ARTICLE

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Additions to the geographical distribution of the Malagasy family Microcharmidae Lourenço 1996 (Scorpiones: Buthoidea) and description of three new species of *Microcharmus* Lourenço 1995

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ABSTRACT

A more up to date biogeographic analysis of the patterns of distribution presented by the scorpions of the family Microcharmidae Lourenço 1996 are presented. This family is revalidated here based on numerous morphological characters. This Malagasy group of scorpions is represented by two genera, *Microcharmus* Lourenço 1995 and *Neoprotobuthus* Lourenço 2000 both endemic to the Island. The family Microcharmidae seems to be restricted to dry and wet forests formations in the northern and northwestern portions of the island. Here we describe three species new to science: *Microcharmus andrei* sp. n., *Microcharmus antongil* sp. n. and *Microcharmus djangoa* sp. n. The distribution of these new species seems to be restricted to the northern range of Madagascar, in habitats ranging from dry to wet forests, confirming therefore the patterns previously observed.

RÉSUMÉ

Une analyse biogéographique à jour portant sur les schémas de distribution des scorpions de la famille des Microcharmidae Lourenço 1996 est présentée. La famille est ici revalidée sur la base de nombreux caractères morphologiques. Ce groupe de scorpions de Madagascar est représenté par deux genres, *Microcharmus* Lourenço 1995 et *Neoprotobuthus* Lourenço 2000 tous deux endémiques de l'île. La famille des Microcharmidae semble avoir une distribution limitée aux formations forestières sèches et humides des parties nord et nord-ouest de l'île. Ici, nous décrivons trois espèces nouvelles pour la science : *Microcharmus andrei* sp. n., *Microcharmus antongil* sp. n. et *Microcharmus djangoa* sp. n. La distribution de ces trois nouvelles espèces semble limitée à la partie septentrionale de Madagascar, dans des habitats allant des forêts sèches à humides, ce qui confirme ainsi les schémas préalablement observés.

INTRODUCTION

As already outlined in previous publications humiculous scorpions living in organic soil are rare in most regions of the world (Vachon 1974, Lamoral 1976, Lourenço 1998, 2003, 2004, 2005, Lourenço et al. 2006, Rossi and Lourenço 2015). In Madagascar, the most characteristic soil scorpions belong to the family Microcharmidae Lourenço which is represented by two genera *Microcharmus* Lourenço and *Neoprotobuthus* Lourenço. The genus *Microcharmus* was described by Lourenço (1995), based on one new species *Microcharmus cloudsleythompsoni* Lourenço having as holotype one female specimen collected by the Professor Jacques Millot in the region of Zangoa in the northwest of Madagascar in 1947 (Lourenço 1995). It is unclear however, how this specimen was collected or obtained, since no specific information was provided in the labels. No matter, in this same year of 1947 J. Millot collected a second specimen on the Island of Nosy Be which was described as *Microcharmus jussarae* Lourenço 1996 (Lourenço 1996a). This species was apparently collected under a piece of bark found in the soil. Coincidently two other species were described also in 1996, *Microcharmus hauseri* Lourenço and *Microcharmus sabineae* Lourenço, respectively from Nosy Be and the Marojejy Mountain. In both cases the specimens were obtained with the use of extractions methods of the Berlese type (Lourenço 1996a,b).

In the following years, two other genera were described in the family Microcharmidae, *Neoprotobuthus* Lourenço 2000 and *Ankaranocharmus* Lourenço 2004 (Lourenço 2000, 2004). Subse-

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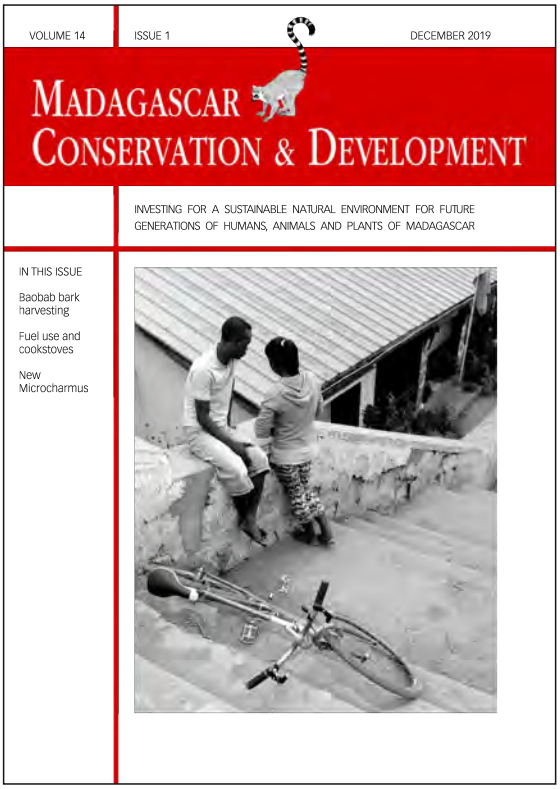

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quently, the validity of the genus *Ankaranocharmus* was questioned and this genus was placed in the synonymy of *Microcharmus* (Lourenço et al. 2006).

After the description of the first species in the family Microcharmidae in 1995 (Lourenço 1995), the slow pace of new descriptions was largely associated with the difficulties of collecting. In fact, these scorpions are difficult to collect by ordinary methods as rock-rolling, pit-fall traps and even the use of UV light mainly due to their minute sizes, apparently low vagilities and cryptic behaviors. Finally, thanks to precise systematic invertebrate surveys at several sites in Madagascar mainly by B. L. Fisher and colleagues of the California Academy of Sciences, but also a team of Malagasy field biologists, a first global synthesis on this scorpion group was possible (Lourenço et al. 2006). Until this main revision of the group, seven species were recognized in the genus *Microcharmus*, while *Neoprotobuthus* was monotypic. With the new descriptions the number of species and subspecies of *Microcharmus* was raised to 15.

