

Species of *Grosphus* Simon, 1880,
associated to the group *madagascariensis* / *hirtus*
(Scorpiones: Buthidae); description of a peculiar
new species from the humid eastern forests
of Madagascar

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(with 19 figures)

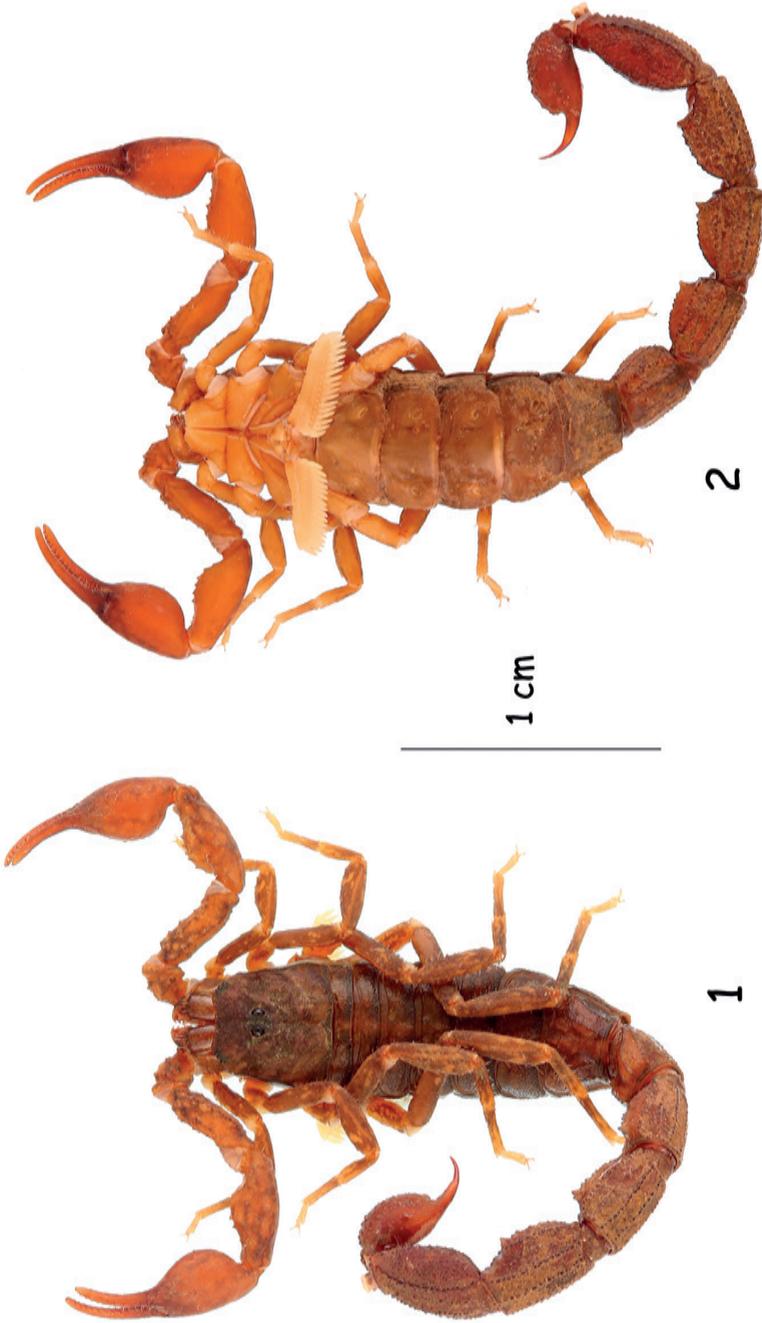
Abstract

Uplands areas of the central eastern Madagascar are not considered amongst the regions of the island that show high levels of scorpion diversity. Previous surveys conducted in the Ambatovy-Analamay-Torotorofotsy humid forests at around 1000 m, revealed the presence of different species of *Grosphus*. The detailed study of several individuals of one of these populations indicates the presence of a new species associated with *Grosphus hirtus* Kraepelin, 1900. This new species, *G. voahangyae* sp. n., is described in the paper. Some comments on biogeographic aspects linking the new species with both *G. madagascariensis* (Gervais, 1843) and *G. hirtus* are also provided.

Key words: Scorpiones, Buthidae, *Grosphus*, new species, Central/ Eastern/Western distributions, Madagascar.

