Mantella cowanii Action Plan 2021–2025

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Plan d'Action *Mantella cowanii* 2021-2025

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Published by: Museo Regionale di Scienze Naturali and Amphibian Survival Alliance, Turin.

Publication date: 30th November 2020

Recommended citation: Andreone F., Andriantsimanarilafy R.R., Crottini A., Edmonds D., Garcia G., Hansen-Hendrikx C.M., Rakotoarison A., Razafimanahaka J.H. (eds.), 2020. *Mantella cowanii* Action Plan 2021-2025 / Plan d'Action *Mantella cowanii* 2021-2025. Museo Regionale di Scienze Naturali and Amphibian Survival Alliance, Turin.

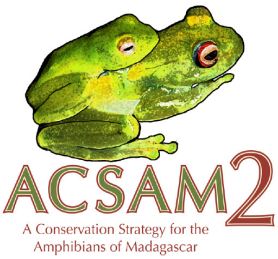
ISBN: 978-88-9718-951-0

Layout by: Candace M. Hansen-Hendrikx, Amphibian Survival Alliance

Translation into French: Olivier Marquis, Parc Zoologique de Paris, France and Andolalao Rakotoarison, Antananarivo University, Madagascar

Printed by: Centro Stampa Regione Piemonte, Turin

Photographs: F. Andreone, D. Edmonds and Gerardo Garcia, unless otherwise stated



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ACRONYMS AND ABBREVIATIONS

ACSAM: A Conservation Strategy for the Amphibians of Madagascar

Bd: *Batrachochytrium dendrobatidis*

BIODEV: BIODEV International Environment consultancy agency

CAMP: Conservation Assessment and Management Plan

CEPF: Critical Ecosystem Partnership Fund

CI: Conservation International

CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora

DREDD: Direction Régionale de l'Environnement et du Développement Durable

IGA: Income Generating Activity

IUCN: The International Union for Conservation of Nature

IUCN SSC ASG: Amphibian Specialist Group

MATE: Man and the Environnent / L'Homme et l'Environnement

MEDD: Ministère de l'Environnement et du Développement Durable

MISA: Association Miaro ny Sahona

Mitsinjo: Association Mitsinjo

MV: Madagasikara Voakajy

PBZT: Parc Botanique et Zoologique Tsimbazaza

VOI: Vondron'Olona Ifotony / Community Association

ZAP: Zone d'Admininistration Pédagogique

GLOSSARY

Anthropogenic (pressure): A pressure due to human activities.

Aposematic (colouration): A contrasted colouration (i.e., black/yellow or red/yellow) in an animal, indicating that it is toxic or dangerous.

Bd: *Batrachochytrium dendrobatidis*. A microscopic fungus disease affecting amphibians worldwide, contributing to population declines and extinctions.

Candidate (species): A species identified (i.e., thanks to morphological and/or genetic analysis), but not yet formally described.

Central Highlands: A mountainous biogeographic region in central Madagascar, including the contiguous part of the island's interior above 800 m of altitude.

Climate change: Significant changes in global temperature, precipitation, wind patterns and other measures over several decades, or longer, due to human activities.

Dina: A set of local customs and social norms for managing natural resource use.

Endemic: An animal/plant whose distribution is restricted to a certain geographic area.

Fomisame: Fohisokina Miaro ny Sahonamena, the local community group managing the Fohisokina / Vohisokina site.

Habitat: The place or environment where a plant or animal naturally or normally lives.

Hybrid: An animal or plant derived from the mating of two different species.

Larva: Young animal that will change (metamorphose) during its development into something different. In anuran amphibians it is usually aquatic and called tadpole.

Metamorphosis: Change in morphology, physiology and habits occurring in animals, usually with a larval stage/phase.

Savannah: Open grasslands, usually with scattered bushes or trees.

Pet trade: The trade of wild animals for human pleasure or companionship.

Pumiliotoxin: One of several toxins, originally found and described in the skin of frogs of the family Dendrobatidae. These compounds are known to occur also in the species of the genus *Mantella*.

Skeletochronology: A technique used to determine the individual chronological ages of vertebrates by counting lines of arrested annual growth within bones.

Sympatry: Term used to describe populations, varieties, or species that occur in the same place at the same time.

Tavy: Slash-and-burn-agriculture, one of the main causes of deforestation in Madagascar.

THE WORKSHOP IN AMBOSITRA

The *Mantella cowanii* Workshop in Ambositra

On the 4th-6th December 2018, a workshop on the conservation of *Mantella cowanii* was held in Ambositra, Madagascar. During this meeting, participants from government, academia, conservation organizations, and local communities met to discuss the future of this peculiar and threatened frog. The action plan presented here is the outcome of this workshop and represents an update to the first *Mantella cowanii* Action Plan produced a decade earlier.

The Mission

To ensure the conservation of *Mantella cowanii* in its natural habitat through the transmission of knowledge for sustainable development in respect of the environment.

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Some moments of the *Mantella cowanii* workshop held in Ambositra. Photographs by IUCN SSC ASG Madagascar.

