



## The genus *Salfacarus* (Acari: Opilioacarida) in Madagascar

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### Abstract

The opilioacarid genus *Salfacarus* in Madagascar is revised, with description of four new species, *S. antsiranensis*, *S. kirindiensis*, *S. mahafaliensis*, and *S. ranobensis*, and a new delimitation for the type species, *S. legendrei*. *Salfacarus* is widespread in Madagascar but individual species appear restricted to relatively small areas. A key to the adults of *Salfacarus* in Madagascar is provided.

**Key words:** Parasitiformes, Opilioacaridae, taxonomy

### Introduction

Recent collections by personnel of the California Academy of Sciences in Madagascar turned up a substantial number of Opilioacaridae. All specimens collected belong to the genus *Salfacarus* Van der Hammen 1977. The genus *Salfacarus* currently includes 5 species, 2 from Madagascar (*S. legendrei* Van der Hammen 1977, *S. robustipes* Van der Hammen 1977), 2 from Rep. South Africa (*S. lawrencei* Van der Hammen 1977, *S. dispar* Van der Hammen 1977), and 1 from Tanzania (*S. tanzaniensis* Van der Hammen 1977). Adults of *Salfacarus* differ from those in most other genera of Opilioacaridae by the presence of numerous setae on the portion of the idiosoma posterior to the dorsal shield (shared with *Panchaetus* Naudo 1963 and *Vanderhammenacarus* Leclerc 1989). *Salfacarus* differs from *Panchaetus* by the absence of “coronidia”, thin, smooth, bent sensilla, on tibiae II–IV (shared with *Vanderhammenacarus*), and from *Vanderhammenacarus* by having multiple setae on all opisthogastral segments in the adults (shared with *Panchaetus*; limited to the 3 most posterior segments in *Vanderhammenacarus*).

Unfortunately the available species descriptions of *Salfacarus* species are inadequate by modern standards, often omitting detailed information on critical character systems, such as the ovipositor structure, and setation patterns in the sternitogenital region. Instead, characters such as the number of anterior dorsal shield setae are used as species characteristics. Unfortunately, that particular character is notoriously variable (Vázquez & Klompen 2002). The newly available material allows us to re-evaluate species level characters in the genus *Salfacarus*, and to describe four new species from Madagascar.

### Material and methods

Most material was studied as slide-mounted specimens, although some specimens were examined using temporary preparations in cavity slides. Terminology for the palp tarsal sensilla follows Grandjean (1936) as modified by Vázquez and Klompen (2002). All measurements are in micrometers (µm) and presented in tabular form (Table 1). These measurements are presented with some caveats. They are based on slide-mounted specimens. This means that measurements of soft structures, e.g. total length and total width, are

almost certainly distorted (in this case exaggerated). While still of use in comparing individuals considered in this study, cross comparisons with measurements based on fluid preserved specimens are inappropriate. Total width was measured at the level of the spiracles, and shield width at the level of the eyes (the posterior corners of the shield are often difficult to identify). Where multiple specimens could be measured, numbers are presented as average (range). Measurements for females and males are combined unless sexual dimorphism was indicated.

All material was collected by personnel of the California Academy of Sciences (CAS). Unless otherwise indicated, all specimens are deposited in that collection. Abbreviations for other depositories: OSAL: Ohio State University Acarology Collection, Columbus; RMNH: Nationaal Natuurhistorisch Museum, Naturalis, Leiden; UQRoo: Universidad de Quintana Roo, Chetumal. Instar abbreviations: L= larva; PN= protonymph; DN= deutonymph; TN= tritonymph; F= female; M= male.

## Taxonomic section

### *Salfacarus* Van der Hammen 1977

*Salfacarus* Van der Hammen 1977: 53

*Salfacarus* Van der Hammen 1979, in: Coineau & Van der Hammen (1979): 441

Type species *Salfacarus legendrei* Van der Hammen 1977

**Diagnosis:** Opisthosoma in DN, TN, and adults with numerous papilliform setae on all segments (Fig. 1). Arrangement of idiosomal setae appears random, arrangement of lyrifissures may be idionymic. Tibiae II–IV with median dorsal setae, but without coronidia. Coronidia present on basitarsi II–IV.

**Note:** The genus and type species appear to be described twice, once in the 1977 paper, and a second time in a brief description by Van der Hammen in a proceedings volume (Coineau & Van der Hammen 1979). The latter included contributions from a conference held in 1974. However, this volume did not appear in print until 1979, well after the 1977 paper.

### *Salfacarus legendrei* Van der Hammen 1977

*Salfacarus legendrei* Hammen 1977: 54, Figs 5–8

*Salfacarus legendrei* Van der Hammen 1979, in: Coineau & Van der Hammen (1979): 441

**Diagnosis** (as listed by Van der Hammen (1977)): (1) legs IV shorter than legs I in female, (2) a relatively small number of prodorsal setae and a “narrower and rounded rostrum”, and (3) ratios of legs I : idiosoma and legs IV : idiosoma < 1.9 and < 1.7, respectively. Character (1) is the condition observed in all of our material; it is assumed to be primitive. Character (2) features the number of shield setae, which is highly variable within species (Vázquez & Klompen 2002). For example, in adults of *S. kirindiensis* **n. sp.** those numbers varied from 128–170, spanning almost the entire range observed across all specimens examined for this study. The shape of the rostrum may be subject to some preservation artifacts, especially in slide-mounted specimens, but is likely to be a valid character. Character (3) is potentially a good character, but once again vulnerable to severe distortions in slide-mounted specimens. Our material is largely slide-mounted, disallowing reliable estimates of these ratios.

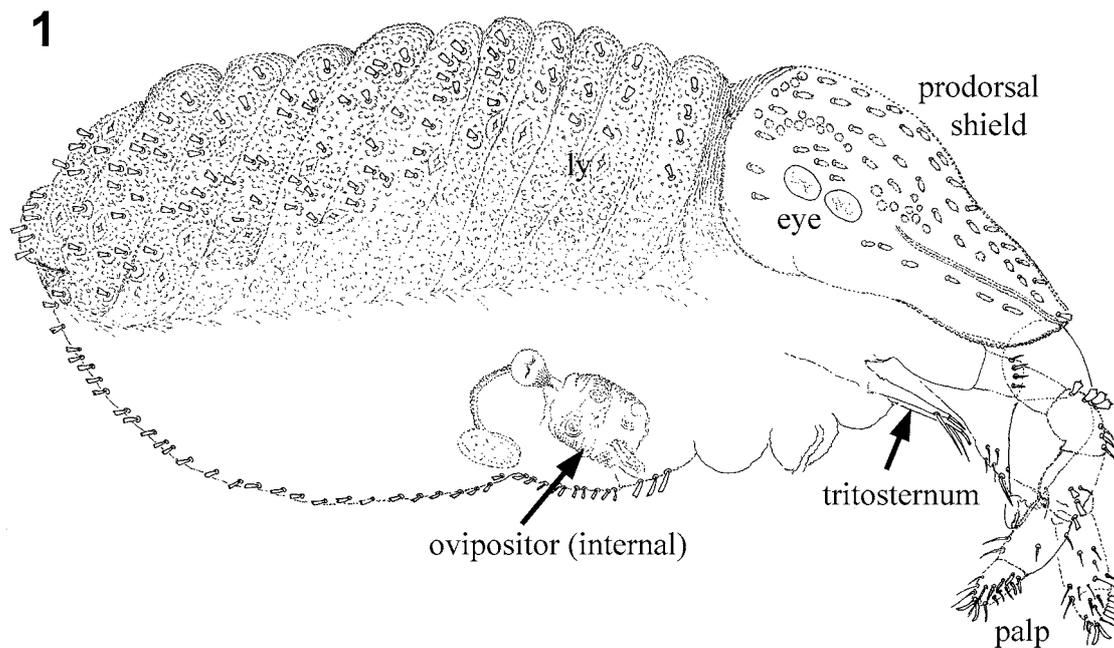
Examination of a specimen (code B-20) from the type locality (RMNH collection) showed an ovipositor lacking long terminal setae, small setal structures, or any large basal projections (consistent with Van der Hammen’s general description). The original description can be supplemented by the observation of 3 pairs of distinct small patches of rounded structures, reminiscent of the ovipositor in *S. mahafaliensis* **n. sp.** (Fig. 26). However, the patches in *S. legendrei* show a different pattern: a large pair of patches basally, and 2 much smaller pairs more distal (all patches of equal size in *S. mahafaliensis*). Specimen B-20 lacked the gnathosoma so gnathosomal structures could not be examined.

TABLE 1. Comparative measurements and setal counts for *Salfacarus* species from Madagascar (adults only). Format: average (range).

	<i>legendrei</i>		<i>robustipes</i>		this study	<i>antisiranensis</i>		<i>kirindensis</i>		<i>mahafaliensis</i>		<i>ranobensis</i>	
	Hammen 1977	Hammen 1977	Hammen 1977	Hammen 1977		N=1	N=6	N=4	N=4	N=3	N=4		
total length	1400–1800	1810			2117		1909 (1777–2041)						
total width	700–900	880–900			1240		1181 (1077–1285)						
length chelicera						445 (416–518)				482 (444–501)			454 (416–491)
width subcapitulum						282 (274–295)				323 (261–372)			277 (255–312)
length palp					529	652 (580–794)				618 (NA)			695 (662–728)
length prodorsal shield					813	588 (561–610)				641 (582–699)			602 (548–662)
width prodorsal shield (1)					4857	798 (767–851)				718 (680–756)			843 (813–888)
length leg I	2600–3080	3100				3553 (3402–3553)							2192 (NA)
length leg II	1470–1830	2390			2306	1796 (NA)							2098 (2041–
length leg III	1390–1780	2370			2381	1768 (1644–				1777 (1625–			2155)
						1939)				1928)			
length leg IV	2220–2770	3500			3553	2892 (2835–				2835 (NA)			3213 (3024–
						2948)				2788 (2684–3137)			3478)
chelicera ventral denticles					4	4 (3–5)				4.5 (4–5)			3 (3–4)
palp trochanter					6	6 (5–7)				5 (NA)			5 (5)
palp femur: r-type setae					23	10 (7–13)				7 (NA)			12 (12)
p-type setae					11	17 (15–19)				12 (NA)			7 (6–9)
palp genu: r-type setae					40	35 (31–43)				24 (NA)			31 (27–35)
p-type setae					4	6 (5–8)				7 (NA)			5 (3–7)
prodorsal shield setae					170	168 (156–184)				174 (158–190)			159 (150–174)
anal valve setae						22 (21–22)				16 (15–19)			18 (14–23)
sternal verrucae					1p+3	1p+4 (3–6)				1p+4 (2–6)			1p+2 (1–3)
sternal					2p+7–8	2p+6 (4–9)				2p+10 (8–13)			2p+7 (4–9)
genital verrucae					1p+3–4	1p+4 (4–5)				1p+6 (5–7)			1p+4 (3–6)
pregenital female (2)	0 or 5b	2–3b				0 or 2b				2b			9p (3–9p)
genital female (2)	???	b				0				0			15p (6–24p) or 0
pregenital male (2)	6b				5b	8b (5–9b)				5–6b			7b (5–8b)
genital male (2)	7p				9p on sclerite	8 p on sclerite				8p on sclerite			12p on sclerite
					sclerite	(7–10 p)				(11–13p)			

NA: not applicable; only 1 specimen measured

(1) measured at level of eyes; (2) b: papilliform, ribbed with a blunt tip; p: ribbed, with a pointed, tapering tip



**FIGURE 1.** *Salfacarus kirindiensis* n. sp. female, lateral view idiosoma. Legs omitted; ventral side shows internal structure (ovipositor). ly: “standard” lyrifissure.