Since this main revision, almost no new element was added to the family Microcharmidae. The single exception being the description of a new species *Microcharmus henderickxi* Lourenço 2009 found however in Copal (Lourenço 2009).

In this paper three new species are described, and some biogeographical aspects are proposed for this family.

METHODS

Illustrations and measurements were produce using a Wild M5 stereo-microscope with a drawing tube and ocular micrometer (at 25 and 50x). Measurements follow Stahnke (1970) and are given in mm. Trichobothrial notations follow Vachon (1974, 1975), and morphological terminology mostly follows Vachon (1952), Hjelle (1990). Hemispermatophore terminology mostly follows Lamoral (1979). Specimens used in this taxonomic contribution are now deposited in the Muséum national d'Histoire naturelle, Paris, France (MNHN).

The characters color and pigmentation are the most conspicuous external ones in scorpions, especially amongst buthoids. These are largely used for in taxonomy of several groups of microbuthoids. 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 and Cloudsley-Thompson 1996). In the case of microbuthoid scorpions, color and pigments are very useful characters for species identification, as is the case for other scorpion genera such as *Ananteris* (Lourenço 1982) and *Tityobuthus* (Lourenço 1996a). In the present study, the diagnosis and descriptions of the different new taxa were largely based on precise patterns of pigmentation.

TAXONOMIC POSITION OF THE FAMILY MICROCHARMIDAE

Among the new genera described for the Malagasy fauna since 1995 (Lourenço 1995) *Microcharmus* appears as one of the most remarkable discoveries. Initially, this genus was placed in the family Buthidae, but soon after, and in view of some notable distinct characters, it was accommodated in a new subfamily Microcharminae (Lourenço 1996a). Subsequent new analysis led the subfamily to be raised to the familial rank (Lourenço 1998); this decision was supported by the discoveries of new taxa within the Microcharmidae and in particular a second genus *Neoprotobuthus* Lourenço (Lourenço 2000). Further data to support the position of this family was also provided by the analysis of several characters with the use of Scanning Electron Microscopy technics (SEM). Detailed results based on about ten characters were presented first by Lourenço (2002a) and again by Lourenço et al. (2006).

Subsequently some authors rejected the validity of the family Microcharmidae, but in many cases this divergence of opinion was not globally justified. In a publication treating on the comparative anatomy of the mesosomal organs of scorpions, Volschenk et al. (2008) reached to the conclusion that Microcharmidae presented the same characteristics of several other buthid genera. Consequently, they considered it as a synonym of Buthidae. To justify their opinion, these authors stated as follows: "Our observations on the ovariuterine anatomy also support mounting evidence that the genus *Microcharmus* Lourenço 1996, currently placed in a unique family, Microcharmidae Lourenço 1996, is a buthid (…) We observed the complex open form of the eight-celled ovariuterus in *M. pauliani ambre* and two buthids, *Babycurus jacksoni* (Pocock 1890) and *Lychas tricarinatus. Microcharmus* also lacks lateral lymphoid organs, which is another buthid characteristic. These anatomical characters support numerous external morphological characters (e.g. the presence of the type-A trichobothrial pattern on the pedipalps) otherwise unique to Buthidae, [from which Microcharmidae is separated principally on the basis of size and ecology] (Lourenço 2000b). The balance of evidence does not, in our opinion, warrant continued recognition of Microcharmidae, which renders Buthidae paraphyletic (E. S. Volschenk & L. Prendini, unpubl. data). We therefore propose the following new synonymy: Microcharmidae Lourenço 1996 = Buthidae C.L. Koch, 1837."

It seems obvious that this character taken from the type of ovariuterus found in Microcharmidae and Buthidae attests to the close relationships between these two families. In fact, from the beginning Lourenço (1998, 2000, 2002a, Lourenço et al. 2006) considered Microcharmidae within a buthoid group together with buthids. What, however is not acceptable is the fact that Volschenk et al. (2008) globally ignore all the characters used by Lourenço (2002a) and Lourenço et al. (2006) to justify the family Microcharmidae, stating that the family was based "principally on the basis of size and ecology" what is incorrect. In the publication by Volschenk et al. (2008), other unjustified contradictions can also be noticed. One peculiar example calls the attention: On page 667, the authors stated as follows: "Lourenço (2002) speculated that *Lisposoma* would possess well-developed diverticulae like other scorpionoid taxa, contrary to Stockwell (1989) and Prendini (2000)." This statement is not only incorrect, but can also be considered bizarre since in the article by Lourenço (2002b), or any other article even published by this author, the genus *Lisposoma* was never treated or discussed.

In conclusion, we revalidate the family Microcharmidae at present and the diagnostic characters already used in the previous diagnosis are listed again here below. For some characters,

especially those taken from the morphology of hemispermatophores, new observations were done for other species than those cited both by Lourenço (2002a) and Lourenço et al. (2006).

