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Host and Seasonal Distribution of Fish Acanthocephalans from the Lake Biwa Basin, Japan

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ABSTRACT: Six species of acanthocephalans were collected from 30 of 62 surveyed species of fish in Lake Biwa, the most ancient lake in Japan, and from various water bodies in the lake's drainage basin including the Seta and Daido Rivers. The 3 most common species were *Acanthocephalus opsariichthydis* Yamaguti, 1935 (8 new host records), *Echinorhynchus cotti* Yamaguti, 1935 (7 new host records), and *Pseudorhadinorhynchus samegaiensis* Nakajima and Egusa, 1975 (7 new host records; perhaps endemic to Lake Biwa and its basin). The latter 2 species were found only in the spring. Specimens of both species were also found in *Gymnogobius isaza* (Tanaka, 1916) in the autumn. Gravid females of all 3 species were found in the spring. Developed cystacanths of *Southwellina hispida* (Van Cleave, 1925) Witenberg, 1932 were also collected (5 new host records). Anatomical similarities between these species and the original descriptions are clearly evident, but differences in certain key characteristics are noted. Two recently described species of *Acanthogyrus* (*Acanthosentis*) Verma and Datta, 1929, *Acanthogyrus* (*Acanthosentis*) *alternatspinus* Amin, 2005, and *Acanthogyrus* (*Acanthosentis*) *parareceptaclis* Amin, 2005 were also first collected in the course of this survey. Three species previously recorded in the 1920s and 1930s from Lake Biwa were not found in the present survey: *Acanthocephalus aculeatus* Van Cleave, 1931, *Acanthocephalus gotoi* Van Cleave, 1925, and *Echinorhynchus parasiluri* Fukui, 1929.

KEY WORDS: Acanthocephala, fish parasites, Lake Biwa, Japan, new host records, seasonality.

Lake Biwa is the only ancient lake (4 million yr old) in Japan. Its present basin was formed some 400,000 yr ago and its present size is 674 km^2, with about 460 rivers, streams, and irrigation canals flowing into it. The Seta River is the lake's outlet, and the Daido River is a major tributary of the Seta River. The boundaries of the lake's watershed (including that of the Daido River) nearly correspond to the borders of Shiga Prefecture. The lake's biota of over 1,000 species includes at least 50 endemic species, primarily fish and molluscs. Reviews of the lake's geological history and biological features are provided by Nakajima and Nakai (1994), Nishino and Watanabe (2000), and Rossiter (2000).

Many studies of Lake Biwa fish parasites have been reported previously. Those involving acanthocephalans include Fujita (1927), Fukui (1929), Kataoka and Momma (1933, 1934), Yamaguti (1935, 1939), and Fukui and Morisita (1937). Ito (1959), Nakajima et al. (1975), and Nakajima and Egusa (1975a, b) also reported on acanthocephalans from a fish hatchery (the Samegai Trout Experimental Station) located on a river within the Lake Biwa watershed. Shimazu (1999) reviewed the literature on acanthocephalans of freshwater fishes of Japan, including those from Lake Biwa and its watershed. Of the 74 species and subspecies of fish in 17 families known to be present in Lake Biwa and its tributaries (Yuma et al., 1998), 62 species representing all families were surveyed between 1997 and 2002 in a large-scale systematic study of their parasites conducted by the Lake Biwa Museum. This survey also covered parts of the Seta and Daido rivers. This paper addresses the acanthocephalan component of these collections.

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MATERIALS AND METHODS

Almost all of the fish from the Lake Biwa basin and Seta and Daido rivers that yielded the acanthocephalan parasites reported here were examined during the course of 5 fish-parasite workshops conducted at the Lake Biwa Museum during November of 1997 and 2000 and May of 1998, 2000, and 2001. Fish were collected from Lake Biwa proper (mostly from "eri"—large-scale labyrinth traps), as well as from various rivers (sometimes from a "yana"—a barrier trap constructed across a river), irrigation canals, and ponds (especially the Kaya-ike satellite lake, or "Katata-naiko"). Fish were obtained using various types of net or small traps or, in the case of eri or yana, often as donations from commercial fishermen. The periods of fish collection and the dates of the workshops were as follows: (1) 17–31 October 1997 (workshop 1–3 November); (2) 14–21 May 1998 (22–24 May); (3) 26 April to 4 May 2000 (5–7 May); (4) 10 October to 2 November 2000 (3–5 November); (5) (exceptionally 28 Feb) 10 April to 11 May 2001 (1–11

