Distribution and habitat of the invasive giant day gecko *Phelsuma grandis* Gray 1870 (Sauria: Gekkonidae) in Reunion Island, and conservation implication

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Abstract. The giant day gecko *Phelsuma grandis*, endemic to Madagascar, was introduced to Reunion Island (Indian Ocean) in the mid-1990s. No studies have been conducted so far to define its precise distribution and habitat. To fill the knowledge gap about this invasive species, we compiled available data and performed field work during 2007-2014. We detected 13 distinct populations of *P. grandis*, occurring mainly in the northern part of Reunion Island and on the west coast. This gecko inhabits human disturbed areas (gardens, urban parks, bamboos, orchards, coconuts, and banana plantation) and secondary habitats (shrubby savanna, and secondary dry woodlands, secondary dry and wet thickets). Its distribution strongly suggests that saltatory dispersal (through deliberate and/or accidental transport) and natural colonization are the mechanisms of spreading through Reunion Island. All our data in combination with both *P. grandis* ecology and native environmental range suggested that this gecko may colonize native forest, and constitutes a potential important threat to the native biodiversity of Reunion Island (arthropods and lizards).

Key words. *Phelsuma grandis*, Reunion Island, distribution, invasive species, conservation.

Introduction

Day geckos of the genus *Phelsuma* are distributed in the western Indian Ocean (Austin *et al.* 2004). This group is monophyletic and contained at least 52 species (Rocha *et al.* 2009; 2010; Uetz 2013). *Phelsuma* species are colorful, attractive lizards and represent one of the most popular Gekkonidae group for herpetoculturists. The international trade has induced many introductions in several countries of the world (Lever 2003; Mozzi *et al.* 2005; Cheke & Hume 2008; Cole 2009; Kraus 2009; Krysko *et al.* 2011; Meshaka 2011). The giant day gecko *Phelsuma grandis* Gray, 1870 is the perfect illustration of this phenomenon. Native to the north of Madagascar, this species has been reported to be a successful invader in different environments. Additionally, available literature indicates that *P. grandis* constitutes an important threat to native fauna and lizards in particular (Allison 2002; Krysko *et al.* 2003; Cole 2009; Sanchez & Gandar 2010a; Sanchez & Probst 2012; Dervin *et al.* 2013; Buckland *et al.* 2014).

On Reunion Island, the first invasive population of *P. grandis* was reported in

the mid-1990s (Probst 1997a). The tropical climate and a broad range of habitat have probably facilitated its establishment. Due to the potential negative impact on endemic threatened geckos (i.e. *P. inexpectata* Mertens, 1966 and *P. borbonica* Mertens 1966, respectively considered as Critically Endangered and Endangered (IUCN France & MNHN 2010)), since 2012 French law prohibits introduction and trading of all *Phelsuma* species in Reunion Island. The administrative destruction of *P. grandis*, *P. laticauda* (Boettger, 1880) and *P. madagascariensis* Gray, 1831 is also allowed. However, the ecology and distribution of *P. grandis* are poorly known on Reunion Island: only few data are published and no precise distribution map is currently available. The aim of this study is to fill the knowledge gap about habitats and distribution of *P. grandis* on Reunion Island.

Materials and methods

Study area

Together with Mauritius and Rodrigues, Reunion Island belongs to the Mascarene archipelago (Indian Ocean). Located 800 km east of Madagascar, it is an oceanic volcanic island. Dramatic topographical changes have generated numerous and diverse ecosystems, from the lowland xeric forest (western part, leeward side) to the lowland rain forest (eastern coast, windward side), through tropical mountain cloud forest. In contrast to Mauritius and Rodrigues where less than 1 % of the original vegetation still remains (Strahm 1996), original habitats are still well preserved on approximately 30 % of the surface of Reunion Island. The native vegetation is found at higher elevations (> 1000 m) and scarcely in lowland natural habitats (Strasberg *et al.* 2005).

Study species

Phelsuma grandis is an arboreal and diurnal gecko. In its native range, it inhabits secondary habitats (various plantations and orchards, palms or buildings), primary rainforest and deciduous dry forest (Glaw & Vences 2007; D'Cruze *et al.* 2009). The dorsal colour patterns consist of red spots on a brightly green background. Males have a larger size, a larger head and are more colourful than females (maximum total length 300 mm) (Wanger *et al.* 2009a; 2009b) (Fig. 1). Immatures (total length 65-70 mm) are also different from adults by exhibiting a dorsal pattern with more colour spots. Like other *Phelsuma* species, this species is territorial (Demeter 1976; Krysko *et al.* 2003). The diet consists of arthropods, snails, others geckos, plant resources such as floral nectar, fruits and seeds (Demeter 1976; Tytle 1992; Probst 1999; Dervin *et al.* 2013; Minnaar *et al.* 2013). On Reunion Island, *P. grandis* shows an opportunistic foraging behaviour by consuming a wide range of prey (Dervin *et al.* 2013).

