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A NEW SPECIES OF SUCKING LOUSE (PHTHIRAPTERA: ANOPLURA: LINOGNATHIDAE) FROM GÜNTHER'S DIKDIK (*MADOQUA GUENTHERI*) IN KENYA

Lance A. Durden, Andrei D. Mihalca*, Attila D. Sándor*, and Paul W. N. Kanyari†

Department of Biology, Georgia Southern University, 4324 Old Register Road, Statesboro, Georgia 30458. Correspondence should be sent to: *ldurden@georgiasouthern.edu*

ABSTRACT: *Linognathus samburi* n. sp. is described from adult male and female specimens collected from a juvenile female Günther's dikdik (*Madoqua guentheri*) live-trapped near Olturot Village, Samburu district (Rift Valley Province) in northern Kenya. The new species is distinguished from other species of *Linognathus* including *Linognathus geigyi* and *Linognathus damarensis,* both of which parasitize Kirk's dikdik (*Madoqua kirkii*). A dichotomous key to the species of *Linognathus* that are known to parasitize dikdiks is included.

Globally, more than 530 valid species of sucking lice (Phthiraptera: Anoplura) have been described (Durden and Musser, 1994). Sucking lice parasitize various groups of placental mammals with especially rich faunas associated with rodents and, to a lesser extent, ungulates. Members of the sucking louse genus *Linognathus* are mostly associated with ungulates (48 of the 52 described species of *Linognathus*) although another 4 species parasitize carnivores (certain members of the family Canidae) (Weisser, 1975; Kim and Ludwig, 1978; Ledger, 1980; Durden and Musser, 1994; Pajot, 2000). Previous taxonomic assessments for the genus *Linognathus* include the works of Ferris (1932) who illustrated all species in the genus known at that time and also described 4 new species, Fiedler and Stampa (1958a, 1958b) who assessed the validity of several African species of *Linognathus* and also described 3 new species, Weisser (1975) who illustrated and reviewed all species of *Linognathus* known at that time, and Ledger (1980) who reviewed the Afrotropical species.

Some members of the genus *Linognathus* have major veterinary importance as ectoparasites of pets or livestock animals, and, under certain conditions, they can result in pruritus, intense grooming, alopecia, anemia, allergic reactions, or low weight gains in their hosts; further, some species can transmit pathogens (Durden and Lloyd, 2009). Members of this genus that parasitize domestic mammals are the dog sucking louse, *Linognathus setosus* (von Olfers), the sheep face louse, *Linognathus ovillus* (Neumann), the sheep foot louse, *Linognathus pedalis* (Osborn), the goat sucking louse, *Linognathus stenopsis* (Burmeister), the long-nosed cattle louse, *Linognathus vituli* (Linnaeus), and *Linognathus africanus* Kellogg and Paine (no conventional common name) of goats and sheep (Price and Graham, 1997; Durden and Lloyd, 2009). All 6 of these species are globally widespread and have accompanied their hosts from the Old World (Africa or Eurasia) as humans have transported them around the world. Detrimental effects of lice on wild mammals have been poorly documented (Durden, 2001), but, presumably, some species can adversely affect their hosts under certain conditions or they could transmit pathogens. The majority of described species of *Linognathus* are associated with feral mammals in the Afrotropical region where 40 of the 46 (87%) described species parasitize artiodactyls (antelopes, gazelles, giraffe, wildebeest, Cape buffalo, and others) (Weisser, 1975; Durden and Musser, 1994; Pajot, 2000; Durden and Horak, 2004).

It is important to document new taxa of ectoparasites in order to increase knowledge of parasite biodiversity and because ectoparasites can detrimentally affect their hosts through blood-feeding behaviors that can sometimes also result in parasite or pathogen transmission. In this paper, we describe a new species of *Linognathus* from the Afrotropical region that was collected from a live-captured individual of Guenther's dikdik (*Madoqua guentheri*) (Artiodactyla: Bovidae) in Kenya. This small antelope occurs in certain semi-arid zones in Somalia, Ethiopia, Kenya, Uganda, and Sudan where it typically congregates in small groups of 3 to 4 individuals in semi-arid thornbush habitat, savanna, or riverine grassland-woodland, as well as disturbed or grazed areas (Kingswood and Kumamoto, 1996).

