

A New Species of the Genus *Orobdella* (Hirudinida: Arhynchobdellida: Gastrostomobdellidae) from Kumamoto, Japan, and a Redescription of *O. whitmani* with the Designation of the Lectotype

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Orobdella whitmani has three syntype localities, Mt. Kinkazan, Gifu Pref., Mt. Kodaijiyama, Kyoto Pref. and Mt. Kimposan, Kumamoto Pref. The specimens from Mt. Kimposan can be distinguished from those from Mt. Kinkazan and Mt. Kodaijiyama by an annulation of somite XXVI, and possession of a tubular gastroporal duct. Specimens from Mt. Kimposan are described as representing a new species, *Orobdella esulcata*. *Orobdella whitmani* is redescribed with designation of a specimen from Mt. Kinkazan deposited at The University Museum, The University of Tokyo, as the lectotype.

Key words: Hirudinida, Gastrostomobdellidae, *Orobdella whitmani*, new species, gastroporous, Japan

INTRODUCTION

The genus *Orobdella* was described by Oka (1895) without designating the type species. Oka (1895) described three new species of *Orobdella*, *Orobdella whitmani* Oka, 1895, *Orobdella ijimai* Oka, 1895 and *Orobdella octonaria* Oka, 1895, from various localities in Japan. Soós (1966) subsequently designated *O. whitmani* as the type species by “position precedence” (Richardson, 1971, 1975). Oka (1895, 1910a, b, 1935) and Soós (1966) placed it in the family Erpobdellidae. Richardson (1971) examined a specimen of *O. octonaria*, and found that this species had a gastropore and a gastroporal duct. He also described a new gastroporous species, *Orobdella kawakatsuorum* Richardson, 1975, from Hokkaido, Japan (Richardson, 1975). He placed the genus *Orobdella* in the family Gastrostomobdellidae Richardson, 1971, based on the gastropore and gastroporal duct (Richardson, 1971, 1975). Later, Sawyer (1986) classified this taxon as the subfamily Gastrostomobdellinae Richardson, 1971, belonging to the family Cylicobdellidae Ringuélet, 1972.

Oka (1895) described *Orobdella whitmani* based on a limited number of features, mainly in external morphology, based on 18 specimens from three localities: Mt. Kinkazan, Gifu Pref. (Kinkwazan near Gifu in his paper); Mt. Kodaijiyama, Kyoto Pref. (Chi-on-in in Kiōto); Mt. Kimposan, Kumamoto Pref. (Kibōzan near Kumamoto) (Fig. 1). He did not designate a holotype. Therefore, all of the 18 specimens are automatically its syntypes, in accordance with Article 73.2 of the International Code of Zoological Nomenclature

(International Commission on Zoological Nomenclature, 1999). Oka's leech collection, formerly kept at the Tokyo University of Education (Richardson, 1971), is now deposited at the National Museum of Nature and Science, Tokyo (Komatsu, personal communication). In addition, a part of his leech collection has been also stored at The University Museum, The University of Tokyo (Itoh, personal communication). I surveyed his collection at both museums and found eight syntypes of *O. whitmani* from Mt. Kinkazan, Gifu Pref., stored at The University Museum, The University of Tokyo.

In addition, I collected specimens of *O. whitmani* from three syntype localities during my revisional survey of leeches described by Oka. After morphological examination of these specimens and syntypes of *O. whitmani*, I found that the supposed topotypes of *O. whitmani* from Mt. Kimposan were different from those from two other type localities, Mt. Kinkazan, and Mt. Kodaijiyama, and syntypes in several features. Herein I designate a lectotype for *O. whitmani* for the purpose of clarifying its type locality. I further redescribe *O. whitmani* and describe a new terrestrial quadrannulate species from Mt. Kimposan.

MATERIALS AND METHODS

In addition to Oka's specimens, leeches were collected from three syntype localities of *Orobdella whitmani*: Mt. Kinkazan, Gifu Pref.; Mt. Kodaijiyama behind Chion-in Temple, Kyoto Pref.; Mt. Kimposan, Kumamoto Pref. (Fig. 1). These were found under rocks along forest or mountain trails. They were also found crawling on the ground or preying upon earthworms, especially at night. Altitudes and coordinates for localities were obtained using a Garmin eTrex GPS unit.

Specimens were relaxed with the gradual addition of 95% ethanol, and botryoidal tissue was taken from every specimen for DNA extraction. Then specimens were fixed by 10% formalin for dissec-

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tion and preserved in 70% ethanol. Two body measurements were taken: body length, from the anterior margin of oral sucker to the posterior margin of caudal sucker (BL), and maximum body width (BW). Examination, dissection, and drawing of the specimens were accomplished under a stereoscopic microscope (LEICA S6E and

WILD HEERBRUGG TYP 308700).

The lectotype and paralectotypes of *O. whitmani* have been deposited in the Department of Zoology, The University Museum, The University of Tokyo (UMUTZ). The other specimens have been stored in the Zoological Collection of the Kyoto University Museum (KUZ).

I also examined two specimens of *Orobdella kawakatsuorum* for comparison: NSMT-An 53, holotype, deposited at the National Museum of Nature and Science, Tokyo (NSMT); KUZ Z24, dissected, collected from the Maruyamakoen Park, Chuo-ku, Sapporo-shi, Hokkaido Pref., Japan, by Naoyuki Nakahama on July 14, 2009.

Numbering conventions are those traditionally used for leeches: 1) body somites are denoted by roman numerals; and 2) annuli in each somite are given alphanumeric designation.

Abbreviations used in the figures are as follows: ac, atrial cornu; an, anus; at, atrium; cod, common oviduct; cp, crop; ep, epididymis; fp, female gonopore; gd, gastroporal duct; gp, gastropore; mp, male gonopore; np, nephridiopore; o, ovisac; od, oviduct; ph, pharynx; t, testisac.

