Rediscovery of a Fish Acanthocephalan, Acanthocephalus minor (Echinorhynchida: Echinorhynchidae), in the Lake Biwa Basin, Central Japan, with a Review of the Fish Acanthocephalan Fauna of the Basin

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Specimens of the echinorhynchid acanthocephalan Acanthocephalus minor Yamaguti, 1935 were collected from the rectum of a dark sleeper, Odontobutis obscura (Temminck and Schlegel, 1845), in an irrigation canal near Lake Biwa, Shiga Prefecture, west-central Japan. This represents a rediscovery of A. minor in the Lake Biwa basin after a gap of nearly 80 years. It appears not to be distributed in Lake Biwa proper, but to occur rarely in rivers and irrigation canals of a limited coastal area around the lake. To date, 10 nominal species of acanthocephalan in four families and three orders have been reported from fish in the Lake Biwa basin. Among these, striking morphological similarities between Acanthocephalus aculeatus Van Cleave, 1931 and its congener A. opsariichthydis Yamaguti, 1935 are noted. It is furthermore suggested that A. gotoi Van Cleave, 1925 could not maintain its population after the basin’s wild population of its major host, Anguilla japonica Temminck and Schlegel, 1846, disappeared in the mid-1960s.

Key Words: Acanthocephalus minor, Acanthocephala, Odontobutis obscura, fish parasite, faunistic review, Lake Biwa basin, Japan.

Introduction

Lake Biwa is located in west-central Honshu, being the largest (670 km²) and oldest (over four million years old) lake in Japan (Horie 1984). The fauna of this lake and its watershed has been intensively studied and includes many endemic species (Timoshkin et al. 2011; Kawanabe et al. 2012). The acanthocephalan fauna of fish in the Lake Biwa basin is also well studied: to date, 10 nominal species in four families and three orders have been reported (Table 1). Among these species, the extent of occurrence of Acanthocephalus minor Yamaguti, 1935 in Lake Biwa and the lake’s drainage basin remains poorly understood. This species has not been reported since 1936, when it was collected from the dark sleeper Odontobutis obscura (Temminck and Schlegel, 1845) caught in Lake Biwa (Fukui and Morisita 1936). Amin (2005) and Amin et al. (2007) examined the acanthocephalans isolated from more than 500 inspected fish belonging to 30 species in 12 families collected in Lake Biwa and its tributaries between 1997 and 2002 as part of a large-scale survey involving 62 fish species in total from the region, but did not recover A. minor from them; moreover, they did not mention A. minor in their discussion of the fish acanthocephalan fauna of the Lake Biwa basin.

Recently, we found 10 individuals of A. minor infecting the rectum of a specimen of O. obscura collected in an irrigation canal near the Ado River, one of the rivers flowing into Lake Biwa. Here we report on this find which represents a rediscovery of the species in the Lake Biwa basin after a gap of nearly 80 years. We also take this opportunity to review the fish acanthocephalan fauna of the Lake Biwa basin based on the literature published between 1918 and 2014.

Materials and Methods

One specimen of O. obscura was collected using a hand net on 14 July 2014 in an irrigation canal (35°19′54″N, 136°2′44″E) along the lower reaches of the Ado River at Adogawacho-Kawashima, Takashima city, Shiga Prefecture, Honshu, west-central Japan. The fish was transported alive to the laboratory at Hiroshima University, Higashi-Hiroshima city, Hiroshima Prefecture, where it was measured for standard length (SL) in millimeters and examined for metazoan parasites. Of the 10 acanthocephalans found, eight individuals were flattened between slides and cover glasses with slight pressure, fixed in 70% ethanol, stained in Heidenhain’s iron hematoxylin, dehydrated through a graded ethanol series, cleared in xylene, and mounted in Canada balsam, while the remaining two individuals were preserved in 100% ethanol for future molecular study. The stained specimens were used for measurements and counts.
Table 1. Acanthocephalans reported from fish in the Lake Biwa basin, Shiga Prefecture, Japan.

