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FURTHER CONSIDERATIONS ON THE GEOGRAPHICAL DISTRIBUTION OF THE ENDEMIC MALAGASY GENUS *NEOGROSPHUS* LOURENÇO, 1995 (SCORPIONES: BUTHIDAE)

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Abstract: We review the distributional patterns of Malagasy scorpions belonging to the endemic genus *Neogrosphus*, restricted to dry forest formations in the southern and western portions of the island. Revised diagnoses are proposed for the genus and one of the two known species. We conclude that the actual range of the members of this genus is not simply associated with the current biome features of the landscape, as they occur in several different types of dry forest. An analysis of soils in the Mahafaly Plateau region does not show consistent differences with the micro-distribution of *N. griveaudi* (Vachon, 1969) in that region.
Key words: Scorpiones, Buthidae, *Neogrosphus*, soil types, distributional patterns, Madagascar.

Consideraciones adicionales sobre la distribución geográfica del género *Neogrosphus* Lourenço, 1995, endémico de Madagascar (Scorpiones: Buthidae)
Resumen: Analizamos los modelos de distribución de los escorpiones malgaches del género *Neogrosphus*, restringidos a formaciones de bosque seco del sur y oeste de la isla. Se presentan diagnosis revisadas para el género y para una de las dos especies conocidas. Llegamos a la conclusión de que la distribución real de los miembros de este género no se debe simplemente a las características biológicas actuales del paisaje, dado que están presentes en varios tipos diferentes de bosque seco. El análisis de los suelos de la región de la meseta de Mahafaly no pone de manifiesto diferencias sistemáticas con la microdistribución de *N. griveaudi* (Vachon, 1969) en la región.
Palabras clave: Scorpiones, Buthidae, *Neogrosphus*, tipos de suelo, modelos de distribución, Madagascar.

Introduction

As already discussed in previous papers (Lourenço, 1996, 2000, 2003, 2004, 2005), the near totality of the scorpion genera represented in Madagascar are endemic and in most cases representing very ancient lineages. The genus *Neogrosphus* Lourenço was created for the species *Grosphus griveaudi* Vachon, 1969, which was described based on five males and two females collected in dry southwestern vegetation formations at two sites in the Province de Toliara: 1) Tanandava in the Mikea Forest, east of Lake Ihotry and north of Toliara (estimated coordinates 21°42'S, 43°45'E) and 2) Evazy, S of Toliara (estimated coordinates 24°42'S, 44°45'E). According to Vachon (1969), the specimens from Tanandava were found in a baobab (*Adansonia*) forest on red sands, and those from Evazy in the spiny bush biome composed of Didiereaceae.

The description of the new genus *Neogrosphus* by Lourenço (1995) was to accommodate the species *G. griveaudi* that demonstrated a range of morphological characters falling outside of typical members of the genus *Grosphus*. In Vachon's original description of *G. griveaudi* it was already clear that he questioned the generic placement of this new species based on morphological differences and (p. 481) stated "La détermination des spécimens qui ont permis la création de cette espèce nouvelle nous a pose maints problèmes…Il est donc fort possible que l'espèce *griveaudi* appartienne à un sous-genre nouveau ou à un genre nouveau." A short period after the description of the genus *Neogrosphus* (Lourenço, 1995), another new species, *N. blanchi* Lourenço, 1996 was described based on one male specimen held in the collections of the Muséum national d'Histoire naturelle, Paris, collected from an imprecise locality in the center of Madagascar.

Over the past decade considerable biological exploration of a wide range of habitats on the island, using survey techniques (large pit-fall buckets and large scale leaf litter sampling) that were not previously widely employed, have result in substantial new collections of Malagasy scorpions. Until the specimens reviewed in the current paper were collected, no additional material to our knowledge had been obtained for the genus *Neogrosphus*, which has been previously considered as rare. These new collections come from a range of sites in different types of natural dry forests, further supporting that members of this genus are restricted to these biomes. Moreover, based on the new material, revised diagnoses are proposed for members of this genus. Also some new data located in some personal notes of the late Prof. M. Vachon, suggests that *N. blanci* was possibly collected nearby the region of Isalo.

