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Effects of land use change on amphibian community from Kianjavato forest station, south eastern Madagascar

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Abstract: *An assessment of amphibian species was carried out in the Forêt Classée de Kianjavato (FCK), part of the Dense Humid Evergreen Forests of eastern Madagascar. The research was carried out in two phases, first during the cool season (June - July 2012) and then during the wet season (November - December 2014), covering three types of habitat: deforested area, reforestation area and forest area. Three standard inventory methods were used: direct observation, systematic excavation and trapping. A total of 26 amphibian species were recorded, including one new to the site. Most of these species are classified as Least Concern by the IUCN, represented by low numbers of individuals. The distribution of amphibian species is influenced by biotic factors such as the structure of the vegetation cover. Amphibians are found in both forested and degraded areas. The degraded areas share several species, forming a habitat distinct from the forested area. The study highlights the extension of the range of distribution of amphibian species and emphasises that the conditions necessary for their presence in degraded areas are not yet in place. The FCK, with its varied ecological landscape, is crucial to the preservation of biological diversity in eastern Madagascar.*

Keywords: *amphibians; Kianjavato; species richness; reforestation area; deadland*

I. Introduction

Madagascar is known of its high rate of endemism and classified as a hotspot for biodiversity conservation (Meyers et al., 2000). Endemism of the island is observed at different levels from species to family. In other side; the country is known for a high rate of forest loss resulting from slash-and-burn agriculture commonly used by farmer. A recent study found that Madagascar has lost 44% of its forest cover between 1953 and 2014 and that the deforestation rate was increasing alarmingly in the later years measured (99,000 ha/year in 2011–2014) (Vieilledent et al., 2018a). For the period 2015–2017, this trend had accelerated further, reaching levels of 162,000 ha/year with roughly half of Madagascar's remaining and fragmented forests now being less than 100 m from a forest edge (Vieilledent et al., 2018b).

With the average deforestation rate in the period 2010–2019, undisturbed humid forests in Madagascar are predicted to have completely disappeared in less than 30 years (Vancutsem et al., 2021). Consequently; vegetation structure change according the land uses and agriculture management. Depending on external temperature and others ecological factors; amphibians and reptiles are affected by the land cover structure and they were

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already used as an indicator of environmental stress or change (Stafford et al., 1976, Ohlendorfet al., 1988, Power et al., 1989, Vitt et al., 1990).

However, very little monitoring or follow-up has yet been established to assess the richness in terms of faunal diversity in newly reforested areas. In other words, the availability of data, especially from secondary formations, remains scarce. Whereas several amphibian species depend on forest cover.

The general objective is to determine the distribution of the amphibian population in the different types of habitat in Kianjavato.

The specific objectives are: to study the diversity of amphibians on the study site; evaluate the effect of reforestation by comparing different habitat types.

II. Research Methods

2.1 Study site

The study site lies within the Kianjavato Rural Commune, between 21°17' and 21°30' south latitude and 47°47' and 47°58' east longitude (Figure 1), with an altitudinal variation ranging from 90m to 290m.

The Kianjavato Classified Forest covers an area of around 1,100 hectares. Its climatic vegetation is a Dense Humid Evergreen Forest on ferralitic soil. The phytogeographical division shows that the vegetation of Kianjavato is part of the low altitude (0 to 800m) eastern eco-floristic zone of the Anthostema and Myristicaceae series (Faramalala ,1995).

Various types of facies currently present to this vegetation following anthropic activities especially slash-and-burn cultivation, selective logging over a long period:
-primary forest more or less intact in the conserved area;
- secondary formations such as "Savoka" (Savoka with Ravenala madagascariensis and Savoka with Bamboo) and fallows that regrow after a primary formation has been felled or burned;
- low vegetation locally called "Roranga" where Poaceae and Ferns dominate.

The variation in temperature (T) and precipitation (P) is given by the Gaussen umbrothermal diagram (Figure2). Analysis of this diagram shows two seasons:
- The cool season from May to September, marked by a very short dry season in September;
- Wet season from October to April.

The sampling period was divided into two distinct seasons: the cool season and the wet season. Two runs were made respectively parallel to these two seasons. The first took place from June 12 to July 19, 2012 (corresponding to the cool season). The second was carried out from November 12 to December 9, 2014 (corresponding to the wet season).

a. Sampling area

Three types of habitat were chosen as the sampling area, namely a forest zone (Sangasanga Forest, Figure 1), a reforestation zone and an deadland (the last two were chosen in the vicinity of MBP's Kianjavato Ahamson Field Station "KAFS", Figure 1, located in Kianjavato).