DIAGNOSIS FOR THE FAMILY MICROCHARMIDAE

Scorpions of small size, ranging from 8 to 18 mm in total length. Carapace: anterior margin with a weak concavity or straight; carinae and granulations generally very weak; furrows inconspicuous; median ocular tubercle distinctly located on the anterior third of the carapace; three pairs of lateral eyes (in one case only two pairs). Sternum pentagonal; one median carina moderate or sometimes weak in all tergites. Tergite VII pentacarinate. Pectines, generally moderate to small in size, although may be larger in some taxa; the distal extremity or distal tooth is always rounded (diagnostic character); basal middle lamellae of the pectines not dilated; fulcra absent. Images made with a scanning electron microscope (Lourenço 2002a; Lourenço et al. 2006) show that the peg-shaped sensillae of the pectines have a rounded structure (diagnostic character), somewhat bottle-shaped. Most buthid groups, by comparison, have very short peg-shaped sensillae with a spatula-shaped structure. Sternites with short, oval or semi-oval spiracles (diagnostic character); in only a few species are these completely oval to round. Metasoma: all segments show strongly marked carinae; in some species dorsal and latero-dorsal carinae of segments II to IV present one posterior spinoid granule. Telson with a very elongated pear-shaped structure, smooth with strong setation; aculeus short, weakly curved; subaculear tooth absent. Cheliceral dentition characteristic of buthoid; fixed finger with two well-marked basal teeth; movable finger with external distal tooth shorter than internal distal tooth, and two very weak and sometimes fused basal teeth. Internal face of pedipalp patella with two to six spinoid granules; fixed and movable fingers of pedipalp chela with six to seven almost linear rows of granules; two accessory granules present at the base of each row; extremity of fixed and movable fingers with one long and sharp denticle. Trichobothriotaxy; orthobothriotaxy A-alpha. Legs: tarsus with numerous fine ventrally-located median setae. Pedal spurs reduced in general; tibial spurs reduced to absent on leg III, and moderate to absent on leg IV. Hemispermatophore: Two basic types of spermatophores or hemispermatophores have been initially defined for scorpions (Hjelle 1990): flagelliform and lamelliform. The first one being typical of the buthids and the second type to all the other scorpion families. Stockwell (1989) defined a third type, fusiform, restricted to the family Chaerilidae. A distinct type was also described for the Pseudochactidae family (Prendini et al. 2006). The flagelliform type is defined by a rather long and thin trunk terminating in its distal portion by a long filament referred to as the flagellum. The few studies carried out on the structure of the microcharmid hemispermatophore (3-4 species examined) indicate that it is somewhat different from the typical flagelliform type. The trunk is somewhat elongated, but larger at its base; a truncal flexure is not clearly observed, and two structures, the small hook and the flagellum, appear to be absent from the distal portion; in fact the flagellum if present is clearly reduced (diagnostic character). However, the study of more species would be necessary to conclusively define this kind of spermatophore, but the preliminary results indicates that these are rather simple in microcharmids. The type presented by the species of this family could be the primitive form leading to the evolution of the different types.

TAXONOMY

Family Microcharmidae Lourenço 1996
Genus *Microcharmus*, Lourenço 1996

DESCRIPTION OF THREE NEW SPECIES

Microcharmus andrei sp. n. (Figures 1–6)
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<http://zoobank.org/NomenclaturalActs/C3920C03-C96C-45AE-8358-7CB5FCF11FF9>

Type Material: Madagascar, Mardutsara (= Mandritsara), Wet Forest, IX/1957 (J. Millot leg.), 1 male holotype, 1 male paratype. Types deposited in the Muséum, national d'Histoire naturelle, Paris, France.

Etymology: The specific name honors André Peyrieras (1927–2018) who strongly contributed to the natural sciences knowledge of Madagascar.

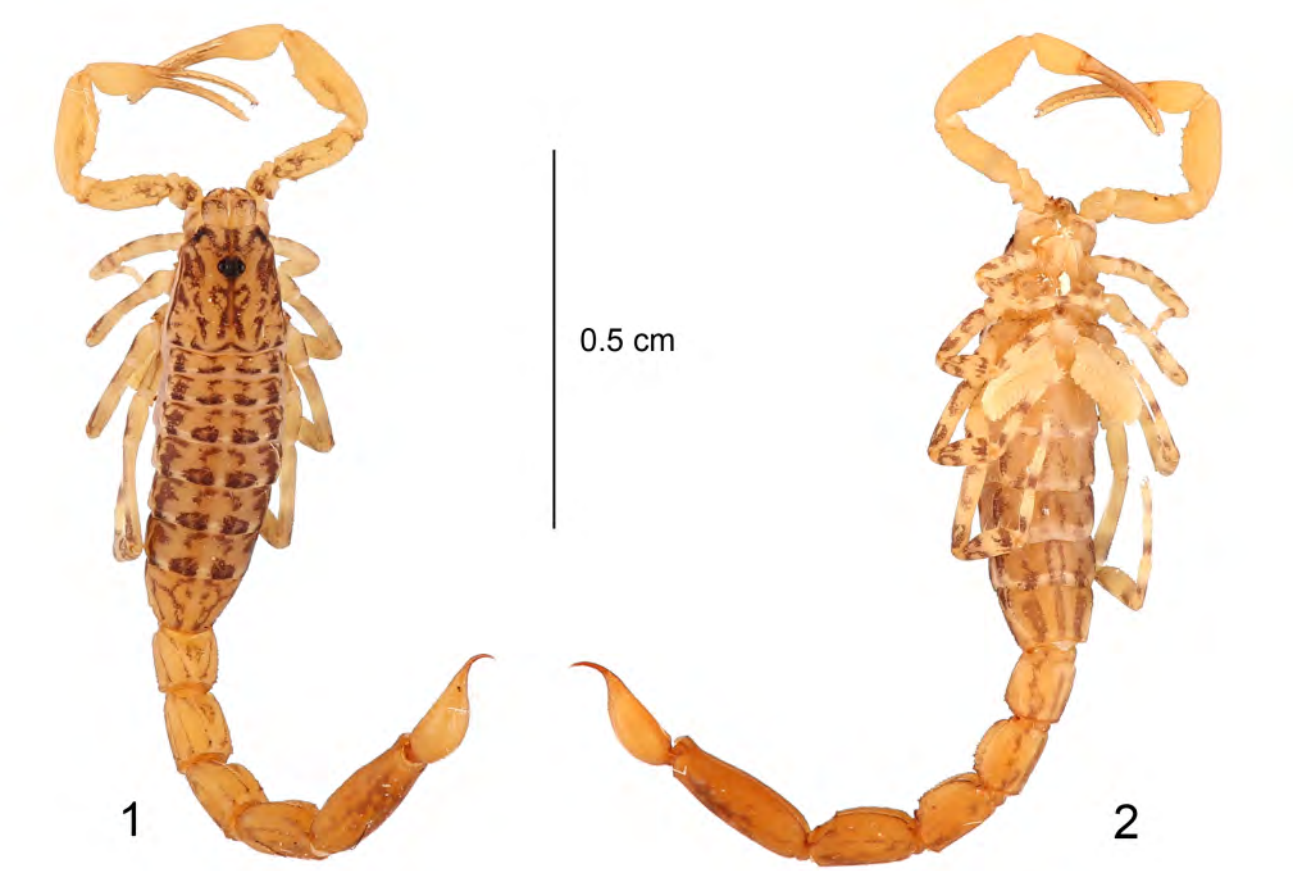
Diagnosis: Scorpions of moderate size when compared with most species of the genus *Microcharmus*, with 14.10 mm of total length for the male holotype (see morphometric values). General coloration yellow with variegated spots over body and appendages. Carinae and granulations moderately marked on body and appendages.

