

A new species of *Paroedura* Günther from northern Madagascar

(Reptilia, Squamata, Gekkonidae)

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Paroedura lohatsara, spec. nov. is described from Montagne des Français, a deciduous dry forest on a karstic underground in the far north of Madagascar. The new gecko species is relatively large (up to 80.6 mm snout-vent length and 156.1 mm total length) and has blackish markings on the head which can form a vermiculated pattern. It is further characterized by having the nostril excluded from contact with the rostral scale, distinctly enlarged and spinous tubercles on the dorsal surface, and specific colouration of juveniles and adults. The relationships of the new species are obscure: Based on the nostril position, *P. lohatsara* belongs to the phenetic *Paroedura picta* species group which was hitherto considered as largely restricted to southern Madagascar. Other morphological and chromatic characters indicate a closer relationship of *P. lohatsara* with the syntopic *P. stumpffi* which is a member of the *P. sanctijohannis* species group. Two further species of *Paroedura*, *P. stumpffi* and *P. karstophila*, are recorded from Montagne des Français for the first time.

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Introduction

The genus *Paroedura* Günther, 1879 comprises nocturnal geckos which are endemic to Madagascar and the Comoro islands (Guibé 1956, Dixon & Kroll 1974), although fossil remains are also known from the Aldabra Atoll (Arnold 1976). The genus was recently reviewed by Nussbaum & Raxworthy (2000). According to these authors, *Paroedura* currently contains 14 species and can be divided into two phenetic species groups. The *sanctijohannis* group is defined by having the nostril in contact with the rostral scale whereas the *picta* group is defined by having the nostril excluded from contact with the rostral scale. The *picta* group was hitherto considered as restricted to the dry southern and western Madagascar, whereas species of the *sanctijohannis* group generally occur in less dry regions.

In this paper we describe a new species of *Paroedura* from northern Madagascar which belongs to the *picta* group according to the nostril position, but also shares similarities with a species of the *P. sanctijohannis* group.

Material and methods

Specimens were anesthetized by injection with chlorobutanol, fixed with 96 % ethanol and stored in 70 % ethanol. To make comparisons easier, the terminology and abbreviations of characters largely follow Nussbaum & Raxworthy (2000). Abbreviations used: UADBA = Université d'Antananarivo, Département de Biologie Animale; ZFMK = Zoologisches Forschungsinstitut und Museum Alexander Koenig, Bonn; ZSM = Zoologische Staatssammlung, München. SVL = snout-vent length; TL = tail length; HL = head length; HW = head width, at widest point; SL = snout length, anterior edge of eye to tip of snout; ED = horizontal eye diameter; EO = ear opening diameter; AGL = axilla-groin length; Forelimb = forelimb length, from axilla to tip of longest finger; Hindlimb = hindlimb length, from groin to tip of longest toe; Supralab = number of supralabial scales; Infralab = number of infralabial scales; Sdlm = number of subdigital lamellae on digits I-V of manus; Sdlp = number of subdigital lamellae on digits I-V of pes. Counts are listed left-right. All measurements were done with a caliper to the nearest 0.1 mm by the same person (FG). Material of 11 of the 14 *Paroedura* species (all except *P. maingoka*, *P. vahiny* and *P. homalorhina*) from the ZSM and ZFMK collections was available for comparison.

Paroedura lohatsara, spec. nov.

Figs 1-3

Types. **Holotype:** ZSM 985/2001, adult male, collected 14-21 March 2000 at Montagne des Français (between 12°19'17"S, 49°20'13"E, 174 m altitude and 12°19'34"S, 49°20'09"E, 334 m altitude), northern Madagascar, by F. Glaw, K. Schmidt & M. Vences. Captured as adult and kept for more than one year in captivity before preserved. – **Paratypes:** ZSM 529/2000 (adult male), ZSM 807/2001 (adult female, captured as adult and kept for about one year in captivity before preserved), ZSM 530/2000 (juvenile), and three further uncatalogued adult specimens (one male and two females which are still kept alive in the vivarium), all collected 14-21 March 2000 at the same locality by the same collectors as the holotype. ZSM 986/2001, just hatched juvenile, and ZSM 987/2001, 7-14 days old juvenile, both captive bred, being offspring of the holotype and of one of the two uncatalogued female paratypes.