MATERIALS AND METHODS

The study was conducted in pastoral communities in northern Kenya, in the Marsabit and Samburu districts (Rift Valley Province). Approximately 75% of the surface area of the 2 districts is classified as rangeland, and the main mode of land use is extensive grazing (Little, 1992). The region still supports a rich wildlife fauna including communities of antelopes (de Leeuw et al., 2001). While performing a vaccination campaign of household dogs against rabies (D'Amico et al., 2013), live captured wild mammals were occasionally brought by local people, and, hence, they were surveyed for ectoparasites. These animals were caught either using small mammal traps or hand-caught by local Samburu tribesmen and always released following examination.

A juvenile female Günther's dikdik (*Madoqua guentheri*) was live-trapped close to Olturot village (Samburu District, Rift Valley Province) on the evening of 13 January 2012. The animal was screened, and lice were observed on its fur and skin. The lice were collected by 2 of the authors (A.D.S. and A.D.M.) with fine forceps by thoroughly examining the fur with the aid of a headlamp. All visible specimens were collected and stored in 70% ethanol. All work was completed under permits issued by the Kenyan Wildlife Service and in collaboration with Veterinary Faculty at the University of Nairobi.

Eight louse specimens (4 males, 4 females) were selected from 21 sucking lice that were collected from the host and stored in 70% ethanol. These 8 specimens were cleared in 10% potassium hydroxide, rinsed in distilled water, dehydrated in an ethanol series of ascending concentration, further cleared in xylene, slide-mounted in Canada balsam and oven-dried following standard protocols (Kim et al., 1986). Dried specimen slides were labeled, and specimens were examined and drawn using an Olympus BH-2 compound microscope (Olympus, Center Valley, Pennsylvania). Throughout this paper, sucking louse descriptive terminology follows Kim and Ludwig (1978) and Durden and Horak (2004) whereas host taxonomy and nomenclature follows Wilson and Reeder (2005).

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* Department of Parasitology and Parasitic Diseases, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Calea Mănăştur 3-5, Cluj-Napoca, 400372, Romania.

† Department of Veterinary Pathology, Microbiology and Parasitology, Faculty of Veterinary Medicine, University of Nairobi, P.O. Box 29053, Nairobi, Kenya.

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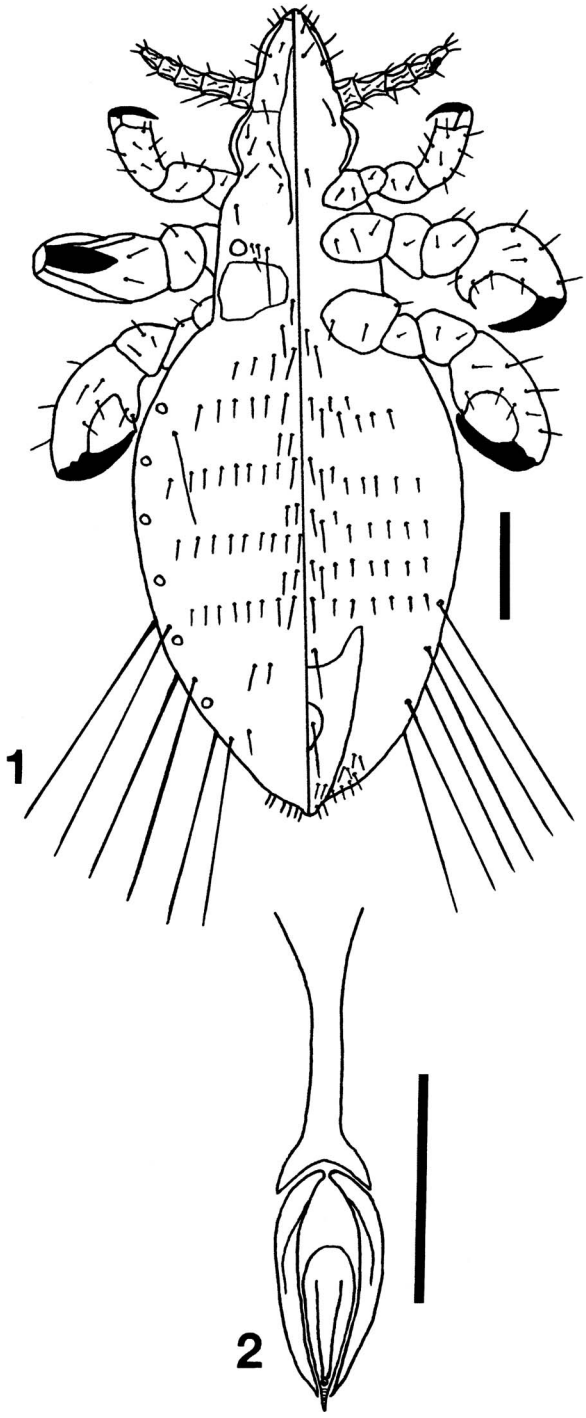


FIGURES 1, 2. *Linognathus samburi*, n. sp., male. (**1**) Dorsoventral view showing ventral morphology to the right of the midline and dorsal morphology to the left (scale bar, 0.2 mm). (**2**) Genitalia (scale bar, 0.1 mm).