SYSTEMATICS

Family Gastrostomobdellidae
Richardson, 1971

Genus *Orobdella* Oka, 1895

Emended diagnosis

Annulation variable (complete quadr-, sex- or octannulate); pharynx terminating in XIV; gastropore median ventrally in XIII a1, or absent; gastroporal duct single, joining with crop in XIV, or absent; nephridiopores variable, 17–20 pairs; male gonopore at last annulus of XI; female gonopore at first annulus of XIII, or in XIII a1/a2; gonopores separated by one full somite; testisacs multiple per somite; male median reproductive system being weakly muscularized atrium with atrial cornua (erobodelloid), without penis sheath or penis, or essentially lacking (micromorphic); ovisacs globular, in XIII; oviducts short, converging into common oviduct or independently into female gonopore; female median reproductive system essentially lacking (micromorphic).

Type species

Orobdella whitmani Oka, 1895

Additional species

Orobdella esulcata sp. nov.

Orobdella ijimai Oka, 1895

Orobdella kawakatsuorum

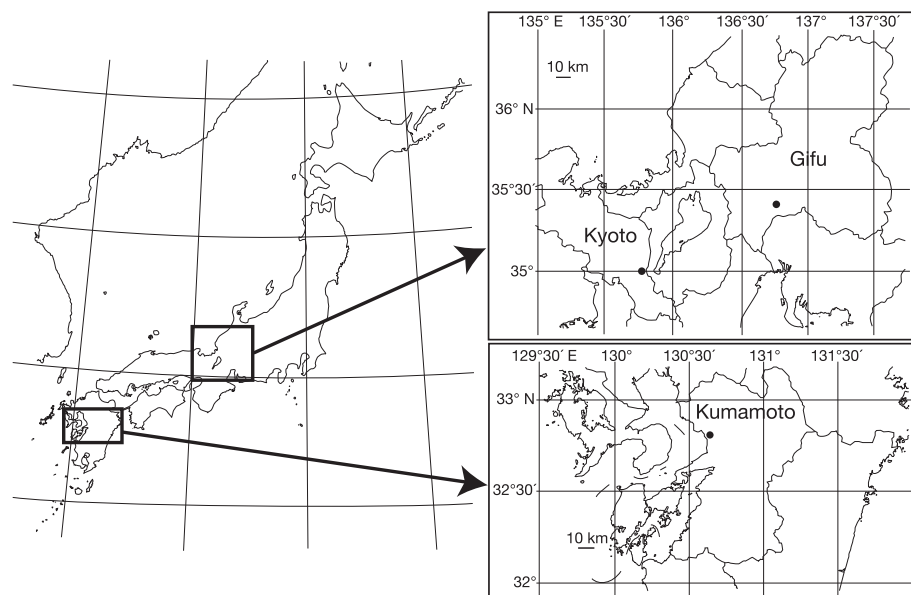


Fig. 1. Location of three syntype localities of *Orobdella whitmani*.

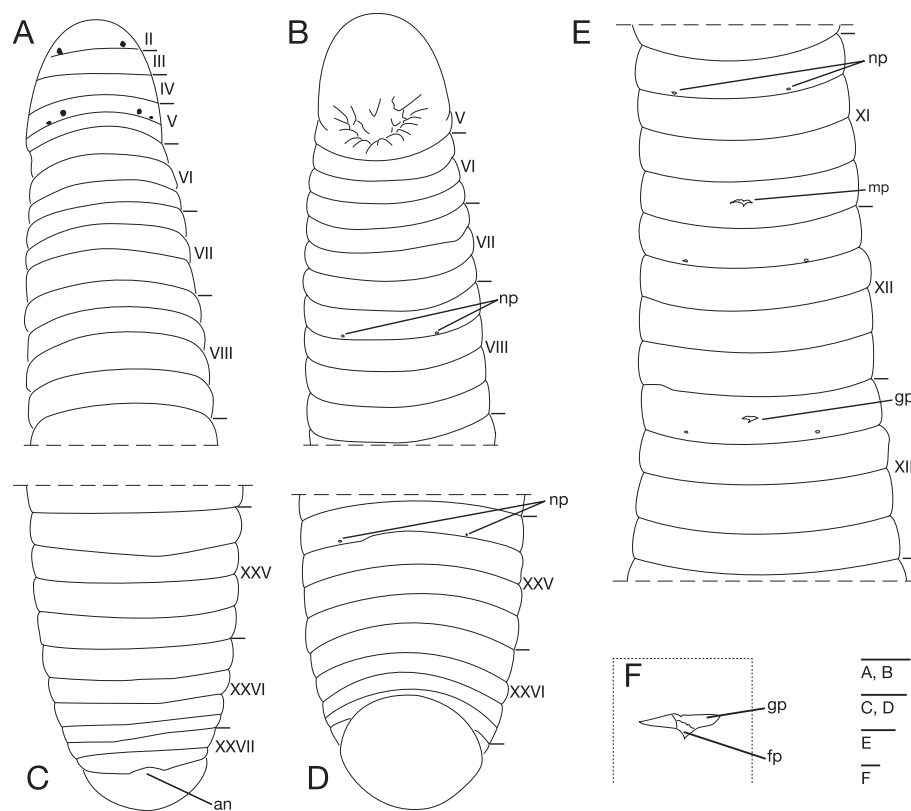


Fig. 2. *Orobdella whitmani*, lectotype, UMUTZ-Ann-Hir-5-1. (A) Dorsal, and (B) ventral views of somites I–VIII. (C) Dorsal and (D) ventral views of somites XXV–XXVII and caudal sucker. (E) Ventral view of somites XI–XIII. (F) Ventral view of gastropore and female gonopore. Scale bars, 1 mm (A–E), 0.25 mm (F).

Richardson, 1975
Orobdella octonaria Oka, 1895

Orobdella whitmani Oka, 1895
 (Japanese name: *yotsuwa-kugabiru*)
 (Figs. 2, 3, 4)

Orobdella whitmani Oka, 1895: 282–284 (in part), pl. 28, figs. 1, 4–8, pl. 29, fig. A, pl. 30, figs. 1, 3–4; Oka, 1935: 240; Soós, 1966: 377, 397; Gilyarov et al., 1969: 235–237; Richardson, 1971: 599–600; Sawyer, 1986, 680, 747.