**Remarks.** *Salfacarus legendrei* was described based on material from 3 localities, large numbers from Amboihao, and a few specimens from two additional localities, Mahafaly plateau and Marofandilia. This result, finding the same species in three widely separate localities, is inconsistent with our observations. We found that different collecting sites nearly always yielded different *Salfacarus* species, suggesting strong local endemism. Among the new material available for this study were specimens from Mahafaly plateau and an area very close to Marofandilia. Specimens from these localities can be distinguished readily by characteristics of the ovipositor (plus some other, less obvious characters, see below) and are assigned to new species, respectively, *S. mahafaliensis* n. sp. and *S. kirindiensis* n. sp. To test the possibility that the Mahafaly and Marofandilia specimens studied by Van der Hammen also belong to these new species we examined material deposited in the RMNH collection. The critical character is the female ovipositor, so we examined one alleged female each from Amboihao (type locality; specimen B-20), Mahafaly plateau (B-9), and Marofandilia (B-19). The Amboihao female has a distinct ovipositor structure (see above), but the specimens labeled as female from Mahafaly plateau and Marofandilia proved to be tritonymphs (no ovipositor, only 4 (not 5) leaf-like setae on the palp tarsus). Even though this test proved inapplicable, we tentatively consider the Mahafaly plateau and Marofandilia material studied by Van der Hammen as belonging to, respectively, *S. mahafaliensis* and *S. kirindiensis*.

**Ecology.** Van der Hammen (1977) stated that this species was recovered regularly at Amboihao, especially in the rainy season (November – February), usually in small groups of 6–12 specimens, and often under rocks. In line with our experience collecting Opilioacaridae in the New World, specimens were never recovered from under rocks with ant nests.

**Collection information.** Type locality: MADAGASCAR, Antananarivo, Amboihao, 18°20' S 47°47' E, coll. Legendre, R, Dec 1958, ex under humid rocks in forest of *Eucalyptus*: 1 M, 3 F, 2 TN.

Additional material assigned to this species (Hammen 1977): MADAGASCAR: Toliara, Mahafaly plateau, 24°30' S 44°30' E, zone with “dolines” near the “aven Andramoetse Be”, coll. Betsch, J M, 28 Jul 1967, ex under rocks: 1 M 1 F? 1 TN (listed as F) (B-9). Probably *S. mahafaliensis* n. sp. MADAGASCAR: Toliara, Marofandilia (listed as “Marafandila”), Morandawa region, Forêt d'Andranomena, 20°10' S 44°28' E, coll. Betsch, J M, 16 Dec 1969, ex under dead wood: 1 TN (listed as F) (B-19). Probably *S. kirindiensis* n. sp. Coordinates listed are approximate and refer to, respectively, Amboihao, Mahafaly plateau, and Andranomena. Specimens at RMNH.

## *Salfacarus robustipes* Van der Hammen 1977

*Salfacarus robustipes* Van der Hammen 1977: 60, figs. 9–11

**Diagnosis** (as listed by Van der Hammen (1977)): (1) strong development of the legs, specifically legs IV, which in the female are longer than legs I, (2) long papilliform setae on the posterior legs, and (3) pale terminal part of legs IV. Character (1) is a significant character, as we did not observe that state in any of the *Salfacarus* specimens examined (important caveat: many of our specimens have lost legs I, making our sampling size smaller than hoped for). Notably, Van der Hammen did not observe this unusual state in the deutonymph. Character (2) specifically concerns the relative length of the laterodorsal setae on tibiae IV. They are as long as, or longer than, the diameter of the tibia in *S. robustipes*, while shorter in all other *Salfacarus*. Measurements on specimens from all available collecting localities confirm the value of character (2). The ratio of the laterodorsal setae on tibia IV to width of tibia IV is somewhat variable within species (ratio 0.6–0.9, N=12, 8 collection localities), but never exceeds 1 except in one case: a male collected from the type locality (ratio 1.2). Even though the length of legs IV in this specimen does not exceed that of legs I (as in DN?), the absolute lengths of legs II–IV correspond very well with those listed for the female by Van der Hammen. We tentatively assign this specimen to *S. robustipes*. As this instar was not previously described, we can add the following: dorsal shield with approximately 170 papilliform setae, rostrum broad, pregenital area with 7 stout, ribbed (= papilliform of Van der Hammen 1966) setae, genital area with 8 ribbed, tapering setae. Basic measurements in table I. Character (3) may be valid, but does not work well with the cleared specimens available in this study.

**Remarks:** Van der Hammen (1977) notes that the PN carries 11 setae on the preanal segment. This would be quite unusual, as we never found more than 3 setae on that segment in all of our material. Perhaps he was dealing with a DN.

**Collection information.** This species was described from a single locality: MADAGASCAR: Antananarivo, Tampoketsa d'Ankazobe, Forêt d'Ambohitantly (18°10' S 47°17' E), coll Betsch, J M, 10 Apr 1967, ex litter (2 F); same data, 27 Jun 1967 (1TNf, 1 DN, 1PN).

**New material:** MADAGASCAR: Antananarivo, 4.1 km 59° NE d'Ankazobe, R.S. d'Ambohitantly, Jardin Botanique, 1620 m, 18°10'17"S 47°16'55"E, coll. Fisher, B L & Griswold, C E, 17–20 Apr 2001, ex montane rain forest (EBO09, BLF3720): M (3 slides, OSAL007787–7788, 7790). Specimen at CAS.

## *Salfacarus antsiranensis* Vázquez & Klompen n. sp.

(Figs. 2–12)

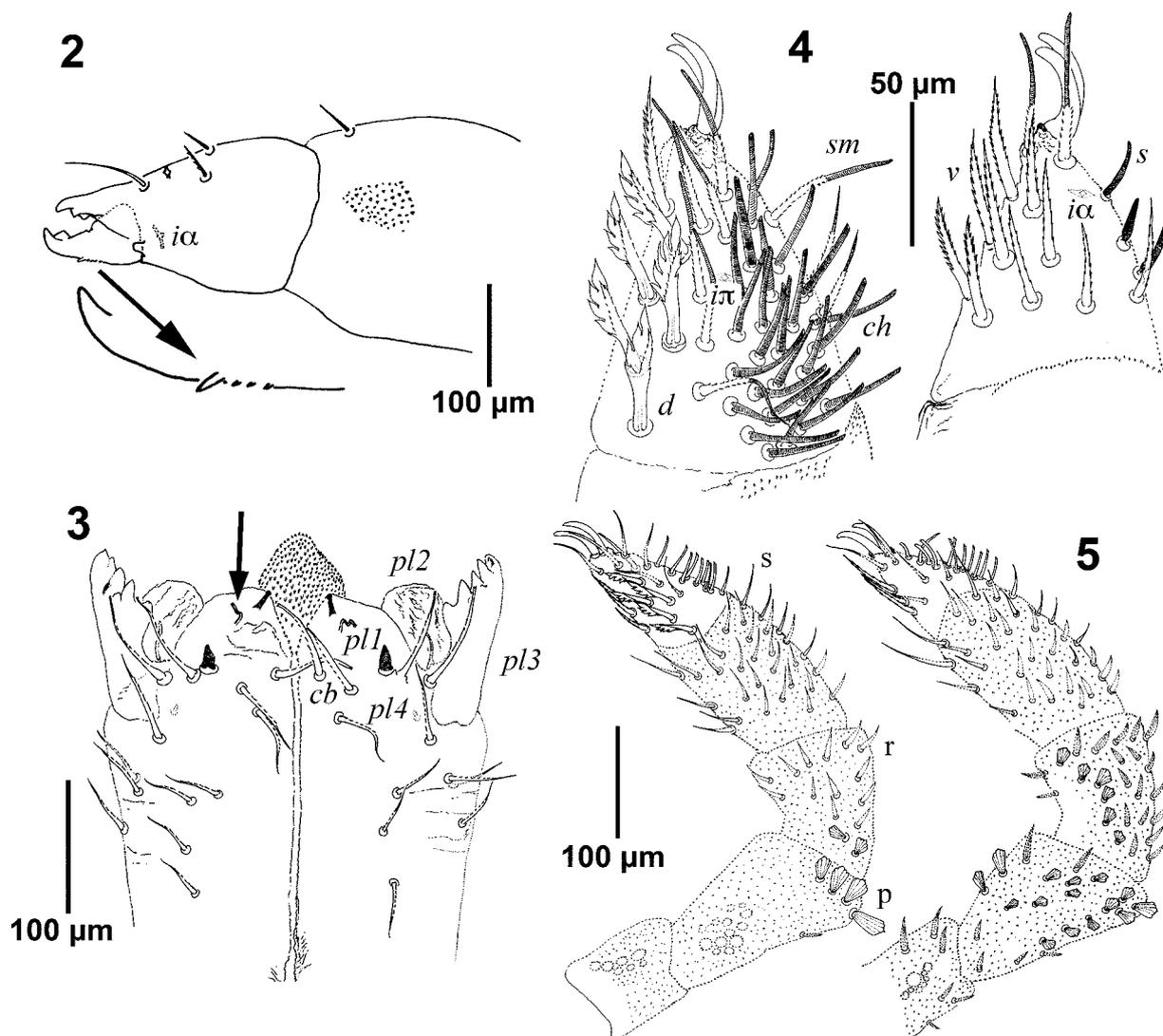
**Diagnosis.** With an unusually large number of papilliform setae on the palp femur of the adults (15–19, relative to 6–12 in other species). Ovipositor with a pair of large spinose structures and 1–2 pairs of small structures (gland ducts?).

**Description.** Based on observations on 1 larva, 2 protonymphs, 10 deutonymphs, 3 tritonymphs, 7 females, 4 males.

**Gnathosoma.** Chelicera (Fig. 2). Basal segment without setae in L, PN and DN. One seta added in TN, fixed digit with 3 setae in all instars. All setae lightly barbed. Dorsal and antiaxial lyrifissure well developed in nymphs and adults, not observed in L. Fixed digit with 1 distinct tooth, movable digit with 2 teeth and a well developed terminal hook. Movable digit with one ventral denticle in L, PN and most DNs, two in some DNs and TN, and 3–5, in adults. Most distal denticle in adults largest. Internal surface of movable digit with a small sensillum (Fig. 28, arrow).

Subcapitulum (Fig. 3). All 4 pairs of paralabial setae present: *pl1* small, conical; With's organ (*pl2*) membranous with a distinct, undivided (not forked) support structure; rutella (*pl3*) with 1 row of 5 teeth, inserted dorso-laterally; *pl4* very small, inserted dorsally on subcapitulum. In addition, 4 circumbuccal (*cb*), and 10–11 median and subcapitular (*vm* (in part), *lvm*, *ldm*, *vp*, *lvp*) setae. Sexual dimorphism absent. L, PN, DN and TN similar but number of median and subcapitular setae smaller, 0, 2, 3, and 7–10, respectively. Lateral lips with distinct canals in all instars (*dll* and/or *dl2* of Grandjean (1936)) (Fig. 3, arrow).

