



NEW SPECIES OF *ALIPPISTRONGYLUS* (TRICHOSTRONGYLINA: NIPPOSTRONGYLINAE) FROM THE ELEGANT RICE RAT, *EURYORYZOMYS NITIDUS*, OF LA CONVENCIÓN, PERU

Guinevere O. Drabik¹, Elena Vivar², and F. Agustín Jiménez¹

¹ School of Biological Sciences, Southern Illinois University, 1125 Lincoln Drive, Carbondale, Illinois 62901-6501.

² Colección Científica de Mamíferos del Museo de Historia Natural de la Universidad Mayor de San Marcos Av. Gral. Antonio Alvarez de Arenales 1256, Jesús María 15072, Lima, Peru.

Correspondence should be sent to Guinevere O. Drabik (<https://orcid.org/0000-0003-2801-4968>) at: guinevere.drabik@siu.edu

KEY WORDS ABSTRACT

Heligmonellidae
Nippostrongylinae
Allippistrongylus
Oryzomyine
Euryoryzomys nitidus
Elegant rice rat
Amazon rainforest
Cashiriari La Convencion,
Cuzco, Peru
Collecting expeditions

A new species of *Allippistrongylus* Digiani and Kinsella, 2014, was found in the intestines of the elegant rice rat, *Euryoryzomys nitidus*, collected in the Amazon rainforest. These mammals were preserved in alcohol and archived in the Colección Científica de Mamíferos del Museo de Historia Natural de la Universidad Mayor de San Marcos and accessed for the observation and investigation for the diversity of their endo-parasites. A total of 857 worms were recovered from the 3 individuals examined. Morphological investigations and comparisons with the only known species of the genus indicate that this is an undescribed species. These nematodes feature the diagnostic characteristic of the genus, being a bifurcated posterior end that consists of a tail and a conical appendage near the level of the vulva and uninterrupted ridges in the synlophe of unequal size. However, the orientation of this conical appendage on the female tail, features of the synlophe, and shape of the copulatory bursa warrant the proposal of an amended diagnosis to include character variability detected in the new species.

In the current study, we describe a new species of nematode, *Allippistrongylus* Digiani and Kinsella, 2014, collected from the small intestines of 3 elegant rice rats, *Euryoryzomys nitidus* (Thomas, 1884), from Cashiriari, La Convención, Cuzco, Peru. Peru is considered a particularly diverse country, containing vast species richness of vertebrates, invertebrates, and plants (Myers et al., 2000). This diversity is greater in the Amazonian region where 200 species of mammals are known to occur (Voss and Emmons, 1996). Coincidentally, the richness of natural resources in western Amazonia includes deposits of oil and natural gas that have been explored and developed since the late part of the 20th century (Solari et al., 2001, Finer et al., 2008). To assess and monitor the effects of mineral extraction on the environment, a systematic survey of mammals was completed between 1997 and 1998. This effort resulted in vouchered mammalian specimens collected during the Smithsonian Institution's Monitoring and Assessment of Biodiversity Program with permission from Instituto Nacional de Recursos Naturales. These specimens were deposited in the Colección Científica de Mamíferos del Museo de Historia Natural de la Universidad Mayor de San Marcos (MUSM) in Lima, Peru (Solari et al., 2001, 2002). The

diversity of parasites associated with these mammals has yet to be documented.

During this expedition, data on habitat, habits, and biological associates of the mammals collected at this site were documented and archived in MUSM. This provides a permanent record of the conditions and life histories of mammals at the time and place of collection that may no longer be available to sample. These archives act as the cornerstone for documenting and characterizing the patterns of host-parasite association and the changes that these may experience through time (Dunnum et al., 2017; Colella et al., 2021).

Oryzomyine rodents have a broad distribution through the New World from the southeastern United States to the southern cone of South America in addition to the Galapagos Islands (Weksler et al., 2006; Percequillo et al., 2021). One of these species, the omnivorous elegant rice rat, is distributed mainly along the Andean foothills and in adjacent lowlands in Peru, Bolivia, and western Brazil. Scattered records have indicated its eastward extension through south-central Brazil to Paraguay and northeastern Argentina (Musser et al., 1998; Wilson and Reeder, 2005). According to the literature, 13 species of members of the Nippostrongylinae use rodents of *Euryoryzomys* as hosts; the species are included in *Hassalstrongylus* Durette-Desset, 1971, *Guerrerostrongylus* Sutton and

Version of Record, first published online with fixed content and layout, in compliance with ICZN Arts. 8.1.3.2, 8.5, and 21.8.2 as amended, 2012. ZooBank publication registration: [urn:lsid:zoobank.org:pub:7C7F3750-C309-442C-9CC8-422387891E73](https://zoobank.org/pub:7C7F3750-C309-442C-9CC8-422387891E73).