Data collection and field sampling

To determine species distribution, precise geographic data (i.e., referring locality and/or GPS coordinates) were first compiled from literature (Girard 1997; Probst 1997a; 1997b; 1999; Deso 2001; Probst *et al.* 2002; Sanchez & Probst 2012). Dubos (2013) described a new introduced population in Manapany-les-Bains, but this population was

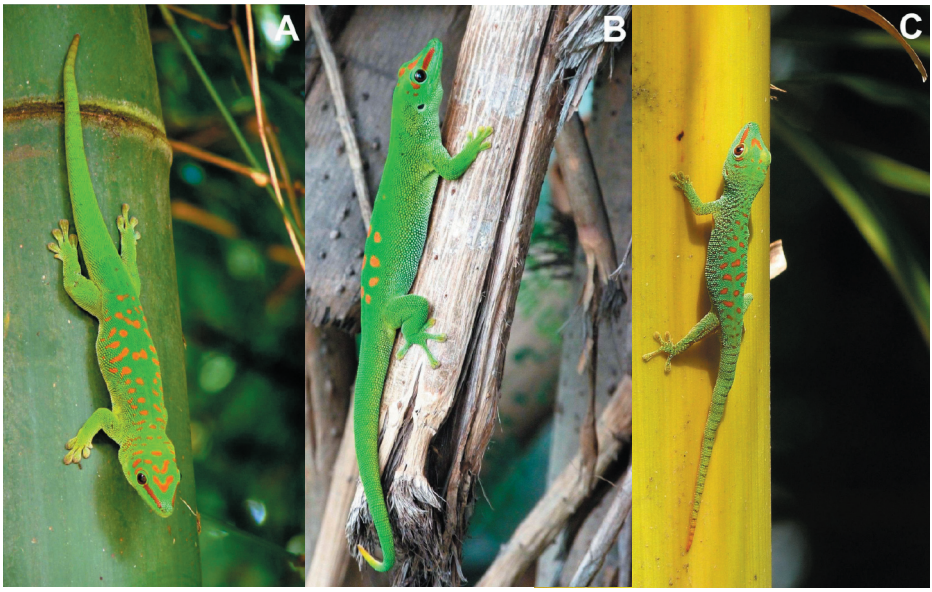

Fig. 1. The giant day gecko *Phelsuma grandis* on Reunion Island. A: male; B: female; C: immature.

eradicated in 2010 (Sanchez & Gandar 2010a; 2010b). As a consequence, these obsolete data from Dubos (2013) were excluded from our compiled dataset.

From 1996 to 2006, opportunistic observations were performed and were also included in our data. During 2007-2014, we recorded all data from local environmental services (naturalists, local NGO, etc.), and field oriented researches were performed, focusing nearby known sites of species distribution and on sites with doubtful observations. We surveyed suitable micro-habitats (eg. palm species, *Pandanus* thicket) during daytime for at least 20 minutes (list of surveys in Appendix I). Geckos were detected on visual cues using binoculars (10x42). For each observation, we collected different information: date, site, coordinates (UTM40S-WGS84 system), elevation, hour, sex and age, activity (e.g., insolation, movement, and alimentation), micro-habitat (plant or artificial structure), plant species used and natural habitat (according to Dupont *et al.* 2000). Our observations were divided in two age classes based on estimated total length of the gecko (TL<10 cm for immature; TL >10 cm for adult). Gender was distinguished using external sexual characters (hemipenal bulges and anofemoral pores for male, developed endolymphatic chalks sacs for female). In the field, we also collected data from testimonies of local person, notably information about the origin and the introduction date of this species.

Data analysis

Data are classified into two categories: (1) site where a breeding population

is established (with breeding clue and/or with several individual from different sex), name "population" and (2) site where the establishment of a breeding population is not confirmed (only one gecko and no breeding clue), name "station". Two sites separated from at least 1 km were considered as two distinct populations. Geographical data were mapped on a metric square grid (1 km²) using QUANTUM-GIS (Q-GIS 2013).

Results

A total of 170 records of *P. grandis* were gathered, 1 from literature, 7 collected opportunistically before 2007, 138 from field study performed between 2007 and 2014, and 24 from environmental services. From 2007 to 2014, we carried out 74 hours of surveys during which we counted 193 geckos, wherein 30 males, 26 females, 87 unsexed adults, and 50 immatures.

The distribution map of *P. grandis* on Reunion Island is shown in Figure 2. We identified 13 populations of this gecko, mainly occurring in the north and in the west coast (Table 1). Populations are distributed between 0 m and 600 m a.s.l. The largest population is localized in the north (Population n°11, "Niagara", Table 1) and corresponds to the first known introduction point on the island (Probst 1997a). Besides, 12 stations are identified, 9 in the north and 3 in the south. One station is in Saint-Joseph district, within the distribution area of the endemic Manapany-day-gecko (*P. inexpectata*).

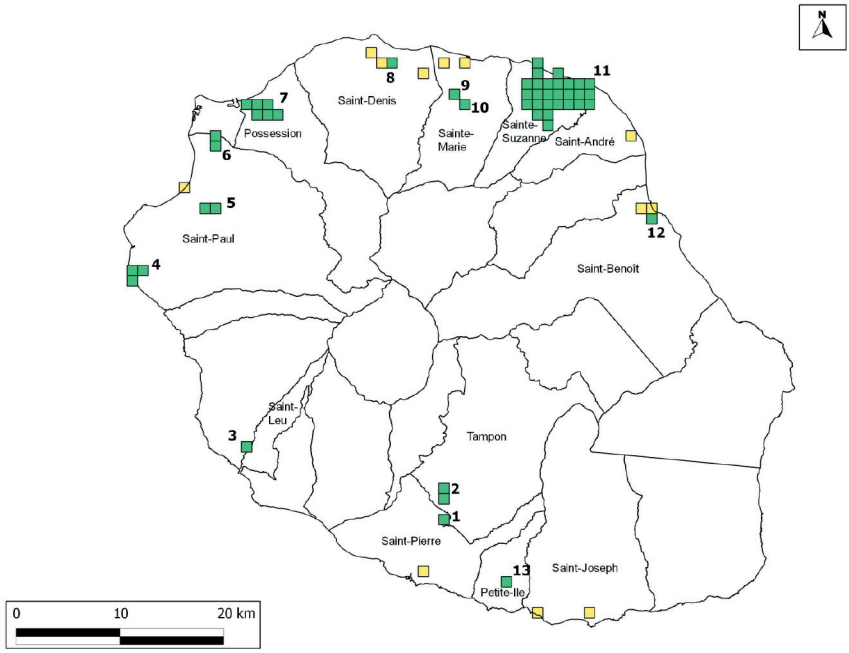

Fig. 2. Distribution map of *Phelsuma grandis* on Reunion Island. Black numbers refers to the population described in Table 1. Green square: breeding population; Yellow square: station; Black line: district limits.

