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Notes on the natural history, distribution and malformations of day geckos (*Phelsuma*) from Madagascar

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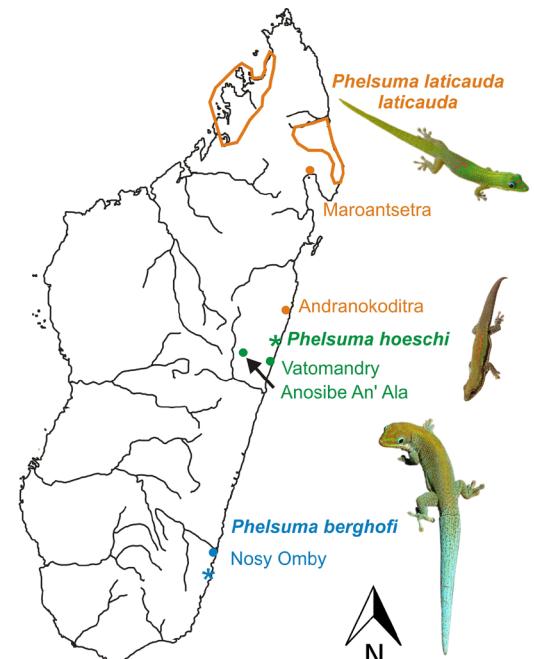
Abstract. Day geckos of the genus *Phelsuma* (Gekkonidae) were observed at different localities in Madagascar. New distribution records are reported for *Phelsuma laticauda laticauda* in Maroantsetra (north-east coast), for *Phelsuma hoeschi* at Anosibe An' Ala (central east) and for *Phelsuma berghofi* in Nosy Omby (south-east coast). In several populations highly malformed individuals were encountered; the causes for these malformations remain largely unclear. Furthermore some behavioral observations on a rival fight between two males of *Phelsuma lineata lineata* and a case of predation of *Phelsuma laticauda laticauda* on a juvenile *Hemidactylus* sp. are reported.

Keywords. *Phelsuma*, Squamata: Gekkonidae, new distribution records, malformations, territoriality, predation, Madagascar.

Introduction

With currently 42 recognized species and subspecies the genus *Phelsuma* represents the most diverse lizard genus of the western Indian Ocean island Madagascar. *Phelsuma* are mostly colorful diurnal and morphologically rather homogeneous geckos. The coloration ranges from bright green, often with red spots and markings in most species to dull grey or brownish in a few others. Despite the extensive published works on *Phelsuma* taxonomy, ecology, biogeography and ethology (e.g. Loveridge 1942; Mertens 1955; Kästle 1964; Meier 1993; Krüger 1996; Berghof 2005; Glaw and Vences 2007; Hallmann, Krüger and Trautmann 2008; D'Cruze et al. 2009; Rocha et al. 2009, 2010) detailed informations on distribution ranges and natural history of these charismatic lizards are still unknown.

Herein we report on some interesting observations on wild *Phelsuma* populations which are either new distribution records, notes on behavior and predation or remarkable malformations.



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Figure 1. Map of Madagascar with locality data of different *Phelsuma* species. The known distribution area of *P. l. laticauda* in northern Madagascar is outlined in orange, new distribution records are indicated as orange dots. Type localities for *P. hoeschi* (green) and *P. berghofi* (blue) are indicated by stars, new distribution records are shown as dots.

Material and Methods

Day geckos (*Phelsuma* ssp.) were recorded in north-eastern, eastern and central Madagascar, by PSG, FG and FR from April to May 2009 and 2010 and in southern and northern Madagascar by AC, SH and FR in October and November 2009. Selected specimens were collected and some of those discussed in this article (FGZC 4520, FGZC 4521, FGZC 4523, ZCMV 12025, ZCMV 12026, ZCMV 12027) were subsequently deposited in the collection of the Zoologische Staatssammlung München (ZSM), Munich, Germany or in the collection of the Université d'Antananarivo, Département de Biologie Animale (UADBA), Antananarivo, Madagascar, but are not yet catalogued. If specimens were collected, geckos were anesthetized by injection with chlorobutanol, fixed with 90% ethanol and stored in 70% ethanol. Tissue samples were taken by tail clipping and were stored in 100% ethanol for further genetic analyses and are deposited at the Technical University of Braunschweig, (Germany). PSG, ACZC, FGZC and ZCMV refer to field numbers of P.-S. Gehring, A. Crottini, F. Glaw and M. Vences.

