Amphibians and Reptiles of the “Montagne Des Français”: Update of the Distribution and Regional Endemicity

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Posted Date: 21 June 2023

doi: 10.20944/preprints202306.1499.v1

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Article

Amphibians and Reptiles of the "Montagne des Français": Update of the Distribution and Regional Endemicity

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Simple Summary: From 2014 to 2020, investigations were conducted at Montagne des Français Protected Area. This location is well-known about its fauna level with high endemism rate. The biological surveys dealing about herpetofaunal were conducted to identify priority area. Our inventory consists to gather, and updating bio-ecological information, such as diversity and species distribution, conservation status, endemicity, and threats. Here, we compare the species richness during the both surveys 2014 and 2020. Four amphibian, and one reptile species considered as either a new distribution or a new for science. Moreover, a snake not observed since 2007 were discovered during the 2020's study, namely *Langaha psedoalluaudi*. The information gathered in this research can help the Site manager to update Conservation Management Plan.

Abstract: The Harmonious Protected Landscape of Ambohitr'Antsingy Montagne des Français is one of the protected area located in the extreme northern of Madagascar. An assessment of the Herpetofauna community were made on the eastern and western slopes regarding the forest degradation level, the availability of the streams and the habitat types in the massif during the years of 2014 and 2020. This survey was done in order to updating the herpetofaunal database and recording the distribution ranges of the Herpetofauna community in the PA. Three methods were used, including direct observation, systematic microhabitat searching and pitfall-traps with drift fences at three sampling sites during the day and night with headlamp. Twenty species of amphibians and 50 species of reptiles were recorded. Four species of Amphibians, and 03 species of Reptiles (snake) are potentially new to science and/or newly recorded at Montagne des Français. One snake (*Langaha pseudoalluaudi*) last inventoried in 2007 has reappeared during this investigation. Here, we present the mapping of all species recorded. This new database can help the manager site to update the management plan to guarantee the herpetofaunal conservation facing habitat change. That is what we think also for all of the current PA in Madagascar.

Keywords: amphibians; reptiles; Montagne des Français; update; distribution; regional endemicity

1. Introduction

Madagascar is well-known as a hotspot for biodiversity in the worlwide [1]. Due to its remote location, a current high level of the endemism and diversity are observed [2,3]. Protected Areas were created to assure the preservation of this biodiversity [4] and their ecosystem services. The Isle home high endemism of herpetofauna, and 90% of them found nowhere else [5]. The "Montagne des Français", our site study research is one of the Madagascar's protected area, situated far from the northern of Madagascar, namely "Harmonious Landscape of Ambohitr'Antsingy". This site is

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calcareous massif [6] and home a remarkable community of herpetofauna [7], any of them are native to this area [8].

Unfortunately, the majority of the wildlife, faunal and floral, in this protected area experienced with biodiversity crisis due to human activities. These anthropogenic pressures impact habitat loss and considerable ecosystem alterations [6,9] and of course landscape erosion. Although several studies indicated that the herpetofauna species are among the highly threatened vertebrate in the world [10–12], this assertion is typically observed within the tropical region [13]. However, research were working there, gapping information is documented regarding the distribution and status of the species within this area [6,14–16], and each field research a new data are collecting.

Thus, this paper updates the current knowledge of the herpetofaunal biodiversity, biogeography and endemicity of the Montagne des Français. The eastern and western slopes of the mountain surveyed in 2014 and 2020. A number of ecological parameters were considered, including the degree of degradation, the presence of streams, and the types of habitat.

The biodiversity database done during these both surveys dealing about Amphibian and Reptile supports not only focusing on species-based priority but also to mitigate the pressure on the core area of this Protected area, and can help the site manager to smooth the new management plan [14]. In light of the numerous hazards surrounding to this Protected Area, this new data can help also to implement the new Conservation strategy [17,18]

2. Materials and Methods

2.1. Study Site

Ambohitr'Antsingy Montagne des Français is a limestone plateaus intersected by narrow canyons, located in northern of Madagascar, between 12° 18 and 12°27' latitudes south and 49° 21 and 49°23' longitudes east, with a maximum pic elevation at 425 m asl. The forest massif is very close to Antsiranana (Urban city), far from 7 km and, with 6,049 ha (Figure 1). This site had a full protected status as a New protected area, category V since April 28, 2015 (Decree No. 2015-780), with collaborative co-management governance, mainly managed by "Service d'Appui pour la Gestion de l'Environment" (SAGE).

