

Redescription of *Paraproteocephalus parasiluri* (Yamaguti, 1934) n. comb.
(Cestoidea: Proteocephalidae), with Notes on Four Species of the Genus
Proteocephalus, from Japanese Freshwater Fishes

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Abstract: *Paraproteocephalus parasiluri* (Yamaguti, 1934) n. comb. (= *Proteocephalus parasiluri* Yamaguti, 1934) (Cestoidea: Proteocephalidae) is redescribed and figured from the type metacestode and new adult specimens found in *Silurus asotus* (Siluridae) from Japan. Its relationship to *Paraproteocephalus parasiluri* (Zmееv, 1936) Chen in Dubinina, 1962, and related problems of homonymy and synonymy are discussed. Additional data are given on *Proteocephalus fluviatilis* Bangham, 1925, *P. midoriensis* Shimazu, 1990, *P. plecoglossi* Yamaguti, 1934, and *P. tetrastomus* (Rudolphi, 1810) Willemse, 1965, all from Japanese freshwater fishes.

Key words: *Paraproteocephalus parasiluri* (Yamaguti, 1934) n. comb., species of *Proteocephalus*, cestodes, freshwater fishes, Japan.

Yamaguti (1934) described a new cestode, *Proteocephalus parasiluri*, from *Parasilurus asotus* of Japan. I recently obtained new specimens of this cestode in Japan. Close examination of them and Yamaguti's type material revealed that the cestode should be allocated not to the genus *Proteocephalus* Weinland, 1858, but to the genus *Paraproteocephalus* Chen in Dubinina, 1962. In this paper, the species is redescribed from its type and new specimens, and related taxonomic problems are discussed.

In 1990, I published a review of species of the genus *Proteocephalus* parasitic in Japanese freshwater fishes (Shimazu, 1990). This paper also gives additional data gathered since then on some of these species.

Materials and Methods

Yamaguti's (1934) type material of

Proteocephalus parasiluri was borrowed from the collection of the Meguro Parasitological Museum (MPM), Tokyo. It consisted of the holotype and two paratypes (MPM Coll. No. 22617): the holotype and one paratype, whole-mounted worms found in the small intestine of *Parasilurus* [= *Silurus*] *asotus* (Siluridae) from Lake Ogura, Kyoto Prefecture, on 14 November 1931 and 9 February 1932, respectively (Yamaguti described the excretory system from this paratype); and the other paratype, whole-mounted and serially-sectioned fragments of various lengths of a mature strobila without the scolex found in the small intestine of *P. asotus* from the same lake on 9 November 1931 (Yamaguti lost the scolex while examining the fish). Also reexamined were two whole-mounted plerocercoids (MPM Coll. No. 22619) of *Proteocephalus* larva of Yamaguti (unpublished) found in the large intestine [= rectum] of *Mogurnda* [= *Odontobutis*] *obscura* (Gobiidae) from Lake

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Ogura on 9 June 1932 (The plerocercoids that Yamaguti [1934] obtained from the same species fish of the same lake on 14 May 1928 and 14 January 1932 have not been located); and a whole-mounted plerocercoid (MPM Coll. No. 22618) of *Proteocephalus* larva of Yamaguti (unpublished) found in the rectum of *Chaenogobius urotaenia* (Gobiidae) from Lake Ogura on 11 October 1931.

New specimens (NSMT-P1 4031 and 4033-4041) were found in fresh or formalin-preserved intestines (upper dilated part) of *S. asotus* from Lake Biwa at Ono'e, Shiga Prefecture, on 4 May 1992; and Lake Suwa in Nagano Prefecture from April 1992 to July 1993. Live worms were fixed in hot 10% formalin without flattening or AFA after flattening. Whole-mounts were stained with Delafield's hematoxylin, Borax carmine, alum carmine or Heidenhain's iron hematoxylin, and mounted in Canada balsam. Serial-sections (10 μ m thick) were stained with Delafield's hematoxylin and eosin. Eleven metacestodes (NSMT-P1 4032 and 4042-4045) were also obtained from the intestine of *Chaenogobius isaza* from Lake Biwa at Omatsu on 30 April 1992 and the rectum of *C. urotaenia* and *C. laevis* from Lake Suwa in May to September 1992. They were flattened, fixed in AFA, stained with Heidenhain's iron hematoxylin, and mounted in Canada balsam. New *Proteocephalus* specimens were treated as described above.