DESCRIPTION

Linognathus samburi n. sp.

(Figs. 1–4)

Male (Figs. 1–2): Length of slide-mounted Holotype, 1.44 mm, range (holotype and 3 slide-mounted male paratypes), 1.44–1.60 mm, mean, 1.50 mm.

Head conically elongate anterior to antennae extending to broadly acute apex; bulging semi-circular lateral margins posterior to antennae; distinctly sclerotized lateral and antero-lateral margins. Eyes absent (as in other species of *Linognathus*). Antennae 5-segmented with first segment broader than second segment. Three pairs of submarginally inserted dorsal marginal head setae (DMHS), 1 pair of small Dorsal Posterior Central Head Setae (DPoCHS), 1 pair of relatively short Dorsal Principal Head Setae (DPHS), 1 pair of Dorsal Anterior Central Head Setae (DAnCHS), 1 pair of Sutural Head Setae (SHS), 2 pairs of Supraantennal Head Setae (1 pair dorsal, 1 pair ventral), 2 pairs of Dorsal Preantennal Lateral Setae (1 pair dorsal, 1 pair ventral), 3 pairs of Apical Head Setae (ApHS), 1 pair of Ventral Preantennal Head Setae (VPaHS), 1 pair of Ventral Principal Head Setae (VPHS), and 1 pair of Ventral Posterior Head Setae (VPoHS) present.

Thorax broader than head, slightly increasing in width posteriorly. Thoracic sternal plate absent (as in other species of *Linognathus*). One Dorsal Prothoracic Seta (DPtS), 3 small Mesothoracic Setae (DMsS), and 1 fairly short Dorsal Principal Thoracic Seta (DPTS) (0.11 mm long) on each side. Mesothoracic spiracle moderate in size (0.029 mm in diameter). Three pairs of legs, each culminating in tibio-tarsal claw; forelegs and claw distinctly smaller than midlegs and hindlegs which are subequal in size. Fore-coxae subtriangular; mid- and hind-coxae subtriangular to sub-oval with rounded angles. Tibio-tarsal thumbs well developed on mid- and hindlegs.

Abdomen wider than thorax with 6 pairs of fairly small spiracles on each side; paratergal plates, tergites, and sternites (other than subgenital plate) absent (as in other species of *Linognathus*). Three pairs of long Dorsal Marginal Abdominal Setae (DMAS) and 3 pairs of long Ventral Marginal Abdominal Setae (VMAS) along posterior margins of abdomen; 1 long DMAS inserted submarginally between spiracles 1 and 2 on each side. Twelve rows of dorsal abdominal setae: rows 1 and 2 each with 2 setae of intermediate length, row 3 with 8 setae (with lateral setae shorter than central setae), rows 4, 6, 8, and 10 each with 16–18 setae (with most lateral setae shorter than central setae), rows 5, 7, 9, and 11 each with 4 setae of intermediate length, row 12 with 2 fairly short lateral setae. Twelve rows of ventral abdominal setae: rows 1 and 2 with 2 setae of intermediate length, rows 3, 5, and 7 each with 4–6 setae (with lateral setae shorter than central setae), rows 4, 6, and 8–10 each with 10–14 setae (with lateral setae shorter than central setae), rows 11 and 12 each with 2 fairly long setae; rows 3, 5, and 7 barely separated from adjoining rows 4, 6, and 8; both setae in row 12 inserted inside medial lacuna of subgenital plate; 20–26 small setae inserted near abdominal apex.