SUMMARY

The harlequin mantella, *Mantella cowanii*, is one of the most threatened Malagasy amphibians. This iconic species has a scattered range across the high plateau, and none of the known populations are currently included within a protected area. In the past, *M. cowanii* was heavily collected for the international pet trade. Studies on its conservation began in 1995, confirming a small distribution and low densities of individuals. The results of these studies led to the inclusion of *M. cowanii* in Appendix II of CITES and ultimately to a ban on export of live wild specimens from Madagascar beginning in 2003. Further field studies in the early 2000s confirmed that collection for the pet trade represented a threat to the species, along with habitat loss and degradation. Furthermore, erosion of the species' genetic identity by hybridization with *M. baroni* at a site close to Antoetra was also confirmed. This action plan summarizes the current state of knowledge of *M. cowanii* population status, taxonomy, and ecology, and of the threats facing the species, and describes the institutional framework for conservation management in Madagascar by listing the key stakeholders, vision, goals, objectives, and needed conservation actions.

KEY WORDS: amphibians, harlequin mantella, Madagascar, Sahonagasy Action Plan.

ACKNOWLEDGEMENTS

We are grateful to many people who assisted us during the realization of this action plan for the implementation of actions oriented towards the conservation of the amphibians of Madagascar. Thanks in particular to Jade Newton-Youens and Christian J. Randrianantoandro for having allowed us to quote their still unpublished data and information, to Ariadne Angulo, Phil Bishop and Sally Wren for the assistance during the redaction, to Achille P. Raselimanana for kindly preparing the foreword, and to the involved ministries for having supported the scheduled conservation actions. Finally, we also add our thanks to all the donors, who contributed to the conservation activities through the years and sustained the realisation of the Ambositra workshop.

FOREWORD

Madagascar is home to about 7% of the world's amphibian species diversity, with 99% being endemic to the island. Unfortunately, this natural heritage is facing various types of pressures and threats, mainly of human origin. The risk of extinction is indeed very high for many species.

Scientists, being aware of the gravity of the situation with respect to the preservation of this unique biodiversity have not spared any effort in seeking the means to ensure its conservation, in particular threatened species with restricted distributional ranges. The information acquired from the various biological investigations carried out across the island have been employed to develop a clear and realistic strategy, transformed into a concrete action plan.

Since the workshop “A Conservation Strategy for the Amphibians of Madagascar” held in 2006, which was a directly linked to the global Amphibian Conservation Action Plan for Madagascar, Malagasy and foreigner herpetologists collaborated to transform the strategic axes into tangible activities to address the fundamental issues. Considering the importance of the actions to be carried out and the challenges to be overcome, informing and mobilization of all stakeholders, ranging from local communities to the official authorities, was necessary. In the spirit of efficiency and taking into consideration the complexity of the situation, the strategy has been developed separately for a few Endangered species with high risk of extinction due to their restricted distribution, intense pressure from overharvesting for the pet trade, and habitat loss; as is the case for the harlequin mantella (*Mantella cowanii*). The strategic program presented herein has been divided into discrete activities describing the main actions to be implemented.

The action plan for *Mantella cowanii* is the logical extension of the first action plan drawn up 10 years ago for a period of five years for the conservation of this species. The acquired experiences and the lessons learned from the implementation of this first plan, the gaps to be fill in, and the negative evolution of the situation since the first plan, require a revision of the strategy. Thanks to the efforts and dedication of the participating scientists enamored with Malagasy amphibians, this current action plan for the conservation of this magnificent species is more relevant, refined from the exchanges during the 2018 workshop on this species, and of paramount importance is its urgent implementation at the level of a few decades before its complete extinction. It is important to highlight that this species, which has been almost extirpated in its habitat due to abusive commercial exploitation, frequently uses grassland and wooded savannah of the Central Highlands, an ecosystem previously considered of anthropogenic origin, therefore neglected with respect to integration in the protected area network, but now we understand that this was an incorrect generalization.

There is still a long way to go to truly protect this species and the challenges are enormous, so good luck and never give up because "with a valiant heart, nothing is impossible" and "together, we can make the difference".

By Achille P. Raselimanana

Madagascar has some of the highest amphibian diversity of any country. With over 365 described frog species (as of July 2020) and another 200 candidate species waiting for description (Perl et al., 2014), the island supports nearly 7% of the world's amphibian species. All but two introduced species (*Hoplobatrachus tigerinus* and *Duttaphrynus melanostictus*) are endemic. Alarmingly, the IUCN Red List considers nearly 40% of Madagascar's described amphibian species to be threatened with extinction (Bowers et al., 2017). Habitat destruction and degradation are currently the major threats, and together with climate change, emerging diseases, and invasive species, the unique frogs of Madagascar are at increasing risk of extinction (Andreone et al., 2005; Stuart et al., 2004).