Diagnosis

In life, dorsal surface yellowish green, ventral surface

whitish yellow; somite III uniannulate; somite IV uniannulate or biannulate; somites VII–XXV complete quadrannulate; somite XVI quadrannulate, annular furrow of b5/b6 developed; gastropore conspicuous at XIII a1; gastroporal duct muscular, bulbiform, tortuous at junction with gastropore; male gonopore at XI b6 (posterior); female gonopore inconspicuous at XIII a1, behind gastropore; gonopores separated by $1/3 + 4 + 2/3$ annuli.

Designation of lectotype

Eight syntypes deposited in UMUTZ consist of five dissected specimens and three non-dissected specimens. They are labeled '*Orobdella whitmanii* Oka', 'type specimen', 'Gifu' and 'Nawa'. Oka (1895) stated that the specimens from Gifu were collected at Mt. Kinkazan, Gifu, by Nawa in the original description of *O. whitmani*. 'Nawa' may indicate Yasushi Nawa (1857–1926), Japanese entomologist active in Gifu Pref.

I chose UMUTZ-Ann-Hir-5-1, one of the eight syntypes of *Orobdella whitmani* from Mt. Kinkazan, Gifu Pref., as its lectotype. However, the lectotype and all paralectotypes are immature specimens. It was additionally very difficult to dissect these syntypes, due to the fragility of their internal organs. Therefore, I gave up newly dissecting the syntypes.

Lectotype

UMUTZ-Ann-Hir-5-1, immature specimen of 55.9 mm length, dissected partially, collected from Mt. Kinkazan, Gifu-shi, Gifu Pref., Japan, by Yasushi Nawa, date unknown.

Paralectotype

UMUTZ-Ann-Hir-5-2, -5-3, -5-4, dissected, lacking from somite XIV to caudal sucker, -5-5, dissected, lacking from somite I to somite XI b5 and somite XXIV to caudal sucker, -5-6, dissected, lacking from somite I to somite X a1, -5-7, dissected, lacking from somite I to somite XVII a1, -5-8, dissected, collected from the type locality, Mt. Kinkazan, Gifu-shi, Gifu Pref., Japan, by Yasushi Nawa, date unknown.

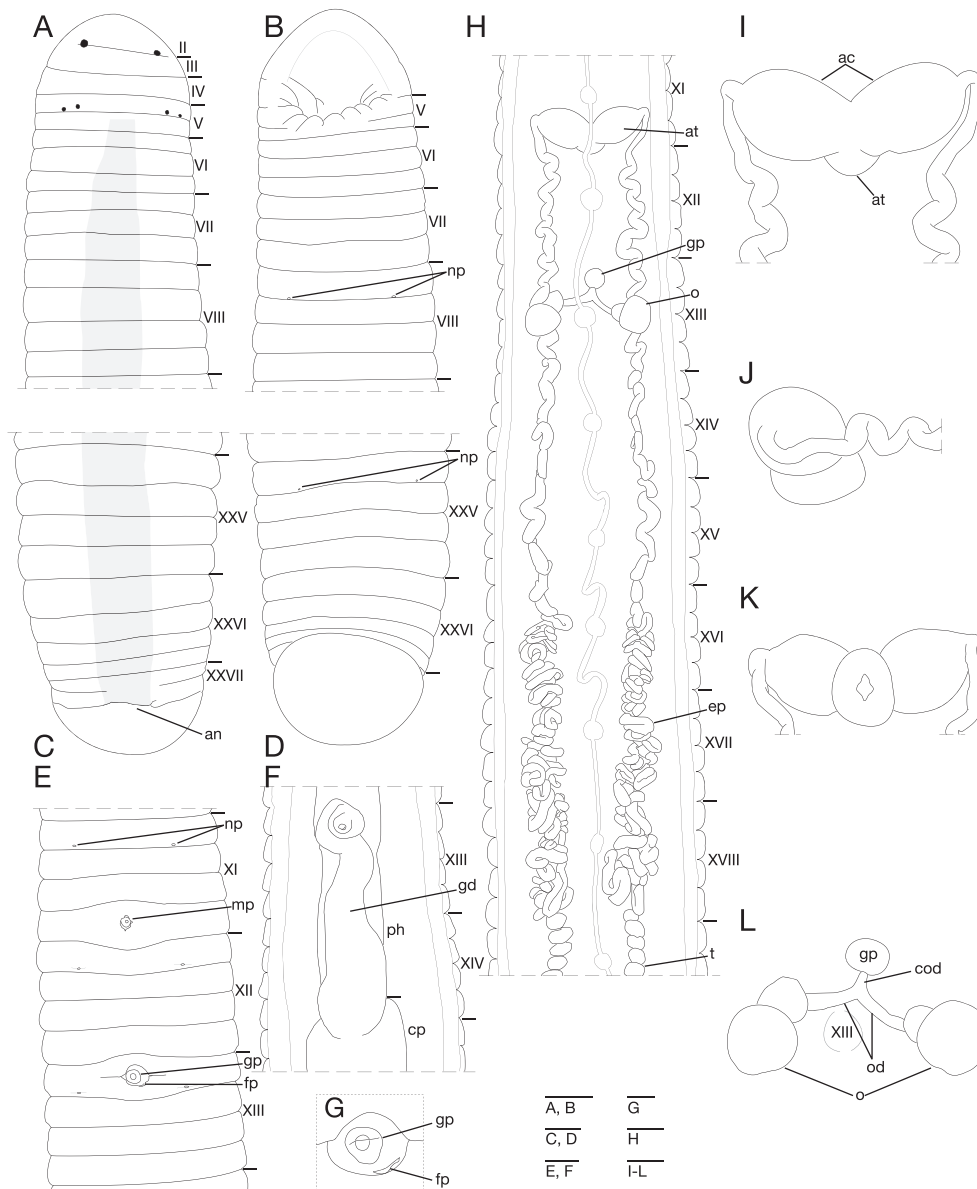


Fig. 3. *Orobdella whitmani*, KUZ Z45, from the type locality. (A) Dorsal, and (B) ventral views of somites I–VIII. (C) Dorsal and (D) ventral views of somites XXV–XXVII and caudal sucker. (E) Ventral view of somites XI–XIII. (F) Ventral view of gastroporal duct. (G) Ventral view of gastropore and female gonopore. (H) Dorsal view of reproductive system including ventral nervous system. (I) Dorsal, (J) lateral, (K) ventral views of male atrium. (L) Dorsal view of female reproductive system including position of ganglion XIII. Scale bars, 1 mm (A–F, H), 0.5 mm (I–L), 0.25 mm (G).

