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The alien monogenean *Ligictaluridus pricei* (Mueller, 1936), parasitic on the gills of the channel catfish *Ictalurus punctatus* (Rafinesque, 1818), is described from Lake Kasumigaura, Ibaraki Prefecture, central Honshū, Japan, as a new country record. This monogenean is native to North America and is known as an introduced parasite in Eurasia. As it is not strictly host-specific to ictalurids, native freshwater fishes in Japan have a risk of infection by this monogenean species.

**Key Words:** *Ligictaluridus pricei*, Monogenea, *Ictalurus punctatus*, alien species, new country record, Japan.

**Introduction**

Since 1971, the channel catfish *Ictalurus punctatus* (Rafinesque, 1818) (Siluriformes: Ictaluridae) has been transplanted to Japan from the U.S.A. multiple times for aquaculture (Maruyama et al. 1987). In 1982, channel cat fish escaped from typhoon-damaged culture cages set in the Edo River of the Tone River system, central Honshū, and have since become established in this river system and its connecting lake, Lake Kasumigaura (Ashihara 1984; Hirata and Nagano 2000; Hanzawa 2004). Recently, the channel cat fish population has increased dramatically in this lake (Hanzawa 2004; Matsuzaki et al. 2011; Arayama and Iwasaki 2012). This species also has been introduced from North America to many other countries and regions of Europe and Asia for aquaculture and recreational fishing (Welcomme 1981, 1988). This paper reports on the ancyrocephalid monogenean *Ligictaluridus pricei* (Mueller, 1936) from the gills of *I. punctatus* in Lake Kasumigaura, Japan, as a new country record.

**Materials and Methods**

One channel catfish (standard length: 358 mm) was collected by angling in Lake Kasumigaura (36°04′05″N, 140°15′23″E) at Okijuku, Tsuchiura city, Ibaraki Prefecture, Japan, on 13 June 2014. The fish was killed by icing in the field and examined for parasites under a dissecting microscope. Monogeneans were picked up from the gills using small needles and flattened on glass slides under cover slips, whereupon some were fixed between the slide and cover glass in ammonium picrate glycerin (Lim 1991), while others were fixed in 70% ethanol. The latter specimens were stained in Heidenhain’s iron hematoxylin, and both sets of specimens were dehydrated through a graded ethanol series, cleared in xylene, and mounted permanently in Canada balsam. Drawings were made with the aid of a drawing tube fitted on an Olympus BX51 light microscope. The basic method of measuring sclerotized structures (Fig. 1) and the morphological terminology employed herein follow Klassen and Beverley-Burton (1985a, b) and Beverley-Burton (1984), respectively. All measurements were obtained from images taken by an Olympus DP20 digital camera using ImageJ software (version 1.48i). Measurements, in micrometers, are expressed as the mean ± standard deviation followed in parentheses by the range and the number (n) of specimens examined. The numbering of marginal hook pairs follows Llewellyn (1963). Fish identification was based on Hosoya (2013), and the scientific and common names of fishes used in this paper follow Froese and Pauly (2014). Specimens are deposited in the Platyhelminthes collection of the National Museum of Nature and Science, Tsukuba city, Ibaraki Prefecture, Japan (NSMT-Pl).

*Ligictaluridus pricei* (Mueller, 1936) (Fig. 2)


Material examined. In total, 28 specimens (NSMT-Pl 6166) were used for the description. Soft anatomy was observed in seven specimens stained in Heidenhain’s iron hematoxylin, and sclerotized structures were measured in 21 specimens fixed in ammonium picrate glycerin.

Description. Body (Fig. 2A) elongate, length 695±91.9 (554–833; n=13) including haptor, width at mid-body 127±13.5 (105–155; n=13). Cephalic glands opening on anterolateral sides of head. Two pairs of eyes. Pharynx round, diameter 34±4.9 (26–45; n=13); esophagus present; part of intestinal caeca extending to end of body and rejoining there to form elongate loop. Testis pyriform, postero-dorsal to ovary. Vas deferens arising from anterior margin of testis, looping dorsoventrally around left intestinal caecum. Seminal vesicle located posterior to two saccate prostatic reservoirs. Penis (Fig. 2M, N) a slender, curved tube, length 35±2.9 (29–41; n=21), diameter 2±0.3 (2–3; n=21), diameter to length ratio 1:13–19. Accessory piece (Fig. 2M, N) 33±2.3 (29–38; n=21) in length, touching base of penis (i.e., concave portion near base of accessory piece fitting base of penis) and extending to tip of penis, twisted one time near tip and also at midlength, usually straight in overall shape (Fig. 2M), but in a few specimens bent in middle (Fig. 2N). Ovary in mid-body, ovoid. Oviduct arising from anterior side of ovary, continuing as oötype and uterus. Mehlis’ gland connecting lowest part of oötype. Vagina exiting from left side of oviduct, running between vas deferens and left intestinal caecum to vaginal opening on left side of ventral body surface. Vitellaria approximately co-extensive with intestinal caecum.