Relationships: The new species shows some affinities with *Microcharmus variegatus* Lourenço, Goodman and Fisher 2006 but can be distinguished from this last species by a much less intense pigmentation on the body and appendages. In particular (i) a ventral aspect much less spotted, (ii) pedipalps almost spotless with only the chela-fingers darker, (iii) chelicerae yellow but much more densely spotted than in *M. variegatus*.

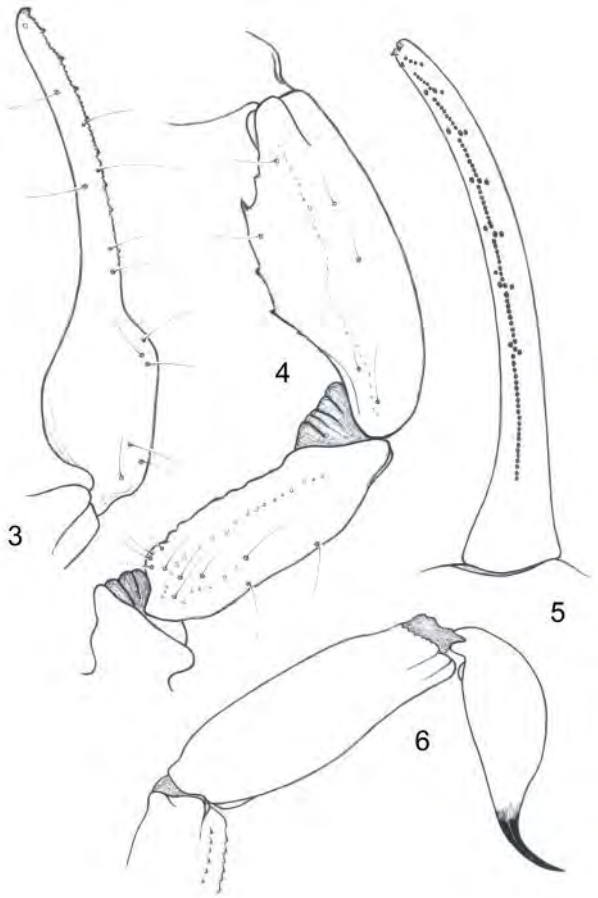
Description based on Male holotype and male paratype.

Coloration. Basically yellow with dark variegated spots over the body and appendages. Carapace, tergites, metasomal segments, and vesicle with variegated spots; pedipalp femur and patella inconspicuously spotted; chela hand yellow without spots; proximal two-thirds of fingers dark and the extremity yellow; chelicerae yellow with variegated spots on its entire surface; fingers and teeth yellow with some dark spots; venter with inconspicuous variegated spots on coxapophysis, sternum and genital operculum; spots better marked on sternites; legs more heavily spotted.

Morphology. Carapace with moderately marked granulation; anterior margin with a moderate concavity. Carinae weak; furrows inconspicuous. Median ocular tubercle located distinctly on the anterior third of the carapace; median eyes separated by approximately one ocular diameter. Three pairs of lateral eyes. Sternum pentagonal. Mesosoma: tergites with a thin granulation. Median carina moderate to weak in all tergites. Tergite VII pentacarinate. Venter: genital operculum divided longitudinally, each plate with a more or less triangular shape. Pectines moderate to small: pectinal tooth count 12-12 for both holotype and paratype; basal middle lamellae of the pectines not dilated; fulcra absent. Sternites with some minor granulations, almost smooth, and with small oval spiracles; VII slightly more granulated and with vestigial carinae. Metasoma: segments I to III with ten carinae, crenulate; segment IV with eight carinae and ventral carinae vestigial; intercarinal spa-



Figures 1–2. *Microcharmus andrei* sp. n. Male holotype. Habitus, dorsal and ventral aspects.



Figures 3–6. *Microcharmus andrei* sp. n. Male holotype. 3–4. Trichobothrial pattern. 3. Chela, dorso-external aspect. 4. Femur and patella, dorsal aspect. 5. Cutting edge of movable finger showing rows of granules. 6. Metasomal segment V and telson, lateral aspect.

ces weakly granular. Segment V rounded with 5 carinae. Telson with an elongated pear-shaped structure, smooth with moderate setation; aculeus short and weakly curved; subaculear tooth absent. Cheliceral dentition characteristic of buthoid (Vachon 1963); fixed finger with two strong basal teeth; movable finger with two very weak but fused basal teeth; ventral aspect of both finger and manus with dense, long setae. Pedipalps: femur pentacarinate; patella with vestigial carinae; internal face of patella with four to five spinoid granules; chela without carinae, smooth; all faces weakly granular to smooth. Fixed and movable fingers with seven almost linear rows of granules; two accessory granules present at the base of each row; extremity of fixed and movable fingers with one long and sharp denticle. Trichobothriotaxy; orthobothriotaxy A-alpha (Vachon 1974, 1975). Legs: tarsus with very numerous fine ventral median setae. Pedal spurs reduced; tibial spurs vestigial on legs III and weak on IV.

Morphometric measurements (in mm) of the male holotype.

