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Economics of captive breeding applied to the conservation of selected amphibian and reptile species from Madagascar

Abstract - The present study analyses the cost of breeding Malagasy amphibians and reptiles, integrating research data with analysis of data collected from private owners and hobbyists. The species under consideration were chosen as these are the ones most in demand in the commercial pet trade, and are therefore the most frequently exported species from Madagascar. All the information available on the reproductive biology of each species, and the costs of its captive management and breeding, are organized in such a way that the cost of captive breeding of a single specimen can be calculated. The market prices from different countries have been compared with the cost of a single specimen and the conclusions consider the possibility of using captive breeding of selected species as a tool for conservation management strategies.

Key words: amphibians, reptiles, economics, captive breeding, Madagascar, conservation.

Riassunto - Aspetti economici dell'allevamento in cattività applicato alla conservazione di alcune specie selezionate di anfibi e di rettili del Madagascar.

È stata condotta un'analisi sui costi dell'allevamento in cattività di specie di anfibi e rettili del Madagascar e i dati integrati dove necessario con quelli di allevatori privati. Le specie selezionate sono state scelte fra le più ricercate sul mercato terrariofilo internazionale e sono, quindi, fra le più esportate dal Madagascar. I dati ottenuti sulla biologia riproduttiva e sui costi di gestione sono stati elaborati in modo tale da ottenere una formula per il calcolo del costo del singolo animale riprodotto. I prezzi di mercato per animali di cattura sono stati confrontati con il costo di animali riprodotti. Sono infine discussi e commentati i possibili utilizzi di animali riprodotti a fini conservazionistici.

Parole chiave: anfibi, rettili, aspetti economici, allevamento in cattività, Madagascar, conservazione.

Introduction

The herpetofauna of Madagascar is extremely diverse and is characterized by a high degree of endemism (Glaw & Vences, 1994). This fauna, such as the colourful genera *Phelsuma* and *Mantella*, the curious and amazing genus *Uro-*

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platus, the large *Astrochelys radiata*, the diminutive *Pyxis arachnoides*, and more that half of all living chameleon species, is a source of wonder even to people not ordinarily interested in such organisms. For this reason the scale of the international pet trade increases year-on-year, driven mostly by demand in North America, Europe and Japan (Carpenter *et al.*, 2004; Rabemanajara *et al.*, in press). In parallel, the levels of threats facing these animals in the wild increase for different reasons, and the principal threat is that of habitat destruction (Green & Sussman, 1990), while the trade in live animals does not occupy the position of the next most serious threat (JNCC, 1993). Due to the fact that Madagascar is a well-known biodiversity hot spot (Myers *et al.*, 2000), many zoos and aquaria focus part of their exhibits on this region and its animals. This is just what has been done at the Acquario di Genova and Zürich Zoo (Graf, 2005). The aims of such displays are to explain to visitors the significance and importance of biodiversity and to promote campaigns for its protection. Animals are currently bred in zoos in order to maintain sustainable captive populations, to increase public awareness, and to educate the public about the need for sustainable conservation projects; zoos and aquaria in this sense therefore create a living "ark" maintaining the species in captivity should they go extinct in the wild, and avoiding collection of wild animals.
Intensive breeding of these *ex situ* (colonies could therefore represent a new method of reducing the number of wild-caught animals for the pet trade, create the basis for exporting breeding techniques to their countries of origin, provide local populations with different livelihood activities instead of capturing the animals, and use the sales proceeds to finance local conservation projects and public awareness-raising activities.

Material and methods

For this study we considered species of amphibians and reptiles belonging to the Malagasy herpetofauna. Some of these species had been imported to the Acquario di Genova directly from Madagascar in 1997/1998 (e.g. *Dyscophus guineti*, *Mantella aurantiaca*, *Scaphiophryne marmorata*, *Calumma parsoni*, and *Pyxis arachnoides*), while other species were obtained in exchanges with private breeders or other facilities (e.g, *Phelsuma madagascariensis*, *Phelsuma standingi*, *Uroplatus phantasticus*, and *Uroplatus lineatus*), both in an agreed framework of scientific cooperation for conservation and educational purposes.
All the wild-caught specimens were collected during scientific expeditions carried out in Madagascar with the University of Antananarivo, and were imported with permits provided by the CITES authority where necessary. The purposes of importing these species were to develop ex situ reproduction protocols, to create a special exhibit on Madagascar in the Acquario di Genova, to increase public awareness about conservation of wildlife and the environment in Madagascar, and to investigate practical opportunities for progressively limiting and ultimately halting the trade in protected wild-caught animals from Madagascar by transferring relevant knowledge to public-sector Malagasy facilities.
Some of the data in the present study were collected through communications with private breeders. For each of the species we carried out a period of observation and data collection of at least two years. The initial six months in their new facility were dedicated to acclimatisation to the new captive conditions. Each species received