Haptor length 79±13.0 (60–100; n=13), width 107±12.7 (89–129; n=13). Each hamulus lacking deep root. Dorsal hamuli (Fig. 2B) smaller than ventral hamuli, total length 45±3.0 (40–49; n=21), length to notch 43±2.2 (39–48; n=21), superficial root length 13±1.5 (10–16; n=21), blade length 18±1.1 (15–20; n=21). Ventral hamuli (Fig. 2C) with total length 51±2.4 (46–55; n=21), length to notch 47±1.9 (44–50; n=21), superficial root length 15±1.6 (12–18; n=21), blade length 18±1.6 (15–21; n=21). Dorsal bar (Fig. 2D) with lamella-like flange at midsection, length 49±3.0 (42–54; n=21), median width 10±1.7 (7–13; n=21). Ventral bar (Fig. 2E) V-shaped, length 45±2.4 (41–50; n=21), median width 7±1.2 (6–11; n=21). Marginal hooks of larval type, 7 pairs; hook pair I, hook pair II,
Fig. 2. *Ligictaluridus pricei* (Mueller, 1936). NSMT-Pl 6166. A, Whole mount (ventral view); B, dorsal hamuli; C, ventral hamuli; D, dorsal bar; E, ventral bar; F, marginal hook of pair I; G, marginal hook of pair II; H, marginal hook of pair III; I, marginal hook of pair IV; J, marginal hook of pair V; K, marginal hook of pair VI; L, marginal hook of pair VII; M and N, penes and accessory pieces from two specimens. Scale bars: A, 50 µm; B–N, 10 µm. Abbreviations: ap, accessory piece; cgo, opening of cephalic gland; e, eye; i, marginal hook of pair I; ii, marginal hook of pair II; iii, marginal hook of pair III; iv, intestinal caeca; iv, marginal hook of pair IV; mg, Mehlis’ gland; o, ootype; od, oviduct; ov, ovary; p, penis; ph, pharynx; pr, prostatic reservoir; sv, seminal vesicle; t, testis; u, uterus; v, marginal hook of pair V; vi, marginal hook of pair VI; vii, marginal hook of pair VII; vl, vitellaria; va, vagina; vp, vaginal pore; vd, vas deferens.
and hook pairs III–VII located at center, tip, and each side of haptor, respectively (Fig. 2A); in length, pair I (Fig. 2E) 14±0.8 (13–16; n=16); pair II (Fig. 2F) 12±0.8 (11–13; n=16), smallest; pair III (Fig. 2G) 15±0.8 (14–17; n=16); pair IV (Fig. 2H) 15±0.7 (14–16; n=16); pair V (Fig. 2I) 15±0.6 (14–16; n=16); pair VI (Fig. 2J) 15±0.4 (14–16; n=16); pair VII (Fig. 2K) 15±0.4 (15–16; n=16).

Host. Channel catfish Ictalurus punctatus (Siluriformes: Ictaluridae).

Locality. Lake Kasumigaura, Tsuchiura city, Ibaraki Prefecture, Japan.

Site of infection. Gills.

Remarks. This monogenean was originally described by Mueller (1936) as Cleidodiscus pricei from Ictalurus punctatus, Ameiurus nebulosus (Lesueur, 1819) (as I. micrurus nebulosus), and A. natalis (Lesueur, 1819) (as I. natalis) (Siluriformes: Ictaluridae) in Florida, U.S.A. It was transferred to the genus Ligictaluridus by Beverley-Burton (1984). The specimens examined in this study approximately conform to the descriptions of L. pricei by Mueller (1936), Mizelle and Cronin (1943), Mizelle and Regensberger (1945), Prost (1973), Kiskaroly (1977), Žitňan (1965), Gussev (1985), Klassen and Beverley-Burton (1985a, b), Truong (2011), and Wang et al. (2013). The sclerotized structures of L. pricei are known to show marked variation in morphology and measurements (Seamster 1938b, Mizelle and Donahue 1944, Mizelle and Regensberger 1945), but Mizelle and Donahue (1944) suggested that such variation is caused by differences in fixation method. On the other hand, the length of the accessory piece reported by Hargis (1953) is quite short: 10–18 µm. He presented no drawings of the accessory piece, but since it is sometimes bent (cf. Prost 1973: fig. 2f, this study: fig. 2N), Hargis (1953) probably measured a bent one. Until now, the vagina has not been described clearly, because it is obscured by well-developed vitellaria (Klassen and Beverley-Burton 1985a). Based on the specimens stained in Heidenhain’s iron hematoxylin, the present study has revealed that it runs between the vas deferens and the left intestinal caecum (Fig. 2A).

