

Franco Andreone*, Vincenzo Mercurio** & Fabio Mattioli***

Between environmental degradation and international pet trade: conservation strategies for the threatened amphibians of Madagascar****

Abstract - We present and discuss data on the conservation status and threats regarding some “critically endangered” and “endangered” frogs of Madagascar (*Mantella cowani*, *M. bernhardi*, *M. viridis*, *M. expectata*, *Scaphiophryne gottlebei*), and one species currently classified as “near threatened” and included in CITES I (*Dyscophus antongilii*). All these frogs suffer from a combination of habitat degradation and – to some extent – collection for the international pet trade. Updated data indicate however that some of these species are locally abundant and could possibly be harvested (sometimes at varying quotas) for the terrarium market. We also discuss the significant differences between collecting for commercial and scientific purposes, together with modalities for establishing commercial export quotas. Furthermore, we comment and present possible conservation strategies, showing the main results based on an understanding of the sensitivities and needs of amphibian conservation in Madagascar.

Key words: Amphibia, Anura, conservation, habitat loss, pet trade, CITES, Madagascar.

Riassunto – Fra degrado ambientale e commercio internazionale: strategie per la conservazione delle specie minacciate di anfibi del Madagascar.

Presentiamo dati sullo status di conservazione e sulle problematiche riguardanti alcune specie “criticamente minacciate” e “minacciate” di anfibi del Madagascar (*Mantella cowani*, *M. bernhardi*, *M. viridis*, *M. expectata*, *Scaphiophryne gottlebei*) e di una specie attualmente classificata come “quasi minacciata” e inclusa in CITES I (*Dyscophus antongilii*). Tutte queste specie stanno attualmente subendo la degradazione degli habitat e lo sfruttamento per il commercio terraristico internazionale. Dati aggiornati, tuttavia, indicano che alcune di queste specie sono tuttora localmente abbondanti e potrebbero essere raccolte (anche in numero superiore di quello attuale) per il mercato amatoriale.

* Museo Regionale di Scienze Naturali, Sezione di Zoologia, Via G. Giolitti, 36, 10123 Torino, Italia, e-mail: f.andreone@libero.it

** Department of Ecology and Evolution, Johann Wolfgang Goethe University and Forschungsinstitut und Naturhistorisches Museum Senckenberg, Senckenberganlage 25, D-60325 Frankfurt a.M., Germany, e-mail: vincenzomercurio@gmx.de

*** Acquario di Genova, Area Porto Antico, Ponte Spinola, 16128 Genova, Italia, e-mail: fmattioli@acquariodigenova.it

**** Final report of the project *Arovy ny sahona gasy*.

This paper is dedicated to the memory of J. L. Behler, in recognition of his outstanding passion and love for the Malagasy herpetofauna.

Poiché vi è un interesse nella gestione sostenibile dello sfruttamento commerciale si discute anche la sostanziale differenza fra la raccolta (e l'esportazione) per finalità scientifiche e per finalità commerciali, insieme a modalità per stabilire quote commerciali di esportazione. Inoltre, si commentano possibili alcuni aspetti di sensibilità ecologica per la conservazione degli anfibi in generale.

Parole chiave: Amphibia, Anura, conservazione, perdita d'habitat, commercio internazionale, CITES, Madagascar.

Introduction

A recent workshop on the Global Amphibian Assessment (GAA) held at the IUCN headquarters in Gland, Switzerland, evaluated the status of the endemic species of amphibians of Madagascar, under the coordination of the Center of Applied Biodiversity Science at Conservation International (CABS) and the IUCN Species Survival Commission (IUCN/SSC). This led, among other things, to the publication of a paper by Andreone *et al.* (2005a), in which the main aspects and problems affecting all the Malagasy species have been highlighted. The overall results are reported in the web page "www.globalamphibians.org". As a conclusion, it became evident that the endemic amphibians of Madagascar are at a critical point, as a result of the increasing deforestation of remaining tropical forests. Of the 220 species evaluated, 9 turned to be Critically Endangered (CR), 21 Endangered (EN) and 25 Vulnerable (VU). This gave a total of 55 threatened species (corresponding to 25% of the total). However, the real situation might turn out to be even worse, because many of the 46 species that were listed as Data Deficient (DD) might eventually prove to be threatened. Furthermore, the discovery rate of new species is exceptionally high, and will lead to the description of species with limited distributions, facing serious threats to their habitats.

Furthermore, very little is known generally about the decline of amphibians in mainland Africa and Madagascar, mainly due to the fact that quantitative data are largely missing, and taxonomic studies (needed to identify species at risk) are still at a pioneering phase. However, the situation of some Malagasy species is better known since they are the subject of a significant commercial trade for the terrarium market (Behra & Raxworthy, 1991; Andreone & Luiselli, 2003; Rabemanjara *et al.*, in press). Due to their biological peculiarities and remarkable colouration, thousands of individuals of some of these frogs are exported for the pet trade each year. These frogs are mainly those belonging to the genus *Mantella* (Malagasy poison frogs) and others with an attractive appearance (e.g. some species belonging to the genera *Dyscophus* and *Scaphiophryne*).

