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The European Captive Population of Crowned Sifaka: 25 Years of Management

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Abstract: A European Endangered Species Program (EEP) was set up for the crowned sifaka (*Propithecus coronatus*) in 2007, and the European captive population was identified as a conservation priority for the species during the first technical meeting on its conservation in 2011. In this article I trace the history of the European population over 25 years of management, and report on the main problems encountered during this time: the lack of females, high mortality rates of infants, and the management, of surplus males. I also present general information on the demography and genetics of the captive population, as well the principle findings of studies on the biology of the species in captivity, including, particularly, observations on reproduction: number and duration of estrus, inter-estrus interval, detection of estrus by the change in behavior of both sexes, data on fertility by age in both sexes, age at first estrus and first birth, gestation length, body weight at birth, and interbirth interval. Records of the breeding success of each female and for each pair are summarized: number of offspring, infant mortality rate, age at first birth, specific management of each female/pair, and interbirth interval. I discuss the contribution of the European holders, including the Parc Zoologique de Paris, to the conservation of the crowned sifaka through their strong involvement in *in situ* projects, among them a metapopulation project recently initiated by the EEP. In this project, the European captive population is included in a global management plan for the species, in particular to contribute to the management of the smallest wild populations living in isolated fragments of forest. The educational activities developed by the European holders and then by the EEP increase awareness and knowledge of the species and facilitate fundraising for the *in situ* projects supported.

Key words: Crowned sifaka, captive breeding program, captivity, research in captivity, *in situ* conservation, education

Introduction

The crowned sifaka, *Propithecus coronatus*, is endemic to Madagascar and classified as Endangered on the IUCN Red List of Threatened Species (IUCN 2012; Salmona *et al.* 2014). The European captive population of crowned sifaka was founded in the late 1980s by the Parc Zoologique de Paris. During the following 25 years very few zoos managed to successfully maintain and breed this species in captivity: only four European zoos achieved successful births. Outside of Europe, the species is kept in only one zoo in Madagascar, where it has never bred (single-sex group).

All crowned sifakas in Europe are part of a European Endangered Species Programme (EEP), a breeding program initiated and coordinated by the Parc Zoologique de Paris. The observations that were made over 25 years, especially at the Parc Zoologique de Paris — the institution with the most experience in the husbandry of crowned sifakas — have improved our knowledge of the species and its management in captivity. Additionally, some zoos that hold the species are involved in *in situ* conservation projects, partly through the initiative of the EEP. For example, a metapopulation conservation project was initiated by European zoos during an EEP meeting in 2007. The project was subsequently approved at the first technical meeting for the conservation of the crowned sifaka, with the captive population in Europe being identified as an important element (MEF/GERP/TAF 2011). This article presents information on 25 years of management and research of the European captive population, and on the activities of the breeding program and its participants for the conservation of the crowned sifaka.

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History of the Captive Population

The first crowned sifakas were imported to Paris from Madagascar in 1987—one male and three females. Only one female survived from this first group. A second group arrived in 1993, consisting of two females and two males. These five individuals were the founders of today's captive population, of which two were still alive in 2012. These animals and their descendants were entrusted to the Parc Zoologique de Paris by the Malagasy Government under an "accord de collaboration et d'assistance" signed in 1993 to found a captive breeding program. This agreement aimed to: a) establish a captive population for potential reinforcement projects for the wild population; and b) develop research activities in order to contribute to our knowledge of the species.

In 2007, the Parc Zoologique de Paris proposed that it would establish and coordinate a European Endangered species Program (EEP) for the crowned sifaka. EEPs were created in the mid 1980s to develop sustainable captive populations of the most endangered species (Nogge 2003). They are managed by the European Association of Zoos and Aquaria (EAZA); an association created in 1988 that currently has 322 members in 36 countries. The EEPs are managed by appointed coordinators from EAZA institutions. They are assisted by a Species Committee, usually composed of representatives of the holding institutions as well as advisors (on conservation or veterinary medicine, for example). The EEP coordinator ensures that the population fulfils the roles (for example, conservation, research, education) and reaches the targets (for example, population size and genetic diversity) identified in the Regional Collection Plan (RCP). The RCP is established by the respective EAZA Taxon Advisory Group (TAG). The objectives of the crowned sifaka EEP are established by the Prosimian TAG.

Studbook Management and Analysis

Records of every individual sifaka currently or historically included in the EEP population are held and regularly updated using the studbook management database software SPARKS v1.6 (Single Population Analysis & Records Keeping System, developed by ISIS; Scobie 1997). Data from SPARKS are exported to the studbook analysis software PMx (Lacy *et al.* 2012) for calculation and analysis of demographic, kinship, and inbreeding measures. Results presented in this paper are based on studbook data updated to mid 2011, complemented by qualitative observations of the captive animals.