Measurements (length by width) are given in millimeters unless otherwise stated. Most of the new specimens are deposited in the collection of the National Science Museum, Tokyo (NSMT).

Class Cestoidea Rudolphi, 1808
Family Proteocephalidae La Rue, 1911

Genus *Paraproteocephalus* Chen in
Dubinina, 1962

Paraproteocephalus parasiluri (Yamaguti,
1934) n. comb.
(Figs. 1-13)

Proteocephalus parasiluri Yamaguti, 1934, pp. 42 and
44, fig. 67.

Description. 1) The holotype (Fig. 1), one (Fig. 2) of the paratypes and the three specimens of Yamaguti were plerocercoids, or metacestodes, without strobilation. They were 1.20-3.20 in body length. The scolex was spherical and 0.43-1.20 wide. Four suckers were rounded and 0.14-0.25 in diameter, with an oval aperture. An apical sucker, 0.09-0.13 in diameter, was present anterior to the four suckers. The other paratype will be dealt with later.

2) The eleven metacestodes from *S. asotus*, *C. isaza*, *C. laevis* and *C. urotaenia* were morphologically similar to those described above: body 1.44-3.36 long; scolex 1.02-1.76 wide; suckers 0.19-0.31 in diameter; and apical sucker 0.11-0.13 in diameter.