Fig. 3. Habitats occupied by *Phelsuma grandis* in Reunion Island: A: bamboos; B: coconuts; C: shrubland savanna; D: secondary dry thickets.

Table 1. List of population of *Phelsuma grandis* on Reunion Island. Latitude and longitude are given in Universal Transverse of Mercator system (UTM, map datum: WGS84).

District	Lat.	Long.	Elevation (m)	Habitat	Introduction date	Origin	Sources
1 Condé Saint-Pierre	345166	7644235	380	Garden	<2009	Unknown	Testimony collected in field
2 Université du Tampon	345245	7647209	530-570	Garden, urban park	<2001	Unknown	G. Deso pers. comm,
3 Le Plateau, Saint-Leu	326148	7651656	310	Garden	<2009	Unknown	Testimony collected in field
4 Hermitage, Saint-Paul	315665	7667982	10	Garden, urban park	<1999	Deliberate introduction from Madagascar?	Probst et al. 2002; Testimony collected in field
5 Bellemène, Saint-Paul	322973	7674611	370	Garden	<2009	Deliberate introduction of unknown origin	Testimony collected in field
6 Cambaie, Saint-Paul	323431	7681156	100	Garden	<1999	Unknown	Probst et al. 2002; Testimony collected in field
7 Lataniers, Possession	328000	7683327	40-300	varied*	<2001	Unknown	Probst et al. 2002
8 Montgaillard, Saint-Denis	340336	7688015	130	Garden	<2009	Unknown	Testimony collected in field
9 Grande Montée, Sainte-Marie	346480	7685272	240	Garden	<2010	Unknown	Testimony collected in field
10 La Ressource, Sainte-Marie	347352	7684393	320	Garden	<2010	Unknown	Testimony collected in field
11 Niagara, Sainte-Suzanne Saint-André	356478	7685519	0-250	varied*,	1994 (first observation on Reunion Island)	Volontary release by reptile breeder	Probst 1997a
12 Palmiers Royals Saint-Benoit	365357	7673873	50	Garden	<2009	Unknown	Testimony collected in field
13 Chemin Mirabelle, Petite-Ile	351832	7638295	340	Garden	<2012	Unknown	Testimony collected in field

* varied = garden, bamboo, orchads, shrublands savanna, secondary dry thickets and woodland

Phelsuma grandis inhabits different types of habitats on Reunion Island (Fig. 3): human perturbed areas as gardens, urban parks, bamboos, orchards, coconuts, and banana plantation, as well as secondary and disturbed habitats, as shrubland savanna (dominated by *Pithecellobium dulce* and *Albizia lebbeck*), secondary dry thickets (dominated by *Leucaena leucocephala, Litsea glutinosa* and *A. lebbeck* or dominated by *Schinus terebinthifolius* and *Furcraea foetida*), secondary dry woodlands (dominated by *P. dulce*) and secondary wet thickets (dominated by *Syzygium jambos*). Most populations are located in urban areas (mainly in gardens), but two populations (Lataniers, n°7 and Niagara, n°11, Fig. 2, Table 1) are both urban areas and disturbed natural habitats (shrubland savanna, secondary thickets and woodlands).

Phelsuma grandis were observed on plant species and artificial structures (mainly on concrete wall and posts). Bamboos (*Dendrocalamus giganteus*), *Pandanus* sp., coconuts (*Cocos nucifera*), and others palm species (*Dypsis lutescens*, *Phoenix* sp., *Ravenala madagascariensis, Roystonea* sp., *Veitchia merrillii* and non-identified palm species) were the most frequently recorded plant species, followed by fruit trees (*Carica papaya*, *Litchi chinensis*, *Mangifera* sp.) and various other taxa (e.g., *A. lebbeck*, *Calophyllum inophyllum*, *Casuarina equisetifolia*, *Coccoloba uvifera*, *Dracaena* sp., *Eucalyptus* sp., *Furcaea. foetida*, *Heliconia* sp., *Hiptage benghalensis*, *Leucaena leucocephala*, *Litsea glutinosa*, *Musa* sp., *Pithocellobium dulce*, *Saccharum officinarum*, *Senna* sp., *Schinus terebinthifolius*, *Syzygium cumini*, *Terminalia catappa* and non-identified plants species).

Discussion

Phelsuma grandis on Reunion Island was first recorded in 1994 (Probst 1997a), but the number of introduction events from Madagascar, or from reptile nurseries, is unknown. In this study, 13 breeding populations are identified, mainly distributed in the northern and western part of the island. The broad pattern of distribution and the number of populations suggest that multiple and independent introductions from Madagascar or from existing populations on Reunion Island are probably common. Moreover, *P. grandis* can be transported accidentally over vast distances. "Vehicular-rafting" could be an important diffusion agent for geckos (Gill *et al.* 2001; Norval *et al.* 2012), and presumably for *P. grandis* in particular (Deso 2001). Additionally, dissemination (eggs and geckos) can also occur by transporting plants and materials (pers. obs. J.-M.P. & M.S.)**.** The number of stations without observed breeding (n=12) could be explained by these saltatory dispersal processes.