Introduction

In recent years, a considerable number of new species have been added to the genus *Grosphus* Simon, which is endemic to Madagascar (e.g., Lourenço 1996, 2003, 2014; Lourenço & Goodman 2003, 2006; Lourenço *et al.* 2004, 2007, 2009). Among these various cases, some of the recently described species showed some clear associations with other members of this genus described well over 100 years ago, specifically members of the *G. madagascariensis* / *G. hirtus* group. The taxonomy of *Grosphus* is notably complicated, particularly aspects of species' delimitations. Lourenço and Goodman (2006) attempted to, at least, clearly define the taxonomic status of *Grosphus madagascariensis* (Gervais, 1843) and *Grosphus hirtus* Kraepelin, 1900. Previous to this publication *G. madagascariensis*, the type species of the genus had been reported from numerous sites on the island; many of these records are certainly misidentifications. A similar situation also exists for several published records of *G. hirtus*. This species was described from Makaraingo (17°59'S, 45°35'E), at 1000 m, which is 55 km north-north-east of the Réserve Spéciale (RS) d'Ambohijanahary. This site is located at



Figs 1-2. *Grophus voahangyae* sp. n. Male holotype.

the western edge of the Central Highlands, 120 km northeast of the Parc National (PN) de Bemaraha. Ambohijanahary forest contains a mixture of transitional dry-humid montane forest and the local fauna contains many dry forest elements. In an attempt to stabilize the taxonomic position of *G. hirtus*, Lourenço et al. (2007), proposed a redescription of this species based on specimens from the Tsingy forest of the PN de Bemaraha. The specimens used for this description presented the same pale yellowish coloration with a variegated pigmentation as the holotype and also a similar number of pectinial teeth count: 17-17 for the female holotype; 19-18 and 18-17 for the male and female used for the redescription (Lourenço *et al.*, 2007). For a more detailed discussion about the characters used in the taxonomy of *Grosphus*, see Lourenço (2014) and Lourenço *et al.* (2007, 2009).

Previous examination of some specimens of associated to *Grosphus hirtus* collected in the east Central Highlands, conduct the first author to suggest the existence of a possible distinct new species. In fact, the study of specimens, five males and two female, collected in Torotorofotsy Forest, situated in the Central eastern to the northeast of Moramanga, and in close vicinity to the lower montane humid forests of Ambatovy-Analamay by J.-M. Betsch and other members of the RCP-225 during the 1970s attested the existence of some differences in coloration and morphology of this population associated with *G. hirtus*.

Subsequently, new specimens were reported and collected in the Ambatovy-Analamay Forest. These, perfectly correspond to the Torotorofotsy samples, and the same differences in coloration and morphology between these animals and those from the typical locality of *G. hirtus* and from Ambohijanahary are confirmed. In this note we comment on the taxonomic identification of this population and a new species is described. Some biogeographic comments are also added attempting to explain this new case of disrupted distribution between elements of the previously defined *Grosphus* groups.

Material and methods

Material related with the new species, as well as to *Grosphus madagascariensis* and *Grosphus hirtus* are now deposited in three Museums:

MNHN = Muséum national d'Histoire naturelle, Paris.

ZMH = Zoologisches Museum, Hamburg.

FMNH = Field Museum of Natural History, Chicago.

Illustrations and measurements were produced using a Wild M5 stereomicroscope with a drawing tube and an ocular micrometer. Measurements follow Stahnke (1970) and are given in mm. Trichobothrial notations follow Vachon (1974) and morphological terminology is after Vachon (1952) and Hjelle (1990).

Taxonomic treatment

Family Buthidae C. L. Koch, 1837

Genus *Grosphus* Simon, 1880

Species considered in the present note:



Figs 3-4. *Grophus voahangyae* sp. n. Female paratype. Habitus, dorsal and ventral aspects.

Grosphus madagascariensis (Gervais, 1843)

Grosphus hirtus Kraepelin, 1900

Grosphus hirtus garciai Lourenço, 2001

Grosphus voahangyae sp. n.

Grosphus madagascariensis (Gervais, 1843)

Scorpions of medium size, ranging from 45 to 60 mm in total length. General coloration reddish-brown to dark brown. Metasomal segments reddish-brown; segments IV and V slightly darker. All segments longer than wide with carinae strongly marked and with 10-10-10-8-5 carinae: dorsal carinae on segments II to IV with at least one posterior spinoid granule strongly developed. Subaculear tooth weak to vestigial. Dentate margins of pedipalp-chela fixed and movable fingers composed of 11 to 13 oblique rows of granules. Pectines with 18 to 20 teeth in males, 15 to 17 in females; basal middle lamellae of female pectines dilated and with an oval shape. See Lourenço & Goodman (2006) for a detailed redescription of this species.