There have been several important conservation initiatives for Madagascar's amphibians in recent years. Two conservation planning workshops were organized in Madagascar, both called "A Conservation Strategy for the Amphibians of Madagascar" (ACSAM). They were held in 2006 (Antananarivo) and in 2014 (Ranomafana). The aim of these workshops, organized by the IUCN SSC Amphibian Specialist Group – Madagascar (ASG Madagascar) and with the collaboration of many partners and stakeholders, was to implement the global Amphibian Conservation Action Plan (ACAP) on a regional scale (Andreone, 2008; Andreone et al., 2016). These workshops led to the development of the "Vision Sahonagasy" ("sahona" in Malagasy means "frog", while "gasy" is a contraction of the adjective Malagasy), a national strategy implemented through the Sahonagasy Action Plan (Andreone et al., 2016).

All of Madagascar's endemic frog species deserve conservation attention should human activities threaten their existence. In this regard, many surveys of remote and isolated residual habitats have been carried out, with special attention to population trends in recent years (i.e., Dubos et al., 2020). Additionally, a few particularly charismatic yet highly threatened species (i.e. the golden frog *Mantella aurantiaca*, and the tomato frog *Dyscophus antongilii*) have also been the target of several field investigations and conservation programs. This brings us to the harlequin mantella, *Mantella cowanii*, which has also been the focus of conservation efforts during the last decade. The species is characterized by striking black and red colouration and it is only known from a small number of scattered localities in the Central Highlands. Given its highly restricted distribution, low densities and threatened status, coupled with its iconic colouration, the species is an important conservation target.

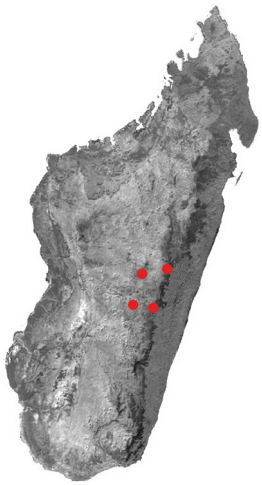
The action plan presented here sets out the "Vision Sahonagasy" at the species level for *Mantella cowanii*. It brings together historic and ongoing research, expert knowledge, and local stakeholder inputs, to develop a comprehensive assessment of the conservation status and threats faced by the species. By doing so, the action plan aims to mitigate the threats faced by *M. cowanii* and assure its survival.

Mantella cowanii is a typical terrestrial member of the genus *Mantella*, distinguished by its distinct colour pattern. The dorsum and flanks are usually black, while at the insertion of the limbs there are red-orange or rarely orange-yellow spots. The spots extend down most of the forearm. The shank and upper part of the lower hind limb possess several vivid yellow-orange, orange, or red bands. An orange spot is sometimes present on the upper lip. The belly is black with pale bluish irregular dots. The eyes are brownish, and the pupil is round and black. The species shows sexual dimorphism, with females often slightly larger than males (snout-vent length = 25-31 versus 22-27 mm , and males having femoral glands.

The species was described in 1882 by the Belgian-British zoologist George A. Boulenger, who received some preserved specimens from "East Betsileo, Madagascar," collected by the reverend William Deans Cowan (1844-1923), to whom the species was subsequently dedicated. Although the specific epitaph was written *cowanii* in the original description, many authors use the spelling *cowani* (Vences et al., 1999). The International Code of Zoological Nomenclature allows both variations. For the sake of consistency, the spelling *cowanii* will be used throughout this document. Until the revisionary work of Vences et al. (1999), often other *Mantella* species were erroneously included within or identified as *M. cowanii*. The most used common names are harlequin mantella, Halloween mantella, or Cowan's mantella (English) and "mantelle arlequin" or "mantelle noire-rouge" (French).

"East Betsileo" refers to a wide region of the central highlands of Madagascar. Data reported in revisionary works (Vences et al., 1999) and field guides are from specimens housed in natural history museums. All recorded localities of *M. cowanii* are centered around four isolated sites: Antakasina, Antoetra, Betafo, and Itremo. The sites are separated from one another over an area of more than 10,000 km^2. Observations in the Antoetra region confirmed the persistence of some important population nuclei, and these populations have been the focus of most studies and conservation actions. In the Itremo area, the species was reported at a few sites but in very small numbers, while the record from Antakasina refers to a single individual found in 2003 but never confirmed since then. The most recent detection of *M. cowanii* was in the Betafo area, where its presence was confirmed at a few locations.

A living individual of *Mantella cowanii* from the Itremo locality in lateral view showing black dorsal colouration and patterning of flanks and limbs (left and center) and ventral view showing speckling of venter (right).



Map of known distribution of *Mantella cowanii*, based upon confirmed (red dots) findings.

Like other species belonging to the genus *Mantella*, *M. cowanii* is mainly active during the warm-humid season. It appears to start its activity around October/November, coinciding with higher temperatures and increased rain. In such a period males become particularly vocal. They call from refuges such as within grass patches, under stones, or within rock cavities. In terms of intensity, the call is low and usually consists of short single clicks, 4-5 KHz in frequency (Glaw & Vences, 2007). Even though many herpetologists have already visited the most well-known *M. cowanii* sites near Antoetra, mating, eggs, and tadpoles have never been observed in the wild. Most likely breeding activity occurs only for quite a limited time and in secretive locations such as rock cavities or other sheltered areas. Notwithstanding, observations in captivity confirm the typical modality of many *Mantella* species, notably those of the *M. baroni* group, with egg clutches laid on the ground close to water bodies.