Total length, 14.1. Carapace: length, 1.7; anterior width, 1.1; posterior width, 1.7. Mesosoma length, 3.8. Metasomal segments I: length, 0.9; width, 0.9. II: length, 1.1; width, 0.8. III: length, 1.2; width, 0.7. IV: length, 1.4; width, 0.7. V: length, 2.2; width, 0.7; depth, 0.8. Telson length, 1.8; vesicle: width, 0.6; depth, 0.5. Pedipalp: femur length, 1.3, width, 0.4; patella length, 1.5, width, 0.6; chela length, 2.2, width, 0.4, depth, 0.4; movable finger length, 1.6.

Distribution: Only known from the type locality.

Microcharmus antongil sp. n. (Figures 7–13)

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<http://zoobank.org/NomenclaturalActs/646F87DB-6083-48B1-A7FB-09C5011D150C>

Type Material: Madagascar, Baie d'Antongil, Tanjona-Masoala, NW Vinanivao, dense wet forest, XI/1969 (J.-M. Betsch), collected with Berlese, 1 female holotype. Type deposited in the Muséum national d'Histoire naturelle, Paris, France.

Etymology: The specific name is placed in apposition to the generic name and refers to the type locality of the new species.

Diagnosis: Scorpions of moderate size when compared with most species of the genus *Microcharmus*, with 15.8 mm in total length for the female holotype (see morphometric values). General coloration yellow to slightly reddish-yellow with variegated spots over the body and appendages. Carinae and granulations moderately marked on body and appendages. Anterior margin of carapace straight.

Relationships: The new species shows some affinities with *Microcharmus variegatus* Lourenço, Goodman and Fisher 2006 but can be distinguished from this last species by a quite distinct pattern of pigmentation. Both species show a more or less intense variegated pigmentation of the body and appendages but differ in the following aspects: (i) sternites and ventral aspect of metasoma much less spotted in the new species, (ii) coxapophysis darker in the new species, (iii) Anterior margin of carapace straight in the new species whereas in *M. variegatus* it shows a strong concavity, (iv) metasomal segments I-IV with 10 carinae.

Description based on female holotype

Coloration. Basically yellow to slightly reddish-yellow with dark variegated spots over the body and appendages. Carapace, tergites, metasomal segments, and vesicle with variegated dark spots, strongly marked on metasomal carinae; pedipalp femur and patella intensely marked with dark spots, except on the zones where trichobothria are inserted; chela hand yellow without minute spots; proximal two-thirds of fingers dark and the extremity yellowish; chelicerae yellow with dark spots on base of the fingers; fingers and teeth yellowish without spots; venter with variegated spots strongly marked on coxapophysis and sternum; sternites weakly spotted; legs heavily spotted.

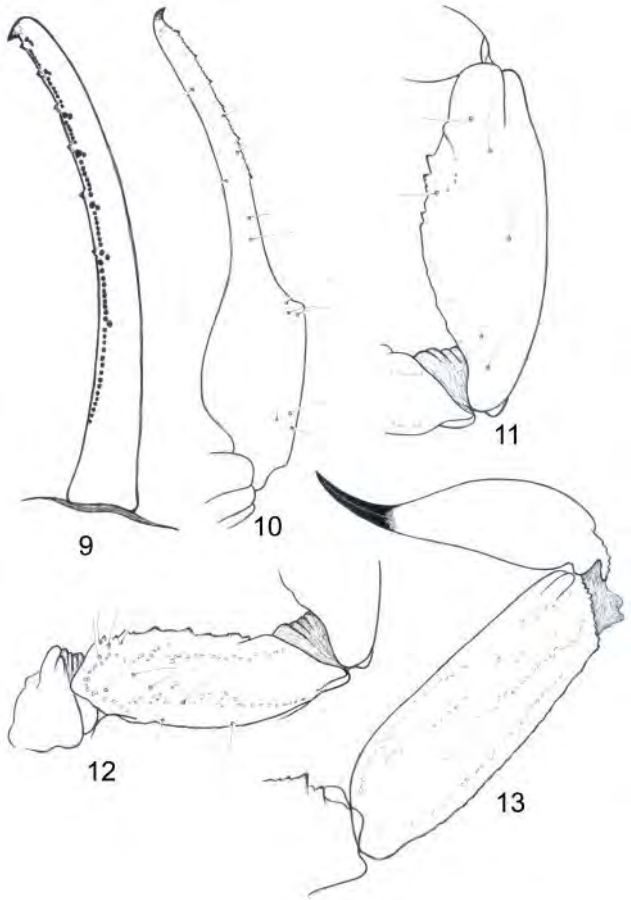
Morphology. Carapace with moderately marked granulation; anterior margin straight. Carinae weak; furrows inconspicuous. Median ocular tubercle located distinctly on the anterior third of the carapace; median eyes separated by one ocular diameter. Three pairs of lateral eyes. Sternum pentagonal. Mesosoma: tergites with a thin granulation. Median carina moderate to weak in all tergites. Tergite VII pentacarinate. Venter: genital operculum divided longitudinally, each plate having a semi-oval to semi-triangular shape. Pectines small: pectinal tooth count 7-8 for female holotype; basal middle lamellae of the pectines not dilated; fulcra absent. Sternites with some minute granulations, almost smooth, and with short oval spiracles; VII with vestigial carinae. Metasoma: segments I to IV with ten carinae, crenulate; intercarinal spaces weakly granular. Segment V rounded but strongly granular and with 5 carinae. Telson with a very elongated pear-shaped structure, smooth with moderate setation; aculeus short and very weakly curved; subaculear tooth absent. Cheliceral dentition characteristic of buthoid (Vachon 1963); fixed finger with two strong basal teeth; movable finger with two very weak but not fused basal teeth; ventral aspect of both finger and manus with dense, long setae. Pedipalps: femur pentacarinate; patella with vestigial carinae; internal face of patella with four to five spinoid granules; chela without carinae, smooth; all faces weakly granular to smooth. Fixed and movable fingers with seven almost linear rows of granules; two accessory granules present at the base of each row; extremity of fixed and movable fingers with one long and sharp denticle. Trichobothriotaxy; orthobothriotaxy A-alpha (Vachon 1974, 1975). Legs: tarsus with very numerous fine ventral median setae. Pedal spurs reduced; tibial spurs absent on leg III and weak on leg IV.