May). All collection sites for these workshops are indicated, but not labeled, on a previously published map (Grygier, 2004: Fig. 2); the sites from which acanthocephalans were recovered (Fig. 1) are (1) open water, north basin (precise location unknown); (2) yana trap, near mouth of Chinai River, Takashima city (35°27′N; 136°03′E); (3) Kaya-ike satellite lake, Otsu city (35°07′N; 135°56′E); (4) Seta River, Otsu city (34°55′N; 135°55′E); (5) Mano River, Otsu city (35°08′N; 135°55′E); (6) upper Yasu River, Koka city (34°56′N; 136°16′E); (7) Kusano River, Nagahama city (35°27′N; 136°20′E); (8) eri trap, SW part of north basin off Hachiyado, Otsu city (35°11′N; 135°55′E); (9) unspecified eri traps, NW part of north basin off Takashima city (approximately 35°27′N; 136°05′E to 35°24′N; 136°03′E); (10) Tenjin River, Otsu city (35°07′N; 135°55′E); (11) Amano River, Maibara city (35°20′N; 136°21′E); (12) Uryu River, Higashiomi city (35°10′N; 136°11′E); (13) Daido River and a tributary, Otsu city (34°57′N; 135°56′E); (14) irrigation canal, Hamabun, Takashima city (35°23′N; 136°03′E); (15) Yanamune River, Konan city (35°00′N; 136°05′E); (16) Ooyama River, Konan city (35°03′N; 136°04′E); (17) irrigation canal, Miyake, Moriyama city (35°03′N; 135°59′E); (18) Tamura River, Koka city (34°56′N; 136°17′E); (19) Nyuu River, Maibara city (35°20′N; 136°20′E); (20) mouth of Yasu River, Moriyama city (35°07′N; 135°58′E); and (21) east shore of south basin, Oroshimo, Kusatsu city (35°04′N; 135°56′E).

Aside from the five workshops, one other infected fish considered here, a specimen of *Tanakia limbata* (Temminck and Schlegel, 1846), was collected in June of 1999 from an irrigation canal in Mano-Ono, Otsu city (35°08′N, 135°55′E).

The scientific names and authors of fish in this report mostly follow Matsuura et al. (2000), except for *Gymnogobius* spp. (see Stevenson, 2000) and *Rhynchocypris* spp. (Sakai et al., 2006).

Fish were dissected in the laboratory usually within 3 d to a week after capture, but sometimes immediately. In most cases, isolated acanthocephalans were initially fixed in AFA (alcohol, formalin, acetic acid) on glass slides pressed by a cover glass; the slides were then stored in 70% ethanol. In cases of great numbers of adults or cystacanths from a single host or host lot, only some were mounted, whereas others were preserved in 70% ethanol; only mounted specimens are considered here. Slides were stained usually in Meyer's acid hematoxylin but occasionally in Grenacher's alum carmine or Heidenhain's iron hematoxylin, carried through ascending concentrations of ethanol, cleared in creosote, and whole-mounted in Canada balsam. Adults from the first 2 workshops were identified initially by K.N.; these identifications were confirmed later by O.M.A., who identified all other adults and some cystacanths. Remaining cystacanths were identified by M.J.G.

All specimens are deposited in the Lake Biwa Museum; some, along with other recovered parasites, are under the accession numbers LBM Misc. Invert. FY2001-2, -4, -17, -24, and -37 (those from the first 2 workshops lack an accession number). All measurements are in micrometers unless otherwise stated.