Unpublished recent observations provided by J. Newton-Younes and C.J. Randrianantoandro at one of the Antoetra populations supported information about the temporal activity and its links to environmental conditions. In their study, the activity pattern of *M. cowanii* appears linked to the temporal changes in environmental conditions, with the species being active at relatively low temperatures (16-22ºC), low UV indexes, and high humidity. These conditions only occur during or after periods of heavy rain, or in the early morning and late evening. In fact, by midday, rock surfaces in their habitat reach very high temperatures, sometimes greater than 50ºC, thus totally unfit for the species activity. During peak breeding season (December-January), individuals were nearly crepuscular, active on rock surfaces only very early in the morning (05:00-07:00), after which they sheltered in caves, crevices, or vegetation refuges. At around 16:00, frogs would reemerge and remain active until ca. 21:00, afterwards sheltering in cooler (< 18ºC) hidden locations. Such activity patterns could be characteristic of the species or just a behavioural adaptation to deforested areas, like at the study site near Antoetra.

Although breeding has never been observed in the wild, Tessa et al. (2009) determined fecundity by analyzing preserved specimens in natural history museum collections. They found that *M. cowanii* has quite large eggs compared to other *Mantella* species but that they are present in low numbers (20–57). In captivity clutches of 40-47 eggs measuring 2.2 mm in diameter are reported (Glaw & Vences, 2007), with a hatching time of about 12 days. Larvae are whitish, around 10 mm long, thus larger than in other *Mantella* species. Larvae attain a total length of 29 mm after around 60 days. Hind limbs appear at 72-80 days and metamorphosis is completed after about 100 days.

A study carried out using skeletochronology, whereby age is determined by counting the number of lines of arrested growth in skeletal tissues, indicated that wild *M. cowanii* can live just for 3 years, which is a longer life-span than most other *Mantella* species (Guarino et al., 2008). In captivity, individuals are known to live more than 10 years. Like the other mantellas, *M. cowanii* is poisonous, accumulating alkaloids at the epidermic level, which are obtained by invertebrates (ants, millipedes, and mites) upon which it feeds. Pumiliotoxins are the main alkaloids present, occurring in high concentrations. The striking colouration of the body is clearly aposematic, warning potential predators (especially birds and to some extent mammals) about the toxicity of the species. *Mantella cowanii* is likely not a major prey of other species, although it is possible that some snakes present in the area can actively feed on it. That said, tadpoles and juveniles that have yet to sequester high levels of alkaloid toxins may be important prey for some invertebrates and small vertebrates.

HABITAT

Mantella cowanii is known only from the Central Highlands of Madagascar, where it occurs at higher altitudes than other *Mantella* species (1300-2140 m a.s.l.). The Central Highlands are dominated by grasslands, which are shaped by fire and grazing. Most of the forest in the region has been converted to pasture or cropland through slash and burn agriculture. Known *M. cowanii* populations are restricted to patches of relict vegetation present along montane streams and humid cliffs, as well as a few areas of relict high altitude forest (Andreone et al., 2007). It is likely that *M. cowanii* originally inhabited forest edges bordering grassland, as is seen at sites where the species occurs near Itremo. Noteworthy, the habitat and general ecology of most of populations may not be representative of the natural condition of the species, but rather recent adaptations to anthropogenic pressure and habitat alteration.

The environmental parameters preferred by *M. cowanii* have been studied by J. Newton-Younes and C.J. Randrianantoandro at a site near Antoetra (unpubl.), who found the species frequents hillsides within the mountainous savannah environment (roughly 80% of records were on sloped hillsides in their study). Frogs were often encountered in vegetation "islands" composed by lichens, mosses, and small trees, which provided a moist and humid microhabitat, indispensable for the survivorship of the species when active on the surface. When the populations of *M. cowanii* were found in grassland or along streams, most individuals were observed in or near cave refuges.

Different habitat inhabited by *Mantella cowanii*, in clockwise direction: falaise (Antoetra surroundings); maize field cultivated along a cut rainforest (Antoetra); small montane stream (Antoetra surroundings), montane forest edges (Itremo); collector (Antoetra surroundings); montane stream (Antakasina); boulders within a montane rainforest (Itremo).

Population monitoring on *M. cowanii* has been carried out sporadically at a single site located near Antoetra. In December 1996, an assessment estimated 598 individuals / ha. This number decreased to 48 i/ha after intense collection for the international pet trade. Further visits carried out by Conservation International in 2008 confirmed a density 40 i/ha in January and only 12 individuals total in March. In 2012, the total number of captured individuals was 191 within a 2,500 m^2 surface, with an estimated population size of about 750 i/ha (Rabibisoa et al., 2013). A recent 2-year long study recorded 282 individuals between 9th and 12th December 2014 and 172 individuals between 29th January and 7th February 2015. The most recent assessment was carried out from 27th November to 20th December 2015 (J. Newton-Younes, unpublished data). On this occasion, 102 individuals were captured at the site over the course of the investigation.

