Sustainability and Biodiversity Conservation

Long-term surveys of pond occupancy and seasonal dynamics of the golden Mantella frog from Mangabe-Ranomena-Sahasarotra Reserve

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Abstract

We conducted an eight-year monitoring of the golden mantella frog, *Mantella aurantiaca,* from the Mangabe-Ranomena-Sahasarotra reserve with the objective of assessing its status within the reserve. We surveyed breeding ponds and the adjacent forests to study the evolution of pond occupancy and seasonal movement of the species. A diurnal search was carried out along transects from the breeding ponds and the adjacent forest within this reserve. Animal presence and the number of encountered individuals were recorded. In addition, ponds status based on the impact of threats was also assessed, and they were classified into three categories such as good, intermediate, and bad. Our results indicated that the number of recognized ponds within the reserve increased during the survey period, and ponds occupied by the golden mantella follow the same path. The proportion of pond status changed every year, and we noticed that the number of good ponds increased during the last five years. Sex and age of encountered animals vary between seasons of survey and the topography of the transect. Despite the improvement of its conservation status on the IUCN Red List, the golden mantella is still under pressure from forest destruction and gold mining.
Keywords: Conservation, Humid Forest, *Mantella aurantiaca*, Monitoring, Protected Area

Introduction

The golden mantella frog (*Mantella aurantiaca*) is one of the 16 species of the mantella genus (Glaw & Vences, 2006). This species has a restricted range within the Moramanga District (Bora et al., 2008) and inhabits the mid-altitude humid forest of the central eastern Madagascar, where it relies on ponds for breeding (Randrianavelona et al., 2010). Within its geographic range, the population of the golden mantella frog is divided into two clusters: the first cluster is located southwest of Moramanga town, around the Mangabe reserve, and the

second cluster is situated northeast of Moramanga town, which includes the mining area of Ambatovy and the Ramsar site of Torotorofotsy (Randrianavelona et al., 2010; Piludu et al., 2015). Its red list status changed respectively from Critically Endangered to Endangered based on the criteria B2ab (iii,v) in 2008 (Vences & Raxworthy, 2008) and B1ab(ii, iii,v)+2ab(ii, iii,v) in 2018 (IUCN SSC/ASG, 2020). The main threats to the golden mantella are the destruction of breeding ponds due to mining activity, forest clearance to make way for subsistence agriculture, logging, illegal collection for the pet trade, and climate change (Vences & Raxworthy, 2008; Piludu et al., 2015). Therefore, the *Mantella* genus is well known due to its aposematic coloration and presence in the international pet trade (Edmond et al., 2015). Currently, all *Mantella* species are listed in Appendix II on the CITES convention, and the golden mantella is one of the eight species that Madagascar can export. Currently, the export quota of *Mantella aurantiaca* is 280 individuals per year since 2014, and Madagascar has exported in total of 2,988 individuals, with a maximum of exports in 2013 with 565 exports (CITES Secretariat & UNEP-WCMC, 2022). Two conservation strategies of the species were developed and undertaken during the last fifteen years (Randrianavelona et al., 2010; Rakotondrasoa et al., 2017). The change of its conservation status under the UICN red list can be considered as the result of both strategies. Research on distribution, population trend, life history, and threats to the species was recommended during its two last assessments. To reply to those recommendations, we surveyed the golden MantelIa frog from Mangabe-Ranomena-Sahasarotra, which represents about 60% of its total population. Our research objective is to study the relationship between pond quality and the number of frogs encountered. This paper summarizes results from nine years of surveys and conservation efforts of the golden mantella from the southern subpopulation within the Mangabe reserve.

Material and methods

Study Site

Mangabe reserve is situated in the central eastern part of Madagascar between latitude 19°00 to 19°28 and longitude 48°05 to 48°25 (Madagasikara Voakajy, 2015). Its vegetation is dominated by the mid-altitude evergreen rainforest of Madagascar (Du Puy & Moat, 1996) (Figure 1).