Durette-Desset, 1991, and *Stilestrongylus* Freitas, Lent, and Almeida, 1937.

Alippistrongylus was monotypic containing *Alippistrongylus bicaudatus* Digiani and Kinsella, 2014. These nematodes have a reduced buccal cavity and continuous cuticular ridges supported by struts of different sizes. Ridges on the left dorsal quadrant with reduced struts and oriented perpendicularly to the body. The axis of orientation of ridges is directed from ventral right to dorsal left quadrant, with inclinations of about 60° to the sagittal axis at mid-body. Bursa is highly dissymmetrical, with a well-developed genital cone, filiform spicules, gubernaculum, and a bifurcated posterior region in females consisting of a dorsal conical appendage at the level of the vulva (Digiani and Kinsella, 2014).

Based on the configuration of the homologous characters present in worms studied herein, we believe that specimens collected in Peru belong to a new species of *Alippistrongylus*. Since this is the second species in the genus, the study of the variation of the characters once considered diagnostic for the genus allows us to propose an amended diagnosis.

MATERIALS AND METHODS

Rodents were prepared as fluid specimens, preserved in 70% ethanol, and archived in MUSM. Carcasses were requested from this collection and subsequently necropsied. Nematodes were removed from the small intestine and transferred to 70% ethanol for preservation and storage. Parasite specimens were deposited in the Helminthological Collection of the Departamento de Protozoología, Helminología e Invertebrados Afines of the MUSMH and the Harold W. Manter Laboratory of Parasitology (HWML) in Lincoln, Nebraska.

For examination, specimens were cleared in glycerin and mounted on temporary slides in glycerin or glycerin jelly. All specimens were measured and imaged with Leica LAS V4.4 (Leica Co. Ltd., Tokyo, Japan), and drawings were made with the aid of a camera lucida attached to an Olympus BX50 microscope (Olympus Co. Ltd., Tokyo, Japan). For detailed observation of the genital structures, 4 male specimens were dissected, and the posterior ends were cleared in lactophenol. Cross sections of four specimens were made to observe the synlophe and reproductive structures.

Two specimens, a male and a female, were prepared for DNA extractions. These specimens were washed, measured, and excised. A piece of these worms was processed using the Qiagen Micro AMP DNA kit (Valencia, California) following manufacturer recommendations, with extended time for digestion. However, the loci we attempted to amplify, Internal Transcribed Spacer (*ITS1*, *ITS2*), and cytochrome *c* oxidase following protocols described in Jiménez et al. (2012), had likely been degraded and as such could not be successfully amplified and sequenced.

For SEM, 9 specimens were washed 3 times in a 10% mixture of near-boiling water and formalin and then dehydrated and stored in 100% ethanol for transport. The specimen was then critically point dried in CO₂, sputter-coated with a gold-palladium layer approximately 20 nm thick, and examined with an FEI Quanta FEG 450 SEM with EDS detectors (FEI Co. Ltd., Hillsboro, Oregon) at the Southern Illinois University Integrated Microscopy and Graphics Expertise Center.

RESULTS

The following description is based on 25 worms from 3 individual elegant rice rats. For each character, the range is given, followed by the mean, coefficient variation (Sokal and Rohlf, 1995), and sample size. Measurements are given in micrometers unless otherwise stated. The nomenclature used for the study of the caudal bursa and the synlophe follows Durette-Desset and Digiani (2005, 2012).

Amended diagnosis

Alippistrongylus Digiani and Kinsella, 2012

Diagnosis: Synlophe with uninterrupted ridges, unequal in size but not markedly so. Ridges on left dorsal quadrant with reduced struts and oriented perpendicularly to body surface. Axis of orientation of ridges directed from ventral right to dorsal left quadrant, with inclination between 50° and 60° to sagittal axis. Bursa dissymmetrical with hypertrophied right lobe and pattern 1-4 or 4-1 or symmetrical with pattern 2-2-1. Genital cone well developed. Females with cuticularized conical appendage at level or near the opening of the vulva. Parasites of Neotropical Sigmodontinae (Rodentia, Cricetidae).