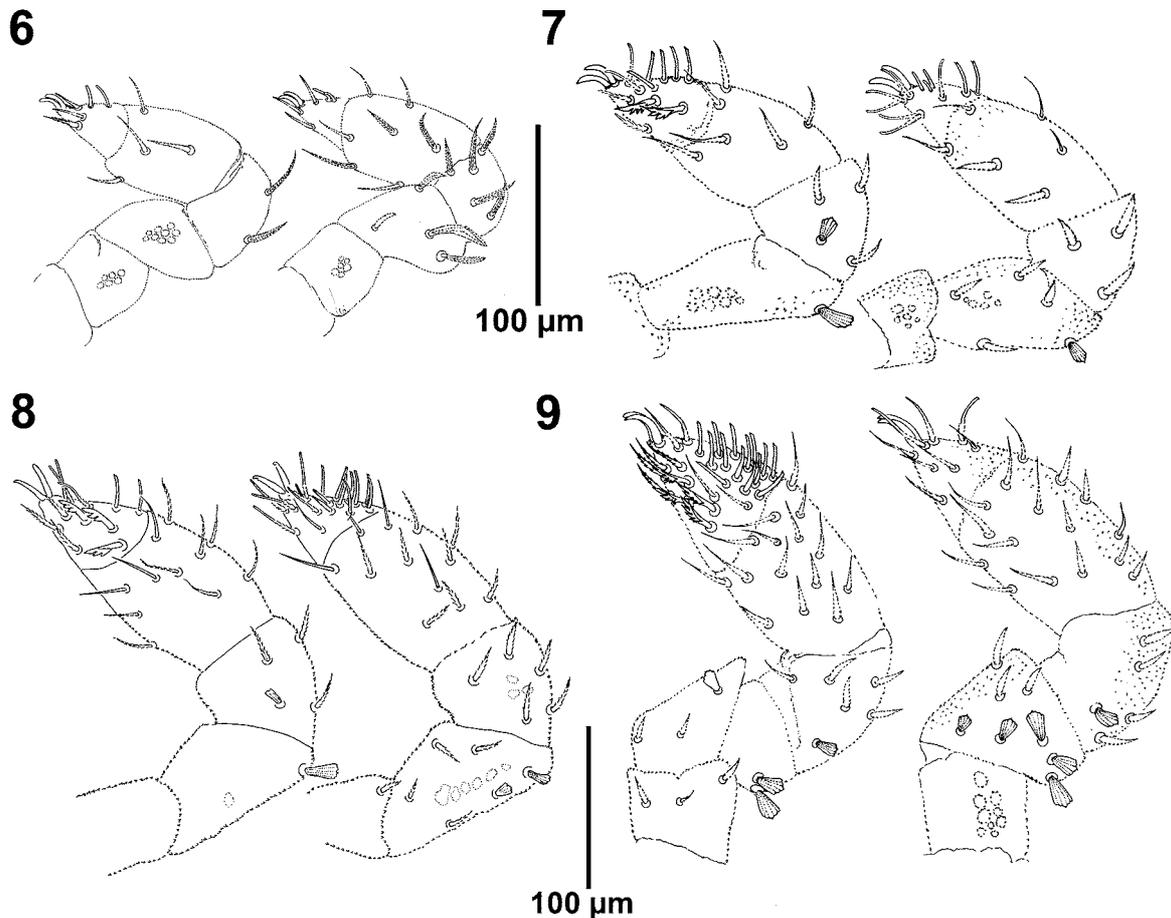
Palps. Adult (Figs. 4–5). Trochanter with 6–7 ribbed, tapering (r-type) setae; femur with 7–8 r-type and 18–19 papilliform or mucronate (= p-type) setae in female, 10–13 r and 15–16 p-type setae in male; genu with 31–43 r and 8 (females) or 5–6 (males) p-type setae. Tibia and tarsus partially fused. Tibia with approximately 12 smooth (s-type) and 51 r-type setae. Palp tarsus with lyrifissures  $i\pi$  and  $i\alpha$ . Setation including 3 *s*, 5 *d* (leaf-like), and approximately 26 *ch*, 11 *sm*, and 10 *v* setae. Sexual differentiation in tibiotarsus absent or indistinct. Pretarsus in shape of a pair of well developed sessile claws. Immatures (Figs. 6–9). Trochanter: L, PN, 0 setae; DN, 1 (rarely 2) r-type, TN, 3–5. Femur: L 4–5 r-type and 0 p-type setae; PN, 3–4 r and 1–2 p; DN, 3–4 r and 2–3 p; TN, 3–5 r and 5–9 p. Genu: L, 8 r and 0 p setae; PN, 6 r and 1 p; DN, 8–9 r and 0–2 p; TN, 15 r and 2–3 p. Tibia: L, 11 setae; PN, 12; DN, 28; TN, 34. Palp tarsus of L, PN, DN and TN with, respectively, 0, 2, 3 and 4 *d* setae; L with 2 *s* setae, other instars with 3; numbers of *v*, *ch*, and *sm* setae not scored for immatures.



**FIGURES 2–5.** *Salfacarus antsiranensis* n. sp., gnathosoma. 2, Chelicera, male, axial view (OSAL007763); 3, Subcapitulum, male (OSAL007763), arrow indicated canal in lateral lips; 4, Palp tarsus, male, dorsal (left) and ventral (right) view (OSAL007764); 5, Palp, female, dorsal (left) and ventral (right) view (OSAL007756)

*Idiosoma.* Anterior dorsal shield of adults with 78–92 (N=3) papilliform setae, and two pairs of eyes. Lyrifissures absent. Rostrum more or less blunt. L, PN, and DN with, respectively, 24, 24–28, and 44–54 shield setae (setae could not be counted in tritonymph). Remaining idiosoma with lyrifissures arranged in more or less transverse rows. Setation limited to 1 dorsal and 2 ventral setae on preanal segment in L and PN;

subsequent instars all with more than 200 papilliform setae. Setae predominantly mid-dorsal and mid-ventral. Anal valves each with 21–22 papilliform setae in adults; L, PN, DN and TN with, respectively, 1, 2, 6–10, and 9–11 setae on each valve.



**FIGURES 6–9.** *Salfacarus antsiranensis* n. sp., palp immatures. 6, Larva (OSAL007728); 7, Protonymph (OSAL007730); 8, Deutonymph (OSAL007736); 9, Tritonymph (OSAL007772).

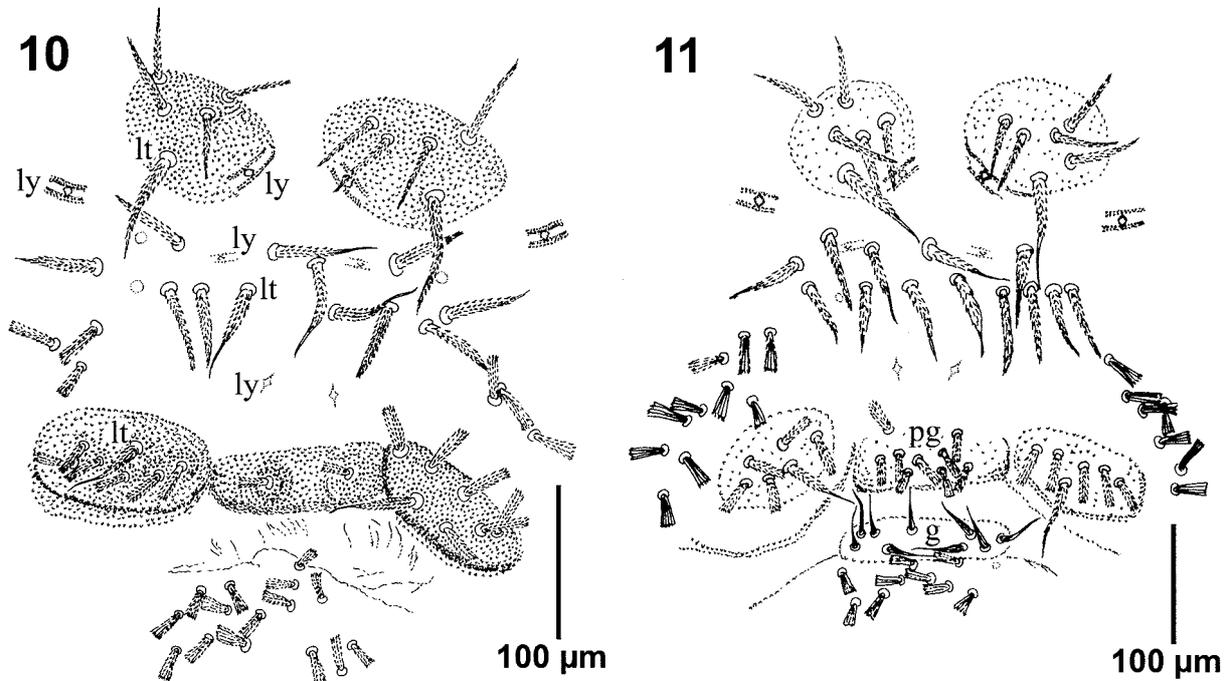
Sternitogenital region (Figs. 10–11). Sternal verrucae in adults with 1 long, tapering, and 4 (rarely 3–6) shorter setae each. Remaining sternal area with 2 pairs of long tapering and 8–9 (female) or 4–6 (male) pairs of papilliform setae, plus 3 pairs of lyrifissures (two pairs very large, the third smaller; all different in shape and size from “standard” opisthosomal lyrifissures). L, DN and TN with, respectively, 0, 1, and 3–4 shorter setae on sternal verrucae, and 0, 1, and 4–8 papilliform setae in remaining sternal area (numbers unclear in PN).

Pregenital capsules of adults with 1 long tapering (lt) and 4–5 (rarely 6) papilliform setae each (0, 2, and 2–4 papilliform setae, respectively, in L, DN and TN). Pregenital area and genital sclerite in male with, respectively, 6–9 papilliform and 7–10 ribbed, tapering setae. Pregenital and genital areas in female with, respectively, 2 papilliform and 0 setae. Numbers for the L, DN and TN, respectively, 0 and 0, 0 and 0, 0–1 and 0–2. Ovipositor (Fig. 12). Without long, lightly barbed terminal setae. With two large spinose basal structures and 1–2 pairs of very small structures (gland ducts?).

*Legs.* Tarsi II each with a dorsal bifurcate seta and two smooth sensilla resembling solenidia. Tarsi II–IV of adults with distinct acrotarsus; first visible on tarsi II–III in TN, on tarsi IV in DN. Trochanters III–IV subdivided in TN and adults. Pretarsi II–IV each with two pairs of setae and a pair of claws.

**Collection information.** Multiple numbers refer to multiple slides representing a single, dissected, individual. Holotype female (OSAL007754–57), MADAGASCAR: Antsiranana, Forêt de Orangea, 3.6 km 128° SE Remena, 90 m, 12°15'32"S 49°22'29"E, coll. Fisher, B L & Griswold, C E, 22–28 Feb 2001, ex littoral rainforest, sifted litter (BLF3200). Paratypes, same data as holotype: L (OSAL007728), PN

(OSAL007729), PN (OSAL007730), DN (OSAL007731), DN (OSAL007736), DN (OSAL007739), DN (OSAL007740–41), DN (OSAL007746), TN (OSAL007732–33), TN (OSAL007742–43), TN (OSAL007744–45), TN (OSAL007734–35), TN (OSAL007737–38), TN (OSAL007747–48), TN (OSAL007749), TN (OSAL007750–51), F (OSAL007752–53), F (OSAL007766), F (OSAL92012–13), F (OSAL92014–16), F (OSAL92017–18), F (OSAL92022–23), M (OSAL007758–59), M (OSAL007760–61), M (OSAL007762–63), M (OSAL92019). Same locality, coll. Boutin, L J, 22 Feb 2001, ex remnant dry forest: M (OSAL007764–65), M (OSAL007767).



**FIGURES 10–11.** *Salfacarus antsiranensis* n. sp., sternitogenital region. 10, Female (OSAL007754); 11, Male (OSAL007765). lt: long, tapering setae; ly: lyrifissure (different types); pg: pregenital; g: genital.

Additional material (non-paratype): MADAGASCAR: Antsiranana, Montagne des Français, 7.2 km 142° SE Antsiranana, elev. 180 m, 12°19'22"S 49°20'17"E, coll. Boutin, L J, 23–25 Feb 2001, ex unknown: M (OSAL007768–7770), M (OSAL007771–7772), F (OSAL007773). MADAGASCAR: Antsiranana, R.S. de l'Ankarana, 22.9 km 224°SW Anivorano Nord, Camp Anglaise, elev. 80 m, 12°54'32"S 49°06'35"E, 10–16 Feb 2001, coll. Boutin, L J, ex general collecting: TN (OSAL007774–7776), M (OSAL007777–7778), M (OSAL007781–7782), M (OSAL007783–7784); same locality, coll. Fisher, B L & Griswold, C E, 10–16 Feb 2001, ex tropical dry forest; sifted litter (EF19, BLF2858): M (OSAL007779–7780).

**Deposition of types.** Holotype female at CAS (CAS18500) (4 slides OSAL007754–57). Other specimens at CAS, OSAL, UQRoo.

**Etymology.** The species is named after the province of Antsiranana in which all available collections were made.

***Salfacarus kirindiensis* Vázquez & Klompen n. sp.**

(Figs. 1, 13–19)

*Salfacarus legendrei* Van der Hammen 1979, in part

**Diagnosis.** Ovipositor with 2 pairs of large, tapering, spinose structures near its base. Movable digit of chelicera in males with only 1–2 ventral denticles (2–4 in females and 3–5 in other Malagasy species).