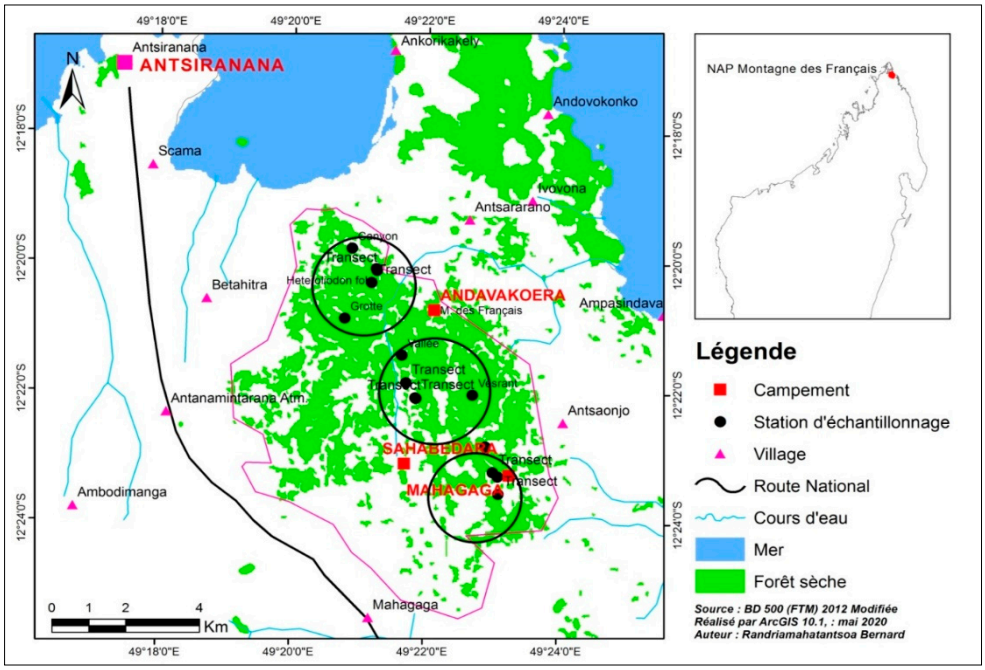

Figure 1. Map of the study sites in Montagne des Français.

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2.2. Data Collection

The biological inventory was conducted between 13-24 January 2014, and 3-21 May, 2020, were the animals are active. The first study focused only at Andavakoera site, and the second one at Sahabedara, Ampitiliantsambo, and Andavakoera (Figure 1). The Andavakoera site is located in the core area, while Sahabedara and Ampitiliantsambo are located in the peripheral zones.

- SAHABEDARA located between 049° 21′ 41.7′′ E and 12° 23′ 05.8′′ S, with 159 m elevation asl. It is characterized by gallery forest with sandy and rocky. The forest here is moderately degraded with open canopy; this site is outside the core area of the Montagne des Francais.
- AMPITILIANTSAMBO is located between 049° 23′ 05.5′′ E and 12° 23′ 16.6′′ S, with 204 m elevation asl. It characterized by semi-caduc natural forest or gallery and fragmented forest with open canopy; this site is outside the core area of the Montagne des Francais.
- ANDAVAKOERA is located between 049° 20′ 58.1′′ E and 12° 19′ 49.6′′ S, with 173 m elevation asl. It is characterized by Sambirano forest or Gallery relict forest with sandy and rocky. The site here is core area of the Montagne des Francais.

During these expeditions, three field techniques standard were used to sample herpetofauna community: 1) opportunistic day and night searching using headlamp along a sample trail or way or stream; 2) refuge/microhabitat examination, and 3) pitfall traps with drift fences [19]. This survey follows the "Rapid Assessment Program" of CI, and standards that have already been extensively tested and used in Madagascar

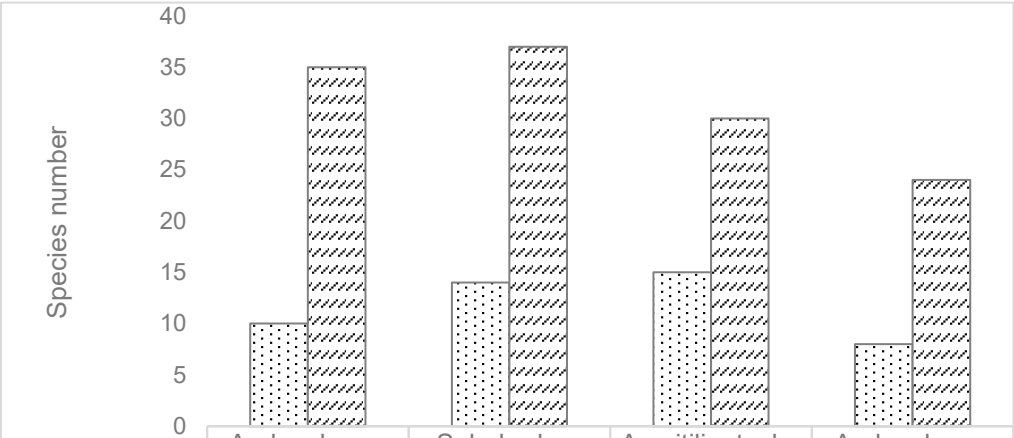
2.3. Data Analysis

To define the structure of the community, the following parameters were considered: species richness and species composition. We used $\chi 2$ test to compare all sites.