Phelsuma grandis inhabits only disturbed habitat, outside of native forest. It has a wide range of habitats, but it mainly occurs in human-disturbed habitats. Two populations, initially restricted to urban area (e.g., Lataniers, n°7 and Niagara, n°11; Probst 1997a; Probst et al. 2002), are now distributed in disturbed natural habitats (shrubland savanna, secondary thickets and woodlands), suggesting range expansion through natural colonization. The presence of viable populations in these kinds of habitats in combination, with the native environmental ranges of *P. grandis* in Madagascar (i.e., primary rainforest and deciduous dry forest) point out that this invasive gecko could colonize native forests of Reunion Island. Given the *P. grandis* diet, and that the

proportion of endemic species of arthropods and terrestrial snails increases related to the level of preservation of the habitats (Quilici et al. 2002; Ledoux 2004; Griffith & Florens 2006; Ledoux 2007; Attié et al. 2008; Martiré & Rochat 2008), this invasive species may have an important negative impact on these fauna groups.

As observed in its native range (Van Heygen 2004; D'Cruze *et al.* 2009) and other invaded countries (Florida, Bartlett & Bartlett 1999; Krysko & Hooper 2006; 2007; Mauritius, Cole 2009), *P. grandis* frequently uses bamboos, coconuts, fruit trees and others palm species. These habitats are similar to those where the native geckos (*P. inexpectata* and *P. borbonica*) have been reported (Sanchez *et al.* 2009; Sanchez 2012). Except for the station discovered within the distribution area of the endemic *P. inexpectata* (despite several field searches, occurrence of a breeding population is not proven), the distribution of *P. grandis* does not overlap with the distribution of native day geckos. In case of sympatry with native geckos, given the similarity in ecological preferences, behaviour, diet, and larger size, the invasive species may increase the inter-specific competition for space and food resources (plant and animal). Also, direct predation (observed on several geckos included *Phelsuma* sp.; Cole 2009; Buckland *et al.* 2014) might lead to the sharp decline of native geckos. On Mauritius, Buckland *et al.* (2014) have shown that native *Phelsuma* sp. suffer from the presence of *P. grandis* (strong decrease in abundance and local extinction), but causes leading to the decline are not clearly identified.

By providing a precise picture of the distribution of *P. grandis* on Reunion Island, this study is a critical step in the Regional Management Plan (Sanchez 2013) defined (1) to control the expansion of *P. grandis* through the island and (2) to avoid settlement of this invasive species in natural areas where it could directly threaten the native fauna, notably day gecko species. In order to complete these objectives, several actions (e.g., communication toward general public and conservation workers, and population control) are in progress or will be conducted during the coming years. The former natural colonization and saltatory dispersal suggest that the spread of *P. grandis* will continue on Reunion Island: this species will probably established viable populations in native forests and in the range of native day geckos. Given its potential negative impacts, it is crucial to take dispersal process into consideration (saltatory dispersal and natural colonization) for the management of this invasive species.

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References

Allison, A. (2002) New record of *Phelsuma madagascariensis* in Hawaii. Available at: http://www.phelsumania.com/public/artoc;es/biogeography_hawaii.html. Last accessed on 13 August 2013.

Attié, M., T. Bourgoin, J. Veslot & A. Soulier-Perkins. (2008) Patterns of trophic relationships between planthoppers (Hemiptera: Fulgoromorpha) and their host plants on the Mascarene Islands. J*ournal of Natural History* **42** (23-24): 1591-1638.

Austin, J.J., E.N. Arnold & C.G Jones. (2004) Reconstructing an island radiation using ancient and recent DNA: the extinct and living day geckos (*Phelsuma*) of the Mascarene islands. *Molecular Phylogenetics and Evolution* **31**: 109-122.

Bartlett, R.D. & P.P. Bartlett. (1999) *A Field Guide to Florida Reptiles and Amphibians.* Gulf Publishing Company, Houston, Texas, USA, 278 pp.

Buckland, S., N.C. Cole, J. Aguirre-Gutiérrez, L.E. Gallagher, S.M. Henshaw, A. Besnard, R.M. Tucker, V. Bachraz, K. Ruhomaun & S. Harris. (2014) Ecological Effects of the Invasive Giant Madagascar Day Gecko on Endemic Mauritian Geckos: Applications of Binomial-Mixture and Species Distribution Models. *Plos One* **9**(4). doi e88798.

Cheke A.S. & L. Hume. (2008) *Lost Land of the Dodo. An Ecological History of Mauritius, Réunion & Rodrigues.* T & Ad Poyser ed., London, 464 pp.

Cole, N.C. (2009) *A Field Guide to the Reptiles and Amphibians of Mauritius.* Defra's Darwin Initiative & Mauritian Wildlife Foundation, Mauritius, 80 pp.

D'Cruze, N., J. Sabel, J. Dawson & S. Kumar. (2009) The influence of habitat type and structure on the abundance of *Phelsuma madagascariensis grandis* (Gekkonidae) in northern Madagascar. *Herpetological Conservation and Biology* **4**: 55-61.

Demeter, B.J. (1976) Observations on the care, breeding and behaviour of the giant day gecko *Phelsuma madagascariensis* at the National Zoological Park, Washington. *International Zoo Yearbook* **16**: 130-133.

Dervin, S., S. Baret, L. Penin & M. Sanchez. (2013) Régime alimentaire du grand gecko vert de Madagascar, *Phelsuma grandis* Gray, 1870 (Squamata : Gekkonidae) sur l'île de La Réunion. *Cahiers Scientifiques de l'océan Indien occidental* **4**: 29-38.

