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A rapid herpetofaunal assessment of Nosy Komba Island, northwestern Madagascar, with new locality records for seventeen species

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Abstract. A rapid assessment of the herpetofauna on the offshore island of Nosy Komba, northwestern Madagascar, found six species of amphibian and 26 species of reptile. Seventeen of these species have not previously been recorded on the island, to the best of our knowledge. The list of newly recorded species includes mostly nocturnal animals such as *Uroplatus henkeli, Paroedura oviceps, Lycodryas granuliceps* and *Geckolepis maculata,* suggesting that previous surveys on the island were undertaken during the day. Our findings raise the island's currently known herpetofaunal species count to 38, being represented by nine amphibian and 29 reptile species. This paper expands upon the currently modest amount of information available for the small island's herpetological composition and reveals the need for stricter protection of its forests in the future. The aim of this paper is to increase the knowledge on the herpetofauna of Nosy Komba and help future environmental management to protect this unique insular fauna and flora.

Key words. Amphibia, Squamata, Nosy Komba, Madagascar, island diversity, new records.

Introduction

The offshore island of Nosy Komba (known locally as Nosy Ambariovato) is situated approximately 2.7 km from Nosy Be off the northwest coast of Madagascar. Unlike its larger island neighbour, the species composition of Nosy Komba is relatively unstudied, with the island's herpetofauna being surprisingly neglected. Nosy Komba was previously merged to its neighbouring offshore islands, including Nosy Be, around 15,000 years ago and has been isolated as an island from mainland Madagascar for approximately 8,000 years (Andreone et al. 2003). Due to the island's small size and location, its herpetofauna is presumed to represent a small subset of what is found on nearby Nosy Be and within suitable Sambirano forest habitats on the adjacent mainland (Andreone et al. 2003).

Studying island faunae is very interesting, as not only does it help explain current distribution and historical dispersal patterns, but also allows finer insight into the causes and mechanisms of extinction (Andreone et al. 2003). Nosy Komba appears to have very little primary forest remaining due to historical felling, and currently has essentially no environmental protection in place (Rasamimahavonjy, pers. comm., 22 July 2013). Current knowledge and research concerning the extent and status of secondary and unprotected forest is limited (Andreone et al. 2003), and its future is uncertain.

At the higher reaches of the island, there are remains of an old arboretum, although it has suffered significant storm damage since its installation during colonial times. This installation covers an area of around 60 ha and is currently under the protectorate of the Ministry of the Environment and Forest. However, logging still continues within this zone, as there is essentially no active policy enforcement. There are also no current restrictions towards development on the island and no permanent research station or resident monitors. The impact that forest clearance and anthropogenic disturbance is having on the islands biodiversity trends remains unclear.

Nosy Komba rises sharply from its shores on all sides and reaches around 622 m at its highest point. The higher altitudes support agriculture, with many banana, sugar cane, pepper and coffee plantations present, yet there remains a surprising amount of recovered secondary forest. Notably, there is also a large bamboo forest covering the upper reaches of the northern side of the island, composed of a species that is presumably native to Madagascar, but has been introduced to Nosy Komba (Rasamimahavonjy, pers. comm., 22 July 2013). The island is a popular tourist destination, with many luxury resorts and hotels established along the beaches, although no tourist infrastructure exists inland or at higher altitudes. The economy is primarily driven by a combination of leisure and ecotourism, with several groups of habituated black lemur (*Eulemur macaco macaco*) helping to attract European visitors.

Methods

Three separate trips were made to Nosy Komba (Fig. 1) during the Austral winter of 2013, specifically to assess the diversity of the reptile and amphibian community on the island. Each rapid biodiversity assessment (RBA) period took place on the island for a period of three days, during which intensive surveys were conducted both during the day and night in all weather conditions. The surveys were conducted with roughly a month's separation in between, from 23–25 July, 26–28 August, and 11–13 September. Unfortunately, no surveys could be conducted during the Malagasy rainy season, a period of peak activity of the native herpetofauna (Glaw & Vences 2007). Organised active searches were conducted during the early mornings, afternoons, at dusk and during the night on each of our expeditions. Each survey lasted approximately two hours, and combined with the recording of casual observations, our methods were designed to record the diverse herpetological community as efficiently as possible.