Size and Composition of the European Captive Population

The size of the European captive population of crowned sifaka has evolved from 1987 to 2011 (Fig. 1). Of four sifakas imported in 1987, only one was still alive in 1992. In 1993 another four sifakas were imported. The population subsequently increased from 1994 to 2005, but has been decreasing overall since 2005; especially the number of females has fallen dramatically (Fig. 1). As of mid 2011, the European studbook has registered a total of 53 animals (30 males, 20 females, and three aborted fetuses) since the start of the program. Seventeen of these (13 males, 4 females) were still alive in 2011, and were held in six institutions (Roullet 2011). There are currently three mixed-sex groups, two of which are breeding groups, whilst the third is composed of two young animals that should become mature before the next breeding season.

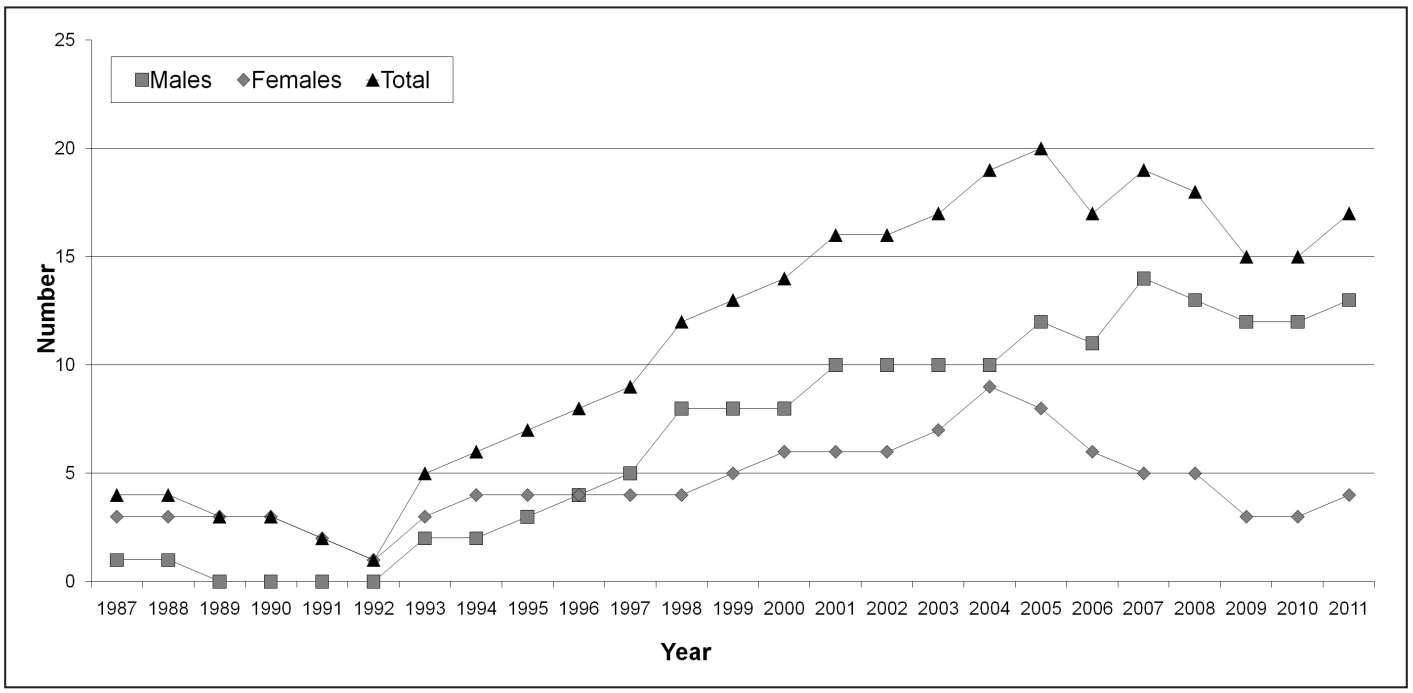


Figure 1. Evolution of the European captive population of crowned sifaka (*Propithecus coronatus*) from 1987 to 2011.

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Current retained gene diversity (as a percentage of the genetic diversity present in the wild-caught founder population, excluding the wild-caught individuals that did not reproduce) is 84.4%, which is lower than the target of 90% but still fairly high considering the low number of founders. Inbreeding coefficients are all zero, but population mean kinship (a measure of the average degree of relatedness between individuals) is 0.145 (Table 1), a rather high value due to the low number of founders.