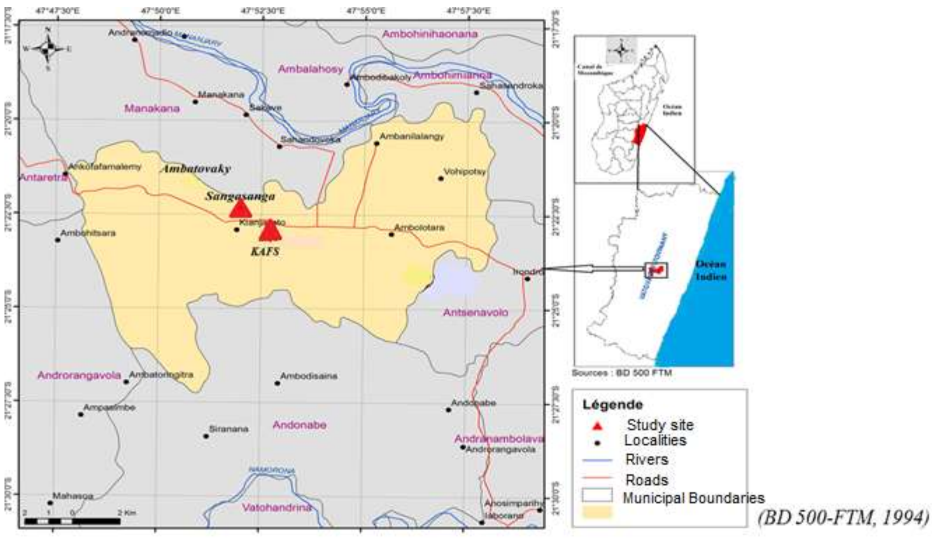

Figure 1. *Location map of Kianjavato*

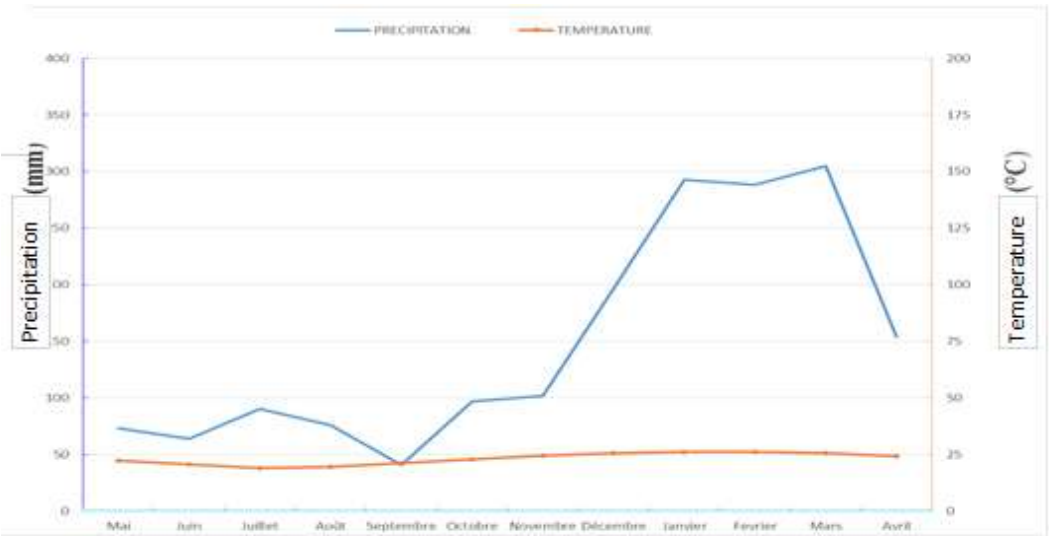

Figure 2. *Ombrothermique Gaussen curve (2010-2014)*

Forest zone

The Sangasanga forest is located near the FOFIFA station. It lies between 21°22'18.7" South and 47°51'59.3" East, at altitudes ranging from 150 to 358 m, and is covered by dense low-altitude moist evergreen forest. The upper canopy reaches heights of up to 20 m and is made up of four strata :