Deso, G. (2001) Note sur le transport insolite de geckos verts, le cas du *Phelsuma inexpectata*. *Bulletin Phaethon* **13**: 56.

Dubos, N. (2013) New locality record for *Phelsuma grandis* (Sauria: Gekkonidae) in Reunion, in sympatry with the critically endangered *Phelsuma inexpectata*. *Herpetology Notes* **6**: 309-311.

Dupont, J., D. Strasberg & J.-C. Rameau. (2000) Typologie des Milieux Naturels et des Habitats de La Réunion. Version 2010 modifié par F. PICOT et M. SALIMAN. DIREN Réunion/Université de La Réunion, 27 pp.

Gill, B.J., D. Bejakovtch & A.H. Whitaker. (2001) Records of foreign reptiles and amphibians accidentally imported to New Zealand. *New Zealand Journal of Zoology* **28**: 351-359.

Girard, F. (1997) Présentation des espèces du genre Phelsuma vivant sur l'île de La Réunion. *Bulletin de la Société Herpétologique de France* **84**: 55-56.

Glaw, F. & M. Vences. (2007) *A Field Guide to the Amphibians and Reptiles of Madagascar.* 3rd Edition, M. Vences & F. Glaw Verlag, Germany, 495 pp.

Griffiths, O.L. & F.B.V. Florens. (2006) *A field guide to the non-marine molluscs of the Mascarene Islands (Mauritius, Rodrigues and Réunion) and the Northern* Dependencies of Mauritius. Bioculture Press, Mauritius, 185 pp.

IUCN France & MNHN (2010) La Liste rouge des espèces menacées en France. Premiers résultats pour la faune de La Réunion. Dossier de presse. 1 july 2010. MNHN, IUCN France, 26 pp.

Kraus, F. (2009) *Alien Reptiles and Amphibians. A Scientific Compendium and Analysis. Series: Invading Nature* - Springer Series in Invasion Ecology Vol. 4, Germany, 564 pp.

Krysko, K.L., J.P. Burgess, M.R. Rochford, C.R. Gillette, D. Cueva, K.M. Enge, L.A. Somma, J.L. Stabile, D.C. Smith, J.A. Wasilewski, G.N. Kieckhefer, M.C. III Granatosky & S.V. Nielsen. (2011) Verified non-indigenous amphibians and reptiles in Florida from 1863 through 2010: Outlining the invasion process and identifying invasion pathways and stages. *Zootaxa* **3028**: 1-64.

Krysko, K.L. & A.N. Hooper. (2006) *Phelsuma madagascariensis grandis* (Madagascar Giant Day Gecko). Nectarivory; Potential pollination. *Herpetological Review* **37**(2): 226.

Krysko, K.L. & A.N. Hooper. (2007) Potential Pollination of Non-native Coconut Palms, *Cocos nucifera* (Arecales: Arecaceae), by Non-native Madagascar Giant Day Geckos, *Phelsuma madagascariensis grandi*s (Sauria: Gekkonidae), in the Florida Keys. *Gekko* **5**: 33-38.

Krysko, K.L., A.N. Hooper & C.M. III. Sheehy. (2003) The *Phelsuma madagascariensis grandis* (Gray, 1970) (Sauria: Gekkonidae): a New established species. *Florida Scientist* **66** (3): 222-225.

Ledoux, J.C. (2004) Araignées de l'île de La Réunion: I. Hahniidae, Ctenidae, Thomisidae et Clubionidae. *Revue Arachnologique* 14: 159-191.

Ledoux, J.C. (2007) Araignées de l'île de La Réunion : II. Salticidae (Araneae). *Revue Arachnologique* 17: 9-34.

Lever, C. (2003) *Naturalized Reptiles and Amphibians of the World.* Oxford University Press, Oxford, U.K, 338 pp.

Martiré, D. & J. Rochat. (2008) *Les Papillons de la Réunion et leurs chenilles*. Biotope Edt, Museum National d'Histoire Naturelle, Paris, 496 pp.

Meshaka, W.E. (2011) *A Runaway Train in the Making: The Exotic Amphibians, Reptiles, Turtles, and Crocodilians of Florida.* Monograph 1. Herpetological Conservation and Biology 6: 1-101.

Minnaar, I.A., A. Köhler, C. Purchase & S.W. Nicolson. (2013) Coloured and Toxic Nectar: Feeding Choices of the Madagascar Giant Day Gecko, P*helsuma grandis. Ethology* 119: 417-426.

Mozzi, R., G. Deso & J.-M. Probst. (2005) Un nouveau gecko vert introduit à La Réunion le *Phelsuma astriata semicarinata* (Cheke, 1982). *Bulletin Phaethon* 21: 1-4.

Norval, G., F.-Y. Lu, J.-J. Mao & K. Slater. (2012) It is not inside, it is on top! An example of vehicular-rafting by a house gecko (Hemidactylus frenatus Schlegel, 1836). *Herpetology Notes* **5**: 451-452.

Probst, J.-M. (1997a) *Animaux de La Réunion - Guide d'identification des oiseaux, mammifères, reptiles et amphibiens*. Azalées Editions, Réunion, 168 pp.

Probst, J.-M. (1997b) Contribution à la connaissance plus précise du milieu d'origine de quatre reptiles naturalisés à La Réunion avec une présentation des sous-espèces concernées. *Bulletin Phaethon* 6: 71-74.

Probst, J.-M. (1999) Guide préliminaire des reptiles sédentaires de l'île de La Réunion et des îles éparses avec une liste des espèces migratrices et erratiques répertoriées depuis 10 ans. *Bulletin Phaethon* 10: 57-91.