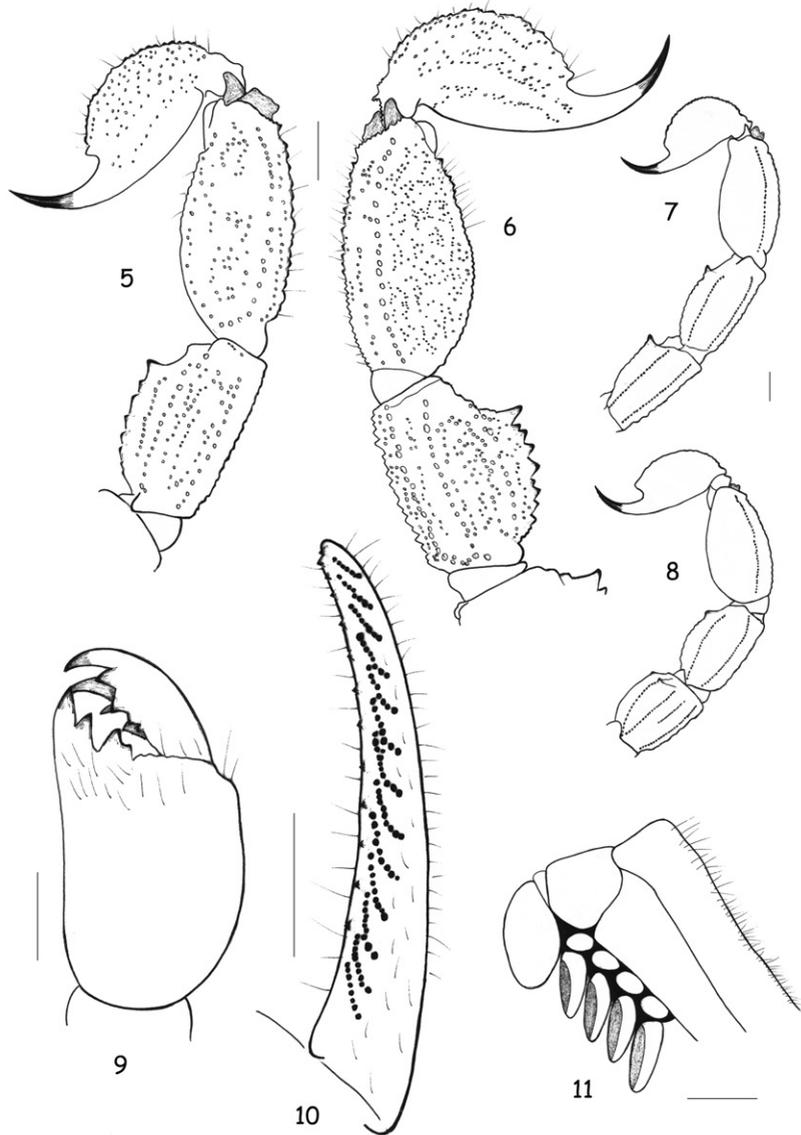
DISTRIBUTION. Given that many of the older specimens and publications that refer individuals to this taxon are doubtful, without a detailed review of existing material it is difficult to accurately summarize its distribution. Based on verified specimens the following localities are known from eastern rain forest belt (south to north): Parc National de Ranomafana (Fianarantsoa), Kianjavato (Fianarantsoa), Réserve Spéciale de Périnet (forêt d'Analamazaotra), "Tananarive region", Masoala Peninsula, Massif d'Anjanaharibe-Sud, Massif de Marojejy [=Parc National de Marojejy], Baie d'Antongil, Massif de Manongarivo, and Nosy Be (Réserve Spéciale de Lokobe).

ECOLOGY. This species appears to be limited to humid forest formations (Fage 1929, Lourenço & Goodman 2006) and includes zones such as the Masoala Peninsula, which is one of the wettest zone on the island. A total annual rainfall exceeding 6m has been reported for Masoala Peninsula (Thorstrom *et al.* 1997), but data were only collected over a period of some years, spanning some years with active cyclones, while means for other stations has been calculated over 30 years (Cornet 1974). This species' elevation distribution spans the gamut from lowland forests to montane zones.

NEW MATERIAL STUDIED: Madagascar, Nosy Be (Réserve Spéciale de Lokobe), Sept. 2001 (local people to W. Lourenço); 3 males (ZMH), 2 males (MNHN).

Grosphus hirtus Kraepelin, 1900

Scorpions of medium size, ranging from 30 to 50 mm in total length. General coloration yellowish to sometimes reddish-yellow with variegated brownish spots over the body and appendages. Metasomal segments I to V reddish-yellow; all segments with variegated dark pigmentation. Segment I wider than long; segments II to V longer than wide; carinae strongly marked and with 10-10-10-8-5 carinae: dorsal carinae on segments II to IV with one posterior spinoid granule strongly developed. Subaculear tooth vestigial.



Figs 5-8. Metasomal segments and telson, lateral aspect: **5-6.** *Grophus voahangyae* sp. n., male holotype and female paratype. **7-8.** *G. madagascariensis* Gervais and *G. hirtus* Kraepelin (males). **9-11.** *G. voahangyae* sp. n., male holotype and female paratype. **9.** Chelicera (male). **10.** Cutting edge of movable finger, showing rows of granules (male). **11.** Proximal aspect of pecten, showing basal middle lamella (female). Scale bars = 1 mm.

Dentate margins of pedipalp-chela fixed and movable fingers composed of 11 to 12 oblique rows of granules. Pectines with 18 to 19 teeth in males, 17 to 18 in females; basal middle lamellae of female pectines dilated and with an oval to semi-square shape. See Lourenço et al. (2007) for a detailed redescription of this taxon.

Holotype female reexamined. Madagascar, Makaraingo, 76-98 (D. Escoffre), MNHN-RS-1545. The specimen shows 17-17 teeth on pectines and 12-13 rows of granules on fixed and movable fingers of pedipalp chela.