Locality information were recorded with GPS receivers. Identification of species followed Glaw and Vences (2007) and Hallmann, Krüger and Trautmann (2008).

New distribution records

Phelsuma laticauda laticauda (Boettger, 1880)

This species is very abundant in the humid regions of northern Madagascar, especially at the north eastern coast and in the Sambirano region. The southernmost record at Madagascar's north-east coast is Cap Est on the east side of the Masoala peninsula. To our knowledge, there are no records of *Phelsuma l. laticauda* from localities along the Bay of Antongil existing. In April 2010 we found adult *Phelsuma l. laticauda* in the village of Maroantsetra at the northern tip of the Bay of Antongil (15° 25' 55.29" S, 49° 44' 24.21" E, 9 m a.s.l., Fig. 1). The animals were encountered at several typical wooden huts along Maroantsetra's main road. Tissue samples for genetic analyses were taken from one individual (PSG 2302).

Maroantsetra has one of the major ports and airports in the region, with regular connections and intensive traffic to the ports in Antalaha and Vohemar, where *P. l. laticauda* is very common, therefore an introduction by humans appears quite likely, although we cannot exclude that this population has expanded its range along the western parts of the Masoala peninsula.

Pearson and Raxworthy (2009) and Gehring et al. (2010) reported on the occurrence of this species in the village of Andranokoditra and around the Lac Ampitabe, which is part of Canal des Pangalanes at the central east coast of Madagascar. Most probably this species has been introduced in this region of Madagascar and is now

expanding its range. The impact of this introduction on the original *Phelsuma* species assemblage of this region remains unclear.

Phelsuma hoeschi Berghof and Trautmann, 2009

Until now this species is only known from its type locality: south of Ampasimanolotra (= Brickaville, 18° 49' 5.74" S, 49° 4' 2.13" E, ca. 12 m a.s.l., Berghof and Trautmann 2009), and close to Vatomandry (Gehring et al. 2010) in coastal low-land areas at Madagascar's central east-coast (Fig. 1). *Phelsuma hoeschi* inhabits big trees at the beachfront and was found in secondary vegetation (Berghof and Trautmann 2009; Gehring et al. submitted). It is a small species, with a distinct sexual dichromatism, with males being more colorful and with a bright green dorsal coloration, two rows of red spots, and a bright blue color pattern between the eyes. Females are greyish-brown on the dorsum with some dark spots. Both sexes have a dark lateral band. Until now little is known about the distribution range and ecology of this recently described species, and its differentiation from *P. pusilla hallmanni* needs further study.

In April 2010 at Anosibe An'Ala (19° 25.681' S, 48° 12.513' E, 594 m a.s.l.), we found *P. hoeschi* close to the village in secondary vegetation which consisted of several isolated trees along a street close to rice fields. One male (FGZC 4520; UADBA) and one female (FGZC 4521; UADBA) were found on an isolated tree, that was comparable sparsely foliated. Another male (FGZC 4523; ZSM) was found in a shrub under a large Mango tree with a freshly lost tail. Most likely it had escaped a predation attempt by dropping its tail.

This record of *P. hoeschi* in Anosibe An'Ala enlarges the distribution range of this day gecko species significantly to the west and thus to higher elevation, and therefore it is reasonable to assume that most probably there are more populations between the coastal localities Ampasimanolotra and Vatomandry and the more inland locality Anosibe An'Ala.

Preliminary data based on mitochondrial 16S rRNA gene sequences confirmed species identification although the new population from Anosibe An'Ala reported here is genetically somewhat differentiated from the coastal populations.