One of the best known examples of commercial exploitation concerns the golden frog, *Mantella aurantiaca*, a species that was usually in very high demand by the market, due to its bright yellow-red coloration and, in general, its ease of keeping and breeding in captivity. Almost all the species of *Mantella* are potentially of interest to the commercial trade, and for this reason the whole genus was recently included in CITES Appendix II. Although some species, such as *Mantella betsileo* and *M. baroni* are quite adaptable to habitat alteration, may locally reach high densities, and are presumably still widely distributed, others (e.g., *M. haraldmeieri*, *M. bernhardi*, and *M. cowani*) have a very restricted distribution, and are potentially threatened by local extirpation as a result of a combination of habitat alteration and commercial collection. Despite their potential susceptibility, little information is

available on their abundance in nature, although some more rigorous data are available concerning their occurrence in the commercial trade (Rabemanjara *et al.*, in press). Whether and how this intensive collecting may affect the survival of species with high population densities and reproductive potential is largely unknown and still a matter of controversy, but some species with restricted distributions are likely to suffer from uncontrolled harvesting.

These considerations clearly highlighted the urgent need to gather data on the Critically Endangered (CR) and Endangered (EN) amphibian species and to propose action plans for correct management of them. The GAA identified nine CR species: *Mantella aurantiaca*, *M. cowani*, *M. expectata*, *M. milotympanum*, *M. viridis*, *Scaphiophryne gottlebei*, *Mantidactylus pauliani*, *Boophis williamsi*, and *Stumpffia helenae* (Andreone *et al.*, 2005a). This first data set (which has the potential to change in the future as a result of the discovery of new species and/or re-ranking of the threat status of other species) clearly highlighted the species that major conservation actions should address. As a consequence, it was decided to start a research programme soon that allows a focused study of some selected species. Within this programme we identified two crucial steps: (1) focus first on those CR and EN species which are subject to the pet trade, and (2) gather information on the remaining species included in these threat categories.

The aim of this paper therefore is to provide a final report on the results and major conservation aspects determined for the frog species studied during a project informally named ‘*Arovy ny sahona-gasy*’, supported by the Nando Peretti Foundation and by other non-governmental organisations (see the acknowledgements for a complete list). This project allowed us to reveal some important life history and distribution data on a set of CR and EN species, and one species included in CITES I, providing a significant update to data reported by Andreone *et al.* (2005a). We will conclude by providing some considerations on the influence of the pet trade and habitat degradation on the conservation of these frog species.

Material and methods

The species presented here were selected based upon their inclusion within the CR and EN species lists established by the GAA. Other significant points such as (1) the fact that there is little knowledge of their biology, and (2) the availability of the results for comparative studies of ecological and natural history traits, have also been considered. The selected species are as follows: *Mantella bernhardi*, *M. cowani*, *M. expectata*, *M. viridis*, *S. gottlebei* and *D. antongilii*.

In the preliminary phase we assessed the state of knowledge of the biology of each species and gathered data on the commercial trade by consulting published literature (see Glaw & Vences, 1994 and Rabemanjara *et al.*, in press) and the available databases of the UNEP/WCMC (United Nations Environment Programme/World Conservation Monitoring Centre), and the CITES webpage (<http://sea.unep-wcmc.org/citestrade/trade.cfm>). We also interviewed members of professions linked with the pet trade, such as local collectors, intermediary persons, international exporters and importers.

During the field research we also gathered information on some basic life history traits by studying: (1) body size and weight, (2) estimating (where possible) population size, and (3) beginning an age structure analysis. Most of these data are still

under investigation and will be presented elsewhere. Furthermore, a mitochondrial DNA analysis (mainly by *cyt b*) was conducted on all the species, and these data are already available. For each species we present updated considerations and the threat category according to Andreone *et al.* (2005a).

Results

An overview of the species and their specific requirements and threats

Here we present the main results of the research project “*Arovy ny sahona gasy*” specifying, according to current knowledge, the conservation status and suggesting protection strategies together with some new data on these species’ biology, including pertinent bibliographical references. The photographs of some living individuals and their habitats are given in Figures 1-12.

Mantella bernhardi [EN]. Bernhard’s mantella is one among the least known *Mantella* species. It was discovered in the 1990s, and until recently was known only from the type locality (next to Tolongoina, south-east Madagascar). The habitat conditions at this site were heavily affected by deforestation. A first visit (by Andreone F.) was performed in 1995, followed by a second visit ten years later. During this interval the original rainforest was observed to have diminished in extent by at least 40% (F. Andreone, pers. obs.). More recently, the species was discovered around the boundaries of Ranomafana National Park, and at some sites next to Manombo and Vevembe (Andreone *et al.*, 2005a; Rabemanjara *et al.*, 2005). A genetic study ascertained that two conservation units can be identified, and as a result that particular attention should be paid to their conservation (Vieites *et al.*, 2006). Although this is a species currently included within the EN category (and therefore potentially less threatened than the CR species), it is clear that its restricted distribution, continued degradation of the typical habitats, and the presence of two genetically differentiated population clusters, suggest that very close attention should be paid to its conservation. Since most of the collection for the pet-trade occurred at a single locality (the Ambohimanana/Ambohimandroso territory), the Malagasy authorities established an exportation quota of zero. Captive breeding for this species is not yet clearly documented. The species is present at one non-protected site (Ambohimanana/Ambohimandroso), and at two protected sites (Mangevo, Vevembe/Manombo), so its situation appears better than formerly believed. However, since the populations belong to two different conservation units, particular attention should be paid to preserving the ecological conditions of at least one site per conservation unit.