- a herbaceous stratum no higher than 2m, discontinuous and with a 62% cover rate. It is composed mainly of Clidemia hirta, Pittosporum polyspermum, and seedlings of individuals from the upper stratum ;
- a shrub stratum between 3 and 6 m high, semi-open, with a degree of cover of 46 to 51%. This stratum is made up of Tambourissa purpurea, Sterculia tavia and Ochna ciliata ;
- an open tree stratum 7 to 14 m high, with a fairly low cover rate of around 23 to 31%. It is composed of Ouratea anceps, Ocotea garyi and Sideroxylon betsimisarakum ;
- an upper stratum up to 20m high, with an open canopy allowing light rays to penetrate to the underlying strata. Its maximum degree of cover is 16% and it is made up of Canarium boivinii, Cryptocarya acuminata, Dalbergia baroni and Olea lanceolata (Andriamampianina, 2013).

The soil beneath the forest has a silty-clay-sandy texture and a very strongly acidic pH

(4.75), very rich in organic matter, moderately rich in nitrogen, assimilable phosphorus, potassium and sodium. Calcium and magnesium contents are low and the soil is very fertile (Manjaribe, 2014).

Reforestation zone

The reforestation zone lies between 21°38'57"south and 47°59'46"east, at an altitude of between 60 and 99 m, and comprises the hills between the KAFS station and the Vatovavy forest. A section approximately 200 m south-east of the station was selected. This is one of the areas where the reforestation carried out by MBP took place.

Two types of vegetation can be distinguished:

- abandoned agricultural land, locally known as "Roranga" , making up 80% of reforestation sites;
- secondary forest or "Savoka", occupying 20% of the reforestation site. (which is not accessible for lack of authorization from the owners).

The study was carried out on "roranga", which is defined as low vegetation 0.4 to 1.5 m high, dominated by Ferns and Poaceae and sometimes dotted with small trees and shrubs. This terminology"Roranga"is common and is used by the local population in the Vatovavy Fitovinany Region (Manjaribe et al., 2013).

b. Deadland.

The selected deadland lies between 21° 38' 09" south and 47° 29' 18"east, at an altitude of 50 to 100 m, 900 m south of the KAFS station. It has the same vegetation types as the reforestation zone. It would be the object of future reforestation.

2.2 Data collection

a. Inventory

Three complementary methods that have been systematically used by many researchers since the mid-1990s are thus adopted. These are: direct observations along sample routes, systematic searches of refuge sites, and trap-hole trapping or " pit-fall traps" with plastic barriers (Raxworthy & Nussbaum, 1994a).

In each of the three sampling zones, two transects of equal length, each 200 m long, were set up. A total of six transects were set up.

For direct observation and systematic searching, the daytime search began at around 8:30 a.m. to detect diurnal species. And to detect active nocturnal species as well as resting diurnal species, the night search was started at 7 pm using headlamps.

Trap-hole visits were made very early in the morning, just after sunrise, and before sunset in the afternoon. For this study, the observation period for each transect was set at 6 days and 6 nights.

b. Direct observation on sample route

Direct observation consisted in inspecting the presence of amphibians along the main track 200 m away. This track was taken as a sample route through all types of plant formations, taking into account the heterogeneity of the habitat at the study site. This enabled us to assess the distribution and ecological preferences of the species.

Observations should therefore cover all microhabitats at the sampling station, including degraded areas.

As some groups or species are diurnal and others nocturnal, observations should be carried out during the day as well as at night.

Diurnal species resting on their perches were also the subject of nocturnal observations.

c. Systematic search of refuge areas

The aim of this technique is to search all areas likely to be potential activity or refuge zones for amphibians, sheltered from any direct disturbance. This technique enables us to appreciate the specific habitat requirements of amphibian and reptile species.

The main track was taken as a sample itinerary. Excavation was carried out on both sides of the track, and in places likely to constitute:

- animal shelters, such as dead wood, under bark, at the foot of tall trees, under rotting wood, under litter, under rocks, and in plant tufts;
- the homes of burrowing species, species leading a cryptic life or species with a special biotope have been investigated, such as rock interstices and fissures, tree holes, the feet and armpits of sheathing leaves [for example, Ravenala madagascariensis. (Stretliziacae)]. This method is usually conducted simultaneously with direct observations.

Trapping using trap-hole systems with plastic barriers

Trap-holes or "pitfall traps " (Figure 10) are devices designed above all to count terrestrial species, in some cases burrowers, which are difficult to capture using the other two techniques described above. In Madagascar, the species targeted by this technique are mainly terrestrial amphibians, mainly of the Microhylidae family. However, other species can also be captured using this technique. It works in such a way that animals living on the ground encounter and follow a plastic strip that leads them straight into the trap-holes.

