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# Distribution, threats and conservation of a Critically Endangered amphibian (*Mantella aurantiaca*) in Eastern Madagascar

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**Abstract**. The golden mantella frog, *Mantella aurantiaca,* is a brightly-coloured terrestrial and diurnal species that is endemic to a relatively small area of humid forest in eastern Madagascar. We present the results of a three-year survey covering the whole known distribution area of the species. Breeding ponds, as well as visible threats to both the pond and the surrounding forest, were recorded. The number of breeding sites increased from 26 in 2010 to 139 in 2014. We show that several threats affect half of the breeding ponds, regardless of the conservation status of the site, and discuss future conservation strategies for the species.

**Keywords.** gold mining, *Mantella baroni*, *M. crocea*, pet trade, protected areas, slash and burn

## Introduction

The golden mantella frog *Mantella aurantiaca* is restricted to the Moramanga District in eastern Madagascar (Bora et al., 2008). Due to its limited area of occupancy, ongoing population decline and continued habitat loss, it is listed as Critically Endangered (CR) on the IUCN Red List of Threatened Species (Vences and Raxworthy, 2004). *Mantella aurantiaca* inhabits mid-elevation humid forest and requires forest ponds for breeding (Randrianavelona et al., 2010b). The forests occupied by this species are subject to legal and illegal extraction of natural resources and in some areas the species is collected for the international pet trade (Andreone et al., 2006; CITES, 2013). Many of the breeding ponds are the focus of ongoing conservation activities (see Jenkins and Randrianavelona, 2011).

## Material and methods

In this paper we describe the results of field surveys carried out between April 2010 and July 2013 conducted by Madagasikara Voakajy, a Malagasy conservation organisation that works in the region. We re-visited 23 of the 26 ponds where *M. aurantiaca* was observed by Randrianavelona et al. (2010a) and conducted daylight searches of the surrounding vegetation in an additional 168 potential breeding ponds in the Moramanga District. The presence of all *Mantell*a species, including *M. aurantiaca, M. baroni* and *M. crocea*, in the proximity of each pond was recorded.

Geographical coordinates of all visited ponds were recorded with GPS devices and reported on GIS computed under Quantum GIS version 2.0.1 (Quantum GIS Development Team, 2013). To avoid potential abuse by local semi-professional collectors, we rasterised the data into a 1 km grid cell under R v.3.1.2

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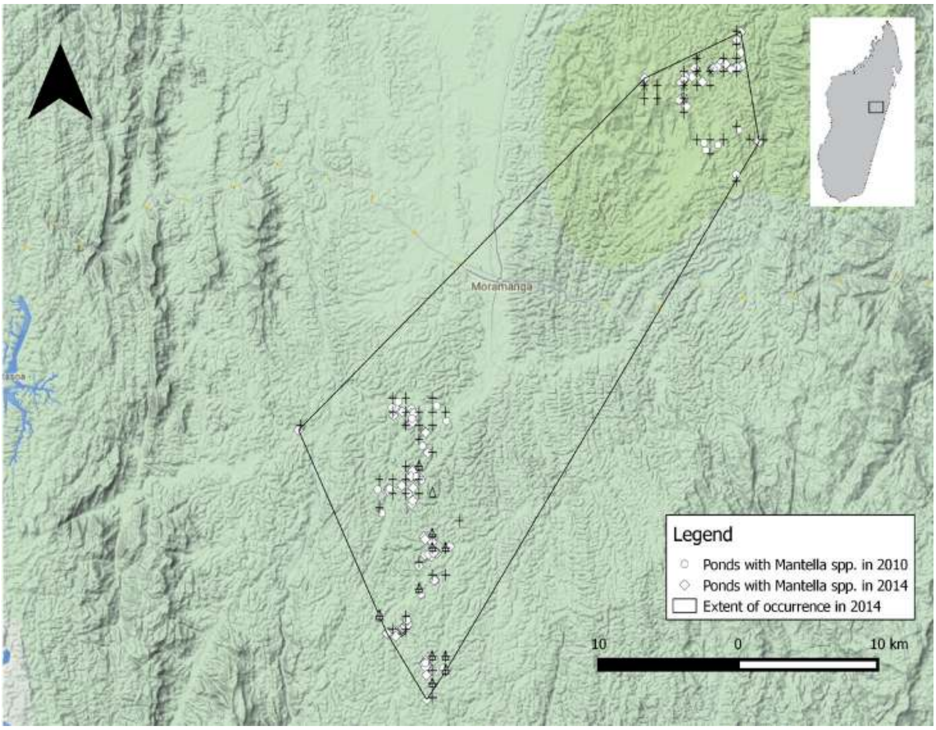