Mantella cowani [CR]. The harlequin mantella is an attractive mantella, currently known only from a few sites on the high plateau of Madagascar (Raxworthy & Nussbaum, 1996, 2000; Andreone & Randrianirina, 2003; Brinkman & Hoffstetter, 2005; Andreone *et al.*, in press). The remaining populations are restricted to a very few altitude moors, surrounded by secondary savannah. The habitat degradation at these sites is particular severe, since only scattered and residual forest trees survive along some of the streams where the species lives. During the study we located two main population nuclei, quite far apart from each other: the first around the Antoetra region, and the second in the Tsinjoarivo area, at about 200 km from Antoetra. Furthermore, at one of the Antoetra sites we also detected hybridisation between

M. cowani and *M. baroni* (Chiari *et al.*, 2005a), although the former appears to be more of a savannah or heathland species, while the second is located much more within the thick forest. *Mantella baroni* also seems able to colonise nearby *tavy* (slash and burn) fields. The amount of collecting activity focussed on *M. cowani* was very high until a few years ago. Available data state that collectors used to collect 2,000 individuals per day, but in 2003 only 100-150 individuals per day were collected by an entire village. Now, the Malagasy government has imposed a total ban of any commercial activity regarding this species. Captive breeding has never been documented, and even popular books dealing with mantellas in captivity do not report reliable information. Given the low number of individuals surviving in nature, and the continued shrinking of its natural habitats, it is necessary to propose an urgent action plan, that takes into consideration the creation of at least a protected area (likely to be managed by local populations in collaboration with local NGOs), and the creation of captive assurance colonies (although captive requirements should be carefully established).

Mantella expectata [CR]. The blue-legged mantella was formerly known from only a few sites in the Isalo National Park, an arid sandstone area in south-central Madagascar (Busse & Böhme, 1992; Glaw & Vences, 1994, Andreone *et al.*, 2005a, 2005b, 2005e). Our recent survey work has allowed the discovery of a large number of populations, and provided proof that - in general - the species is widely distributed. A paper on the distribution and natural history traits of this frog is currently in preparation. We did not succeed in confirming this species' presence on the rather isolated "inselberg" of Tsitorina, which is separated from the main Isalo Massif. In some places we found the species in syntopy with *M. betsileo*, and we observed some putative hybrids. The current exportation quota is 1,000 individuals per year. This species does not appear to suffer from habitat degradation and appears to be quite well adapted to recurrent savannah fires. Nonetheless, its relatively small distribution restricted to the Isalo Massif and the need to clarify the effects of the putative hybridisation make a long term monitoring programme necessary for sustainable collection of this species.

Mantella viridis [CR]. The green mantella was until recently known only from a limited number of localities in northern Madagascar (Vences *et al.*, 1999). Our survey work allowed us to discover a great number of populations in the Montagne des Français and Antongombato area (Andreone *et al.*, 2005e). Furthermore, we were able to confirm its presence within the boundaries of the Montagne d'Ambre National Park, the first finding of it in a protected area. The species appears to be locally abundant and to live in extended mango plantations, rather than in pristine forested habitats. At some sites the coloration of the species shades towards that of *M. betsileo*, and in some cases we also discovered putative hybrids. As for *M. expectata* it is crucial to estimate the importance and the incidental taxonomic significance of this putative hybridisation. Even though in the relevant area habitat degradation is generally high, the species appears to respond well to the changing habitat. The total population size is likely to be very large (although further more accurate assessments are needed), and collecting activity for the pet trade could easily be continued with the current export quota of 1,000 individuals per year.

Scaphiophryne gottlebei [CR]. Like *M. expectata*, the rainbow frog is present in the Isalo Massif, but until recently its distribution was significantly underestimated. Our fieldwork allowed us to discover many new populations, and to

observe some aspects of its reproductive and larval biology (Andreone *et al.*, 2005b, 2005d; Mercurio & Andreone, 2006). A paper on the distribution and natural history traits of this species is currently in preparation. Apart from this small increase of the species' known distribution and the improvement of the state of knowledge of some aspects of the reproductive traits of its biology, this enigmatic frog remains still completely unknown. Data yet to be published suggest that although the species is largely fossorial and specialised to live within the narrow and wet canyons of the Isalo Massif, it has a high dispersal capability (most likely during the storms occurring in the rainy season), leading to generally high panmixis of the populations, which show very low genetic differentiation (Y. Chiari, pers. comm.). Based on our observations adults are characterised by a very secretive life style, and commercial collecting mainly refers to juveniles, or even newly metamorphosed individuals sometimes not reaching 25 mm in snout-vent length. Numerical evaluations of the reproductive proportion of the population as well as understanding of the possible effects of this collecting of juveniles are badly needed. Under this perspective, the current export quota of 1,000 individuals per year should be regarded as temporary until new and more accurate data are available.