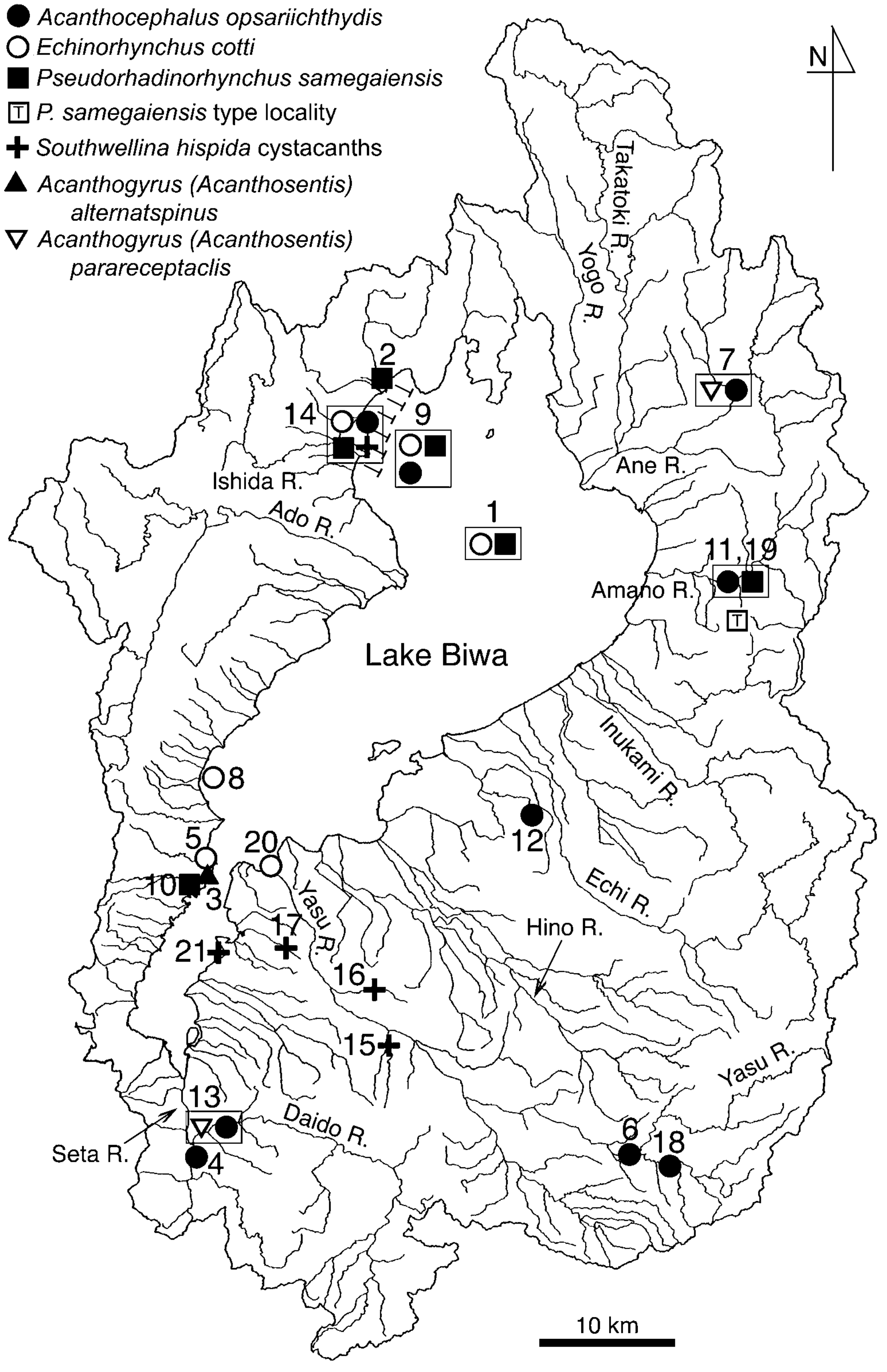
RESULTS

Sixty-two species of fish were examined during these 5 workshops or, rarely, on other occasions. Six species of acanthocephalan parasites were found among the 30 fish species infected: *Acanthocephalus opsariichthydis* Yamaguti, 1935; *Echinorhynchus cotti* Yamaguti, 1935; *Pseudorhadinorhynchus samegaiensis* Nakajima and Egusa, 1975 (Table 1); *Southwellina hispida* (Van Cleave, 1925) Witenberg, 1932; *Acanthogyrus* (*Acanthosentis*) *alternatspinus* Amin, 2005; and *A.* (*A.*) *parareceptaclis* Amin, 2005. The first 4 species will be addressed below in some detail.

Acanthocephalus opsariichthydis Yamaguti, 1935

This species was originally described from 7 species of fish (3 families) in Lake Biwa, Lake Ogura (since drained), and the Yodo River (type locality), all part of the Lake Biwa/Yodo River drainage system (Yamaguti 1935). The hosts reported were *Cyprinus carpio* Linnaeus, 1758; *Hemibarbus barbus* (Temminck and Schlegel, 1846); *Hymenophysa* (currently *Leptobotia*) *curta* (Temminck and Schlegel, 1846); *Opsalichthys* (sic; i.e., *Opsariichthys*) *uncirostris* (Temminck and Schlegel, 1846) (type); *Parasilurus* (currently *Silurus*) *asotus* Linnaeus, 1758; *Pseudorasbora parva* (Temminck and Schlegel, 1846); and *Zacco platypus* (Temminck and Schlegel, 1846). The original text does not state which of the host fishes were from Lake Biwa. Kamegai and Ichihara (1972) stated that at least *C. carpio* and some of the *O. u. uncirostris* individuals were from Lake Biwa. Some of Yamaguti's specimens of *A. opsariichthydis* are deposited in the Meguro Parasitological Museum in Tokyo. Of these, the only host from Lake Biwa is *P. parva*; the specimens of *A. opsariichthydis* from *O. u. uncirostris* (including the holotype) and from *H. barbus* were from the Yodo River, and those from *P. asotus* and *H. curta* were from Lake Ogura. A slide labeled "paratype" from *C. carpio* pertains to a carp from Koumi, Nagano Prefecture, not to the Lake Biwa/Yodo River area. There are no slides of *A. opsariichthydis* from *Z. platypus*.