DESCRIPTION

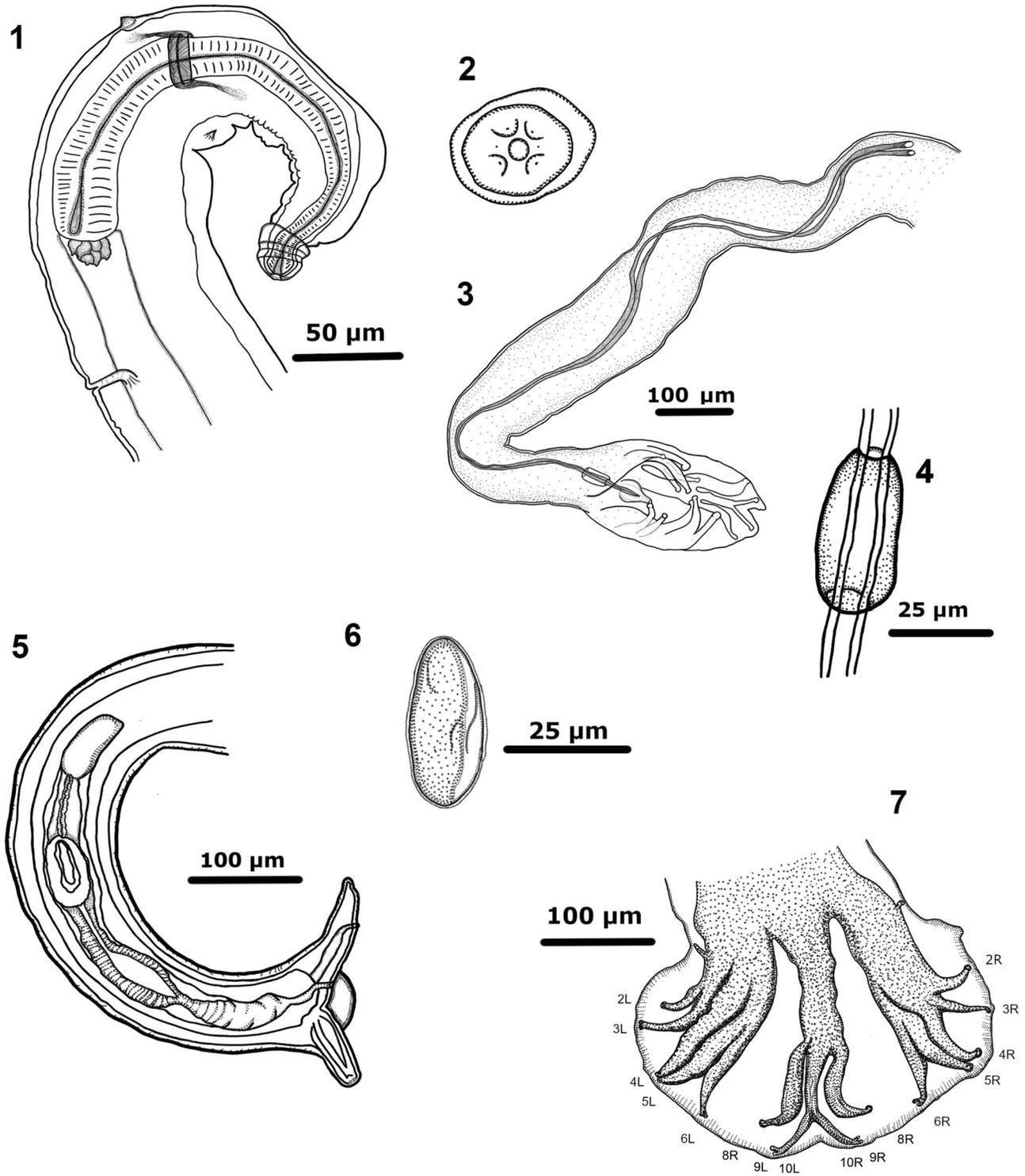
Alippistrongylus marki n. sp.

(Figs. 1–13)