appropriate housing and appropriate changes of habitat were provided to the species that required it for reproduction (i.e. a rain chamber for amphibians).
The data collected for the different species are: (i) number of egg-laying events per year; (ii) number of eggs produced per egg-laying event; (iii) number of hatchings per egg- event (for amphibians we considered the number of larvae); (iv) number of individuals reaching metamorphosis; (v) number of animals reaching commercial size; (vi) time frame to reach commercial size; (vii) type of food provided; (viii) number of feeds per day/week; (ix) daily labour time dedicated to the individual species; (x) estimate of daily calorific intake.
The gross daily cost of manpower is based on the mean salary of an Italian keeper in euros (€) (Tab. 1). Electricity costs are based on the actual cost of a kilowatt-hour (kWh) in € in Italy (Tab. 1). The cost of food for the animals is based on the cost per week to purchase it or the cost of the manpower and electricity required to artificially culture the food items or capture them from natural sources (Tab. 1).
All the prices of fruits, vegetables, vitamins, calcium, and nutritional supplements, are based on the Italian costs of the products. The costs of building the facilities and the cages were not taken into consideration as they had already been constructed for other uses before the present research.
The costs involved in rearing each animal were calculated according to the parameters above. The Italian purchasing prices for these animals are based on the data available from importers, from whom the market prices are given for both captive-bred and wild-caught animals, whenever available. The lists of prices provided by exporters from the countries of origin are also specified. We obtained all prices and information by directly interviewing exporters, importers, and private breeders.

Tab. 1 - Italian prices for maintaining and feeding the animals, broken down by input (2006).
Tab. 1 - Costi in Italia per mantenimento e allevamento (2006).

Input	**Cost (€)**	**Unit**
Electricity kW	0.10	hour
Worker time	9.70	hour
Water	1.12	m^3
Adult crickets	0.08	feeding dose
Small crickets	0.50	feeding dose
Pinhead crickets	0.30	feeding dose
Grasshoppers	0.50	feeding dose
Waxworms	0.08	feeding dose
Mealworms	0.06	feeding dose
Flies	0.20	feeding dose
Buffalo worms	0.13	feeding dose
Spring tails (Collembola)	0.01	feeding dose
Fruit flies	0.17	feeding dose
Ants	0.09	feeding dose
Firebrats	1.30	feeding dose

Results

The reproductive biology data in Table 2 demonstrate that of all the species considered, the only ones that are well suited to intensive captive breeding are: *Mantella aurantiaca*, *Dyscophus guineti*, *Scaphiophryne marmorata*, *Phelsuma* spp., *Uroplatus* spp., and *Furcifer pardalis*. The other species, such as *Calumma parsoni*, *Pyxis arachnoides*, *Furcifer* spp., and *Uroplatus phantasticus/ebenaui*, are presently not suitable, but further studies might prove this situation to be otherwise.

As stated above, some of these species are not good candidates for commercial captive breeding purposes for the following reasons:

1- these species are not presently threatened in nature, and still live in numerous well-distributed wild populations;

2- there is minimal demand for them from the market;

3- some species (e.g., *Calumma parsoni* and *Pyxis arachnoids*) that - beside having a K-oriented breeding strategy (low number of eggs-per clutch) - are affected by a low fertility and/or difficulty to reach a commercial size.

The cost of raising a single animal in captivity is calculated as follows: (TRCS*MMC)/NCIL, where TRCS is the time taken to reach a commercial size (in months), MMC is the monthly management cost, and NCIL is the mean number of commercial individuals in each egg-laying event. MMC is obtained by adding the monthly costs of food, manpower and energy (Tab. 1).

Below, we provide some calculations for the most relevant species.

Tab. 2 - MS/SR = Minimum number of specimens/sex ratio; Clutch = Number of clutches per year laid by one female; Eggs = mean number of eggs per clutch; Hat = Percentage of hatched individuals per clutch; Market = Percentage of specimens that reach market size after hatching.