Probst, J.-M., A. Turpin, G. Deso, L. Albert, P. Brial & K. Abhaya. (2002) Un gecko vert devenant très envahissant : *Phelsuma madagascariensis grandis* à La Réunion. *Bulletin Phaethon* 15: 46.

Q-GIS (2013) Quantum-GIS, version 1.8.0-Lisboa.

Quilici, S., M. Attié, F. Chiroleu, P. Ryckewaert, B. Reynaud, C. Guillermet, J. Poussereau, S. Ribes, R. Parnaudeau & S. Couteyen. (2002) Eléments pour une synthèse des connaissances sur l'entomofaune endémique des Hauts de La Réunion. Mission Parc National des Hauts de La Réunion / CIRAD / Insectarium de La Réunion / M.H.N. de La Réunion, 91 pp.

Rocha, S., H. Rosler, P.S. Gehring, F. Glaw, D. Posada, D.J. Harris & M. Vences. (2010) Phylogenetic systematics of day geckos, genus Phelsuma based on molecular and morphological data (Squamata: Gekkonidae). *Zootaxa* 2429: 1-28.

Rocha, S., M. Vences, F. Glaw, D. Posada & D.J. Harris. (2009) Multigene Phylogeny of Malagasy day geckos of the genus *Phelsuma. Molecular Phylogenetics and Evolution* 52: 530-537.

Sanchez, M. (2012) Le gecko vert de Bourbon, *Phelsuma borbonica* Mertens 1966, atlas de répartition, écologie et conservation. Nature Océan Indien unpublished report, La Réunion, 65 pp.

Sanchez, M. (2013) Plan Régional de Lutte contre le grand gecko vert de Madagascar, *Phelsuma grandis* Gray 1870, sur l'île de La Réunion. Nature Océan Indien unpublished report, La Réunion, 54 pp.

Sanchez, M. & A. Gandar. (2010a) Le grand gecko vert malgache, *Phelsuma grandis* Gray, 1870 (Squamata : Gekkonidae) introduit à Manapany-les-Bains : compte rendu des opérations visant à enrayer l'invasion. *Bulletin Phaethon* 30: 20-22.

Sanchez, M. & A. Gandar. (2010b) Etat des lieux de la population introduite à Manapany-les-Bains du grand gecko vert malgache, *Phelsuma grandis* Gray 1870. Nature Océan Indien unpublished report, La Réunion, 26 pp.

Sanchez, M. & J.-M. Probst. (2012) Présentation et clé de détermination des geckos verts du genre *Phelsuma* (Gray, 1825) de l'île de La Réunion (Squamata : Gekkonidae). *Cahiers Scientifiques de l'océan Indien occidental* 3: 11-17.

Sanchez, M., J.-M. Probst & G. Deso. (2009) *Phelsuma inexpectata,* Mertens, 1966 (Sauria : Gekkonidae) sur l'île de La Réunion : Ecologie, répartition et menaces. *Bulletin de la Société Herpétologique de France* 132: 43-69.

Strahm, W. (1996) Conservation of the flora of the Mascarene islands. *Curtis's Botanical Magazine* 13: 214-217.

Strasberg, D., M. Rouget, D.M. Richardson, S. Baret, J. Dupont & R.M. Cowling (2005)

An assessment of habitat diversity, transformation and threats to biodiversity on Réunion Island (Mascarene Islands, Indian Ocean) as a basis for conservation planning. *Biodiversity and Conservation* 14 (12): 3015-3032.

Tytle, T. (1992) Day geckos: *Phelsuma* The captive maintenance and propagation of day geckos. *Vivarium* 2: 15-19.

Uetz, P. (2013) The Reptile Database. Available at: http://www.reptile-database.org. Last accessed on 5 September 2013.

Van Heygen, E. (2004) The genus *Phelsuma* GRAY, 1825 on the Ampasindava peninsula, Madagascar. *Phelsuma* 12: 99-117.

Wanger, T.C., I. Motzje, S.C. Furrer, B.W. Brook & B. Gruber. (2009a) How to monitor elusive lizards: comparison of capture–recapture methods on giant day geckos (Gekkonidae, *Phelsuma madagascariensis grandis*) in the Masoala rainforest exhibit, Zurich Zoo. *Ecological Research* 24: 345-353.

Wanger, T.C., I. Motzje, S.C. Furrer & B. Gruber. (2009b) Movement patterns and habitat selection of the giant day gecko (*Phelsuma madagascariensis grandis*) in the Masoala rainforest exhibit, Zurich Zoo. *Salamandra* 45 (3): 147-153.

Appendix I

List of locality surveys during the study. Latitude and longitude are given in Universal Transverse of Mercator system (UTM, map datum: WGS84).