DISTRIBUTION. A portion of the published records of *G. hirtus* probably represent misidentifications and in order to properly delineate this species distribution a review of available material is needed (Lourenço et al. 2009). Confirmed localities for *G. hirtus* includes dry forest sites: PN de Bemaraha, PN de Namoroka, Ambilobe, PN d'Ankarafantsika, Ankoririka (a locality within PN d'Ankarafantsika), Anabohizo (= Anabohazo, Antsiranana), PN de la Montagne d'Ambre, Diego-Suarez region, Îlot Baie de Diego-Suarez, and Forêt d'Ampondrabe (Antsiranana).

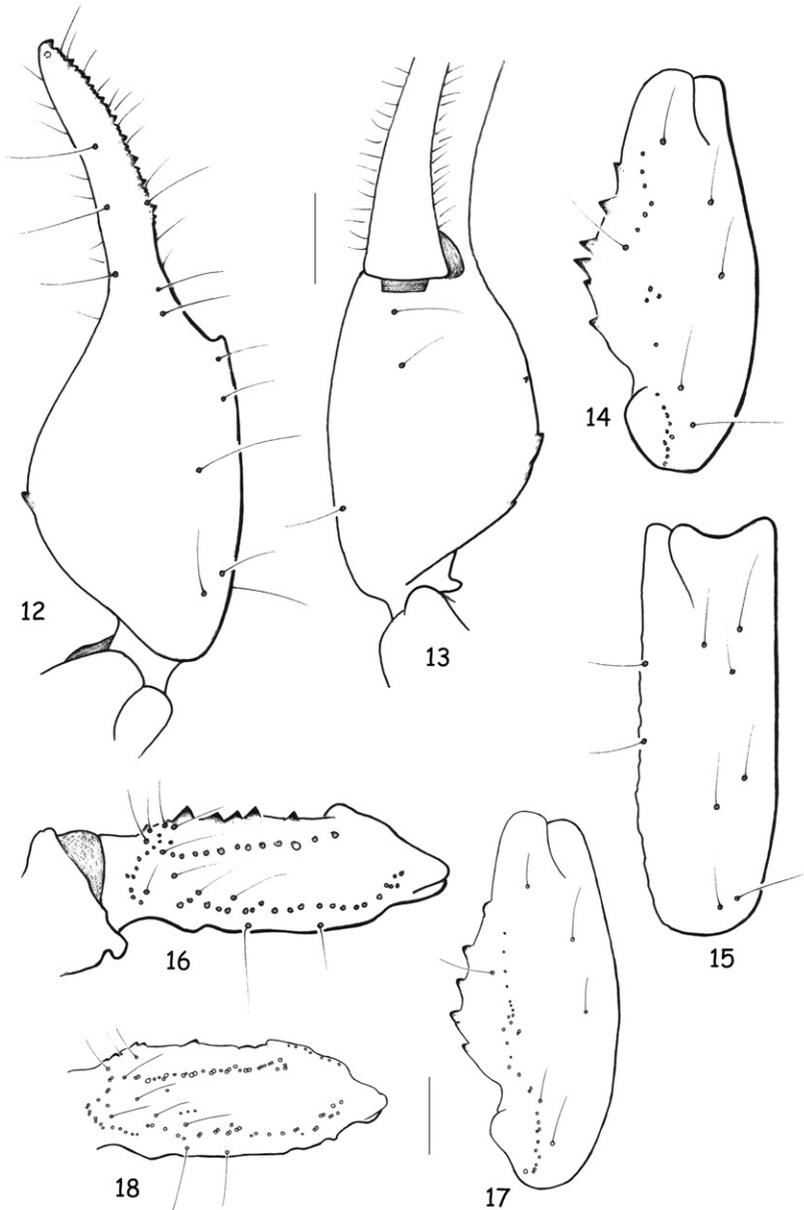
ECOLOGY. *Grosphus hirtus* is most frequently found in dry deciduous forest formations (Fage 1929, Lourenço & Goodman 2006, Lourenço et al. 2009), which in many cases are on sandy substrates.

NEW MATERIAL STUDIED: Madagascar, P. N. Bemaraha, Oct. 1972 (J.-M. Betsch); 5 males, 1 female (ZMH), 6 males, (MNHN).

Grosphus hirtus garciai Lourenço, 2001

Scorpions of small to moderate size, ranging from 28 to 32 mm in total length. General coloration yellowish to reddish-yellow with variegated brownish spots over the body and appendages. Metasomal segments I to V reddish-yellow; all segments with variegated brownish pigmentation. Segments I with the length similar to the wide; segments II to V longer than wide; carinae moderately marked and with 10-10-8-8-5 carinae: dorsal carinae on segments I to IV with one moderately pronounced posterior spinoid granule. Subaculear tooth weakly pronounced. Dentate margins of pedipalp-chela fixed and movable fingers composed of 11 to 13 oblique rows of granules. Pectines with 18 to 20 teeth in males, 16 to 17 in females; basal middle lamellae of female pectines dilated and with an oval to semi-square shape. For the original description of this species see Lourenço (2001).