Two trap-hole lines, each 100 m long, were installed in each sampling zone to target the different types of habitat used by amphibians and reptiles.

The location of the devices was as follows

- Eleven plastic buckets with characteristics: capacity = 12.5 l; upper internal diameter = 290 mm; lower internal diameter = 220 mm; height = 275 mm. Numbered, they were buried up to their upper edge. The buckets were aligned and spaced 10 m apart. The bottom of each bucket was pierced to allow rainwater to drain away;
- Then vertically, a 100 m-long plastic strip was erected and laid continuously from the first to the last bucket, passing through the diameter of each bucket. This strip, 0.70 m high above the ground, was stretched and held in place by wooden stakes which were driven into the ground along its entire length, then the 10 to 20 cm at its base was driven into the ground and covered with litter and other debris to guide the animals towards the buckets and prevent them from passing over to the other side of the strip. Staples were available to secure the belt with the stakes. Because of the need to go around tall trees and other obstacles, the strip was not quite straight.
- The trap-holes were in place for six days and nights.

Each animal captured during the trap-hole visit was placed in a bag bearing the line and bucket numbers to be inventoried. The debris accumulated in each bucket was removed during each visit.

- Data analysis

d. Biological diversity

The species richness was obtained from the list of species recorded at the level of each community, and it is therefore time to produce a list for all the amphibians in the Kianjavato region. The cumulative curve, which represents the number of species inventoried on each inventory day, is obtained after accumulating the numbers of individuals captured on each sampling day. It provides information on the existing heritage of the site and the effectiveness of the methods adopted.

e. Site similarity analysis

Analyses of amphibian similarity between the three sampling zones of the study sites were carried out by calculating Jaccard's (1908) similarity indices, to assess the effect of reforestation on the amphibian population. Jaccard's similarity index (i) is given by the formula

$$i = c / (a + b - c)$$

Where a = number of species in environment A, b in environment B and c = number of species common to both sites. The closer this index is to 1, the closer the specific composition of the two environments compared, and it is 1 when the two sites have the same specific composition. Similarity indices were used to perform cluster analysis. The data were processed with SYSTAT version 10.2 for Windows, and the results are presented in the form of similarity trees or dendrograms. These similarity diagrams are used to assess the similarity and similarity distances between sites. Species with uncertain determination have been eliminated from this analysis.

III. Results and Discussion

3.1 Results

a. Specific richness

26 amphibian species have been encountered on the site.

The Figure 3 shows the cumulative number of amphibian species at the three sites.