Tab. 2 - MS/SR = Minimo di esemplari/sex ratio; Clutch = Numero di ovature annuali per femmina; Eggs = numero medio di uova per ovatura; Hat = Percentuale di esemplari che raggiungono la schiusa per ovatura; Market = Percentuale di esemplari che raggiungono la taglia di mercato dopo la schiusa.

Species	**MS / SR**	**Clutch**	**Eggs**	**Hat**	**Market**
Mantella aurantiaca	9/1:3	2-3	80	60%	80%
Dyscophus guineti	15/1:2	1	5,000	30%	50%
Scaphiophryne marmorata	15/1:2	1	1,000	80%	90%
Furcifer pardalis	2/1:1	6	30-50	not available	not available
Calumma parsoni	3/1:2	1	40	not available	not available
Uroplatus lineatus	2/1:1	4	2	93%	100%
Uroplatus phantasticus	2/1:1	3-4	2	not available	not available
Phelsuma madagascariensis	2/1:1	8	2	95%	100%
Phelsuma standingi	2/1:1	8	2	93%	100%
Pyxis arachnoides	4/1:3	3	1	25%	100%

Mantella aurantiaca - The genus *Mantella* was included in Appendix II of CITES on July 19th 2000, but *M. aurantiaca* had already been listed since 1995 (www.cites.org), since this species was already one of the most sought after by herpetological hobbyists. It is now actually forbidden to bring specimens of the genus *Mantella* into the European Community, with the exception of *M. betsileo*, and due to the poor knowledge of its management and ecology there are only a few reproductive groups of *Mantella aurantiaca* left in Europe. The Acquario di Genova started a breeding programme that produced a stable breeding population of 60 individuals that currently creates a surplus which is used for exchanges with other facilities (such as Zürich Zoo) and private owners. The price of exporting the frogs is 5 € per individual (E. J. Edwards, pers. comm.). The price at which they are sold in the USA varies from 25 US dollars ($) (www.gherp.com), to 55 $ (w ww.understoryenterprise.com), for wild-caught individuals, and 70 $ for captive-bred individuals. In Europe there are not many wild-caught individuals available, and captive-bred individuals were sold at a periodically-held terrarium exhibition (Terraristika Hamm) in September 2005 at around 50 € per individual (Tab. 3). The time elapsed from egg-laying to reaching commercial size is approximately nine months. The mean time estimated as being required for daily management is 10 minutes. Feeding occurs twice a day for the first six months and once a day for the following three months. Food items are represented by springtails (*Collembola* species), pinhead crickets (*Gryllus* and *Acheta* species), fruit flies (*Drosophila*), ants (*Linephitema humile*), and firebrats (*Thermobia* sp.). Therefore the estimated cost of a captive-bred and captive-raised individual is: (9*50)/60 = 7.50 €.

Dyscophus guineti - This species is not yet protected by CITES, and its trade is not regulated. This tomato frog is highly sought after by hobbyists due to its large size, easy management, and very appealing colouration. For these reasons, the very similar species *D. antongili* was included in Appendix I of CITES due to the massive collection of it that occurred during the 1980s (Andreone *et al.*, 2005a; Andreone *et al.*, 2006). The Acquario di Genova acquired six individuals of *D. guineti* in 1998 and started a breeding programme, arriving at a population of 100 individuals which breed regularly and which are exchanged with other institutions (such as Bioparco in Rome, Zürich Zoo, and Warsaw Zoo), and private hobbyists. Considering all the information on their breeding activity (Tab. 2), we are convinced that the market demand for this species can easily be met by captive breeding only. The cost of exporting individuals from Madagascar is 10 € per individual (E. J. Edwards, pers. comm.). The price for the public in the USA is 20 $ for adult animals (www.gherp.com); in Italy the price for adult wild-caught animals is 40 €, while captive-bred animals measuring 2.5 - 3.5 cm cost is approximately 20 € (R. Schneider, pers. comm.). The time taken to reach commercial size is related to the temperature at which they are kept: at approximately 24-25°C the time required to reach sufficient size is 12 months. This species usually lays a large number of eggs and a high number of individuals reach metamorphosis. Commercial size is reached after different durations in different groups due to the release of inhibiting hormones by the larvae stages, particularly if they live in a space-limited environment. Feeding should occur once a day for the first month following metamorphosis, and then three to four times a week for the following months. Food items include: fruit flies, ants, buffaloworms (*Alphithobius* sp.), flies, waxworms (*Galleria mellonella*), and mealworms (*Tenebrio molitor*). Thus, the estimated cost for one captive-bred and captive-raised individual is (12*195.2)/750 = 3.12 €.