Phelsuma berghofi Krüger, 1996

So far little is known about this day gecko species from southeastern Madagascar. Besides the observations on the type specimens, close to the village Somisiky (Krüger 1996; Berghof 2005, 2008) the existence of



Figure 2. A. Malformed *Phelsuma modesta leiogaster* in dorsal and (B) lateral view. Note the deformed spinal column with three humps (A) and the “accordion”-like shape of the tail (B). C. Malformed male of *P. pusilla pusilla* from Andaparaty; D. *P. berghofi* female and (E) male of *P. berghofi* from Nosy Omby. Note the extremely swollen left thigh (E).

Phelsuma berghofi was only reported from the Special Reserve of Manombo, approximately 50 km north of the type locality (Rocha et al. 2009; Pearson and Raxworthy 2009; Glaw and Vences 2007). *Phelsuma berghofi* has rarely been found outside the villages and if found, it was exclusively encountered on traveller’s tree (*Ravenala madagascariensis*). Due to its limited distribution range and the continuing decline in the extent and quality of its habitat in south-eastern Madagascar, *Phelsuma berghofi* was suggested to be evaluated as endangered (Schneider 2004; Berghof 2005; Hallmann, Krüger and Trautmann 2008). In 2010 we detected *Phelsuma berghofi* in the area between the villages Vangaindrano ($23^{\circ} 20' 52''$

S, $47^{\circ} 36' 03''$ E, 5 m a.s.l.) and Nosy Omby ($23^{\circ} 34' 30''$ S, $47^{\circ} 37' 11''$ E, 51 m a.s.l.) in the south (Fig. 1), following a stretch of ca. 30 km length along the coastal road Route Nationale 12 (RN 12). These new records enlarge the known distribution range of *P. berghofi* for about 60 km to the north.

The vegetation consisted of degraded secondary, mostly savannah like vegetation, with single *Ravenala madagascariensis* trees, screw palms (*Pandanus* sp.) and sisal agavas (*Agave sisalana*) in which *P. berghofi* was commonly encountered. Due to its larger size, the number of encountered animals on *Ravenala madagascariensis* was higher than in other plants.

During 30 minutes of searching with five persons in an area <2 ha we encountered 20 individuals of *Phelsuma berghofi* in this degraded type of vegetation. Close to and within the villages we found it in banana and sugarcane plantations, and even on the huts of the villagers, where *P. berghofi* was the predominant species of day gecko. These observations indicate that *P. berghofi* is somewhat tolerant to habitat destructions and can survive in vital populations within anthropogenic secondary biotopes. *Phelsuma berghofi* was found syntopically with *P. lineata lineata* and *P. cf. parva*, although we never observed *P. berghofi* and one of the other species together in the same microhabitat. Tissue samples for genetic analyses were collected from ten individuals (PSG 2911-2918, PSG 2939, PSG 2941, PSG 2948).

Malformations

Phelsuma modesta leiogaster Mertens, 1970

This subspecies typically lives in the arid areas of southwestern Madagascar and is generally abundant in anthropogenic areas. It is characterized by a fairly strong sexual dimorphism with males generally more brightly colored than females (Glaw and Vences 2007). A mature female with strong malformations (Fig. 2A-B) was found on the 2nd December 2009 on a palm inside the garden of the hotel "Le Recif" in Toliara (Tuléar), south-western Madagascar (23° 21' 39" S, 43° 40' 08" E, <10 m a.s.l.) together with several other males and females. Despite this handicap the presence of a broad tail indicate a surprisingly good condition of this female (Fig. 2A). The spinal column was highly deformed and characterized by three humps. Fore- and hindlimbs showed no obvious deformations but the tail had a "accordion"-like shape, an osteological malformation already reported for another free living Malagasy reptile, *Furcifer pardalis* (Gehring 2009). A tissue sample of the malformed individual was collected for genetic analyses (ACZC 1871).

Phelsuma pusilla pusilla Mertens, 1964

This species is locally common at the north-east coast where it inhabits palm trees, banana plants, and human buildings. It often occurs in groups of several females and one dominant male. We observed a stunted male of *P. p. pusilla* on a hut close to the village Andaparaty, located at the Antainambalana River, approximately 26 km north-west of Maroantsetra on the north-eastern slopes of the Makira plateau (15° 12' 20.5" S, 49° 36' 73.0" E, 110 m a.s.l.). The right hand and lower arm were severed from the elbow on, and two fingers of

the left hand were missing. The tail has been nearly completely lost, but was already regenerating (Fig. 2C). Despite these major injuries the animal appeared very healthy, well-fed and it seemed that its handicaps caused no major restrictions for it.