The only other *M. cowanii* locality where surveys have taken place is Itremo. Here, four individuals were found in 2003 by a team of Missouri Botanical Gardens. Subsequently, five individuals were observed in 2008.

Local collectors in Antoetra reported that during the breeding season in the 1980s, up to 2000 individuals could be collected in a single day, whereas by 2003 communities reported collecting only 250 individuals in a week from five sites, giving a mean capture capacity per person of around one individual per day (Andreone & Randrianirina, 2003). Though vague, these statements suggest a severe decline in the *M. cowanii* population over the last forty years.

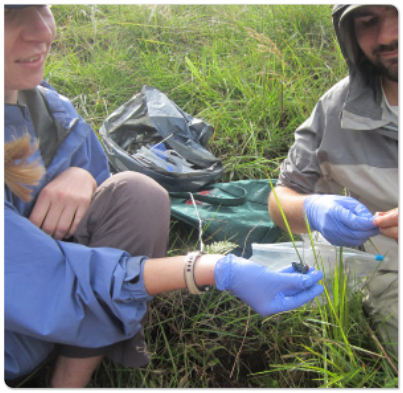
From these data, it is not possible to reliably estimate population size for the species due to the inconsistency of the techniques used, the time-scales, and different periods of the year.

STATUS

The critical situation of *Mantella cowanii* has been pointed out on several occasions when it was recognized to be a sensible target for the pet trade. Notably, early discussion of *M. cowanii* conservation was discussed at the CAMP meeting held in Mantasoa in 2001. Subsequently, the Global Amphibian Assessment in Gland, Switzerland in 2005 established the first comprehensive list of threatened amphibians for Madagascar.

Artisanal mining at an *M. cowanii* site near Antoetra.

Mantella cowanii was first assessed as Critically Endangered. This led to a growing concern that the species was doomed, a situation also highlighted in 2003 by the publication of an informative opinion paper in FrogLog (Andreone & Randrianirina, 2003). The main concerns raised for the conservation of *M. cowanii* included a combination of habitat degradation and over-collection for the pet trade, effects of climate change, emerging diseases, and hybridization with *M. baroni.* Increased attention from the international community led to the inclusion of *M. cowani*i and other *Mantella* species in CITES Appendix II. The species was intensively collected for the pet trade since at least the late 1980s. Trade in live specimens was suspended in 2004, applying a zero export quota in 2005 (United Nations Environment Programme & World Conservation Monitoring Centre, 2009). Data on UN Environment Programme World Conservation Monitoring Centre website indicated that Madagascar exported 3642 individuals of *M. cowanii* between 1998 and 2004. The maximum was in 2002 with 1520 individuals.



In 2014, *M. cowanii* was reclassified as Endangered (EN) because over-collection for the pet trade had been stopped (IUCN SSC Amphibian Specialist Group 2014). Despite this, the habitat quality for the remaining populations continues to decline. The

continuing loss of forest habitat (Harper et al., 2007) approximated at more than 80% during the last three generations (estimated at 15 years) means the species continues to be at high risk of extinction.

One major challenge for the species is its restricted distribution. The known populations are isolated from one another by great distances of uninhabitable land for the species. This increases the risk of genetic bottlenecks and inbreeding. There are no habitat corridors between populations, even within the four main sites, and this exacerbates the risks related to maintaining genetic diversity.

Climate change is another threat to *M. cowanii*. Intense warming caused by climate change is known to threaten the herpetofauna of Madagascar (Raxworthy et al., 2008). It can cause upslope elevation shifts and lead to the loss of suitable habitats or to the disappearance of suitable microclimates. In general, species more at risk are the small-ranged montane endemics, such as *M. cowanii*. The increased drought accompanying this temperature warming likely affects fire occurrence as well, exacerbating habitat degradation.

M. cowanii is known to hybridize with the closely related species *M. baroni*, which is classified as Least Concern by the IUCN Red List (IUCN SSC Amphibian Specialist Group, 2016). The two hybridize at a locality close to Antoetra where the two species are known to occur in sympatry. Here, up to 10% of the *M. cowanii* population was found to be of hybrid origin (Chiari et al., 2005). A potential range shift of *M. baroni* into higher elevations stimulated by climate change (Raxworthy et al., 2008) puts *M. cowanii* at increasing risk of hybridization.

Furthermore, the majority of known populations occur at mountainous sites (Andreone et al., 2007), and have likely already experienced declines. Such populations already occupy microhabitats within high altitude savannahs with very specific environmental conditions (e.g. bare rock hillsides with percolating water), possibly a recent adaptation to current habitat condition, and only a few *M. cowanii* populations occur in primary montane forest habitats (e.g. Itremo).