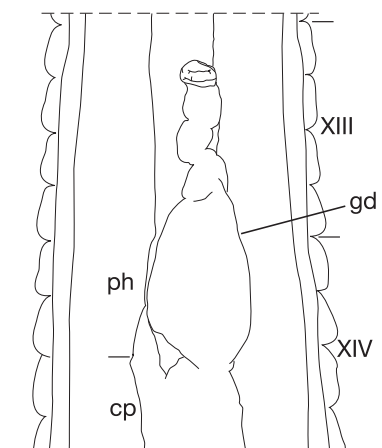


Fig. 4. Ventral view of gastroporal duct of *Orobdella whitmani*, KUZ Z39, from Mt. Kodaijyama, Kyoto Pref. Scale bar, 1 mm.

Additional materials

A total of 25 specimens, 13 specimens collected from the type locality, Mt. Kinkazan in Gifu-shi, Gifu Pref., Japan. Six specimens: KUZ Z18, Z19 (alt. 81 m, 35°25'40"N, 136°46'55"E), KUZ Z20 (alt. 81 m, 35°25'40"N, 136°46'53"E), KUZ Z21, Z22 (alt. 78 m, 35°25'40"N, 136°46'53"E), dissected, KUZ Z23 (alt. 71 m, 35°25'40"N, 136°46'53"E), from under a rock by Takafumi Nakano on 10 June 2009; KUZ Z25, dissected, from under the rock (alt. 35 m, 35°25'40"N, 136°46'54"E), by Keiko Tsubokawa on 18 June 2009; two specimens: KUZ Z26 from under a rock (alt. 88 m, 35°25'39"N, 136°46'46"E), KUZ Z27, dissected, from under a rock (alt. 30 m, 35°25'40"N, 136°46'54"E) by Takafumi Nakano on 20 July 2009; four specimens: KUZ Z43 (alt. 59 m, 35°25'38"N, 136°46'55"E), KUZ Z44 (alt. 59 m, 35°25'39"N, 136°46'54"E), KUZ Z46 (alt. 9 m, 35°25'58"N, 136°46'25"E), from under a rock, KUZ Z45, dissected, from beneath rubbish (alt. 58 m, 35°25'39"N, 136°46'54"E), by Takafumi Nakano on 12 December 2009. The other 12 specimens collected from under a rock at Mt. Kodaijyama, Higashiyama-ku, Kyoto-shi, Kyoto Pref., Japan, by Takafumi Nakano. Three specimens: KUZ Z33, Z34 (alt. 103 m, 35°00'14"N, 135°47'08"E), KUZ Z39 (alt. 109 m, 35°00'14"N, 135°47'09"E), dissected, on 10 November 2009; four specimens: KUZ Z35, Z36 (alt. 104 m, 35°00'15"N, 135°47'07"E), KUZ Z37 (alt. 103 m, 35°00'14"N, 135°47'08"E), KUZ Z38 (alt. 103 m, 35°00'14"N, 135°47'08"E), dissected, on 2 November 2009; two specimens: KUZ Z40 (alt. 108 m, 35°00'15"N, 135°47'08"E), dissected, KUZ Z47 (alt. 88 m, 35°00'15"N, 135°47'08"E), on 3 December 2009; two specimens: KUZ Z41 (alt. 108 m, 35°00'15"N, 135°47'08"E), dissected, KUZ Z42 (alt. 106 m, 35°00'14"N, 135°47'07"E), on 11 December 2009; KUZ Z50 (alt. 100m, 35°00'13"N, 135°47'08"E), dissected, on 20 January 2010.

Description of lectotype

Body firm, muscular, elongated, BL 55.9 mm, BW 5.0 mm; caudal sucker ventral, oval, in diameter as large as maximum body width (Fig. 2D); in life, color unknown; color faded in preservative.

Somite I completely merged with prostomium (Fig. 2A);

somite II uniannulate, slightly separated from I (Fig. 2A); somite III–IV uniannulate (Fig. 2A); somite V biannulate, a3 forming posterior margin of oral sucker (Fig. 2A, B); somites VI–VII complete triannulate (Fig. 2A, B); somites VIII–XXV complete quadrannulate, a1 = a2 = b5 = b6 (Fig. 2A–E); somite XXVI quadrannulate, a1 > a2 > b5 = b6, annular furrow of b5/b6 slightly developed, b6 the last fully formed annulus on the venter (Fig. 2C, D); somite XXVII biannulate (Fig. 2C); anus behind XXVII (Fig. 2C); post-anal annulus absent (Fig. 2C).

Eyes three pairs, first pair dorsally on posterior margin of II, second and third pairs dorsolaterally on posterior margin of V (a1 + a2) (Fig. 2A); nephridiopores 18 pairs, ventrally at posterior margin of a1 of each somite, at VIII–XXV (Fig. 2B, D, E); papillae numerous, minute, hardly visible, one row on every annulus.

Pharynx agnathous, euthylaematous; gastropore conspicuous, ventrally at middle of XIII a1 (Fig. 2E, F).

Male gonopore at middle of XI b6 (Fig. 2E); female gonopore at XIII a1, inconspicuous, diagonally behind gastropore (Fig. 2F); gonopores separated by 1/2 + 4 + 1/2 annuli (Fig. 2E).