Material and methods

Specimens in this study are based primarily on samples from pitfall traps. Color and pigmentation are the most conspicuous external characters in scorpions, especially amongst buthoids. It is important to distinguish two aspects of coloration. One is the color of the cuticle itself, which

can vary from clear (transparent) to black. Among some scorpions, coloration changes with the age. Juvenile stages of several species are variegated yellow, whereas the adults are black. A second type of coloration is due to the presence of sub-cuticular pigments, which form a variety of configurations or etched-like patterns over the body, pedipalps, and chelicerae. This second type of pigmentation does not normally change with age, but it can be masked by sclerification (Lourenço, 1983; Lourenço & Cloudsley-Thompson, 1996). In the case of buthoid scorpions, color and pigments are very useful characters for species identification. In the present study, the diagnosis and descriptions of the two known species were largely based on precise patterns of pigmentation.

Illustrations and measurements were produce using a Wild M5 stereo-microscope with a drawing tube and ocular micrometer (at 25x). Measurements follow Stahnke (1970) and are given in mm. Trichobothrial notations follow Vachon (1974, 1975), and morphological terminology mostly follows Hjelle (1990).

Museum acronyms of studied specimens:

CAS – California Academy of Sciences, San Francisco, California

FMNH – Field Museum of Natural History, Chicago

MNHN – Muséum national d`Histoire naturelle, Paris

The pattern of distribution presented by the genus *Neogrosphus*

New studied material of *Neogrosphus griveaudi*:

(1) Madagascar, Toliara Province, Réserve Spéciale de Cap Sainte Marie, 14.9 km W Marovato (elev. 160 m) (25°35'40"S, 45°8'49"E), 13-19/II/2002 (Fisher & Griswold *et al*.), pitfall trap, in spiny forest (BLF [= B. L. Fisher] 5650, CAS), 1 male. (2) 12.3 km 262° W Marovato (elev. 200 m) (25°34'54"S, 45°10'6"E), 11-15/II/2002 (Fisher & Griswold *et al*., CAS), general collecting in spiny forest thicket, 1 female. (3) PN de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77° ENE Efoetse, 17.4 km 170° S Beheloka (elev. 40 m) (24°2'50"S, 43°45'11"E), 18-22/III/2002 (Fisher & Griswold *et al*., CAS), pitfall trap in spiny forest thicket, 1 male juvenile. (4) Efoetse no other data, 1 female (MNHN).

Toliara Province, Fiv. Ampanihy-West, Rural Commune of Itampolo, 4 km NE of Vohombe village (80 m) (24°23.9'S, 43°50.8 'E), 27/II/2005 (VS [=V. Soarimalala] 535, FMNH), littoral bush of Didiereaceae and Euphorbiaceae reaching 5 to 8 m in height and with dense understory, 1 female. Idem, 1/III/2005 (VS 546, FMNH), xerophytic bush vegetation dominated by Didiereaceae and Euphorbiaceae on limestone plateau, 10 males, 1 female. Idem, 3/III/2005 (VS 551, FMNH), 1 male, 1 female. PN de Tsimanampetsotsa, Fiv. Ampanihy-West, Rural Commune of Beheloka, 13.5 km SSE Efoetse, 2 km E Soarano, (elev. 40 m) (24°11.3'S, 43°46.7 'E), 7/IV/2005 (V. Soarimalala & E. Ranoarivony, VS 613, FMNH), littoral bush of Didiereaceae and Euphorbiaceae reaching 5 to 8 m in height and with open understory, 3 males, 2 females.

Mahajanga Province, Forêt de Tsimembo, 8.7 km 336° NNW Soatana (elev. 20 m) (19°1'17"S, 44°26'26"E), 21-26/X/2001 (Fisher & Griswold *et al*., CAS), pitfall trap, tropical dry forest, 1 male (CAS).