Acanthocephalus opsariichthydis was later reported (as *Acanthocephalus* sp.) from rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1792), at the Samegai Trout Experimental Station in Shiga Prefecture (in the Lake Biwa basin) and from this and 10 additional host species (5 families) in Tokyo, Nagano, and Tochigi Prefectures (Yamaguti, 1939; Ichihara, 1964; Nagasawa et al., 1983, 1987). These host species (some names updated here) were *Gymnogobius urotaenia* (Hilgendorf, 1879), *Gnathopogon elongatus elongatus* (Temminck and Schlegel,



Acanthocephalus opsariichthydis
Echinorhynchus cotti
Pseudorhadinorhynchus samegaiensis
P. samegaiensis type locality
Southwellina hispida cystacanths
Acanthogyrus (Acanthosentis) alternatspinus
Acanthogyrus (Acanthosentis) parareceptaclis
N
Takatoki R.
Yogo R.
Ane R.
Amano R.
Ishida R.
Ado R.
Lake Biwa
Inukami R.
Echi R.
Hino R.
Yasu R.
Daido R.
Seta R.
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1846), *Tribolodon hakonensis* (Gunther, 1880), *Misgurnus anguillicaudatus* (Cantor, 1842), *Rhynchocypris lagowskii steindachneri* (Sauvage, 1883), *Plecoglossus altivelis* Temminck and Schlegel, 1846, *Oncorhynchus nerka* (Wallbaum, 1792), *Oncorhynchus rhodurus* Jordan and McGregor, 1925, *O. mykiss*, and *Salvelinus fontinalis* (Mitchill, 1814). One of the hosts reported by Nagasawa et al. (1987) from Lake Yunoko in Tochigi Prefecture, the Biwa salmon *O. rhodurus* (also known as *O. masou rhodurus* or *O. masou* subsp.), is originally endemic to Lake Biwa. Six of the above-mentioned fish species were collected from Lake Biwa in our study but were not infected with *A. opsariichthydis*. These are *C. carpio*, *O. uncirostris*, *P. parva*, *Z. platypus*, *P. altivelis*, and *S. asotus*.

In our study, *A. opsariichthydis* was found in 10 fish species of 4 families from Lake Biwa and vicinity (Table 1), including the following 8 new host records: *Cobitis biwae* Jordan and Snyder, 1901, *Hemibarbus labeo* (Pallas, 1776), *Hemibarbus longirostris* (Regan, 1908), *Rhynchocypris oxycephalus jouyi* (Jordan and Snyder, 1901), *Pseudogobio esocinus esocinus* (Temminck and Schlegel, 1846), *Pungtungia herzi* Herzenstein, 1892, *Gasterosteus microcephalus* (Girard, 1854), and *Oncorhynchus masou ishikawae* Jordan and McGregor, 1925. The other 2 host species, *G. e. elongatus* and *H. barbus*, represent new locality records for Lake Biwa. This acanthocephalan was recovered during both autumn and spring and gravid females were present in both seasons. It was found predominantly from fish caught in rivers. Eight sites, some of them far upstream, were in rivers to the east, southeast, and south of Lake Biwa (Fig. 1). However, a single specimen was also found in *H. barbus* along the northwestern shore of Lake Biwa. It is not certain, however, whether the infected fish came from an eri trap in the lake proper or from an irrigation canal near shore.

Our specimens are similar to those described by Yamaguti (1935, 1939) and Nakajima and Egusa (1975a) but differ in the shape of the proboscis hooks and hook roots, and the dimensions of the neck. Anterior and posterior hooks are not markedly different in size. The longest hooks in males reach 125 and the shortest reach 35. In females, they reach 195 and 55, respectively. Corresponding measurements reported by Yamaguti (1935, 1939) were 84–120 to 27–51 in males and 150 to 25–51 in females. The 2 anterior proboscis hooks were inaccurately shown by Yamaguti (1935: Fig. 7) to be about half as long as the next posterior hook. In the same figure, Yamaguti (1935) showed all 6 hooks in one row to have similar hook roots having an identical slight "anterior prolongation." Nakajima and Egusa (1975a: Fig. 1), on the other hand, illustrated one representative hook with a root having a flat anterior end and lacking a manubrium. Our specimens consistently have a well-developed anterior manubrium on the root of the anterior-most hook, with a gradual decrease in size of the manubrium posteriorly until it is almost absent in the posterior-most hook root. Most of our specimens had proboscis hook rows usually with only 5 hooks each. Yamaguti (1935) referred to a "short neck" with the lemnisci "a little shorter than the proboscis sheath." Yamaguti's (1935) specimens were anteriorly retracted (his Figs. 6–8) and the neck appeared unremarkable. Like those shown by Nakajima and Egusa (1975a), our specimens had a long neck (312–416 long dorsally and 281–302 wide at base), with the proboscis receptacle (markedly shorter than the lemnisci) extending about half of its (the receptacle's) length into the neck.