Description of additional materials

Maximum BL 107.15 mm (KUZ Z41), maximum BW 6.8 mm (KUZ Z41); in life, color variable, generally yellowish, dorsal surface darker than ventral; color faded in preservative median black line present thorough dorsal surface.

Somite III uniannulate (Fig. 3A) or rarely biannulate (KUZ Z41); somite IV uniannulate or biannulate (a1 + a2) >> a3 (Fig. 3A); somite V biannulate, a3 forming posterior margin of oral sucker (Fig. 3A, B).

Anterior ganglionic mass in VI a2 and a3; ganglion VII in a2; ganglia VIII–XXV in a2 of each somite, except ganglia XIII, XIV in a2, or a2 and a3 of each somite; ganglion XXVI in a1; posterior ganglionic mass in XXVI b5 and b6.

Nephridiopores variable, usually 17 pairs (VIII–XXIV), but 18 or, rarely, 19 pairs (–XXV or XXVI), ventrally at posterior margin of a1 of each somite (Fig. 3B, D, E).

Pharynx agnathous, euthylaematous, descending to XIV a1–b5/b6; crop tubular, acecate, descending to XX a2–XXI a1/a2; gastropore conspicuous, ventrally at middle or posterior of XIII a1 (Fig. 3E, G); gastroporal duct muscular, tortuous at junction with gastropore, bulbiform, joining with crop in XIV a2–XV a2 (Figs. 3F, 4); intestine tubular, acecate, descending to XXIII a1/a2–XXIV b6, one pair of undeveloped chamber at junction with crop or chamber absent; rectum tubular, thin-walled.

Male gonopore at middle or posterior of XI b6 (Fig. 3E); female gonopore at XIII a1, inconspicuous, diagonally behind gastropore (Fig. 3G); gonopores separated by 1/2 + 4 + 1/2 or 1/3 + 4 + 2/3 annuli (Fig. 3E); testisacs multiple, two or three testisacs on both sides in each annulus, in XVII a2/b5–XVIII/XIX to XXIV b5/b6–XXV b5/b6 (Fig. 3H); epididymides in XV/XVI–XVI b5/b6 to XVII a2/b5–XVIII/XIX (Fig. 3H); ejaculatory ducts in XI b5 to XV/XVI–XVI b5/b6, loosely coiled, widen gradually from each junction with epididymis, narrow at each junction with atrial cornu, turning gently or sharply inward each atrial cornu (Fig. 3H–K); atrial cornua in XI b5 and b6, muscular, nearly ovate or fusiform (Fig. 3H–K); atrium short, muscular, cylindrical in XI b6 (Fig.

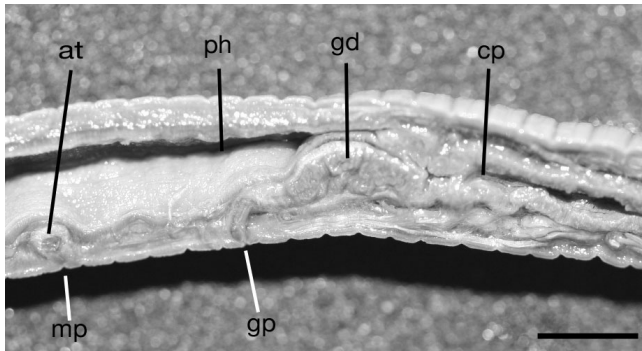


Fig. 5. Sagittal view of paralectotype of *Orobdella whitmani*, UMUTZ-Ann-Hir-5-8, dissected by Oka, having gastroporal duct. Scale bar, 5 mm.

3I–K); penis sheath and penis absent; ovisacs one pair, thin-walled, globular, in XIII a2 and b5 (Fig. 3H, L); oviduct thin-walled, right or left oviduct crossing ventrally to nerve cord, both oviducts converging into common oviduct in XIII a2 (Fig. 3H, L); common oviduct thin-walled, short, directly ascending to female gonopore (Fig. 3L); median female reproductive system absent.

Remarks

Although Oka (1895) did not state that *O. whitmani* was a gastroporous species, one figure in his paper (pl. 30, fig. 1) shows that there was an internal muscular organ above the expected position of the pore. Richardson (1975) assumed this to be a gastroporal duct, but he was unable to examine any specimen of *O. whitmani*. I found that one of the paralectotypes of *O. whitmani* (UTUMZ-Ann-Hir-5-8), probably the origin of the figure in Oka's (1895) description, possesses a gastroporal duct (Fig. 5), which Oka may not have noticed.

Oka (1895) noted that this species had post-ceca. Richardson (1975) assumed this to be a pocket-like structure of the intestine. *Orobdella whitmani* does not have crop ceca or intestinal ceca. But the intestine of *O. whitmani* has an undeveloped chamber at the junction with crop. Therefore, the post-ceca in Oka's (1895) description may be an undeveloped chamber of the intestine, as Richardson (1975) supposed.

Oka (1895) noted that *Orobdella whitmani* possesses two ganglia in XXIV b5 and b6, the first pair of eyes on the anterior margin of III and the first pair of nephridiopores at IX a1. However, I could not find these two ganglia. In addition, the first pair of eyes is on the posterior margin of II and the first pair of nephridiopores is at VIII a1.

Distribution

Known from Honshu, Japan (Mt. Kinkazan, Gifu Pref.; Mt. Kodaijyama, Kyoto Pref.). Gilyarov et al. (1969) recorded *O. whitmani* from the Primorsky Krai, Russia, but its taxonomic status remains in doubt.

Orobdella esulcata sp. nov.

(Proposed Japanese name: *mizokake-yotsuwa-kugabiru*)
(Fig. 6)

Orobdella whitmani: Oka, 1895: 282–284 (in part).

Diagnosis

In life, dorsal surface bluish gray, ventral surface gray; somites III–IV uniannulate; somites VII–XXV complete quadrannulate; somite XXVI triannulate, annular furrow of b5/b6 absent; gastropore conspicuous at XIII a1 (anterior); gastroporal duct tubular but bulbous at junction with gastropore; male gonopore at XI b6 (anterior); female gonopore inconspicuous at XIII a1, behind gastropore; gonopores separated by $1/2 + 4 + 1/2$, or $2/3 + 4 + 1/3$ annuli.

