FULL PAPER *Wildlife Science*

Syphacia (*Syphacia*) *maxomyos* sp. n. (Nematoda: Oxyuridae) from *Maxomys* spp. (Rodentia: Muridae) from Sulawesi and Sumatra, Indonesia

Kartika DEWI[1)], Hideo HASEGAWA[2)], Yuli Sulistya FITRIANA[1)] and Mitsuhiko ASAKAWA[3)]*

[1)]*Zoology Division, Museum Zoologicum Bogoriense, RC. Biology-LIPI, Jl. Raya Jakarta-Bogor, Km. 46. Cibinong, West Java 16911, Indonesia*
[2)]*Department of Biology, Faculty of Medicine, Oita University, Hasama, Yufu, Oita 879–5593, Japan*
[3)]*Department of Pathobiology, School of Veterinary Medicine, Rakuno Gakuen University, Ebetsu, Hokkaido 069–8501, Japan*

(Received 12 December 2014/Accepted 27 April 2015/Published online in J-STAGE 9 June 2015)

ABSTRACT. The present report describes *Syphacia* (*Syphacia*) *maxomyos* sp. n. (Nematoda: Oxyuridae) from two species of spiny rats, *Maxomys musschenbroekii* from Sulawesi and *M. whiteheadi* from Sumatra. It is characterized by a cephalic plate extending laterally with dorsoventral constriction and stumpy eggs with an operculum rim reaching pole. It is readily distinguishable by the former feature from all of hitherto known representatives of this genus in Indonesia, but it resembles parasites in Murini and Hydromyni rodents in continental Asia and Sahul. This is the first *Syphacia* species distributed in both the Sunda Shelf and Sulawesi with the exception of *Syphacia muris*, a cosmopolitan pinworm found in rodents of the of genus *Rattus*. It is surmised that *S. maxomyos* is specific to *Maxomys* and that it was introduced to Sulawesi by dispersal of some *Maxomys* from the Sunda Shelf.
KEY WORDS: Indonesia, *Maxomys,* Nematoda, new species, *Syphacia*

doi: 10.1292/jvms.14-0659; *J. Vet. Med. Sci.* 77(10): 1217–1222, 2015

Murine rodents (Rodentia: Muridae) can transmit many diseases either directly or indirectly to humans and livestock. One of these diseases is nematodiasis. *Syphacia* (Nematoda: Oxyuridae) is well known as a pinworm nematode occurring in the rodent Cricetidae and Muridae families [13]. This oxyurid genus is distributed worldwide and has zoonotic potential [23], and a human case infested with *Syphacia obvelata* has been reported in the Philippines [16]. For this reason, it is important to study the parasites of rodents, especially nematodes.

As an endemic genus of rodents in Asia, eighteen species of *Maxomys* are currently known in the area of mainland Southeast Asia extending east throughout the Sunda Shelf and to some neighboring oceanic islands [1]. Two of them are *M. whiteheadi* and *M. musschenbroekii*. *M. musschenbroekii* is endemic to Sulawesi, whereas *M. whiteheadi* is widely distributed throughout Sumatra, the Malay Peninsula, Thailand and Borneo/Kalimantan [1]. Observing both of these murid rodents, we found pinworm nematodes representing a new species of *Syphacia* Seurat, 1916 (Oxyuridae: Syphaciinae).

Seven species of *Syphacia* (*Syphacia*) from Indonesia are currently recognized i.e., *S. longaecauda* Smales, 2001, from Papua; *S. sulawesiensis* Hasegawa & Tarore, 1996, *S. rifaii* Dewi & Hasegawa, 2010, *S. taeromyos* Dewi & Hasegawa, 2014, and *S. paruromyos* Dewi & Hasegawa, 2014, from Sulawesi; *S. semiadii* Dewi, Asakawa & Fitriana, 2014, from Halmahera; and *Syphacia muris* (Yamaguti, 1935), a cosmopolitan species [3–5, 10, 17]. Moreover, *Syphacia* (*Rumbaisyphacia*) *kumis* Dewi, Hasegawa and Asakawa, 2014 and *Syphacia* (*Segienamsyphacia*) *yuniae* Dewi, Hasegawa and Asakawa, 2014 from Sulawesi have also been described under new subgenera [6]. However, there is no record of *Syphacia* from west Indonesia, which formed so-called the Sunda Land in the Pleistocene, except for the cosmopolitan *S. muris* of *Rattus* spp. Therefore, this is the first *Syphacia* species from west Indonesia, although it is also found in Sulawesi. This new species is described herein with a biogeographical discussion.