The founder representation (i.e., the contribution of each founder to the current living population) varies in the five founders (Fig. 2). This is due to the unequal contributions of the founders and their offspring. The situation is improving, however, with two of the three least-represented founders (founders 7 and 8) still able to breed.

Table 1. Inbreeding coefficients (F) and Mean kinship values (MK) of the living captive crowned sifakas (*Propithecus coronatus*). Animals with a lower mean kinship values have relatively fewer genes in common with the rest of the population, and are therefore more genetically valuable in a breeding program.

Studbook number	Sex	Age	F (Inbreeding coefficient)	MK (Mean kinship)
7	M	25*	0	0.092
8	F	22*	0	0.050
13	M	15	0	0.175
14	M	14	0	0.175
16	M	13	0	0.175
17	M	12	0	0.083
18	F	12	0	0.200
23	M	11	0	0.154
24	M	10	0	0.183
36	M	5	0	0.129
37	M	5	0	0.162
38	M	5	0	0.154
43	M	3	0	0.162
44	F	3	0	0.154
45	M	3	0	0.129
50	M	1	0	0.162
51	F	1	0	0.133

*Estimated age, as they are wild-born.

Age-specific Survival and Fertility

Annual mortality rates by age-class (Table 2) show high infant mortality, no recorded male mortality from age 4 to 11 or female mortality from age 6 to 13, and increasing adult mortality thereafter. The EEP data show that females can live to at least 20 years, and males to at least 25 years. However, the deaths of several adults have been related to transfers. Captive male Coquerel's sifakas (*Propithecus coquereli*) can live to thirty years, but females die younger (Weigl 2005; Duke Lemur Center, pers. comm.).

Age-specific fertility rates show an onset of fertility at age 3 (Table 2), although high mortality rates mean that only 54% of males and 36.4% of females survive to the age of first reproduction (Table 2). Fertility increases at age 4 for the males and 6 for the females (Table 2).

Reproduction

The first birth in the crowned sifaka EEP population took place in 1994. There have now been 27 males and 15 females born, plus three aborted pregnancies, a ratio of 1.8 males for each female newborn. Of the 42 infants born alive, seventeen (40.5%) died a few days after birth, illustrating that the first three days following birth are critical to infant survival prospects. Offspring survival rate to three days after birth is variable between females, with one of the population founders ("Daya") being the most successful at 80%, whilst others have only 50% success (Table 3).

As in the wild (Richard 1974, for *P. verreauxi*), there is a pronounced breeding season in captivity. Births occurred from November to April, most (68%) of them in December

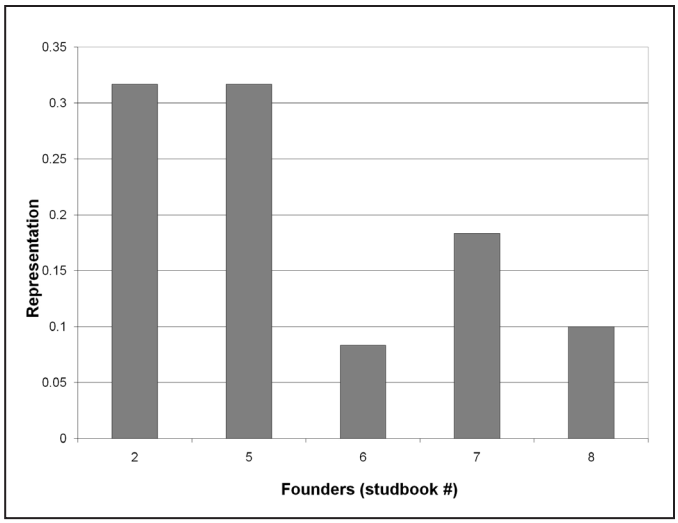


Figure 2. Founder representation in the European captive population of crowned sifaka (*Propithecus coronatus*) 2011.

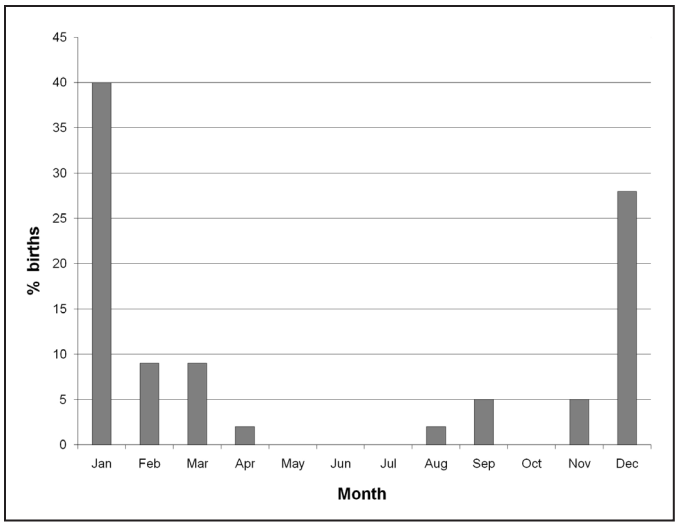


Figure 3. Birth seasonality in the European captive population of crowned sifaka (*Propithecus coronatus*) 1987 to 2011.

