved tube, 25–29 (26, n=7) long; its base touching base of rod of accessory piece. Sclerotized accessory piece, 25–28 (26, n=7) long, consisting of half-cylindrical shaped plate with hook-like projection on distal tip, and rod connected to postero-dextral side of the plate; hook-like projection bending inward; plate supporting the tip of the penis dorsally; rod slightly bent (n=6), sometimes divided into two parts (n=1, Fig. 2: MCO1).

Germarium ovate in mid-body, 47–50 (49, n=2) long, 27–30 (29, n=2) wide. Oviduct arising from anterior margin of germarium, continuing to oötype. Melli’s gland connecting base of oötype. Vagina unsclerotized, opening on left lateral side, mid-length of body, leading to seminal receptacle. Seminal receptacle lying left of oviduct, connecting at junction of oviduct and oötype by short, narrow duct.
Dactylogyrus petruschewskyi from Japan

Vitellaria approximately co-extensive with intestinal ceca. Egg not collected.

**Materials examined.** 11 specimens (NSMT-Pl 6451, 6452)

**Locality.** Ono River flowing into Lake Kasumigaura (35°58′14.5″N, 140°21′11.4″E), Inashiki City, Ibaraki Prefecture.

**Host.** Megalobrama amblycephala Yih, 1955 (Cypriniformes: Cyprinidae: Cultrinae).

**Site on host.** Gill filaments.

**Prevalence and intensity.** 100% and 2 and 9 worms were collected from two fish.

**Representative DNA sequences.** The partial 28S rDNA (796 bp) sequences from the two specimens (NSMT-Pl 6452) were identical and submitted to the DDBJ (accession number LC538183).

**Etymology.** The new Japanese name, "dantōbō" refers to the host, *M. amblycephala*, in Japanese, and "yubigatamushi" means the genus *Dactylogyrus*.

**Remarks.** *Dactylogyrus petruschewskyi* was originally described after being taken from the gills of *Parabramis pekinensis* in Lake Hanka at Astrakhanka, Primorsky Krai, Far East Russia (Gussev 1955). The species was transferred to the genus *Neodactylogyrus* Price, 1938 by Yamaguti (1963), although this genus had been synonymized with *Dactylogyrus* Diesing, 1850 by Mizelle and Donahue (1944). As a native parasite, the monogenean was then reported with the same host species in Hubei, Zhejiang, Guangxi, and in Hunan, China (Anonymous 1973; Wu et al. 1991; Li and Zhang 1992; Jin et al. 1993c). It was also reportedly obtained from *Megalobrama terminalis* (Richardson, 1846) in Hubei, Zhejiang, and in Guangxi (Anonymous 1973; Wu et al. 1991; Li and Zhang 1992); from *M. amblycephala* in Hunan (Wang et al. 2012); from *Sinibrama wui* (Anonymous 1973) (Cyprinidae) as *S. wui polylepis* Yih and Wu, 1964 and *S. wui typus* Yih and Wu, 1964 in Guizhou (Long and Tao 1981); and from *Simbrana macrops* (Günther, 1868) in Zhejiang and Guangxi, China (Wu et al. 1991; Li and Zhang 1992). In addition, Gussev et al. (2010) regarded *M. terminalis*, listed as the parasite host by Gussev (1985), to be *Megalobrama mantschuricus* (Basilewsky, 1855) as *M. skolkovii* Dybowsky, 1872.

The measurements and morphology of sclerotized parts...
of the specimens collected in the present study were almost identical to descriptions of D. petruschewskyi by Gussev (1955, 1985), Anonymous (1973), Wu et al. (1991), Long (2000), and Gussev et al. (2010). There are two types of accessory piece rod: the normal type consisting of a single rod (Gussev 1955, 1985; Gussev et al. 2010) and the two-rod type (Anonymous 1973). Both types were found in this study (Fig. 2); thus, these forms are judged to demonstrate intraspecific variation.

As found through a BLAST search, the newly obtained partial 28S rDNA sequence (LC538183) was identical to D. petruschewskyi (AY548927). Although this accession sequence has been used for molecular phylogenetic studies on dactylogyrids (Ding and Liao 2004, 2005; Šimková et al. 2006, 2017; Singh and Chaudhary 2010; Rajvanshi and Agrawal 2013; Tan 2013; Mendoza-Palmero et al. 2015, 2017; Nitta and Nagasawa 2016, 2017, 2020; Chiary and Singh 2019; Daghigh Roohi et al. 2020), the sequence data were not based on a published record of specimens morphologically identified. The present results support the correctness of the identification.

This dactylogyrid has been recorded in Megalobrama amblycephala from Datong Lake, Yangtze River basin, China, (Wang et al. 2012) but the specimens have not been described morphologically nor obtained molecular information. According to morphological and molecular information, we identified the dactylogyrid taken from M. amblycephala as D. petruschewskyi for the first time in Japan. Other than D. petruschewskyi, only D. strelkowi Gussev, 1955 has been recorded from M. amblycephala (Jin et al. 1993b) and resembles D. petruschewskyi in the T-shaped ventral bar and the shape of the dorsal hamulus (Gussev 1955; Long 2000; Gussev et al. 2010). However, D. petruschewskyi differs from D. strelkowi which has the longer and thicker penis (Gussev 1955; Long 2000; Gussev et al. 2010).

The internal structure of D. petruschewskyi has not been described. The results of our redescription show a common morphological feature between this species and D. bicorniculus Nitta and Nagasawa, 2016, which is the only closely related species whose internal morphology has been described (Nitta and Nagasawa 2016): both the prostatic reservoirs are round and small; the vagina is not sclerotized and leads parallel to the seminal receptacle; the vas deferens and the seminal vesicle do not extend above the male copulatory organ; and the testis is pyriform and located posteroventral to the germarium. Even in recent years, the internal morphology of D. petruschewskyi has been important for future taxonomic organization of this genus, which consists of over 1,000 species (Gibson et al. 1996; WoRMS 2020).

All recorded hosts of D. petruschewskyi are not native to Japan (Hosoya 2015; Froese and Pauly 2019), and the dactylogyrid has not been collected in any native fish examined from the Tone River system to date (Nitta and Ishikawa, unpublished data); therefore, this species was determined to be an alien parasite that was introduced with M. amblycephala from China.

Dactylogyrus strelkowi has also been obtained from M. amblycephala (Jin et al. 1993b). Although we examined only two fish specimens in the present study, no invasion of D. strelkowi was found. In Datong Lake, the native habitat of M. amblycephala, D. strelkowi prevalence on this cyprinid was low, at 33% (Jin et al. 1993b), and it has not been rediscovered in the survey by Wang et al. (2012). In contrast, all M. amblycephala examined in the area were infected by D. petruschewskyi (Wang et al. 2012). Based on this difference in parasitism, we conclude that only D. petruschewskyi may have been co-introduced into Japan.

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