Phelsuma berghofi Krüger, 1996

Most of the encountered animals were without pathological findings but three of the adult *P. berghofi* close to Nosy Omby showed impressive malformations. These animals looked very portly, lateral with sack-like bulges on their sides which sometimes covered the forearms and parts of the head (Fig. 2D). In one individual the left thigh was extremely swollen (Fig. 2E). Generally the malformed individuals appeared very well-fed, as indicated by exceptionally broadened tails. Three animals with these extreme malformations were collected (ZCMV 12025-12027) for further examinations. Whether these malformations were induced by adiposis, parasites or other factors, remains unclear.

Behavioral observations

Rival fight between two males of Phelsuma lineata lineata Gray, 1842

In mid April 2010 we observed a rival fight between two males of *Phelsuma lineata lineata* in a banana plantation within the village of Anosibe An'Ala (19° 25.681' S, 48° 12.513' E, 594 m a.s.l.). This species of day gecko is well adapted to secondary habitats, especially to banana plantation where it can be very abundant. An adult male was captured for obtaining tissue samples and was immediately released on a big banana plant that was already occupied by another conspecific adult male. Soon after being released the introduced male (IM) crossed the resident male (RM) and both animals started a tongue flicking/lolling behavior, but kept distance to each other. At first, both animals showed a rather inconspicuous coloration: the RM because of the cloudy and rainy weather and the IM because of the stress we had caused it with handling. After a few minutes of looking at each other, the IM slowly moved towards the RM and thereby it curved its body "S-shapedly" (Fig. 3A). The RM turned to the IM, attacked it with a very fast approach and made a squeezing noise. After this attack, the RM displayed a sideward threat with a lifted back in direction to the IM, showing his conspicuous red markings on the back, as well as bluish spots on the head, neck and tail, which became more prominent in both males and were in



Figure 3. Rival fight of two *P. l. lineata* males on a banana plant in Anosibe An'Ala. A. Introduced male (IM) curving its body in a s-shape; B. sideward threat with a lifted back; C. both rivals showing sideward threat with a lifted back; D. both males sitting motionless side by side; E. resident male (RE) in splendid coloration, note the blue spots on the head, neck and tail.



Figure 4. *Phelsuma l. laticauda* capturing a *Hemidactylus* specimen in Ankify, northwestern Madagascar.

strong contrast with the green coloration of the back (Fig. 3B). Soon after, the IM showed the same behavior and both opponents lifted alternately their back towards each other while moving slowly in a circle, always keeping a certain distance to each other (Fig. 3C). During the whole fight tail-wriggling occurred and may have indicated the excitement of both opponents. The sideward tilting was interrupted by short breaks in which both males preserved their positions more or less without any movements, always keeping an eye on each other and displaying occasional tongue-flicking. The RM started several fast assaults at the IM during which intensive horizontal trembling of the head and slow movements towards the rival marked the beginning. The IM did not try to avoid the attacks and remained motionless in his position. After several of these attacks, the RM slowly approached its opponent, accompanied by intensive tongue-flicking and both rivals remained motionless sitting side by side for several minutes (Fig. 3D). After a last fast attack of the RM which was accompanied by a squeezing short noise, the IM left the banana leaf and disappeared inside the banana plant.

Whether the observed tongue-flicking in *Phelsuma* served as chemosensory perception of the rival or as a threat gesture (as described by Kästle 1964), remains

unclear. Kästle (1964) reports on a comment fight in captive *P. l. lineata* and suggests a connection of the sideward threat with lifted back and the appearance of striking dorsal color patterns. The observation, that the formerly dull colored males became splendidly colored within a few seconds, without any environmental changes, supports the assumption that the dorsal color patterns play a distinct role in the social communication in *Phelsuma*, as it is known from other reptile groups (e.g. chameleons and iguanids). In addition to this visible color patterns there might be a connection to UV-reflecting patterns, invisible to the human eye. Especially the blue spots on the head, neck and tail of the males (Fig. 3E), probably are highly reflecting in the UV-light as it is already known from Malagasy chameleons of the genus *Furcifer* (Gehring and Witte 2007), and they are giving the rivaling males a more impressive appearance.