3. Results

3.1. Species Richness

A total of 20 amphibians, and 50 reptiles were recorded at NPA Montagne des Francais during the two surveys in 2014, and 2020 with 10 amphibians, and 35 reptiles in 2014, and 17 amphibians and 44 reptiles in 2020 (Table 1). In 2014, these species richness interested the Andavakoera site only, but during the year 2020, the amphibians and reptiles recorded concerned Sahabedara (14 amphibians / 37 reptiles), Ampitiliantsambo (15 amphibians / 30 reptiles), and Andavakoera (8 amphibians / 24 reptiles) (Figure 2). And we noticed that Andavakoera had less species recorded in 2020 in comparison with the reptiles according all of the sites sampled, but this is not significantly different ($p = 0.49 > 0.05$; ddl = 3; $\chi 2 = 2.39$).



	Andavakoera 2014	Sahabedara	Ampitiliantsabo	Andavakoera
		2020		
Amphibians	10	14	15	8
Reptiles	35	37	30	24

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Figure 2. Species richness of the herpetofaunal community in Montagne des Français.

Table 1. Species composition of the herpetofaunal community recorded in the NAP Montagne des Français during the years 2014 and 2020. AND: Andavakoera, AMP: Ampitiliantsambo, SAH: Sahabedara. End : endémicity.

TAXON	2014 AND	2020 AND	2020 AMP	2020 SAH	IUCN	End
AMPHIBIANS						
MANTELLIDAE						
Boophis sp. aff. *majori*	-	-	+	-	NE	E
Boophis cf. *madagascariensis*	-	-	-	+	NE	E
Boophis cf. *occidentalis*	-	-	+	+	NE	E
Boophis tephraeomystax	+	+	+	+	LC	E
Gephyromantis pseudoasper	-	-	+	+	LC	E
Gephyromantis sp.	-	-	+	-	NE	E
Aglyptodactylus securifer	+	-	-	-	LC	E
Laliostoma labrosum	+	-	+	-	LC	ER
Mantella viridis	+	+	+	+	EN	EL
Mantidactylus bellyi	+	+	+	+	LC	E
Mantidactylus betsileanus	+	-	-	-	LC	E
Mantidactylus ulcerosus	+	+	+	+	LC	E
PTYCHADENIDAE						
Ptychadena mascareniensis	+	+	+	+	LC	C
MICROHYLIDAE						
Stumpffia analamaina	-	-	+	+	LC	E
Stumpffia angeluci		+	+	+	LC	ER
Stumpffia gimmeli	+	-	-	+	LC	ER
Stumpffia cf. *madagascariensis*	-	-	+	+	LC	ER
Stumpffia roseifemoralis	-	+	+	+	EN	E
Stumpffia staffordi	-	+	+	+	VU	E
DICROGLOSSIDAE						
Hoplobatrachus tigerinus	+	-	-	-		NE
REPTILES						
BOIDAE						
Acrantophis madagascariensis	-	-	+	+	LC	E
Sanzinia madagascariensis	+	-	-	+	LC	E
CHAMAELEONIDAE						
Brookesia ebenaui	+	-	-	+	VU	E
Brookesia stumpffi	+	+	-	-	VU	E
Brookesia tristis	+	-	-	-	NE	E
Furcifer oustaleti	+	-	+	-	LC	E
Furcifer pardalis	+	-	+	-	LC	ER
Furcifer petteri	+	+	+	+	VU	E
GEKKONIDAE						
Blaesodactylus boivini	+	+	+	+	VU	ER
Geckolepis maculata	+	-	+	-	NE	E
Geckolepis typica	+	+	-	-	LC	E
Hemidactylus frenatus	+	+	-	+	LC	E
Hemidactylus mercatorius	+	-	-	-	LC	E
Lygodactylus hetererus	-	-	+	+	LC	ER