Morphometric measurements (in mm) of the female holotype

Total length, 15.8. Carapace: length, 2.1; anterior width, 1.3; posterior width, 2.2. Mesosoma length, 4.5. Metasomal segments I: length, 0.8; width, 1.2. II: length, 1.1; width, 1.1. III: length, 1.2; width, 1.0. IV: length, 1.4; width, 1.0. V: length, 2.5; width, 0.9; depth, 0.8. Telson length, 2.2; vesicle: width, 0.6; depth, 0.6. Pedipalp: femur length, 1.7, width, 0.6; patella length, 2.2, width, 0.7; chela length, 2.8, width, 0.6, depth, 0.6; movable finger length, 1.8.

Distribution: Only known from the type locality.

Figures 7–8. *Microcharmus antongil* sp. n. Female holotype. Habitus, dorsal and ventral aspects.



Figures 9–13. *Microcharmus antongil* sp. n. Female holotype. 9. Cutting edge of movable finger showing rows of granules. 10–12. Trichobothrial pattern. 10 Chela dorso-external aspect. 11. Patella, dorsal aspect. 12. Femur, dorsal aspect. 13. Metasomal segment V and telson, lateral aspect.

Microcharmus djangoa sp. n. (Figures 14–19)

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<http://zoobank.org/NomenclaturalActs/83BBA31B-FA5B-4FC8-9BB2-08E5ABD29BC9>

Type Material: Madagascar, Road between Djangoa and Maromandia, 3 km S of Djangoa, transition between wet forest and dry forest, IX/2001 (W. Lourenço), 1 female holotype. Type deposited in the Muséum national d'Histoire naturelle, Paris, France.

Etymology: The specific name is placed in apposition to the generic name and refers to the type locality of the new species.

Diagnosis: Scorpions of moderate size when compared with most species of the genus with 14.4 mm in total length for female holotype (see morphometric values). General coloration dark yellow, with moderately marked dark spots; spotting pattern less marked on pedipalps and ventral aspect of metasoma. Carinae and granulations moderately marked on body and appendages. Femur trichobothrium e1, distal in relation to trichobothrium d5.

Relationships: The new species shows some affinities with *Microcharmus maculatus* Lourenço, Goodman and Fisher 2006 but can be distinguished from this last species by a distinct pattern of pigmentation. Both species show a more or less intense variegated pigmentation of the body and appendages but differ in the following aspects: (i) sternites and ventral aspect of metasoma much less spotted in the new species, (ii) pedipalps less spotted in the new species, (iii), in the new species the femur trichobothrium e1, is distal in relation to trichobothrium d5 (iv) tibial spurs absent on leg III and moderate on leg IV.

Description based on female holotype

Coloration. Basically yellow with dark spots over the body and appendages; spots moderately marked on ventral aspect of metasomal segments and pedipalps; vesicle without spots. Carapace with dense variegated blackish spots; tergites with confluent spots; metasomal segments paler than carapace, yellowish with diffused spots. Venter weakly spotted, marbled on coxapophysis, sternum, genital operculum and sternites; pectines with only two minute diffused spots; chelicera yellow with variegated spots over almost the entire surface.

Morphology. Carapace with a weakly marked granulation; anterior margin with a moderate concavity. Carinae weak; furrows inconspicuous. Median ocular tubercle distinctly on the anterior third of the carapace; median eyes separated by less than one ocular diameter. Three pairs of lateral eyes. Sternum pentagonal. Mesosoma: tergites moderately to weakly granular. Median carina moderate to weak in all tergites. Tergite VII pentacarinate. Venter: genital operculum divided longitudinally, each plate more or less triangular in shape. Pectines moderately large: pectinal tooth count 11-11 in female holotype; basal middle lamellae of the pectines not dilated; fulcra absent. Sternites smooth with short oval spiracles; VII with a few granulations and vestigial carinae. Metasoma: segments I to III with ten carinae, crenulate; IV with eight carinae; intermediate carinae incomplete; ventral carinae vestigial on segment IV; intercarinal spaces weakly granular. Segment V rounded with five carinae. Telson with a very elongated pear-shaped structure, smooth with moderate setation; aculeus short, weakly curved; subaculear tooth absent. Cheliceral dentition characteristic of the buthoids (Vachon 1963); fixed finger with two moderate basal teeth; movable finger with two very weak and almost fused basal teeth; ventral aspect of both finger and manus with dense, long setae. Pedipalps: femur pentacarinate; patella with some vestigial carinae; internal face of patella with three to four weakly spinoid granules; chela smooth; all faces weakly granular to smooth. Fixed and movable fingers with seven almost linear rows of granules; two accessory granules present at the base of each row; extremity of fixed and movable fingers with one long and sharp denticle. Trichobothriotaxy; orthobothriotaxy A-alpha (Vachon 1974, 1975). Legs: tarsus with very numerous fine median setae ventrally. Pedal spurs reduced; tibial spurs absent on leg III and moderate on leg IV.

Morphometric measurements (in mm) of the female holotype

Total length, 14.4. Carapace: length, 1.8; anterior width, 1.2; posterior width, 2.0. Mesosoma length, 3.8. Metasomal segments I: length, 0.9; width, 1.1. II: length, 1.1; width, 1.0. III: length, 1.2; width, 0.9. IV: length, 1.4; width, 0.8. V: length, 2.3; width, 0.8; depth, 0.8. Telson length, 2.1; vesicle: width, 0.6; depth, 0.6. Pedipalp: femur length, 1.6, width, 0.5; patella length, 2.0, width, 0.8; chela length, 2.6, width, 0.5, depth, 0.5; movable finger length, 1.8.