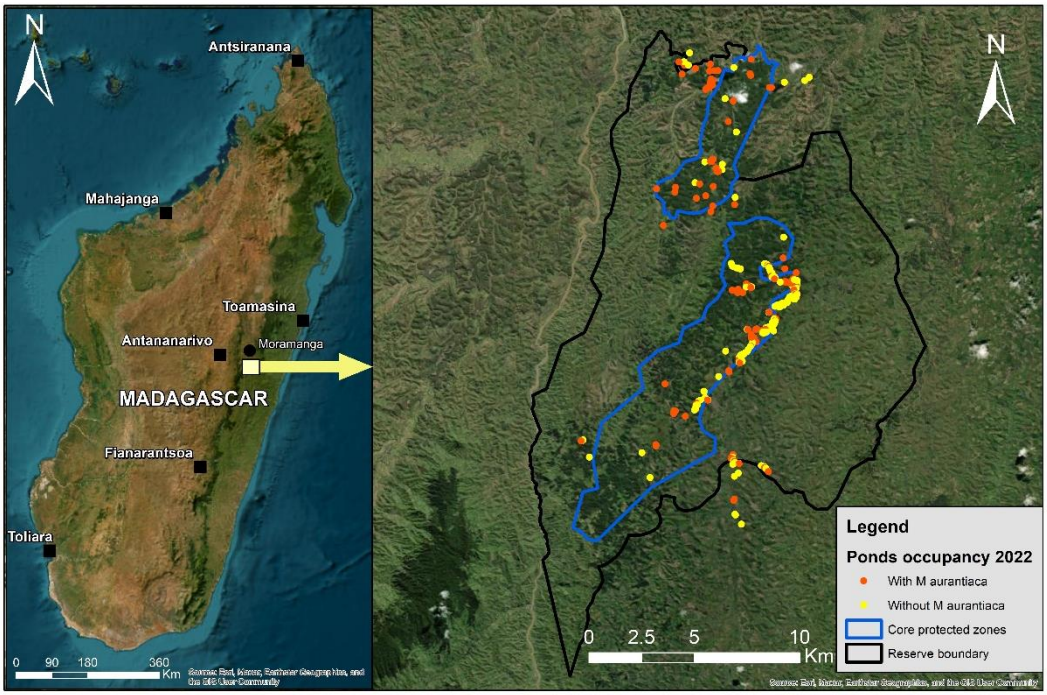

Figure 1. Map showing pond occupancy by the golden mantella during the last survey in 2022

Data Collection

The field surveys were conducted from 2014 to 2021 during the rainy season from November of the year to March of the next year, when the animal is more active. Three sessions of fieldwork were undertaken during this period, such as the first conducted in mid-November and December, which corresponded to the start of the rain, the second visit was in mid-January and February during the middle of the rainy season, and the last was from mid-march to April, which coincided with the end of the rainy season. Each transect was visited once during each session of fieldwork, which meant that they were visited three times for one season. Animal research was carried out along transects around the ponds from 6:00 AM to 2:00 PM. An animal search was carried out from the pond areas up to the ridge tops of the forest, following a series of transects described in Edwards et al. (2019). The number of transects varies depending on the length of the slope from the edge of the pond to the top of the forest (Figure 2). The transects were grouped into three categories according to the topography, such as:

Bottom: composed of the first two transects inside and at the pond's edge.

Middle: transects located on the slope between the ponds and the top of the forest.

Top: the last two transects located on the ridge tops of the forest.

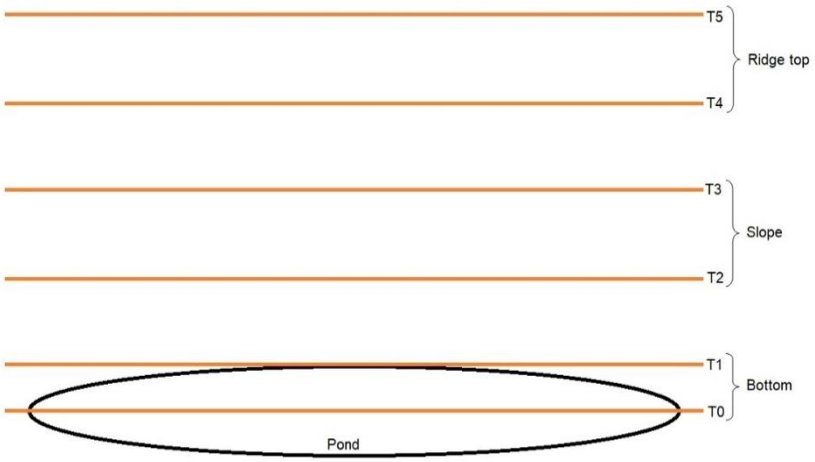

Figure 2. Diagram of transect lines (T0 to T5) from the pond into the top of the adjacent forest

Animal Search

The surveys were conducted by a team of four individuals who are highly qualified in surveying the target species. The presence of the species within the ponds or along transects was recorded through direct observation or by hearing males calling from their refuges. The confirmation of the pond occupancy was confirmed by at least one of the direct observation or hearing calling male from one of the transects during the three-period surveys. From 2019 to 2021, we took into account the biology of the animals from direct observation. We recorded the total number of the encountered individuals with their respective age and sex from each breeding pond and its adjacent forest.