Locality	District	LAT.	LONG.	Elevation (m)	Research effort (min.)	n gecko	Cited by
Camp Magloire	POSSESSION	327770	7685147	10	20	0	_
Camp Magloire, Petite Ravine Lataniers	POSSESSION	327495	7684712	50	40	2	_
Grande Ravine des Lataniers	POSSESSION	329082	7683402	110	45	0	_
Grande Ravine des Lataniers	POSSESSION	328840	7683603	80	105	20	_
Grande Ravine des Lataniers	POSSESSION	327216	7684006	20	20	0	_
Grande Ravine des Lataniers	POSSESSION	327968	7683833	34	25	8	_
Grande Ravine des Lataniers	POSSESSION	328327	7683790	60	40	9	_
Grande Ravine des Lataniers	POSSESSION	327338	7683935	35	45	4	_
Le vingt-huitième	POSSESSION	328327	7684890	160	60	0	_
Pépinière	POSSESSION	326858	7683773	27	20	0	_
Petite Ravine Lataniers	POSSESSION	328029	7684523	50	35	0	_
Petite Ravine Lataniers	POSSESSION	327064	7684186	32	25	0	_
Grande Montagne, résidence	POSSESSION	327200	7683820	37	20	0	_
Grande Ravine Lataniers, Rive Gauche	POSSESSION	327853	7683317	100	165	6	_
Commune Ango, Arrêt Bus Paille en Queue	SAINT ANDRE	357667	7684890	10	20	0	_
Cascade Delice	SAINT ANDRE	358278	7684408	36	20	0	_
Collège de Cambuston	SAINT ANDRE	359107	7685135	10	25	0	_
Collège des Milles Roches	SAINT ANDRE	359611	7680665	110	35	0	Probst et al., 2002
Hangar agricole Petit Etang	SAINT ANDRE	359684	7685747	5	45	1	_
Littoral de Cambuston, STEP	SAINT ANDRE	360540	7685871	0	20	0	_
Maison Tony, rue E. Thomas	SAINT ANDRE	359479	7684669	20	35	2	_
Parc du Colosse	SAINT ANDRE	360897	7685190	20	30	0	_
Quartier de Cambuston	SAINT ANDRE	359352	7685014	0	20	0	_
Rue des Saphirs	SAINT ANDRE	358123	7683596	100	20	0	_
Chemin des Palmiers Royals	SAINT BENOIT	365357	7673873	50	20	4	_
La Marine, Bourbier	SAINT BENOIT	365518	7674368	10	60	0	_
La Marine, Bourbier	SAINT BENOIT	365528	7674359	0	55	0	_
La Montagne, Chemin de la Vigie	SAINT DENIS	336365	7689919	345	25	0	Probst et al., 2002
Chemin Grand Canal	SAINT DENIS	343209	7687068	120	35	1	_

Locality	District	LAT.	LONG.	Elevation (m)	Research effort (min.)	n gecko	Cited by
Grande Montée	SAINT DENIS	346670	7685361	250	60	1	_
Grande Montée	SAINT DENIS	346480	7685272	230	20	1	_
La Bretagne, Eglise	SAINT DENIS	343361	7684905	310	40	0	_
Montgaillard	SAINT DENIS	340342	7688034	120	20	1	_
Parc de la Providence	SAINT DENIS	339373	7688270	47	40	0	Probst et al., 2002
La Montagne, Résidence	SAINT DENIS	336822	7689559	405	20	0	Probst et al., 2002
La Montagne, Résidence	SAINT DENIS	335458	7689388	354	30	0	Probst et al., 2002
La Montagne, Rue des Pétrels	SAINT DENIS	334659	7689345	270	20	0	_
Rue Montgaillard	SAINT DENIS	340336	7688015	130	30	1	_
Piton Saint Leu, le Plateau	SAINT LEU	326164	7651648	310	20	8	_
Cambaie, résidence	SAINT PAUL	323305	7681023	57	60	3	_
Cambaie, zone industrielle	SAINT PAUL	322995	7681227	50	30	0	_
Bellemène	SAINT PAUL	322808	7674592	370	20	1	_
Bellemène	SAINT PAUL	322928	7674652	350	25	2	_
Bellemène	SAINT PAUL	323081	7674521	370	45	10	_
Bellemène, amont du Chemin Lougnon	SAINT PAUL	322698	7675040	290	25	0	_
Bellemène r	SAINT PAUL	323183	7674494	380	30	0	_
Bellemène, Chemin Lougnon	SAINT PAUL	322499	7675174	230	30	0	_
Bellemène, école catholique	SAINT PAUL	322991	7674509	380	25	0	_
Cambaie résidence	SAINT PAUL	323474	7681094	10	70	16	_
La Saline	SAINT PAUL	315682	7668031	0	40	2	_
La Saline, bord de mer	SAINT PAUL	315785	7667578	0	60	0	_
La Saline, école primaire	SAINT PAUL	315715	7668477	5	50	0	_
La Saline, Casino	SAINT PAUL	315456	7669043	0	20	0	_
Rue Pothier, Vieux Plongeur	SAINT PAUL	321077	7676436	0	60	0	_
Condé, Ancienne National	SAINT PIERRE	345066	7644165	390	55	1	_
Condé, Ancienne National	SAINT PIERRE	345795	7645052	460	20	0	_
IUT de Terre Sainte, Nord	SAINT PIERRE	343372	7639437	45	55	0	_
IUT de Terre Sainte, Sud	SAINT PIERRE	343531	7639305	60	55	0	_
Allée coco	SAINTE MARIE	347312	7684401	320	40	5	_
Allée coco, aval	SAINTE MARIE	347232	7684843	280	30	0	_
La Ressource, Chemin des Evis	SAINTE MARIE	346968	7684491	280	20	0	_
La Ressource les Hauts	SAINTE MARIE	347304	7684358	320	60	3	_