Infectious diseases were reported as a major cause of amphibian decline worldwide and are source of further concern for *M. cowanii*. Chytridiomycosis is a fungal disease caused by the chytrid fungus *Batrachochytrium dendrobatidis*, known to have caused catastrophic amphibian population declines around the world. Early screening of Bd in Madagascar did not detect the pathogen in Malagasy amphibians. Bd was first detected in 2010 and later confirmed in 2012 in individuals destined for the US pet market. These finding were later supported by the analyses of samples collected in the field between 2005-2014. Bd has now been identified in multiple places, including at a *M. cowanii* site near Antoetra in 2014 (Bletz et al., 2015). Despite the presence of Bd in at least one *M. cowanii* population, it is unclear if and how the pathogen is impacting the population.

Hybrids between *M. cowanii* and *M. baroni* from Farimazava, Antoetra surroundings.

CONSERVATION ACTIONS

Within the Sahonagasy Action Plan, *Mantella cowanii* has always been of particular attention from a conservation point of view. The first researches aimed to identify the distribution of the species and included several preliminary natural history investigations. The first actions were taken with the support of a "Declining Amphibian Population Task Force" seed grant obtained in 2003. After receiving this, some important ecological works were done, for example age structure analysis (Guarino et al., 2008). In 2008 the *Mantella cowanii* Action Plan was published, reporting the current known species distribution, population status, and habitat conditions, as well as defining key actions that were necessary for protecting the species (Rabibisoa, 2008). One of the main actions put forward was establishing a dedicated protected area in the Antoetra region. A conservation program for the site has since been established alongside a local organisation, FOMISAME, which is composed of members of the local community (Rabibisoa et al., 2013).

The 2008 action plan also addressed for a possible role for a conservation breeding program, due to the uncertain future of populations in the wild. However, as the expertise and resources needed to establish an *ex situ* population were limited in Madagascar, it was put forward that a partnership with a member of EAZA (European Association of Zoos and Aquaria) would be needed. There are currently no zoo or aquaria institutions that house this species and it is reported that only a small number of individuals can still be found among private collectors, with reports of breeding being highly infrequent or unreliable. Since the initial Action Plan, some important actions focused on sustainable development have been carried out near Antoetra. These initiatives were put together to provide a sustainable means of income for the local community. Notably, a small pisciculture operation was developed, along with an initiative to produce essential oils. Unfortunately, following a cyclone in 2012, much of the infrastructure supporting these sustainable development initiatives was destroyed and since then they have not provided income for the Antoetra community.

The 2008 Action Plan was fully revised on the occasion of the process aimed to launch a new conservation strategy. The different themes approached by Rabibisoa (2008) were evaluated during a dedicated meeting held in 2016 in Antananarivo and then re-analysed one by one during the Ambositra meeting in 2018, involving all the people and conservation actors present there. As a general rule it was verified if the objectives drawn in the first Action Plan were fully, partly or not reached. Then, further possible objectives were discussed and approved basing upon group discussions.

The five-year action plan is split into five broad themes as follows:

Theme 1. Habitat protection and management

By 2025, there will be a habitat management plan for all *M. cowanii sites*, with clearly defined boundaries around critical habitat. The plan should include strategies to protect sites from wildfires. It is also necessary to identify landowners and discuss potential animal transfers with the community (e.g. Dina, VOI). Finally, key areas must remain protected to mitigate the anticipated effects of climate change. The end goal is a complete network of protected *M. cowanii* populations.

Theme 2. Scientific research

The main research areas relate to understanding the species distribution, conservation genetics, disease dynamics, and population trends. Site-specific studies, especially of population ecology in different habitat types, are required to assess local threats to each population. Given ample data, population viability should be assessed with genetic and demographic modelling. Another target should be to evaluate the role of an *ex situ* conservation programme. This can be an important conservation tool that could be used to facilitate reintroductions or augment declining populations if threats cannot be mitigated to prevent further decline.

Theme 3. Local development

Enacting effective conservation measures for *M. cowanii* requires the support and involvement of local communities. Sustainable livelihoods initiatives and actions improving the wellbeing of the communities who live near *M. cowanii* habitat are key to enabling a successful conservation plan. Socioeconomic studies will be carried out to identify needs and potential sources of sustainable livelihoods for communities near each site. Based on the results, investment will be made in infrastructure supporting the proposed local development projects, which will also serve as center of dissemination of the about conservation actions for the species.

Theme 4. Environmental awareness

An awareness campaign focused on the importance of conserving *M. cowanii* and maintaining an ecologically healthy environment will be developed with local communities at each site. The programme will also focus on building in-country capacity to work on amphibian conservation efforts more generally, disseminating the knowledge gained by protecting *M. cowanii* to other areas and species in Madagascar.

Theme 5. Training, sharing information and long-term sustainability

This theme focuses on identifying local, regional, and international funding sources for project activities. Monitoring will be carried out and a national committee with external advisors will be set up to regularly evaluate progress of the action plan, secure the involvement of all the partners, and maintain communication.