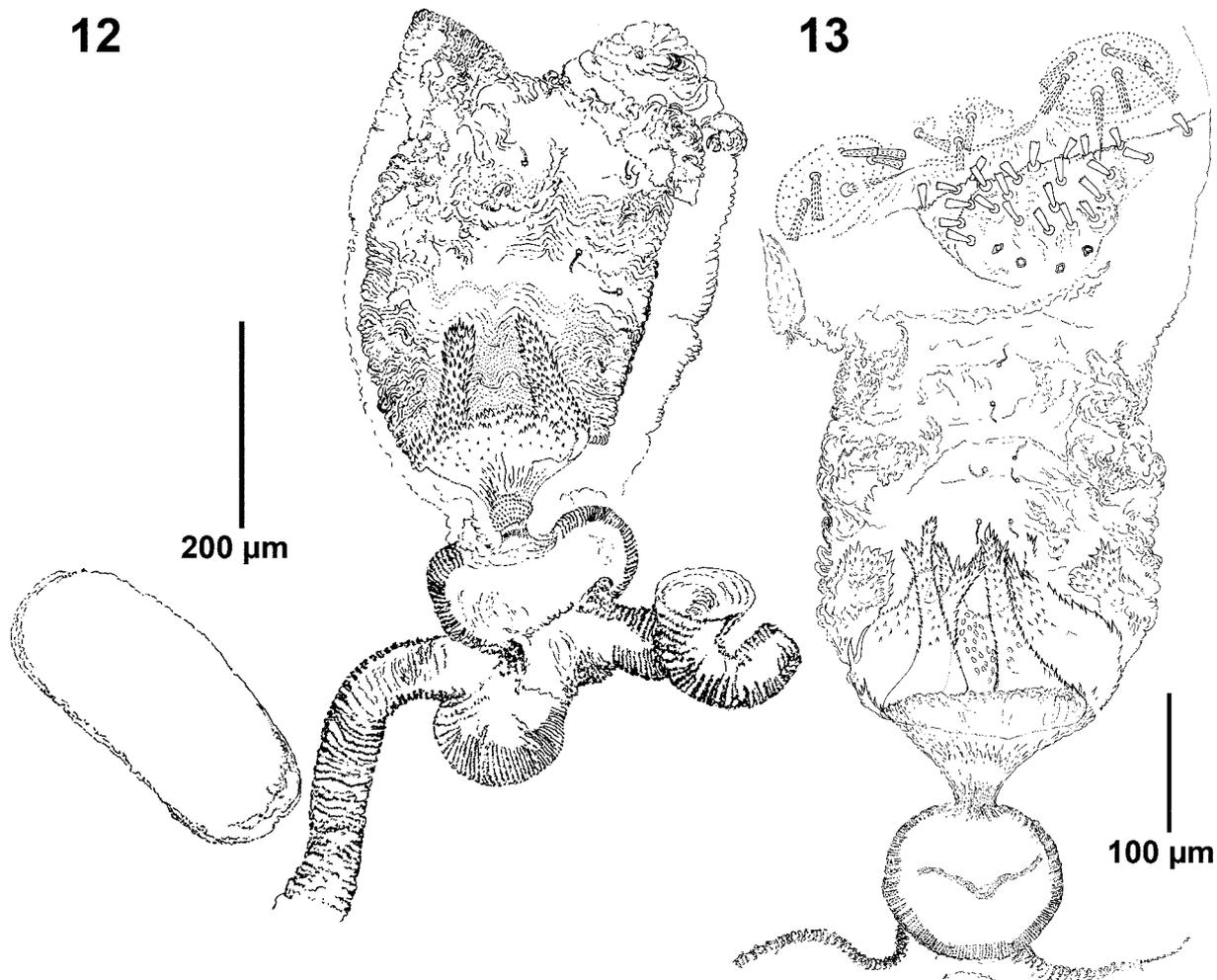
**Description.** Based on observations on 7 females, 3 males. Immature instars unknown.

*Gnathosoma*. Chelicera (Fig. 14). Basal segment with 1, fixed digit with 3 setae. Setae lightly barbed, rarely smooth. Dorsal and antiaxial lyrifissure well developed. Fixed digit with 1–2, movable digit with 2 teeth and a well developed terminal hook. Movable digit with 1–2 ventral denticles in the males, 2–4 in females. Internal surface of movable digit with a small sensillum.

Subcapitulum (Fig. 15). All 4 pairs of paralabial setae present: *pl1* small, conical; With's organ (*pl2*) membranous; rutella (*pl3*) with 1 distinct row of 5 teeth, inserted dorso-laterally; *pl4* very small, inserted dorsal on subcapitulum. With 4 circumbuccal (*cb*), and 7–10 median and subcapitular (*vm* (in part), *lvm*, *ldm*, *vp*, *lvp*) setae. Males appear to have fewer median and subcapitular setae than females (7–8 vs. 8–10). Lateral lips with distinct canals.

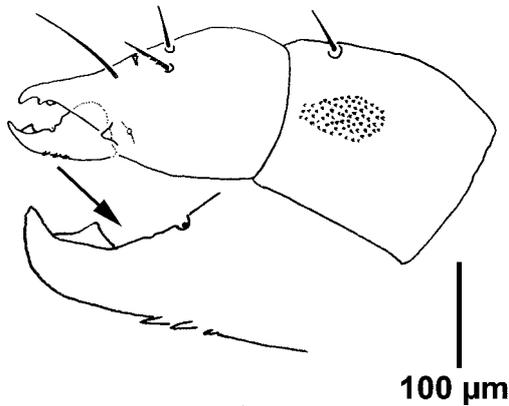
Palp (Figs. 16–17). Trochanter with 5–6 ribbed, tapering (= r-type) setae; femur with 7–9 r and 9–12 papilliform (= p-type) setae; genu with 21–32 (higher numbers in males) r and 5–7 p-type setae. Tibia and tarsus partially fused. Tibia with 7 smooth (s-type) and 46 r-type setae. Palp tarsus with lyrifissures *iπ* and *iα*. Setation including 3 *s*, 5 *d* (leaf-like), and approximately 15 *ch*, 8 *sm* and 9 *v* setae. Sexual differentiation indistinct or absent. Pretarsus in shape of a pair of well developed sessile claws.

*Idiosoma* (Fig. 1). Anterior dorsal shield with 128–170 (N= 6) papilliform setae, and two pairs of eyes. Lyrifissures absent. Rostrum rounded. Remaining idiosoma with lyrifissures arranged in more or less transverse rows, and more than 200 papilliform setae. Setae predominantly mid-dorsal and mid-ventral. Anal valves each with 13–20 papilliform setae.

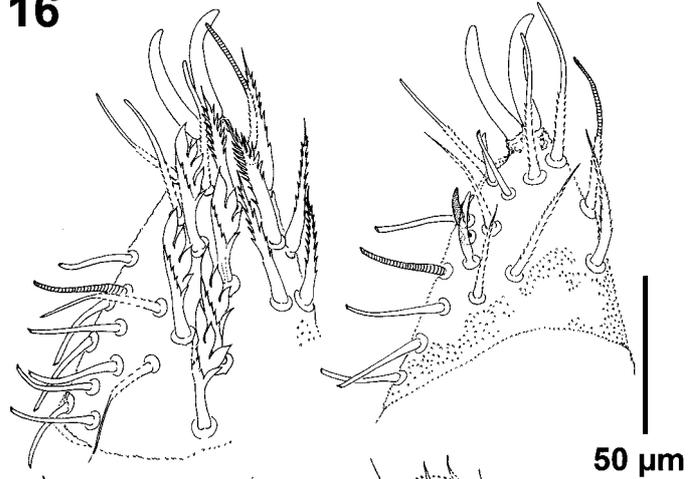


**FIGURE 12–13.** Ovipositor. 12, *Salfacarus antsiranensis* n. sp. (OSAL007755). 13, *Salfacarus kirindiensis* n. sp. (OSAL007323).

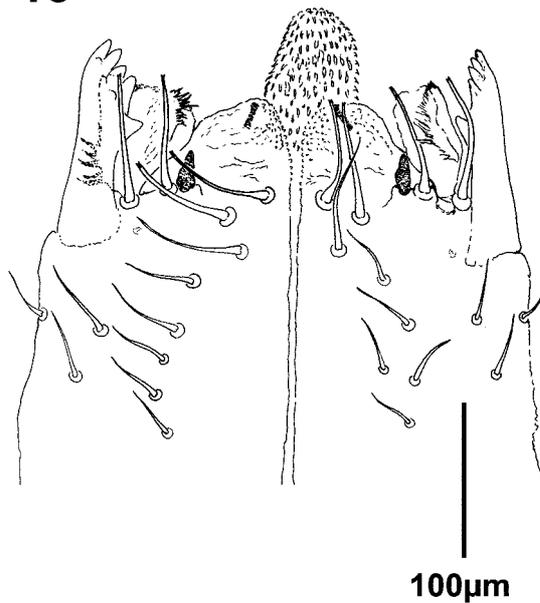
14



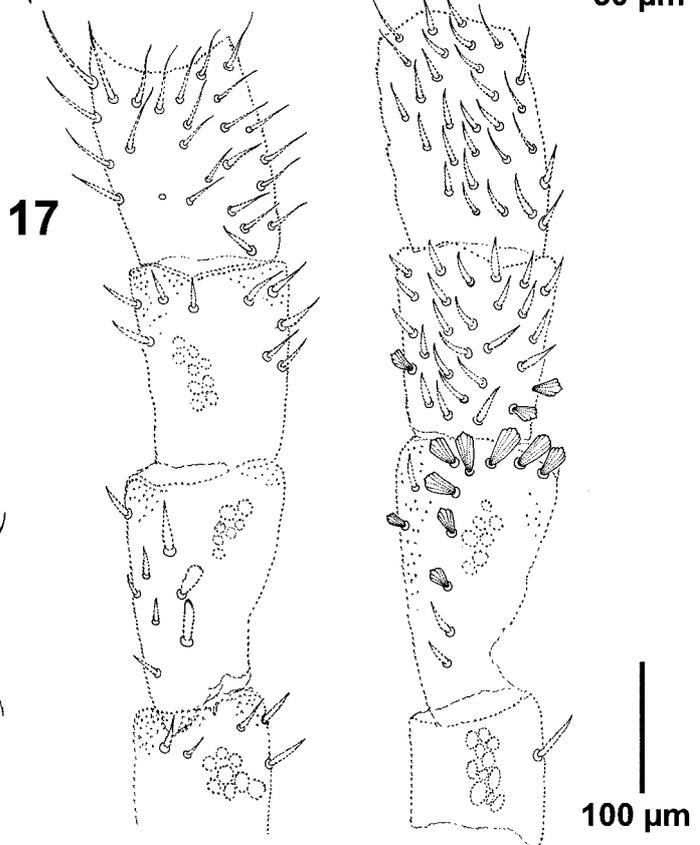
16



15

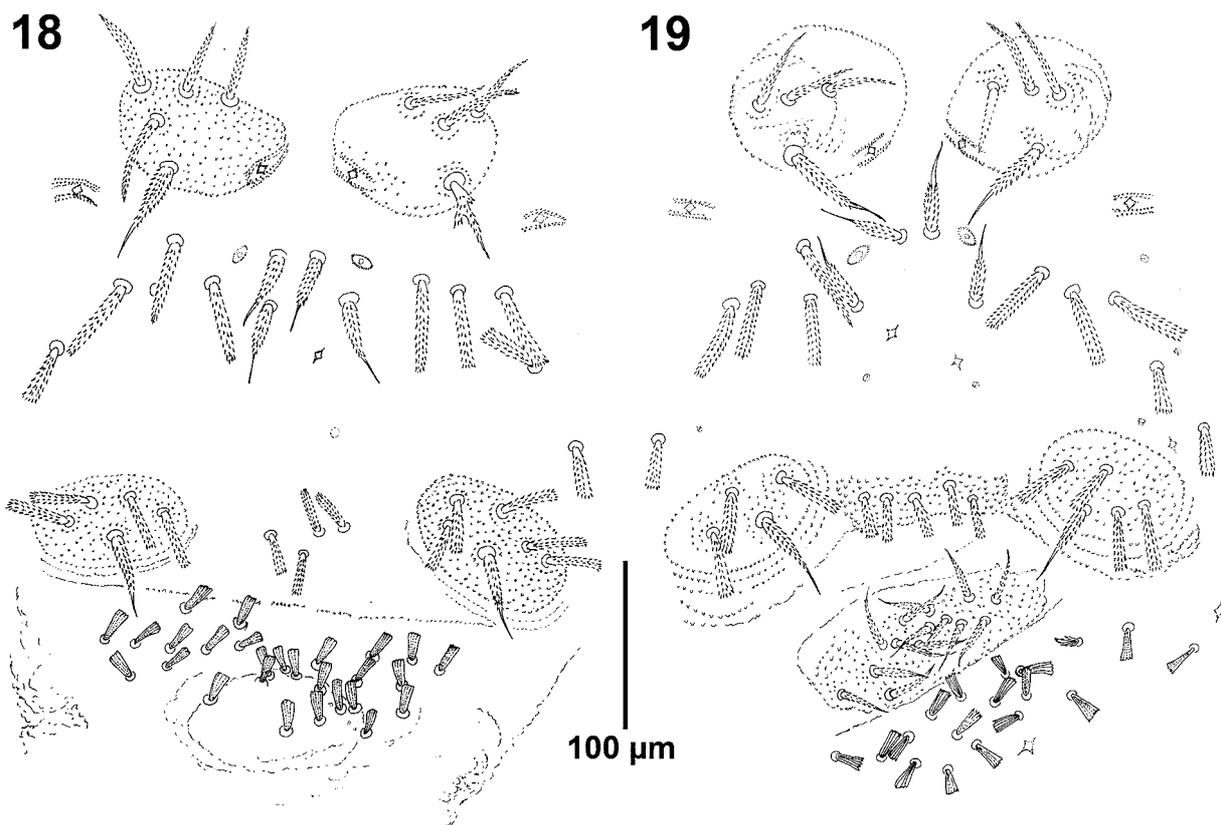


17



**FIGURES 14–17.** *Salfacarus kirindiensis* n. sp., gnathosoma. 14, Chelicera, female, axial view (OSAL006772); 15, Subcapitulum, female (OSAL007324); 16, Palp tarsus, male, dorsal (left) and ventral (right) view (OSAL007326); 17, Palp, male, dorsal (left) and ventral (right) view (OSAL007326).