Locality	District	LAT.	LONG.	Elevation (m)	Research effort (min.)	n gecko	Cited by
Le Verger, Allée Coco	SAINTE MARIE	347144	7683852	390	50	0	_
Ravine des Figues	SAINTE MARIE	347807	7684917	260	25	0	_
Littoral Ste Marie, médiathèque	SAINTE MARIE	349220	7688726	0	30	0	_
Chemin Marencourt, Cascade Niagara	SAINTE SUZANNE	356135	7686379	10	30	2	_
Commune Ango	SAINTE SUZANNE	355423	7682209	180	20	1	_
Commune Ango	SAINTE SUZANNE	354471	7681914	278	20	0	_
Embouchure Rivière Sainte Suzanne	SAINTE SUZANNE	356216	7687105	0	75	1	_
Amont Rivière Saint Jean	SAINTE SUZANNE	356821	7683033	157	30	0	_
Pointe Canal	SAINTE SUZANNE	352767	7683815	300	20	0	_
Bassin Bœuf, aval	SAINTE SUZANNE	352984	7683528	317	35	0	_
Bagatelle, sommet de ravine	SAINTE SUZANNE	352982	7684404	260	55	0	_
Bagatelle, sommet de ravine	SAINTE SUZANNE	352980	7684405	270	30	0	_
Bagatelle, sommet de ravine	SAINTE SUZANNE	353180	7684692	250	20	0	_
Grand Rivière Saint Jean	SAINTE SUZANNE	355906	7681816	210	20	0	_
Camp des Evis, Arrêt Bus Pablo Neruda	SAINTE SUZANNE	357750	7683780	90	20	0	_
Camp Hazier	SAINTE SUZANNE	353804	7687621	60	30	0	_
Cascade Délice, Est	SAINTE SUZANNE	358200	7684420	34	20	0	_
Cascade Délice, Ouest	SAINTE SUZANNE	357799	7684462	44	30	0	_
Cascade Niagara	SAINTE SUZANNE	354927	7686019	20	30	4	_
Chemin Marencourt, Cascade Niagara	SAINTE SUZANNE	355663	7686383	10	20	7	_
Commune Ango	SAINTE SUZANNE	356764	7683720	120	40	0	_
Commune Ango les Bas	SAINTE SUZANNE	357674	7684886	15	50	1	_
Commune Ango, Arrêt de Bus Longani	SAINTE SUZANNE	356135	7683432	165	20	0	_
Commune Carron, Bellevue	SAINTE SUZANNE	355584	7684351	150	30	2	_
Commune Carron, Bellevue	SAINTE SUZANNE	354914	7684138	230	30	1	_
Deux Rives	SAINTE SUZANNE	356304	7682335	176	30	0	_
Etang de Bois Rouge	SAINTE SUZANNE	359022	7686669	0	20	2	_
Front de mer de Sainte Suzanne	SAINTE SUZANNE	354910	7687913	0	20	4	_
Grande Montée	SAINTE SUZANNE	353793	7685310	160	25	2	_
Hauts de Bellevue, ruisseau la Vigne	SAINTE SUZANNE	354635	7683646	250	60	0	_
Hauts de Bellevue, ruisseau la Vigne	SAINTE SUZANNE	354699	7683735	240	30	0	_
La Liberté	SAINTE SUZANNE	354823	7684667	190	20	5	_
La Liberté	SAINTE SUZANNE	354530	7684032	230	20	0	_

Locality	District	LAT.	LONG.	Elevation (m)	Research effort (min.)	n gecko	Cited by
La Liberté	SAINTE SUZANNE	354183	7683876	270	20	0	_
La Libertée	SAINTE SUZANNE	355021	7684661	180	30	4	_
La Marine	SAINTE SUZANNE	357079	7687070	0	40	0	_
L'Espérance	SAINTE SUZANNE	355176	7682435	190	30	2	_
Littoral Sainte Suzanne	SAINTE SUZANNE	354238	7688290	40	35	2	_
Littoral Camp Hazier, temple Tamoul	SAINTE SUZANNE	353069	7688528	20	20	0	_
Littoral de Sainte Suzanne, SDIS	SAINTE SUZANNE	355363	7687700	0	20	1	_
Mairie annexe Saint Suzanne	SAINTE SUZANNE	358041	7685172	7	55	2	_
Niagara, Renaissance	SAINTE SUZANNE	355057	7685521	52	20	1	_
Petite Rivière Saint Jean	SAINTE SUZANNE	355997	7682646	140	40	0	_
Bel Air	SAINTE SUZANNE	353767	7686922	90	20	0	_
Jacque Cargot	SAINTE SUZANNE	353926	7686388	110	30	0	_
Résidentiel de Bagatelle	SAINTE SUZANNE	352574	7685180	560	25	0	_
Radier Rivière Sainte Suzanne	SAINTE SUZANNE	353725	7684845	200	50	2	_
Ravine du centre d'enfouissement	SAINTE SUZANNE	354287	7686595	90	30	0	_
Rivière Sainte Suzanne	SAINTE SUZANNE	353616	7684704	165	40	1	_
Route	SAINTE SUZANNE	357170	7685745	0	25	9	_
Ruisseau Marie Jeanne	SAINTE SUZANNE	353354	7683911	290	25	0	_
Usine de Bois Rouge, stade	SAINTE SUZANNE	358740	7686740	0	20	5	_
Bois Rouge, Temple Tamoul	SAINTE SUZANNE	357676	7686478	0	20	7	_
Clinique Durieux	TAMPON	345574	7647007	570	35	0	_
Clinique Durieux	TAMPON	345129	7646690	510	30	1	_
Impasse du père Maunier	TAMPON	345817	7647480	605	55	0	_
La Chatoire	TAMPON	345403	7646595	520	30	0	_
Résidence Fushia	TAMPON	345196	7646788	515	20	3	_
Université du Tampon	TAMPON	345245	7647209	540	30	3	_
Université du Tampon	TAMPON	345113	7647086	550	40	2	_
Université du Tampon, impasse Archambaud	TAMPON	345419	7647444	570	40	2	_
Chemin des Mirabelles	PETITE ILE	351832	7638295	340	135	2	_