Diagnosis. *Paroedura lohatsara*, spec. nov. is a relatively large-sized species (maximum SVL 80.6 mm, maximum total length 156.1 mm) with prominent dorsal tubercles which are arranged into distinct longitudinal rows. It differs from the species of the *sanctijohannis* group (*P. gracilis*, *P. homalorhina*, *P. karstophila*, *P. oviceps*, *P. masobe*, *P. sanctijohannis*, *P. stumpffi*, *P. tanjaka* and *P. vazimba*) in having the nostril excluded from contact with the rostral scale by interposition of a large prenasal scale. *P. lohatsara* shares the nostril position with the species of the *picta* group (*P. maingoka*, *P. bastardi*, *P. picta*, *P. vahiny* and *P. androyensis*), but differs from *P. androyensis* and *P. vahiny* in much larger size (80.6 compared to 47 mm maximum SVL); from *P. maingoka* and *P. picta* by distinctly larger dorsal tubercles which are arranged into obvious longitudinal rows. It differs from *P. bastardi* (including the recently described subspecies *P. b. ibityensis*, see Rösler & Krüger 1998) by mainly tetrahedral dorsal tubercles (mainly trihedral in *P. bastardi*), a relatively longer and thinner tail, and the shape of the postmental scales (distinctly longer than wide in *P. lohatsara* versus regular hexagonal in *P. bastardi*). Furthermore, *P. lohatsara* differs from all other *Paroedura* species by its distinct adult colouration and from *P. bastardi*, *P. maingoka*, *P. picta*, and *P. stumpffi* by juvenile colouration (the juvenile colourations of the other species are still undescribed).

Description of the holotype

Measurements and counts in tab. 1. Well preserved, with complete original tail. Hemipenis extruded, head wider than neck, about as wide as body. Snout angled downward to tip, slight depression between prominent canthal ridges. Ear opening is a vertical slit. Tail longer than snout-vent length, nearly round in cross section, with sharply pointed tip; ventral pygal section with pair of postcloacal sacs. Digits moderately expanded at tips. Rostral scale rectangular, wider than tall, as wide as mental. Nostril in contact with large prenasal anteriorly, and four further scales, but not with first supralabial. First supralabial largest, labials smooth. Snout and interorbital scales juxtaposed, some raised, scales in front of orbits tuberculate, as are larger lateral occipital scales. Dorsolateral neck and body scales very heterogeneous with about 12 distinct longitudinal rows at midbody of enlarged, spiny, mainly tetrahedral tubercles; enlarged tubercles separated mostly by small flat scales and smaller tubercles. Dorsal scales of forelimbs flat or tuberculate and weakly imbricate. Dorsal scales of hindlimbs large and



Fig. 1. *Paroedura lohatsara*, spec. nov. Male holotype (ZSM 985/2001).



Fig. 2. *Paroedura lohatsara*, spec. nov. Female paratype (uncatalogued).

strongly tuberculate, much smaller above kneejoint. Ventral scales of forelimbs and hindlimbs slightly smaller than surrounding ventral scales of the body. Dorsal pygal scales like dorsal body scales; lateroventral pygals tuberculate but less spinous. First 19 postpygal tail segments each with transverse row of spiny tubercles dorsolaterally; first four rows with 10-12 tubercles, gradually decreasing to the last rows with about four tubercles; posterior tail with flat scales. Mental triangular, bordered posteriorly by a pair of elongate, irregular hexagonal postmentals. Postmentals contact mental, first infralabial, one enlarged lateral gular, one smaller posterolateral gular, and one slightly larger central gular. First three infralabials significantly larger than others. Gulars small, granular. Ventrals of chest and abdomen flat, posterior abdominals largest. Proximal subdigitals in rows of 2-3, distally to narrow leaf-like rows of scales followed by enlarged row supporting terminal pads. Pair of squarish, terminal pads, each pad about 1 mm across. Claws curving downwards between terminal pads of digits.

Colour after one day in alcohol virtually identical to that in life (Fig 1). Head dorsally beige with more or less symmetrical blackish markings. A black band from the second supralabial to anterior eye and from posterior eye to a point above the ear opening. A beige mid-dorsal stripe (of 2 mm diameter at midbody) runs from the neck to the pygal portion of tail. Neck and dorsum beige with blackish spots which are arranged into four irregular longitudinal rows; two rows border the mid-dorsal stripe, the other two rows run more dorsolaterally to the pygal portion of the tail. Additional black spots are present on the flanks. Many of the enlarged tubercles on the flanks are whitish. Dorsal surface of forelimbs and hindlimbs beige with dark brown markings. Postpygal tail dorsally with about nine whitish and nine black alternating transverse bands which are partly not well delimited in the proximal portion of the tail. Throat, chest, venter, pygal tail portion and ventral parts of forelimbs and hindlimbs whitish; ventral side of tail light brownish. Tongue dark grey at its distal tip. A yellow ring around the eye. Iris silvery-golden with small veins in life, not recognizable when preserved since pupil was much enlarged after preservation.