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>Genus and species</th>
<th>Fish species (family)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gyracanthocephala</td>
<td>Quadrigrigarida</td>
<td>Acanthosentis (Acanthosentis alternatspinus) Amin, 2005</td>
<td>Rhodius ocellatus ocellatus (Cyprinidae)</td>
<td>Amin (2005), Amin et al. (2007), Nagasawa and Grygier (2011, as Neoechinorhynchus sp)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acanthosentis (Acanthosentis) parareoparalis Amin, 2005</td>
<td>Cobitis biwa (Cobitidae)</td>
<td>Amin (2005), Amin et al. (2007)</td>
</tr>
<tr>
<td>Echinorhynidae</td>
<td></td>
<td>Acanthocephalus aculeatus Van Cleave, 1934</td>
<td>Plecoglossus altivelis altivelis (Plecoglossidae)</td>
<td>Katoaka and Momma (1933, 1934)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acanthocephalus gotoi Van Cleave, 1925</td>
<td>Gymnogobius urotaenia (as Chienogobius annulatus urotaenia) (Gobiidae)</td>
<td>Yamaguti (1959)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acanthocephalus minor Yamaguti, 1935</td>
<td>Cobitis biwa (Cobitidae); Gobias lanceolatus elongatus, Hemibarbus barbus, Hemibarbus labros, Hemibarbus longirostris, Opsariichthys platypus (as Zacco platypus), Pseudorasbora parva, Pungtungia microoculus (as Rhyynchocypris a. jouyi), Pseudogobio esocinus esocinus, Pseudorasbora parva, Pangasianodon herzi (Cyprinidae); Gasterosteus aculeatus subsp. 2 (as G. microcephalus) (Gasterosteidae); Oncorhyncus masou idukawa, Oncorhyncus mykiss (as Salmo gairdneri irideus), Oncorhyncus sp. (Salmonidae); Silurus asotus (as Pseudobranchtus asotus) (Siluridae)</td>
<td>Fukui and Morista (1936), this study</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acanthocephalus oparichthydis Yamaguti, 1935</td>
<td>Anguilla japonica (Anguilidae); Tachynurus nudiceps (as Pelteobagrus nudiceps) (Bagridae); Channa argus (Channidae); Cottus pollux (Cottidae); Cyprinus carpio, Gobius gurnardus, Hemibarbus barbus, Opsariichthys uncirostris uncirostris, Sarcocheilichthys variegatus microoculus (Cyprinidae); Gymnogobius izasa, Rhinogobius sp., Triodontiger brevipinnis (Gobiidae); Hypomesus nipponiensis (as H. transpacificus nipponiensis) (Osmeridae); Plecoglossus altivelis altivelis (as P. altivelis) (Plecoglossidae); Pseudogobio esocinus (as P. esocinus) (Siluridae)</td>
<td>Katoaka and Momma (1933, 1934), Yamaguti (1935), Ito (1959, as Acanthocephalus [sic] sp.), Nakajima et al. (1975), Nakajima and Egusa (1975a), Amin et al. (2007)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Echinorhynchus cotti Yamaguti, 1935</td>
<td>Anguilla japonica (Anguilidae); Tachynurus nudiceps (as Pelteobagrus nudiceps) (Bagridae); Channa argus (Channidae); Gobius gurnardus, Hemibarbus barbus, Opsariichthys uncirostris uncirostris, Sarcocheilichthys variegatus microoculus (Cyprinidae); Gymnogobius izasa, Rhinogobius sp., Triodontiger brevipinnis (Gobiidae); Hypomesus nipponiensis (as H. transpacificus nipponiensis) (Osmeridae); Plecoglossus altivelis altivelis (as P. altivelis) (Plecoglossidae); Pseudogobio esocinus (as P. esocinus) (Siluridae)</td>
<td>Katoaka and Momma (1933, 1934), Echinorhynchus sp., Yamaguti (1935, 1939), Fukui and Morista (1937), Shimazu (1999), Amin et al. (2007)</td>
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<td></td>
<td></td>
<td>Edinorhynchus parasulphur Fukui, 1929</td>
<td>Silurus asotus (as Parasilurus asotus) (Siluridae)</td>
<td>Fukui (1929)</td>
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<td></td>
<td></td>
<td>Edinorhynchus sp.</td>
<td>Silurus asotus (as Parasilurus asotus) (Siluridae)</td>
<td>Kawanura (1918)</td>
</tr>
<tr>
<td></td>
<td>Illosentidae</td>
<td>Pseudorhadinorhynchus samegaiensis Nakajima and Egusa, 1975</td>
<td>Anguilla japonica (Anguilidae); Cyprinus carpio (Cyprinidae)</td>
<td>Nakajima et al. (1975), Nakajima and Egusa (1975b), Grygier (2004), Amin et al. (2007), Nagasawa and Grygier (2011)</td>
</tr>
<tr>
<td></td>
<td>Polymorphida</td>
<td>Southwellina hispida (Van Cleave, 1925)</td>
<td>Micropterus salmoides (Centrarchidae); Leuca chrysiptera (Cobitidae); Cottus reini (Cottidae); Coreoperca kawamebari (Sinipercaidae)</td>
<td>Amin et al. (2007), Nagasawa and Grygier (2011)</td>
</tr>
<tr>
<td></td>
<td>Rhinogobius</td>
<td>Southwellina hispida (Van Cleave, 1925)</td>
<td>Micropterus salmoides (Centrarchidae); Leuca chrysiptera (Cobitidae); Cottus reini (Cottidae); Coreoperca kawamebari (Sinipercaidae)</td>
<td>Amin et al. (2007), Nagasawa and Grygier (2011)</td>
</tr>
</tbody>
</table>