Our surveys covered all major habitat types and all regions of the island. On each expedition, base camp was set near an old Christian monastery, situated at mid/high altitude in a central position on the island. From here, it was possible to reach the majority of our intended sample habitats within a short time, allowing us maximum surveying time in specific environments. On each expedition, a small group of local guides were hired to help us access the more remote regions of the island's interior.

Our methodology fundamentally followed the standard survey protocol as outlined by D'Cruze et al. (2007). During an active search, each microhabitat was explored and checked thoroughly yet circumspectly, minimising our impact at the survey location. Each level of the forest was scrutinised, with binoculars being used to identify any species observed high up in the canopy, and a thin stick to agitate and reveal any species hidden in the leaf litter. Photographic evidence (Figs. 2–3) was taken for verifying species identifications. Any individuals that still could not be positively identified were omitted from the results. Frog calls were not used as an identification tool during this assessment, as no recording equipment was available. Casual observations are also included in our results.

In this study, the surveyed environments were categorised as belonging to either areas of established forest or as degraded habitats. Established forest areas were defined as those that contained numerous mature trees, thick leaf litter, experienced no regular human disturbance, and have some level of protection. In contrast, the degraded habitats consisted of plantation- or agricultural-type lands, bamboo forest, village environs, and areas of secondary forest that regularly experience human disturbance.

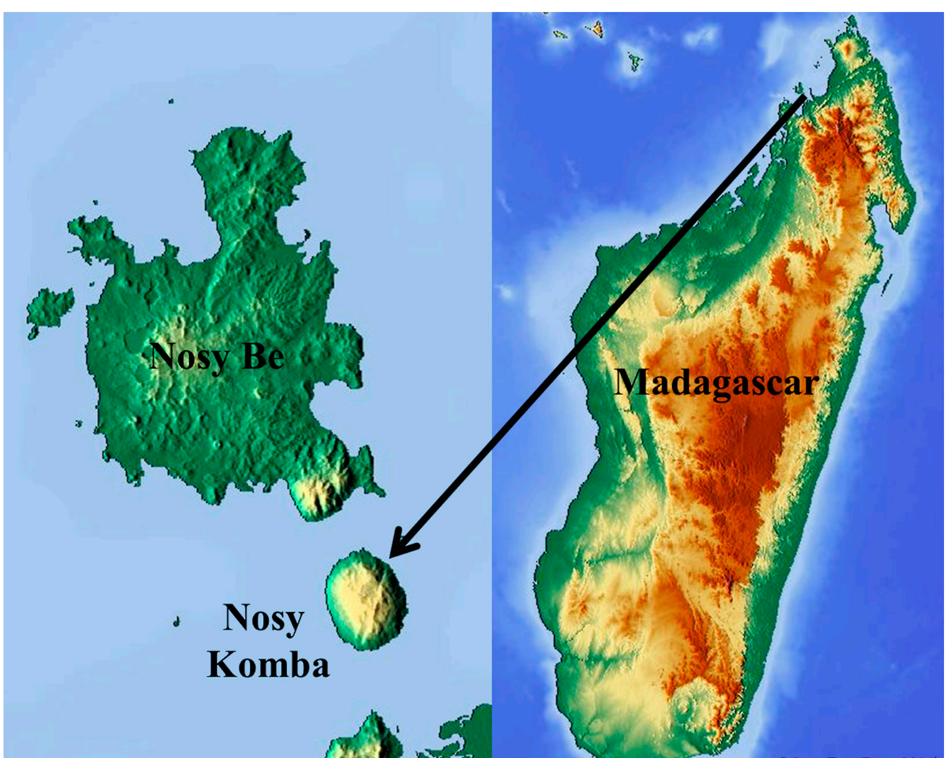

Figure 1. The geographical location of Nosy Komba, between Nosy Be and mainland North West Madagascar.

Figure 2. Photographs of the additional species recently found on Nosy Komba: A) *Blommersia wittei*, B) *Mantidactylus ulcerosus*, C) *Calumma boettgeri*, D) *Trachylepis gravenhorstii*, E) *Lycodryas granuliceps*, F) *Sanzinia volontany*, G) *Uroplatus henkeli*, H) *Uroplatus ebenaui.* (Photographs by C. Daly & Frontier).