Sternitogenital region (Figs. 18–19). Sternal verrucae in adults with 1 long, tapering, and 3–4 shorter setae each. Remaining sternal area with 2 pairs of long tapering and 4–8 pairs of papilliform setae, and 3 pairs of lyrifissures (two pairs very large, the third smaller; all different in shape and size from “standard” opisthosomal lyrifissures). Pregenital capsules each with 1 long tapering and 4–5 (female) or 3–4 (male) papilliform setae. Pregenital area and genital sclerite in male with, respectively, 4–5 papilliform and 11 ribbed, tapering setae. In female pregenital and genital area with, respectively, 3–5 papilliform and 0 setae. Ovipositor (Fig. 13). Without long terminal setae, or very small structures on the ovipositor (setae, gland ducts). With two pairs of large, spinose lobes near base, tapering and bifid near their apex.



**FIGURES 18–19.** *Salfacarus kirindiensis* n. sp., sternitogenital region. 18, Female (OSAL007323); 19, Male (OSAL092000).

*Legs.* No leg I recovered. Tarsi II each with a dorsal bifurcate seta and two smooth sensilla resembling solenidia. Tarsi II–IV with an acrotarsus. Trochanters of legs III–IV divided. Pretarsi II–IV each with two pairs of setae and a pair of claws.

**Collection information.** Multiple numbers refer to multiple slides representing a single, dissected, individual. Holotype female (OSAL092006–07), MADAGASCAR: Toliara, Forêt de Kirindy, 15.5 km 64° ENE Marofandilia, 100 m, 20°02'42"S 44°39'44"E, coll. Fisher, B L & Griswold, C E, 28 Nov – 3 Dec 2001, ex tropical dry forest; litter, leaf mold, rotten wood (EF19,BLF4600). Paratypes, same data as holotype: F (OSAL007330–31), F (OSAL007332–34), F (OSAL006772–73), F (OSAL006768–69), F (OSAL006767–68), F (OSAL092004–05), M (OSAL007335–36), M (OSAL007337–38), M (OSAL006770–71).

**Additional material** (non-paratype): Some of the material included in *S. legendrei* was collected from Forêt de Andranomena, Morandawa region. Forêt de Andranomena is geographically close to Forêt de Kirindy, and we tentatively include this material in the new species (see discussion *S. legendrei*).

**Deposition of types.** Holotype female at CAS (CAS18501) (2 slides OSAL092006–07). Other specimens at CAS, OSAL, UQRoo.

**Etymology.** The specific name is derived from the collecting locality, the town of Kirindy.

***Salfacarus mahafaliensis* Vázquez & Klompen n. sp.**

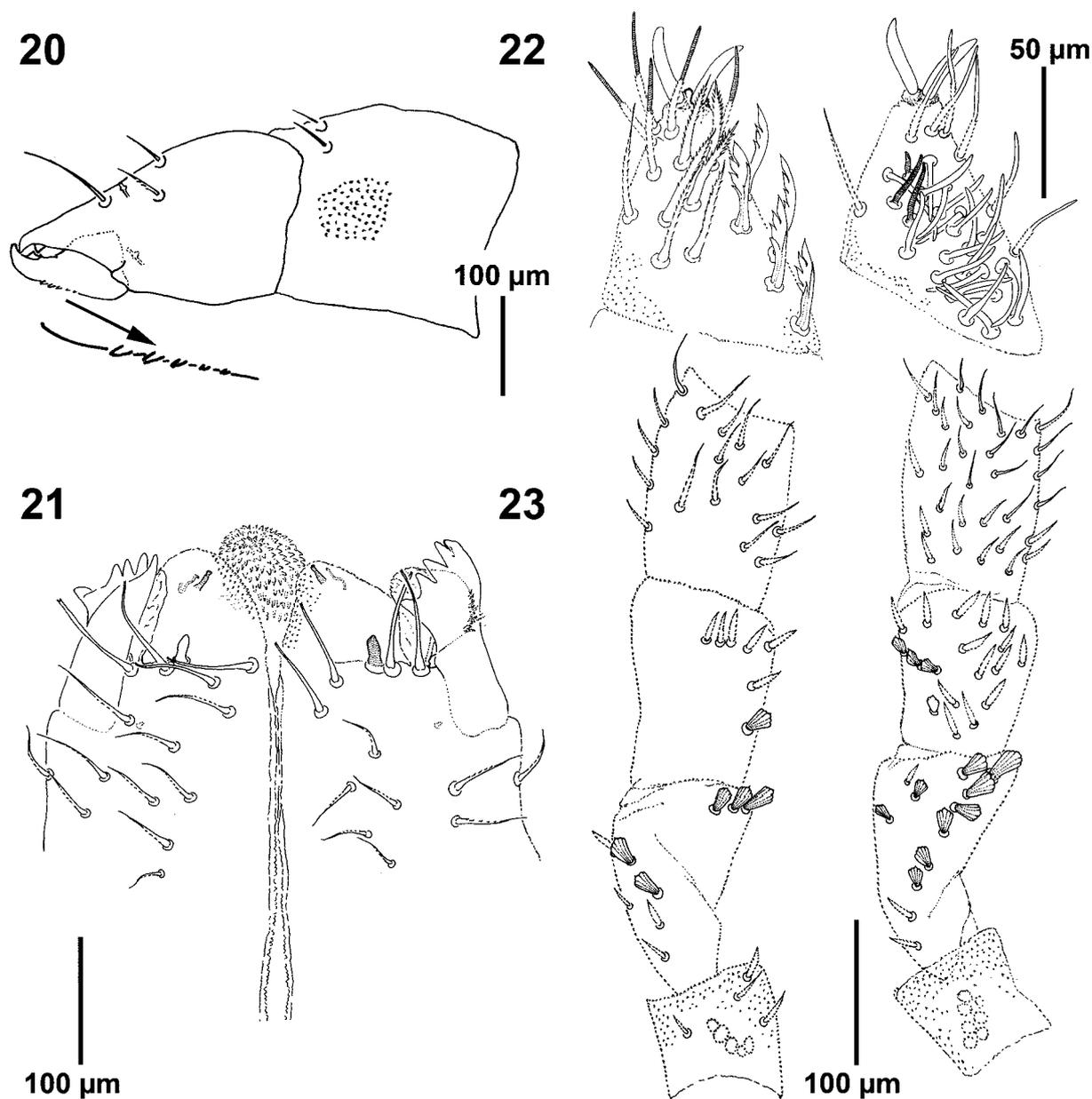
(Figs. 20–26)

*Salfacarus legendrei* Van der Hammen 1979, in part

**Diagnosis.** Ovipositor without long terminal setae, distinct basal setae or glands, or spinose basal structures, but with a characteristic pattern of patches (Fig. 26).

**Description.** Based on observations on 2 tritonymphs, 3 females, 2 males. Other immature instars unknown.

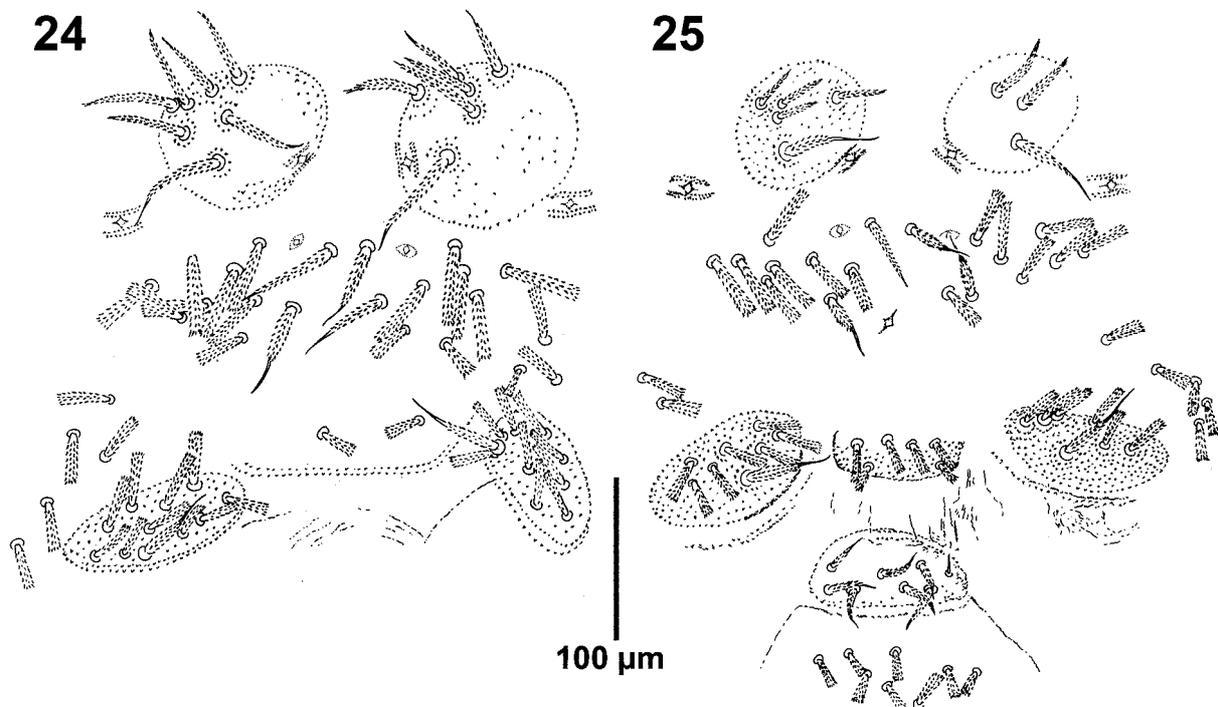
*Gnathosoma*. Chelicera (Fig. 20). Basal segment with 1 (2 in one female), fixed digit with 3 setae. All setae very lightly barbed. Dorsal and antiaxial lyrifissure well developed. Fixed digit with 1, movable digit with 2 teeth and a well developed terminal hook. Movable digit with 4–5 distinct denticles on ventral surface; 3 in TN. Internal surface of movable digit with a small sensillum.



**FIGURES 20–23.** *Salfacarus mahafaliensis* n. sp., gnathosoma. 20, Chelicera, female, axial view (OSAL007324); 21, Subcapitulum, female (OSAL007324); 22, Palp tarsus, male, dorsal (left) and ventral (right) view (OSAL007326); 23, Palp, male, dorsal (left) and ventral (right) view (OSAL007326).