*The manuscript of Nagasawa and Grygier’s report, including information on Neoechinorhynchus sp., was first prepared in 1998 but was not published until 2011. This acanthocephalan was described as Acanthosentis (Acanthosentis) alternatspinus by Amin (2005). Acanthocephalus aculeatus had been synonymized with Acanthocephalus echinocephalus by Harada (1935), but Petrochenko (1956) and Yamaguti (1963) listed the former species as valid. Yamaguti (1935) described Acanthocephalus oparichthydis using specimens from seven species of fish (P. curta, C. carpio, H. barbus, O. uncirostris uncirostris, G. izasa, and P. esocinus) caught in three localities, Lake Biwa (Shiga Prefecture), Lake Oguni (Kyoto Prefecture), and the Yodo River (Osaka Prefecture), all of which belong to the same river system, but he did not differentiate these localities from each other in his description of the species. However, according to Amin et al. (2007), only P. parva was collected in Lake Biwa. Thus, this fish is cited here from Yamaguti (1935). Golvan (1969) described a new species, Echinorhynchus oblitus, by citing Katoaka and Momma (1937), but Nagasawa et al. (2007) relegated E. oblitus to a junior synonym of E. cotti. The paper of Katoaka and Momma (1937) was part of a set of collected papers, and the original work was Katoaka and Momma (1934), in which Echinorhynchus sp. was described. The fish reported as Cottus pollux by Yamaguti (1939) from Lake Biwa was actually C. reini (Amin et al. 2007). Because three species and subspecies of Sarcocheilichthys (S. biwaensis, S. variegatus variegatus, and S. variegatus microoculus) occur in Lake Biwa and its watershed (Hosoya 2013), the fish reported by Fujita (1927) as S. variegatus cannot be exactly identified.
All measurements in the text are given in millimeters as the range followed by the mean in parentheses, unless otherwise stated. Drawings were made with the aid of a drawing tube fitted on an Olympus BX 51 compound microscope. The mounted specimens are deposited in the Aschelminthes (As) collection of the National Museum of Nature and Science (NSMT–As 4293), Tsukuba city, Ibaraki Prefecture, Japan. The scientific names of fish, amphipods, and isopods used in this paper follow those recommended by Nakabo (2013), Tomikawa and Morino (2012), and Matsumoto (1973), respectively.