Revised diagnosis for the genus *Neogrosphus*

Scorpions of average size when compared with most species of Malagasy buthids. Males much smaller than females measuring from 24 to 30 mm in total length, whereas females may reach up to 45 mm (see Table I with morphometric values). General coloration pale yellow to reddish-yellow with or without dark spots over the body and appendages. Disposition of granulations on the dentate margins of the pedipalp chela fingers, arranged in 8 to 9 rows of granules instead of 11 to 14 rows of granules as in the genus *Grosphus*. Subaculear tooth absent even in juvenile forms. This tooth can be observed in juvenile forms of *Grosphus*. Trichobothriotaxie type A with a alpha-α disposition for the dorsal trichobothria of femur (Vachon, 1974, 1975).

Table I. Morphometric values (in mm) for some adult specimens of *N. griveaudi* (L= length)

Length:	♀ type 4483	♀ VS613	♂♂ VS 546	♂ type
Total	45.7	42.9	32.7/31.3/28.5	24.0
Carapace	5.4	5.1	4.1/3.7/3.4	4.0
Mesosoma	12.1	13.1	7.9/8.2/7.8	6.0
Metasomal segment:				
I	4.2	3.8	3.3/3.0/2.6	2.5
II	5.0	4.4	3.7/3.5/3.2	2.5
III	5.4	4.8	3.9/3.7/3.3	3.0
IV	6.3	5.4	4.6/4.2/3.7	4.0
V	7.3	6.3	5.3/5.0/4.5	4.8

Revised diagnosis and distributions of the two known species of *Neogrosphus*

Neogrosphus griveaudi (Fig. 1-4)

Same diagnosis as for the genus. General pattern of pigmentation yellowish, with dark spots over the body and appendages. Carapace yellowish with an inverted dark triangle extending from the anterior edge to the zone behind the median eyes. Tergites with confluent dark zones, less marked on tergite VII. Metasomal segments I to V with the anterior half marked by a dark ring. Telson yellowish without spots. Pedipalps yellowish; femur and patella with spots on the internal and external faces; chela and chelicera without spots. Legs with spots only in the anterior segments. Pectinial teeth count: 27 to 29 for females and 29 to 31 for males. Some specimens from the southern limit of this species` distribution, Réserve Spéciale de Cap Sainte Marie, show some variation in the pigmentation pattern. The carapace lacks the inverted dark triangle, and the general pigmentation can be notably less spotted. We do not have sufficient specimen material from a given locality to quantify precise color pattern differentiation in this species; however, this variation may represent a case of polymorphism. This phenomenon has already been observed for scorpions in the Amazon region of South America (Lourenço, 1988).

On the basis of the original description of *N. griveaudi*, it was previously known from the transitional dry deciduous forests of the Mikea region, to the north of Toliara, and the spiny bush habitat to the south of Toliara (Vachon, 1969; Figure 5). Based on recent collections, the known distribution of this species is notably greater in both of terms of geography and habitat diversity. The northern most specimens are from the dry deciduous forests of the Tsimembo region, to the west of the limestone deposits surrounding the PN de Bemaraha. The next known locality to the south is from the Mikea Forest, where one of the type specimens was collected, which is composed of a transitional dry deciduous—spiny bush habitat resting on red