Subcapitulum (Fig. 21). All 4 pairs of paralabial setae present: *pl1* small, conical; With's organ (*pl2*) membranous; rutella (*pl3*) with 1 row of 5 teeth, inserted dorso-laterally; *pl4* very small, inserted dorso-laterally. In addition, 4 circumbuccal (*cb*), and 6–11 median and subcapitular (*vm* (in part), *lvm*, *ldm*, *vp*, *lvp*) setae. Males with fewer median and subcapitular setae (6–8) than females (10–11). TN with 4 such setae. Lateral lips with distinct canals.

Palps (Figs. 22–23). Trochanter of adults with 5–7 ribbed, tapering (= r-type) setae; femur with 7 r and 12 papilliform (= p-type) setae; genu with 24 r and 7 p-type setae. Tibia and tarsus partially fused. Tibia with 11 smooth (s-type) and 41 r-type setae. Palp tarsus with lyrifissures  $i\pi$  and  $i\alpha$ . Setation including 3 *s*, 5 *d* (leaf-like), and approximately 19 *ch*, 10 *sm*, and 7 *v* setae. Sexual differentiation in tibiotarsus absent or indistinct. Pretarsus in shape of a pair of well developed sessile claws. Tritonymph: trochanter: 2 r; femur: 6–8 r and 5–6 p; genu: 10–12 r and 3 p. Tarsus with 4 *d* setae.



**FIGURE 24–25.** *Salfacarus mahafaliensis* n. sp., sternitogenital region. 24, Female (OSAL007323); 25, Male (OSAL092000).

*Idiosoma.* Anterior dorsal shield with 79–95 papilliform setae and two pairs of eyes. Lyrifissures absent. Rostrum rounded. Remaining idiosoma with lyrifissures arranged in more or less transverse rows. More than 200 papilliform setae occurring predominantly mid-dorsal and mid-ventral, arranged in rough rows, but not in series. Anal valves each with 15–19 papilliform setae in adults; 11–13 in TN.

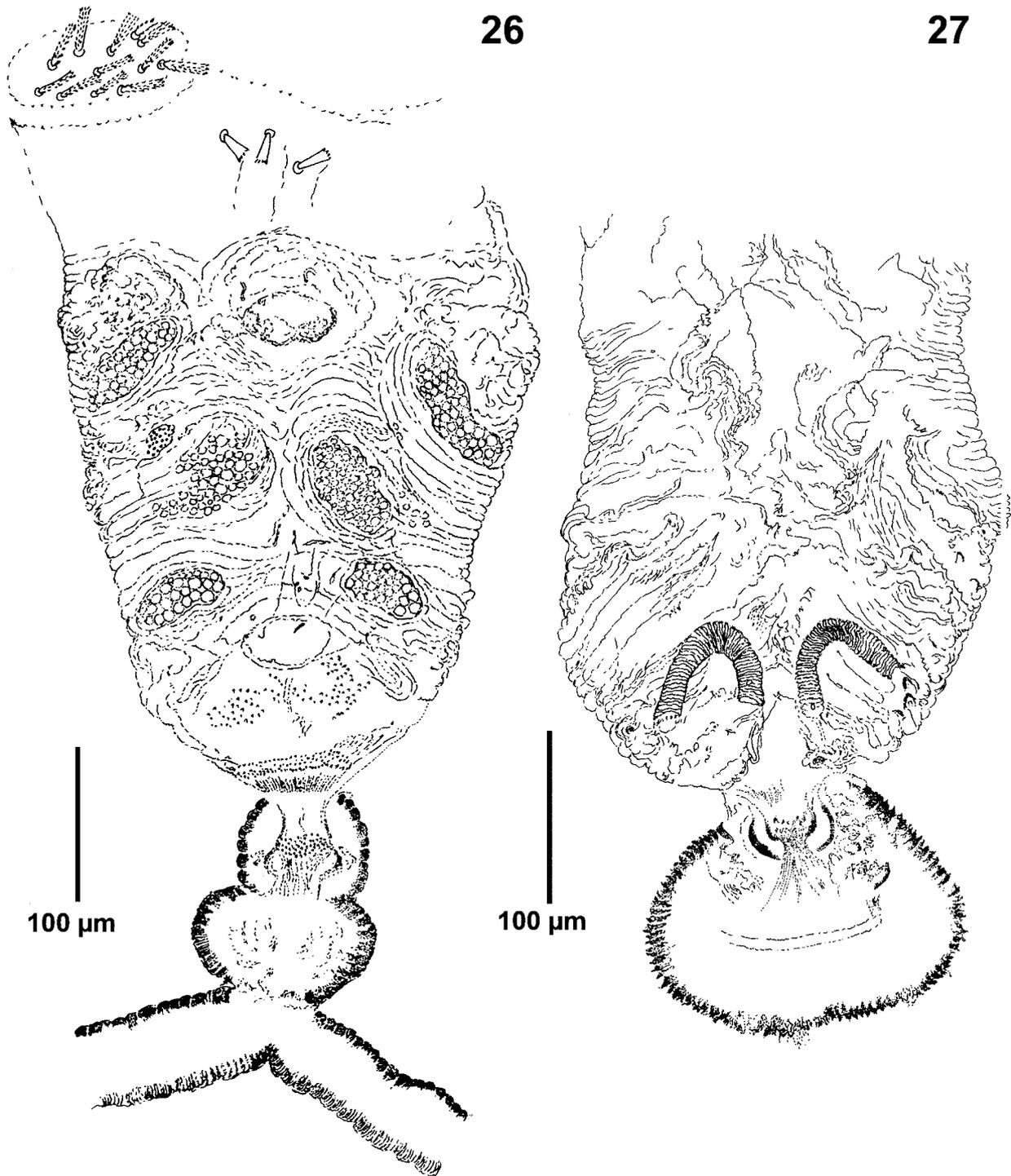
Sternitogenital region (Figs. 24–25). Sternal verrucae in adults with 1 long, tapering, and 3–6 shorter setae each. Remaining sternal area with 2 pairs of long tapering and 8–11 (female) or 5–9 (male) pairs of papilliform setae, plus 3 pairs of lyrifissures (two pairs very large, the third smaller; all different in shape and size from “standard” opisthosomal lyrifissures). TN with 2–3 shorter setae on sternal verrucae, and 5–6 papilliform setae in remaining sternal area. Pregenital capsules of adults with 1 long tapering and 5–8 papilliform setae each (4–5 papilliform setae in TN). Pregenital area and genital sclerite in male with, respectively, 5 papilliform, and 7 ribbed, tapering setae. Pregenital and genital areas in female with, respectively, 2 papilliform and 0 setae. Numbers for the TN 2 and 4 papilliform setae, respectively. Ovipositor (Fig. 26). Without long terminal setae or distinct basal setae or glands, but with a characteristic pattern of patches not observed in other species.

*Legs.* No leg I recovered. Tarsi II each with dorsal bifurcate seta and two smooth sensilla resembling solenidia. Tarsi II–IV in TN and adults with an acrotarsus. Trochanters of legs III–IV in TN and adults divided. Pretarsi II–IV each with two pairs of setae and a pair of claws.

**Collection information.** Multiple numbers refer to multiple slides representing a single, dissected individual. Holotype female (OSAL007323–7324), MADAGASCAR: Toliara, Mahafaly Plateau, 6.2 km 74° ENE Itampolo, 80 m, 24°39'13"S 43°59'48"E, coll. Fisher, B L & Griswold, C E, 21–25 Feb 2002, ex spiny forest / thicket (EH18, BLF5763). Paratypes, same data as holotype: TN (OSAL007283–84), TN (OSAL007285–86), F (OSAL007320–22), F (OSAL092002–03), M (OSAL007325–27), M (OSAL092000–01).

26

27



**FIGURES 26–27.** Ovipositor. 26, *Salfacarus mahafaliensis* n. sp. (OSAL007323). 27, *Salfacarus ranobensis* n. sp., ovipositor. (OSAL007268).

**Additional material** (non-paratype): Some of the material included in *S. legendrei* Van der Hammen was also collected from the Mahafaly plateau and we tentatively include this material in the new species (see discussion *S. legendrei*).

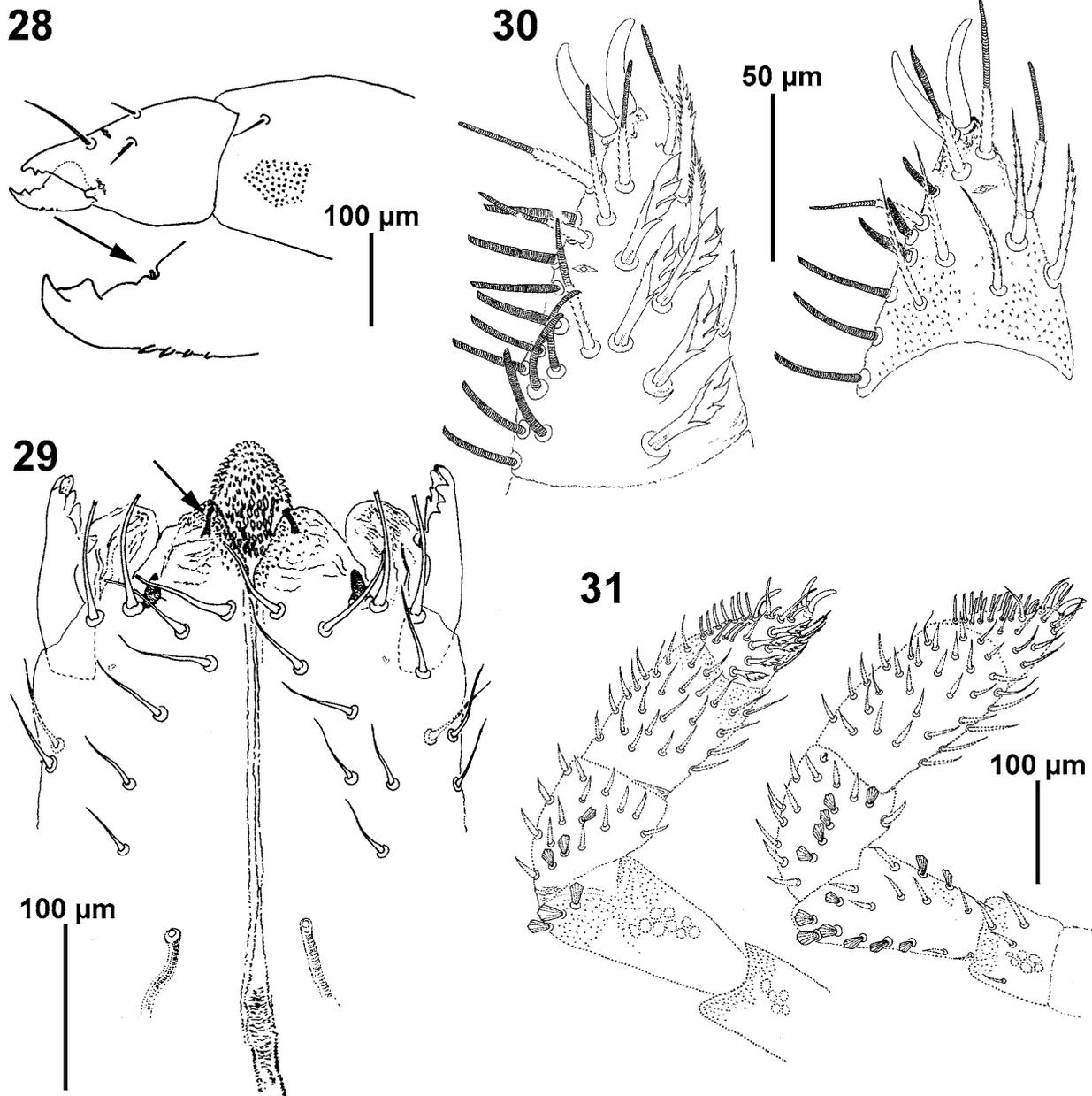
**Deposition of types.** Holotype female at CAS (CAS18502) (2 slides OSAL007323–24). Other specimens at CAS, OSAL, UQRoo.