Holotype

KUZ Z29, mature specimen of 97.1 mm length, dissected, collected from under a rock along a mountain trail at Mt. Kimposan (alt. 412 m, $32^{\circ}48'36''N$, $130^{\circ}38'29''E$), Kumamoto-shi, Kumamoto Pref., Japan, by Takafumi Nakano on 15 October 2009.

Paratypes

A total of seven specimens, all collected from the type locality, Mt. Kimposan, and surrounding area, in Kumamoto-shi, Kumamoto Pref., Japan, by Takafumi Nakano. KUZ Z28, from under a rock along a forest trail in Kawachimachitake-taishojin (alt. 373 m, $32^{\circ}48'34''N$, $130^{\circ}38'39''E$), on 15 October 2009; four specimens: KUZ Z30 (alt. 481 m, $32^{\circ}48'42''N$, $130^{\circ}38'27''E$), KUZ Z31, Z32 (alt. 479 m, $32^{\circ}48'41''N$, $130^{\circ}38'27''E$), KUZ Z51 (alt. 504 m, $32^{\circ}48'43''N$, $130^{\circ}38'28''E$), dissected, from under a rock at the type locality on 15 October 2009; two specimens: KUZ Z48, from under a rock along a forest trail in Kawachimachitake-taishojin (alt. 358 m, $32^{\circ}48'34''N$, $130^{\circ}38'39''E$), KUZ Z49, from under a rock at the type locality (alt. 355 m, $32^{\circ}48'52''N$, $130^{\circ}38'43''E$), on 15 December 2009.

Etymology

The specific epithet is an adjective derived from the Latin words, e (lacks), and sulcus (furrow), referring to the absence of annular furrows of IV (a1 + a2)/a3 and XXVI b5/b6 in the new species.

Description of holotype

Body firm, muscular, BL 97.1 mm, BW 4.8 mm; caudal sucker ventral, oval, in diameter as large as maximum body width (Fig. 6D); in life, dorsal surface bluish gray, darker than ventral surface; color faded in preservative, median black line present on anterior dorsal surface.

Somite I completely merged with prostomium (Fig. 6A); somite II uniannulate, not separated from I (Fig. 6A); somites III and IV uniannulate (Fig. 6A); somite V biannulate, a3 forming posterior margin of oral sucker (Fig. 6A, B); somites VI–VII complete triannulate (Fig. 6A, B); somites VIII–XXV complete quadrannulate, a1 = a2 = b5 = b6 (Fig. 6A–E); somite XXVI triannulate, a1 > a2 < a3; a3 the last fully formed annulus on the venter (Fig. 6C, D); somite XXVII incomplete uniannulate (Fig. 6C); anus behind XXVII (Fig. 6C); post-anal annulus absent (Fig. 6C).

Anterior ganglionic mass in VI a2 and a3; ganglion VII in a2; ganglia VIII–XXIV in a2 of each somite; ganglion XXV in a1 and a2; ganglion XXVI in a1; posterior ganglionic mass in XXVI a2 and a3.

Eyes three pairs, first pair dorsal in II/III, second and third pairs dorsolaterally on posterior margin of V (a1 + a2)