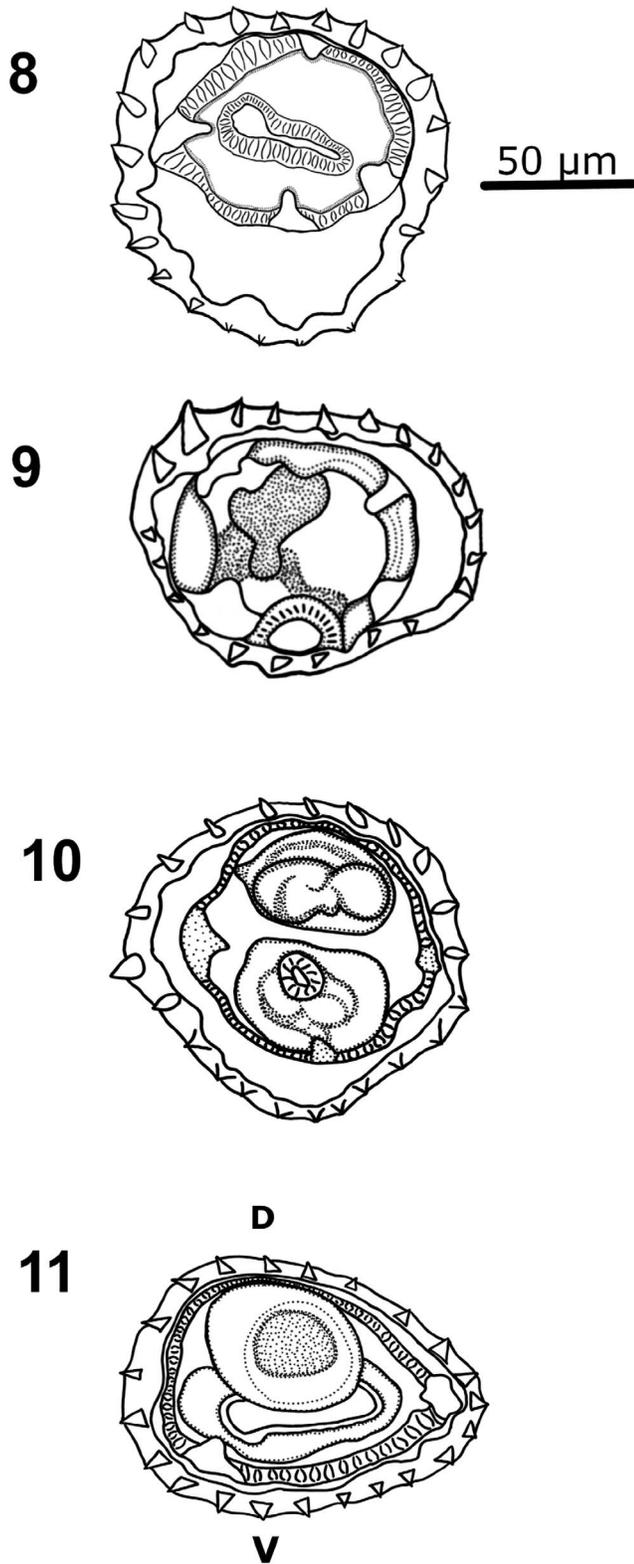
General: Small nematodes, tightly and irregularly coiled. Cuticular ridges along the body. Conspicuous cephalic vesicle (Fig. 1). Two amphids, 4 externolabial papillae, and 4 submedian cephalic papillae are positioned around a small ring that surrounds the buccal cavity (Fig. 2). Papillae and amphids barely visible. Derids near level of excretory pore (Fig. 1). Esophagus club-shaped. Nerve ring in anterior half of the esophagus, anterior to the excretory pore (Fig. 1). Females larger than males; males with well-developed copulatory bursa (Figs. 3, 7). Female with cuticularized ventral conical appendage and tail bifurcating at the level of the vulva (Fig. 5).

Synlophe: (Studied in 2 males and 3 females, all paratypes): In both sexes cuticle bearing longitudinal, uninterrupted ridges appearing just posterior to cephalic vesicle and ending just anterior of the bursa in the male and reaching the caudal appendage in the female. Number of ridges constant along the body, with 21 to 24 ridges at the anterior end, midbody, and posterior end in both sexes (Figs. 8–11). The ridges oriented in oblique axis, and ridges are similar in size and shape, albeit ventral ridges appear larger and dorsal ridges reduced featuring a slight gradient in size at midbody.