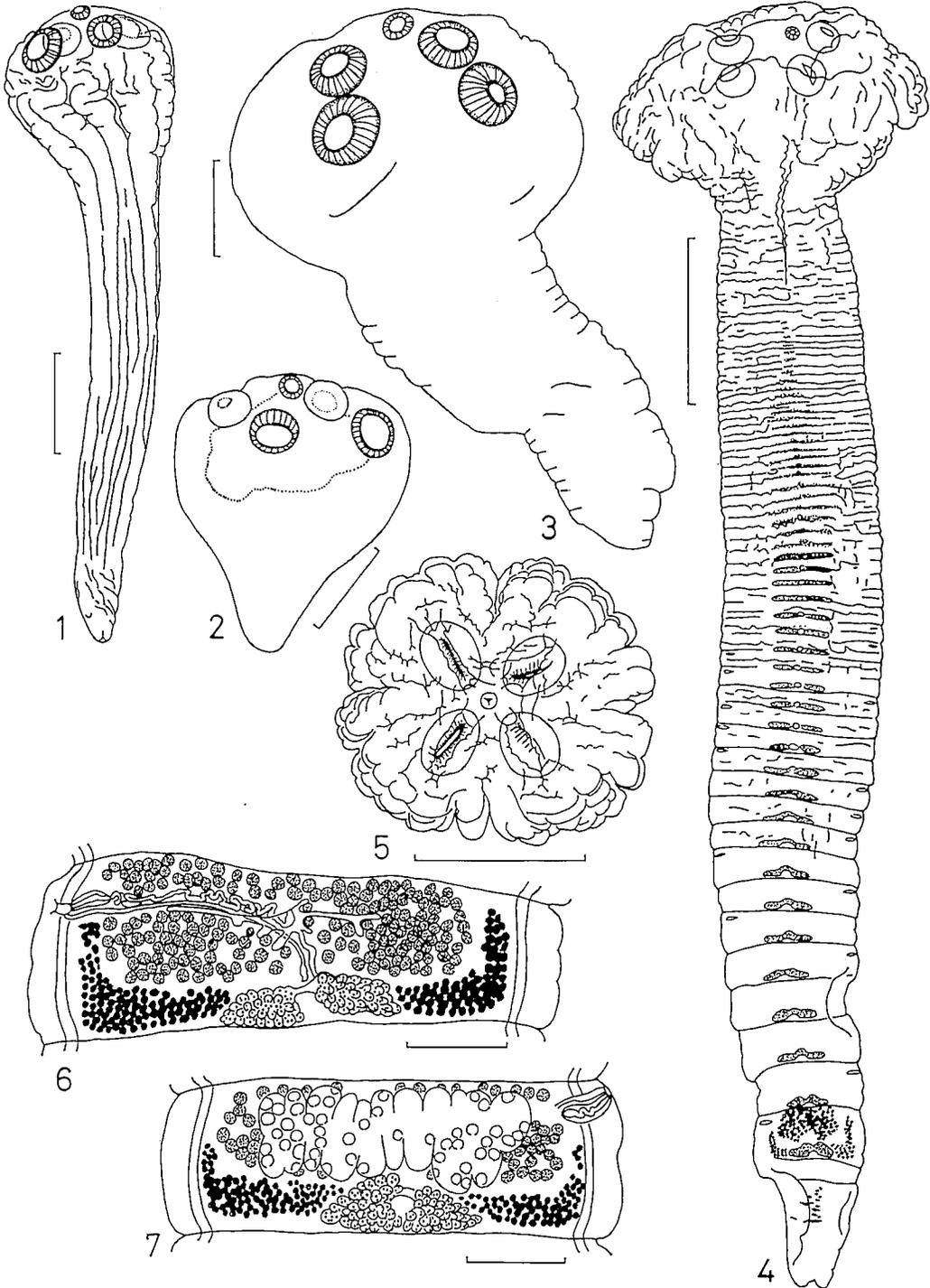
3) Two small specimens (Fig. 3), with slight strobilation, from *S. asotus* of Lake Suwa had the following measurements: body 3.04-5.60 long; scolex globose, 1.28-1.92 by 1.76-2.08; suckers 0.30-0.36 in diameter; and apical sucker 0.13-0.14 in diameter.

4) The following is a description of mature and gravid worms from *S. asotus* of Lake Suwa (Fig. 4-13).

Body having ridges and irregular wrinkles.

Figs. 1-7. *Paraproteocephalus parasiluri* (Yamaguti, 1934) n. comb. 1 and 2: Holotype and paratype of *Proteocephalus parasiluri* Yamaguti, 1934, metacestodes (MPM Coll. No. 22617) from *Silurus asotus* of Lake Ogura, Kyoto Prefecture. 3: Metacestode from *S. asotus* of Lake Suwa, Nagano Prefecture. 4-7: Mature and gravid worms from *S. asotus* of Lake Suwa. 4: Entire body of a mature worm, fixed in hot formalin. 5: Scolex of another mature worm fixed in hot formalin, apical view. 6: Mature proglottid, flattened, ventral view. 7: Gravid proglottid, flattened, not all testes figured, ventral view.

(Scale bars: 2 mm in Fig. 4; 1 mm in Fig. 5; 0.5 mm in Fig. 1-3, 6 and 7.)



Scolex globose, rather flattened anterotermally, bearing 4 large and several smaller longitudinal ridges; metascolex well developed; 4 suckers spherical, directed anteriorly in central field of scolex; apical sucker anterior to them. Neck indistinct. Strobila acraspedote, anapolytic; proglottids increasing in length but decreasing in width with growth, numbering up to 80. In mature specimens fixed in hot formalin, body up to 27 by 3; scolex 1.60-1.92 by 2.00-