MATERIALS AND METHODS

Three individuals of *Maxomys musschenbroekii* were purchased from a farmer, who captured them using traditional snap traps in the forests in Lambanan and Mambulillin, West Sulawesi, and one individual of this species was also captured using a snap trap by staff of a schistosomiasis control project in Tomado, Central Sulawesi, in 1992 [11]. Meanwhile, *M. whiteheadi* individuals were trapped by one of the junior authors (YSF) in Riau, Sumatra, in 2011 using live traps, 28 × 12 × 12 cm in size, and the rats were then killed using chloroform. Identification of the host murids was based on classical external, cranial and dental qualitative morphological characters and was verified by Dr. G. G. Musser, American Museum of Natural History (AMNH), New York, U.S.A., for materials from Sulawesi and by Maharadatunkamsi, curator of mammalogy, Museum Zoologicum Bogoriense (MZB), Bogor, Indonesia, for materials from Sumatra. The viscera were removed in the field, fixed in 8% formalin and then examined for helminths in the laboratory. Nematodes recov-

*CORRESPONDENCE TO: ASAKAWA, M. Department of Pathobiology, School of Veterinary Medicine, Rakuno Gakuen University, Ebetsu, Hokkaido 069–8501, Japan. e-mail: askam@rakuno.ac.jp

ered were stored in 70% ethanol. The contents of the cecum were transferred to a petri dish and observed for helminths under a stereomicroscope. Prior to examination, specimens were cleared in glycerol alcohol solution and then studied as temporary wet mounts under a compound Olympus BH-2 series microscope with a drawing tube. Cross sections were made "free hand" using a small piece of razor blade. Measurements were made with an ocular micrometer. For SEM examination, specimens were post-fixed in glutaraldehyde, dehydrated through an ethanol series and vacuum-dried using a TAITEC VC–96N Spin Dryer for at least 30 min. Dried specimens were then mounted on double-sided tape, coated with gold at 5–8 mA for 5 min and examined in a JEOL JSM5310LV scanning electron microscope (SEM) at an accelerating voltage of 20 kV. Measurements, in micrometers unless otherwise stated, are given for holotype male and allotype female in the description section except for the distance between amphidial pores and egg size, which were measured on the head severed from the body and eggs excised from the uterus, respectively. Measurements of paratypes are summarized in Tables 1 and 2. Type specimens were deposited in the MZB, Bogor, Indonesia. Symbiotype specimens were deposited in the MZB and AMNH.

Table 1. Measurements of paratype males of *Syphacia* (*Syphacia*) *maxomyos* collected from *Maxomys* spp. (range followed by mean in parenthesis in μm unless otherwise stated)

Host	*M. musschenbroekii*	*M. whiteheadi*
(No. worms measured)	10	2
Total body length, mm	1.29–1.78 (1.63)	>1.11–1.22
Maximum width	101–138 (122)	109–115 (112)
Total esophageal length[a)]	176–230 (209)	209–222 (216)
Pharynx length	14–19 (17)	13–16 (15)
Corpus length[b)]	110–152 (133)	138–145 (142)
Corpus width	27–37 (33)	34–37 (36)
Isthmus minimum width	13–24 (20)	18–25 (22)
Bulb length	50–64 (58)	58–61 (60)
Bulb width	51–64 (58)	58–61 (60)
Nerve ring[c)]	86–125 (106)	96–99 (98)
Excretory pore[c)]	364–505 (454)	235–241 (238)
1st mamelon[c)]	439–632 (559)	314–363 (339)
2nd mamelon[c)]	598–830 (757)	437–500 (469)
3rd mamelon[c)]	794–1,126 (1041)	630–703 (667)
1st mamelon length	48–75 (63)	64–67 (66)
2nd mamelon length	40–69 (60)	59–61 (60)
3rd mamelon length	56–83 (73)	64–72 (68)
Spicule length	64–78 (72)	59–64 (62)
Ratio to TBL (%)	3.8–5.6 (4.5)	4.8 (n=1)
Gubernaculum length	27–35 (32)	30–32 (31)
Accessory piece length	21–24 (23)	18–24 (21)
Tail length	213–269 (245)	217 (n=1)
Ratio to TBL (%)	13.1–17.8 (15.1)	17.8 (n=1)

a) Including pharynx, corpus, isthmus and bulb. b) Including isthmus. c) Distance from cephalic apex.

RESULTS

All three individuals of *M. musschenbroekii* captured in Lambanan (n=1) and Mambulillin (n=2) harbored both sexes of a species of pinworm, with the intensities being 18, 25 and 35, respectively. One *M. musschenbroekii* trapped at Tomado was negative for pinworms. Among 12 individuals of *M. whiteheadi* from Sumatra examined, four were positive for pinworms, with the intensities being 17, 17, 9 and >100. Only 2 males were found in the individual with the highest intensity.