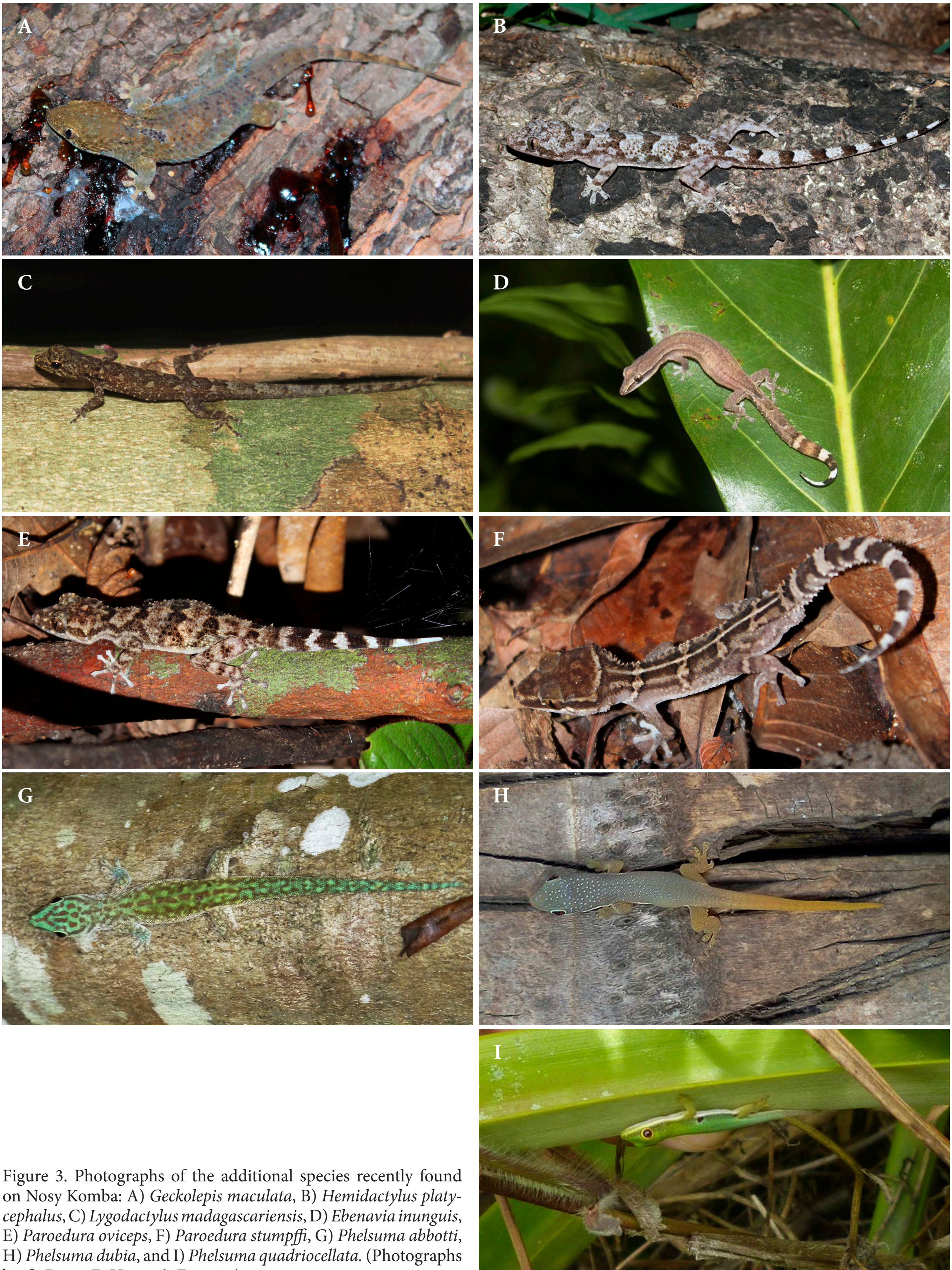

Figure 3. Photographs of the additional species recently found on Nosy Komba: A) *Geckolepis maculata*, B) *Hemidactylus platycephalus*, C) *Lygodactylus madagascariensis*, D) *Ebenavia inunguis*, E) *Paroedura oviceps*, F) *Paroedura stumpffi*, G) *Phelsuma abbotti*, H) *Phelsuma dubia*, and I) *Phelsuma quadriocellata*. (Photographs by C. Daly, E. Hails & Frontier).

Results

Over a combined period of 26 survey hours, a total of six amphibian and 26 reptile species were recorded on Nosy Komba throughout all habitat types. As expected, all six species of amphibians were anurans, whilst the reptile species consisted of 14 gecko species, five snake species, four chameleon species, two plated lizards, and one species of skink. A list of all recorded species is presented in Table 1.