Habitat Quality Assessment

Within the reserve, target species and their habitat are threatened by slash-and-burn agriculture, illegal gold mining, and selective logging (Randrianavelona et al., 2010). The threats contributing to these disturbances were recorded, such as:

- slash-and-burn agriculture (Tavy): trees around the ponds and the adjacent forest were cut and burnt for agricultural purposes,
- selective logging: selective big trees were cut for wood exploitation and fruit harvest, which affects the surrounding trees,
- bush fires: non-controlled fire from the savannah area or fires left unattended used for honey harvest,
- Small-scale mining: artisanal gold mining is damaging the ponds in general.

The pond's quality was assessed based on the presence or not of threats and the proportion of the impacted area. Ponds were classified into three categories such as: (1) in good quality if no threats were observed or if present threats affect less than 25% around the pond and/or the surrounding forest, (2) in intermediate if threats cover from 25% to 75% of the pond and/or its

surrounding habitat, but where the Mantella frogs can still live, and finally (3) bad stage if the proportion of ponds are disturbance is more than 75% of the its area or if it's totally destroyed.

Statistical Analysis

Statistical analysis was done using RStudio with R4.5.2 (R core team, 2024). All the statistical tests were nonparametric with a Poisson distribution data family. For the analysis, we set as a factor the seasons of surveys and the topography of the transects. We used the Kruskal-Wallis test for the comparison of the number of animals encountered between the seasons of surveys and the topography of the transects. The General Linear Model (GLM) was used to confirm the main factor affecting the change in the number of observations. Mumin (Burnham & Anderson, 2002) and lme4 (Bates et al., 2010) packages were used for the analysis.

Results

Pond Occupancy

In total, we identified 326 ponds within the Mangabe-Ranomena-Sahasarotra reserve during the last survey in April 2021. The number of identified ponds increased each year with a new discovery, especially in 2019, with 135 new ponds, while the number increased almost double from the previous year, which brought the number from 140 in 2018 to 275. In general, 46.36% (±3.33) of the ponds are occupied by the golden mantella frog, but this rate changes between the years, with the maximum was recorded in 2018, which was 57.17%, and the lowest rate was encountered in 2019, when only 29.09% of the existing ponds were occupied by the species. Moreover, the number of ponds occupied by the golden mantella frog showed the same trend as the number of surveyed ponds (Figure 2). According to the management plan of the reserve, 51% of identified ponds are located within the core protected zone of the reserve, while the rest of them are situated in the buffer zone (Figure 3).

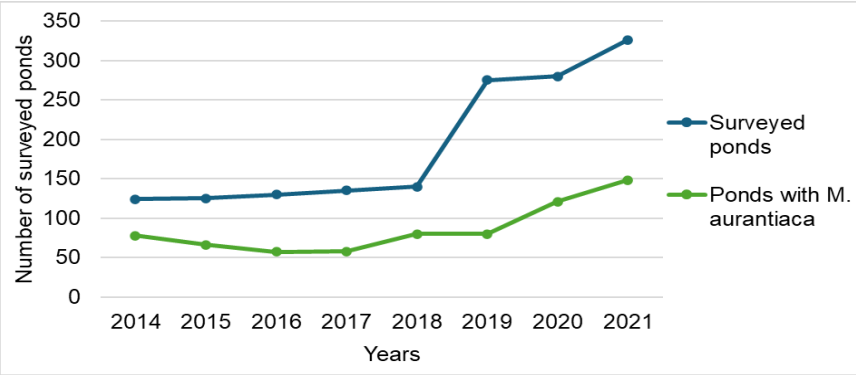

Figure 3. Number of identified ponds and occupied ponds by *Mantella aurantiaca* from 2014 to 2021

Habitat Quality

The golden mantella habitat quality, including the breeding pond and the adjacent forest, is under pressure, even in general they are generally in good condition in all nine years of monitoring. However, the number or percentage of ponds classified for each category varies year by year. We highest records for good ponds in 2019 and 2021, respectively, representing 81.45% and 81.59% and the year with the lowest good ponds proportion was in 2016, which represents 50.76% of all surveyed ponds during this period. Moreover, this low rate of good ponds was accompanied by the high number of destroyed ponds, which represented 32.30% in 2016 and 32.59% in 2017 (Figure 4). The presence of the golden mantella is related to the good pond and the adjacent forest.