At present, the genus Ligictaluridus consists of six valid species (Klassen and Beverley-Burton 1985a, b): L. bychowskyi (Price and Mura, 1969), L. floridanus (Mueller, 1936), L. mirabilis (Mueller, 1937), L. monticellii (Cognetti de Martiis, 1924), L. posthon Klassen, Beverley-Burton and Dechtiar, 1985, and L. pricei. Ligictaluridus pricei is readily separated from L. monticellii by the presence of a deep root (Klassen and Beverley-Burton 1985a) on each hamulus. The distal limb of the accessory piece has a single terminal projection in L. pricei, while those of L. floridanus and L. mirabilis have two and four terminal projections, respectively (Mueller 1936, 1937; Klassen and Beverley-Burton 1985a). Unlike L. pricei, L. bychowskyi has a tapered penis (Price and Mura 1969; Klassen and Beverley-Burton 1985a). Ligictaluridus pricei and L. posthon are separated from each other by the diameter to length ratio of the penis: 1:18 (Klassen and Beverley-Burton 1985b) or 1:13–19 (this study) for L. pricei versus 1:6 (Klassen and Beverley-Burton 1985b) for L. posthon.

Roman-Chiriac (1960) reported a monogenean as Ancyrocephalus pricei (Mueller, 1934) Mizelle and Cronin, 1943, an attribution later repeated by Adamczyk (1973). However, Mueller (1934a, b) did not describe the species, nor did Mizelle and Cronin (1943) transfer it to Ancyrocephalus. Rather, Mueller (1936) described it, and it has recently been placed in Ligictaluridus (Beverley-Burton 1984). Specimens reported by Dechtiar (1972a) as Cleidodiscus pricei from stonecat Noturus flavus Rafinesque, 1818 (Siluriformes: Ictaluridae) were regarded as Ligictaluridus posthon by Klassen and Beverley-Burton (1985b).

Discussion

While L. pricei is native to North America, it has been co-introduced with fishes of the family Ictaluridae into the Eurasian continent and the West Indies (Table 1). Similarly in Lake Kasumigaura, this monogenean has most likely become established along with channel catfish from the U.S.A. Recently, the fish has spread to and become established in

Table 1. Records of Ligictaluridus pricei (Mueller, 1936) as alien species from ictalurids in Europe, Asia, and the West Indies.

<table>
<thead>
<tr>
<th>Country</th>
<th>Hosts</th>
<th>References</th>
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<tbody>
<tr>
<td>Europe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
<td>Ameiurus nebulosus (as Ictalurus nebulosus)</td>
<td>Kiskaroly (1977)</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>A. nebulosus (as I. nebulosus)</td>
<td>Šmikoňová et al. (2003)</td>
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<td>France</td>
<td>A. melas (as I. melas)</td>
<td>Lambert (1977)</td>
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<tr>
<td>Hungary</td>
<td>A. nebulosus</td>
<td>Molnár (1968)</td>
</tr>
<tr>
<td>Poland</td>
<td>A. nebulosus (as I. nebulosus)</td>
<td>Prost (1973), Adamczyk (1973)</td>
</tr>
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<td>Romania</td>
<td>A. nebulosus</td>
<td>Roman-Chiriac (1960)</td>
</tr>
<tr>
<td>Slovakia</td>
<td>A. nebulosus</td>
<td>Žitňan (1965)</td>
</tr>
<tr>
<td>Asia</td>
<td></td>
<td></td>
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<tr>
<td>China</td>
<td>I. punctatus</td>
<td>Wang et al. (2013)</td>
</tr>
<tr>
<td>Japan</td>
<td>I. punctatus</td>
<td>This study</td>
</tr>
<tr>
<td>Russia</td>
<td>A. nebulosus (as I. nebulosus), I. punctatus</td>
<td>Musselius et al. (1976), Gussev (1985), Mirzoyeva (1988)</td>
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<tr>
<td>West Indies</td>
<td></td>
<td></td>
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<tr>
<td>Puerto Rico</td>
<td>A. catus, A. nebulosus, I. punctatus</td>
<td>Bunkley-Williams and Williams (1994)</td>
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other waters of Japan (Katano et al. 2010), and the monogenean has likely accompanied it. Originally, *L. pricei* was widely and continuously distributed in temperate and subarctic areas of North America (Table 2), ranging from 25°14′N (Nazar River, Mexico: Pérez-Ponce de León et al. 2010) to 49°07′N (Lake of the Woods, Canada: Dechtiar 1972b). These climates and latitudes overlap with those of the Japanese Archipelago, which implies that *L. pricei* has the capacity to become established throughout Japan. More study is necessary in order to determine the geographical distribution of this monogenean in Japan.