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Figs 1-6 - The species of amphibians and reptiles from Madagascar for which the captive breeding proved to reproduce economic fallouts. (Le specie di anfibi e rettili del Madagascar per le quali l'allevamento in cattività ha dimostrato di essere economicamente vantaggioso). 1) *Mantella aurantiaca*; 2) *Dyscophus guineti*; 3) *Scaphiophryne marmorata*; 4) *Phelsuma m. grandis;* 5) *Uroplatus lineatus*; 6) *Furcifer pardalis.*

Scaphiophryne marmorata - This species is not yet protected by CITES (although this was suggested by Andreone *et al.*, 2005a), and there is no regulation of its commercial trade. This fossorial frog is mainly nocturnal, and because of this, and the fact that it spends a significant amount of time underground, it is not a very appealing public exhibit in zoos or aquaria, although it is still highly sought after by private terrarium keepers and herpetological amateurs due to its peculiar morphology and colouration. All these considerations can be applied to all species of this genus apart from *S. gottlebei* which is in fact more colourful and more ecologically enigmatic (Andreone *et al.,* 2005a; Andreone *et al.*, 2005b); importation of the latter has been restricted since February 13th 2003 (www.cites.org), when it was included in the Appendix II of CITES. Data concerning the reproductive biology of *S. marmorata* (see Tab. 2) allow us to confirm that it is possible to saturate the market demand with captive-bred individuals. Ecological data concerning the other eight species of the genus *Scaphiophryne* (Vences *et al.*, 2003; Glos *et al.*, 2005) lead us to conclude that the same results could be achieved with captive breeding of those as well. The only exception could be *S. gottlebei,* due to its particular reproductive biology (Mercurio & Andreone, 2006) and the fact that is not currently successfully bred in the captive environment. The cost of exportation of *S. marmorata* is around 4 € (E. J. Edwards, pers. comm.). The market price in the USA is around 30 $ for wild-caught adult individuals (www.eastbayvivarium.com), while in Italy the price for is approximately 20 €, and at the exhibition in Hamm the price reached 25 €. Prices for captive-bred animals are not yet available. *Scaphiophryne marmorata* lays a large number of eggs, and has a very high hatching rate (Tab. 2). The larvae begin to metamorphose after around 17 days and reach commercial size in only two months. Food items include fruit flies, ants, buffaloworms and fruit flies. The estimated cost per captive-bred and captive-raised individual is: (2*195.2)/720 = 0.540 €.

Phelsuma spp. - The diurnal geckoes of the genus *Phelsuma* have been included in Appendix II of CITES since April 2nd, 1977. These geckos are very colourful and attractive to private owners. Most of the species are regularly kept and bred by private hobbyists. All the species have similar reproductive biology (Rundquist, 1994) and the data in Table 2 for *P. standingi* and *P. madagascariensis* are indicative of all the species of this genus. The cost of exporting them is between 20 € and 30 € (E. J. Edwards, pers. comm.). In the Italian market the price for wild-caught adult individuals varies between 69 € and 90 € (R. Schneider, pers. comm.), while captive-bred sub-adult individuals cost between 80 € and 90 € (www.mcserpenti.com). They generally lay two eggs at a time, and the incubation is normally successful (see Tab. 2). The newborn babies reach a commercial size in two months. Food items include fruit flies, crickets, flies, waxworms, and mealworms. The estimated cost per captive-bred and captive-raised individual is: (2*44.5)/2 = 44.50 €.

Uroplatus spp. - The genus *Uroplatus* has recently been included in Appendix II of CITES (January 1st, 2005). This decision was probably made on the basis of the restrictions on other species, as well as the fact that new species have been recently discovered (e.g. Böhle & Schonecker, 2004). These species are not easy to maintain and breeding in captivity is easier with wild-caught animals than with captive-bred ones. Raising the offspring of the small species such as *U. phantasticus* and *U. ebenaui* is still difficult (E. Del Bo, pers. comm.) and they are not good candidates to become commercially viable species. However, these species are among the most in demand by the market. The cost of exporting them varies between 25 €

and 75 € depending on the species (E. J. Edwards, pers. comm.). The price in the Italian market varies according to the species, so that wild-caught *U. phantasticus* is usually sold for between 100 € and 120 € (www.reptilica.de) per individual, and *U. lineatus* from 129 $ (www.reptilica.de) to 150 $ (www.geckosunlimited.com). These species usually lay two eggs at a time, and they both generally hatch successfully (Tab. 2). The commercial size is reached after around eight months. Food items include crickets, flies, waxworms, and mealworms. The estimated cost of a captive-bred and captive-raised animal is (8*15)/2= 60.00 €.