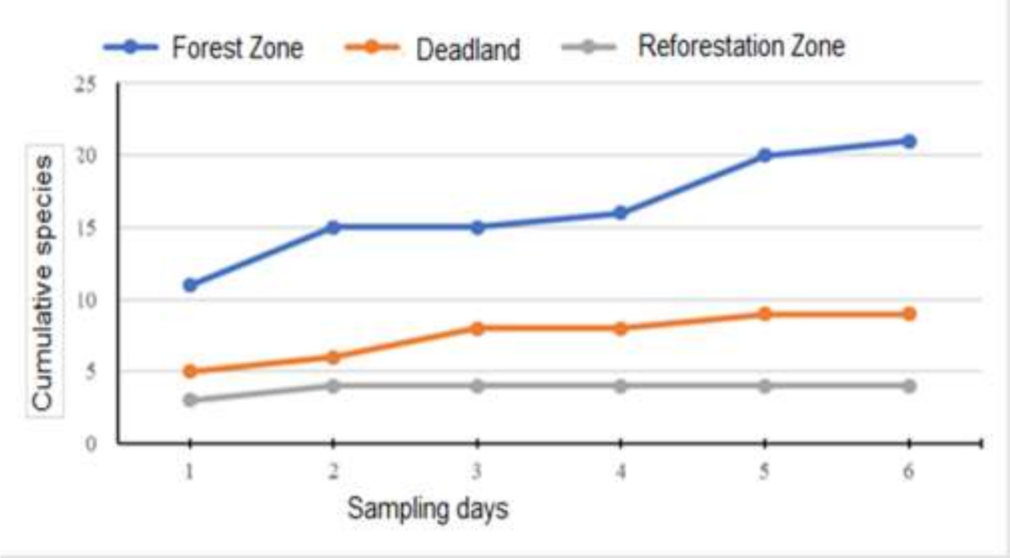

Figure 3. *Amphibian species cumulative curve*

b. Species richness, status and endemicity

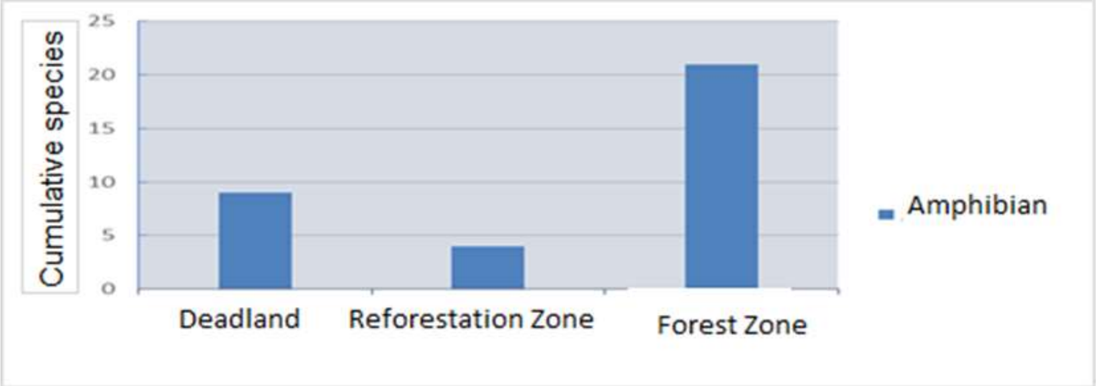

Figure 4. *Species richness in each habitat type*

The forest zone is the richest site compared with the others, with 21 species, while the reforestation zone is the poorest, with 4 amphibians.

It should be noted that during the inventory, three amphibian species were captured by trap-holes.

Table 1 below summarizes the distribution of species present at each site, with their IUCN status noted.

Table 1. Aspect of amphibian species richness at the 3 sites

Taxons	Sites						Status IUCN
	Deadland		Reforestation zone		Forest zone		
	Seasons		Seasons		Seasons		
	Fresh	Wet	Fresh	Wet	Fresh	Wet	
Family :Hyperoliidae							
Heterixalus alboguttatus	+	+	+	+	+	+	LC
H. betsileo		+		+			LC
H. luteostruatus		+					LC
H. sp.		+					LC
Family: Mantellidae							
Sub_Family : Mantellinae							
Gephyromantis boulengeri	+				+	+	LC
G. luteus						+	LC
G.pseudoaster						+	LC
G. sculpturatus					+	+	LC
G. sp.	+				+	+	
G. timidus						+	LC
Guibemantis sp.						+	
Mantidactylus charlotteae					+		LC
Mantidactylus sp					+	+	
Sous-Famille :Boophinae							
Boophis madagascariensis					+		LC
B.tephraeomystax		+	+				LC
B. sp.1						+	
B. sp.2						+	
Sous-Famille : Laliostominae							
Aglyptodactylus madagascariensis						+	LC
*A.*sp.					+		
Famille : Microhylidae							
Sous-Famille : Cophylinae							
Anodonthyla boulengeri						+	NT
A. sp.						+	
Platypelis grandis						+	LC
P. sp.						+	

Plethodontohyla aff.notortica						+	LC
Stympfia sp.	+				+	+	
Family: Ranidae							
Subfamily : Ptychadenidae							
Ptychadena mascareniensis	+	+	+	+			LC
Total amphibians: 26 species	**05**	**06**	**03**	**03**	**09**	**18**	

(+) Présence ( ) Absence LC : Least Consern NT : Near Threatned

Four amphibian families are represented in five Sub-Families, distributed in 11 genera with 26 species.

For amphibians, only Heterixalus alboguttatus, manages to colonize the three habitat types existing at Kianjavato with a total frequency of 74 individuals. Ptychadena mascareniensis, Boophis tephraeomystax, Heterrixalus sp., H. luteostruatus, H. betsileo, are only found in the two non-forest habitats (Deadland and reforestation). These species are therefore able to adapt to the conditions of these degraded habitats.

The forest zone is richer in amphibians than the other two degraded zones. The composition varies according to site and habitat type. The forest zone is the richest with 21 amphibians, the deadland is the second richest with 9 amphibians, followed by the reforestation zone which is the poorest with 4 amphibians.