**Figure 1**. Distribution of 1 km grid cells occupied by *Mantella spp*. in Mangabe and Analamay, eastern Madagascar, and the extent of occurrence of *Mantella aurantiaca*. The pluses (+) indicate cells occupied by *M. aurantiaca*; the crosses (×) indicate cells occupied by *M. crocea*; the triangles (Δ) indicate cells occupied by *M. baroni*.

(package raster; R Core Team, 2015), and provide the coordinates of the centre of the cells occupied by *M. aurantiaca*. For practical reporting and management purposes we categorized the ponds as occurring in one of two clusters: (A) Mangabe, to the south-west of Moramanga town and (B) Analamay, to the north-east of Moramanga town (Fig. 1).

Visible threats (e.g. forest clearance, fire, gold mining and slash and burn agriculture) were noted during each visit and for analysis purposes we attributed them to either (1) expanding subsistence agriculture, (2) illegal artisanal mining or (3) legal nickel and cobalt mining (Dickinson and Berner, 2010).

## Results

A total of 194 ponds were visited: 127 in the southern cluster and 67 in the northern cluster. *Mantella aurantiaca* were observed in the immediate vicinity of 139 ponds. Of these, 103 were in the Mangabe cluster and 36 were in the Analamay cluster (Fig. 1; see coordinates in Table 1). In the Mangabe cluster, nine occupied ponds were located outside the provisional boundary of the Nouvelle Aire Protegée (NAP; New Protected Area) Mangabe-Ranomena-Sasarotra, whilst the remaining 94 were located within the NAP. In Analamay, 14 ponds were located in the northern part of the footprint of the Ambatovy nickel and cobalt mine, while the remaining 22 were located in forests adjacent to the mine footprint, including areas under conservation management. *Mantella aurantiaca* and *M. crocea* occurred together in nine ponds across both areas including five that are found in areas subject to future deforestation for purposes of legal mining. *Mantella baroni* was found in 11 ponds in Mangabe, although it is also known from Analamay (Raselimanana, 2010). Evidence of active illegal artisanal gold mining was found in 14 ponds, whilst 37 ponds were directly affected by agricultural activities (Table 2). Of the 139 occupied ponds, 50% ($n$ = 69) were considered to be actively threatened by habitat

**Table 1**. Geographical coordinates of the centre of 1km² grid cells occupied by *Mantella aurantiaca*, with sympatric *Mantella spp*. To prevent from potential collector abuses, we provide here 71 occurrence cells (1 x 1 km) in which the 139 occupied ponds are included.