General: Small nematodes; cuticle with fine transversal striations; cephalic vesicle well developed, soft, making waved contour in apical view; cephalic plate laterally-elongated with dorsoventral constriction; mouth opening triradiate, surrounded by 3 protruded lips, dorsal lip smaller than subventral ones. Two submedian papillae and one amphid, closely set, located at each lateral side of cephalic plate; amphids with porous patches laterally; cervical alae absent; deirids not seen; excretory pore posterior to esophago–intestinal junction; esophagus club–shaped with posterior bulb containing valvular apparatus.

Male (Fig. 1; holotype and 10 paratypes from M. musschenbroekii *and 2 paratypes from* M. whiteheadi*)*: Posterior body bent ventrally. Length 1.64 mm, maximum width 134; distance between amphidial pores 29–30 (n=2); lateral alae as slight cuticular thickenings with median furrow; total esophagus 211 long: pharynx 18 long, corpus 134 long and 40 wide, isthmus 22 wide, bulb 59 long by 67 wide; nerve ring 112, and excretory pore 435 from cephalic end; 3 mamelons developed at ventral posterior body; first mamelon 67 long, second mamelon 61 long and third mamelon 85 long; distance from cephalic end to anterior edges of first, second and third mamelons 535, 723 and 1,010, respectively; testis recurrent at level of first mamelon; spicule single, relatively short, thin, needle-shaped, slightly constricted at 1/3 length from proximal end, sharply pointed distally, 65 long [i.e., 4.0% of TBL (total body length)]; gubernaculum, 34 long with relatively large, unornamented accessory piece 22 long; caudal papillae 3 pairs: 2 pairs small, near cloaca and 1 pair large, postanal, protruding posterolaterally; tail tapered, forming whip–like process, 267 long (i.e., 16.3% of TBL).

Female (Figs. 2 and 3; allotype and 10 paratypes from M. musschenbroekii *and 10 paratypes from* M. whiteheadi*)*: Body relatively stout; length 3.81 mm, width 211; distance between amphidial pores 38–39 (n=2); lateral alae absent; total esophagus 298 long: pharynx 19, corpus 186 long and 45 wide, isthmus 29 wide at narrowest level and bulb 93 long by 106 wide; nerve ring at midlevel of esophageal corpus and excretory pore 118 and 531 from cephalic end, respectively; vulva protruding and surrounded by smooth cuticle, 642 from cephalic end (i.e., 16.9% of TBL); vagina and ovejector directed posteriorly; distance between excretory pore and vulva short, 122 (i.e., 3.2% of TBL); eggs elliptical, stumpy, asymmetrical with one side flattened, both poles rounded, operculum reaching polar end, surface not pitted, embryonated in uteri, [57.8 (54–59)] × [24.1 (23–26)] (n=20); tail long, tapering to pointed end, 790 long (i.e., 20.7% of TBL).