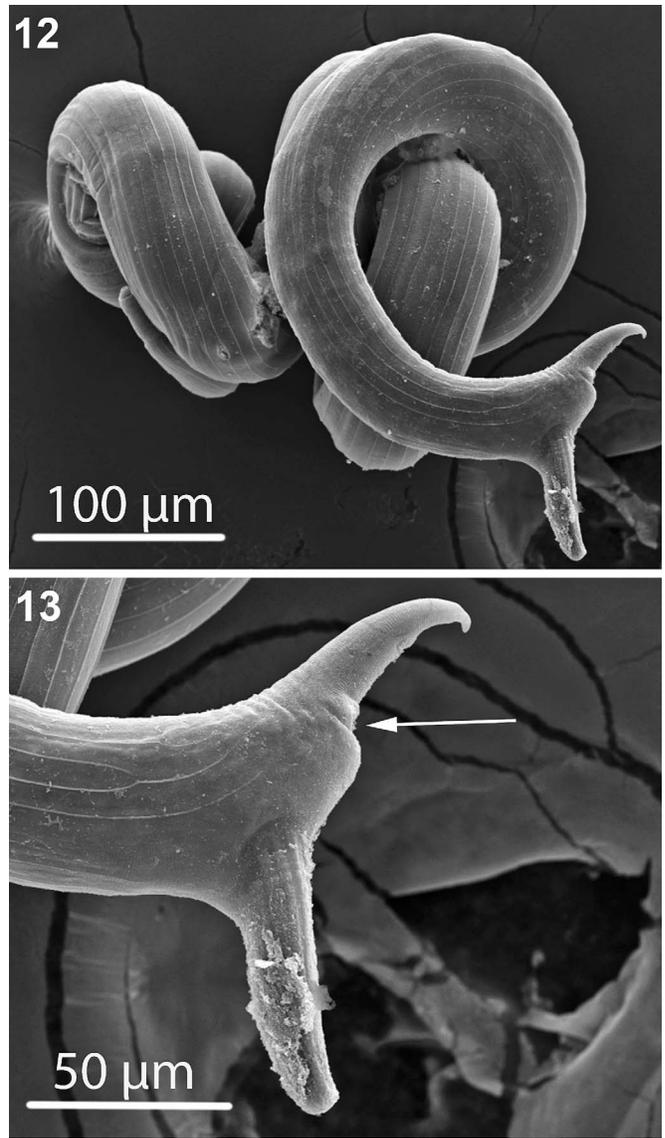
Male (measurements based on 13 worms unless otherwise noted): Length 2.1–3.4 mm (2.9, 364%, n = 11) maximum width 66.5–95.4 (77, 8%, n = 11). Cephalic vesicle length 20.4–62.5 (46, 13.4%, n = 10), width 25.9–46.8 (32, 6.5%, n = 10). Esophagus 146.7–278.9 (232.9, 60.7%, n = 4), corpus width 11–22.4 (18.6, 4.1%, n = 6). Distance from anterior end to nerve ring 77.5–130.3 (98.5, 20.5%, n = 7), and to excretory pore 46.7–198.5 (118.14, 62.9%, n = 4). Spicules setaceous and sub-equal, situated in the posterior half of the body (Fig. 3). Manubrium of spicule similar in shape to the eye of a needle (Fig. 3). Length of left spicule 1,004.7–1,461 (1,211.8, 124.4%, n = 10), right spicule 1,007.7–1,434.7 (1,198.4,



Figures 1–7. *Alippistrongylus marki* n. sp. from elegant rice rat, *Euryoryzomys nitidus*. (1) Male, anterior end, lateral left view featuring esophagus, deirids and excretory pore. (2) Head apical view, schematic not in scale. (3) Posterior end of male featuring spicules, gubernaculum, and bursa. (4) Gubernaculum. (5) Female posterior featuring ovejector with well-developed infundibulum, sphincter muscles, and vestibule. These are labeled I = infundibulum, S = sphincter, VS = vestibule. (6) Egg. (7) Ventral view of bursa with labels to the rays in both right (2-6 R) and left (2-6 L) lobes.



Figures 8–11. *Alippistrongylus marki* n. sp. from elegant rice rat, *Euryoryzomys nitidus*. (8) Synlophe in transverse sections of the body at anterior of female. (9) At mid-body of male. (10) At mid-body of female. (11) Within distal third of the body (female). Abbreviations: R = right, v = ventral. All sections are oriented as in Figure 6.



Figures 12, 13. SEM micrographs of *Alippistrongylus marki* n. sp. from elegant rice rat, *Euryoryzomys nitidus*. (12) Full body of female. (13) Posterior third of female. Arrows indicate vulva aperture.

106.7%, n = 11). Proportion of spicules relative to body length 0.19–0.60 (0.4, 11%, n = 11). Gubernaculum well developed (Figs. 3, 4), length 27.7–39.4 (34.4, 3.8%, n = 12), maximum width 13.2–20.4 (16.6, 2.6%, n = 12) (Fig. 4).

Copulatory bursa cordiform and symmetrical, of type 2-2-1. Rays short, all arising from a common trunk formed by rays 2–6. Rays 4–5 fused, while rays 2, 3, 6 are separated. Dorsal ray long, bifurcating into 2 rays (rays 8R and 8L) at its distal half, then into 2 branches again at the distal quarter of rays 9 and 10. Each tip of the dorsal ray divided into 2 sub-branches ending in papillae that reach the vellum of copulatory bursa (Fig. 3).

Female (measurements based on 11 worms unless otherwise noted): Length 2,136.6–3,885 (3,321.1, 650%, n = 6), maximum width, 82–140 (107.7, 18%, n = 8). Cephalic vesicle length, 32.1–60.3 (44.2, 7.7%, n = 10), width 26–43.2 (33.5, 6.6%, n = 10). Esophagus length 201.6–318.6 (257, 52.4%, n = 4), corpus width