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and January (Fig. 3). An exception to this were three births in August and September, all to the same female and in each case following the death of a previous baby in January or February; it is important to note that this was always the same female. The shortest interbirth interval was 219 days (7.2 months, following death of a baby), but most were approximately 12 months (range 9 to 14 months), and one female twice went two years without breeding (Table 3). In the wild, females usually have one baby every two years (Pochron *et al.* 2005 for Milne-Edwards' sifaka *Propithecus edwardsi*; J. Razafindramanana, pers. comm. and C. Pichon, pers. comm. for crowned sifaka). A shorter interbirth interval following the death of an infant has been observed in the wild for Milne-Edwards' sifaka (Pochron *et al.* 2005).

The age of the youngest captive-born male at the birth of his first offspring was 3 years, 7 months, and 4 days. The youngest female to have her first baby was 3 years, 2 months, 22 days. The age of the oldest female to have given birth is over 20 years; wild-born, her exact age is unknown. On the two occasions we could be sure of the dates of conception, gestation length was 169 and 170 days. Mating between sifakas (Fig. 4) is very rarely observed. Estrus is more readily observed, as the animals' behavior changes. They become more active; in particular, a lot of marking can be observed, with the male systematically covering the marks of the female (Fig. 5). Additionally, the male follows the female when she moves, and she becomes more aggressive with him. Estrus is usually observed from May to August, with most occurring in July. Observations of estrus in February occurred 20 days after a female lost her baby (death of the baby or removal to be hand-raised). Only one female had a baby after such a postpartum estrus. There are usually three to five estruses per

Table 2. Annual mortality rates, cumulative survivorship (Lx) and fertility (Mx) of captive crowned sifakas (*Propithecus coronatus*) by age and by sex.

	Males	Females	Males	Females	Males	Females
Age	Mortality	Mortality	Lx	Lx	Mx	Mx
0	0.38	0.49	1	1	0	0
1	0.13	0.14	0.62	0.51	0	0
2	0	0.17	0.54	0.44	0	0
3	0.07	0	0.54	0.36	0.04	0.09
4	0	0.15	0.50	0.36	0.22	0.17
5	0	0.2	0.50	0.31	0.06	0.12
6	0	0	0.50	0.25	0.2	0.3
7	0	0	0.50	0.25	0.15	0.1
8	0	0	0.50	0.25	0.25	0.4
9	0	0	0.50	0.25	0.25	0.39
10	0	0	0.50	0.25	0.16	0.42
11	0.11	0	0.50	0.25	0.23	0.34
12	0.14	0	0.45	0.25	0.24	0.3
13	0.21	0.2	0.38	0.25	0.12	0.22
14	0	0.24	0.30	0.20	0	0.43
15	0	0	0.30	0.15	0	0.25
16	0.5	0	0.30	0.15	0.38	0.25
17	0	0	0.15	0.15	0.5	0.25
18	0	0	0.15	0.15	0.5	0.25
19	0	0.25	0.15	0.15	0.5	0.14
20	0	0	0.15	0.11	0.5	0.17
21	0	0.37	0.15	0.11	0.5	0
22	0	1	0.15	0.07	0.5	0
23	0	1	0.15	0	0.5	0
24	0	1	0.15	0	0	0
25	1	1	0.15	0	0	0
26	1	1	0	0	0	0

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Table 3. Breeding success rates of captive crowned sifaka females (including information on breeding pairs).