Prior to this investigation, only 21 species of amphibian and reptile were recorded on Nosy Komba. Our findings raise the island's currently known herpetofaunal species count to 38 species, being represented by nine amphibian and 29 reptile species. The species list that we have compiled includes 17 species (Figs. 2–3), which, to our knowledge, have not been previously recorded on the island (Glaw & Vences 2007). These additional species consist of two frog, eleven gecko, one chameleon, one skink species, and two species of snake. The species representing range extension are given in Table 1. Unfortunately, due to the lack of the necessary permits, neither tissue samples nor voucher specimens could be collected, and therefore observational and photographic evidence had to be relied upon.

Interestingly, when the relative abundances of all species were calculated, the herptile community found away from human settlements appeared to be dominated by just one species, the chameleon *Calumma boettgeri* (Tab. 1). This single species represented 27.7% of the total number of individuals observed during the survey period. This species is also present on Nosy Be, however its abundance there is greatly reduced in comparison (Hyde Roberts et al. 2013). The most diverse group that was found on Nosy Komba was the geckos, which in total contributed 36.5% of all individual records during the survey, spread across 14 species.

Our findings reveal that the majority of the newly recorded species are either nocturnal, or are animals that are most easily discovered at night (*Calumma boettgeri* is diurnal, but is easily found asleep on vegetation margins during the night). Only four of the newly detected species were found during the day. This finding represents an interesting dichotomy, and suggests that previous studies and surveys have been undertaken primarily during the day. These results, collected within a small sampling window, demonstrate that the island holds great potential for future research.

Our results show that total herptile diversity was found to be greater during the night, with 19 species being recorded even though not all of these were nocturnal. Searches conducted during daylight hours produced a total of 14 species, whilst some were recorded during both day and night time surveys. The vast majority of the species observed and recorded during our three assessments were found within degraded habitats, agricultural lands, or forests that experience high levels of human disturbance. A total of 28 different species were recorded in such habitats, including the shroud of bamboo forest found on the plateau and northern slopes of the island. A total of 16 species were found within in the remaining established forests, while only four species were exclusively found in this habitat (*Lycodryas granuliceps, Sanzinia volontany, Boophis tephraeomystax* and *Stumpffia pygmaea).*

One interesting detail of our dataset is the surprisingly low number of amphibian species found on the island, particularly when compared to Nosy Be (Hyde Roberts et al. 2013). Previously, seven species of frog were known to inhabit Nosy Komba, and here we can confirm the presence of a further two species (*Blommersia wittei* and *Mantidactylus ulcerosus*). In total, we found six species of frog throughout our study, with two species found solely in degraded habitats, two species only in the established forests, and the remaining two species in both habitat types. An additional three species reported by Andreone et al. (2003) and Glaw & Vences (2007) were not observed during our visits.

Two of the 38 species recorded on the island are classified as Endangered by the International Union for Conservation of Nature (IUCN 2013) (Tab. 1). Both *Phelsuma seippi* and *Zonosaurus subunicolor* are categorised as Endangered due to their fragmented and restricted ranges, within habitats that are undergoing persistent degradation or conversion (Ratsoavina et al. 2011 and Raxworthy & Rakotondravony 2011, respectively). A number of species, including two amphibian species (*Rhombophryne testudo* and *Stumpffia pygmaea*), the pygmy chameleon *Brookesia stumpffi*, and the two species of leaf-tailed geckos (*Uroplatus henkeli* and *Uroplatus ebenaui*) are classified as Vulnerable to extinction. The abundance of the leaf-tailed gecko *Uroplatus ebenaui* on Nosy Komba is particularly compelling, as overall populations are thought to be decreasing throughout its range (Raxworthy et al. 2011). However, it was found to be common on the island with 22 individuals observed during our assessment.

Discussion

This relatively short study confirms the value of rapid biodiversity assessments as a baseline conservation tool. Our three short expeditions have culminated in the observation of 17 additional species for Nosy Komba, extending the previously known distributions of these species in each case. These new populations must now be considered when future conservation statuses are assessed and added to their recognised abundances. These isolated island populations may prove to have important future conservation roles if successfully managed and could even be used to bolster ailing populations. At present, it remains unclear whether the populations found on Nosy Komba differ from their conspecifics on Nosy Be and on mainland Madagascar, either genetically or by exhibiting different behaviours. After 8,000 years of separation, this might make for an interesting study subject.