Grosphus garciai was originally described, as a valid species, based on specimens collected in the Station Forestière d'Ampijoroa, part of the ex. Réserve Naturelle Intégrale d'Ankarafantsika, which is now a Parc National, where *G. hirtus* was also subsequently confirmed to occur (Lourenço & Goodman 2006). Based on new material, it is clear that many morphological characteristics are identical between *G. hirtus* and *G. hirtus garciai*. These two taxa seem to differ only by size - the former being larger than the latter. For this reason, it would appear that *G. hirtus garciai* is a local isolated population of *G. hirtus* and for this reason, it was demoted to the level of subspecies, *G. hirtus garciai* (Lourenço & Goodman 2006).



Figs 12-18. *Grophus voahangyae* sp. n., male holotype (12-16) and female paratype (17-18). Trichobothrial pattern. **12-13.** Chela dorso-external and ventral aspects. **14-15.** Patella, dorsal and external aspects. **16.** Femur, dorsal aspect. **17-18.** Idem female. Scale bars = 1 mm.

DISTRIBUTION. Only known from the type locality, Boeny Region, ex-Province de Mahajanga, Parc National d'Ankarafantsika, Station Forestière d'Ampijoroa, 16°18'45.2"S, 46°48'54.2"E.

ECOLOGY. *Grosphus hirtus garciai* has only been recorded in the dry deciduous forest formations on sandy substrates within the Parc National d'Ankarafantsika. The park lies in the Mahajanga sedimentary basin. The locality within the PN lies on Cretaceous marl and clay. Here annual precipitation ranges from 1000 to 1500 mm, most of which falls between November and April (Nicoll & Langrand 1989). January experiences the greatest rainfall, with slightly less than 50% of the annual total. A very pronounced dry and cool period occurs between May and September. During this latter period, little to no rain falls and the forest suffers from negative hydrological balance. Monthly mean temperatures across the year at Ankarafantsika range from 17° to 35° C, and the annual average temperature is 26°C.

Grosphus voahangyae sp. n. (Figs 1-18)

TYPE MATERIAL: Madagascar, ex-Province of Toamasina, Region of Alaotra-Mangoro, District of Moramanga, Torotorofotsy Forest (dense humid forest), some specimens covered with mud, 1170 m, Nov. 1974 (J.-M. Betsch –RCP-225): 1 male holotype, 5 male, 2 female paratypes (MNHN).

Other paratypes. Madagascar: ex-Province of Toamasina, Region of Alaotra-Mangoro, District of Moramanga, Analamay Forest, 10 km E of Ambohimanarivo Village, Dense humid forest, 15-31 Jan. 2009 (V. Soarimalala). (18°47'55.4"S-48°19'23.6"E), 1106 m [VS1634]: 2 males, covered with mud (FMNH). (18°47'36.1"S-48°20'37"E), 1105 m [VS1659]: 8 males (FMNH). (18°48'29.4"S-48°20'13.8"E), 1060 m [VS1675]: 4 males, 2 females (FMNH). (18°48'20.8"S-48°21'38.1"E), 1006 m [VS1704]: 4 males, 1 female (FMNH). (18°49'25.9"S-48°20'18"E), 1045 m [VS1739]: 1 female (FMNH). (18°49'25.9"S-48°20'18"E), 1045 m [VS1740]: 8 males, 5 females (ZMH).

ETYMOLOGY: Name honors Voahangy Soarimalala of the University of Antananarivo, for her intensive efforts in the field and for having collected numerous specimens of the new species.

DIAGNOSIS based on male holotype and paratypes. Scorpions of medium size, ranging from 38 to 40 mm in total length. General coloration yellowish-brown to dark brown with variegated brownish to blackish spots over the body and appendages. Metasomal segments I to V reddish-brown; segments IV and V slightly darker; all segments with variegated dark pigmentation. Segment I wider than long in male and female; segments II to V longer than wide; segments I to V with 10-10-10-8-5 strongly marked carinae: dorsal carinae on segments II to IV with several posterior spinoid granules strongly developed, better marked in females. Vesicle with a granulation strongly marked; subaculear tooth weak to vestigial in males and females. Dentate margins of pedipalp-chela fixed and movable fingers composed of 12 to 13 oblique rows of granules. Pectines with 15 to 19 teeth in males, 14 to 16 in females; basal middle lamellae of female pectines dilated and with an elongate oval shape.

General morphological characters indicate that *Grosphus voahangyae* sp. n. is close to the *G. madagascariensis* / *G. hirtus* group, and in particular of *G. hirtus*, but it can be readily distinguished from this last species by the following characters: (i) a darker overall coloration of the body and appendages; legs globally dark, almost blackish, (ii) dorsal carinae on metasomal segments II to IV with 4 to 6 strongly developed spinoid granules, whereas in *G. hirtus* only one spinoid granule is observed, (iii) basal middle lamella on females oval in shape but more elongated than in *G. hirtus*.