Furcifer pardalis - The entire family Chamaleonidae has been included in CITES Appendix II since 1977. At present, only four species of chameleons can be regularly imported into Europe, and they all belong to the genus *Furcifer* (*F. pardalis, F. verrucosus, F. lateralis*, and *F. oustaleti*). The quantity allowed is 2,000 specimens per species per year (www.cites.org; Andreone *et al.*, 2005c). Currently, the panther chameleon (*F. pardalis*) is the most sought after species by hobbyists, and so 2,000 individuals do not meet the demands of the market (R. Schneider, pers. comm.). The situation with the other species is the opposite: very often these species are included in shipments, obliging importers to buy equal numbers of *F. pardalis* compared to the other species (R. Schneider, pers. comm.). Exportation costs for *F. pardalis* vary from 50 € to 120 € (depending on the location of origin), while the other three *Furcifer* species do not cost more than 35 € (E. J. Edwards, pers. comm.). On the Italian market the price for adult wild-caught individuals varies from 130 € to 350 € (R. Schneider, pers. comm.), while the price for three month old captive-bred individuals is 100-130 € (G. Carimati, pers. comm.). These individuals are very colourful and this feature is typical of a certain location of origin that leads their price to sometimes even reach 600 € per individual (www.reptilica.de). The percentage of captive breeding success with this species is very high, as shown in Table 2 (G. Carimati, pers. comm.). Newborn babies reach a commercial size at three months of age. Food items include fruit flies, grassophers (*Locusta migratoria*), crickets, flies, waxworms, and mealworms. The estimated captive breeding cost per specimen is (3*65)/31 = 6.30 €.

Others species. Other species have been considered, but they still present some difficulties in terms of breeding them and rearing their offspring. The chameleon species of the genus *Calumma* cannot be exported from Madagascar and therefore the number of available specimens among zoos, aquaria, and private breeders, is very small. Captive-bred individuals originate from east Europe, such as Ukraine (R. Schneider, pers. comm.) and Slovenia (G. Carimati, pers. comm.). Captive husbandry of *Calumma parsoni* has achieved good results in terms of longevity but sustainable reproduction is still to be achieved. *Astrochelys radiata* and *Pyxis arachnoides* are the two Malagasy tortoise species that have been sold in large numbers in the previous years but they are both currently included in Appendix I of CITES. Therefore, their values have increased enormously and TRAFFIC (a joint programme of the World Wildlife Fund - WWF - and the International Conservation Union - the IUCN) - which monitors the illegal trade in wild life reports prices of 5,000 € for illegal *Astrochelys* specimens, while officially imported individuals cost between 4,000 $ and 5,000 $ (www.abbottsturtlefarm.com). Captive born individuals that are one to two years old cost approximately 1,500 € (www.reptilica.de). *Pyxis arachnoides* is smaller and reaches lower prices, such as 350 € for captive-bred young (www.faunaclassified.com), and 1,000 - 1,200 € for adults (www.reptilica.de). Breeding of both species is currently well established but

research still needs to be conducted in order to increase the percentage of successful hatching (Tab. 2). Other species such as those belonging to the genera *Paroedura*, *Zonosaurus*, *Oplurus*, *Chalarodon*, *Heterixalus*, and *Boophis*, experience low demand, and their natural populations are also quite abundant (Andreone *et al.*, 2005a). This low current demaned does not create a clear need therefore to establish captive breeding programmes for these species.