Remarks: By having three mamelons in males, this spe-

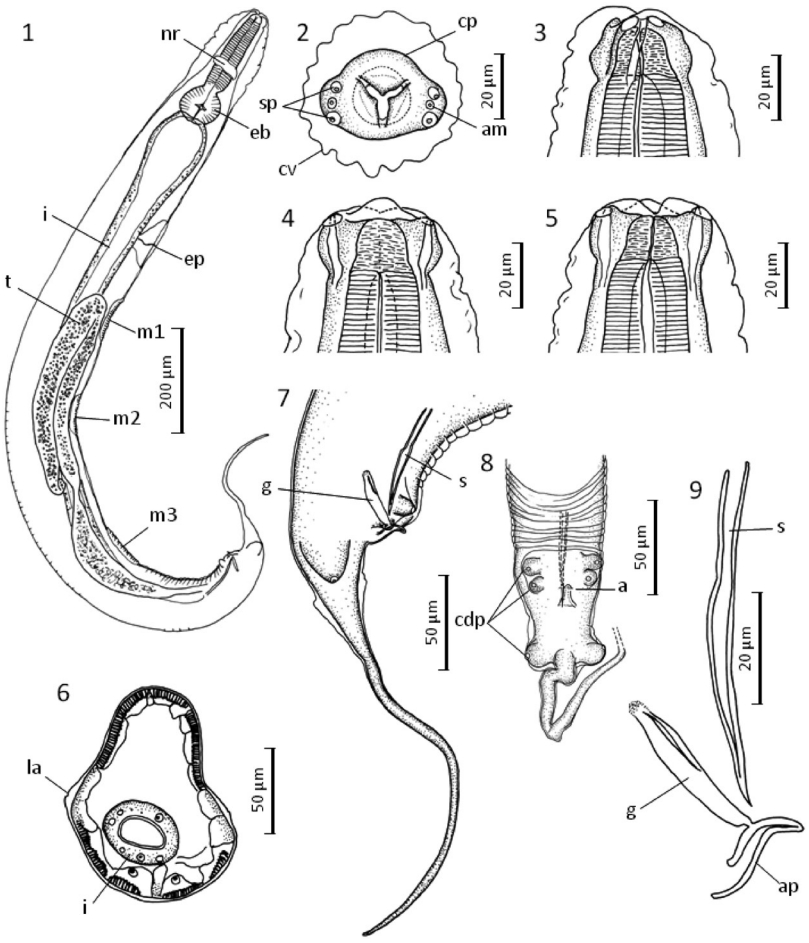

Fig. 1. Male of *Syphacia maxomyos* n. sp. from *Maxomys musschenbroekii* in Sulawesi, Indonesia. (1) Male, holotype, lateral view; Cephalic portion (2–5): (2) apical, (3) lateral, (4) dorsal and (5) ventral views. (6) Cross section through midbody. Posterior extremity (7–8): (7) right lateral and (8) ventral views. (9) Spicule and gubernaculum, lateral view. Abbreviations: a, anus; am, amphid; ap, accessory piece of gubernaculum; cdp, caudal papillae; cp, cephalic plate; cv, cephalic vesicle; eb, esophageal bulb; ep, excretory pore; g, gubernaculum; i, intestine; la, lateral ala; m1, first mamelon; m2, second mamelon; m3, third mamelon; nr, nerve ring; s, spicule; sp, submedian papillae; t, testis.

cies is assigned to the genus *Syphacia* Seurat, 1916 [13, 15]. Among the five subgenera currently recognized, it is assigned to the subgenus *Syphacia* Seurat, 1916, based on the lack of cervical alae, developed deirids and setae in the oral cavity and the presence of a triradiate oral aperture in both sexes and an unornamented accessory piece of gubernaculum in males [6, 13]. Among the species in the subgenus *Syphacia* that have been described from Oriental to Australian bioregions, this new species shares a common feature, i.e., a cephalic plate that is laterally-elongated with lateral dorsoventral constrictions, with the following species: *S. ohtaorum* Hasegawa, 1991, from Okinawa Island and Nepal; *S. boodjamullaensis* Weaver & Smales, 2010, *S. brevicaudata* Weaver & Smales, 2008, *S. carnarvonensis* Weaver & Smales, 2010, *S. helidonensis* Weaver & Smales, 2010, and *S. pseudomyos* Weaver & Smales, 2008, from Australia; and *S. coccymyos* Smales, 2011, from Papua New Guinea [2, 9, 18, 21, 22]. However, the present species differs from those with a relatively short tail in males, i.e., *S. ohtaorum*, *S. boodjamullaensis*, *S. brevicaudata*, *S. carnarvonensis*, *S. helidonensis* and *S. pseudomyos* [2, 9, 21, 22]. Although *S. coccymyos* has a rather long tail in males, it has an excretory pore closer to the esophago-intestinal junction than to the first mamelon, and it is readily distinguishable from the present species [18]. The stumpy eggs with an operculum rim reaching to pole are also characteristic of this new species. The eggs of *S. coccymyos* have a somewhat similar shape, but are much larger (88–99 by 33–40 μm) [18].

There were slight morphological differences between the individuals from *M. whiteheadi* and *M. musschenbroekii*. The uterus was restricted posterior to the vulva in the females from *M. musschenbroekii*, but it extended anteriorly beyond the vulval level to esophageal bulb in the females from *M. whiteheadi*. Eggs were slightly longer in the individuals from *M. musschenbroekii* (Table 2).