DESCRIPTION based on male holotype and paratypes. Measurements in Table 1.

General coloration yellowish-brown to dark-brown. Carapace and tergites brownish; eyes surrounded by black pigment. Metasoma: all segments reddish-brown to dark brown, with segments IV and V slightly darker; all segments with variegated dark pigmentation; carinae blackish-brown. Telson reddish to dark red; aculeus with reddish-yellow base and reddish-brown tip. Venter: coxapophysis and sternum yellowish; genital operculum and pectines pale yellow; sternites greenish-brown. Chelicerae reddish-yellow with dark variegated pigmentation; fingers reddish-brown with the teeth reddish. Pedipalps reddish-yellow to reddish-brown with variegated spots; legs reddish-yellow, marked with blackish-brown spots.

MORPHOLOGY: Carapace strongly granular, better marked in females; anterior margin with a discrete median concavity. All carinae moderate to weak; furrows moderately developed. Median ocular tubercle anterior to the centre of the carapace; median eyes separated by one ocular diameter. Three pairs of lateral eyes; the first pair smaller than the other two. Sternum between sub-triangular and sub-pentagonal in shape. Mesosoma: tergites with minute but intense granulation. Median carina weakly to moderately developed in all tergites. Tergite VII pentacarinata. Venter: genital operculum consisting of two semi-triangular plates. Pectines: pectinal tooth count 17-17 in male holotype (see Table II for variation); basal middle lamella not dilated in male, strongly dilated in female with an elongated oval-shape. Sternites smooth, with weakly elongated semi-oval stigmata. Metasoma: segment I wider than long; segments II to V longer than wide; segments I to III with 10 carinae, segment IV with 8 carinae, segment V with five carinae; all carinae strongly marked. Dorsal carinae on segments II to IV with 4 to 6 spinoid granules strongly developed, better marked in females. Intercarinal spaces strongly granular. Telson strongly granular with granules over latero-ventral and ventral surfaces; its dorsal surface smooth; aculeus moderately curved and shorter than the vesicle; subaculear tooth weak to vestigial. Cheliceral dentition characteristic of the family Buthidae (Vachon, 1963); two distinct small basal teeth present on the movable finger; ventral aspect of both fingers and of manus with dense, long setae. Pedipalps: femur pentacarinata; patella with dorsointernal and ventrointernal carinae and with several spinoid granules on the internal face; chela almost smooth, with isolated granules on the internal face. Fixed and movable fingers with

Table 1. Comparative morphometric values (in mm) of the male and female of *Grosphus hirtus* Kraepelin from Tsingy de Bemaraha and male holotype and a female paratype of *G. voahangyae* sp. n.

	<i>G. hirtus</i>		<i>G. voahangyae</i> sp. n.	
	M	F	M	F
Total length	35.3	35.5	39.8	39.4
Carapace:				
- length	4.1	4.3	4.5	4.5
- anterior width	3.1	3.3	3.1	3.3
- posterior width	4.9	5.3	5.0	5.3
Mesosoma length	9.8	9.6	11.4	11.9
Metasomal segment I:				
-length	2.4	2.4	2.6	2.6
-width	2.8	2.9	2.8	3.0
Metasomal segment II:				
-length	2.6	2.8	3.2	2.9
-width	2.4	2.7	2.6	2.8
Metasomal segment III:				
-length	3.1	3.2	3.6	3.3
-width	2.5	2.7	2.6	2.7
Metasomal segment IV:				
-length	3.8	3.7	4.2	3.9
-width	2.6	2.8	2.6	2.6
Metasomal segment V:				
- length	4.8	4.6	5.0	4.8
- width	2.6	2.5	2.4	2.6
- depth	2.4	2.4	2.2	2.3
Telson length	4.7	4.9	5.3	5.5
Vesicle:				
- width	2.2	2.2	2.2	2.2
- depth	1.9	2.0	2.0	2.1
Pedipalp:				
- Femur length	3.7	3.5	3.8	3.7
- Femur width	1.2	1.3	1.2	1.3
- Patella length	4.4	4.3	4.6	4.6
- Patella width	1.8	1.9	1.9	2.0
- Chela length	7.5	7.0	7.5	7.1
- Chela width	2.3	1.8	2.3	1.9
- Chela depth	2.1	1.6	2.1	1.8
Movable finger:				
- length	4.2	4.4	4.1	4.2

12-13 oblique rows of granules. Trichobothriotaxy; orthobothriotaxy $A-\alpha$ (alpha) (Vachon 1974, 1975). Legs: tarsus with two series of small setae ventrally and numerous other thin setae. Tibial spurs present on legs III and IV; pedal spurs present on legs I to IV; all spurs strong.