Discussion

The reproductive data presented in this study for these Malagasy amphibians and reptiles demonstrate that some of these species can easily meet the market demands of private herpetologists through captive breeding and, as a consequence, decrease the pressure on wild stocks. In this respect, successful breeding programmes have already been performed with other, similarly colourful species, such as *Dendrobates* spp., *Phyllobates* spp. and *Epipedobates* spp.. With regard to these species, in fact, it is currently impossible to find wild-caught animals (F. Zanella, pers. comm.). Prices are quite high and vary from 10 € for *Epipedobates tricolor* to 150 € for *Dendrobates mysteriosus* (F. Zanella, pers. comm.) creating financial income for private breeders, whereas some institutions such as the National Aquarium in Baltimore invest in breeding these species for conservation purposes (www.yale.edu).
The large number of private breeders and their years of experience, their dedication and their publications on the husbandry and reproductive strategies of these species has proven to be essential as a conservation resource. In fact, R. Schulte has planned and built a breeding centre in Peru that sustains 250 families of campesinos by selling captive-bred animals (www.gefweb.org/Documents/Medium-Sized_Project_Proposals/MSP_Proposals).
Other examples of commercial captive breeding programmes concern species that have been very common in the market for many years. In the US significant success is achieved with *Eublepharis macularius* (55,000 individuals captive-bred per year), *Hemitheconyx caudicinctus* (3,000 individuals captive-bred per year), *Elaphe guttata* (12,500 individuals captive-bred per year) and *Lampropeltis getula* (5,000 individuals captive-bred per year) (Brant, 2001). At present none of the Malagasy species are bred in such high numbers, but the information provided in Table 1 suggests that for some species, especially the amphibians, these results can be easily achieved. For example, each female of microhylid species (such as *Dyscophus* and *Scaphiophryne* spp.) lays thousands of eggs and if hatching success is high this allow the price for a single specimen to be kept low, thereby competing successfully with the price set by exporters of wild-caught animals (Tab. 3).
The genus *Mantella* usually lays around 40 eggs or more per clutch, except for *M. laevigata*, which lays a lower number (Glaw & Vences, 1994; Glaw *et al.*, 2000; Staniszewski, 2001; F. Andreone, pers. obs.). The breeding costs for this genus are indeed higher than for the other species, but the difficulty in obtaining wild animals and the high demand increases the cost that hobbyists are prepared to pay per individual. Comparing these species with *Dendrobates* shows very simply, that there are many similarities between them in terms of size, colouration, physiology, morphology, habitat and life history. It seems therefore a valid hypothesis that it would be feasible to start up a farm in Madagascar for captive breeding of this genus with the same objectives of the Peruvian project for *Dendrobates*.

Tab. 3 - Price per specimen (€). n.a. = not available.
Tab. 3 - Prezzi in € per esemplare. n.a. = non disponibile.

Species	Cost of exporting	Purchase price for importer	Wild-caught market price	Breeding cost	Market demand
Amphibians					
Mantella aurantiaca	5	25	40-60	7.5	High
Dyscophus guineti	10	20-40	59-80	3.12	Medium-low
Scaphiophryne marmorata	4	15-20	25-30	0.54	Medium-low
Reptiles					
Furcifer pardalis	50-120	150-350	350-600	6.3	High
Calumma parsoni	n. a.	n. a.	900-1,200	n. a.	High
Uroplatus lineatus	35	n. a.	129	60	Medium
Phelsuma madagascariensis	20	69	80-90	44.5	Medium-high
Pyxis arachnoides	n. a.	n. a.	1,000-1,200	n. a.	High
Astrochelys radiata	n. a.	n. a.	3,360-4,205	n. a.	High

With the exception of still of *Mantella levigata*, for all other species of the genus *Mantella*, we can state and agree with Staniszewski (2001) that it is possible to raise the larvae and the juvenile frogs in large numbers, together, while *Dendrobates* spp. need to be raised individually (Schimidt & Henkel, 2004). This difference in requirements of the genus *Mantella* would allow reduction in the management difficulties and savings in terms of costs compared to the case of the *Dendrobates*. There is therefore a clear critical need to study more closely different captive breeding techniques for the genus *Mantella* that can be exported to Madagascar to provide the fundamental knowledge required to start up such a programme successfully or to support the existing ranching.
Switching attention from amphibians to reptiles, only *Furcifer pardalis* seems to produce high numbers of eggs and hatchlings per year. Females in nature reach reproductive age at six months and live for 1-2 years (Andreone *et al.,* 2005d). Their reproductive strategy therefore relies for its success on a large number of egg-clutches, as confirmed by the information available from studies in captivity (G. Carimati, pers. comm.). Schmidt *et al.* (1994) observed that the female is ready to mate 10 days after laying eggs and that the survival rate of young is higher in captivity. These factors, taken together with the low costs required for breeding, and the high market demand (Tab. 3) make this species an ideal candidate for this type of conservation activity.