**Etymology.** The specific name is derived from the collecting locality, the Mahafaly plateau.

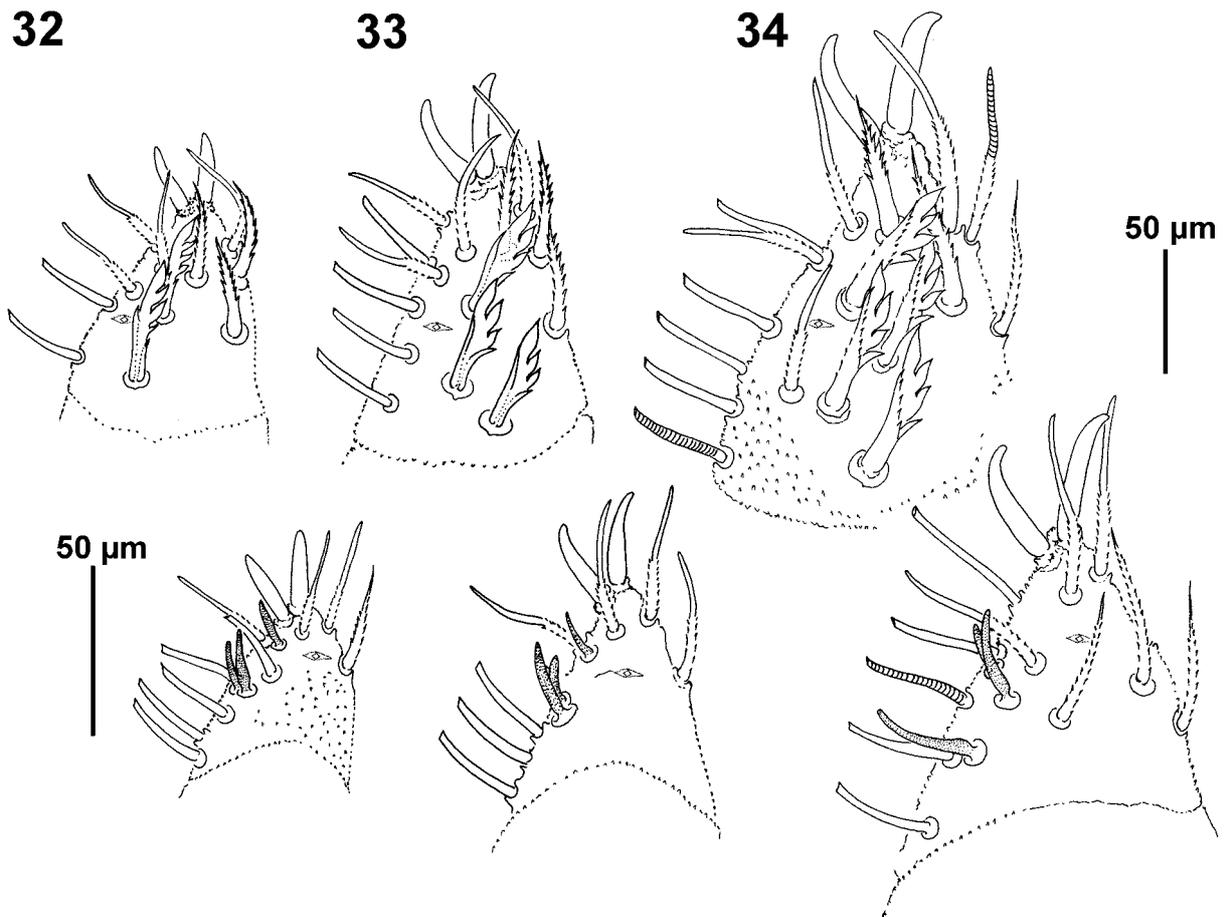
*Salfacarus ranobensis* Vázquez & Klompen n. sp.

(Figs. 27–36)

**Diagnosis.** Ovipositor without long terminal setae, small setae or glands, or large spinose structures, but with a pair of large trachea-like structures near its base (Fig. 27). Female with ribbed, tapering setae in the genital region. The latter characteristic has not been observed in any other *Salfacarus* species in Madagascar (it was reported for *S. lawrencei* from South Africa).



**FIGURES 28–31.** *Salfacarus ranobensis* n. sp., gnathosoma. 28, Chelicera, male, axial view (OSAL007272); 29, Subcapitulum, female (OSAL092011); 30, Palp tarsus, female, dorsal (left) and ventral (right) view (OSAL092011); 31, Palp, female, dorsal (left) and ventral (right) view (OSAL092011).



**FIGURES 32–34.** *Salfacarus ranobensis* n. sp., palp tarsus nymphs. Dorsal (top) and ventral (bottom) view. 32, Protonymph (OSAL007293); 33, Deutonymph (OSAL007298); 34, Tritonymph (OSAL007295). Same scale for proto- and deutonymph. Striation of *ch* and *sm* sensilla not shown for most sensilla.

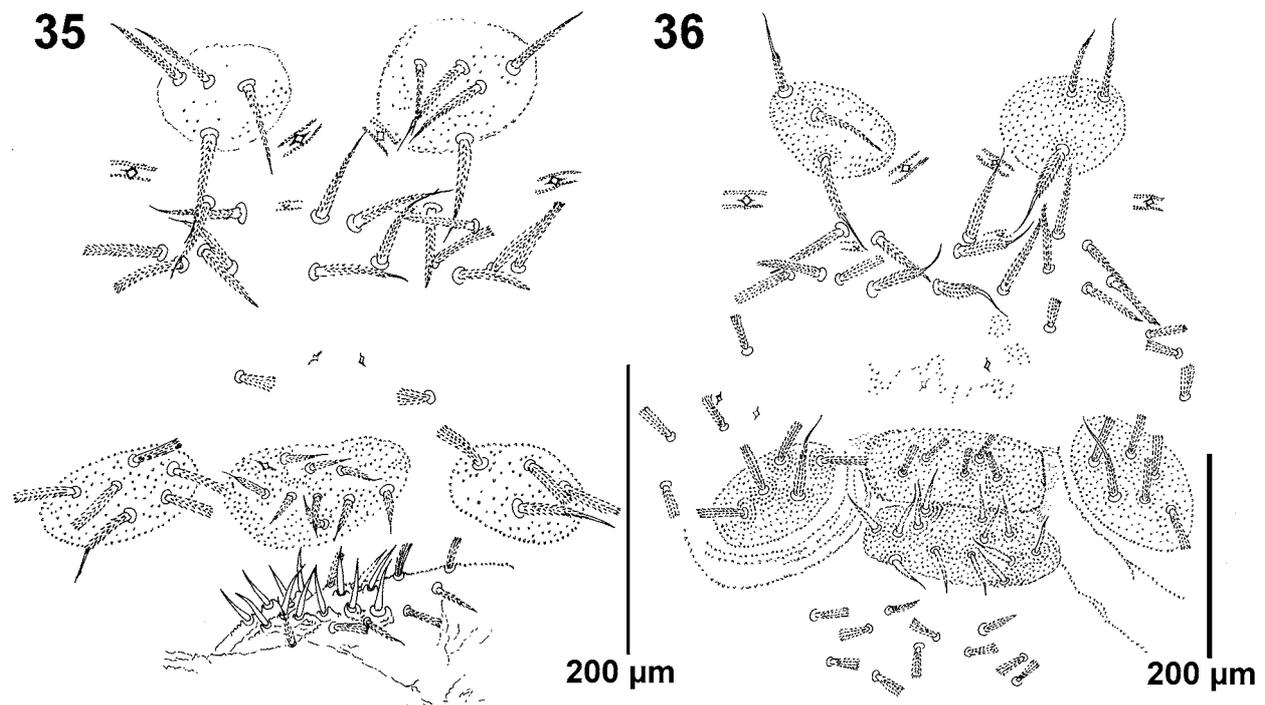
**Description.** Based on observations on 9 protonymphs, 15 deutonymphs, 13 tritonymphs, 2 females, 5 males. Larva unknown.

*Gnathosoma.* Chelicera (Fig. 28). Basal segment without setae in PN and some DNs. One seta added in some DNs and all TNs and adults, fixed digit with 3 setae in all known instars. Axial seta on fixed digit lightly barbed, other cheliceral setae smooth. Dorsal (*id*) and antiaxial (*iα*) lyrifissure well developed in most nymphs and adults, not observed in PN. Fixed digit with 1, rarely 2, teeth, movable digit with 1–2 teeth and a well developed terminal hook. Movable digit with 1–2 ventral denticles in PN and DN, 2–3 in TN, and 3, rarely 4, in adult. Internal surface of movable digit with a small sensillum (arrow).

Subcapitulum (Fig. 29). All 4 pairs of paralabial setae present: *pl1* small, conical; With's organ (*pl2*) membranous; rutella (*pl3*) with 1 distinct row of 5 teeth, inserted dorso-laterally; *pl4* very small, inserted dorsal on subcapitulum (not observed in PN). In addition, adults with 4 circumbuccal (*cb*), and 5–8 median and subcapitular (*vm* (in part), *lvm*, *ldm*, *vp*, *lvp*) setae. Males may have fewer median and subcapitular (5–6) than females, but sampling inadequate. PN, DN and TN similar but number of median and subcapitular setae smaller, 2, 3, and 3–5, respectively. Lateral lips with distinct canals in all instars.

Palp. Adult (Figs. 30–31). Trochanter with 5 ribbed, tapering (= r-type) setae; femur with 9 (female) or 6 (male) papilliform (= p-type) and 12 r-type setae; genu with 7 (females) or 3–4 (males) p-type and 27–35 r-type setae. Tibia and tarsus partially fused. Tibia with approximately 5 smooth (= s-type) and 55 r-type setae. Palp tarsus with lyrifissures *iπ* and *iα*. Setation including 3 *s*, 5 *d* (leaf-like), and approximately 17 *ch*, 9 *sm*, and 9 *v*, setae. Sexual differentiation in tibia and tarsus indistinct. Pretarsus in shape of a pair of well developed sessile claws. Immatures (Figs. 32–34). Trochanter: PN, 0 setae; DN, 0–1 (2 in one specimen); TN, 2–4. Femur: PN, 3–4 r and 2 p setae; DN, 3–4 r plus 2–4 p; TN, 4–9 r plus 6 p. Genu: PN, 5–6 r plus 1 p; DN,

7–8 r plus 1–2 p; TN, 12–20 r plus 2–4 p. Tibia: PN, 15–16; DN, 23–26; TN 24 setae. Tarsus of PN, DN and TN with, respectively, 2, 3, and 4 *d* setae. Number of tarsal *ch*, *sm*, and *v* setae not scored for immatures.