*Acanthocephalus minor* Yamaguti, 1935

(Fig. 1)


**Description.** *General.* Trunk subcylindrical, unarmed, slightly tapering posteriorly. Body wall thick. Proboscis cylindrical, armed with 12–14 (usually 13) longitudinal rows of 5–7 (usually 5 or 6) hooks in both sexes. Second or third hook from distal end largest and basal hook smallest in each row. Hook blade longer than root. Neck short. Proboscis receptacle double-walled, with cerebral ganglion near its posterior end. Lemnisci saccular or elongate, longer than proboscis receptacle. Genital pore terminal.

**Male** (based on four specimens). Trunk 2.45–3.03 (2.72) long, 0.79–0.91 (0.84) wide. Proboscis 0.35–0.45 (0.39) long, 0.21–0.23 (0.21) wide. Blade of largest (i.e. second or third) hook in each row 65–74 (70) μm long; blade of smallest (i.e. basal) hook in each row 38–51 (47) μm long. Neck 0.15–0.21 (0.18) long (n = 2), 0.37–0.41 (0.39) wide at junction with trunk (n = 2). Proboscis receptacle 0.34–0.40 (0.38) long, 0.19–0.23 (0.21) wide. Lemnisci 0.26–0.48 (0.36) long, 0.6–0.18 (0.11) wide. Testes oval, slightly oblique. Anterior testis 0.34–0.35 (0.34) long, 0.22–0.28 (0.25) wide; posterior testis 0.30–0.34 (0.33) long, 0.20–0.27 (0.22) wide. Cement glands pyriform, close together, 0.10–0.18 (0.12) wide in diameter, immediately behind posterior testis. Saefftigen’s pouch bulb-shaped, 0.35–0.43 (0.39) long, 0.20 (0.20) wide (n = 2).

**Female** (based on four specimens). Trunk 2.05–3.35 (2.62) long, 0.88–1.18 (1.03) wide. Proboscis 0.40–0.50 (0.47) long, 0.19–0.29 (0.24) wide. Blade of largest (i.e. second or third) hook in each row 85–92 (87) μm long; blade...
of smallest (i.e. basal) hook in each row 43–75 (60) µm long. Neck 0.17–0.23 (0.19) long, 0.38–0.53 (0.44) wide at junction with trunk. Proboscis receptacle 0.30–0.54 (0.42) long, 0.19–0.26 (0.24) wide. Lemnisci 0.23–0.48 (0.36) long, 0.8–0.15 (0.10) wide. Reproductive system 0.50–0.73 (0.61) long, 21.6–25.5% (23.6%) of trunk length. Mature eggs with polar prolongations of middle shell 96–104 (99) µm long, 17–20 (18) µm wide when measured through body wall.

**Host.** Dark sleeper *Odontobutis obscura* (Perciformes: Odontobutidae).

**Locality.** Irrigation canal near Ado River at Adogawa-cho–Kawashima, Takashima city, Shiga Prefecture, Honshu, Japan.

**Site of infection.** Rectum.

**Occurrence in fish.** Ten individuals of *A. minor* were found in one specimen of *O. obscura* (64.3 mm SL). The eight stained specimens comprised four individuals of each sex.

**Remarks.** The morphology of the specimens collected in this study almost fully corresponds to the original description of *A. minor* by Yamaguti (1935) and the subsequent brief descriptions of the species by Fukui and Morisita (1936), Yamaguti (1939), and Awakura (1972), except that the number (5–7) of hooks per longitudinal row is fewer than in previous reports (7–9: Yamaguti 1935; 6–7: Fukui and Morisita 1936; 6–8: Yamaguti 1939; 7–9: Awakura 1972).