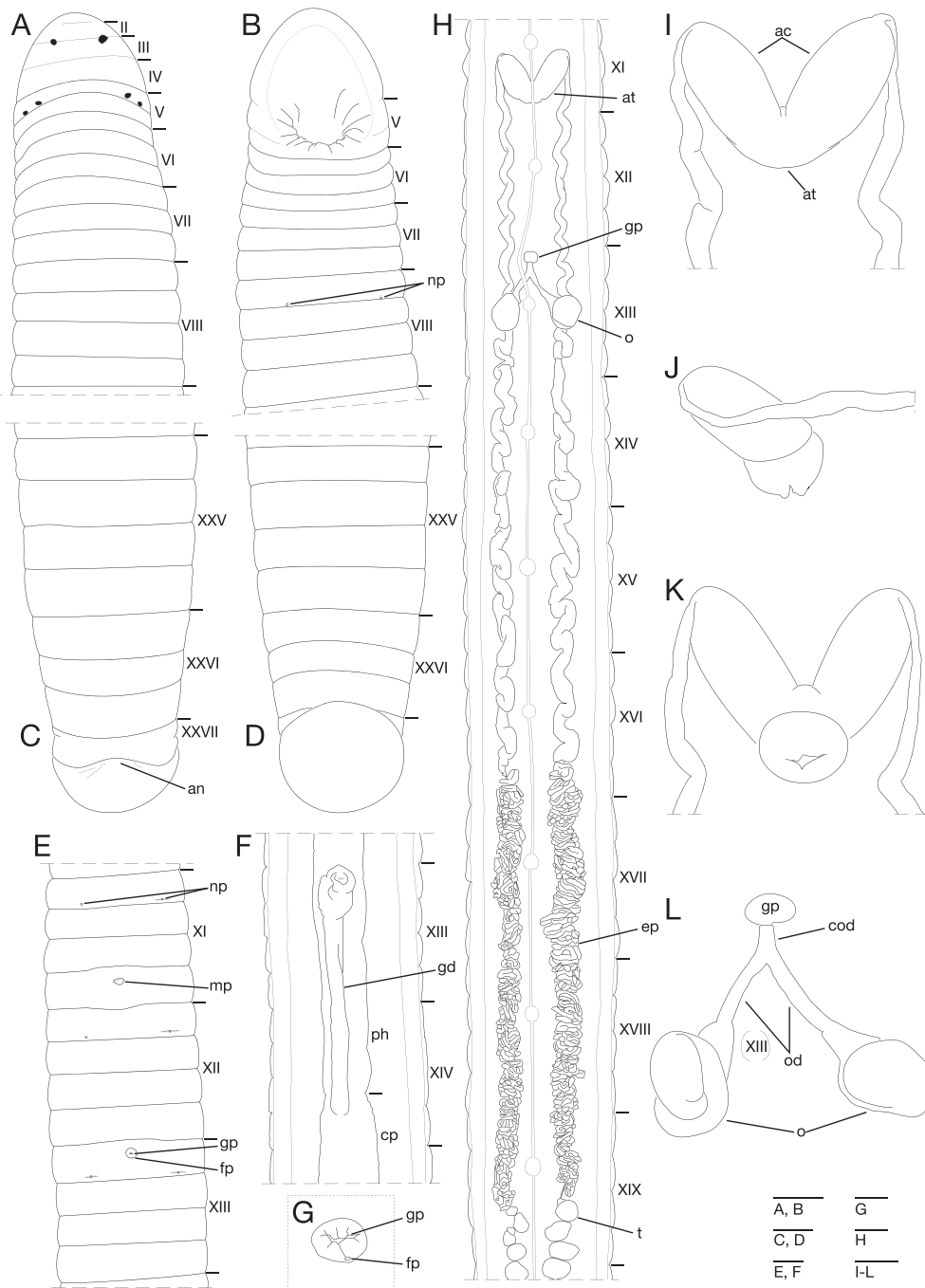


Fig. 6. *Orobdella esulcata* sp. nov., holotype, KUZ Z29. **(A)** Dorsal, and **(B)** ventral views of somites I–VIII. **(C)** Dorsal and **(D)** ventral views of somites XXV–XXVII and caudal sucker. **(E)** Ventral view of somites XI–XIII. **(F)** Ventral view of gastroporal duct. **(G)** Ventral view of gastropore and female gonopore. **(H)** Dorsal view of reproductive system including ventral nervous system. **(I)** Dorsal, **(J)** lateral, **(K)** ventral views of male atrium. **(L)** Dorsal view of female reproductive system including position of ganglion XIII. Scale bars, 1 mm (A–F, H), 0.5 mm (I–L), 0.25 mm (G).

(Fig. 6A); nephridiopores 17 pairs, ventrally at posterior margin of a1 of each somite, at VIII–XXIV (Fig. 6B, E); papillae numerous, minute, hardly visible, one row on every annulus.

Pharynx agnathous, euthylaematous, descending to XIV b5; crop tubular, acecate, in XIV b5 to XX b5; gastropore conspicuous, ventrally at anterior part of XIII a1 (Fig. 6E, G); gastroporal duct tubular but bulbous at junction with gastropore, joining with crop in XIV b5 (Fig. 6F); intestine

tubular, acecate, in XX b5 to XXIII a2/b5, one pair of undeveloped chamber at junction with crop; rectum tubular, thin-walled.

Male gonopore at anterior of XI b6 (Fig. 6E); female gonopore at XIII a1, inconspicuous, behind gastropore (Fig. 6E, G); gonopores separated by $2/3 + 4 + 1/3$ annuli (Fig. 6E); testisacs multiple, two or three testisacs on both sides in each annulus, in XIX b5 to XXV b5 (Fig. 6H); epididymides in XVI b6 to XIX a2, thin-walled, slightly translucent; ejaculatory bulb absent (Fig. 6H); ejaculatory ducts in XI b5 to XVI b5, loosely coiled, widen gradually from each junction with epididymis, narrow at each junction with atrial cornu, turning sharply inward each atrial cornu (Fig. 6H–K); atrial cornua in XI b5 and b6, muscular, fusiform (Fig. 6H–K); atrium short, muscular, cylindrical in XI b6 (Fig. 6I–K); penis sheath and penis absent; ovisacs one pair, thin-walled, globular, in XIII a2 and b5 (Fig. 6H, L); oviduct thin-walled, left oviduct crossing ventrally to nerve cord, both oviducts converging into common oviduct in XIII a1 (Fig. 6H, L); common oviduct thin-walled, short, directly ascending to female gonopore (Fig. 6H, L); median female reproductive system absent.

Variation

Pharynx descending to XIV a2–b5/b6; crop descending to XX b2–b5; gastroporal duct joining crop in XIV b5–b6; intestine descending to XXII b6–XXIII a2/b5, one pair of undeveloped chambers at junction with crop or absent;

epididymides in XVI b5–XVI/XVII to XVIII/XIX–XX a2/b5; testisacs descending to XXV a1–b5/b6; left or right oviduct crossing ventrally to nerve cord.

Remarks

Oka (1895) treated specimens from Mt. Kimposan as conspecifics of those from Mt. Kodaijijama and Mt. Kinkazan. *Orobdella esulcata* is certainly similar to *O. whitmani* in its

Table 1. Comparisons of morphological characters among *Orobdella esulcata* sp. nov., *Orobdella whitmani* and *Orobdella kawakatsuorum*.

Character	<i>Orobdella esulcata</i> sp. nov.	<i>O. whitmani</i>	<i>O. kawakatsuorum</i>
color	bluish gray	yellowish	bluish gray
annulation of III	uniannulate	uniannulate or rarely biannulate	biannulate
annulation of IV	uniannulate	uniannulate or biannulate	biannulate
position of male gonopore	at XI b6 (anterior)	at XI b6 (posterior)	in XI b5/b6
position of gastropore, female gonopore	at XIII a1 (anterior)	at XIII a1 (posterior)	in XIII a1/a2
annulation of XXVI	triannulate	quadrannulate	triannulate
gastroporal duct	tubular but bulbous at junction with gastropore	bulbiform, tortuous at junction with gastropore	simply tubular
epididymis	translucent	not translucent	very short, in a few annuli
atrial cornu	atrial cornu developed	atrial cornu developed	atrial cornu undevelopped

external morphology. However, the former can be distinguished from the latter by the internal morphology, especially by its possession of a tubular gastroporal duct (bulbiform in *O. whitmani*) (Figs. 3F, 4, 6F).

Distribution

Known only from the type locality, Mt. Kimposan, Kumamoto-shi, Kumamoto Pref., Japan (Fig. 1).