It is highly likely that there remain more reptile and amphibian species yet to be added to the inventory for Nosy Komba, particularly as numerous secretive, fossorial and arboreal species are known from the nearby neighbouring island of Nosy Be.

Table 1. Species list of the herpetofauna recorded during our rapid assessment of Nosy Komba. New findings are marked *. Historical species records according to Andreone et al. (2003) and Glaw & Vences (2007). Photographic records – C. Burmester[1] (2012, cited by F. Glaw pers. comm., 14 December 2013) and Glaw (pers. comm., 14 December 2013)[2]. + represents a positive record (find); and – refers to a negative record (not found). Abundance is given as the number of specimens observed during our study. The relative abundance of species is presented in accordance with the system used by D'Cruze et al. (2007) and Labanowski & Lowin (2011). Categories are as follows: abundant (large numbers encountered on a regular basis), common (species recorded on a regular basis), infrequent (unpredictable encounters of only a few individuals), and rare (rarely encountered). The relative abundance represents the species abundance for the rapid biodiversity assessment period and specific survey locations and is likely to show seasonal variation due to changing activity patterns of species. The IUCN Red list categories are as follows: NE = not evaluated, DD = data deficient, LC = least concern, NT = near threatened, V = vulnerable, EN = endangered, CR = critically endangered, EW = extinct in the wild, and EX = extinct. ↓ = population decreasing according to IUCN redlist (2013).

Species	Historically recorded on Nosy Komba	Recorded during Frontier RBA's	Total abundance during RBA's	Abundance – degraded habitat	Abundance – established forest	Relative abundance – Nosy Komba	IUCN status
Anurans							
Heterixalus tricolor	+	–	0	0	0	–	LC
Cophyla phyllodactyla	+	+	4	2	2	I	LC
Rhombophryne testudo	+	–	0	0	0	–	V
Stumpffia pygmaea	+	+	2	0	2	R	V
Blommersia wittei	–	+ *	3	3	0	I	LC
Boophis tephraeomystax	+	+	2	0	2	R	LC
Gephyromantis pseudoasper	+	–	0	0	0	–	LC
Mantella ebenaui	+	+	4	2	2	I	LC
Mantidactylus ulcerosus	–	+ *	3	3	0	I	LC
Chamaeleonidae							
Brookesia minima [2]	+	–	0	0	0	–	V
Brookesia stumpffi	+	+	32	17	15	C	V (↓)
Calumma boettgeri	–	+ *	69	65	4	A	LC
Calumma nasutum	+	+	1	1	0	R	LC
Furcifer pardalis	+	+	5	5	0	I	LC
Gerrhosauridae							
Zonosaurus madagascariensis	+	+	3	3	0	I	LC
Zonosaurus subunicolor	+	+	11	11	0	I	EN (↓)
Scincidae							
Cryptoblepharus b. cognatus [2]	+	–	0	0	0	–	NE
Trachylepis gravenhorstii	–	+ *	11	11	0	I	LC
Gekkonidae							
Ebenavia inunguis	–	+ *	1	1	0	R	LC
Geckolepis maculata	–	+ *	7	3	4	I	LC
Hemidactylus platycephalus	–	+ *	5	4	1	I	NE
Lygodactylus madagascariensis	–	+ *	4	4	0	I	V (↓)
Phelsuma abbotti	–	+ *	1	1	0	R	LC
Phelsuma dubia	–	+ *	2	2	0	R	NE
Phelsuma grandis	+	+	12	9	3	C	LC
Phelsuma laticauda	+	+	3	3	0	I	LC
Paroedura oviceps	–	+ *	1	1	0	R	NT (↓)
Phelsuma quadriocellata	–	+ *	2	2	0	R	LC
Phelsuma seippi	+	+	2	2	0	R	EN
Paroedura stumpffi	–	+ *	11	6	5	I	LC
Uroplatus ebenaui	–	+ *	22	19	3	C	V (↓)
Uroplatus henkeli	–	+ *	18	7	11	I	V