15.2–52 (31.3, 17%, n = 5). Distance from anterior end to nerve ring 81.7–113.6 (95, 53%, n = 4) and to excretory pore 128.1–144.1 (136.1, 11.3%, n = 2). Monodelphic (Fig. 5). Distance from vulva to end of tail 60–116 (88.8, 21.2%, n = 8). Vagina vera, 33–67.6 (49, 12%, n = 8) long; vestibule 92.3–594.8 (389.8, 187.2%, n = 7) long by 34.2–57 (43.5, 8.7%, n = 6) wide; sphincter 31.5–84 (64.2, 18.5%, n = 7) by 24.3–59 (43.1, 13.5%, n = 6); infundibulum 78.1–250.3 (132.2, 62.4%, n = 7) by 32.4–41.4 (36.9, 6.4%, n = 2). Eggs ovoid, 55.7–82 (71, 7.1%, n = 33) by 25.4–46 (34.7, 5.8%, n = 33) (Fig. 6). Typically, 3 eggs are present in vestibule. Posterior extremity bifurcating at the level of the vulva into a ventral conical appendage and the tail (Figs. 12, 13), conical appendage 53.4–125.6 (93.2, 22%, n = 8) long, width at base 30–39 (34.3, 4%, n = 7). Distance anus to end of tail 33.6–66 (42, 12%, n = 7).

Taxonomic summary

Holotype female: MUSM-HELM 4886.

Allotype male: MUSM-HELM 4887 (NP 747_VI).

Paratypes: (NP745)–HWML117636, MUSM-HELM 4890, MUSM-HELM 4891, MUSM-HELM 4892, MUSM-HELM 4894; (NP746)–HWML117637, HWML117638, MUSM-HELM 4893; (NP747)–HWML117639, HWML117640, HWML117641, HWML 117642, HWML117643, HWML117644, HWML117645, HWML117646, HWML117647, HWML117648, HWML117649, HWML117650, HWML-216839, MUSM-HELM 4886, MUSM-HELM 4887, MUSM-HELM 4888, MUSM-HELM 4889.

Symbiotype (see Frey et al., 1992): Elegant rice rat, *Euryoryzomys nitidus* (Goldman, 1918) (Cricetidae: Sigmodontinae). Colección Científica de Mamíferos del Museo de Historia Natural de la Universidad Mayor de San Marcos, catalog no. MUSM 14336, Field Collection Number PMV077♂, Collector: Paúl M. Velazco, date of collection: 30 August 1998.

Type locality: Peru, Cuzco, La Convención Cashiriari.

Date collected: 30 August, 4 September, and 5 September 1998.

Site of infection: Small intestine.

Prevalence and mean intensity: 100%; 286 ± 225 (11–732).

ZooBank registration: urn:lsid:zoobank.org:act:D370D8E2-C37C-4B0A-9DD4-FAFB17FB4A60.

Etymology: The species is named after Mark Drabik, beloved father of G.O.D.

Differential diagnosis

Alippistrongylus marki can be distinguished from *Alippistrongylus bicaudatus* by the position of the caudal conical appendage. In the case of *A. marki*, the conical appendage is ventral and slightly anterior of the opening of the vulva, whereas the conical appendage is dorsal in *A. bicaudatus*. In turn, in *A. marki*, the ventral conical appendage is digitiform (Figs. 5, 12, 13), whereas the dorsal conical appendage is rounded and endowed with lateral cuticular striations in *A. bicaudatus*. The genital cone in *A. marki* is smaller than that of *A. bicaudatus*. Further, the dorsal ray of *A. marki* is very long and bifurcates at the posterior half forming a pronounced Y; lateroventral rays of the copulatory bursa are sub-symmetric, causing the bursa to appear cordiform with sub-symmetric lobes (Figs. 3, 7). In contrast, the dorsal ray in *A. bicaudatus* is short, and the lateroventral rays are dissymmetrical and elongated. A gubernaculum is present in *A. marki* but not observed in *A. bicaudatus*. Finally, the ray arrangement in *A.*

marki is 1-2-1, and *A. bicaudatus* has an asymmetric pattern of left lobe with 1-4 and right lobe 4-1.

DISCUSSION

Studies of parasites of sylvatic animals and research expeditions are becoming rarer, just when populations of wild animals of all kinds dwindle due to loss of habitat. This has become commonplace in Peru as the tropical Andes are continuously being subjected to high rates of natural resource exploitation through extractive industries (Bax et al., 2019). Some industries have begun encroaching onto federally protected land, which suggests that the impacts on places once thought to be protected are at higher risk of losing biodiversity (Asner and Tupayachi, 2017; Bax et al., 2019). The exploitation of natural resources has shown that more than a quarter of Peru's tropical Andes has been leased to mineral mining, timber, and hydrocarbon companies (Bax et al., 2019).