Echinorhynchus cotti Yamaguti, 1935

This acanthocephalan was described from *Cottus pollux* Günther, 1873 in Shiga Prefecture (Yamaguti, 1935). This fish occurs in the upper reaches of certain rivers that flow into Lake Biwa, whereas *Cottus reinii* Hilgendorf, 1879, an endemic sculpin, inhabits the lower reaches of many rivers and the lake itself (Fujioka and Kido, 1998); therefore, Yamaguti's (1939) later record from *C. pollux* in Lake Biwa must

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Figure 1. Map of Shiga Prefecture, Japan, showing workshop collecting sites of 6 species Acanthocephala found in fishes in 1997–2001 in Lake Biwa, its outlet the Seta River, and various inflowing watercourses, and the type locality of *Pseudorhadinorhynchus samegaiensis*. Numbered collecting sites are as follows: 1, open water, north basin; 2, "yana" traps, mouth of Chinai River; 3, Kaya-ike satellite lake; 4, Seta River; 5, Mano River; 6, upper Yasu River; 7, Kusano River; 8, "eri" traps, SW part of north basin; 9, eri traps, NW part of north basin (T-shaped eri symbols show their extent); 10, Tenjin River; 11, Amano River; 12, Uryu River; 13, Daido River and a tributary; 14, irrigation canal, Hamabun, Takashima city; 15, Yanamune River; 16, Ooyama River; 17, irrigation canal, Miyake, Moriyama city; 18, Tamura River; 19, Nyuu River; 20, mouth of Yasu River; 21, east shore of south basin. *Acanthocephalus opsariichthydis* was found in *Hemibarbus barbus* at either site 9 or 14, not both. *Southwellina hispida* occurred in *Micropterus salmoides* at either site 14 or site 21, not both.

Table 1. Host and seasonal distribution of three species of in Lake Biwa basin fishes during autumn (October/November) of 1997 and 2000 and spring (April/May) of 1998, 2000, and 2001.[1]

	Processed worms examined, no. of females (% gravid)							
	Fish examined		*Acanthocephalans opsariichthydis*		*Echinorhynchus cotti*		*Pseudorhadinorhychus samegaiensis*	
Fish species	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
Anguillidae								
Anguilla japonica	0	6	—	—	—	1,0 (0)	—	1,0 (0)
Channidae								
Channa argus	0	4	—	—	—	3,2 (0)	—	—
Cobitidae								
Cobitis biwae	28	15	—	1,1 (0)	—	—	—	—
Cottidae								
Cottus reinii	6	14	—	—	—	74,38 (63)	—	—
Cyprinidae								
Cyprinus carpio	0	13	—	—	—	1,0 (0)	—	—
Gnathopogon e. elongates	9	1	—	1,0 (0)	—	—	—	—
Hemibarbus barbus	0	21	—	1,0 (0)	—	3,1 (100)	—	11,8 (0)
Hemibarbus labeo	0	7	—	19,11 (55)	—	—	—	—
Hemibarbus longirostris	3	10	1,1 (0)	—	—	—	—	—
Opsariichthys u. uncirostris	0	10	—	—	—	1,1 (0)	—	5,3 (0)
Pseudogobio e. esocinus	*8*	*31*	*2,2 (100)*	—	—	—	—	—
Pungtungia herzi	15	7	—	1,1 (0)	—	—	—	—
Rhynchocypris oxycephalus jouy	5	16	2,0 (0)	6,5 (0)	—	—	—	—
Sarcocheilichthys variegates microoculus	3	6	—	—	—	1,1 (0)	—	—
Tribolodon hakonensis	0	31	—	—	—	—	—	42,21 (50)
Gasterosteidae								
Gasterosteus microcephalus	0	22	—	2,1 (0)	—	—	—	6,3 (0)
Gobiidae								
Gymnogobius isaza	20	34	—	—	45,21(0)	24,12 (42)	3,1 (0)	2,2 (0)
Rhinogobius sp.	0	20	—	—	—	5,4 (0)	—	—
Tridentiger brevispini	2	1	—	—	—	5,2 (0)	—	—
Osmeridae								
Hypomesus transpacificus nipponensis	0	12	—	—	—	1,0 (0)	—	—
Plecoglossidae								
Plecoglossus a. altivelis	0	105	—	—	—	4,2 (0)	—	—
Salmonidae								
Oncorhynchus masou ishikawae	0	12	—	5,4 (75)	—	—	—	1,1 (0)
Oncorhynchus sp.	0	1	—	3,1 (100)	—	—	—	—

[1] Three other species of acanthocephalans were also identified, two species of *Acanthogyrus* (*Acanthosentis*) and *Southwellina hispida*; see text. Ethanol-preserved worms from *C. reinii* and *G. isaza* were not processed or identified by OMA and are thus not included in this table; *E. cotti* from *T. limbata*, although identified by OMA, was collected in June 1999 separate from the survey workshops, so it also is not included here.