4.56; suckers 0.38-0.69 in diameter; apical sucker 0.11-0.22 in diameter, ratio of sucker diameter to apical sucker diameter 1: 0.26-0.45; immature proglottids much wider than long, slightly wider than others; mature proglottids 0.51-1.12 by 1.44-2.56, ratio of width to length 1: 0.23-0.77. In 1 gravid specimen obtained from a formalin-preserved intestine, body up to 29 by 3; mature proglottids 0.40-0.48 by 2.97-3.09, ratio of width to length 1:

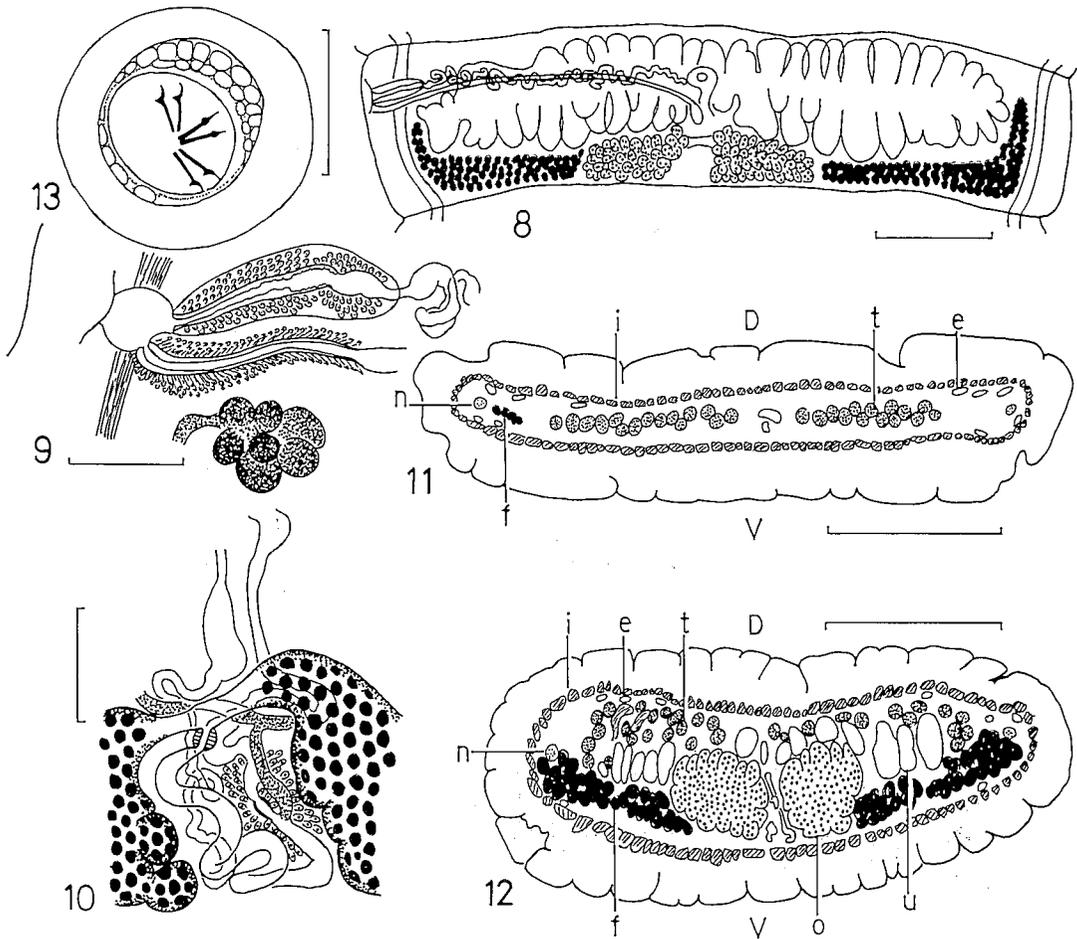


Fig. 8-13. *Paraproteocephalus parasiluri* (continued). 8-10: Gravid proglottid, its terminal genitalia and ootype-complex, flattened, ventral view. 11: Transverse section of a mature proglottid (e, longitudinal excretory canals; f, vitelline follicles; i, inner longitudinal muscle sheath; n, nerve trunk; t, testes; D, dorsal; V, ventral). 12: Transverse section of a gravid proglottid (o, ovary; u, uterus; others as in Fig. 11). 13: Fully-embryonated egg.