Taxonomic summary: Type host: *Maxomys musschen-*

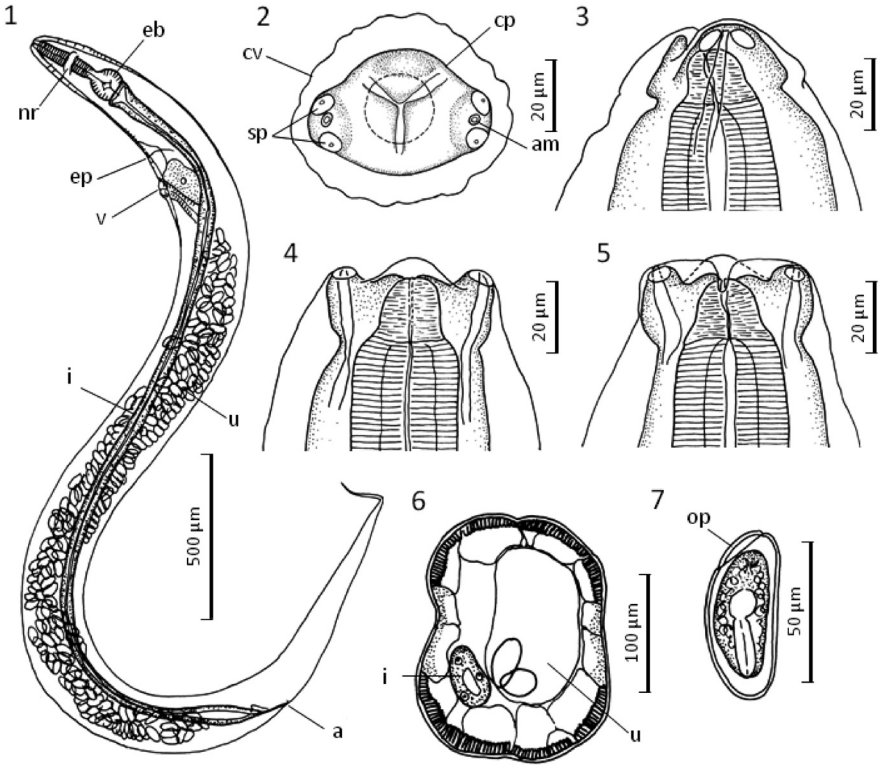

Fig. 2. Female of *Syphacia maxomyos* n. sp. from *Maxomys musschenbroekii* in Sulawesi, Indonesia. (1) Female, allotype, lateral view; Cephalic portion (2–5): (2) apical, (3) lateral, (4). dorsal and (5) ventral views. (6) Cross section through midbody. (7) Egg. Abbreviations: a, anus; am, amphid; cp, cephalic plate; cv, cephalic vesicle; eb, esophageal bulb; ep, excretory pore; i, intestine; nr, nerve ring; op, operculum of egg; sp, submedian papillae; u, uterus; v, vulva.

broekii (Jentink, 1878) (Musschenbroek's spiny rat) (Rodentia: Muridae).

Other host: *Maxomys whiteheadi* (Thomas, 1894) (Whitehead's spiny rat) (Rodentia: Muridae).

Site of infection: Cecum.

Type locality: Lambanan, West Sulawesi, Indonesia.

Other locality: Mambulillin, West Sulawesi; Bengkalis, Riau, Sumatra, Indonesia.

Date of collection: 1 August 1992 (*M. musschenbroekii* in Lambanan); 30 July 1992 (*M. musschenbroekii* in Mambulillin); 6 April 2011 (*M. whiteheadi*).

Specimens deposited: Holotype male and allotype female (host: *M. musschenbroekii*) (MZB Na 675); 10 male and 10 female paratypes (host: *M. musschenbroekii*) (MZB Na 676–678); 2 male and 10 female paratypes (host: *M. whiteheadi*) (MZB Na 679–680).

Symbiotypes: AMNH M–267759–267761; MZB Mamm. 34132, 34133, 34138, 34143.

Etymology: The species epithet of this taxon is derived from the generic name of the host rodent, *Maxomys*.

DISCUSSION

It is known that pinworm species of *Syphacia* have coevolutionary relationships with their hosts and are generally host-genus specific [13]. In the present study, *S. maxomyos* was found in the two *Maxomys* species. This species is the first *Syphacia* found to be distributed in both the Sunda Shelf and Sulawesi, except for *S. muris*, the cosmopolitan pinworm of *Rattus* spp. [10]. One of the junior authors (HH) had an opportunity to observe pinworms collected from *Maxomys surifer* and *Maxomys rajah* captured in Peninsular Malaysia and found that they had cephalic and egg morphologies similar to those of the present species. Although the conditions of the Malaysian materials were not sufficient to make a definitive identification, it is strongly surmised that *S. maxomyos* is specific to the murine genus *Maxomys*. It is hence suggested that other *Maxomys* species also harbor *S. maxomyos*.

There are currently 18 recognized species of *Maxomys*, and all of the Sulawesi representatives of *Maxomys* are endemic to Sulawesi [1, 14]. Recent molecular phylogenetic studies on Rattini have revealed that an ancestor of *Maxomys* diverged from the common ancestor of *Rattus* and *Dacnomys* divisions in the Messinian period of the Miocene epoch and that species diversification occurred in the early and middle Pliocene epoch [7]. It was also proved that *Maxomys* is not monophyletic because *Crunomys,* an old endemic murid genus of Sulawesi and the Philippines, is deeply nested within it [1, 7]. As shown by the present study, two different *Maxomys* species of both the Sunda Shelf and Sulawesi