refer to *C. reinii*, and perhaps the original host was this species as well. This acanthocephalan was subsequently reported from 9 other species of fish (5 families) in Lake Biwa by Fukui and Morisita (1937) and Shimazu (1999) (some names updated here): *C. reinii*, *Gnathopogon caerulescens* (Sauvage, 1883), *Gymnogobius isaza* Tanaka, 1916, *H. barbus*, *P. altivelis*, *Pelteobagrus nudiceps* (Sauvage, 1883), *Sarcocheilichthys variegatus microoculus* Mori, 1927, *Silurus biwaensis* (Tomoda, 1961), and

Tridentiger brevispinis Katsuyama, Arai and Nakamura, 1972; as well as 3 species of salmonid fish in the Kanita River of Aomori Prefecture (Nagasawa and Egusa, 1981): *Oncorhynchus masou masou* (Brevoort, 1856), *Salmo gairdnerii* Richardson, 1836 (i.e., *O. mykiss*), and *Salvelinus leucomaenis leucomanis* (Pallas, 1811).

In our study, *E. cotti* was more common than *A. opsariichthydis*, especially in *C. reinii* and *G. isaza*. Adults were found in 13 fish species of 7 families from Lake Biwa and vicinity (Table 1) and 7 of these species represent new host records: *Anguilla japonica* Temminck and Schlegel, 1846; *Channa argus* (Cantor, 1842); *C. carpio*; *O. u. uncirostris* Temminck and Schlegel, 1846; *T. limbata*, *Rhinogobius* sp.; and *Hypomesus transpacificus nipponensis* McAllister, 1963. The other 6 hosts noted in Table 1 repeat some of the above-mentioned older host records from the Lake Biwa area. Of the other earlier recorded hosts, *G. caerulescens* and *P. nudiceps* were included in our survey but we did not confirm any infection of these with *E. cotti*. *Echinorhynchus cotti* was recovered during autumn and spring, but gravid females were only observed in May. All fish but *T. limbata* of the infected fish were caught in Lake Biwa proper, usually in eri traps, or immediately adjacent to the lake, e.g., in the river mouth or in an irrigation canal near shore. *Echinorhynchus cotti* was found in a total of 6 sites (Fig. 1).

Our specimens are similar to those described from Lake Biwa by Yamaguti (1935, 1939) except for the following points: our males have 6 or 7 cement glands (instead of 5 or 6); the proboscis of females is larger, 625–915 long by 218–250 wide (instead of 500–630 × 120–150); and the proboscis hooks are somewhat smaller, 40–43 apically, 43 subapically, and 28–37 basally (instead of "up to 51"). Nagasawa and Egusa (1981) studied the morphological variability of male and female *E. cotti* collected from various host fishes in the Kanita River, Aomori Prefecture. Up to 8 (usually 5 or 6) cement glands were present, the proboscis of females was intermediate in size between Yamaguti's and ours, with the length of the basal hooks down to 20, and the longest hooks (position unspecified) up to 57. In addition, the interior surface of the male bursa in our specimens was packed with many ovoid to elliptical sensory cell-like pits not reported by other observers. The male specimen reported by Kataoka and Momma (1934) as *Echinorhynchus* sp., before *E. cotti* was described, appears to be *E. cotti*; we agree with the Japanese authors that it does not belong to *Echinorhynchus gadi* Zaega in Müller, 1776 or *Echinorhynchus truttae* Schrank, 1788. It is clearly not *Echinorhynchus parasiluri* Fukui, 1929, which has 22–26 proboscis hook rows with 10–11 hooks each; corresponding numbers in *E. cotti* are 16–18 rows with 13 hooks each (Yamaguti 1935, 1939) or 16–21 (usually 18 or 19) rows with 11–16 (usually 13–14) hooks each (Nagasawa and Egusa 1981). The reference to "16 longitudinal rows of 6 hooks each" on the proboscis by Kataoka and Momma (1934) was apparently an error, as is suggested by their Fig. 2, which shows a partly retracted proboscis. That specimen was, however, described as a new species, *Echinorhynchus oblitus* Golvan, 1969 on the basis of having 6 hooks per row on the proboscis, which is inaccurate, rendering it invalid.

Pseudorhadinorhynchus samegaiensis Nakajima and Egusa, 1975

Except for a study of its chemical susceptibility in rainbow trout by Nakajima et al. (1975), there has been no other study of *P. samegaiensis* since its original description from *Salmo gairdnerii irideus* Gibbons, 1855 (=*O. mykiss*) at the Samegai Trout Experimental Station in Shiga Prefecture (in the Lake Biwa basin) (Fig. 1). A photograph of slide-mounted specimens appears in Grygier (2004: Fig. 6B).