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TAXON	2014 AND	2020 AND	2020 AMP	2020 SAH	IUCN	End
Paroedura hordiesi	+	-	-	+	CR	EL
Paroedura lohatsara	+	+	+	+	CR	EL
Paroedura stumpffi	+	-	-	+	LC	ER
Phelsuma abbotti	+	+	+	+	LC	E
Phelsuma grandis	+	-	+	-	LC	ER
Uroplatus fetsy	-	-	+	+	NE	ER
Uroplatus giganteus	-	-	-	+	VU	E
Uroplatus henkeli	+	-	+	-	VU	E
Uroplatus sameiti	+	+	-	-	LC	E
LAMPROPHIDAE						
Alluaudina bellyi	-	+	-	-	LC	E
Dromicodryas bernieri	-	-	+	+	LC	E
Dromicodryas quadrilineatus	+	-	+	+	LC	E
Heteroliodon fohy	+	-	-	-	EN	EL
Ithycyphus miniatus	+	-	+	+	LC	E
Langaha madagascariensis	+	-	-	-	LC	E
Langaha pseudoalluaudi	-	-	-	+	LC	E
Leioheterodon modestus	+	-	-	+	LC	E
Leioheterodon madagascariensis	+	+	+	+	LC	E
Liophidium therezieni	+	-	-	-	EN	EL
Liophidium torquatum	+	-	+	+	LC	E
Lycodryas inopinae	+	-	+	+	LC	ER
Lycodryas granuliceps	-	-	+	-	LC	E
Lycodryas pseudogranuliceps	-	-	-	+	LC	E
Madagascarophis colubrinus	+	+	+	+	LC	E
Madagascarophis fuschi	+	+	-	-	CR	EL
Mimophis occultus	-	+	+	+	LC	E
Phisalixella sp.	-	-	+	-	NE	EL
Phisalixella artifasciata	+	-	+	+	LC	ER
Pseudoxyrhopus quinquelineatus	+	-	-	+	LC	ER
Thamnosophis martae	-	+	+	-	EN	ER
Thamnosophis stumpffi	-	-	+	-	VU	E
SCINCIDAE						
Madascincus miafina	-	-	-	+	LC	E
Trachylepis elegans	+	+	+	+	LC	E
Trachylepis tavaratra	-	-	-	+	VU	ER
Voeltzkowia sp.	+	-	-	-		
TYPHLOPIDAE						
Indotyphlops braminus	+	-	+	+	NE	E

3.2. Newly Recorded Species at Montagne des Français

The particular interest of biological inventories at both large and small geographic scales, especially for herpetofauna, is the possibility of discovering new species or new biogeographic distributions. Among the 20 amphibian and 48 reptile species encountered, four frogs and one snake are potentially new for science and/or are newly recorded at Montagne des Français. These are respectively *Boophis* cf. *occidentalis*, *B.* cf. *madagascariensis*, *Boophis* sp. aff. *majori*, and *Gephyromantis* sp., and *Phisalixella* sp. In addition, the snake *Langaha pseudoalluaudi* was rediscovered in 2020 fieldwork. They are all observed within the dry deciduous forest associated with karst formation, and a few caves are present. A brief description of these various morphospecies are presented in the following paragraphs.

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3.2.1. *Boophis* cf. *occidentalis*

Seven individuals of this species were observed during this work, with four on a branch of shrub plants at the edge of the stream, and the other three in the streams inside the forest between 6-9 pm.

Medium-sized species with TL = 117.4 mm and SVL = 44.3 mm for n = 7. The color of the dorsal part is generally green. The male has many small tubercles that are remarkable compared to the female. A complete dorsolateral yellow line is well distinct from the tip of the snout to the sacral vertebrae. There is a visible pink color on the underside of the anterior-posterior leg and webbing (Figure 3). The webbing formula is 1(0.25) 2i(0.5) 2e(0.25) 3i(0.25) 3e(0.25) 4i(1) 4e(1) 5(0). *Boophis occidentalis* and *Boophis septentrionalis* are the most similar species.

3.2.2. *Boophis* sp. aff. *majori*

Only one individual of this species was observed during the biological investigation of the daytime observation. This species is observed in the forest, on a leaf of a shrub plant at the edge of a small water courtyard around 9:15 am. It is a small -sized species whose morphometry is as follows: TL = 58.1 mm and SVL = 23.5 mm. The color of the dorsal part is generally light brown. The tip of the fingers and toes tends towards golden yellow. The vein shape on the iris follows the longitudinal configuration of the pupil (Figure 4). The webbing formula is 1(0.5) 2i(0) 2e(0.25) 3i(1) 3e(0.5) 4i(1) 4e(1) 5(0). *Boophis majori* and *Boophis miniatus* are the closest species to this form.