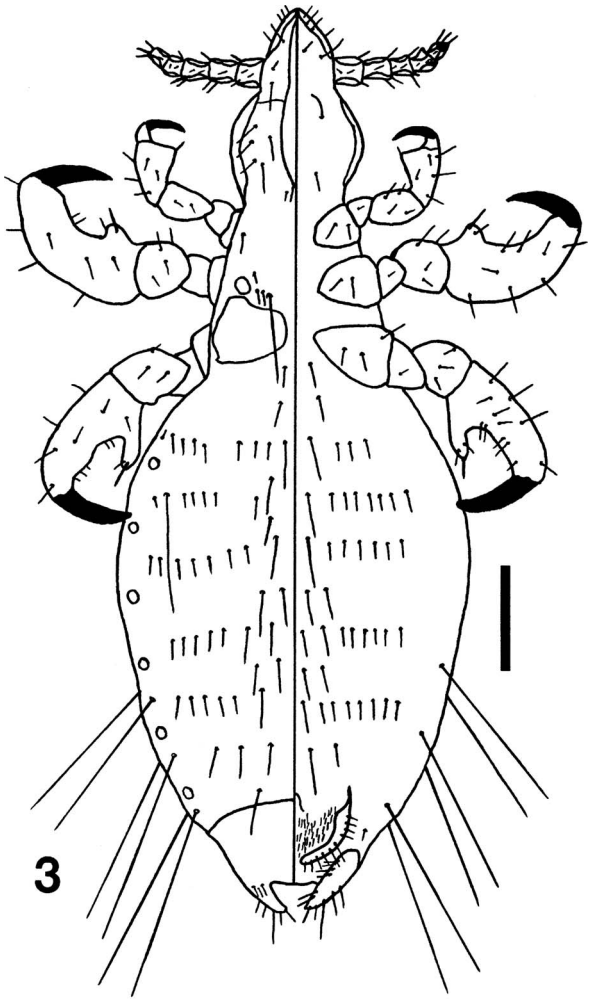
Genitalia (Fig. 2) with basal apodeme distinctly longer than parameres; basal apodeme narrow centrally and diverging posteriorly and anteriorly, terminating posteriorly in bifid acuminate apices just anterior to parameres. Parameres broadly curved with anterior curved ridges and terminating posteriorly into acuminate apices with narrow gap between them. Pseudopenis short, barely extending beyond posterior apices of parameres.

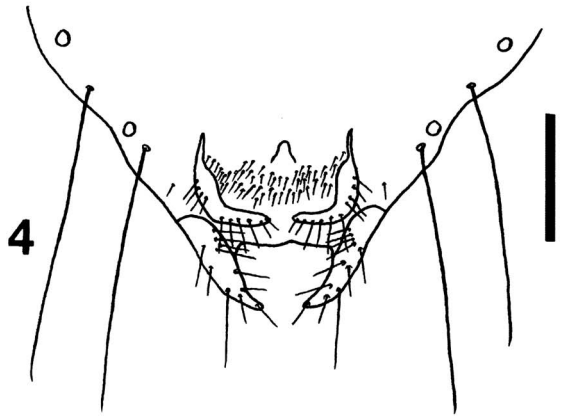
Female (Figs. 3–4): Length of slide-mounted allotype, 1.68 mm, range (allotype and 3 slide-mounted female paratypes), 1.60–1.88 mm, mean, 1.73 mm. Morphology as in male unless designated otherwise.

Head slightly longer in postantennal region than in male. Mesothoracic spiracle diameter, 0.030 mm.

Abdomen with 11 distinct dorsal rows of setae plus small number of additional setae not clearly associated with any setal rows: rows 1 and 2 each with 2 setae of intermediate length, distinct rows 3–5, 7, and 9 each with 12–20 setae (with lateral setae shorter than central setae), rows 6 and 8 each with 4 fairly long central setae, row 10 with 6 fairly long setae, row 11 with 2 long setae; small number of fairly long central setae close to rows 3–5 not definitively associated with any row; small gaps on each side between some setae in rows 3 and 4. Ten ventral rows of setae: rows 1 and 2 each with 2 setae of intermediate length, row 3 with 8 setae (with 1 long central seta and 3 shorter lateral setae on each side), rows 4, 5, 7, and 9 each with 14–16 setae (with lateral setae shorter than central setae), rows 6, 8, and 10 each with 4 fairly long setae; central setae of row 10 distinctly longer than lateral setae on same row. Six to 10 small apical setae.

Genitalia (Fig. 4) with very small subgenital plate anteriorly and 2 pairs of distinct gonopods posteriorly. Gonopods VIII C-shaped each with 10 submarginal lateral setae (4 setae anteriorly, then a gap, then 6 setae posteriorly); posterior setae on gonopods VIII progressively smaller from lateral to medial region; field of many tiny setae present between gonopods VIII. Gonopods XI situated postero-laterally at end of abdomen, elongate





FIGURES 3, 4. *Linognathus samburi*, n. sp., female. (**3**) Dorsoventral view showing ventral morphology to the right of the midline and dorsal morphology to the left (scale bar, 0.2 mm). (**4**) Genitalia (scale bar, 0.1 mm).

with narrowing posterior apex; 11 setae typically associated with each gonopod XI: 4 antero-medial setae in oblique row, 2 postero-medial setae, 1 short apical seta, and 4 lateral setae in row with distinctly long penultimate posterior seta.