The gecko species belonging to the genera *Phelsuma* and *Uroplatus* still require significant further research work to obtain good results in captivity. It would therefore be necessary to have a larger number of founder individuals in the captive population to understand if it is possible to achieve a good number of captive-bred individuals that overcomes the problem of low number of eggs per clutch and so generate specimens that are economically more competitive than the wild-caught ones (Tab. 3). The situation of the two terrestrial tortoise species (*Astrochelys radiata* and *Pyxis arachnoides*) is slightly different, since their exportation is totally banned and therefore the value and value of captive-bred individuals is very high. Human consumption (Leuteriz, 2005) is one of the threats for these two endangered species, but the level of protection *in situ* is so high that not only there is no need to re-introduce captive-bred individuals in order to protect against this threat, there is also no need to substitute captive-bred individuals for wild-caught individuals since there should not be any wild-caught individuals available in the pet-trade as a result of the effective controls on their commercial trade. Table 2 shows that the reproductive success of both species is quite low due to low reproductive fitness and the minimal available knowledge concerning egg incubation needs. These conditions lead to inflation of the prices per individual and money generated from sales of captive-bred individuals of these species could be used to finance programmes to educate local people to conserve tortoises and turtles.

International organizations, such as EAZA and WAZA, have already initiated a communication network between various institutions, zoos and aquaria, to avoid collection of wild animals from nature, and could in future organize a programme of controlled and selective breeding to introduce captive-bred animals into the market. The results in terms of conservation programmes could be many: (i) reduce collection of wild animals; (ii) finance research programmes to study endangered species; (iii) support programs of education of local peole; (iv) clearly establish successful captive breeding techniques and study reproductive biology under artificial conditions allowing easier access to and dissemnation of the research findings; (v) develop and implement *in situ* breeding programmes that can provide sustainable livelihoods for local people using these species as a renewable non-timber forest product; (vi) combat illegal wildlife trade.

Finally, concerning Malagasy species in general, much remains to be discussed about the pressing need to establish captive breeding facilities and programmes for selected taxa. Indeed, although the presence of chytridiomycosis has not yet been proven on Madagascar, the threat of massive extinctions from this disease warrants action to protect against this risk through captive breeding programmes, according to the Amphibian Conservation Action Plan (ACAP) recently debated at a meeting held in Washington D.C. (September 2005). Notwithstanding this point, it is clear that a general database of captive breeding attempts and successes for Malagasy amphibians and reptiles will be a good step in increasing awareness of this need. Some species are particularly suited to captive breeding, but for others the methods of rearing them in captivity are largely unknown. Concerning amphibians specifically, we agree strongly that some species are very easily bred (as stressed previously in this paper), and, just by way of an example, the tomato frogs (*Dyscophus antongili* and *D. guineti*) are easily bred and their captive breeding may also have commercial value and implications. It is even entirely plausible that *D. antongili*, currently included in CITES Appendix I, could easily become a widespread species in captivity. On the other hand, given its narrow distributional range and highly

degraded habitat (Andreone & Randrianirina 2003; Andreone *et al.*, 2005a), the harlequin mantella (*Mantella cowani*) should become soon the object of a specific, fully financed captive breeding project, with the aim of creating captive stocks of the main existing populations (Andreone *et al.*, 2006). Unfortunately, no report has been published so far describing significant success in rearing this high altitude species in captivity, and we suspect that this is mainly due to the extreme environmental requirements of this species, such as significant thermal differences between day and night, and the humidity conditions that it requires. Another critically endangered species that is yet to be assessed for its captive breeding potential is the rainbow frog, *Scaphiophryne gottlebei*. Although this species still appears to be widely distributed within the Isalo Massif, and is likely to be locally abundant, it has been exported in massive numbers in recent years (Andreone *et al.*, 2006), and has not yet been bred in captivity. This is the reason why the exportation of this microhylid is not yet balanced by captive breeding successes, but given that the genus *Scaphiophryne* appears to be successfully reared in captivity, we are confident that the rainbow frog could also be successfully bred and reared in captivity. In this case too, as with the other species, a captive breeding project led by major institutions could be one of the strategies for its conservation.
All these attempts are extremely important for progressively reducing the trade in wild-caught animals, for increasing education and awareness about the Malagasy environment and its fauna and, for transferring knowledge to Malagasy scientists and institutions, and for providing eco-friendly livelihoods supporting the local economies in Madagascar. We conclude that approaches like this will be likely to further reduce the trade in endangered species worldwide.

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References

Andreone F., Cadle J. E., Glaw F., Nussbaum R. A., Raxworthy C. J., Vallan D. & Vences M., 2005a - Species review of amphibian extintion risks in Madagascar: conclusion from the Global Amphibian Assessment. *Conservation Biology*, 19 (6): 1790-1802.