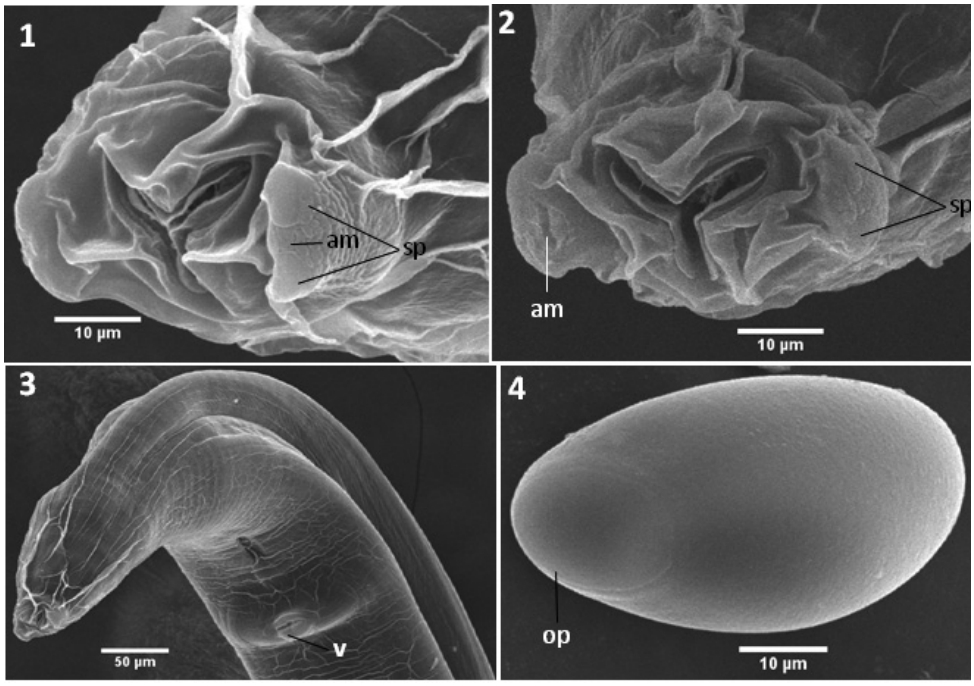

Fig. 3. Scanning electron microscopy of *Syphacia maxomyos* n. sp. collected from *Maxomys musschenbroekii* in Sulawesi, Indonesia. (1 and 2) Cephalic end of female (apical view). (3) Anterior portion of female showing cephalic end and vulva (ventrolateral view). (4) Egg. Abbreviations: am, amphid; op, operculum of egg; sp, submedian papillae; v, vulva.

Table 2. Measurements of paratype females of *Syphacia* (*Syphacia*) *maxomyos* collected from *Maxomys* spp. (range followed by mean in parenthesis in micrometers unless otherwise stated)

Host	*M. musschenbroekii*	*M. whiteheadi*
(No. worms measured)	10	10
Total body length, mm	3.44–4.51 (4.08)	3.29–3.88 (3.54)
Maximum width	192–260 (212)	218–255 (237)
Total esophageal length[a)]	271–324 (302)	306–328 (318)
Pharynx length	18–24 (20)	17–21 (20)
Corpus length[b)]	177–211 (197)	192–214 (203)
Corpus width	45–51 (47)	49–53 (51)
Isthmus minimum width	24–32 (29)	27–35 (30)
Bulb length	75–102 (90)	91–102 (94)
Bulb width	93–101 (97)	88–104 (97)
Nerve ring[c)]	105–160 (127)	108–130 (123)
Excretory pore[c)]	436–711 (558)	439–527 (483)
Vulva[c)]	520–813 (676)	564–655 (610)
Ratio to TBL (%)	14.0–18.6 (16.5)	15.3–18.7 (17.3)
Excretory pore to vulva	60–161 (118)	109–158 (127)
Ratio to TBL (%)	1.4–4.3 (2.9)	3.2–4.6 (3.6)
Tail length	563–934 (777)	546–768 (600)
Ratio to TBL (%)	15.2–21.0 (19.0)	14.8–21.5 (17.0)
Egg	53–59 (58)	49–52 (50)
	x 22–27 (24)	x 24–28 (26)

a) Including pharynx, corpus, isthmus and bulb. b) Including isthmus. c) Distance from cephalic apex.

harbor the same *Syphacia* species. This may mean that this pinworm was introduced by some ancestor (s) of the present *Maxomys* spp. in Sulawesi from the Sunda Shelf. Dispersal of *Maxomys* to Sulawesi might have occurred by drift as in the case of most Sulawesian animals, because there is no evidence of existence of a land bridge connecting both regions during Neogene to Quaternary periods [8, 19, 20].