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Species	Historically recorded on Nosy Komba	Recorded during Frontier RBA's	Total abundance during RBA's	Abundance – degraded habitat	Abundance – established forest	Relative abundance – Nosy Komba	IUCN status
Boidae							
Sanzinia volontany	–	+ *	1	0	1	R	LC
Lamprophiidae							
Dromicodryas quadrilineatus	+	+	2	1	1	R	LC
Ithycyphus miniatus [1]	+	–	0	0	0	–	LC
Leioheterodon madagascariensis	+	+	2	1	1	R	LC
Lycodryas granuliceps	–	+ *	1	0	1	R	LC
Madagascarophis colubrinus	+	+	2	2	0	R	LC
Total abundance	–	–	249	191	58		
Total species richness	**21**	**32**	32	28	16		

During our expeditions, several extremely brief encounters occurred with species that could not be identified with confidence. These observations were omitted from our species list. The first species, observed twice, is most likely to be *Liophidium torquatum,* whilst a second unknown species is probably a species of skink of the genus *Trachylepis.* It seems likely that the majority of the previous surveys conducted on Nosy Komba were restricted to daylight hours, as the majority of the species recorded during our nighttime surveys were absent from the list of species known to exist on the island (Glaw & Vences 2007).

Short survey periods and the timing of the study (during the dry season) may have strongly influenced which species we were able to observe. Many species display seasonal changes within their activity schedules, for example the fossorial frog *Rhombophryne testudo* has a strong association with the rainy season (Glaw & Vences 2007) and may even aestivate throughout the dry Austral winter months. Our failure to detect this frog species, previously recorded from the island, may be indicative of seasonal bias. With longer recording periods, spread out throughout the year, it is likely that the presence of even more species would be revealed.

Examination of the species inventory for the island shows that the vast majority of species found on the island may also be considered generalist, adaptable and often associated with modified habitats: *Phelsuma grandis, Phelsuma laticauda, Trachylepis gravenhorstii, Furcifer pardalis, Zonosaurus madagascariensis* (Glaw & Vences 2007). The presence and distribution of these species is consistent with the prominent notion that the island was almost entirely deforested at some stage during the past two centuries. However, the continued presence of forest-dependent species or those associated with intact primary forests such as *Uroplatus henkeli* and *Paroedura oviceps* suggests that at least remnants of intact primary forest may have always persisted on the island.

It is possible that remnants of primary vegetation supported populations of these sensitive species during periods of intensive clearing and have since become re-established, allowing such populations to re-expand. The topography of the island has most likely helped to preserve much of the amphibian and reptile diversity that is currently found on Nosy Komba. The steep hills and gullies may have acted as refuges for species that are most susceptible to habitat loss and human disturbance. Similarly, it is likely that many tree and plant species valuable for animal diversity also survived the clearance in such areas, and have subsequently become restored in the more remote parts of the island. It is possible that not all forest-dependent species managed to sustain their populations on the island, with the amphibian fauna bearing testament to the ruthlessness of extinction.

It is unlikely that deforestation alone was responsible for the island's reduced diversity in comparison to other islands such as Nosy Be. Although similar selective forces and drivers are evidently in operation, the functional effects of area size are fundamental (Mulongoy et al. 2006). Being a relatively small island, the impacts of deforestation, human disturbance, and severe storms on small populations are magnified. In conjunction with evolutionary factors such as inbreeding depression, biodiversity is under increased pressure on smaller islands. Unfortunately, we will never know the full complement of species originally inhabiting Nosy Komba before deforestation first began, but it is likely that it was similar in composition to that in the forests of the Lokobe Integral Reserve. The reduced number of open water bodies and fluvial environments on Nosy Komba, however, may have resulted in reduced amphibian richness on the island, prior to human colonisation. Yet the current persistence and relative abundance of some species on Nosy Komba, which are considered primary forest specialists elsewhere, indicates the extent of forests recovery from past degradation.

Alternatively, populations of such species may simply be more versatile than previously thought, and able to tolerate significant levels of deforestation and disturbance. Our results show a surprising abundance of leaf-tailed geckos near the islands summit, with both *Uroplatus henkeli* and *Uroplatus ebenaui* found in much greater numbers than in a studied section of primary forest on Nosy Be (Hyde Roberts et al. 2013). It is plausible that an absence of human disturbance across large sections of the island's plateau, particularly at night, has allowed these geckos an opportunity to flourish. The local people rarely enter the forest at night and the forest areas are essentially untouched and have been allowed to rewild. On Nosy Komba, *Uroplatus henkeli* were observed in the bamboo forests as well as in the established forests, an observation that was also made on Nosy Be (Glaw & Vences 2007). Interestingly, the great abundance of *Uroplatus ebenaui*, a species that is considered 'Rare' on Nosy Be (Hyde Roberts et al. 2013), in the secondary forests of Nosy Komba suggests that if the level of human disturbance is reduced, this species is capable of undergoing population expansion. It is highly likely that human activity strongly influences the distribution and population dynamics of *Uroplatus* geckos.