Taxonomic summary: Type host Madoqua guentheri Thomas (Günther's dikdik) (Mammalia: Artiodactyla: Bovidae): a juvenile female live-trapped on 13 January 2012.

Type locality: Kenya (northern): Samburu District (Rift Valley Province), near Olturot village (2.595305N, 37.083769E), elevation, 550 m. The habitat is arid to semi-desert with scattered *Acacia, Commiphora,* and *Balanites* trees and shrubs, and classified as "Somalia-mosaic semi-desert grassland and shrubland." Climate is hot, arid, and tropical with median monthly temperatures of 20–26 C and bimodal rainfall (Nicholson, 1996).

Site of infestation: In the fur and on the skin of the dorsal surface (back) near the tail, and in the perianal region and lower belly.

Type specimens: Holotype male, allotype female and 2 paratypes (1 male, 1 female) deposited in the U.S. National Museum of Natural History (Smithsonian Institution), Washington, DC (accession nos. USNM ENT 00990270, 00990246, 00990204, and 00990084). One paratype male and 1 paratype female deposited in the Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania (accession no. 103416). One paratype male and 1 paratype female deposited in the Insect Collection at Georgia Southern University (accession no. L3687). An additional 13 specimens (1 male, 12 females) have been retained in 95% ethanol and refrigerated (accession no. L3687).

Etymology: This new species is named for the Samburu Tribe whose members live in the region in which the lice were collected.

Remarks:Linognathus samburi n. sp. is the third species of louse to be described from a dikdik. Previously *L. geigyi* Büttiker was described from a host initially reported to be a Salt's dikdik (*Madoqua saltiana* (de Blainville)) maintained in a zoo in Switzerland (Büttiker, 1949) although it had been captured in Tanzania (Ledger, 1971, 1980). However, Ledger (1971) gives valid arguments for believing that the type host was actually *Madoqua kirkii cavendisi* Thomas. Also, *L. damarensis* Ledger was described from *Madoqua kirkii damarensis* (Günther) from Nambia (Ledger, 1971). If the reassessment by Ledger (1971) of the type host of *L. geigyi* is correct, this would mean that different subspecies of *M. kirkii* are parasitized by different species of congeneric lice. Ledger (1971) suggested that separate analyses of the rates of genetic divergence of these hosts and their lice would result in intriguing comparisons between the rates of host and parasite evolution. The presence of more than 1 species of *Linognathus* on the same host species is not unprecedented; Durden and Horak (2004) documented 3 species of *Linognathus* (in addition to 2 species of chewing lice belonging to the genus *Damalinia*) from impala (*Aepyceros melampus*) in sub-Saharan Africa. Also, some species of *Linognathus* are known to parasitize 2 (sometimes 3) closely related host species. Included in this category are *Linognathus africanus*, *Linognathus breviceps, Linognathus fahrenholzi, Linognathus kimi, Linognathus lewisi, Linognathus limnotragi, Linognathus panamensis, Linognathus pedalis, Linognathus raphiceri, Linognathus reduncae, Linognathus setosus, Linognathus stenopsis, Linognathus taeniotrichus, Linognathus taurotragus, Linognathus vulpis,* and *Linognathus zumpti*; Weisser (1975) and Durden and Musser (1994) list the known hosts for these species. Further, 2 species of dikdiks, *M. kirki* and *M. guentheri*, are also known to be parasitized by the trichodectid chewing louse *Tricholipeurus victoriae* (Hopkins) (Price et al., 2003). In fact, the host individual from which the *L. samburi* n. sp. specimens were collected was co-infested with *T. victoriae*.

Linognathus samburi n. sp. males can be distinguished from males of all other species of *Linognathus* using a combination of the following morphological traits:

1) The shape of the parameres, the length and shape of the basal apodeme, and the length of the pseudopenis.
2) The shape of the subgenital plate.
3) The elongate postantennal region of the head and the bulging (curved) lateral head margins posterior to the antennae.
4) The 3 pairs of long marginal setae on each side of the abdomen postero-laterally.
5) The single long dorsal abdominal seta on each side of the abdomen between abdominal spiracles 1 and 2.
6) The arrangement and lengths of the setae in the abdominal rows.