Andreone F., Guarino F. M. & Randrianirina J. E., 2005d - 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., Mattioli F. & Mercurio V., 2005b - The call of *Scaphiopryne gottlebei*, a microhylid frog from the Isalo Massif. South-central Madagascar. *Current Herpetology*, 24 (1): 33-35.

Andreone F., Mercurio V., Mattioli F. & Razafindrabe T. J., 2005c - Good news for three critically endangered and traded frogs from Madagascar. *Froglog*, 72: 2.

Andreone F., Mercurio V. & Mattioli F., 2006 - Between environmental degradation and international pet-trade: conservation strategies for the threatened amphibians of Madagascar. *Natura*, 95 (2): 81-96.

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).

Böhle A. & Schönecker P., 2004 - Eine neue Art der Gattung *Uroplatus* Duméril, 1805 aus Ost-Madagaskar (Reptilia: Squamata: Gekkonidae). *Salamandra,* 39 (3/4): 129-138.

Brant E. W., 2001 - Commercial production of reptiles for the US pet trade. IUCN SSC Commercial captive propagation and wild species conservation. December 7-9, 2001. *White Oak Foundation Jacksonville*, Florida, USA.

Carpenter A. J., Rowcliffe J. M. & Watkinson A. R., 2004 - The dynamics of the global trade in chameleons. *Biological Conservation*, 120: 291-301.

Glaw F., Schmidt K. & Vences M., 2000 - Nachzucht, Juvenilfärbung und Oophagie von *Mantella laevigata* im Vergleich zu anderen Arten der Gattung (Amphibia: Ranidae). *Salamandra*, 36: 1-24.

Glaw F. & Vences M., 1994 - A Fieldguide to the Amphibians and Reptiles of Madagascar, 2nd ed. *Vences and Glaw*, Cologne.

Glos J., Glaw F. & Vences M., 2005 - A new species of *Scaphiophryne* from Western Madagascar. *Copeia*, 2: 252-261.

Graf R., 2005 - La foret pluviale de Masoala au Zoo de Zürich . *Zoo Zürich*.

Green G. M. & Sussman R., 1990 - Deforestation history of the eastern rainforests of Madagascar from satellite images. *Science*, 248: 212-215.

JNCC, 1993 - A preliminary review of the status and distribution of reptile and amphibian species exported from Madagascar. *Joint Nature Conservation Committee Report*, Peterborough.

Leuteriz T. E. J., 2002 - Distribution, status and reproductive biology of the radiate tortoises *Geochelone radiata* (Shaw, 1802) in South West Madagascar. Degree in master of sciences. *University of Michigan*.

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.

Myers N., Mittermeier R. A., Mittermeier C. G., da Fonseca G. A. B. & Kent J., 2000 - Biodiversity hotspots for conservation priorities. *Nature*, 403: 853-858.

Rabemanajara F. C. E., Raminosoa N. R., Ramilijaona O. R., Andreone F., Bora P., Carpenter A. I., Glaw F., Razafindrabe T., Vallan D., Vieites D. & 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.*

Rundquist E. M., 1994 - Day geckos. *T. F. H. publications Inc.,* Neptune City, N. J.

Schmidt W. & Henkel F. W., 2004 - Professional breeders series: Poison frog. *Edition Chimaira*, Frankfurt am Main.
Schmidt W., Tamm K. & Wallikewitz E., 1994 - Chameleons. Volume II. Care & breeding. *T. F. H. publications Inc*., Neptune City, N. J.
Staniszewski M., 2001 - Mantellas. *Edition Chimaira*, Frankfurt am Main.
Vences M., Raxworty C. J., Nussbaum R. A. & Glaw F., 2003 - A revision of the *Scaphiophryne marmorata* complex of marbled toads from Madagascar, including the description of a new species. *Herpetol. J*., 13: 69-79.

Referenced web pages (as accessed on 28 February 2006)

CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora - www.cites.org
Glades Herp Inc. (America's largest and best selection of fine reptiles, amphibians and invertebrates to the collectors, breeders, zoos and educators of the world) - www.gherp.com
Understoryenterprise www.understoryenterprise.com
East Bay Vivarium - www.eastbayvivarium.com
Mc Serpenti, allevamento specializzato - www.mcserpenti.com
Reptilica - www.reptilica.de
www.geckosunlimited.com
Abbott's Turtle Farm – www.abbottsturtlefarm.com
Faunaclassified www.faunaclassified.com