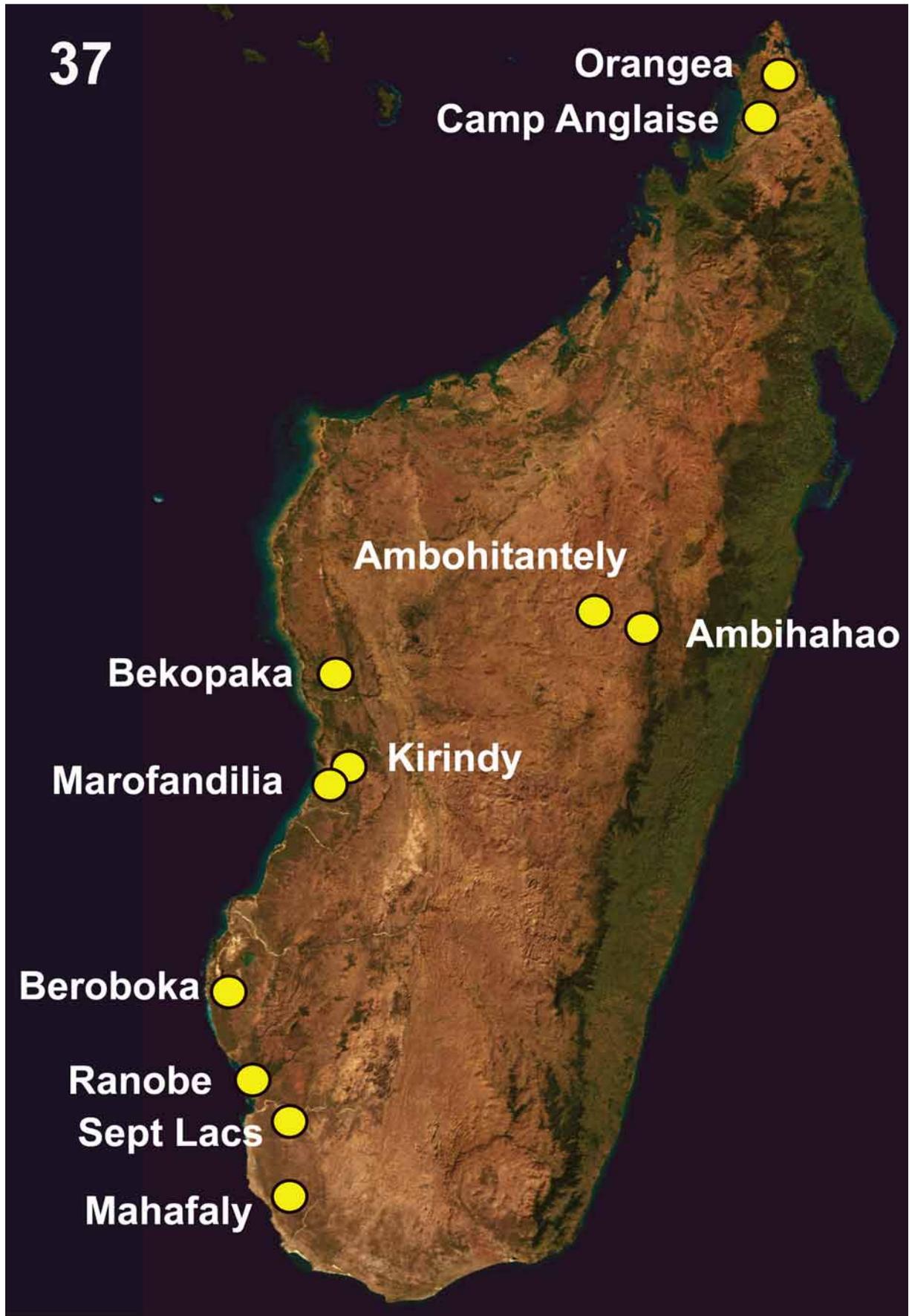


**FIGURES 35–36.** *Salfacarus ranobensis* n. sp., sternitogenital region. 35, Female (OSAL007268); 36, Male (OSAL007277).

*Idiosoma.* Anterior dorsal shield of adults with 94–174 ( $N=4$ ) papilliform setae, and two pairs of eyes. Lyrifissures absent. Rostrum rounded. PN, DN and TN with, respectively, 22–27, 45–56, and 90–108 anterior dorsal shield setae. Remaining idiosoma with lyrifissures arranged in more or less transverse rows. Setation in PN limited to 1 dorsal and 2 ventral seta on preanal segment; subsequent instars all with more than 200 papilliform setae. Setae predominantly mid-dorsal and mid-ventral. Anal valves each with 14–23 papilliform setae in adults; PN, DN and TN with, respectively, 2, 5, and 11–17 setae on each valve.

Sternitogenital region (Figs. 35–36). Sternal verrucae in adults with 1 long, tapering, and 2–3 shorter setae each. Remaining sternal area with 2 pairs of long tapering and 4–9 pairs of papilliform setae, and 3 pairs of lyrifissures (two pairs very large, the third smaller; all different in shape and size from “standard” opisthosomal lyrifissures). PN, DN and TN with, respectively, 0, 1, and 2–3 shorter setae on sternal verrucae, and 0, 1–4, and 6–8 pairs of papilliform setae in remaining sternal area. Pregenital capsules of adults with 1 long tapering and 3–6 papilliform setae each (0, 2–3, and 3–4 in, respectively, PN, DN and TN). Pregenital and genital areas in male with, respectively, 3–6 papilliform and 11–13 ribbed tapering setae. Pregenital area in female with 3–9 ribbed, tapering setae. Condition of genital area less clear. This area appears to have 12 (6–24) smooth, tapering setae, a unique condition for *Salfacarus*, but the area is distorted in the few available specimens, and the zone with smooth setae may in fact be further posterior. In that case the genital area might be without setae (as in all other *Salfacarus*). Still, the presence of smooth tapering setae (in the genital area or in the postgenital ventral area) is highly unusual. Numbers for PN, DN, and TN, respectively, 0 and 0, 0 and 1–3, and 0–2 and 5–8. Ovipositor (Fig. 27). Without long terminal setae, or very small structures on the ovipositor (setae, gland ducts), but with a pair of large trachea-like structures near base.

*Legs.* Tarsus I without distinct acrotarsus but with a basitarsus in all instars. Broad sensillum with “crown-like” tip (Fig. 1S in Vázquez and Klompen (2002)) in main sensillar field. Pretarsi with well developed sessile claws; without setae. Tarsi II each with a thick but not bifurcate dorsal seta and a smooth sensillum resembling a solenidion. Acrotarsus of legs IV present in DN, of legs II–III delayed until TN. Trochanters of legs III–IV divided in most DNs and all TNs. Pretarsi II–IV each with two pairs of setae and a pair of claws.



**FIGURE 37.** Collection localities of *Salfacarus* in Madagascar.

**Collection information.** Multiple numbers refer to multiple slides representing a single, dissected individual. Holotype female (OSAL092010–11), MADAGASCAR: Toliara, Ranobe, 30 m, 23°02'03"S 43°36'43"E, coll. Frontier Project, 25–28 Apr 2003, ex spiny forest/thicket, litter, mold, rotten wood (EH11, MGF064). Paratypes: same data as holotype: M (OSAL092008–09); same locality and collector, 5–9 Feb 2003, (EH11, MGF056): TN (OSAL007262–63), TN (OSAL007265–7266), F (OSAL007267–69), M (OSAL007276–77); same locality and collector, 17–21 Feb 2003 (EH11, MGF061): TN (OSAL007264); same locality and collector, 25 Apr 2003: PN (OSAL007287), PN (OSAL007288), PN (OSAL007289), PN (OSAL007290), PN (OSAL007291), PN (OSAL007292), PN (OSAL007293), PN (OSAL007296), PN (OSAL007297), DN (OSAL007294), DN (OSAL007298), DN (OSAL007299), DN (OSAL007300), DN (OSAL007301–02), DN (OSAL007304–05), DN (OSAL007306), DN (OSAL007307), DN (OSAL007308), DN (OSAL007309), DN (OSAL007310), DN (OSAL007311), DN (OSAL007312), DN (OSAL007313), DN (OSAL007014), TN (OSAL007303), TN (OSAL007314–15), TN (OSAL007295), TN (OSAL007316–17), TN (OSAL007318–19), TN (OSAL007254–55), TN (OSAL007256), TN (OSAL007257), TN (OSAL007258–59), TN (OSAL007260–61), M (OSAL007270–71), M (OSAL007272–73), M (OSAL007274–75).

**Deposition of types.** Holotype female at CAS (CAS18503) (2 slides OSAL092010–11). Paratypes at CAS, OSAL, UQRoo.

**Etymology.** The specific name is derived from the collecting locality, the town of Ranobe.

### *Salfacarus* sp.

The following records concern smaller collections of *Salfacarus*. The number of specimens in each collection or their composition (e.g. no females) was not considered adequate for description. The collections are listed to illustrate the minimal distribution of these mites on Madagascar.

MADAGASCAR: Mahajanga, Parc National Tsingy de Bemaraha, 2.5km 62°ENE Bekopaka, Ankidrodra River, 100 m, 19°07'56"S 44°48'53"E, coll. Fisher, B L & Griswold, C E, 11–15 Nov 2001, ex tropical dry forest on tsingy (EF22,BLF4341): DN (OSAL007785), DN (OSAL007791), M (OSAL007786, 7789),

MADAGASCAR: Toliara, Forêt de Beroboka, 5.9km 131° SE Ankidranoka, 80 m, 22°13'59"S 43°21'59"E, coll. Fisher, B L & Griswold, C E, 12–16 Mar 2002, ex tropical dry forest (EF22): F (OSAL007280–82); same locality and collectors, 12–16 Mar 2002, ex tropical dry forest, leaf mold, rotting wood, sifted litter (EF19, BLF6070): PN (OSAL006765), PN (OSAL007278), DN (OSAL006762), DN (OSAL006763), DN (OSAL007279), TN (OSAL006764), F (OSAL6756–58), F (OSAL006754–55), M (OSAL006759–61).

MADAGASCAR: Toliara, Sept Lacs, 130 m, 23°31'15"S 44°08'35"E, coll. Frontier Project, 20 Aug 2002, ex gallery forest, leaf mold, rotten wood, sifted litter (ER19, MGF037): TN (OSAL007792), TN (OSAL007793–94), TN (OSAL007328–29), F (OSAL007795–96), M (OSAL007797–98),

### Key to the adults of *Salfacarus* species in Madagascar

This key is restricted to the species from Madagascar because the descriptions of the three species known from mainland Africa are incomplete, disallowing proper evaluation of characters.

- 1 Ratio of dorsolateral setae on tibia IV to width of tibia IV distinctly exceeding 1.0; legs IV in female may be longer than legs I ..... *S. robustipes* Van der Hammen 1977
- Ratio less than 1.0; legs IV always shorter than legs I..... 2
- 2 Ovipositor with one or more distinct pairs of spinose structures near its base (Figs. 12, 13)..... 3
- Ovipositor with trachea-like structures, patches of differentiated cuticle or no specific structures (Figs. 26, 27) ..... 4
- 3 Palp femur with a very large (15–19) number of papilliform setae; movable digit of male chelicera with 3–5 ventral denticles ..... *S. antsirananensis* **n. sp.**

- Palp femur with a much smaller (6–12) number of papilliform setae; movable digit of male chelicera with very few ventral denticles (1–2) ..... *S. kirindiensis* **n. sp.**
- 4 Pregonital setae in the female tapering; ovipositor with a pair of trachea-like structures (Fig. 27) .....  
.....*S. ranobensis* **n. sp.**
- Pregonital setae in female papilliform; ovipositor with patches of differentiated cuticle, but without large basal structures ..... 5
- 5 Ovipositor with one large basal, and two much smaller distal patches of differentiated cuticle.....  
..... *S. legendrei* Van der Hammen 1977
- Ovipositor with all three patches of differentiated cuticle of similar size (Fig. 26) ..... *S. mahafaliensis* **n. sp.**

## Discussion

The current results suggest that Opilioacaridae are widespread in Madagascar (Fig. 37). That being said, they do not appear to be very numerous, and their distribution is likely to be patchy, as in Mexico and Cuba (Juvara-Bals & Baltac 1977; Vázquez & Klompen 2002, 2009). Second, the geographical range of individual species of *Salfacarus* appears to be rather narrow. This again fits with our observations for *Neocarus* species in Mexico and Central America. Most specimens were collected in habitats characterized as tropical dry forest (*S. kirindiensis*) or the southern spiny brush (*S. mahafaliensis*, *S. ranobensis*), habitats consistent with the “classical” view of opilioacarids as inhabiting semi-arid zones. These areas have, respectively, between 500–1700 and <500 mm rain / year (Wells 2003). However, some collections are from montane (*S. robustipes*) or littoral (*S. antsiranensis*) rainforest, reinforcing the view that Opilioacaridae are not restricted to just dry habitats. *Salfacarus antsiranensis* was recovered from habitats described as tropical dry and littoral rainforest in extreme northern Madagascar. This suggests considerable within species habitat tolerance. Notably, we have not (yet) seen collections from the eastern rain forest (>1700 mm rain / year). Even so, habitat diversity in Madagascar appears to be comparable to that observed in the Caribbean, Mexico and Central America (Juvara-Bals & Baltac 1977; Palacios-Vargas & Vázquez 1988; Vázquez & Klompen 2002, 2009).

Assuming the observed distribution pattern holds in other parts of the tropics (and preliminary records by colleagues suggest that this may well be so in at least Thailand, India and Brazil), we might expect a moderate diversity of the group, closer to the maximum (170) than the minimum (85) guesstimate of species diversity provided by Walter and Proctor (1999). That being said, species differentiation in Opilioacaridae, and especially in *Salfacarus*, is proving to be quite difficult, with the ovipositor as the only structure providing consistent species-level characters. Future studies will need to be designed to take advantage of additional characters, such as molecular data.

## Acknowledgements

We thank Brian Fisher, Charles Griswold, and Darryll Ubick, California Academy of Sciences, San Francisco for making this material available for study, and Jacques Smit, Nationaal Natuurhistorisch Museum, Naturalis, Leiden for the loan of specimens of *Salfacarus* material in the Van der Hammen collection.

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