Predation of Phelsuma l. laticauda (Boettger, 1880) on a juvenile Hemidactylus sp.

On 11th November 2009 at about 16:15 p.m. an adult *P. l. laticauda* was observed preying upon a juvenile *Hemidactylus* specimen (Fig. 4). The animals were at about 2 meters above ground, inside a traveller's tree, in

the garden of the Hotel “Le Baobab” ($13^{\circ} 33' 06''$ S, $48^{\circ} 21' 54''$ E, <10 m a.s.l) in Ankify (district of Ambanja), Madagascar. Two of us (AC and FR), together with a local guide (Emile Rajeriarison) had the opportunity to witness this behavior in natural and undisturbed conditions. This observation took place on a sunny day. Although we did not see the moment the *Phelsuma* had captured the *Hemidactylus* specimen we suspect that the predation took place shortly before, since the *Hemidactylus* was still alive and fighting. After about one minute, the *Phelsuma* carried away its dead prey and disappeared inside the leaf axils of the *Ravenala*.

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Appendix: List of tissue samples and collected specimens reported in this study. Fieldnumbers refer to: (PSG) Philip-Sebastian Gehring, (ACZC) Angelica Crottini, (FGZC) Frank Glaw and (ZCMV) Miguel Vences. Samples are stored at: (TU BS) Technical University Braunschweig, Germany; (UADBA) Université d’Antananarivo, Département de Biologie Animale (UADBA), Antananarivo, Madagascar and (ZSM) Zoologische Staatssammlung München, Germany.

Species	Fieldnumber	Collection	Locality	Coordinates	Sample
<i>Phelsuma laticauda</i>	PSG 2302	TU BS	Maroantsetra	$15^{\circ} 25' 55.29''$ S, $49^{\circ} 44' 24.21''$ E; 9 m a.s.l	Tissue
<i>Phelsuma hoehschi</i>	FGZC 4520	UADBA	Anosibe An'	$19^{\circ} 25.681'$ S, 48° 12.513' E; 594 m a.s.l	Specimens
<i>Phelsuma hoehschi</i>	FGZC 4521	UADBA	Ala	$19^{\circ} 25.681'$ S, 48° 12.513' E;	
<i>Phelsuma hoehschi</i>	FGZC 4523	ZSM		594 m a.s.l	
<i>Phelsuma berghofi</i>	FGZC 4520	TU BS	Anosibe An'	$19^{\circ} 25.681'$ S, 48° 12.513' E;	Tissue
<i>Phelsuma berghofi</i>	FGZC 4521	TU BS	Ala	$19^{\circ} 25.681'$ S, 48° 12.513' E;	
<i>Phelsuma berghofi</i>	FGZC 4523	TU BS		594 m a.s.l	
<i>Phelsuma berghofi</i>	ZCMV 12025	ZSM	Nosy Omby	$23^{\circ} 34' 30''$ S, 47° 37' 11'' E;	Specimens
<i>Phelsuma berghofi</i>	ZCMV 12026	ZSM		51 m a.s.l	
<i>Phelsuma berghofi</i>	ZCMV 12027	ZSM			
<i>Phelsuma berghofi</i>	PSG 2911-2918, PSG 2939, PSG 2941, PSG 2948, ZCMV 12025, ZCMV 12026, ZCMV 12027	All TU BS	Nosy Omby	$23^{\circ} 34' 30''$ S, 47° 37' 11'' E; 51 m a.s.l	Tissue
<i>Phelsuma modesta</i>	ACZC 1871	TU BS	Toliara	$23^{\circ} 21' 39''$ S, 43° 40' 08'' E; <10m a.s.l	Tissue
<i>Phelsuma lineata</i>	PSG 2483 - 2489, PSG 2494 - 2497	TU BS	Anosibe An' Ala	$19^{\circ} 25.681'$ S, 48° 12.513' E; 594 m a.s.l)	Tissue