Tab. 1. Morphometric and meristic variation among the holotype and two adult paratypes of *Paroedura lohatsara*. Measurements in mm.

Collection number	ZSM 985/2001	ZSM 529/2000	ZSM 807/2001
Status	holotype	paratype	paratype
Sex	male	male	female
Maturity	mature	mature	mature
SVL	70.6	69.0	72.8
TL	75.8	45.8*	65.0
HL	25.1	24.0	25.6
HW	17.5	16.3	17.0
SL	9.7	9.3	9.6
ED	5.7	5.4	5.5
EO	2.7×0.5	2.2×0.5	3.1×0.8
AGL	30.4	30.1	33.0
Forelimb	23.7	25.0	25.9
Hindlimb	36.3	34.4	32.0
Supralab	12-11	10-10	13-12
Infralab	11-12	9-9	11-11
Sdlm I	8-8	10	9-9
Sdlm II	10-9	9	10-11
Sdlm III	11-10	12	11-11
Sdlm IV	12-12	11	11-11
Sdlm V	10-10	11	10-10
Sdlp I	8-9	8-9	9-9
Sdlp II	10-11	9-9	10-11
Sdlp III	12-13	12-13	11-12
Sdlp IV	14-14	13-13	13-13
Sdlp V	13-14	14-12	12-11

* tail regenerated

Variation. Morphometric and meristic variation of two paratypes (ZSM 529/2000 and ZSM 807/2001) are summarized in table 1. ZSM 529/2000 is an adult male with extruded hemipenes; the right forelimb was removed for future DNA studies. The regenerated tail has no spinous tubercles and is irregularly marbled with brown and white. The general colouration is similar to the holotype whereas that of the female ZSM 807/2001 is more contrasting: the largely symmetrical blackish markings on the head form a vermiculated pattern and the black spots on the dorsum are less clearly arranged into longitudinal rows. A distinct white band bordered by a thin blackish band on each side runs from the anterior dorsum to the anterior insertion of arm. The original and complete tail has 11 alternating dark and 10 light bands and is distinctly thinner than in the holotype. The whitish scales on the flanks are very prominent. The three living paratypes (all with original tail) largely agree with the preserved types. Their size (measured 12 July 2001 in life) was 73.9 mm SVL + 82.2 mm TL (male), 80.6 mm SVL + 72.5 mm TL (female, Fig. 2), and 79.7 mm SVL + 57.1 mm TL (female, last tail tip missing). TL is shorter than SVL in the three females, but longer than SVL in the two males with original tail. The SVL of the three adult males (69.0-73.9 mm SVL) is slightly shorter than in the three females (72.8-80.6 mm), but total length appears similar in both sexes. All type specimens and all further captive-bred specimens agree in having distinct dark markings on the head. The juvenile paratypes (ZSM 530/2000, 32.4 mm SVL + 31.3 mm TL; ZSM 986/2001, 32.0 mm SVL + 26.8 mm TL; ZSM 987/2001, 31.2 mm SVL + 29.8 mm TL) have a distinct juvenile colouration which was also typical for the other juveniles which we reared in captivity (Fig. 3): Four distinct whitish transverse bands on the dark brown back and flanks. Laterally, the most anterior band is distinctly narrower than the two following bands and ends pointed slightly anterior of the insertion of the forelimbs. The two bands between forelimbs and hindlimbs are not pointed laterally and have the same width on the entire flanks as on the back. The posteriormost band, positioned between the hindlimbs, is restricted to the back. There is no light mid-dorsal line. The upper surface of the tail is banded with beige and brown in the preserved specimens, but bright orange with dark crossbands in life. Dark symmetrical markings on the head are already well recognizable. The head is relatively broad and short, especially in comparison with similar sized juveniles of *P. stumpffi* and *P. bastardi*. About three months after hatching the juvenile colouration gradually converts into the adult colouration. Subadults still have more or less distinct transversal bands on the back whereas in older adults these bands are poorly or not recognizable. A light mid-dorsal stripe is present in subadults and adults.

Distribution and conservation. *Paroedura lohatsara* is only known from the Montagne des Français in the far north of Madagascar. Numerous animal and plant species appear to be endemic to this karstic massif, among them a still undescribed snake species of the genus *Heteroliodon* (pers. obs.). It is therefore likely that *Paroedura lohatsara* is a further endemic species of the Montagne des Français massif. In this case the new species may be considered as vulnerable due to its small range although its habitat is apparently not immediately threatened by destruction. Regarding the numerous endemics in Montagne des Français this area should be protected as nature reserve.