Regarding their conservation status, the majority of Kianjavato amphibians surveyed are classified as Least Concern (IUCN, 2013).

The low frequency of encounters with forest amphibian species in the "Sangasanga" forest can be explained, on the one hand, by the impossibility of mounting the second transect in this area during the wet season and, on the other hand, by its state of degradation.

Given that both the reforestation zone and the deadland are degraded formations, their composition could be grouped into a single group.

c. Site similarity analysis

The amphibian community similarity index values for the zones are summarized in Table 2. The list of species between the three zones is shown in the appendix.

Table 2. Jaccard's index between sites for amphibians

	Deadland	Forest area	Reforestation zone
Deadland	1.000		
Forest area	0.154	1.000	
Reforestation zone	0.444	0.042	1.00

The value of Jaccard's index ranged from 0.154 to 0.444. A relationship was observed between the reforestation zone and the deadland (0.444). That is, they are the two closest zones in relation to the forest zone.

The relationship between the three zones is supported by the similarity dendrogram Figure 5 (a figure illustrating the relationships between the zones), based on similarity in amphibian communities

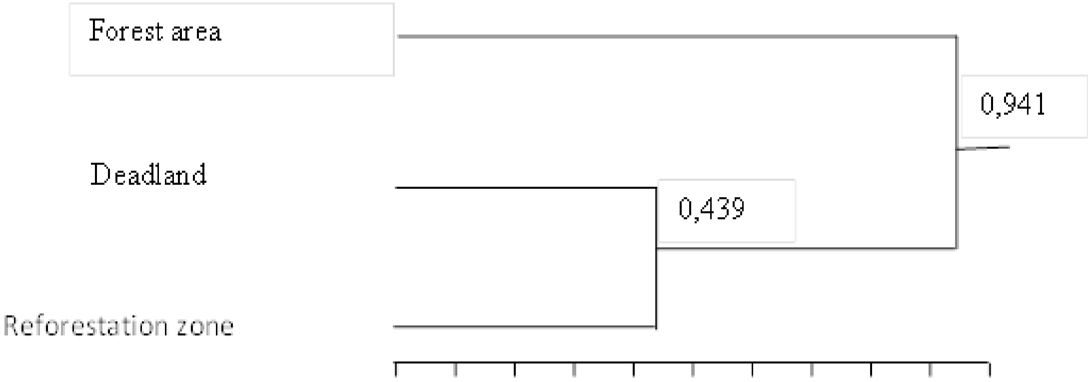

Figure 5. *Site similarity dendrogram for amphibians*

The amphibian similarity dendrogram for the Kianjavato forest shows two main groups, separated by a distance of 0.941 Euclidean Metric Units (E.M.U.). On the one hand, the first group is formed by the deadland and the reforestation zone, which are connected at a distance of 0.439 E.M.U. On the other hand, the second is the forest zone. In other words, the two degraded zones (deadland and reforestation zone) have many species in common and look very similar. The Sangasanga forest, on the other hand, forms a separate block.

In terms of amphibian composition, the Kianjavato region is made up of two distinct habitats: the forest habitat and the degraded habitat.

3.2 Discussions

a. Biological diversity

The amphibian diversity of the Forêt Classée de Kianjavato (FCK), with its 26 species, is quite high when compared with the two eastern forests: Bekaraoka in the Daraina Special Reserve (E 049°42.6'; S 13°11.7, altitude 90 -360 m), with 45 species, and Andasibe (40 species) (Raselimanana & Rakotomalala, 2003). This FCK plays a very important role by being the rare formations where Prolemur simus still lives in its natural state.

b. Cumulative species curve

During the six days of sampling with two transects in each of the three study areas over the two seasons, the plateau is still only reached in the during the wet season. A slight increase in the species list could then occur if the sampling days were extended.

The vegetation cover of each site is directly related to the number of species inventoried.

c. Species richness

The 26 Kianjavato amphibians are divided into four amphibian families and five reptile families. Despite the fact that the list is not exhaustive, as we haven't really reached the plateau of the cumulative curve, given the specific diversity of herpetological fauna in the forests of eastern Madagascar, this specific richness is not negligible. It should also be noted that none of the species inventoried are endemic to Kianjavato.

In comparison with the previous study carried out in Kianjavato with 25 amphibian species, this study allows us to add the specific herpetofauna list of the FCK (Ratsoavina et al., 2010).