This may also be the case for several other species, and appears to hold true for *Calumma boettgeri*. Our study has shown that this chameleon has undergone a population explosion near the plateau of Nosy Komba, and now exists in dramatic abundance in the degraded habitats above 500 m.

This chameleon species is regarded as 'common' in and around secondary forest matrices across its range (Glaw & Vences 2007), although less frequent in the Lokobe region of Nosy Be (Hyde Roberts et al. 2013). Their abundance on Nosy Komba might be the consequence of an apparent absence of significant predators such as the hook-billed vanga (*Vanga curvirostris)*, but is more likely based on a combination of factors. A large proportion of *Calumma boettgeri* was observed on one specific shrub species, with the Malagasy name 'caliber'. Our local guide, knowledgeable in the field of botany, explained that this shrub is common in degraded habitats and considered a pioneer species, thriving in deforested and modified environments. *Calumma boettgeri* is clearly an adaptable species and on Nosy Komba has benefitted greatly from a number of fortuitous ecological circumstances that have led to its current unprecedented abundance.

The species inventory (Tab. 1) shows that only half of the number of frogs present on Nosy Be (19 species; Glaw & Vences 2007) have been recorded on Nosy Komba so far, with the majority of these representative species being those considered tolerant and adaptable. Vieites et al. (2009) suggested that habitat degradation might have more impact on amphibians than previously thought. Current literature on Malagasy amphibians suggests that species that avoid habitat edges and therefore those that are intolerant of deforestation, are most vulnerable to extinction, particularly in fragmented areas (Lehtinen & Ramanamanjato 2006). Research found this to be the case more so in amphibians than in reptiles, and the persistence of several forest-dependent species on Nosy Komba, mostly reptiles, seems to validate Lehtinen & Ramanamanjato's (2006) work. Again, the island's small size is most likely responsible for its reduced amphibian diversity, with fewer suitable fluvial and pristine microhabitats to support the large diversity found elsewhere on larger landmasses. However, it is likely that further investigation, particularly by surveys conducted during the rainy season will find that more frog species are present on Nosy Komba than is currently known. The deterioration of primary to secondary and degraded forest, ultimately affects all species, even though in different ways and to different extents, with specialist or endemic species being replaced by non-endemic and adaptable species (Irwin et al. 2010). Our study found a greater species richness and abundance of animals in degraded forests than in established forests, and highlights the importance of secondary and modified environments for conserving diversity. It appears from our results that secondary habitats, which experience negligible levels of human disturbance, are important not only for sustaining adaptable communities (Andreone et al. 2003), but also more sensitive species.

The response of a species to deforestation or human disturbance also has an ecological impact on the species that share that particular ecosystem, triggering cascades of response until equilibrium is reached. This balance may result in the local extinction of some species, whilst other species may benefit (Phillips 1997). Ecosystems are extremely dynamic, sensitive and prone to stochastic fluctuation as well as direct interference from factors such as human disturbance. The island's small size will have undoubtedly led to a naturally reduced diversity, however by comparing the relative abundances of species present on both Nosy Komba and Nosy Be, it is apparent that the current assemblage of reptiles and amphibians on Nosy Komba has been influenced strongly by habitat destruction.

Nosy Komba is an example in miniature of how human disturbance and habitat degradation can affect and unbalance a natural ecosystem, shifting both the composition and the relative abundance of species within a community.

Recommendations

Nosy Komba exhibits immense biological wealth and diversity for an island of its size that should be conserved and managed assiduously. We recommend that the area of the arboretum and its surrounding secondary regrowth forests should be granted additional protection from exploitation, both from resource use, agricultural encroachment, and the increasing tourism on the island. The modified habitats of Nosy Komba also hold a substantially rich and diverse assemblage of animals, and the future conservation management of such areas should not overlook these landscapes. Any future management regimes must be carefully implemented, with consideration being given to all habitat types and the varied array of animals that need protection. It is our hope that our data can contribute to an informed decision-making process on the island's future and hopefully encourage conservation in the area.

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