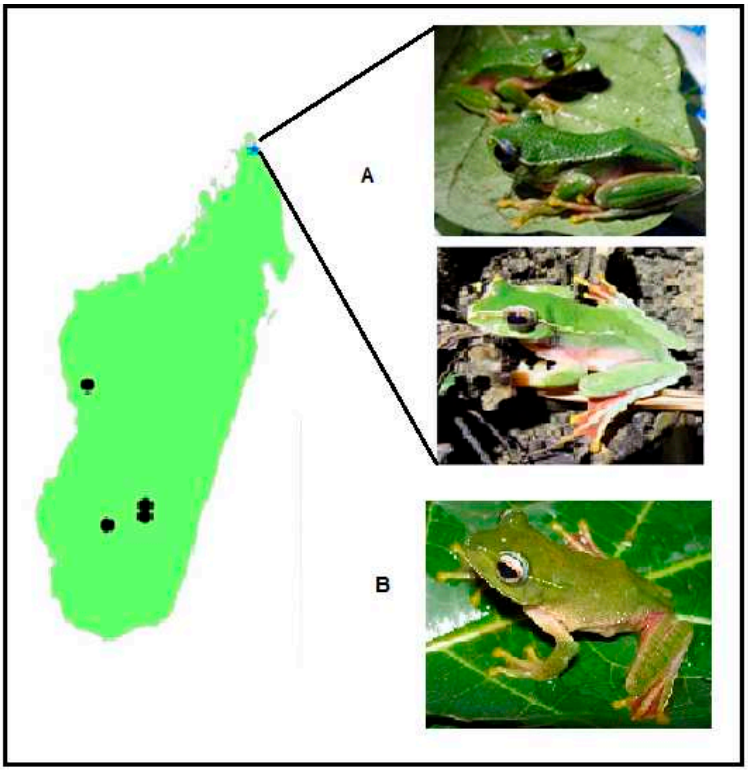

Figure 3. *Boophis* cf. *occidentalis* (credit Randriamahatantsoa, 2020). A: new distribution, B: current distribution.

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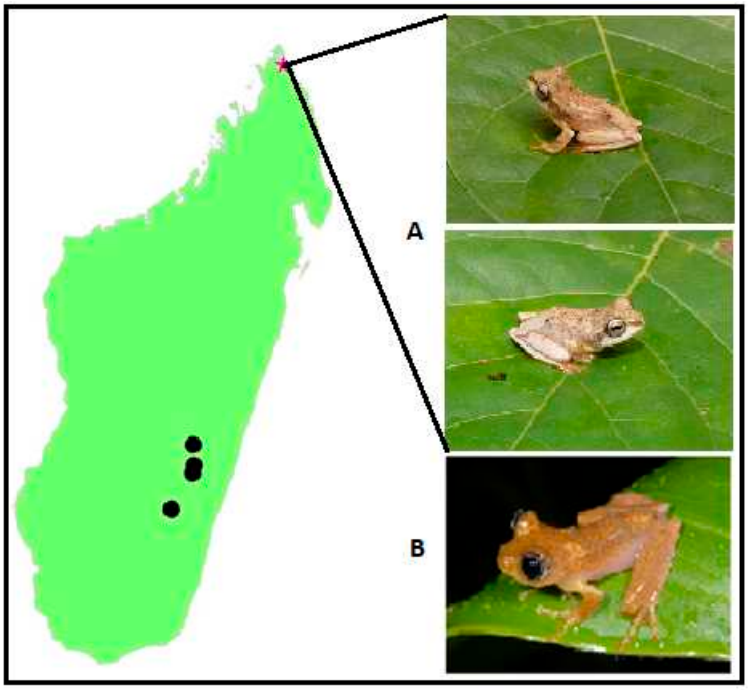

Figure 4. *Boophis* sp. aff. *majori* (credit Randriamahatantsoa, 2020). A: new distribution, B: current distribution.

3.2.3. *Boophis* cf. *madagascariensis*

Only one individual of this species was observed during the field observation. It is a large-sized species, with morphology of TL = 183.2 mm and SVL = 65.5 mm. This individual was observed on a branch of a shrub plant at the edge of a small water courtyard around 10:15 am near the Sahabedara camp. From a morphological point of view, it is identical to *Boophis madagascariensis*, but the difference is noticed in the spine of the hind leg which is not well developed for this morphotype (Figure 5). The webbing formula is 1(0.25) 2i(0) 2e(0) 3i(0.5) 3e(0.25) 4i(0.75) 4e(0.75) 5(0), which is not consistent with *B. madagascariensis.*