THEME 1 – HABITAT PROTECTION AND MANAGEMENT

No.	Project and Activities	Priority	Agencies Responsible	Partners	Timescale	Indicators	Risks	Opportunities
1.1	Identify the specific conservation features for each of the known localities with *M. cowanii.*	LOW	PARTNERS FOR EACH SITE, MV	ALL PARTNERS	Year 1 to 2	List of options adopted for each site.	Needs a specific and site-oriented approach.	Adaptation to each site.
1.2	Identify landowners for each of the localities where *M. cowanii* is present and collaborate with Property Department.	HIGH	MUNICIPALITY	MUNICIPALITY, DOMAINE SERVICE	Year 1 to 2	Number of management models.	Long process & needs a person coordinating.	Definition of study and protection area.
1.3	Apply and adapt a Management Plan for the areas of presence/ influence (purchase, rental, partnership VOI…).	MEDIUM	PARTNERS FOR EACH SITE	ALL PARTNERS	Year 1 to 2	Number of management models.	Long process & needs a person coordinating.	Adapt models to single needs.
1.4	Development a Management Plan for the areas of presence or influence of the populations of *M. cowanii*.	MEDIUM	VOI, DREED	PARTNERS, MUNICIPALITY, DISTRICTS	Year 1 to 2	Finalisation of the MP.	Perceived as a copy of the action plan.	Define objectives.
1.5	Continue the development of local community forest groups	MEDIUM	DREED	PARTNERS, MUNICIPALITY, DISTRICTS	Year 1 to 2	Number of VOI.	Coordination needed and time-consuming.	Assure management.
1.6	Development and enforcement of procedures using local customs and social norms (DINA) to protect known sites.	MEDIUM	DREED	PARTNERS, MUNICIPALITY, DISTRICTS, COURT, VOI	Year 1 to 2	Number of DINA homologues.	Difficulties to assure its application.	Involvement of local community.
1.7	Formalize the transfer of management of all the sites.	MEDIUM	VOI, DREED	ALL PARTNERS	Year 2 to 3	Number of transfers.	Long process & needs a person coordinating.	Officialization of *M. cowanii* sites as conservation areas.
1.8	Define the boundaries of protection and conservation actions for each of the localities.	HIGH	VOI	DREDD, MUNICIPALITY, FKT, PARTNERS	Year 2 to 5	Number of fully identified sites.	Long process & needs a person coordinating.	Definition of study and protection area.
1.9	Controlled access to all sites.	MEDIUM	VOI	DREDD, MUNICIPALITY	Year 2 to 5	Number of regularized sites.	Difficulty to assure a control.	

1.10	Develop legal protection for all sites where *M. cowanii* is present.	HIGH	PARTNERS	DREDD, REGION, VOI	Year 3 to 5	Number of protected sites.	Difficulties to assure its application.	Officialization of *M. cowanii* sites as conservation areas.
1.11	Monitoring and execute a programme of forest control in all localities.	MEDIUM	DREED	VOI	5 years	Number of checks performed.	Needed people's participation.	Reduce conservation threats.
1.12	Establish firebreaks around sites and maintain them.	HIGH	VOI	DREDD, MUNICIPALITY	5 years	Length compared to surface.	Manutention needed.	Reduce fire risks with a quite limited cost.
1.13	Specific study for each site to restore and reforest the area of presence of *M. cowanii*.	LOW	VOI, PARTNERS FOR EACH SITE	DREED	Year 3 to 5	Surface restored / reforested.	Difficult of perennisation.	Possibility to involve government and local communities.
THEME 2 – SCIENTIFIC RESEARCH								
2.1	Determine the full distribution of *M. cowanii.*	HIGH	ASG /MISA	ALL PARTNERS, CHESTER ZOO	Year 1 to 3	Number of sites visited with presence/ absence.	Associated with insecurity.	Assure a better understanding of species distribution.
2.2	Genetic mapping of all populations of *M. cowanii*.	HIGH	ASG /MISA	ALL PARTNERS, CHESTER ZOO	Year 1 to 3	Number of samples collected.	Difficulties in obtaining research permits and need to get funds.	Good definition of the species differentiation.
2.3	Develop ecological studies for each of the known populations.	MEDIUM	ASG /MISA	CHESTER ZOO, MV	5 years	Number of populations studied.	Quite a long and time investing process.	Good definition of the species ecological requirements.
2.4	Estimate population size and status of the known populations and develop a population monitoring programme.	HIGH	ASG /MISA	CHESTER ZOO. MV	5 years	Number of populations studied.	Difficulty of being put in practice due to ingent human and time investment.	Comparison of populations.
2.5	Feasibility study of establishing an *ex situ* safety net population.	HIGH	CHESTER ZOO	MITSINJO, ASG, MV	Year 1	List of populations kept and bred.	Enough specimens to start the breeding programme. Availability of facilities, staff and funds for the programme.	The need to move on with captive breeding.
2.6	Pilot programme of national and international captive breeding programme.	HIGH	MITSINJO / CHESTER ZOO	CHESTER ZOO, ASG	Year 1 to 3	Report successful breeding of species.	Agreement at national and international levels needed.	Important to create population nuclei in captivity.