Dyscophus antongilii [NT]. The tomato frog is currently the only amphibian from Madagascar included in CITES I (since 1987). Surprising enough, despite the past commercial interest in *Dyscophus* and the high conservation priority of *D. antongilii* (Raxworthy & Nussbaum, 2000), there are no conservation-related publications. With the exception of some general data on the species published by Glaw & Vences (1994), no field research has been carried out on this species, and original captive breeding data are also largely missing, except for a few summaries (e.g. De Vosjoli & Mailloux, 1990; Poole, 2000). Information on its life history traits, distribution, abundance, and genuine genetic differentiation in respect to the closely related *D. guineti* are also scarce. Recent studies in collaboration with M. Vences, indicate that these two species are very similar, and that *D. antongilii* might simply be a colour variant of *D. guineti* (Chiari *et al.* 2005b, 2005c), although further evidence supports the existence of significant differences at the level of nuclear genes. *Dyscophus antongilii* prefers open habitats, and for this reason appears to be less sensitive to ecological alterations. Notwithstanding this, recent surveys carried out in 2006 suggest that the populations of *D. antongilii* around Maroantsetra (the best known locality of this species) seem to be declining (see further, below). Virtually nothing is known about the distribution of this species around Maroantsetra and whether it occurs within the boundaries of the Parc National de Masoala (where Maroantsetra is located), despite the fact that the tomato frog is often used as an iconic or flagship species on brochures and information sheets concerning the protected area. Recent studies carried out by F. Andreone, F. Mattioli and J. E. Randrianirina (unpublished) confirmed the species' presence around the Ambatovaky Special Reserve, but we are still unaware of whether it occurs within its boundaries. We recommend therefore that at least some "urban" populations of *D. antongilii* at Maroantsetra should be managed and protected, and that detailed survey work should be done to establish the species' distribution at Masoala. As a consequence of the total trade ban for *D. antongilii*, the similar *D. guineti* is collected and exported in high numbers from a few (1-2) localities east-central Madagascar. As a result, its current conservation status should be carefully assessed.



1



4



2



5



3



6

Figs. 1-6 - The species of amphibians under consideration by the project *Arovy ny sahona gasy*. 1) *Mantella bernhardi*. Individual from Mangevo, next to Ranomafana; 2) *Mantella cowani*. Individual from Vohisokina. 3) *Mantella expectata*. Male from Zahavola, Isalo Massif. 4) *Scaphiophryne gottlebei*, from Zahavola. 5) *Mantella viridis*. Individual from Antongombato. 6) *Dyscophus antongilii*, individual from Antara.

Figs. 1-6 - Le specie di anfiabi oggetto del progetto *Arovy ny sahona gasy*. 1) *Mantella bernhardi*. Esemplare di Mangevo, nei pressi di Ranomafana. 2) *Mantella cowani*. Esemplare di Vohisokina. 3) *Mantella expectata*. Esemplare di Zahavola, Massiccio dell'Isalo. 4) *Scaphiophryne gottlebei*, di Zahavola. 5) *Mantella viridis*, esemplare di Antongombato. 6) *Dyscophus antongilii*, esemplare di Antara.



7



10



8



11



9



12

Figs. 7-12 - 7) Habitat of *Mantella bernhardi* at Ambohimandroso/Ambohimanana, next to Tolongoina, as photographed in 2005. 8) Habitat of *Mantella cowani* at Vohisokina, Antoetra. 9) Seasonal stream and nearby environments (Isalo Massif), habitat of *Mantella expectata* and *Scaphiophryne gottlebei*. 10) Habitat of *Mantella viridis* at Francom, next to Antongombato. 11) Reproductive habitat of *Dyscophus antongilii* at Iampirano. 12) Temporary pond within the town of Maroantsetra, breeding site of *Dyscophus antongilii*.

Figs. 7-12 - 7) Habitat di *Mantella bernhardi* ad Ambohimandroso/Ambohimanana, nei pressi di Tolongoina, come da fotografia del 2005. 8) Habitat di *Mantella cowani* a Vohisokina, Antoetra. 9) Ruscello temporaneo e ambiente circostante (Massiccio dell'Isalo), habitat di *Mantella expectata* e di *Scaphiophryne gottlebei*. 10) Habitat di *Mantella viridis* a Francom, nei pressi di Antongombato. 11) Habitat di *Dyscophus antongilii* a Iampirano. 12) Sito riproduttivo di *Dyscophus antongilii*, all'interno della città di Maroantsetra.