(Scale bars: 0.5 mm in Figs. 8, 11 and 12; 0.1 mm in Figs. 9 and 10; 0.02 mm in Fig. 13.)

0.13-0.16; gravid proglottids 0.67-0.96 by 2.27-2.88, ratio of width to length 1: 0.26-0.42. Inner longitudinal muscle sheath well developed. Excretory system not worked out; at least 2 ventral and 3 dorsal pairs of longitudinal excretory canals seen beneath inner longitudinal muscle sheath. A large nerve trunk in lateral medullary region on each side of body.

Testes globular, 142-218 per proglottid, 0.05-0.07 in diameter in mature and gravid proglottids, distributed anterior to ovary and vitellaria in almost 1 frontal layer in medullary region. Vas deferens ventral to testes, forming a compact transverse tangle of loops reaching to median line, containing sperm as an external seminal vesicle. Cirrus pouch elongate-claviform or -pyriform, thick-walled, 0.21-0.35 by 0.06-0.09, lying almost transversely slightly beyond inner longitudinal muscle sheath, occupying 10-14% of proglottid width in mature and gravid proglottids. Internal seminal vesicle slightly sinuous, usually containing no sperm but rarely expanded to contain sperm, occupying about 30% of cirrus pouch length; border between ejaculatory duct and cirrus indistinct; ejaculatory duct and cirrus straight in flattened specimens but somewhat undulating in unflattened specimens, occupying about 70% of cirrus pouch length; cirrus aspinose, slightly protrusible. Genital atrium small. Genital pore irregularly alternating, located marginally about junction of first and second quarter of proglottid. Genital papilla absent. Ovary transversely elongate-triangular, bilobed, increasing in length but decreasing in width with proglottid growth, 0.19-0.40 by 0.40-1.28, ratio of width to length 1: 0.15-1.00; each lobe further multilobulated, with lobules of 0.04-0.06 in diameter. Ootype-complex behind ovarian isthmus. Distal portion of vagina slender, muscular, surrounded by a massive glandular lining, not ciliated internally, slightly shorter than cirrus pouch, opening anterior or posterior to cirrus pore, without sphincter; proximal portion of vagina slender, surrounded by a much thinner glandular lining, running ventral to and parallel with vas deferens to near median line and then

turning backward to near ovarian isthmus; seminal receptacle oblong, 0.09-0.13 by 0.04, in front of ovarian isthmus; seminal canal long. Uterus T-shaped, ventral to vagina; median longitudinal stem canalicular; transverse uterus proper dilated, with 22-27 anterior and posterior blind diverticula on either side and 1 uterine pore. In fully-embryonated eggs, external hyaline membrane of egg thin, globular, jagged or smooth in outline, 27-35 μm in diameter; middle membrane globular, thick, granular, 18-21 μm in diameter; oncosphere 13-18 μm in diameter; embryonic hooks 6-8 (blade 2-3; rod 4-6) μm long. Vitelline follicles distributed in a band curved at right angles on each side of medullary region; transverse arm anterolateral and lateral to ovary; longitudinal arm extending to midlevel of proglottid or slightly anterior to it, not reaching anterior border of proglottid, rarely with a few follicles present in front of cirrus pouch.

Discussion. These new specimens were in various degrees of development from metacestode to fully-gravid adult with eggs. The 11 metacestodes morphologically resembled Yamaguti's specimens. The two small specimens from *S. asotus* of Lake Suwa showed a slight strobilation. From the morphological view of point, I regard all of them as belonging to a single species, *Proteocephalus parasiluri* Yamaguti, 1934, in spite of the lack of any experimental evidence. Yamaguti (1934) failed to obtain adults by feeding metacestodes to *P. asotus*.