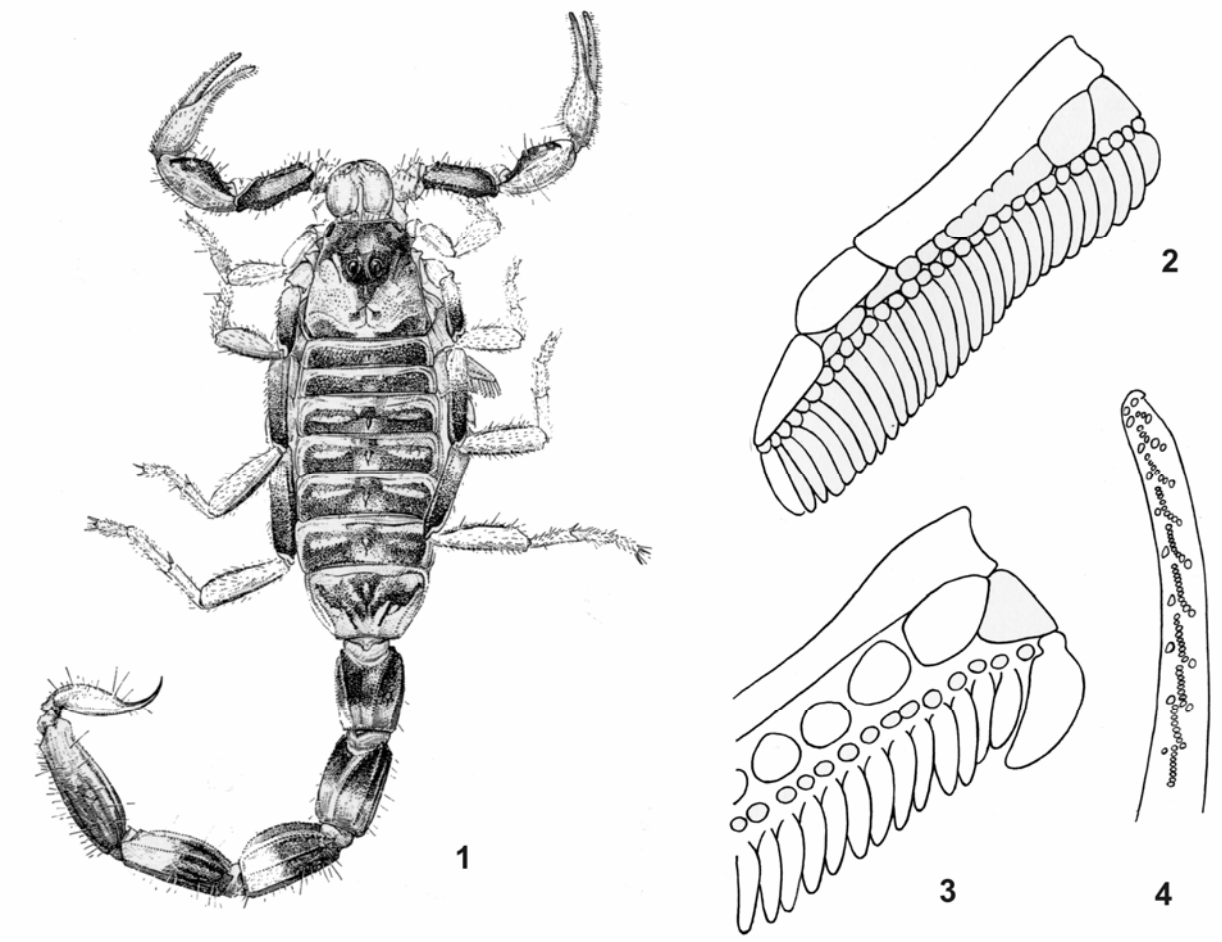
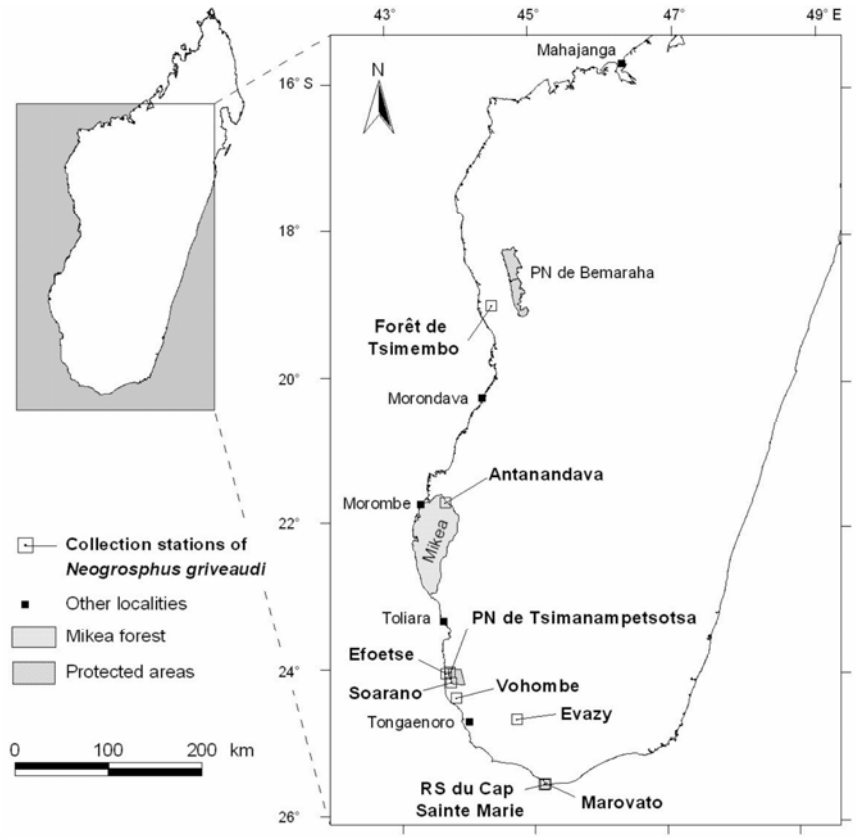