Discussion

Habitat degradation as a major source of threat for Malagasy amphibians

Degradation of the natural habitat clearly plays a major role in the suite of threats affecting the amphibians of Madagascar, as already stressed elsewhere (Andreone, 1994; Andreone & Randrianirina, 2000). In particular, some species (especially the primarily terrestrial ones) appear to be more sensitive to this than others (Andreone & Luiselli, 2003; Andreone, 2004). From analysis of the distribution data provided by the GAA project, it is clearly evident that the major problems in terms of endangering species lie in the central high plateau of Madagascar, where the forest has almost totally gone, and where the human presence is accompanied by reduced biodiversity (Andreone *et al.*, 2005a). Furthermore, only a few rainforest species are able to adapt to the deforested and isolated areas (Vallan, 2000, 2002, 2003; Vallan *et al.*, 2004), although some species can thrive for a certain period (which is difficult to determine) in the secondary habitats, especially along watercourses (Andreone & Luiselli, 2003). Of the species analysed we note that nearly all are experiencing habitat degradation, with the exceptions of *M. expectata* and *S. gottlebei*. In general, the correlation between species' declines and habitat alteration is hard to quantify and is still matter of controversy. In particular, this process is much more clear and evident for the rainforest species (such as *Mantella bernhardi* and *M. cowani*), while being less clear for the species living in more xeric areas and for those that prefer open habitats and still waters for reproduction. Just as an example, *M. viridis* appears still common and abundant despite the clear degradation of its habitat (Andreone *et al.*, 2005b, 2005e).

The pet trade and its influence in terms of conservation

Little is known on the effect of collection for the international pet trade on the amphibians of Madagascar. This is also the situation for most reptile and amphibian species globally, for which very few studies are currently available, and for which most of the considerations that have been arrived at are based upon personal opinions. The scarce data obtained for some species (mainly through the project presented in this paper and other studies carried out by colleagues and associates) suggest that the effects mainly depend on the state of the habitat in which the species under consideration occurs. Collection of a species with low population estimates (e.g. *M. cowani*) could easily lead to local extinction, while other species with high population estimates and a broad distribution (such as *M. expectata* and *M. viridis*) could be exploited as a renewable resource. This has been demonstrated for a reptile species, the panther chameleon (*Furcifer pardalis*), which turns out to be very abundant and able to easily support collection for exportation (Andreone *et al.*, 2005c). Furthermore, such an activity when done in a sustainable way could be a source of economic income, representing a positive feedback method to incentivise nature conservation among the local populations.

Other data on aspects in addition to the biology, distribution, population size estimates and adaptability of species are essential for estimating the influence of the pet trade on the natural populations. Taking as an example the case of the genus *Mantella*, during 1990 the published figures suggest more than 10,000 specimens

were exported in six months (see Vences *et al.*, 1999). More recently, during the five-year period 2000-2004, the exportation rate of the genus *Mantella* for commercial purposes turned out to be very high, at 161,660 individuals, giving a mean rate of 32,332 per year (Tab. 1). In addition, since a large number of individuals captured in nature usually die in the terraria of local collectors and exporters (generally because of lack of care or bad housing conditions), the true amount of specimens collected per year may be much higher than this number. This factor, and related issues inherent to the whole trade process from collecting to export through to captive maintenance are of crucial importance in appraising the real significance of the phenomenon and should also be carefully investigated.

Tab. 1 - Summary data regarding the conservation status and export parameters for the species under consideration in the study. Data from UNEP/WCMC and CITES.

Tab. 1 - Dati riassuntivi dello status di conservazione e dei parametri di esportazione delle specie di anfibi studiati nel corso del progetto. Dati dal sito UNEP/WCMC e CITES.

Species	Conservation categorisation	Allowed export quota 2005	Commercial exports 2000-2004	Scientific collecting
<i>Mantella bernhardi</i>	EN	0	2,397	132
<i>Mantella cowani</i>	CR	0	3,474	54
<i>Mantella expectata</i>	CR	1,000	11,126	25
<i>Mantella viridis</i>	CR	1,000	12,425	33
<i>Scaphiophryne gottlebei</i>	CR	1,000	1,905	30
<i>Dyscophus antongilii</i>	NT	0	0	Not available

Scientific collection and its constraints

Strictly speaking, another kind of collecting of the amphibians and reptiles of Madagascar, and other organisms, does occur, separate to the collection for commercial purposes. This scientific collecting of specimens (dead or alive) is vital for scientific research. As stressed by Andreone & Gavetti (2000), the collecting of voucher specimens represents an important phase in any biodiversity survey, since it witnesses and warrants the presence of a certain species at a certain site, and allows to perform biomolecular and taxonomic studies.

It could be asked whether scientific collecting could represent a conservation threat for some rare or localised species. A capture limit of 5 individuals per species for amphibians (and reptiles) has been currently established per site by the scientific authorities of Madagascar. This limit sometimes poses problems in terms of the availability of museum specimens (and thus in their scientific value) when the number of sites per survey is higher than five. This would mean that - if this 5 individuals limit is respected - for some sites it would be impossible to get any specimen.

Curiously enough, the number of individuals per species is not subject to any restriction when destined for the commercial trade: a single authorised collector could easily collect hundreds of individuals, even from a single site. By contrast, a scientist wishing to obtain some voucher specimens during a survey is severely limited. Such a difference does not have a clear justification, particularly taking into account that the data obtained by scientists (e.g. during biodiversity surveys) have a clear conservation purpose, seeing as the results are usually used to define the biological richness in well-determined areas.

Furthermore, the individuals captured for the pet trade are mostly destined for amateurs and to the terrarium market, with scientific results rarely being produced, while the voucher specimens housed in natural history collections bear important taxonomic implications, allow the study of several biological parameters, and could be used for instructive exhibits.