Yamaguti (1934, pp. 42-44, figs. 68-72) adequately described and figured the other paratype in his description of *P. parasiluri* (see Shimazu, 1990). However, the present study showed that it differs in morphology from the new material and that it should be identified as *Gangesia parasiluri* Yamaguti, 1934 (Proteocephalidae), which was described also from *P. asotus* taken in Lake Ogura (Yamaguti, 1934). Morphologically, it agreed well with the type material of *G. parasiluri* (the holotype, MPM Coll. No. 22793, a whole-mounted gravid worm found in the small intestine of *P. asotus* from

Table 1. Comparison between *Paraproteocephalus parasiluri* (Yamaguti, 1934) n. comb. (= *Proteocephalus parasiluri* Yamaguti, 1934) and *Paraproteocephalus parasiluri* (Zmееv, 1936) Chen in Dubinina, 1962 (= *Corallobothrium parasiluri* Zmееv, 1936)

Species	<i>Proteocephalus parasiluri</i>		<i>Corallobothrium parasiluri</i>	
	Yamaguti (1934) ¹⁾ (Japan)	This paper (Japan)	Chen (1984) (China)	Freze (1965) (Russia)
Shape and extent of vas deferens	————	Forming a compact transverse tangle of loops extending to median line	Forming a compact transverse tangle of loops extending to median line	Forming a much larger tangle of loops confined to lateral half of poral part of proglottid
Number of testes per proglottid	————	142-218	260-280 ²⁾	160-200 ³⁾ 190-240 ⁴⁾
Number of longitudinal excretory canals	1 ventral and 1 dorsal pair of main canals	At least 2 ventral and 3 dorsal pairs of canals	1 pair of main dorsal canals and 3-4 smaller canals distributed irregularly	14-16 canals on each side of body

¹⁾In a metacestode (others in adults).

²⁾This is somewhat doubtful (Freze, 1965).

³⁾In the material from *Parasilurus asotus*.

⁴⁾In the material from *Silurus soldatovi*.

[Ainoki-mura, Nakaniikawa-gun.] Toyama Prefecture on 29 October 1929; and the paratype, MPM Coll. No. 22794, a whole-mounted immature worm found in the small intestine of *P. asotus* from Lake Ogura on 14 November 1931). Consequently, the specimen must be excluded from the type series of *P. parasiluri*.

Proteocephalus parasiluri is characterized by the shape of the scolex with a well-developed metascolex, presence of four suckers and one apical sucker, shape and position of the transversely elongated uterus with anterior and posterior diverticula and one pore, and shape and position of the vitelline bands. Because of these features, the species should be transferred from the genus *Proteocephalus* Weinland, 1858, to the genus *Paraproteocephalus* Chen in Dubinina, 1962, as *Paraproteocephalus parasiluri* (Yamaguti, 1934) n. comb.

The genus *Paraproteocephalus* was erected by Chen with *Corallobothrium parasiluri* Zmееv, 1936, as the type and so far sole species. Chen's paper had been cited by Dubinina (1962) long

before its publication in 1984. The generic diagnosis originally proposed by Chen (see Chen, 1984) was emended by Dubinina (1962, 1987) and Freze (1965). The type species *C. parasiluri*, or *Paraproteocephalus parasiluri* (Zmееv, 1936) Chen in Dubinina, 1962, was briefly described by Zmееv (1936) from the intestine of *P. asotus* of the Amur basin, Russia. Chen (1984) described the specimens, whose morphology Chen created the new genus from, found in *P. asotus*, *S. soldatovi*, *P. asotus* × *S. soldatovi* and *Ophiocephalus argus* (Ophiocephalidae) from the Liao River at Haicheng-Niuzhuang and Taian-Changtou, Liaoning, China. Chen also obtained metacestodes, which are similar to the present metacestode, from the intestine of several species of fishes. Dubinina (1962) gave a specific diagnosis based chiefly on Chen's description with a few modifications. Freze (1965) described the material from *P. asotus* and *S. soldatovi* from the Amur basin. Dubinina (1987) presented another specific diagnosis based chiefly on Freze's description. These

descriptions and specific diagnoses are different in morphology and measurements from one another, as will be discussed later. The original specimens of Zmeev (1936), Freze (1965) and Chen (1984) need reexamination.