Distribution: Only known from the type locality.

BIOGEOGRAPHY

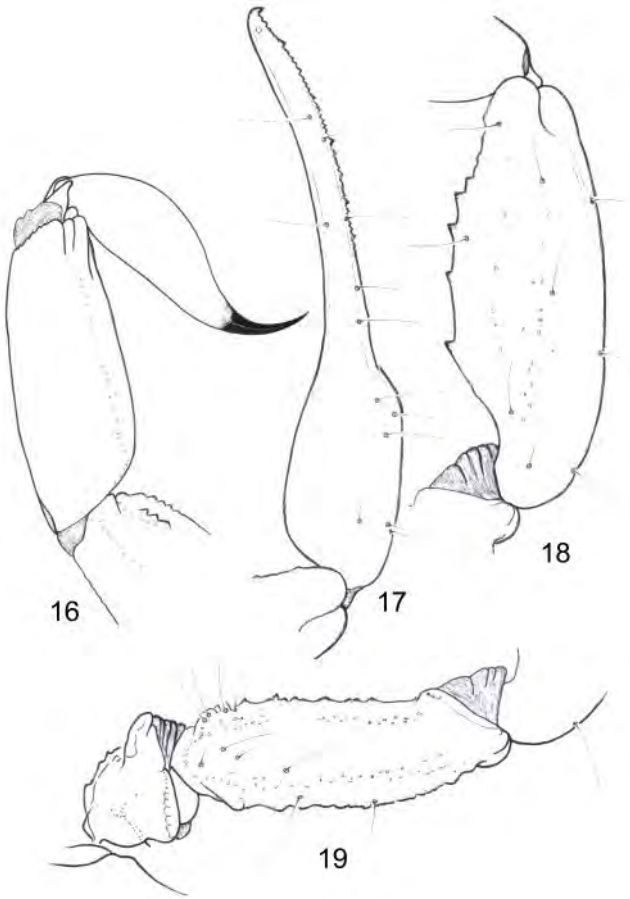
The three new species have been described from localities circumscribed in the known range of the genus *Microcharmus* (Figure 20).

Microcharmus djangoa sp. n. has been collected in a transitional subhumid forest in the Sambirano region. The Sambirano has experienced a monsoon regime with a significant increase in rainfall relatively recently, probably at the end of the Miocene or early Pliocene, about 5–4 million years ago (Wells 2007). The description of this new species brings the number of *Microcharmus* species in the Sambirano region to six. They are all distributed at low altitude over area of less than 150 km².

Microcharmus andrei sp. n. has been recorded from Mandritsara. Mandritsara is a town lying on patches of igneous rocks surrounded by metamorphic rocks. There are two types of vegetation encountered in the region, mainly western dry forests with some patches of humid forests encountered to the east of the city (Moat and Smith 2007). The label indicates a wet forest which could refer to the humid forest of the or the Réserve Spéciale du Tampoketsa d'Analamaitso some 60 km to the southwest of Mandritsara or to the humid forests of the Réserve Spéciale de Marotandrano lying at a similar distance from Mandritsara along a road. More patches of humid forests are also encountered to the northwest of Mandritsara along the Route nationale N. 32. The discovery of the species in this region is nevertheless interesting given that the genus was mainly known from a coastal belt before.

Microcharmus antongil sp. n. occurs on the Masoala peninsula where the mean annual rainfall is one of the highest in Madagascar, nevertheless similar to the rainfall reported on Montagne d'Ambre where *M. pauliani amber* has been collected. The distribution of *M. antongil* sp. n. extends the eastern known range of the *Microcharmus* ca. 100 km to the southeast. Peninsulas, like islands but to a lesser extent, are generally species-poorer (MacArthur and Wilson 1967). Given that the genus *Microcharmus*

Figures 14–15. *Microcharmus djangoa* sp. n. Female holotype. Habitus, dorsal and ventral aspects.



Figures 16–19. *Microcharmus djangoa* sp. n. Female holotype. 16. Metasomal segment V and telson, lateral aspect. 17–19. Trichobothrial pattern. 17. Chela, dorso-external aspect. 18. Patella, dorsal aspect. 19. Femur, dorsal aspect.