The percentage of individuals collected for scientific purposes in relation to the overall exported *Mantella* species is very low. In the period 2000-2005, this percentage varied from 0.05% to 3.15%, as shown in Table 2. In the species studied during the present project the numbers are of the same proportion. It is therefore clear that scientific collecting does not carry any threat to conservation. For this reason, the maximum number of specimens that can be collected per site could be increased. Given that a maximum of 5 specimens is to be considered very low and to have minimal scientific meaning (and also taking into consideration that half of this number has to be deposited in a Malagasy institution), we suggest that it is increased at least to 10.

Tab. 2 - Number of live and preserved individuals of all species of the genus *Mantella* exported per year from 2000 to 2004 for commercial (pet trade) and scientific purposes (voucher specimens). The percentage in relation to the overall exported number is reported within parentheses.

Tab. 2 - Numero di esemplari (vivi e preservati) appartenenti al genere *Mantella* (appartenenti a tutte le specie), esportati per anno dal 2000 al 2004 per fini commerciali (mercato terraristico) e per scopi scientifici (voucher specimen). La percentuale in relazione alla quota totale esportata è riportata fra parentesi. Sono stati esclusi dalla stima i campioni tissutali, non facilmente riconducibili a esemplari *in toto*.

	2000	2001	2002	2003	2004	TOTAL
Commercial collecting (live animals)	36,080 (99.76%)	51,714 (99.81%)	24,450 (99.94%)	18,671 (98.44%)	30,745 (96.85%)	161,660 (99.11%)
Scientific collecting (live and preserved animals)	87 (0.24%)	96 (0.19%)	14 (0.06%)	292 (1.56%)	970 (3.15%)	1,459 (0.89%)
Total number of exported specimens of the genus <i>Mantella</i>	36,167	51,810	24,464	18,963	31,715	163,119

Setting of export quotas and proposals for inclusion in CITES of some species

The current system of quota definition for the amphibians and reptiles of Madagascar is based mainly on personal opinions and/or consensus arrived by the scientific community, and at the end screened by the relevant scientific authority. Although this adheres to good sense, it is evident that more data are needed to establish a more rational system of capture quotas. This could be done via the application of data processing models such as *population viability analysis* (PVA) to the critical species, by determining the main biological features requested by the software, such as population size estimate, population sex ratio, age structure, life span, number of hatchlings, and dispersal capacity, et cetera (Beissinger & McCullough, 2002). Although most of these parameters are not easy to estimate with precision it is possible to obtain some general indications useful for understanding whether collection could be performed at a certain population size. As already stressed by Andreone *et al.* (2005a), almost all the traded species are included in the CITES lists, and in addition the traded species classified as CR, EN, or VU are included in CITES II or CITES I. The only exceptions are some species of the genus *Scaphiophryne*, such as *S. marmorata* and *S. boribory*, which are not yet included in any CITES listing. We propose that the inclusion of the whole genus *Scaphiophryne* would represent a useful tool for the conservation of these species, given the characteristics of the current commercial trade, and given that, for example, all the *Mantella* species are listed under CITES II. Similarly, *Dyscophus guineti* could be usefully included in CITES II, especially given that most of its collection occurs at two major locations, Antsihanaka and Fierenana (E. J. Edwards, pers. comm.).

Conclusions and recommendations for frog conservation

Given the high number of frog species inhabiting Madagascar, the fact that their overall distribution is concentrated along the eastern rainforest belt (which is currently highly degraded), and the overall number of threatened species, we are convinced that an overall conservation project for the amphibians of Madagascar is clearly urgently needed, to define the main conservation strategies in the forthcoming years.

Up until now, single researchers or independent teams have carried out research on the endangered species, and often the results have not been published. The *Declining Amphibian Populations Task Force* (DAPTF), of which one of us (F. Andreone) is chair, started some forms of coordination, through continuous and regular contact and the exchanges of ideas and opinions through a dedicated email list. The reorganisation of such a group could hopefully lead to the implementation of a general conservation project in Madagascar led by an international organisation (either already in existence or created specifically for this).

This project, which should be developed following on from the *Amphibian Conservation Action Plan* meeting held in Washington D.C., USA, in September 2005, should address several key aspects, including: (i) increasing research activity in the field and focussing it on the most threatened species, (ii) obtaining the designation of some protected areas specifically (or mainly) devoted to amphibians, an action that until now has not yet been done (ANGAP, 2001), (iii) increasing public awareness regarding the importance of conserving and protecting endemic Malagasy

amphibians, (iv) capacity building by facilitating the training and the scientific education of local researchers, (v) exploring the possibilities of captive breeding applied to the conservation of some selected species of amphibians. Furthermore, the CR and EN species should be continually monitored, in order to gather first hand data on their status. In order to do this, the other Malagasy CR species as established by the GAA (Andreone *et al.*, 2005a) should become the objects of a continuous study. In order to achieve this support to the conservation of Malagasy amphibians should involve an increased coordination and an efficient scientific leadership.

We are convinced that all these points will be realised if local coordination exists in Madagascar. This could be done via the creation of an organisation specifically devoted to the conservation of amphibians (e.g. using *BirdLife* as a model), or via the empowering of some existing conservation agencies and organisations. The existence of such a structure will allow continuous monitoring and coordination, and will facilitate the regular organisation of workshops and initiatives that are the basis of concrete conservation actions.