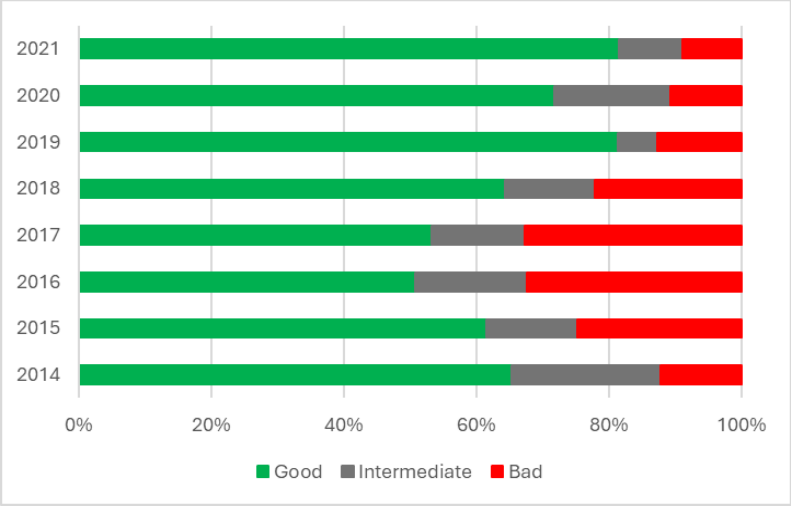

Figure 4. Percentage of pond quality evolution during the survey period: Good state if threats cover less than 25% of the ponds and the adjacent forest, intermediate quality if threats occur between 25 to 75% of the ponds and the surrounding forest, bad quality if threats destroy more than 75% of the ponds and their surrounding forest

Animal Encounter Rate

In total, we recorded 10,294 frogs during the last three years of our surveys. The encounter rate of the golden mantella frog varies across the different seasons of the surveys. The highest encounter rate was recorded at the start of the rainy season, with an average of 6.62(±0.93) individuals from one pond, followed by the middle rain with a mean number of 2.03(±0.24), while the lowest rate was observed towards the end of the rainy season with only 1.74(±0.23). (Figure 5). The Kruskal-Wallis test confirms that the change in the number the encountered frogs from different seasons is significant, with a $p\text{-value}<0.0001$.

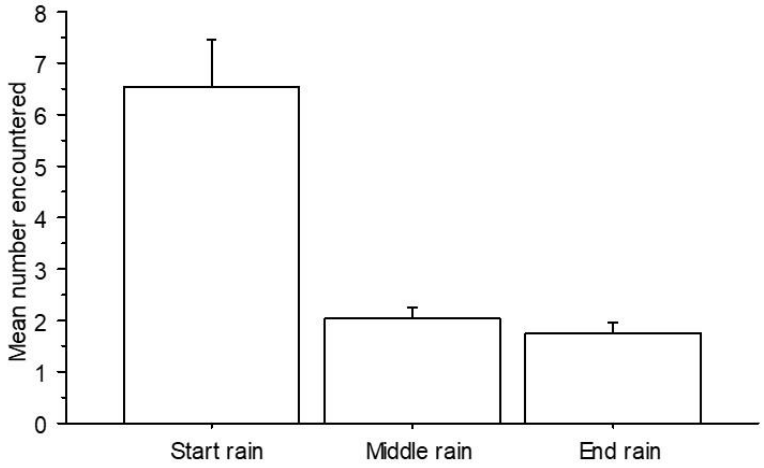

Figure 5. Bar chart showing the variation in the mean number of the golden mantella frog encountered at one pond during the three seasons of surveys

Seasonal and Topography Distribution

Our results indicated a spatial change in animals' repartition during the different periods of their activities. Our highest record was from the bottom section, which is near the breeding pond at the start of the rainy season, with 6,164 individuals (8.10±1.23). However, we recorded only 854 (1.19±0.24) individuals from the same topography at the end of the rainy season (Table 1). In a general way, the change in the number of animals encountered from different topography is significant (*p-value<0.0001*), but in pair-wise comparison, the difference in the number of individuals recorded from the slope and the top of the forest is not significant (*p-value=0.37*).