Similar to *Syphacia* species, *Maxomystrongylus*, a trichostrongyloid nematode genus, has representatives in both of the *Maxomys* species: *M. whiteheadi* in Kalimantan harbors *Maxomystrongylus yasumai*, whereas *M. musschenbroekii* in Sulawesi is a host for *Maxomystrongylus musseri*, though their host specificity seems to be less strict than *Syphacia* [11, 12]. In *Maxomystrongylus,* morphological discrimination is easy between the two species. Meanwhile, only slight differences, such as egg size, were noticed between the present pinworm individuals from the two hosts. Although morphological differences were not prominent between the pinworms from *M. mussenbroekii* and *M. whiteheadi*, the process of dispersal and coevolution must have left traces in their genomes. It is expected that DNA sequence analysis of *S. maxomyos* from various *Maxomys* species could give substantial evidence of coevolution of the pinworms and their host murines.

As pointed out in the remarks, the laterally-elongated cephalic plate with lateral dorsoventral constriction found in *S. maxomyos* is also common in eight representatives of *Syphacia*. Their host genera are *Mus* (*S. ohtaorum*), *Zyzo-*

mys (*S. boodjamullaensis*), *Pseudomys* (*S. brevicaudata*, *S. carnarvonensis, S. helidonensis* and *S. pseudomyos*) and *Coccymys* (*S. coccymyos*). Among them, *Mus* belongs to Murini, while the others are included in Hydromyini. Murini and Hydromyini were derived in the Tortonian period of the Miocene epoch, much earlier than the diversification of Rattini, which produced the *Maxomys* lineage at an early stage [7]. It is speculated that the pinworm that parasitized ancestral murine species in Miocene had a laterally-elongated cephalic plate and then this lineage has been maintained in Murini, Hydromyni and *Maxomys*. Nevertheless, it is also possible that the resemblance in cephalic morphology was only homoplasy or due to secondary capture of pinworms from unrelated murines. In order to solve this problem, molecular systematic of Syphaciinae is necessary.

ACKNOWLEDGMENTS. Sincere thanks are due to Dr. G. G. Musser, American Museum of Natural History, and Maharadatunkamsi, MZB, for their kindness in identifying host murids. This study was supported financially in part by the RONPAKU Program of the Japan Society for the Promotion of Science (JSPS) (ID NO. LIPI-11317, year 2013 to 2015) and Grants-in-Aid for Scientific Research 03041065 from the Ministry of Education, Culture, Sports, Science and Technology of Japan and Grant-in-Aid for Scientific Research (C) 23570120 from JSPS. The SEM observation was funded by the Indonesian Government through DIPA 2014 under the project "Pengendalian hama terpadu umbi prioritas."