Fig. 1-4. *Neogrosphus griveaudi.* **1.** female paratype. Habitus (from Vachon, 1969). **2-4.** *Neogrosphus griveaudi*. **2**. Pecten, male holotype. **3**. Idem, female paratype, showing the strong dilatation of the basal middle lamella. **4**. Disposition of granulations on the dentate margins of the pedipalp chela fingers, female paratype.

Fig. 5. Map of the southern and western portions of Madagascar showing the known distribution of *Neogrosphus* species. →



sands. Further to the south, this species has been collected at several localities (Tsimanampetsotsa, Efoetse, Vohombe) at the foot of and on the limestone Mahafaly Plateau and in zones with xerophytic spiny bush vegetation resting on sandy soils. At one locality in this region, Mitoho Cave, the collection site is on the plateau escarpment, in an area on limestone substrate. At the southern end of the island, near Cap Sainte Marie, this species was captured along the upper portion of an escarpment jutting out of the sea, that has a mixture of sand and limestone substrate.

The vast majority of dated specimens of *N. griveaudi* were collected during the months of January to March. This is the period in western Madagascar when daily average temperatures reach their maximum and the vast majority of the annual precipitation falls -- presumably coinciding with activity cycles of this species. During the months of February and March 2005, during the period the series was collected at Vohombe and near Soarano, another site was inventoried on the Mahafaly Plateau near Tongaenoro, using exactly the same trapping protocol, and no evidence of *N. griveaudi* was found. The March 2002 expedition of scientists from the CAS to the Mitoho Cave region near Tsimanampetsotsa resulted in the capture of a single male juvenile of this species, but fieldwork at this site by a team of WWF in February and March of that same year did not result in a single specimen of this animal. By extrapolation, there maybe some subtle habitat or environmental specificity of this species at a very local level and it apparently does not have a continuous distribution across its known range. Another explanation is that densities of this species in certain portions of its distribution are notably low and during rapid biological surveys it is inventoried at certain sites and at others not.

The specimens from the Tsimembo region are separated from the closest known site for this species, the Mikea Forest, by about 400 km direct distance. Further, the Tsiribihina and Mangoky rivers draining into the Mozambique Channel bisect this zone in and east-west direction. These two rivers have their origin in the eastern portion of the Central Highlands at high elevations and in the western lowlands form large meandering rivers, which would presumably form important dispersal barriers for this scorpion. Molecular genetic research on specimens from these two areas would useful to examine levels of differentiation between populations to the north and south of these rivers.

Neogrosphus blanci

Same diagnosis as for the genus. General pattern of pigmentation yellowish to reddish-yellow without any spots over the body and appendages. Pectinial teeth count: 27-27 in male. Female unknown.

Biogeography of *Neogrosphus*

The exclusive presence of the genus *Neogrosphus* in the western and southern portions of the island, in rather unique and highly endemic plant formations can, however, be attributed to historical biogeographical factors. This idea is supported by the phylogenetic affinities of *Neogrosphus* with African relict elements and particularly associated with the antiquity of this scorpion lineage.