*Acanthocephalus minor* was originally described based on specimens from Amur catfish *Silurus asotus* Linnaeus, 1758 (as *Parasilurus asotus*) in Toyama Prefecture, central Honshu, Japan (Yamaguti 1935). Subsequently, this acanthocephalan has been recorded from various freshwater fish in central Honshu and Hokkaido, Japan (Fukui and Morisita 1936; Yamaguti 1939; Awakura 1972; Nagasawa et al. 1982). There is no record of this species from other countries. Petrochenko (1956: 293) doubted the generic assignment of the species, but subsequent authors (e.g., Yamaguti 1963; Golvan 1969, 1994; Amin 1985, 2013) have continued to place it in *Acanthocephalus* Koelreuther, 1771. Awakura (1973) used *Acanthocephalus echigoensis* Fujita, 1920 as the scientific name of acanthocephalans that had heavily infected fish at a trout hatchery in Hokkaido (see also Anonymous 1972), but this was definitely wrong because the same author (Awakura 1972) had already identified the parasite as *A. minor* based on its morphological characteristics.

In 1936, *A. minor* was found in *Odontobutis obscura* in “Lake Biwa” (Fukui and Morisita 1936; see the Discussion section herein concerning this locality), but this acanthocephalan has not been reported from the lake or associated waters by any subsequent researcher (e.g., Fukui and Morisita 1937; Yamaguti 1939; Amin et al. 2007). The finding of *A. minor* in this study confirmed its occurrence in the Lake Biwa basin.

All of the present individuals of *A. minor* were found in the rectum of the fish examined. This site specificity of *A. minor* within the host’s intestine was previously noticed by Nagasawa et al. (1982).

**Discussion**

**Occurrence and geographical distribution of *Acanthocephalus minor* in the Lake Biwa basin.** There is a nearly 100-year history of research on the fish acanthocephalans of Lake Biwa and its drainage basin (Kawamura 1918; Fujita 1927; Fukui 1929; Katoaka and Momma 1933, 1934; Yamaguti 1935, 1939; Fukui and Morisita 1936, 1937; Ito 1959; Nakajima et al. 1975; Nakajima and Egusa 1975a, 1975b; Shimazu 1999; Grygier 2004; Amin 2005; Amin et al. 2007a, 2007b). In particular, during the 1930s, Yamaguti (1935, 1939) conducted a systematic survey of fish parasites in Japan including the Lake Biwa basin but did not report *A. minor* from the basin. Later, Amin et al. (2007) reported acanthocephalans recovered from an examination of over 500 individuals of fish belonging to 30 species in 12 families collected from 22 localities including Lake Biwa proper and various rivers, irrigation canals, and ponds in Shiga Prefecture during 1997–2002, but did not report *A. minor* among them. Only Fukui and Morisita (1936) found *A. minor* in *O. obscura* from the Lake Biwa basin 80 years ago, which suggests that this acanthocephalan is a rare species occurring in a limited area of this basin.

Fukui and Morisita (1936) simply reported “Lake Biwa” as the sampling locality of *A. minor*, but this may not be wholly accurate because Lake Biwa is the largest lake in Japan and many rivers, streams, and irrigation canals flow into it. The acanthocephalan specimens were not collected by these authors but were given to them by a colleague. The host, *Odontobutis obscura*, is usually found in the upper and middle reaches of the lake’s tributaries and only rarely occurs in coastal waters of the lake (Shiga-Kenritsu Biwako-Bunkakkan 1980). Two large-scale surveys of the freshwater fish fauna of Lake Biwa and its tributaries conducted in 1994–1995 and 2002–2003 also showed that the fish does not occur in Lake Biwa proper (Anonymous 1996, 2004). Therefore, the specimen of *O. obscura* reported by Fukui and Morisita (1936) most probably was not caught in “Lake Biwa” but in one of the rivers flowing into the lake. Since *A. minor* utilizes the asellid isopod *Asellus hilgardorfii* Bovallius, 1886 as its intermediate host (Awakura 1972; Nagasawa et al. 1982), it is desirable to clarify the distribution pattern of infected isopods in those rivers and irrigation canals.