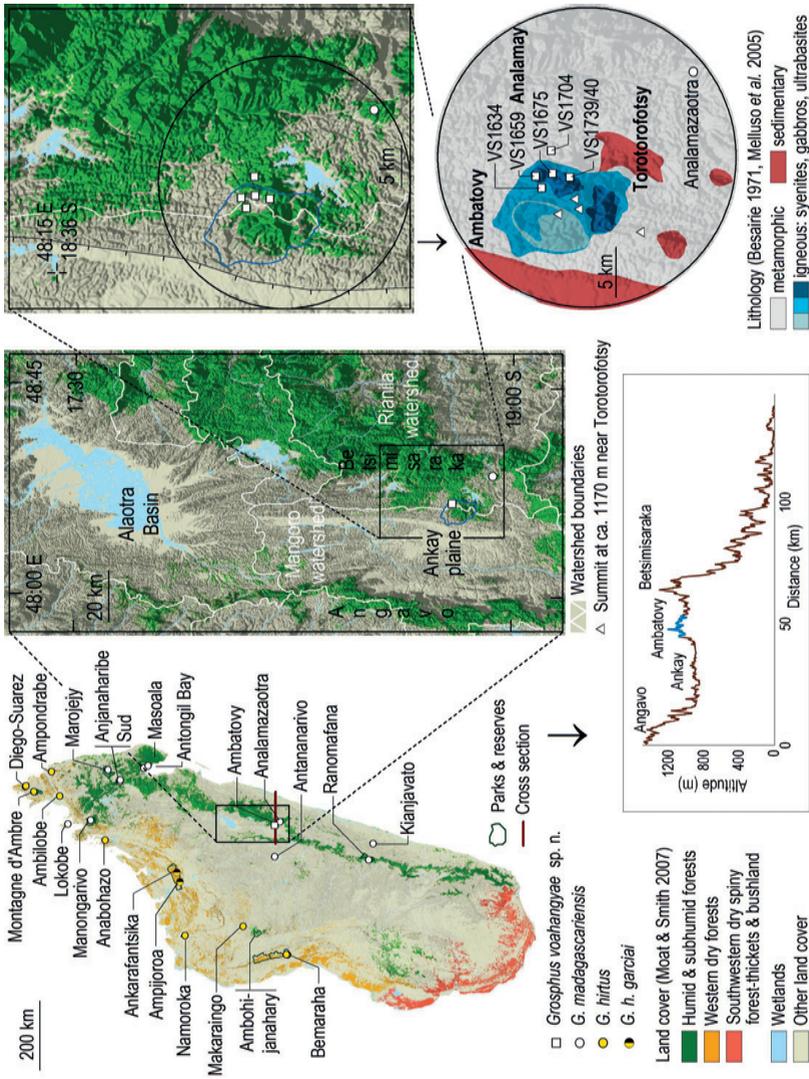


Fig. 19 (map). Verified collection localities of *Grosphus madagascariensis* and *G. hirtus*, according to land cover (left). Distribution of *G. voahangyae* sp. n. in Ambatovy, to the east of the fault bordering the Alaotra-Ankay rift valley, and in the rain shadow of the Betsimisaraka mountains belt (centre and top right). Cross section from the dividing line between western and eastern watersheds towards the Indian Ocean through Ambatovy (bottom centre) illustrates the position of Ambatovy in the rainshadow of Betsimisaraka mountains to the east, and the Alaotra-Ankay rift valley to the west. Lithology of Ambatovy and collection localities of *G. voahangyae* sp. n. nested within the mining site (bottom right).

Table 2. Variation of the number of pectinal teeth of *Grosphus voahangyae* sp. n. (NTP - number of teeth in each pecten)

NTP	Male pectines	Female pectines
13	-	2
14	-	12
15	1	11
16	17	1
17	29	-
18	11	-
19	2	-

Ecological aspects

Grosphus voahangyae sp. n. (from Analamay) was obtained in Ambatovy-Analamay forest situated in the central eastern portion of Madagascar and to the northeast of Moramanga. The type of vegetation at this site, classified as 'Humid Forest' (Moat & Smith 2007), and at about 1000 m altitude, spans a large latitudinal swath band of the island. The soil substrates in Ambatovy-Analamay are largely igneous in origin with low concentrations of silica and high concentrations of magnesium, nickel, and iron (Melluso *et al.* 2005).

Among the specimens collected with the use of pitfalls in Analamay, several were covered with mud, suggesting a possible fossorial behaviour. This suggestion was in part rejected by the collectors, who argued that the pitfalls could simply be filled with sediment during the rainy season and the collected specimens were dirty. Nevertheless among the specimens collected by J.-M. Betsch in Torotorofotsy Forest, and in this case using a 'rocking-rolled' method, again a number of specimens were covered with mud. This seems to confirm a possible fossorial behaviour of the new species.

Biogeographic considerations

Grosphus madagascariensis and *G. hirtus* have a wide distribution in Madagascar (Fig. 19; map, left). *G. madagascariensis* is distributed in the humid and sub-humid forests, including in the Special Reserve of Manongarivo in the northwestern Sambirano region. It is replaced in the Quaternary volcanic Montagne d'Ambre covered with humid forest in the far north by *G. hirtus* (Moat & Smith 2007, Fig. 19; map left). *G. hirtus* occurs in the western dry forests, with a disjunct distribution; it has not been reported in the subhumid Sambirano in the northwest, but occurs north and south of the Sambirano region. In the extreme north of the island, *G. hirtus* is encountered in the dry forest and the humid forest (Fig. 19; map, left).