REFERENCES

1. Achmadi, A. S., Esselstyn, J. A., Rowe, K. C., Maryanto, I. and Abdullah, M. T. 2013. Phylogeny, diversity, and biogeography of Southeast Asian spiny rats (*Maxomys)*. *J. Mammal.* **94**: 1412–1423. [CrossRef]
2. Asakawa, M., Koyasu, K., Harada, M., Shrestha, K. C., Mekada, K., Tsuchiya, K., Oda, S.I. and Hasegawa, H. 2013. Parasitic nematodes obtained from *Niviventer eha* and *Mus* spp. (Murinae: Rodentia) captured in the Himalayas, Nepal. *Biogeography* **15**: 73–77.
3. Dewi, K. and Hasegawa, H. 2010. A new *Syphacia* species (Nematoda: Oxyuridae) collected from *Bunomys* spp. (Rodentia: Muridae) in Central Sulawesi, Indonesia. *J. Parasitol.* **96**: 125–128. [Medline] [CrossRef]
4. Dewi, K. and Hasegawa, H. 2014. Two new species of *Syphacia* (Nematoda: Oxyuridae) in endemic murid rodents from Sulawesi, Indonesia. *J. Helminthol.* **88**: 41–49. [Medline] [CrossRef]
5. Dewi, K., Asakawa, M. and Fitriana, Y. S. 2014. *Syphacia* (*Syphacia*) *semiadii* n. sp. (Nematoda: Oxyuridae) from *Halmaheramys bokimekot* Fabre *et al.*, 2013. (Rodentia: Muridae) on Halmahera Island, Indonesia and a key to the species present in Sulawesi and the Australian Bioregion. *Trans. R. Soc. S. Aust.* **138**: 98–104.
6. Dewi, K., Hasegawa, H. and Asakawa, M. 2014. Description of two new species of *Syphacia* (Nematoda: Oxyuridae) collected from *Eropeplus canus* (Rodentia: Muridae), an endemic rat of Sulawesi, Indonesia, with proposal of new subgenera. *Raffles Bull. Zool.* **62**: 647–654.
7. Fabre, P–H., Pagès, M., Musser, G. G., Fitriana, Y. S., Fjeldså, J., Jennings, A., Jønsson, K. A., Kennedy, J., Michaux, J., Semiadi, G., Supriatna, N. and Helgen, K. M. 2013. A new genus of rodent from Wallacea (Rodentia: Muridae: Murinae: Rattini) and its implication for biogeography and Indo–Pacific Rattini systematics. *Zool. J. Linn. Soc.* **169**: 408–447. [CrossRef]
8. Hall, R. 1998. The plate tectonics of Cenozoic SE Asia and the distribution of land and sea. pp. 99–131. *In*: Biogeography and Geological Evolution of SE Asia. (Hall, R. and Holloway, J. D. eds.). Backhuys Publishers, Leiden.
9. Hasegawa, H. 1991. *Syphacia* (*Syphacia*) *ohtaorum* n. sp. (Nematoda: Oxyuridae) from *Mus caroli* on Okinawa Island, Japan. *Syst. Parasitol.* **18**: 221–226. [CrossRef]
10. Hasegawa, H. and Tarore, D. 1996. *Syphacia* (*Syphacia*) *sulawesiensis* n.sp. and *S.* (*S.*) *muris* (Yamaguti, 1935) (Nematoda Oxyuridae) collected from *Rattus xanthurus* (Gray 1867) (Rodentia: Muridae) in North Sulawesi, Indonesia. *Trop. Zool.* **9**: 165–173. [CrossRef]
11. Hasegawa, H. and Syafruddin. 1994. *Hasanuddinia maxomyos* n. gen., n. sp. and *Heligmonoides musseri* n. sp. (Nematoda: Heligmonellidae) collected from endemic murines of Sulawesi, Indonesia. *J. Parasitol.* **80**: 781–788. [Medline] [CrossRef]
12. Hasegawa, H. and Syafruddin. 1997. *Maxomystrongylus yasumai* gen. and sp. n. (Nematoda: Trichostrongylina: Heligmonellidae) collected from murid rodents of Kalimantan, Indonesia. *J. Helminthol. Soc. Wash.* **64**: 263–268.
13. Hugot, J. P. 1988. Les Nématodes Syphaciinae, parasites de Rongeurs et de Lagomorphes. *Mém. Mus. Natl. Hist. Nat. Sér. A.* **141**: 1–148.
14. Musser, G. G. and Carleton, M. D. 2005. Superfamily Muroidea. pp. 894–1531. *In*: Mammal Species of The World: A Taxonomic and Geographic Reference (Wilson, D. E. and Reeder, D. M. eds.). 3rd ed. Johns Hopkins University Press, Baltimore.
15. Petter, A. J. and Quentin, J. C. 1976. No. 4. Keys to genera of the Oxyuroidea. pp. 1–30. *In*: CIH Keys to the Nematode Parasites of Vertebrates (Anderson, R. C., Chabaud, A. J. and Willmott, S. eds.). Commonwealth Agricultural Bureaux, Farnham Royal, Buckinghamshire.
16. Riley, W. A. 1919. A mouse oxyurid, *Syphacia obvelata,* as a parasite of man. *J. Parasitol.* **6**: 89–93. [CrossRef]
17. Smales, L. R. 2001. *Syphacia longaecauda* n. sp. (Nematoda: Oxyuridae) Syphacinea from *Melomys* spp. (Muridae: Hydromyinae) from Papua New Guinea and Irian Jaya, Indonesia. *Parasite* **8**: 39–43. [Medline] [CrossRef]
18. Smales, L. R. 2011. Gastrointestinal nematodes of *Coccymys ruemmleri* (Rodentia, Muridae) with the description *Montistrongylus giluwensis* sp. nov. (Heligmonellidae) and *Syphacia coccymyos* sp. nov. (Oxyuridae) from Papua New Guinea. *Acta Parasitol.* **56**: 418–426. [CrossRef]
19. Stelbrink, B., Albrecht, C., Hall, R. and von Rintelen, T. 2012. The biogeography of Sulawesi revisited: is there evidence for a vicariant origin of taxa on Wallace's "anomalous island"? *Evolution* **66**: 2252–2271. [Medline] [CrossRef]
20. Voris, H. K. 2000. Maps of Pleistocene sea levels in Southeast Asia: shorelines, river systems and time durations. *J. Biogeogr.* **27**: 1153–1167. [CrossRef]
21. Weaver, H. J. and Smales, L. R. 2008. New species of *Syphacia* (*Syphacia*) Seurat (Nematoda: Oxyuridae) from *Pseudomys* species (Rodentia: Muridae) from Central Australia. *Zootaxa* **1775**: 39–50. [CrossRef]
22. Weaver, H. J. and Smales, L. R. 2010. Three new species of *Syphacia (Syphacia)* (Oxyurida: Oxyuridae) from Queensland, Australia, and a key to the species present in the Australian Bioregion. *Comp. Parasitol.* **77**: 9–19. [CrossRef]
23. Yamaguti, S. 1961. Systema Helminthum. Vol. 3. The Nematodes of Vertebrates. Interscience Publishers., New York.