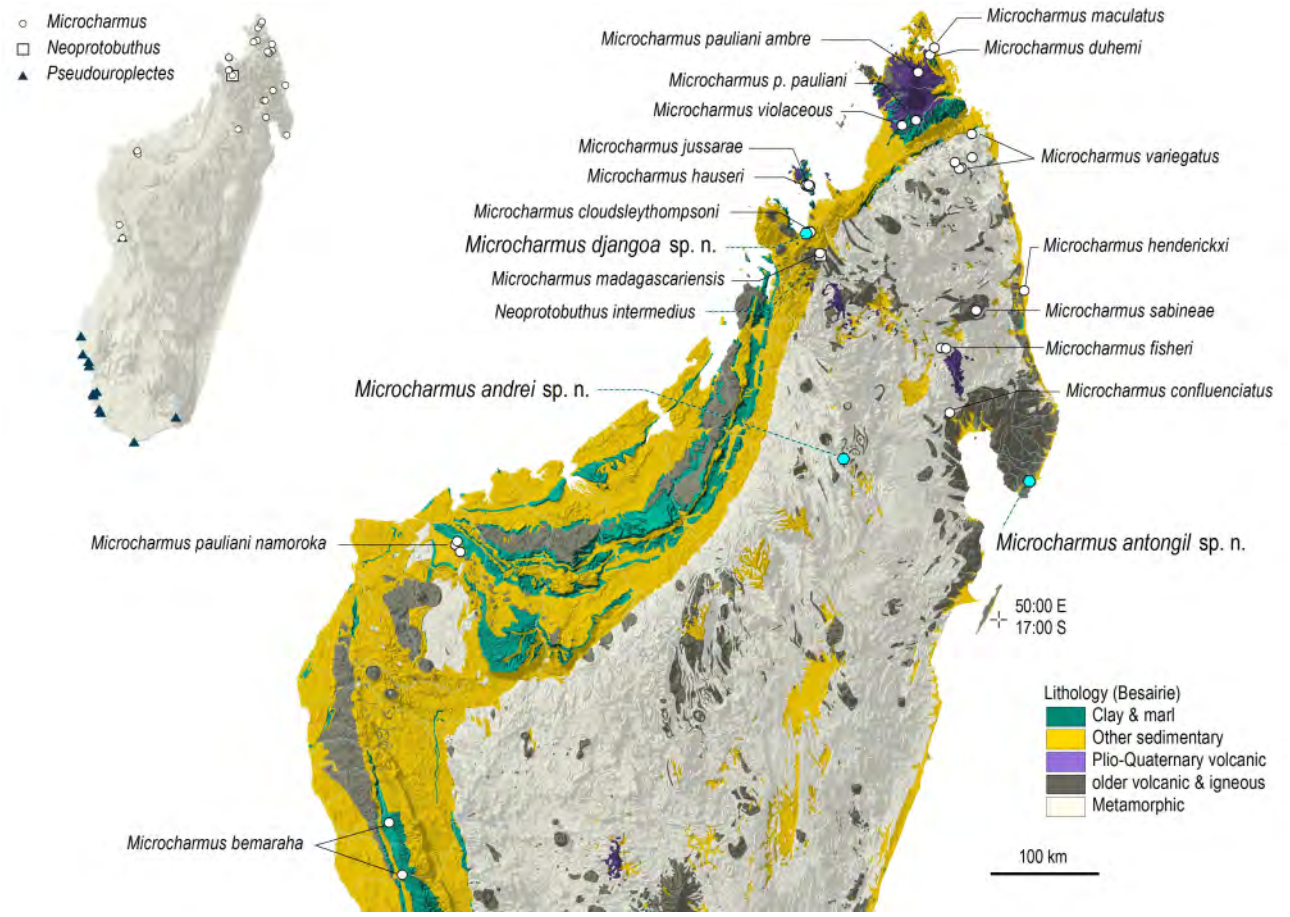


Figure 20. Distribution of the 20 species included in the family Microcharmidae, including the type localities of the three new species. (white circles for the species in the genus *Microcharmus*, white square for *Neoprotobuthus intermedius*, black triangle for the species in the genus *Pseudouroplectes* in the family Buthidae, the later only in the inset top left)

is already known from the island of Nosy Be, with two species, its presence on the Masoala peninsula is therefore not remarkable.

The scorpions belonging to the Microcharmidae and to the genus *Pseudouroplecetes* in the Buthidae family have retained a basal behavior in living in the upper humid soil surface (Lourenço et al. 2016).

The family Microcharmidae, mainly the genus *Microcharmus*, has a distribution that is reminiscent of an evolutionary radiation, with a common ancestor that is likely to have originated from the northern, narrow and elongated, part of the island where the diversity of vegetation types, climate, bioclimates, elevation is by far the highest on a relatively small area (Wilmé and Callmander 2006). *Microcharmus* is encountered in humid, subhumid and dry forests, in most bioclimates ranging from perhumid to almost subarid, including the humid, subhumid, dry bioclimates (Cornet 1974). The ancestral character retained by the Microcharmidae, i.e., the basal behavior in living in the upper humid soil surface (Lourenço et al. 2016), certainly allowed them to adapt to the diversity of environments encountered in northern Madagascar. The northern part of the island has experienced major changes in the last million years with several drastic phenomena, including Quaternary volcanism along the eastern part of the Masoala peninsula and to the northwest of the peninsula, in the southern part of the Sambirano region, and in Montagne d'Ambre (Figure 20). Another major change also occurred when Madagascar exited the Desert belt starting in the Eocene and its northern part entered the monsoon regime with an increase in rainfall, especially the orographic rains some 5 to 4 million years ago (Wells 2007). The great diversity of species in this family, which will certainly increase with new exploration of the island, has in parallel a great diversity in mor-

Table 1. Distribution of the genera in the families Microcharmidae and Buthidae. (colors according to humidity, blue = humid, green = humid—subhumid, yellow = dry, red = subarid)

	Northeast	East	Center	Southeast	South	Northwest	West
Microcharmidae	■					■	■
Microcharmus	■					■	■
Neoprotobuthus						■	
Buthidae	■	■	■	■	■	■	■
Grosphus	■	■	■	■	■	■	■
Neogrosphus					■	■	■
Palaeogrosphus	■						
Pseudouroplectes					■	■	■
Tityobuthus	■	■	■	■	■	■	■
Troglotityobuthus						■	

phology and ecology, also pointing towards a radiation. The range of the family Microcharmidae is limited to the north and to a lesser extent to the west of the island. It is much more restricted than the range of the closely related family Buthidae (Table 1).

The evolutionary radiation of the Microcharmidae in the north of the island is reminiscent of another group that could illustrate a similar case: the *Propithecus* for which the distribution pattern in the north is poorly explained (Wilmé and Callmander 2006, Wilmé et al. 2006, 2012, Waeber et al. 2015). In view of the pattern described for the Microcharmidae, one could nevertheless propose an ancestor of the smallest of the *Propithecus*, namely the western and southern species/subspecies *Propithecus verreauxi* sspp. in the north of the island. The events mentioned above over the past few million years could explain a population adaptation in the dry forests of the north-east (*Propithecus tattersalli*), limited to the north and south by the largest *Propithecus perrieri* and *Propithecus diadema*. In this scheme, a population could have adapted to the dry forests of the north-west (*Propithecus coquereli*) which could have disappeared from the Sambirano region or the entire northwest following a cataclysm, like the Quaternary volcanic activity. As in the case of the evolutionary radiation proposed for the Microcharmidae, with ancestral populations diversifying rapidly into several new forms after major changes in the environment and the opening of new niches, it is a hypothesis to test.

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