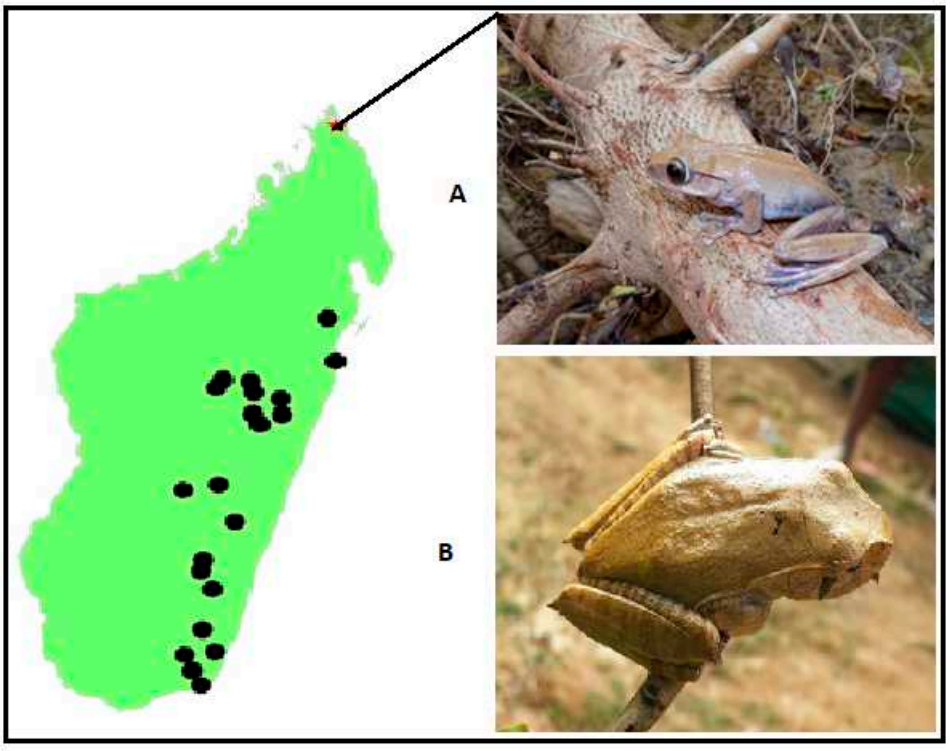

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Figure 5. *Boophis* cf. *madagascariensis* (credit Randriamahatantsoa, 2020). A: new distribution, B: current distribution.

3.2.4. *Gephyromantis* sp.

Only one individual of this species was observed during the nocturnal observation. This species was found in the water under a rock at around 8:30 pm. It is a medium-sized species with TL = 79.4 mm and SVL = 30 mm. The dorsal area is brown with a longitudinal brown band widening towards the head (Figure 12). The webbing formula is 1(1) 2i(1) 2e(1) 3i(1.5) 3e(1) 4i(2.5) 4e(2.5) 5 (1), which is similar to *Gephyromantis pseudoasper*.

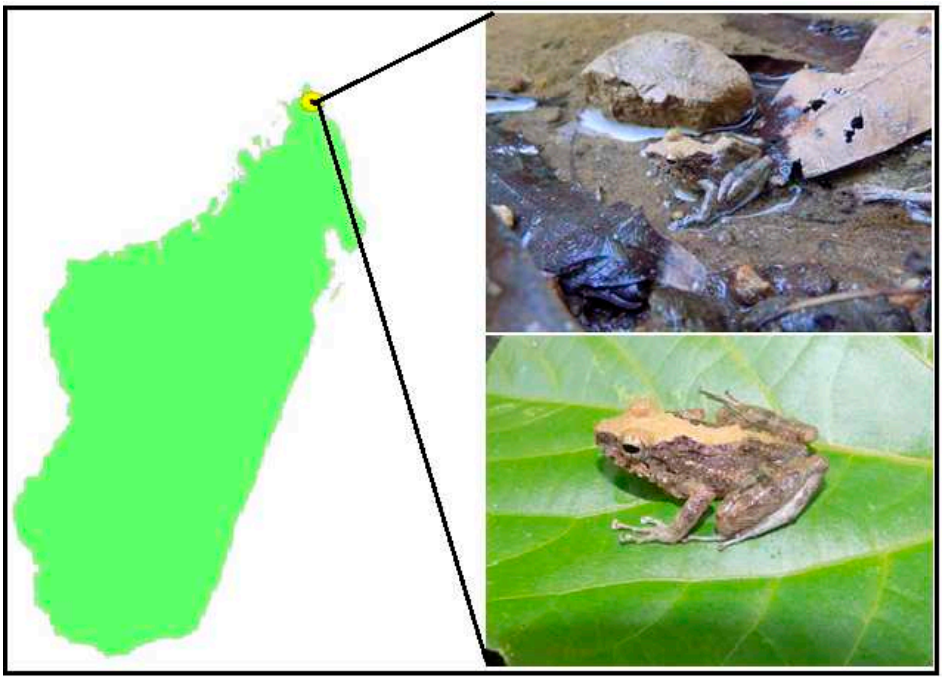

Figure 6. *Gephyromantis* sp. (credit Randriamahatantsoa, 2020).

3.2.5. *Phisalixella* sp. nov.