2.7	Establish training programme on captive husbandry for technicians.	HIGH	MITSINJO / CHESTER ZOO	CHESTER ZOO	Year 2 to 5	Number of technicians being trained.	Time investing.	Needed to get expertise
2.8	Monitoring Bd in the known localities with presence of *M. cowanii*.	LOW	ASG/MRSN/ CIBIO	CHESTER ZOO	5 years	Number of samples analysed.	Time investing Needed to export samples.	Integration with the national monitoring and control of populations Obtaining a good scenario of pathogens.
THEME 3 – LOCAL DEVELOPMENT								
3.1	Develop alternative income generating activities specific for each locality where the species is present.	HIGH	PARTNERS FOR EACH SITE	DREDD, REGION, VOI	Year 1 to 2	Number of IGAS identified.	Considerable time dedicated to work out these IGAs.	Involvement of local community.
3.2	Establish the identified alternative income generating activities specific for each locality where the species is present.	MEDIUM	PARTNERS FOR EACH SITE	DREDD, REGION, VOI	5 years	Number of plans developed.	Considerable time dedicated to work out these IGAs.	Involvement of local community.
3.3	Establish socio-economic studies on the localities with *M. cowanii* identifying the needs of the communities.	HIGH	PARTNERS FOR EACH SITE	ASG / MISA	Year 1 to 2	Reports.	Considerable time required for this study.	Involvement of local community.
3.4	Identify, build and rehabilitate community infrastructures as core areas of conservation dissemination (e.g. interpretation centre, school…).	MEDIUM	PARTNERS FOR EACH SITE	REGIONAL GOVERNMENT, MUNICIPALITY, CHESTER ZOO	5 years	Number of infrastructures put in place or rehabilitated.	Considerable time required for this study.	Involvement of local community.
THEME 4 – ENVIRONMENTAL AWARENESS								
4.1	Development and dissemination of education and awareness tools for local communities.	MEDIUM	PARTNERS FOR EACH SITE	CHESTER ZOO	Creation year 1; Diffusion 5 years	Number of tools developed and shared.	Need people specifically dedicated to this project.	Knowledge dissemination via unconventional ways.

4.2	Establishment of a global awareness campaign with Day of *M. cowanii* in all the local communities.	HIGH	ASG /MISA	CHESTER ZOO	5 years	Number of events organised, participants and visitors.	Better to associate with amphibian day.	Involve local community.
4.3	Develop a network of communication between the different interpretation centres and community kiosks.	MEDIUM	PARTNERS FOR EACH SITE	CHESTER ZOO	5 years	Number of materials distributed.	Local community is required.	Involve local community.
4.4	Educational school visits promoting the conservation of *M. cowanii* and its habitat.	MEDIUM	PARTNERS FOR EACH SITE	CISCO, ZAP	5 years	Number of schools visited.	Local community is required.	Involve local community.
4.5	Training and dissemination of experiences in conservation education between the different partners.	LOW	PARTNERS FOR EACH SITE	CHESTER ZOO	5 years	Number of training initiatives per site.	Local community is required.	Involve local community.
4.6	Develop guided field trips to the localities by the communities.	MEDIUM	PARTNERS FOR EACH SITE	ASG / MISA	5 years	Number of visits to the communities to develop activities.	Local community is required.	Involve local and international community.
4.7	Participation in national and international conservation events.	LOW	ASG/MISA	REGION, MUNICIPALITY, CHESTER ZOO	5 years	Number of activities.	Local community is required.	Involve local community.
THEME 5 – TRAINING, SHARING INFORMATION, AND LONG-TERM SUSTAINABILITY								
5.1	Development of a strategic plan for fundraising the activities of the new action plan.	HIGH	ASG /MISA	CHESTER ZOO	5 years	Number of grant proposals submitted and succeeded.	Difficulty of duely following this by the concerned entities.	Assure economic independence.
5.2	Program monitoring and evaluation of all activities	HIGH	ASG /MISA	MV, CHESTER ZOO, CPSG	5 years	Follow up reports.	Difficult to implement and follow.	Requires strong coordination.
5.3	Establish a coordinator for the new action plan.	HIGH	ASG /MISA / MATE	CHESTER ZOO	Year 1	Coordinator in place by end of Year 1.	Difficulty to identify an available experienced person in country.	Need to assure funds for coordinator.
5.4	Identify and coordinate training needs for all the partners and stakeholders.	MEDIUM	ASG / MISA	ASG / MISA	5 years	List of training needs.	Difficult to implement and follow.	Requires strong coordination.

5.5	Establish the training agenda for the new action plan (identify trainers, creation of tools, training sessions, evaluations and retraining).	MEDIUM	ASG / MISA	ALL PARTNERS	5 years	Number of programmes and training activities.	Difficult to implement and follow.	Requires strong coordination.
5.6	Create a national committee for the monitoring of the new action plan.	LOW	ASG /MISA	CHESTER ZOO	5 years	Annual follow up reports.	Requires strong coordination.	Requires strong coordination.

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