Proteocephalus parasiluri Yamaguti, 1934, and *Corallobothrium parasiluri* Zmeev, 1936, are very similar in morphology and have similar hosts. It seems almost certain that they are synonymous. However, based on the published descriptions, there are some differences between them in the shape and extent of the vas deferens, number of the testes per proglottid, and number of the longitudinal excretory canals (Table. 1). The two species are provisionally retained as distinct pending clarification of their supposed differences through reexamination of the Russian and Chinese specimens. If they are ultimately shown to be identical, then *Paraproteocephalus parasiluri* (Zmeev, 1936) Chen in Dubinina, 1962, would become a junior synonym, as well as a junior secondary homonym, of *P. parasiluri* (Yamaguti, 1934) n. comb. The latter name and authorship would then be applied to the type species of the genus *Paraproteocephalus*. However, if they prove to be distinct species within this genus, then *P. parasiluri* (Zmeev, 1936), the type species by original designation, would have to be given a new replacement name, because it is a junior secondary homonym of *P. parasiluri* (Yamaguti, 1934).

Notes on Japanese Species of the Genus *Proteocephalus* Weinland, 1858

1) *Proteocephalus fluviatilis* Bangham, 1925

In Japan, this species was first found in *Micropterus salmoides* (Centrarchidae) from Lake Kizaki in Oomachi, Nagano Prefecture, in 1989 (Shimazu, 1990). It has not been recorded since then either from this lake or from other parts of Japan. The route of introduction of the cestode from North America to Lake Kizaki is still unknown.

2) *Proteocephalus midoriensis* Shimazu, 1990

The natural bed of the small stream, the type locality of this species, at Midori, Iiyama, Nagano Prefecture, was altered to a U-shaped concrete bed in the summer of 1991. Because of this, the host fish *Lefua echigonia* (Homalopteridae) can no longer live in the new stream. Fortunately, the cestode was found in *L. echigonia* caught in other nearby streams (23 June 1992, NSMT-PI 4046).

3) *Proteocephalus plecoglossi* Yamaguti, 1934

A large number of specimens (NSMT-PI 4047) of this species were found in *Plecoglossus altivelis* (Plecoglossidae) from Lake Biwa at Omatsu in April and May 1992. Several immature and mature worms were also obtained from *Chaenogobius isaza* (Gobiidae) (Omatsu, 30 April and 1 May 1992, NSMT-PI 4032 and 4048), *Cottus reinii* (Cottidae) (Omatsu, 30 April 1992, NSMT-PI 4049), *Hemibarbus barbus* (Cyprinidae) (Moriyama, 2 May 1992, NSMT-PI 4050), and *Lepomis macrochirus* (Centrarchidae) (Omatsu, 29 April 1992, NSMT-PI 4051).

The following is a brief description based on whole-mounted and serially-sectioned gravid specimens, which were found in *P. altivelis* and fixed in hot formalin, to supplement the descriptions by Yamaguti (1934), Kataoka and Momma (1932, 1933), and Shimazu (1990).