To date, *L. pricei* has been recorded from 11 species and four genera of Perciformes: the green sunfish *Lepomis cyanellus* Rafinesque, 1819; the warmouth *L. gulosus* (Cuvier, 1829) (Centrarchidae); and the striped bass *Morone saxatilis* (Walbaum, 1792) (Moronidae) (Allison and Rogers 1970; Hensley and Nahhas 1975). According to Allison and Rogers (1970), the green sunfish collected in a pond in which cultured channel catfish were densely stocked and became heavily infected by *L. pricei*. These authors regarded this infection as “undoubtedly a case of accidental parasitism,” because the monogenean disappeared from the green sunfish after the catfish were killed. In light of this observation, it is possible that *L. pricei* also infects native fishes in Lake Kasumigaura, where the catfish is very abundant in Lake Kasumigaura (Arayama and Iwasaki 2012). The monogenean fauna of Lake Kasumigaura is almost completely unknown: only two species *Eudiplozoon nipponicum* (Goto, 1891) (as *Diplozoon nipponicum*) (Diplozoidae) and *Bivaginogyrus obscurus* (Gussev, 1955) (Dactylogyridae), has been described from *Cyprinus carpio* Linnaeus, 1758 and *Pseudorasbora parva* (Temminck and

### Table 2. Records of Ligictaluridus pricei (Mueller, 1936) from North America.

<table>
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<tr>
<th>Locality</th>
<th>Hosts</th>
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<td>USA</td>
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<tr>
<td>Arkansas</td>
<td><em>Noturus exilis</em> Nelson, 1876 (Siluriformes: Ictaluridae)</td>
<td>Klassen and Beverley-Burton (1985a)</td>
</tr>
<tr>
<td>California</td>
<td><em>A. catus</em> (as <em>I. catus</em>), <em>A. melas</em> (as <em>I. melas</em>), <em>A. nebulosus</em> (as <em>I. nebulosus</em>), <em>I. melas</em> (as <em>I. melas</em>), <em>I. punctatus</em>, <em>L. gulosus</em> (as <em>Chaenobryttus gulosus</em>), <em>Morone saxatilis</em> (Perciformes: Moronidae)</td>
<td>Mizelle et al. (1961), Miller et al. (1973), Hensley and Nahhas (1975)</td>
</tr>
<tr>
<td>Florida</td>
<td><em>A. natalis</em> (as <em>Ictalurus natalis</em>), <em>A. nebulosus</em> (as <em>I. nebulosus</em>), <em>I. punctatus</em></td>
<td>Mueller (1936)</td>
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<tr>
<td>Georgia</td>
<td><em>I. punctatus</em></td>
<td>Lawson and Fox (1974)</td>
</tr>
<tr>
<td>Kansas</td>
<td><em>A. melas</em> (as <em>I. melas</em>), <em>I. punctatus</em></td>
<td>Cloutman (1974)</td>
</tr>
<tr>
<td>Louisiana</td>
<td><em>A. melas</em> (as <em>I. melas</em>), <em>I. punctatus</em></td>
<td>Summers and Bennett (1938), Seamster (1948), Duobininsky-Gray and Corkum (1985)</td>
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<td>New York</td>
<td><em>A. nebulosus</em></td>
<td>Mueller (1937)</td>
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<td>North Carolina</td>
<td><em>A. platycephalus</em> (as <em>I. platycephalus</em>)</td>
<td>Cloutman (1978)</td>
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<td>North Dakota</td>
<td><em>A. melas</em> (as <em>I. melas</em>)</td>
<td>Sutherland and Holloway (1979)</td>
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<td>Ohio</td>
<td><em>A. nebulosus</em>, <em>A. melas</em></td>
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<td>Oklahoma</td>
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<td>Torres and Price (1971)</td>
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<td>Tennessee</td>
<td><em>A. natalis</em>, <em>A. melas</em>, <em>I. furcatus</em>, <em>I. punctatus</em> (as <em>I. lacustris</em> punctatus)</td>
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<td>Texas</td>
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<td>Mizelle and Regensberger (1945), Mizelle and Klucka (1953), Mizelle and Webb (1953)</td>
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<td>Lake Erie</td>
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<td>Baker and Crites (1976)</td>
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<td><em>A. nebulosus</em> (as <em>I. nebulosus</em>), <em>N. gyroclus</em> (Mitchell, 1817)</td>
<td>Dechtiar (1972b), Hanek and Fernando (1972a, b), Molnar et al. (1974), Klassen and Beverley-Burton (1985a)</td>
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<td>Great Lakes</td>
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