| Cell ID | Longitude | Latitude | Sympatry | Cell ID | Longitude | Latitude | Sympatry |
|---|---|---|---|---|---|---|---|
| 1 | 48.37251 | -18.77905 | - | 37 | 48.07268 | -19.04253 | - |
| 2 | 48.37251 | -18.78813 | - | 38 | 48.14537 | -19.04253 | - |
| 3 | 48.34525 | -18.79722 | *M. crocea* | 39 | 48.15445 | -19.04253 | - |
| 4 | 48.36343 | -18.79722 | - | 40 | 48.16354 | -19.04253 | - |
| 5 | 48.37251 | -18.79722 | - | 41 | 48.15445 | -19.05162 | - |
| 6 | 48.33617 | -18.80630 | - | 42 | 48.16354 | -19.06070 | - |
| 7 | 48.34525 | -18.80630 | *M. crocea* | 43 | 48.14537 | -19.06979 | - |
| 8 | 48.35434 | -18.80630 | *M. crocea* | 44 | 48.15445 | -19.06979 | *M. baroni* |
| 9 | 48.36343 | -18.80630 | - | 45 | 48.12720 | -19.07888 | - |
| 10 | 48.37251 | -18.80630 | - | 46 | 48.13628 | -19.07888 | - |
| 11 | 48.30891 | -18.81539 | *M. crocea* | 47 | 48.14537 | -19.07888 | - |
| 12 | 48.31800 | -18.81539 | - | 48 | 48.15445 | -19.07888 | - |
| 13 | 48.33617 | -18.81539 | *M. crocea* | 49 | 48.13628 | -19.08796 | - |
| 14 | 48.34525 | -18.81539 | - | 50 | 48.14537 | -19.08796 | - |
| 15 | 48.35434 | -18.81539 | - | 51 | 48.15445 | -19.08796 | - |
| 16 | 48.30891 | -18.82447 | - | 52 | 48.12720 | -19.09705 | - |
| 17 | 48.31800 | -18.82447 | - | 53 | 48.18171 | -19.10613 | - |
| 18 | 48.33617 | -18.82447 | *M. crocea* | 54 | 48.16354 | -19.11522 | *M. baroni* |
| 19 | 48.33617 | -18.83356 | - | 55 | 48.16354 | -19.12430 | *M. baroni* |
| 20 | 48.37251 | -18.84265 | - | 56 | 48.17262 | -19.12430 | *M. baroni* |
| 21 | 48.34525 | -18.85173 | - | 57 | 48.15445 | -19.13339 | - |
| 22 | 48.35434 | -18.85173 | - | 58 | 48.16354 | -19.14248 | - |
| 23 | 48.36343 | -18.85173 | - | 59 | 48.17262 | -19.14248 | - |
| 24 | 48.38160 | -18.85173 | - | 60 | 48.15445 | -19.15156 | *M. baroni* |
| 25 | 48.39068 | -18.85173 | - | 61 | 48.12720 | -19.16973 | *M. baroni* |
| 26 | 48.35434 | -18.86082 | - | 62 | 48.14537 | -19.16973 | - |
| 27 | 48.37251 | -18.87899 | - | 63 | 48.13628 | -19.17882 | - |
| 28 | 48.13628 | -19.02436 | - | 64 | 48.14537 | -19.17882 | - |
| 29 | 48.14537 | -19.02436 | - | 65 | 48.09994 | -19.18790 | - |
| 30 | 48.16354 | -19.02436 | - | 66 | 48.16354 | -19.19699 | *M. baroni* |
| 31 | 48.05451 | -19.03345 | - | 67 | 48.17262 | -19.19699 | *M. baroni* |
| 32 | 48.13628 | -19.03345 | - | 68 | 48.16354 | -19.20608 | - |
| 33 | 48.14537 | -19.03345 | - | 69 | 48.17262 | -19.20608 | *M. baroni* |
| 34 | 48.15445 | -19.03345 | - | 70 | 48.16354 | -19.21516 | *M. baroni* |
| 35 | 48.16354 | -19.03345 | - | 71 | 48.16354 | -19.22425 | - |
| 36 | 48.17262 | -19.03345 | - | | | | |

loss and most of these were located inside provisional protected areas ($n = 59$, which represents 51% of the total number of ponds located inside protected areas; Table 2). There is no significant difference between the proportion of threatened ponds located inside protected areas and those located outside protected areas, for both sites (Fisher's exact test, $p = 0.54$ for Mangabe ; $p = 0.76$ for Ambatovy). In addition to the observed destruction of seven ponds since 2008 because of agricultural activities ($n = 6$) and illegal gold mining ($n = 1$), we expect eight ponds to be lost in the near future because of legal mining for nickel and cobalt.