Body measuring up to 36 by 1. Scolex 0.38-0.48 wide; neck 2.48-3.68 long. Suckers 0.13-0.15 in diameter; apical sucker 0.05-0.07 in diameter; ratio of sucker diameter to apical sucker diameter 1 : 0.33-0.48. Proglottids gradually increasing in length but decreasing in width with growth, numbering up to 120; immature proglottids much wider than long, slightly wider than others; mature proglottids 0.27-0.61 by 0.69-1.01, ratio of width to length 1 : 0.27-0.83; gravid proglottids 0.42-1.12 by 0.59-1.08, ratio of width to length 1 : 0.40-1.67. Testes 51-103 per proglottid. Cirrus pouch 0.16-0.25 by 0.06-0.09, occupying 19-34% of proglottid width in mature and gravid proglottids. Uterus having 5-9 lateral diverticula on each

side, some of them further forked; uterine pores 2 or 3. In fully-embryonated eggs, external membrane measuring 80-144 μm in diameter; middle membrane 27-37 μm in diameter; oncosphere 16-25 μm in diameter; and embryonic hooks 9-11 (blade 2-4; rod about 7) μm long.

Shimazu (1990) concluded that the species is valid, differing from *P. neglectus* La Rue, 1911, in morphology and geographical distribution. Hanzelová and Scholz (1992) described *P. neglectus* from several lots of specimens, including the one that they designated as the lectotype, from Europe. These specimens demonstrated the existence of a wide biometrical and morphological variation in the species. It seems to me that *P. plecoglossi* is still distinguishable from *P. neglectus* by having more testes, a smaller vaginal sphincter, a smaller oncosphere, and smaller embryonic hooks (see also Shimazu, 1990).

4) *Proteocephalus tetrastomus* (Rudolphi, 1810) Willemse, 1965

In Japan, this cestode was first recorded from the intestine of *Hypomesus nipponensis* (Osmertiidae) from Lake Suwa in 1983 (Shimazu, 1990). It still abounds in this fish there (9 April 1992, NSMT-P1 4053). It was found in the intestine of *S. asotus* (9 April 1992 and 24 April 1993, NSMT-P1 4054 and 4055); and the pyloric ceca and intestine of "ame," the lake type of *Oncorhynchus masou macrostomus* (Salmonidae) (24 July 1993, NSMT-P1 4056), both from this lake. Evidently, these fishes acquire infection of the cestode by feeding on *H. nipponensis* harboring it. The species was found in *H. nipponensis* (3 September 1991, NSMT-P1 4052), but not in *H. olidus*, both collected in Lake Toro, Shibechea, Hokkaido.

Lakes Abashiri and Toro in Hokkaido (see also Shimazu, 1990) are considered natural areas of occurrence both for *H. nipponensis* and for *P. tetrastomus*. Naturally, *H. nipponensis* was not distributed in Lake Suwa. The fish was frequently introduced to this lake from Kasumigaura, a natural area of occurrence for this fish, in Ibaraki Prefecture since 1914. I

found no worms of *P. tetrastomus* in 77 *H. nipponensis* (52-103 mm in body length) caught in Kasumigaura on 20 September 1993. The cestode may have been introduced to Lake Suwa from Lake Abashiri by accident about ten years ago. The Fisheries Cooperative Association of Lake Suwa stocked Lake Suwa with a huge number of *H. nipponensis* eggs from Lake Abashiri every spring of the years from 1982 to 1989. The eggs were squeezed out of ripe fish collected in Lake Abashiri at Abashiki and carried in a container to Lake Suwa. It is conceivable that, together with the fish eggs, eggs of the cestode were also pressed out of infected fish and brought into Lake Suwa once or twice during the period. The first specimens of the cestode that I obtained were found in *H. nipponensis* from Lake Suwa on 19 December 1983 (Shimazu, 1990). Possibly, the cestode was introduced to Lake Ashinoko in Kanagawa Prefecture (see Shimazu, 1990) in the same manner from Lake Suwa or Lake Abashiri or the both.

I examined 73 *H. nipponensis* (46-86 mm in body length) caught in Lake Shinji, a natural area of occurrence for the fish, in Shimane Prefecture on 29 September 1993, but they were all negative for *P. tetrastomus*.

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