Acknowledgements

We are grateful to all those who provided their help during our research in Madagascar. In particular, the local collectors and members of other professional categories. For sharing important bibliographical information we thank O. Behra, E. J. Edwards, F. Glaw, O. Ramilijaona, H. Randriamahazo, D. Vallan, and M. Vences. Thanks also to A. Sarovy, J. E. Randrianirina, and T. R. Razafindrabe for their assistance in the field. Y. Chiari provided unpublished information, while S. Furrer (Zürich Zoo), G. Malfatti (Nando Peretti Foundation), S. Palumbo (Nando Peretti Foundation), R. Rossi (Istituto Oikos), A. Rübel (Zürich Zoo), and P. Dollinger (WAZA) assisted with logistical and financial support. For the exportation permits we thank the Malagasy authorities, in particular the Ministère des Eaux et Forêts, and the Scientific Authority. For the importation we thank the Italian Scientific Commission of CITES, and in particular C. Picchiotti. R. J. Berridge was so kind to correct the bad English of a first draft of this paper, giving also some precious comments. This work was funded by the Nando Peretti Foundation, Conservation International, Air Madagascar, Acquario di Genova, DAPTF (*seed grants* and *rapid response fund*), Istituto Oikos, Zürich Zoo, WAZA, Wildlife Conservation Society, Madagascar Fauna Group, National Amphibian Conservation Center, and Gondwana Conservation and Research.

References

- Andreone F., 1994 - The amphibians of Ranomafana rain forest, Madagascar - preliminary community analysis and conservation considerations. *Oryx*, 28: 207-214.
- Andreone F., 2004 - Mantellidae: *Mantidactylus*. In: The Natural History of Madagascar. Goodman S. M. & Benstead J. P. (eds.). *The University of Chicago Press*, Chicago: 910-913.

- Andreone F., Cadle J. E., Glaw F., Nussbaum R. A., Raxworthy C. J., Vallan D. & Vences M., 2005a. - Species review of amphibian extinction risks in Madagascar: conclusions from the Global Amphibian Assessment. *Conservation Biology*, 19 (6): 1790-1802.
- Andreone F. & Gavetti E., 2000 - Conservazione & conservazione: riflessioni sul significato del collezionismo erpetologico nei musei di storia naturale. Atti del I Congresso Nazionale della Societas Herpetologica Italica (Torino, 1996). *Museo Regionale di Scienze Naturali*: 29-36.
- Andreone F., Guarino F. M., Mattioli F. & Mercurio V., 2005b - Threatened and traded frogs of Madagascar: novel natural history and distribution traits for the conservation of *Mantella cowani*, *M. expectata*, *M. viridis*, and *Scaphiophryne gottlebei*. Programme and Abstracts of the 13th Ordinary General Meeting (Bonn, 27 September - 2 October 2005). *Societas Europaea Herpetologica (SHE)*: 24-25.
- Andreone F., Guarino F. M. & Randrianirina J. E., 2005c - Life history traits, age profile, and conservation of the panther chameleon, *Furcifer pardalis* (Cuvier, 1829), at Nosy Be, NW Madagascar. *Tropical Zoology*, 18: 209-225.
- Andreone F. & Luiselli L. 2003 - Conservation priorities and potential threats influencing the hyper-diverse amphibians of Madagascar. *Ital. J. Zool.*, 70: 53-63.
- Andreone F., Mattioli F. & Mercurio V., 2005d - The call of *Scaphiophryne gottlebei*, a microhylid frog from the Isalo Massif. Southcentral Madagascar. *Current Herpetology*, 24 (1): 33-35.
- Andreone F., Mercurio V., Mattioli F. & Razafindrabe T. J., 2005e - Good news for three critically endangered and traded frogs from Madagascar. *Froglog*, 72: 2.
- Andreone F. & Randrianirina J. E., 2000 - Biodiversity, rainforests and herpetological communities in Madagascar: what about differences between amphibians and reptiles? In: Diversity and Endemism in Madagascar. Lourenço W. & Goodman S. M. (eds.). *Mémoires de la Société de Biogéographie*: 217-228.
- Andreone F., Randrianirina J. E., 2003 - It's not carnival for the harlequin mantella! Urgent actions needed to conserve *Mantella cowani*, an endangered frog from the high plateau of Madagascar. *Froglog*, 59, 1-2.
- Andreone F., Vences M., Glaw F. & Randrianirina J. E., in press - Remarkable records of amphibians and reptiles on Madagascar's central high plateau. *Tropical Zoology*.
- ANGAP (Association National pour la Gestion des Aires Protégées), 2001 - Plan de gestion du réseau national des aires protégées de Madagascar. Antananarivo. *ANGAP and Ministère de l'Environnement*, Antananarivo, Madagascar.
- Beissinger S. R. & McCullough D. R., 2002 - Population Viability Analysis. *The University Chicago Press Ltd.*, London.
- Brinkman C. & Hoffstetter L., 2005 - Harlequin Mantella (*M. cowani*). Recovery Plan. Unpublished internal report.
- Busse K. & Böhme W., 1992 - Two remarkable frog discoveries of the genera *Mantella* (Ranidae: Mantellinae) and *Scaphiophryne* (Microhylidae: Scaphiophryninae) from the west coast of Madagascar. *Revue française d'Aquariologie*, 19 (1/2): 57-64.
- Chiari Y., Andreone F., Vences M. & Meyer A., 2005a - Genetic variation of an endangered Malagasy frog, *Mantella cowani*, and its phylogeographic relationship to the widespread *M. baroni*. *Conservation Genetics*, 6 (6): 1566-621.