One individual of this arboreal snake was found in the NPA Montagne des Français in 2014. This species were active on a small branch of shrubs at 3.5 meters high near the stream at 100 meters altitude around 11: 00 pm. The overall dorsal shape of this species is yellow-orange with alternating clear blackish transverse bands. It is a relatively large and long species (TL: 864mm; SVL: 288mm), characterized by the presence of dark transverse bands starting at the neck and extending to the end of the tail. The number of these bands (135) is a distinguishing characteristic of this species from other groups in the same genus. The number of ventral and subcaudal scales is also different from those already described. *P. artifasciatus* and *P. tulearensis* are the most similar to this new form.

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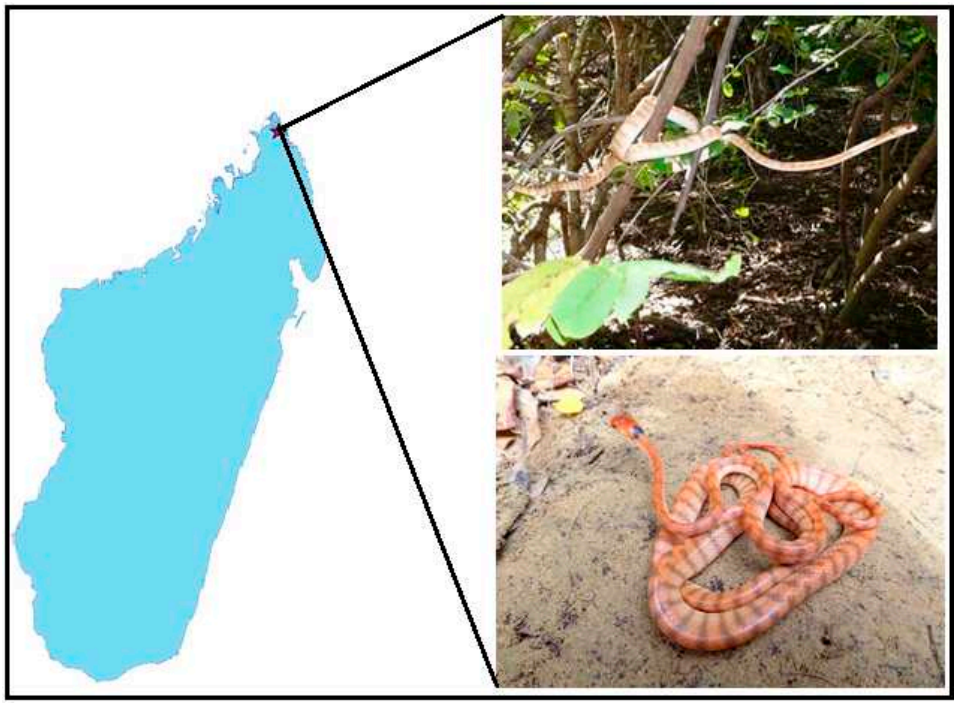

Figure 7. *Phisalixella* sp. nov. (credit Randriamahatantsoa, 2020).

3.2.6. *Langaha pseudoalluaudi*

One male and one female of *Langaha pseudoalluaudi* species were inventoried in the Sahabedara site. This site is characterized by medium degraded ecotone forest with a semi-open vegetation cover associated with the karstic substrate. It is a diurnal and arboreal species nesting mainly at the edge of the forest more or less degraded. *L. pseudoalluaudi* is large and relatively long and very difficult to observe because of its anatomical specificity. These two individuals are found in the same environment, on the plant shrub 2 m and 2.5 m high at the edge of the forest remnant in open environment from to 80 m altitude. This species is found in the north, northwest and south and southwest region of Madagascar.

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Figure 8. *Langaha pseudoalluaudi.* (credit Randriamahatantsoa, 2020). A-B : female, C-D:male.

4. Discussion

Our study provides the new data of the distribution and endemism concerning the species richness of the Amphibian and Reptile within Montagne des Français protected area. These data provide additional information on the previous studies by [6,14–16] of the unique herpetofaunal community of Montagne des Français. All of these study have already highlighted the level of endemicity and habitat loss due to the proximity of this zone to the urban area of Antsiranana.

4.1. Species Richness

Incredible faunal diversity can be found in Madagascar's extreme northern karst formations. This scenario might be brought on by the geographic placement of the mountainous massif, namely Sambirano characteristic. This site is closed to Montagne d'Ambre makes it a transition formation, moist forest and a dry forest characteristic to the north. A total of 70 species have been recorded, indicating a particularly high level of biodiversity in the Montagne des Français even though their restricted area (6,049 ha). The inventory conducted by [6] identified 52 reptile species. Comparing the research data with those gathered during the current inventory, it can be shown that 11 species on the previous list were not observed during this investigation including *Lygodactylus hetererus, Uroplatus* sp, *Zonosaurus aenus* and *Z. boettgeri, Amphiglossus* sp., *Amphiglossus ardouini,Trachylepis tavaratra, Acrantophis madagascariensis, Alluaudina belly, Dromicodryas bernieri, Ithycyphus miniatus, Langaha pseudoalluaudi, Thamnosophis lateralis, T. stumpffi, T. martae, and Ramphotyphlops braminus.* These absences could be due to the seasonal reason when the animal are discreet and rare making observation them more difficult (the end of the rainy season 2020) and also the site survey were not the same (western slope, Andavakoeara *vs* eastern slope, Sahabedara, Ampitiliatsambo) and the end but not least the habitat productivity and stability decreased by human activities especially tree and soil fertilizing by bushfire or charcoal wood where the site are closed to urban area, the boundary area.