Linognathus samburi n. sp. females can be distinguished from females of all other species of *Linognathus* using a combination of the following morphological traits:

1) The distinctive shape of the gonopods, especially the C-shaped gonopods VIII, and the number and lengths of setae on the gonopods.
2) The highly setose region between the gonopods VIII.
3) The elongate postantennal region of the head and the bulging (curved) lateral head margins posterior to the antennae.
4) The 3 pairs of long marginal setae on each side of the abdomen postero-laterally.
5) The single long dorsal abdominal seta on each side of the abdomen between spiracles 1 and 2.
6) The arrangement and lengths of the setae in the abdominal rows.

The 3 species of *Linognathus* now known to parasitize dikdiks (*Madoqua* spp.) can be distinguished based on easily observed morphological characters. Males and females of *L. damarensis* have a short squarish head region anterior to the antennae, dagger-like abdominal setae, and 4 pairs of very long marginal setae in the posterior half of the abdomen, whereas both sexes of *L. samburi* n. sp. have an elongate, acuminate head region anterior to the antennae, unmodified (non-dagger-like) abdominal setae, and 3 pairs of very long marginal setae on posterior abdomen. Both sexes of *L. geigyi* also have an elongate head region, but they have 2 pairs of very long posterior marginal abdominal setae (both sexes of *L. samburi* n. sp. have 3 pairs). Further, the posterior end of the basal apodeme (in males) has broadly rounded bifid apices in *L. geigyi* (these apices are acuminate in *L. samburi* n. sp.), and the gonopods VIII (in females) are broad and straight in *L. geigyi* (they are narrow and C-shaped in *L. samburi* n. sp.). Morphological characters for other described species of *Linognathus* are illustrated in Weisser (1975) and Durden and Horak (2004).

Here we present a dichotomous key to the adult sucking lice (for both sexes) that are known to parasitize dikdiks. However, because additional new species of *Linognathus* could be collected from dikdiks in the future, we further recommend comparing specimens with the original descriptions for these 3 species of lice.

Key to Adult Sucking Lice Known to Parasitize Dikdiks (*Madoqua* spp.)

1A. Head broadly rounded (almost flat) anterior to antennae; 4 pairs of very long setae present on each side of abdomen posteriorly (on *Madoqua kirkii damarensis*) ..... *Linognathus damarensis*

1B. Head significantly elongate anterior to antennae and terminating in distinct apex; 2 or 3 pairs of very long setae present on each side of abdomen posteriorly 2

2A. 2 pairs of very long setae on each side of abdomen posteriorly (on *Madoqua kirkii cavendishi;* see Remarks section) ..... *Linognathus geigyi*

2B. 3 pairs of very long setae on each side of abdomen posteriorly (on *Madoqua guentheri*) ..... *Linognathus samburi* n. sp.

Because many species of lice are host-specific and co-speciation between lice and their hosts has occurred frequently (Kim, 1988; Light and Hafner, 2007), it seems likely that additional undescribed species of *Linognathus* parasitize other species of artiodactyls including dikdiks. Lyal (1987) reported that 79% of the 351 species and subspecies of trichodectid chewing lice recognized at that time had phyletically tracked their hosts during their co-evolutionary history (often referred to as "Fahrenholz's rule") leading to host specificity. Strict host specificity (one louse species on host species) is also widespread in the Anoplura, but some species of sucking lice are known to parasitize 2 or more closely related host species (Durden and Musser, 1994), and for some other species, there is evidence of host switching (resource tracking) during their evolutionary history (Musser and Durden, 2014), which complicates host specificity issues. Four extant species of dikdiks are recognized in Wilson and Reeder (2005), and sucking lice have been reported from only 2 of these species—assuming the reassessment of the type host of *L. geigyi* by Ledger (1971) is correct. It is therefore likely that undescribed species of *Linognathus* parasitize both Placentini's dikdik (*Madoqua placentinii* Drake-Brockman) and Salt's dikdik (*M. saltiana*). However, it is also possible that 1 or more of the known species of *Linognathus* associated with dikdiks also parasitize 1 or both of these species of dikdiks. Additional collections of ectoparasites from dikdiks should resolve these issues. Nevertheless, additional undescribed species of *Linognathus* almost certainly parasitize other species of ungulates, especially in the Afrotropical region where this louse genus is most diverse (Durden and Musser, 1994).

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