Habitat and habits. In nature, the new species was only observed at night in dry forest on a karstic underground, several days after heavy rains. The geckos were mainly climbing on rocks and branches up to two metres above the ground. In captivity, juveniles and adults were able to feed on relatively large insects. Nussbaum & Raxworthy (2000) described a prominent vertical or anteriorly curved tail display in disturbed *Paroedura maingoka* which they interpreted as defensive behaviour. A similar behaviour was sometimes observed by us in disturbed captive-bred subadult *P. lohatsara* and *P. stumpffi*, e.g. when the specimens were faced with torchlight at night. However, it was also observed in undisturbed *P. lohatsara* in the vivarium, indicating that it may also serve for intraspecific communication. A detailed analysis of this and other behavioural traits in *Paroedura picta* was provided by Brillet (1986, 1993).

Sympatric species. Two other species of *Paroedura* were found in sympatry with *P. lohatsara*. Both are hereby recorded for the first time at Montagne des Français: *P. karstophila* (ZSM 531/2000 and 532/2000) was found in close syntopy with *P. lohatsara* in the limestone massif whereas *Paroedura stumpffi* (ZSM 635/2000) was only encountered on the slope between the massif and the sea, outside the karstic underground.

Reproduction. One male and two females of *P. lohatsara*, captured as adults at Montagne des Français in March 2000, were kept and bred in a vivarium (1 m × 0.5 m × 0.8 m) together with a couple of *P. stumpffi* from the same locality. As usual in other *Paroedura* species (Schröder 1987, Rösler 1998), a clutch generally consisted of two single eggs which were neither glued to each other nor to the underground. The white eggs had a hard calcareous shell and were buried singly few millimetres into sandy ground. In comparison to *P. stumpffi*, eggs of *P. lohatsara* were generally deposited in drier places and were always distinctly larger. 15-20 days after egg deposition eggs measured 13.2 × 10.3 mm and 13.4 × 10.4 mm (n=2) in *P. lohatsara* and 10.8 × 8.2 mm to 11.6 × 8.6 mm (n=5) in *P. stumpffi* (a similar size difference was observed but not measured in numerous other cases). Eggs were incubated differently, either at a constant temperature of 27 °C or at 30 °C during the day and 23 °C at night. Juveniles hatched 70-82 days after the discovery of the eggs (at 27 °C) and after 85-87 days under the variable incubation temperatures, indicating that the total time between egg deposition and hatching was ca. 70-90 days. Hatchlings of *P. lohatsara* (total length 59-60 mm, n=2) were distinctly larger than those of *P. stumpffi* (total length 50-52 mm, n=3). All juveniles were identified either as *P. stumpffi* or *P. lohatsara*, indicating that hybridization did not occur in the vivarium.

Only little is known about reproduction of *P. lohatsara* in nature. The total length of a juvenile paratype (ZSM 530/2000), collected 21 March 2000, is only 4 mm longer than that of just hatched juveniles, indicating that it was only few weeks old when captured. Assuming an approximate egg incubation time of 70-90 days (as found in captivity) the corresponding egg was laid at the beginning of the rainy season as is typical in many Madagascan reptiles (Glaw & Vences 1996).

The first eggs laid by the F1 generation were found on 30 June 2001, ten months after hatching of the first juveniles (22 August 2000), indicating that sexual maturity in captivity was reached less than ten months after hatching. To document the adult size at first reproduction, the largest male and female of the F1-group were measured after the first eggs were found: The largest male measured 111 mm total length and the largest female 106 mm total length.

According to our experience, egg laying females of *P. lohatsara*, *P. tanjaka* and *P. bastardi* apparently have an enormous need of calcium and are vulnerable to rachitis. Despite of regular addition of several pulverized Calcium products to the food, the faeces sometimes contained a remarkable amount of sand which was apparently actively ingested to take in calcium. After much pulverized limestone was added to the vivarium the faeces contained less sand. The high need of calcium may explain why several *Paroedura* species like *P. karstophila*, *P. tanjaka*, and *P. lohatsara* seem to be restricted to limestone habitats. This restriction may be true for other oviparous Malagasy reptiles with hard-shelled eggs as well.

Etymology. *loha* (Malagasy) means head; *tsara* (Malagasy) means beautiful or good. The specific name *lohatsara* refers to the beautiful head colouration of the new species and is considered as invariable noun in apposition to the generic name.