Grosphus voahangyae sp. n. is only known from the Ambatovy-Analamay humid forest. The type locality 'Torotorofotsy forest 1170 m' is certainly from the same mountain given that Ambatovy is the only locality in the vicinity of the Torotorofotsy marshland reaching such altitudes (Fig. 19; map). Ambatovy mountain straddles the Mangoro and Rianila watersheds, along the southeastern border of the Alaotra-Ankay rift valley graben (Fig. 19; map).

centre). The Alaotra-Ankay rift valley is the second most seismically active region in Madagascar, an extension of the East African rift system (Kusky *et al.* 2007, 2010; Raharimahefa *et al.* 2013). The Ankay sedimentary valley is shouldered to the west by ca. 500 m high escarpments, the Angavo shear zone. To the east, the basin is bordered by steep mountains forming the Betsimisaraka mountain belt (Kusky *et al.* 2010). The Réserve Spéciale d'Analamazaotra, where *G. madagascariensis* has been collected, is part of these Betsimisaraka mountains (Fig. 19; map, centre).

The collection localities of *G. voahangyae* sp. n. are at 16–19 km in the northwest of Analamazaotra, at similar elevations. Recent biological inventories in the same area have not revealed any micro-endemic vertebrate species (Goodman & Mass 2010), but the botanical inventory has shown that Ambatovy has the most species-rich and the highest family diversity for Madagascar, with at least 196 species of plants of concern and threatened by the mining activity (Phillipson *et al.* 2010).

Ambatovy is located along an active fault bordering the Alaotra-Ankay rift valley, in the rain shadow of the Betsimisaraka mountains. A stretch of humid forests at medium altitude connects the Betsimisaraka mountains and Ambatovy, in a leeward position behind the first 'escarpment' (Fig. 19; map, centre). The parent tributary of the Mangoro river is draining the Alaotra-Ankay rift valley in a north-south direction to the confluence with its main tributary Onive descending from Ankaratra, the third highest mountain in Madagascar. After the confluence, the Mangoro is running in the typical direction for eastern rivers in Madagascar, i.e., west to east towards the Indian Ocean. The Mangoro watershed is not within a center of endemism sensu Wilmé *et al.* (2006, 2012). The subwatershed with the parent Mangoro river in the Alaotra-Ankay rift valley does not have any high elevation, and could therefore be part of the Analanjirifo center of endemism, together with the Rianila watershed (Wilmé *et al.* 2012). To consider the peculiar case of the distribution of *Grosphus voahangyae* sp. n., we propose to consider the Ambatovy landscape within the Eco-Geo-Clim model proposed by Mercier & Wilmé (2013) to understand this case of micro-endemism.

Given its peculiar location, Ambatovy receives less orographic rainfall than the windward Betsimisaraka mountains (Fig. 19; map, centre). Ambatovy lies on a medium altitude ridge between two watersheds, which is also negatively affecting its local hydrological balance (Mercier & Wilmé 2013). When considering the drier phases of the Plio-Quaternary paleoclimate oscillations, the hydrological balance in Ambatovy must have experienced pronounced deficit, and the forest taxa certainly receded. *G. voahangyae* sp. n. may have been isolated in the Ambatovy mountain over several such paleoclimate oscillations, surviving in this unique environment due to its presumed fossorial habits. Such a scenario to explain a micro-endemic species has also been documented in the northern part of the Alaotra-Ankay rift valley, with a lemur species, *Hapalemur alaotrensis* confined to Lake Alaotra, and separated from its sister species *Hapalemur griseus* located in the humid forests to the east (Waeber *et al.*, in press).

Conservation

Over the last million years of paleoclimate oscillations and seismically activities, a unique scorpion has been isolated in Ambatovy's landscape; the only location where *G. voahangyae* has been found to date. However, Ambatovy is renowned for hosting one of the world largest nickel mining operations, with an annual production capacity of 60,000 tons of nickel and 5,600 tons of cobalt (Waeber 2012). Ambatovy's underlying lithology is of young Upper Cretaceous intrusion of syenites, gabbros, and ultrabasites, surrounded by much older metamorphic types of rocks (Melluso *et al.* 2005; Fig. 19; map, bottom right).

Conclusion

The eastern humid forests of Madagascar have shown several cases of micro-endemism, but *Grosphus voahangyae* sp. n. is one of the extreme case with a distribution limited to one mountain, Ambatovy. The case of this newly described but likely extinct scorpion species illustrates the need to carefully address the landscapes attributes when trying to understand a species range. This is especially crucial when designing biodiversity offsettings for extractive industries. The mining activity per se, concentrates on the ultrabasites, but the entire mountain landscape will finally be affected. *Grosphus voahangyae* might as well be a new recently extinct species, and more so because the biodiversity offsetting proposed by the mining company is located at some 70 km in Ankerana (Waeber 2012).

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