DISCUSSION

Comparison

Orobdella whitmani and *O. esulcata* can be distinguished from *O. kawakatsuorum* by the annulation of III, and IV, the position of gonopores and gastropores, and the male median reproductive system. *Orobdella esulcata* differs from *O. whitmani* and *O. kawakatsuorum* in the following characteristics: 1) color; 2) annulation of III; 3) annulation of IV; 4) position of male gonopore; 5) position of gastropore and female gonopore; 6) annulation of XXVI; 7) gastroporal duct; 8) epididymis; and 9) atrial cornu (Table 1). The new species, *Orobdella esulcata*, is unique among quadrannulate *Orobdella* species in its peculiar gastroporal duct shape.

Orobdella esulcata can easily be distinguished from *O. ijimai* and *O. octonaria* by the following features: 1) mid-body somites quadrannulate (sexannulate in *O. ijimai*, octannulate in *O. octonaria*); and 2) complete four annuli between gonopores (complete six annuli in *O. ijimai*, complete eight annuli in *O. octonaria*).

Annulation of somites XXV–XXVII

In leeches, ganglia, nephridia and nephridiopores are somital structures. The leech ganglia can be divided to three regions (Sawyer, 1986): 1) anterior ganglionic mass (ganglia I–VI) in somites I–VI; 2) 21 ganglia, one in each of the somite VII–XXVII; and 3) posterior ganglionic mass (ganglia XXVIII–XXXIV) in caudal sucker. However, *Orobdella whitmani* and *O. esulcata* have just 20 ganglia and a posterior ganglionic mass in somites VII–XXVII. On the other

hand, the leech nephridia and nephridiopores have been considered to be up to 17 pairs in somites VIII–XXIV (Sawyer, 1986). However, in specimens of *Orobdella whitmani*, nephridia and nephridiopores are observed in up to 20 pairs. This is the maximum number of nephridia and nephridiopores of leeches ever reported. These features indicate that the posterior somites (XXV and XXVI) are elongated and possess nephridia and nephridiopores in *Orobdella* leeches, possibly due to their terrestrial life. In contrast, the caudal sucker in these leeches has degenerated and gan-

glia XXVI and XXVII are in unusual positions. Richardson (1975) once suggested that the annulation of XXIV–XXVII of *O. whitmani* by criticizing Oka's description: XXIV, XXV triannulate; XXVI incomplete biannulate; XXVII uniannulate. However, in this report, I count the annulation of XXIV–XXVII of *O. whitmani* and *O. esulcata* as follows: XXIV–XXVI quadrannulate; XXVII incomplete uniannulate (see descriptions above), because of the number and position of nephridia and nephridiopores, and the unusual manner of ganglion XXVI and the posterior ganglionic mass.

Gastropore and gastroporal duct

Both *Orobdella whitmani* and *Orobdella esulcata* have a gastropore and a gastroporal duct. Six of such terrestrial gastroporous species have been described (Sawyer, 1986): 1) *Gastrostomobdella quinqueannulata* Moore, 1946; 2) *Gastrostomobdella dubia* (Horst, 1884); 3) *Gastrostomobdella monticola* Moore, 1929; 4) *Gastrostomobdella vagabunda* Moore, 1935; 5) *Orobdella kawakatsuorum*; and 6) *O. octonaria*. However, the function of the gastropore and the gastroporal duct in terrestrial species remains controversial. Two hypotheses regarding their function have been put forth: 1) accessory reproductive system; and 2) accessory anus (Moore, 1929; Richardson, 1971, 1975; Sawyer, 1986). The female gonopores of *O. whitmani* and *O. esulcata* are so inconspicuous and seemed to be too tiny to allow copulation. In contrast, the gastropores in these species are so conspicuous and easily confused with female gonopore (Figs. 2F, 3G, 6G). These characteristics indicate that the gastropore and gastroporal duct may act as copulatory organs. However, I did not find any conducting tissues around the gastroporal duct; their function thus remains to be open to question. Further anatomical and ecological studies of terrestrial gastroporous leeches are needed to understand the roles of those organs.

I found sexannulate *Orobdella*-like specimens from Amamioshima Island, Japan, that lack gastropore (Nakano, unpublished data). Oka (1910a, b) once treated specimens from the island as *Orobdella ijimai*. Future revisional studies

of *Orobdella* are also needed.

Taxonomic studies of *Orobdella* and other leeches in Japan

Our knowledge on the genus *Orobdella* is seriously limited. To date, four species have been described from Japan. Oka (1910a, b) considered the southern limit of the genus to be Amamioshima Island, Ryukyu Archipelago, Japan. However, leeches in this genus may be distributed much southward, as a possible member of *Orobdella* has been obtained from Okinawajima Island (Sugimoto, personal communication). Furthermore, quadrannulate *Orobdella* leeches have been also collected in Taiwan (Lai, personal communication). But taxonomic studies of *Orobdella* have scarcely been advanced, as the internal morphology of *O. whitmani*, the type species of the genus *Orobdella*, had been uncertain. We are hopeful that this paper can contribute to progress in the taxonomy of *Orobdella* leeches.

Asajiro Oka was a well-known and highly regarded biologist in Japan, and described 33 leech species from 1895 to 1935 (Sket and Trontelj, 2008), but his descriptions and classification of arhynchobdellid leeches were based mainly on external morphology (e.g., Oka, 1923, 1925a, b, 1929, 1931a, b). He thought that he had nearly completed the faunal studies of terrestrial and freshwater leeches (in the family Glossiphoniidae, Hirudinidae and Erpobdellidae) in Japan (Oka, 1910a). And in practical terms, taxonomic studies of leeches in Japan have not been improved after Oka's death (Nagasawa, 1991; Nagasawa et al., 2008). The discovery of *Orobdella esulcata* suggests that the species described by Oka should be revised and that the faunal studies of terrestrial, and probably freshwater, leeches in Japan remain insufficient. Further field and taxonomic surveys are needed to address this situation.

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