## Discussion

We acknowledge that this approach may have overestimated the number of breeding ponds because frog occurrence does not necessarily mean the pond

**Table 2**. Ponds occupied by *Mantella aurantiaca*, conservation status, recorded threats and sympatry with *Mantella* spp.

| Pond conservation and management | Cluster Mangabe (n) | Cluster Analamay (n) |
|---|---|---|
| Number of breeding ponds | 103 | 36 |
| Inside new protected area | 94 | 22 |
| Outside new protected area | 9 | 14 |
| Ponds threatened by agriculture | 25 | 2 |
| Ponds destroyed by agriculture | 4 | 6 |
| Ponds threatened by artisanal mining | 10 | 3 |
| Ponds destroyed by artisanal mining | - | 1 |
| Ponds threatened by industrial mining | - | 14 |
| Ponds destroyed by industrial mining | - | 8 |
| Ponds subject to commercial frog collection | 27 | - |
| Sympatry | | |
| *M. crocea* | - | 9 |
| *M. baroni* | 11 | - |
| Number of threatened ponds | 54 (52%) | 15 (41%) |
| Inside protected areas | 51 (54%) | 8 (36%) |
| Outside protected areas | 3 (33%) | 7 (50%) |

is suitable for breeding (at all, or in any given year). Equally, it may have underestimated the abundance of breeding ponds because surveys may have failed to detect frogs in occupied sites, especially when the number of individuals present was low (or conditions were unsuitable). Notwithstanding these caveats, our results present a useful update on the distribution and conservation of *M. aurantiaca* as the number of known breeding sites has risen from 26 (Randrianavelona et al., 2010a) to 139, and on the extent of occurrence, which has increased from 626 km² (Andreone and Randriamahazo, 2008) to 699 km².

Conservation efforts in Mangabe since 2008 have enabled the majority of the ponds to be included within a new protected area that legally allows the sustainable use of natural resources in most areas. However, a number of threats to the ponds were observed, regardless of the conservation status of the sites, and it appears that the ponds occur in areas that are highly suited for new farmland and gold extraction. Increased efforts, or new approaches, are needed to safeguard the ponds because of these pressures.

In addition to these existing threats, Madagascar may be subject to the emergence of infectious diseases such as chytridiomycosis, caused by the chytrid fungus *Batrachochytrium dendrobatidis* (Rabemananjara, Andreone and Rabibisoa, 2011; Kolby, 2014a). Despite the current non-detection of the chytrid in eastern Madagascar (Crottini et al. 2014), we encourage proactive surveillance of amphibian tissue samples in the vicinity of the Moramanga district. Another cause of concern is the spread of the invasive Asian common toad *Duttaphrynus melanostictus* that was recorded for the first time in Toamasina in March 2014 (Kolby, 2014b). A species distribution model performed by Pearson (2015), showed a high probability of occurrence in the distribution of *M. aurantiaca*, which suggest an increased risk of disease transmission and food-web disruption. Expanding small-scale agriculture and mining present are the primary threats to *M. aurantiaca* because they can result in rapid and complete destruction of breeding ponds over a wide area and conservation attention is rightly focused on habitat protection. In the longer term, because environmental changes (including land use and climate) may question the future suitability of current protected areas, species distribution models should be used to identify future candidate sites for habitat creation and restoration (Leroy et al., 2014). Raxworthy et al. (2008), for example, predicted upslope displacements and distribution range contractions for several Malagasy amphibian and reptile species and we therefore recommend monitoring of both changes in habitat and in local meteorological conditions, and the study of forecasted environmental change effects.

Despite the discovery of potentially new breeding ponds, *M. aurantiaca* habitat is threatened and the species' distribution remains highly localized. We therefore advocate the need to develop spatially explicit population models for the species, as such models can be powerful tools for management (Brook et al., 2002) and for managing collection for pet trade (Carpenter et al., 2008). Few data exist on life history traits of wild *M. aurantiaca* (but see Rabemananjara et al., 2008; Jovanovic and Vences, 2010; Andreone et al., submitted), and there is a need improve our knowledge on population parameters to support evidence-based conservation interventions.

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