Table 1. Total number of encountered animals (with the mean ± standard error) during the different seasons of surveys from the categories of topography of the transetcs

Seasons / Topography	Start rain	Middle rain	End rain
Bottom	6,164 (8.10±1.23)	900 (1.55±0.16)	854 (1.19±0.24)
Slope	476 (2.66±0.81)	436 (1.92±0.42)	542 (3.04±0.60)
Top	124 (1.49±0.44)	502 (5.07±0.68)	296 (3.89±1.20)

Seasonal Population Structure

Encountered animals were composed of adult males, adult females, and juveniles without sex determination. Adult males and females were recorded from all three seasons of surveys. However, juvenile was only found during the start and middle of the rainy season. The number of observed animals from each sex and age varies for each season of survey with the highest for all of them recorded during the start of the rainy season. In general, we encountered more adults from each season of the survey (Figure 6).

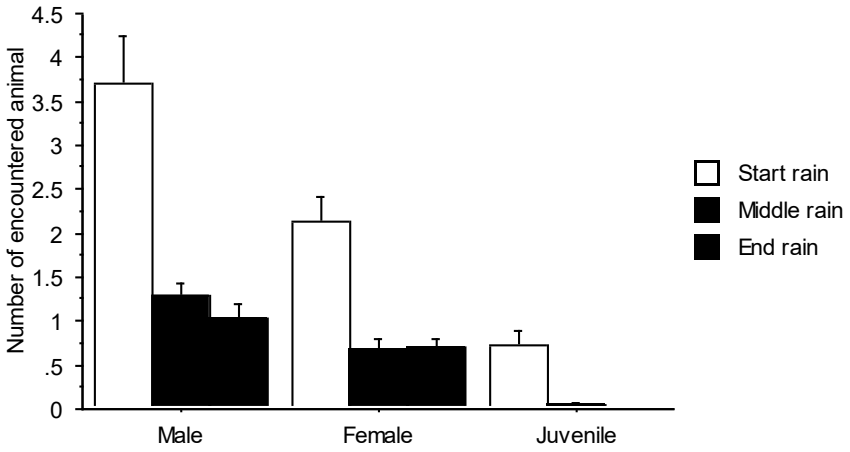

Figure 6. Mean number of encountered animals along transects from different sexes and ages during different seasons of surveys

The GLM analysis indicated that the combination of seasons of observation and the topography of the transects together is the main factor affecting the change in the number of animals encountered during the surveys.

Discussion

Our results showed that the number of identified and occupied breeding ponds for *Mantella aurantiaca* within the Mangabe-Ranomena-Sahasarotra reserve increased during the period

of this study. This case can be considered as an improvement of the conservation situation of the species in their natural habitat, considering that 55% of the ponds are located within the core zone, where they are well protected. This improvement was used during the last red list assessment, and the species was downlisted from Critically Endangered to Endangered in 2020 (IUCN SSC/ASG, 2020). However, previous studies have shown the vulnerability of *Mantella aurantiaca* to climate change, which indicated a potential reduction and shift of its suitable habitat (Dubos et al., 2022). These studies indicated that the viable zone for the species will shift outside of the reserve. In such situations, habitat adaptation and enhancement measures are recommended to maintain the species' viability. Research is recommended within newly identified areas that are either climatically stable or fall within the projected future distribution range under climate change scenarios. This will help assess their suitability for potential future translocation efforts. Where appropriate, this may involve habitat restoration to ensure the availability of water bodies for breeding and the presence of suitable associated microhabitats (Edwards et al., 2019). In addition, research should explore the feasibility of establishing wildlife corridors between the current and potential distribution areas of the golden mantella to facilitate range shifts toward more secure habitats. The number of observations varies depending on the season and the topography of the environment. The species was most frequently observed at the beginning of the rainy season, coinciding with its breeding period, during which it is more active. In contrast, observation numbers declined significantly toward the end of the rainy season, which is common, as the species enters hibernation during the winter months, making it more difficult to detect (Edmond et al., 2020). The high number of observations near the ponds at the beginning of the rainy season confirms the breeding activity of *Mantella aurantiaca*. However, during the middle and latter parts of the rainy season, the species was more frequently encountered on slopes or ridges in the surrounding forest. These findings are consistent with those of Randrianavelona et al. (2010), who also reported a high number of individuals on ridges during March and April.

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