One amphibian species enriches the list (not determined, as the complete list of amphibian species from the previous study only stipulates the number of 25 species, mentioning some of the best-known species).

The forest structure of Kianjavato is made up of at least three different blocks, each with its own characteristic microhabitats: the "Sangasanga" forest (chosen as the forest zone for this study), the "Vatovavy" forest and the "Tsitola" forest.

This situation implies that an investigation in all the forest blocks existing in Kianjavato would be desirable to get a global overview of the amphibian fauna of the region.

The abundance of a species not endemic to Madagascar, Ptychadena mascareniensis, would be due to its wide distribution in Madagascar, the Seychelles, the Mascarene Islands and sub-Saharan Africa (Vences et al., 2004).

d. Analysis of similarity between sites

The similarity dendrograms between the sites bring the reforestation area and the Deadland together into a single block, with reference to their species composition. This similarity is not surprising:

Both areas are covered by low vegetation 0.4 to 1.5 m high, dominated by Ferns and Poaceae and sometimes dotted with small trees and shrubs and referred to locally by the terminology "Roranga". The only difference found on the reforestation area lies in the existence of leguminous species (Albizia saman, A. chinensis and A. lebbeck, Harungana madagascariensis) planted before, followed by fast-growing species (Acacia manguim, A. oricularis, A. leptocarta) which are the object of reforestation. What's more, they are chosen from areas at roughly the same altitude (no higher than 100m). So both have almost the same forest cover.

The "Sangasanga" forest stands apart from these two zones in terms of amphibian composition (verified by similarity dendrograms between sites). This could be due to two complementary reasons: firstly, the Sangasanga forest has a higher floristic diversity, and is even less affected by human activity (tavy, etc.) despite its palpable state of degradation.

The second would be that it has more altitudinal range than the other two zones (chosen between 150 to 358 m). This is an important situation as altitude is among the factors that influence amphibian distribution (Raxworthy, 2003).

To maintain the richness of the Kianjavato region, the reforestation implemented by the MBP deserves to be supported in order to preserve the region's conservation gene pool, despite the fact that in its current state it is not yet able to provide the necessary conditions for forest species to colonize the entire region.

IV. Conclusion

The study carried out in the Kianjavato FCK enabled us to complete the existing data on ecological and biological diversity on the existing formations in the region, namely the "Sangasanga" forest, the reforestation zone (initiated by the MBP project) and the deadland. Thus, during the study, which was carried out in two periods: the first during the cool season in June and July 2012 and the second during the wet season in November-December 2014; the zoological inventories carried out there identified a total of 26 amphibians. None of these species are local or regional endemics, but they may enrich the specific richness of the region compared with previous studies, namely one amphibian species (undetermined).

The plateau has not been reached. Amphibian composition varies according to site and habitat type. Thus, the forest zone is the richest with 21 amphibians, the deadland holds second place with nine amphibians followed by the reforestation zone which is the poorest with four amphibians.

In terms of specific diversity, a well-defined distribution, particularly according to the type of existing habitats. Indeed, a change in taxonomic composition is apparent as vegetation cover varies from one selected study area to another. Species are more abundant in the forest than in the two degraded zones, a situation that confirms the importance of the amphibian population as an indicator of stress in an environment. In addition to vegetation cover, the altitudinal gradient plays a significant role in the distribution of amphibian species, as the Sangasanga forest lies at a higher altitude than the other two study areas.

The deadland and the reforestation zone, which have been subject to long-term anthropogenic altercations, both provide a number of common species and form a similar block to the forest zone, which is another habitat in its own right.

In terms of conservation, the FCK deserves special consideration and its conservation proves very important for the long-term monitoring of biodiversity, especially its position as the Fandriana-Vondrozo Corridor which gives it a particularity in terms of maintaining genetic biodiversity and also it is among the few formations in the world where Prolemur simus can be found in its natural state. Given that this FCK is the source of water to riparian populations and other surrounding regions, it is vital to promote an ecologically and biologically sustainable management system. Given that access to this forest is easy, a situation that complicates any conservation measures, this site can then be used as a training site for students in environmental ecology.

In order to complete the information on the herpetofauna of the FCK and surrounding regions, a complementary inventory in its various forest blocks is desirable backed by permanent monitoring of existing populations so as to be able to capitalize on information on the evolution of faunal richness on formations newly at the rehabilitation stage.

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