In our survey, this species was recovered from 7 additional fish species in 5 families (Table 1), all representing new host records: *A. japonica*, *H. barbus*, *O. u. uncirostris*, *T. hakonensis*, *G. microcephalus*, *G. isaza*, and *O. m. ishikawae*. We found it at 7 sites: farther downstream in the type locality's river drainage (Amano R. and its tributaries), in the north basin of Lake Biwa proper and an irrigation canal located close to the northwestern shore, and in a river flowing into the lake's south basin from the west (Fig. 1). Gravid females were collected in the spring from the most frequently infected host, *T. hakonensis*. Occurrences of *P. samegaiensis* in the body cavity were noted in the present study, particularly in *G. isaza*; in 1 specimen, the proboscis was inserted into the ovary.

Our specimens are similar to those originally described by Nakajima and Egusa (1975b) but differ in some respects. In the following, information from our specimens is listed first, with that from the original description following in parentheses. The proboscis has 13–14 rows of 9–10 hooks each (14 rows of 9–11 hooks each). The longest proboscis hook is often the fourth (third hook is longest). The proboscis hooks are smaller: the apical, third, and tenth hooks in males are 40–42, 53–55, and 23–25 long (same hooks are 45–54, 60–67, and 27–41 long). Corresponding measurements of proboscis hooks in females are 60–70, 65–75, and 32–42 (same hooks are 57–69, 78–85, and 30–46). The lengths of hooks on the dorsal and ventral sides are not as different, if at all, as presented in the original description. Trunk spines extend farther ventrally than dorsally: 18–24 and 9–22, respectively, in males, and 21–22 and 13–20 in females (14–24 and 5–11 in males and 22–27 and 13–21 in females). The eggs are smaller, 88–95 long by 12–18 wide (96–117 by 22–25).

Southwellina hispida (Van Cleave, 1925) Witenberg, 1932

Adults of this species parasitize birds. In reporting *S. hispida* from a heron in the Galapagos Islands, Van Cleave (1940) stated that "The species probably has broad geographical distribution that has not yet been adequately understood." It has been reported in Japan, the United States, and Russia (Schmidt, 1973). In Japan, juveniles similar to our specimens were reported by Van Cleave (1925) from the mesenteries of an amphibian in "Province Musashi" (the area including present-day Tokyo, Saitama, and eastern Kanagawa Prefectures) and by Yamaguti (1935, 1939) from the mesenteries of a frog, fishes, and a snake from Kyoto, Namerikawa in Toyama Prefecture, and Obama in Fukui Prefecture. The fish hosts were recorded by these authors as *Mogurnda* (currently *Odontobutis*) *obscura* Temminck and Schlegel, 1845, *Rhinogobius* sp., and "*Cyprinus carassius*" (evidently an error for *C. carpio* or *Carassius* sp.). Fukui (1929) reported adults (as *Arhythmorhynchus hispidus*) from the black-crowned night heron *Nycticorax nycticorax nycticorax* (Linnaeus, 1758) in Shizuoka.

Many well-developed female cystacanths were recovered from the body cavity of *Coreoperca kawamebari* (Temminck and Schlegel, 1842), and small numbers from *Micropterus salmoides* (Lacépède, 1802), *Tanakia lanceolata* (Temminck and Schlegel, 1846), *T. limbata*, *Zacco sieboldii* (Temminck and Schlegel, 1846), and *Lefua echigonia* Jordan and Richardson, 1907. All of these except *M. salmoides* represent new host and locality records; *M. salmoides* was recorded by Miller et al. (1973) as a host of *S. hispida* in California. The 3 known sites are in rivers east of Lake Biwa's south basin (Fig. 1); the site of collection of the infected *M. salmoides* is uncertain, either an irrigation canal close to the lake or the lakeshore shallows.

The extended or partially extended specimens agree with the descriptions of Van Cleave (1925), Fukui (1929), Yamaguti (1935, 1939), and Schmidt (1973). The proboscis had 20–23 rows of 12–15 hooks each; the apical, middle (largest), and basal hooks were 50–55, 63–68, and 48 long, respectively, and the anterior part of the trunk has 2 distinct fields of spines. The best displayed specimen had the trunk spines irregularly placed except for a single complete ring of spines anteriorly, in agreement with the description of Yamaguti (1939).

Acanthogyrus (*Acanthosentis*) spp.

Amin (2005) provided taxonomic descriptions and other information for *A.* (*A.*) *alternatspinus* from *Rhodeus ocellatus ocellatus* (Kner, 1866) and *A.* (*A.*) *parareceptaclis* from *C. biwae* in the Lake Biwa area (Fig. 1); however, details of the occurrence of the latter species in the Kusano River (collecting site no. 7 herein) were, however, inadvertently omitted. *Cobitis biwae* was collected from the Daido River (34°56.4′N; 135°55.65′E) and from the Kusano River (35°26.5′N; 136°20.2′E) using various nets; eri and yana traps were not used. Some specimens from the Daido River, not Kusano River, were refrigerated before fixation. The 8 worms (6 females, 2 males) from one or more of 14 fish examined in November 1997 were from the Kusano River. The Kusano River specimens (slide 2-40) were not included in the list of formally designated paratypes of *A.* (*A.*) *parareceptaclis*.