Currently, some irrigation canals close to the shore of Lake Biwa have been recognized as habitats of *O. obscura* (Funao et al. 2010; Natsuhara and Akiyama 2012). In the present study, the infected specimen of *O. obscura* came from an irrigation canal in Takashima city, near (7–8 km away from) another irrigation canal in which Amin et al. (2007: fig. 1) found four species of acanthocephalan, viz., *Acanthocephalus opsarichthydis* Yamaguti, 1935; *Echinorhynchus cottii* Yamaguti, 1935; *Pseudorhadinorhynchus samagiensis* Nakajima and Egusa, 1975; and *Southwellina hispida* (Van Cleave, 1925). The irrigation canals sampled are both located near the northwestern shore of Lake Biwa. Abundant water is stably supplied from springs to the irrigation canals throughout the year (Yasuhiro Fujioka, Lake
A fish parasite from the Lake Biwa basin. Considering the fact that as many as five species of acanthocephalan occurred in such irrigation canals, it is likely that the canals provide favorable environmental and biological conditions for the parasites to complete their life cycles.

The fish acanthocephalan fauna of the Lake Biwa basin. To date, 10 nominal species of fish acanthocephalan have been reported from the Lake Biwa basin (Table 1). Nishino (2012) made a similar list of fish acanthocephalans of the basin, but some references (viz., Kawamura 1918; Fujita 1927; Fukui and Morisita 1936; Ito 1959; Amin et al. 2007b; Nagasawa and Grygier 2011) were not cited. Because Lake Biwa is an ancient lake (over four million years old; Horie 1984) and many endemic species occur in it (Nishino and Watanabe 2000; Kawanabe et al. 2012), potential endemism of fish acanthocephalans has also been discussed. In particular, Pseudorhadinorhynchus samegaiensis has been suggested to have such a status (Grygier 2004; Amin et al. 2007; Nagasawa and Grygier 2011). This acanthocephalan was originally described from rainbow trout Oncorhynchus mykiss (Walbaum, 1792) (as Salmo gairdnerii tredeus Gibbons, 1885) at a trout hatchery in the basin (Nakajima and Egusa 1975b), but this salmonid is not a native host, having been introduced into Japan from North America from 1877–1934 and 1951–1955 as eyed eggs (Maruyama et al. 1987). Pseudorhadinorhynchus samegaiensis does not occur in North America (Hoffman 1999), and is surely native to Japan. Among seven other species of infected fish in the basin reported by Amin et al. (2007), only big-scaled redfin Tetrulo don hakonensis (Günther, 1877) harbored gravid females, so this cyprinid may be the native preferred host. If so, endemic status of P. samegaiensis in the Lake Biwa basin would be doubtful because T. hakonensis is not endemic to the basin but is widely distributed in Japan, ranging from Hokkaido to Kyushu (Kurawaka 1977; Sakai 1995). The acanthocephalan fauna of T. hakonensis in other parts of its range should be intensively examined.

Of the four species of Acanthocephalus reported in the Lake Biwa basin, A. opsarichthydis has been found in a total of 15 species of fish in five families, while A. aculeatus Van Cleave, 1931 was collected only from ayu Pseudorhadinorhynchus samegaiensis (Temminck and Schlegel, 1846) (as P. altivelis) in the early 1930s (Kataoka and Momma 1933, 1934). The taxonomic status of A. aculeatus remains poorly understood. It was originally described from sockeye salmon (as the landform of blue-back salmon) Oncorhynchus nerka (Walbaum, 1792) in Lake Aoki (as Aoki Lake), Nagano Prefecture (as Shinano Province), central Japan (Van Cleave 1931). Harada (1935) synonymized it with A. echigoensis, but since then its taxonomic relations with other Japanese species of the genus, including A. opsarichthydis, have not been examined or discussed.