4.2. Proposition of New Priority Species-Based Conservation

A biological inventory serves as the foundation for the ideal conservation of a specific geographic area. Thus, for the herpetofauna, we suggest the effective conservation of species that have a restricted distribution throughout the northern half of Madagascar, namely *Mantella viridis, Paroedura lohatsara, Zonozorus tsingy, Thamnosophis martae,* and *Heteroliodon fohy*.

Another consideration is the species conservation status, which takes into account both the species' range and the condition of the in-situ population, especially those that are highly threatened as Critically Endangered (CR): *Paroedura hordiesi* and *Paroedura lohatsara*; Endangered (EN): *Mantella viridis* and *Stumpffia roseifemoralis*; Vulnerable (VU): *Stumpffia staffordi* and *Uroplatus giganteus*. The next criterion is how the susceptibility of the species home on boundary but rare? Certain species found in both galleries and forests like *Langaha pseudoalluaudi*, *Lycodryas* ssp., *Sanzinia madagascariensis*, and *Madagascarophis colubrinus* are able adapted their behavior to disturbed habitats because according our experience the species in canopy or open area have no more difficult faces degraded habitat. Whilst other species are extremely sensitive to minor habitat change, like *Mantella viridis, Boophis* cf *occidentalis, Boophis* cf *majori, Boophis* cf *madagascariensis* because they a species-humid forest typical. These later are particular biotopes (forest formation associated with the karstic substrate) and needed peculiar attention to smooth conservation care. So, the new gather distribution of these species required considering to respect the forest integrity for the new management plan.

4.3. Endemism and Biogeographic Distribution

The analysis of the biogeographic pattern of the species recorded during this study, as well as the available documented data, allow us to conclude that Madagascar has a high degree of species endemism, especially isolated forest. Indeed, 56 of 59 species recorded (94%) are endemic to the island, and among them, 14 species (24%) are limited to the northern region of Madagascar [6,20]. Some species have a very restricted distribution area, localized only at Montagne des Français: *Paroedura lohatsara, P. hordiesi*, and *Heteroliodon fohy*. Concerning the snake *Langaha pseudoalluaudi*, an inventory conducted in 2007 by [6] mentioned the presence of its species within the Montagne des Français. This observed again in 2020 after absent in 2014.

4.4. Influence of Human Disturbance and Conservation Status

While the Montagne des Français is located near the urban area of Antsiranana, anthropogenic activities as charcoal production, timber harvesting, provoke threats to species habitat and have negative effect to herpetofaunal community [21]. Three of the 20 amphibian species found in Montagne des Français, including two endangered species (*Mantella viridis* and *Stumpffia roseifemoralis*) and one Vulnerable (*Stumpffia staffordi*) and 19 species of reptiles, including 11 Vulnerable, 05 Endangered, and 03 Critically Endangered species (cf. Table 1) are the most threatened species observed at Montagne des Français. And to assure the viability of the site, a permanent monitoring and conservation planning is needed for all of them.

5. Conclusions

Here, our fieldwork conducted in 2014 and 2020 allowed us to update the diversity and occurrence of the herpetofaunal community of Montagne des Français, especially in Ampitiliantsambo where investigation has not been undertook before. Overall, this study highlights the occurrence and update the distribution of the 20 amphibians and 50 reptiles species living within the Montagne des Français Protected Area.

Update information on the amphibian and reptile chorological data collected is highly contribute the effective new management plan of the Montagne des Français that the Manager think to implement in consideration their proximity to Antsiranana city. The human activity in the boundary of this zone is one of the factors that drive habitat loss and consequently species decline. A high new awareness approach to local population are needed with multi stakeholders' participation to assure the viability of the Montagne des Francais by long-term.

Author Contributions: Conceptualization, H.O.R. and B.A.; methodology, B.A. and H.O.R; validation, N.R. and B.A.; investigation, H.O.R and B.A.; writing—original draft preparation, H.O.R.; writing—review and editing, H.O.R and N.R.; supervision, N.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Acknowledgments: We thank the team from the Sciences Department of the University of Mahajanga for data collections in Montagne des Français surveys.

Conflicts of Interest: The authors declare no conflict of interest.

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