To further this problem, stringent permitting for collecting fresh material and exporting specimens makes researching biodiversity more difficult (Smith et al., 2017). The collections and institutions that house data from previous expeditions have become more essential than ever to researchers, placing greater importance on the preservation and accessibility of collections (Dunnun et al., 2017; Colella et al., 2021). The use of natural history collections is integral to completing the biological inventory of the planet because it allows documentation of the association of mammals and parasites as demonstrated in the present study. Currently, natural history collections are at risk of being lost without the continued support that sustains their management, which will hinder future research (Galbreath et al., 2019; Thompson et al., 2021). The archived specimens available at Natural History Collections may be the last resources that biologists have to complete planetary inventories as natural areas continue to be made inaccessible by the processing of their natural resources.

Select specimens used in this study could not be amplified using traditional Sanger sequencing methods. This, compounded by the lack of available molecular data for the genus *Alippistrongylus*, complicated the unequivocal placement of *A. marki*. *Alippistrongylus marki* features a posterior conical appendage on the female tail, the ridges in the synlophe are supported by struts of irregular size, and there is a well-developed genital cone; however, numerous features do not fit the original diagnosis offered by Digiani and Kinsella (2014). In the original diagnosis, the placement of the conical appendage is defined as dorsal, yet it is ventral in the species described herein. Further, the bursa is diagnosed as dissymmetrical with a 1-4 or 4-1 ray arrangement, and it appears as sub-symmetrical and cordiform in *A. marki*. Nevertheless, we posit that *A. marki* should be retained in *Alippistrongylus* owing to the axis of orientation of the ridges and the presence of a posterior conical appendage. As a consequence, we offer an emendation to the diagnosis of the genus.

Some characters within *A. marki*, such as the size of spicules and their proportion relative to the body length have variable ranges. Typically, the size of the spicules has been used as a diagnostic for species, since they typically are uniform in length. However, size variability is not uncommon in trichostrongylid worms, and it has been documented in the spicules of other species of South American nippostrongylines, including *Guerreri-*

sotrongylus marginalis Weirich, Catzefflis, and Jiménez, 2016 (Weirich et al., 2016).

ACKNOWLEDGMENTS

Drs. V. Pacheco, S. Solari, P. M. Velazco, and J. J. Rodríguez collected and curated sigmodontine rodents. Drs. L. Pérez, S. Gardner, and G. Racz accepted the specimens deposited in MUSMS and HWML. The Hagan Funds of the University of Nebraska made it possible to visit collections in Lima, Peru. Work was supported in part by the Vicerrectorado de Investigación UNMSM (B19100991). M. Walker, M. Szubryt, and A. Scott-Elliston provided technical assistance and feedback. Infrastructure for SIU was provided by NSF-CHE 0959568. G.O.D. and F.A.J. were supported by NSF-DUE 1564969.