Other records

Several fish species recorded as hosts of unidentified acanthocephalans from Lake Biwa are noted here as possible targets of future surveys. Fujita (1927) reported acanthocephalans in 1 of 100 examined *M. anguillicaudatus* and 2 of 10 examined *Chloea castanea* (O'Shaughnessy, 1875) (i.e., *Gymnogobius* sp., presumably *G. isaza*), and we noted a single infected *G. caerulescens* in the present study but failed to preserve the worm(s).

DISCUSSION

Three species of fish acanthocephalan reported by early workers were not recovered in the present survey: *Acanthocephalus aculeatus* Van Cleave, 1931, *A. gotoi* Van Cleave, 1925, and *Echinorhynchus parasiluri* Fukui, 1929 (Kataoka and Momma, 1933, 1935; Yamaguti, 1939; Fukui, 1929, respectively). *Acanthocephalus aculeatus* was considered a synonym of *A. echigoensis* Fujita, 1921 (Harada, 1935; Yamaguti, 1963). Of the reported hosts of these 3 acanthocephalans, *P. a. altivelis*, *G. urotaenia* (Hilgendorf, 1879), and *Silurus* sp. (presumably *S. asotus* Linneaus, 1758), we examined 110, 16, and 5 specimens, respectively, as well as 2 specimens of *Silurus lithophilus* (Tomoda, 1961). It is possible that we did not encounter *A. gotoi* and *E. parasiluri* because of the small number of the latter two host species collected.

No parasites were included in the list of Lake Biwa endemic species compiled by Nishino and Watanabe (2000), but Grygier (2004) suggested that *P. samegaiensis* is a candidate for endemic status in the Lake Biwa basin. Until now it had only been recorded from the fish hatchery at Samegai in the lake's drainage basin. Here we report it from the lake proper as well, and from various waterways either not far downstream from the type locality or close to the opposite (northwestern and southern) ends of the lake from there. The absence of records of this apparently common worm in any report on Lake Biwa fish helminths from the 1920s and 1930s is puzzling. No species of *Pseudorhadinorhynchus* occurs in North America (Hoffman, 1999), so the recent introduction of this worm to Japan together with its originally reported host, *O. mykiss*, can be ruled out.

Several species of fish examined in the present survey were parasitized by 2 or 3 species of acanthocephalans. *Anguilla japonica*, *O. u. uncirostris*, and *G. isaza* hosted both *E. cotti* and *P. samegaiensis*. *Gasterosteus microcephalus* and *O. m. ishikawae* hosted both *A. opsariithydis* and *P. samegaiensis*. *Hemibarbus barbus* hosted all 3 of these species. In addition, *T. limbata* was noted as the host of both *E. cotti* and cystacanths of *S. hispida*. The primary data, sometimes representing pooled samples, in general did not allow us to determine the number of host individuals with concurrent infections, but a few such cases were noted: 1 specimen each of *O. u. uncirostris* and *H. barbus* hosting both *E. cotti* and *P. samegaiensis*, and another individual of *H. barbus* with both of these as well as *A. opsariichthydis*.

The present results indicate that the 3 most abundant acanthocephalan species in our samples reproduce in spring. We, however, have only spring records of *E. cotti* and *P. samegaiensis*, aside from some of each species found in *G. isaza* in the autumn. In the Kanita River of Aomori Prefecture, *E. cotti* matures in spring and dies in early summer (Nagasawa, unpublished data). This seasonality is compatible with the reproductive cycle of fish acanthocephalans in temperate areas characterized by spring reproductive peaks (Amin, 1975). In large lakes, however, recruitment, maturation, and reproductive activity occur throughout the year without pronounced reproductive peaks. The latter situation has been observed in Lake Michigan, U.S.A. (Amin and Burrows, 1977), and in Llyn Tegid Lake, U.K. (Chubb, 1964), among others. This may explain the finding of sexually mature populations of *A. opsariichthydis* in both our spring and autumn collections and the presence of *E. cotti* and *P. samegaiensis* in the exclusively lacustrine *G. isaza* in the autumn.

The geographical distribution of our records of each species in and around Lake Biwa (Fig. 1) suggests that *A. opsariichthydis* is largely restricted to rivers, and *E. cotti* to Lake Biwa proper, including river mouths. This pattern may reflect the distributions of the respective intermediate hosts, with some mixing perhaps due to movements of fish between the lake and rivers. No particular preference for fish inhabiting the lake or its rivers is shown by *P. samegaiensis*, whereas records of *S. hispida* are mostly from rivers.

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