Available names. Several available names in the genus *Paroedura* are considered as junior synonyms of valid species names, all of them belonging to species having the nostril separated from the rostral. These names need to be considered as possible earlier names for *P. lohatsara*. *Diplodactylus porogaster* Boulenger, 1896 (type locality: "south-western Madagascar") is considered as synonym of *Paroedura androyensis* (Angel 1942, Guibé 1956), and *Diplodactylus robustus* Boulenger, 1896 (type locality: "south-western Madagascar") as synonym of *P. picta* (Angel 1942, Guibé 1956). The type specimens of both taxa are deposited in the Natural History Museum at London and are not available at present. However, based on the chromatic and morphological characters given in the original descriptions (Boulenger 1896) it seems likely that these synonymies are correct. In addition, the type locality of both taxa is in south-western Madagascar whereas *P. lohatsara* is only known from a karstic massif at the northern tip of the island. The type locality ("Tulléar") of *Phyllodactylus madagascariensis* Mocquard, 1894 is in south-western Madagascar as well. This taxon is considered as synonym of *P. picta* (Angel 1942) which is common around Tulear according to our observations. It is based on a single poorly preserved specimen with a SVL of 40 mm (Mocquard 1895) and the characters given in the original description seem to fit to those of juvenile *P. picta*. *Paroedura guibeae* Dixon & Kroll, 1974 was shown to be a junior synonym of *P. bastardi* by Nussbaum & Raxworthy (2000). Summarizing, none of the synonyms is available as earlier name for *P. lohatsara*.

Relationships. As already noted above, the genus *Paroedura* can be divided into two phenetic species groups based on the position of the nostril (Nussbaum & Raxworthy 2000). The species of the



Fig. 3. Juveniles of *Paroedura bastardi* (left above), *P. lohatsara* (middle) and *P. stumpffi* (right below).

sanctijohannis group are widely distributed in different climatic regions in western (*P. tanjaka*, *P. vazimba*), eastern (*P. gracilis*, *P. masobe*) and northern Madagascar (*P. homalorhina*, *P. oviceps*, *P. stumpffi*, *P. karstophila*), and even on the Comoro Islands (*P. sanctijohannis*). The species of the *picta* group are thought to be largely restricted to arid southwestern Madagascar (*P. maingoka*, *P. bastardi*, *P. picta*, *P. vahiny* and *P. androyensis*). *P. lohatsara* does not support this distributional pattern: It clearly belongs to the *picta* group based on the position of nostrils, but is only known from extreme northern Madagascar. Although the range of *P. lohatsara* is widely separated from the other species of the *picta* group, this fact does not necessarily argue against the monophyly of this phenetic group since several animal and plant taxa of the Montagne des Français have affinities to those of dry western and southern Madagascar. Further research is therefore necessary to clarify whether the two phenetic species groups which are defined by a single morphological character (nostril position) represent natural clusters or not.

Another remarkable morphological character in *Paroedura* is the prominence of the dorsal tubercles. These are very distinct and arranged in obvious longitudinal rows in *P. bastardi*, *P. stumpffi*, and *P. lohatsara* but less prominent (and arranged in obvious longitudinal rows in only some taxa) in the other species (*gracilis*, *oviceps*, *karstophila*, *masobe*, *sanctijohannis*, *androyensis*, *picta*, *vazimba*, *vahiny*, *homalorhina*, *tanjaka*, *maingoka*). The similarity of *P. stumpffi* and *P. bastardi* regarding this character was possibly the reason why Dixon & Kroll (1974) considered their *P. guibeae* (which was synonymized with *P. bastardi* by Nussbaum & Raxworthy 2000) as “mainland form” of *P. stumpffi*. Most of the prominent dorsal tubercles of *P. bastardi* can be described as trihedral whereas those of *P. stumpffi* and *P. lohatsara* are mainly tetrahedral. Further similarities between the latter two species in (1) the shape of the tail (relatively long and always thin in *P. lohatsara* and *P. stumpffi* versus relatively short and often rather thick in *P. bastardi*), (2) the shape of the postmental scales (distinctly longer than wide in *P. lohatsara* and *P. stumpffi* versus regular hexagonal in *P. bastardi*), (3) several characters of adult and juvenile colouration, and (4) geographic distribution (*P. stumpffi* and *P. lohatsara* in the north, *P. bastardi* in the west and south) may indicate that *P. lohatsara* is perhaps more closely related to *P. stumpffi* than to *P. bastardi*.

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