Morphologically, A. aculeatus and A. opsarichthydis are quite similar to each other. The proboscis armament, for example, is 8–10 longitudinal rows of seven or eight hooks in A. aculeatus (Van Cleave 1931), and nine longitudinal rows of 5–7 hooks in A. opsarichthydis (Yamaguti 1935); the blade of the longest hook is 94–161 µm long in A. aculeatus (Van Cleave 1931), and 72–150 µm long in A. opsarichthydis (Yamaguti 1935). The specimens reported as A. aculeatus from Lake Biwa possessed 8–10 longitudinal rows of 3–6 hooks (Kataoka and Momma 1933, 1934), fewer hooks per row than Van Cleave (1931) reported. A clarification of the taxonomic status of A. aculeatus vis-à-vis A. opsarichthydis is necessary but is beyond the scope of this paper.

No similar suggestion of synonymy applies to two other species of Echinorhynchus Zoega in Müller, 1776: E. cotti and E. parasiluri Fukui, 1929. Like A. opsarichthydis, E. cotti is a common parasite of fish in the Lake Biwa basin (Amin et al. 2007; see Table 1 herein), but there is only one record of E. parasiluri from this basin (Fukui 1929). Both species are easily differentiated from each other by the proboscis armament: 16–20 longitudinal rows of 11–13 hooks in E. cotti (Yamaguti 1935, 1939) versus 22–26 longitudinal rows of 10–11 hooks in E. parasiluri (Fukui 1929). Fukui (1929) reported the host of E. parasiluri as Amur catfish Silurus asotus, but because two other, endemic species of Silurus were later described from Lake Biwa, and the identity of Fukui’s fish could not be checked, this host was later reported as “Silurus sp. (presumably S. asotus Linnaeus, 1758)” (Amin et al. 2007). Amin et al. (2007) did not find E. parasiluri in five specimens of S. asotus and two specimens of rocky catfish S. lithophilus (Tomoda, 1961) but these authors attributed the absence of infection to the small number of fish examined.

Acanthocephalus gotoi Van Cleave, 1925 was reported, similarly to A. aculeatus, only once in the late 1930s in the Lake Biwa basin (Yamaguti 1939; see Table 1 herein). Since its original description from Japanese eel Anguilla japonica Temminck and Schlegel, 1846 in Tokyo, Japan (Van Cleave 1925), this acanthocephalan has been found in several freshwater fish, especially from A. japonica, in various parts of Japan (Yamaguti 1935, 1939; Fukui and Morisita 1936; Katahira and Nagasawa 2014; Nagasawa unpublished data), so it cannot be said to be rare in Japan. The current apparent absence of A. gotoi in the Lake Biwa basin is, therefore, unusual. One reason for this absence may be that the wild population of A. japonica disappeared in the basin after 1964 when the Amagase Dam was completed in the Uji River, which flows, first as the Seta River, from Lake Biwa. As a result, the acanthocephalan might have lost its major (perhaps preferred) host (A. japonica), resulting in its disappearance from the basin. Since the dam prevents juveniles of A. japonica from migrating upstream to the lake (Anonymous 2007), no wild population of eels has existed in Lake Biwa and its watershed since the mid-1960s. Currently, A. japonica is found in the lake, released by fishermen after having been raised at fish farms. No infection by A. gotoi was actually detected in recently collected individuals of A. japonica in the Lake Biwa basin (Amin et al. 2007). This may imply, in other words, that A. gotoi needs A. japonica to sustainably maintain its population even though this worm can infect various freshwater fish.