LITERATURE CITED

- ASNER, G. P., AND R. TUPAYACHI. 2017. Accelerated losses of protected forests from gold mining in the Peruvian Amazon. *Environmental Research Letters* 12: 094004. doi:10.1088/1748-9326/aa7dab.
- BAX, V., W. FRENCESCONI, AND A. DELGADO. 2019. Land-use conflicts between biodiversity conservation and extractive industries in the Peruvian Andes. *Journal of Environmental Management* 232:1028–1036.
- COLELLA, J. P., J. BATES, S. BURNEO, A. CAMACHO, C. CARRION, I. CONSTABLE, G. D'ELIA, J. DUNNUM, S. GRIEMAN, E. HOBERG, ET AL. 2021. Leveraging natural history collections as a global, decentralized pathogen surveillance network. *PLoS Pathogens* 17: e1009583. doi:10.1371/journal.ppat.1009583.
- DIGIANI, M. C., AND J. M. KINSELLA. 2014. A new genus and species of Heligmonellidae (Nematoda: Trichostrongylina) parasitic in *Delomys dorsalis* (Rodentia: Sigmodontinae) from Misiones, Argentina. *Folia Parasitologica* 61: 473–478.
- DUNNUM, J. L., R. YANAGIHARA, K. M. JOHNSON, B. ARMIEN, N. BATSAIKHAN, L. MORGAN, AND J. A. COOK. 2017. Biospecimen repositories and integrated databases as critical infrastructure for pathogen discovery and pathobiology research. *PLoS Neglected Tropical Diseases* 11: e0005133. doi:10.1371/journal.pntd.0005133.
- DURETTE-DESSET, M. C., AND M. C. DIGIANI. 2005. The axis of orientation of the synlophe in the Heligmosomoidea (Nematoda, Trichostrongylina): A new approach. *Parasite* 12: 195–202.
- DURETTE-DESSET M.C., AND M. C. DIGIANI. 2012. The caudal bursa in the Heligmonellidae (Nematoda: Trichostrongylina). Characterization and hypothesis on its evolution. *Parasite* 19: 3–13.
- FINER, M., C. N. JENKINS, S. L. PIMM, B. KEANE, AND C. ROSS. 2008. Oil and gas projects in the western Amazon: Threats to wilderness, biodiversity, and indigenous peoples. *PLoS ONE* 3: e2932. doi:10.1371/journal.pone.0002932.
- FREY, J. K., D. W. DUSZYNSKI, W. L. GANNON, T. L. YATES, AND S. L. GARDNER. 1992. Designation and curatorial management of type host specimens (symbiotypes) for new parasite species. *Journal of Parasitology* 78: 930–932.
- GALBREATH, K. E., E. P. HOBERG, J. A. COOK, B. ARMIEN, K. C. BELL, M. L. CAMPBELL, J. L. DUNNUM, A. T. DURSAHINHAN, R. P. ECKERLIN, S. L. GARDNER, ET AL. 2019. Building an integrated infrastructure for exploring biodiversity: Field collections and archives of mammals and parasites. *Journal of Mammalogy* 100: 382–393.
- JIMÉNEZ, F. A., S. L. GARDNER, G. T. NAVONE, AND G. ORTÍ. 2012. Four events of host-switching in Aspidoderidae (Nematoda) involve convergent lineages of mammals. *Journal of Parasitology* 98: 1166–1175.
- MUSSER, G. G., M. D. CARLETON, E. M. BROTHERS, AND A. L. GARDNER. 1998. Systematic studies of oryzomyine rodents (Muridae, Sigmodontinae): Diagnoses and distributions of species formerly assigned to *Oryzomys* “capito.” *Bulletin of the American Museum of Natural History* 236: 1–376.
- MYERS, N., R. A. MITTERMEIER, C. G. MITTERMEIER, G. A. B. DA FONSECA, AND J. KENT. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.
- PERCEQUILLO, A. R., J. RODRIGUES DO PRADO, E. F. ABREU, J. DALAPICCOLA, A. C. PAVAN, E. DE ALMEIDA CHIQUITO P. BRENNAND, S. J. STEPPAN, A. R. LEMMON, E. M. LEMMON, ET AL. 2021. Tempo and mode of evolution of oryzomyine rodents (Rodentia, Cricetidae, Sigmodontinae): A phylogenomic approach. *Molecular Phylogenetics and Evolution* 159: 107–120.
- SMITH, D., M. DA SILVA, J. JACKSON, AND C. LYAL. 2017. Explanation of the Nagoya Protocol on access and benefit sharing and its implication for microbiology. *Microbiology (United Kingdom)* 163: 289–296.
- SOKAL, R. R., AND F. J. ROHLF. 1995. *Biometry: The Principles and Practice of Statistics in Biological Research*, 3rd ed. W. H. Freeman, New York, New York, 887 p.
- SOLARI, S., R. J. J. RODRIGUEZ, E. VIVAR, AND P. M. VELAZCO. 2002. A framework for assessment and monitoring of small mammals in a lowland tropical forest. *Environmental Monitoring and Assessment* 76: 89–104.
- SOLARI, S., E. VIVAR, J. J. RODRIGUES, AND J. L. MENA. 2001. Small mammals community of the lower Urubamba Region, Peru. *In* Urubamba: The Biodiversity of a Peruvian Rainforest, Series 2, A. Alonso, F. Dallmeier, and P. Campbell (eds.). Smithsonian Institution/MAB Biodiversity Program, Washington, D.C., p. 171–181.
- THOMPSON, C. W., C. W. PHELPS, K. L. ALLARD, M. W. COOK, J. A. DUNNUM, J. L. FERGUSON, A. W. GELANG, M. KHAN, F. L. PAUL, D. L. REEDER, ET AL. 2021. Preserve a voucher specimen! The critical need for integrating natural history collections in infectious disease studies. *American Society of Microbiology* 12: 1–20.
- VOSS, R. S., AND L. H. EMMONS. 1996. Mammalian diversity in Neotropical lowland rainforests: A preliminary assessment. *Bulletin of the American Museum of Natural History* 230: 1–115.
- WEIRICH, J. M., F. CATZEFLIS, AND F. A. JIMÉNEZ. 2016. *Guerrerostrongylus marginalis* n. sp. (Trichostrongyloidea: Heligmonellidae) from the Guianan arboreal mouse (*Oecomys auyantepui*) from French Guiana. *Parasite* 23: 9. doi:10.105/parasite/2016009.
- WEKSLER, M., A. R. PERCEQUILLO, AND R. S. VOSS. 2006. Ten new genera of oryzomyine rodents (Cricetidae: Sigmodontinae). *American Museum Novitates* 3537: 1–29.
- WILSON, D. E., AND D. M. REEDER (eds.). 2005. *Mammal Species of the World: A Taxonomic and Geographic Reference*, 3rd ed. Johns Hopkins University Press, Baltimore, Maryland, 1152 p.