The western portion of Madagascar receives less annual precipitation and has a more pronounced dry season than the eastern and central highland areas of the island. Along the west coast there is a pronounced north-south cline in decreasing annual rainfall from 1503 mm at Mahajanga, 780 mm at Morondava, 496 mm at Morombe, and 390 mm at Toliara (Chaperon *et al*., 1993). Inland, at Ranopiso, close to the Isalo Massif, annual rainfall is approximately 910 mm (Chaperon *et al*., 1993). Following this cline, the shift in rainfall gives rise to changes in vegetational types that range from deciduous forest in the northwest to a notably drier deciduous forest along the west-central lowland area, and then a sub-arid spiny bush towards the southwest. The transition zone between the dry deciduous forest and spiny bush transition falls between Belo-sur-Mer and Toliara, and more precisely in the region of the Mikea Forest (from where one of the type specimens of *N. griveaudi* comes from).

On the basis of a series of soil analyses from sites in southwestern Madagascar (Table II), *N. griveaudi* frequents areas dominated by sandy substrates with neutral or slightly acidic pH (6.2 to 6.8) and with little organic material (less than 2.5%). At Vohombe the soils associated with pitfall lines where individuals of this scorpion were captured, are largely sandy with a smaller proportion of lime, a pH from 6.2 to 6.3, and nitrogen content from 0.09 to 0.15 %. Organic material in the soil was not completely decomposed, with C/N ratio values from 6.7 to 17.8. The capacity for ion exchange was very low, as well as the P_2O_5 content. At this site lines 4 and 5 were on the plateau escarpment and line 6 and the foot of the plateau, all of which yielded specimens of *N. griveaudi*.

At the Tsimanampetsotsa (Soarano) site the soils associated with pitfall lines where individuals of *N. griveaudi* were captured are more than 97 % sand, with a pH from 6.6 to 6.7, and nitrogen content from 0.03 to 0.04 %. The C/N ratio of 5.9 to 6.0 indicates that the soil was largely mineralized with virtually no organic material content. The capacity for ion exchange was very low and the P_2O_5 content was not measurable.

A third site, Tongaenoro, in the same immediate area of the Mahafaly Plateau was inventoried using the same techniques and during the same season, and no individual of *N. griveaudi* was obtained. A comparison of soil constitution at this site indicates that the percentage of lime was greater than the other two sites, but the majority of the parameters fall within the range of those at Soarano and Vohombe, where individuals of this scorpion were captured. Further research is needed on the microhabitat selectivity of these scorpions in relationship to their distribution, but based on this current information soil types cannot explain their apparently patchy distribution.

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Table II. Soil analyses from several sites at the foot of or on the Mahafaly Plateau associated with individual pit-fall lines. The lines that captured *Neogrosphus griveaudi* are indicated with an asterisk. Abbreviations: S – sand, A – clay, L – lime, C – carbon, N – nitrogen, CECT –total capacity of cation exchange.

Sites	Pitfall line	Soil color pattern	Physical properties			Chemical properties analysis								
			S%	A%	L%	pH	C%	N%	C/N	P_2O_5	CECT	MgO	CaO	K_2O
Tongaenoro	1	Brown	68.30	5.70	15.75	6.5	2.51	0.15	16.73	0.06	6.00	0.04	0.04	0.03
	2	Brown	73.46	10.40	18.56	6.2	2.56	0.16	16.00	0.05	7.50	0.05	0.05	0.03
	3	Brown	65.70	7.80	17.47	6.6	2.34	0.15	15.60	0.02	8.60	0.05	-	-
Vohombe	*4	Brown	69.20	13.40	15.00	6.2	2.67	0.15	17.80	0.08	7.00	0.04	0.04	0.06
	*5	Brown	70.25	6.10	19.85	6.3	2.48	0.14	17.71	0.06	6.80	0.05	0.06	0.06
	*6	Light gray	95.40	-	2.60	6.8	0.60	0.09	6.66	-	-	-	-	-
Soarano	*13	Light gray with black spots	97.50	-	-	6.6	0.24	0.04	6.00	-	8.00	0.06	0.04	0.01
	*14		96.91	-	-	6.7	0.22	0.03	5.85	-	6.50	0.04	0.04	0.01
	15		95.28	-	1.20	6.7	0.24	0.04	6.20	trace	6.45	0.04	0.04	0.01

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