- Chiari Y., Orozco-ter Wengel P., Vences M. & Meyer A., 2005b - Genetic identification of units for conservation in tomato frogs, genus *Dyscophus*. Programme and Abstracts of the 13th Ordinary General Meeting (Bonn, 27 September – 2 October 2005). *Societas Europaea Herpetologica (SHE)*: 38.
- Chiari Y., Orozco-ter Wengel P., Vences M., Vieites D. R., Sarovy A., Randrianirina J. E., Meyer A. & Louis E. Jr., 2005c - Genetic identification of units for conservation in tomato frogs, genus *Dyscophus*. *Conservation Genetics*.
- De Vosjoli P. & Mailloux R., 1990 - Breeding on thin ice: the husbandry and propagation of the Malagasy Tomato Frogs, *Dyscophus antongilii* and *D. insularis*. In: Proceedings of the 13th International Herpetological Symposium on Captive Propagation & Husbandry. Uricheck M. J. (ed.). *Western Connecticut State University*, Danbury: 181-193.
- Glaw F. & Vences M., 1994 - A fieldguide to the amphibians and reptiles of Madagascar, 2nd edition. Vences and Glaw, Cologne.
- Mattioli F., Gili C. & Andreone F., 2006 - Economics of captive breeding applied to the conservation of some selected amphibians and reptiles from Madagascar. *Natura*, Milano, 95 (2): 67-80.
- Mercurio V. & Andreone F., 2006 - The tadpoles of *Scaphiophryne gottlebei* (Microhylidae, Scaphiophryninae) and *Mantella expectata* (Mantellidae, Mantellinae) from Isalo Massif, central-southern Madagascar. *Alytes*, 23 (3-4): 81-95.
- Poole V., 2000 - Big & red: natural breeding of the tomato frog, *Dyscophus antongilii*, at the Baltimore Zoo.
- Rabemananjara F., Bora P., Cadle J. E., Andreone F., Rajeriarison E., Talata P., Glaw F., Vences M. & Vieites D. R., 2005 - New records, distribution and conservation of *Mantella bernhardi*, an Endangered frog species from south-eastern Madagascar. *Oryx*, 39 (3), 339-342.
- Rabemananjara F. C. E., Rasoamampionona Raminosoa N., Ravoahangimalala Ramilijaona O., Andreone F., Bora P., Carpenter A. I., Glaw F., Razafindrabe T., Vallan D., Vieites D. R. & Vences M., in press - Malagasy poison frogs in the pet trade: a survey of levels of exploitation of species in the genus *Mantella*. *Amphibian and Reptile Conservation*.
- Raxworthy C. J. & Nussbaum R. A., 1996 - Montane amphibian and reptile communities in Madagascar. *Conservation Biology*, 10: 750-756.
- Raxworthy C. J. & Nussbaum R. A., 2000 - Extinction and extinction vulnerability of amphibians and reptiles in Madagascar. *Amphibian and Reptile Conservation*, 2 (1): 15-23.
- Rondinini C., Chiozza F. & Boitani L., 2006 - Aree prioritarie per la conservazione dei Vertebrati africani. *Natura*, Milano, 95 (2): 47-56.
- Vallan D., 2000 - Influence of forest fragmentation on amphibian diversity in the nature reserve of Ambohitantely, highland Madagascar. *Biological Conservation*, 96: 31-43.
- Vallan D., 2002 - Effects of anthropogenic environmental changes on amphibian diversity in the rainforests of eastern Madagascar. *Journal of Tropical Ecology*, 18: 725-742.
- Vallan D., 2003 - Consequences of rain forest fragmentation for herpetofauna: a case study from Ambohitantely. In: The Natural History of Madagascar. Goodman S. M. & Benstead J. P. (eds.). *The University of Chicago Press*, Chicago and London: 899-907.

- Vallan, D., Andreone F., Raherisoa V. & Dolch R., 2004 - Does selective wood exploitation affect amphibian diversity? The case of An'Ala, a tropical rainforest in eastern Madagascar. *Oryx*, 38: 410-417.
- Vences, M., Glaw, F. & Böhme, W., 1999 - A review of the genus *Mantella* (Anura, Ranidae, Mantellinae): taxonomy, distribution and conservation of Malagasy poison frogs. *Alytes*, 17 (1-2): 3-72.
- Vieites D. R., Chiari Y., Vences M., Andreone F., Rabemanjara F., Bora P., Nieto-Román S. & Meyer A., 2006 - Mitochondrial evidence for distinct phylogeographic units in the endangered Malagasy poison frog *Mantella bernhardi*. *Molecular Ecology*, 15, 1617-1625.