Unidentified acanthocephalans were found by Fujita (1927) in eight species of fish in Lake Biwa (see Table 1). These fish were reported as “the most common in Lake Biwa” (Fujita 1927: 39), but yamato char Salvelinus leu-
Two species of the genus Cottus (C. pollux, 1758, H. Linnaeus, 1758, and C. reinii, Linnaeus, 1758, 16 rows in the P. samegaiensis, 1929) at a trout hatchery. However, two species of acanthocephalan, Acanthocephalus opsariichthys and Pseudorhadinorhynchus samegaiensis, and the anisogammarid amphipod Jesogammarus (Annanogammarus) fluvialis Morino, 1985 (as J. fluvialis) are known to occur at this hatchery (Nakajima et al. 1975; Nakajima and Egusa 1975a, 1975b for the acanthocephalans; Morino 1985; Kusano 2009 for the amphipod), thus Itô’s (1959) work needs a re-study.

Without providing any information on the larval morphology of E. cotti, sampling locality, or date, Shimazu (1999) stated that the intermediate host of E. cotti in Lake Biwa is the anisogammarid amphipod Jesogammarus (Annanogammarus) naritai Morino, 1985 (as J. naritai). This amphipod is found in coastal waters of the lake throughout the year (Narita 1976; Morino 1985, 1994). A detailed life-history study of E. cotti using this amphipod intermediate host is desired in the field and the laboratory. In addition, another species of anisogammarid amphipod Jesogammarus (Annanogammarus) annandalei (Tattersall, 1922) occurs in offshore, deeper waters of Lake Biwa (Narita 1976; Morino 1985, 1994; Ishikawa and Urabe 2002). It is thus important to search for larval E. cotti in material of this amphipod as well, and assess a difference in host utilization by the acanthocephalan in these congeneric amphipods at various depths in the lake.

Asakawa and Nishino (2011) reported 10 juveniles of a polymorph acanthocephalan collected in a free condition from a benthos sample taken in Lake Biwa. These authors stated that the juveniles resembled an acanthocephalan of aquatic-birds, Polymorphus (Polymorphus) strumosoides Lundström, 1942, but based on the morphological features given by the authors, they seem almost identical with Pseudorhadinorhynchus samegaiensis. The only difference is the number of hook rows on the proboscis, i.e., 16 rows in the benthic-caught juveniles (Asakawa and Nishino 2011) and 13–14 rows in P. samegaiensis (Nakajima and Egusa 1975b; Amin et al. 2007). It is desirable to re-examine Asakawa and Nishino’s (2011) specimens to ascertain their identity at the generic and specific levels.

Amin et al. (2007) examined well-developed cystacanths of S. hispida from the body cavity of six species of fish in the Lake Biwa basin. The final hosts of this acanthocephalan are fish-eating birds (García-Verela et al. 2012), and the fish reported by Amin et al. (2007) are considered to serve as paratenic hosts for the parasite. Yamaguti (1935, 1939) and Katahira and Nagasawa (2014) provide the other known fish hosts from Japan. It is necessary to discover the first intermediate hosts of this species (e.g., amphipods; see Lisitsyna 2011) in order to clarify its life cycle in the basin. No information is yet available on the life history of these amphipods; see Lisitsyna 2011 in order to clarify its life cycle in the basin. No information is yet available on the life history of these amphipods; see Lisitsyna 2011 in order to clarify its life cycle in the basin. No information is yet available on the life history of these amphipods; see Lisitsyna 2011 in order to clarify its life cycle in the basin.
whether this acanthocephalan is an introduced species.

In conclusion, the Lake Biwa basin is the best studied body of freshwater in Japan as concerns the fish acanthocephalan fauna, and no other lake basin in Japan has been reported to bear such a rich fauna of these parasites. Nevertheless, the past investigations of fish acanthocephalans in this basin have focused on their taxonomy. As reviewed above, no paper except Amin et al. (2007) has treated their ecology and host-parasite relationships, and much remains poorly understood about their life cycles. More work is needed on various aspects of the biology of fish acanthocephalans in the Lake Biwa basin.

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