Pairs: **Female** **Male** **(studbook no.)**	**N. of offspring**	**No. of offspring still alive after 3 days**	**No. of offspring still alive today**	**Management of the group**	**Age of female at the time of the first birth**	**Rearing of the first baby**	**Age of the female at the time of the introduction to a male**	**Interval between the introduction to a male and the first birth**	**Interbirth Interval**
Daya (2) **Solofo (5)** Pair established in May 1994	10 (5.4.1) Breeding from 1994 to 2001 (no successful breeding from 2002)	8 (1 stillborn,+1 abortion) Mortality =20%	5 Mortality = 37.5	No specific management Max size group = 8	? (wild-born female)	Yes	? (wild-born female)	8 months	1year (very regular) 2 offspring born during the same year (January–December)
Hadja (6) **Andry (7)** Pair established in April 1995	4 (4.0) Breeding from 1995 to 1998–(last breeding of the female in 1998)	3 (1 stillborn) Mortality = 25%	1 Mortality = 66.6%	Andry isolated from the mother and her young during 2 months from the day of birth; used to kidnap baby	? (wild-born female)	No (stillborn)	? (wild-born female)	9 months	11 to 14 months
Linoa (18) **Andry (7)** Pair established in 2002	8 (7.1)	5 (2 stillborn) Mortality = 37.5%	3 (Mortality = 62.5 %) Current group composition : 4.1		4 years	Yes	2.5 years	1 year 9 months	9 to 13 months
Vick (9) **Ulrick (12)** Pair established in June 1999	10 (6.4) Breeding from 1995 to 2008 (death of the female)	5 (1 hand-reared animal) Mortality = 50%	3 Mortality= 70%	The females are very nervous at the time of birth and have to be isolated/ become less nervous with age	6 years and 2 months	No	4 years and 7 months.	1 year 7months	7–7.5 months if the baby does not survive 10 to 12 months
Cixi (30) **Tao (17)** Pair established in June 2006	2 (1.1) Breeding from 1995 to 2008 (death of the female)	1 Mortality = 50%	0 Mortality=100%		~3 years	No	2.5 years	9 months	10 months
Holly (8) **Locky (10)** air established in May 1998	10 (4.4.2) Breeding from 1995 to 2009 (death of the male)	5 (hand-reared animals) (2 abortions)	2	All the young hand-reared. Female has abnormal nipples	? (Wild-born female)	No (Abnormal nipples)	? (Wild-born female)	1 year 9 months	1 year (except 2 years without breeding and if we don't consider the 2 abortions 6 and 7 months after the death of a baby)
Holly (8) **Minos (24)** Pair established in September 2009	1 (0.1)	1 (hand-reared animals)	1 Current group composition : 2.2					1 year 4 months	

reproductive season. Often the females are not very regular, with estruses separated by approximately one month, and lasting about ten days.

Body weights of adults in the captive crowned sifaka population range from 3.5 to 4.5 kg for males, and from 3.5 to 5.0 kg for females. Infant body weight at birth ranges from 67 to 116 g for males (mean 92.6 g) and from 70 to 105 g for females (mean 91.3 g).



Figure 4. Mating of a pair of captive crowned sifaka (*Propithecus coronatus*). Photograph by F.-G. Grandin, MNHN.

Diet

In the wild, the crowned sifaka diet consists mainly of leaves, but fruits, flowers, vegetative buds and sometimes young stems are also eaten (Pichon *et al.* 2010). In the European captive population leaves are also an important part of the diet of the animals, mostly of false acacia *Robinia pseudoacacia*. They are given a mixture of vegetables, Mazuri® Leaf-eater Primate Diet pellets (www.mazuri.eu), some fruits and an in-house mix made with cereal, powdered milk and water.

Social Organization

In the wild the crowned sifaka lives in groups of two to eight individuals (King *et al.* 2012; Pichon 2012; Rakotonirina *et al.* 2014), usually with only one breeding female (Pichon 2012; Rakotonirina *et al.* 2014; pers. obs.). In the European captive population, all the groups are composed of one breeding male and one breeding female and their offspring. When the first animals arrived, several attempts were made to keep more than one breeding male or breeding female in a group, but without success. They are very territorial, and adult animals of the same sex are very aggressive towards each other. The largest group size in captivity that we know of is eight. The females are dominant, coming to the food first and having priority of access. Some females are very aggressive towards males.

It is necessary to remove young females from their group at sexual maturity; at about 2.5 years old when they develop their first estrus. This is due to tension with the mother at this time. The change in behavior of the young females is obvious—they are more isolated from the rest of the group, give the impression of being unhappy, and are more distant with the keepers.



Figure 5. Scent-marking by a captive male crowned sifaka (*Propithecus coronatus*). Photograph by F.-G. Grandin, MNHN.



Figure 6. Part of the hand-rearing protocol for crowned sifaka (*Propithecus coronatus*) set up at Paris. Photograph by F.-G. Grandin, MNHN.

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Figure 7. The Amboloando forest fragment, Dabolava, Madagascar. Photograph by F.-G. Grandin, MNHN.

Adult males seem to be more tolerant of their sons than the females are of their daughters. Indeed, the tension we observed between fathers and sons did not appear until the sons were about five years old. This tension appeared at the time of estrus, as in females. Only one young male was actively rejected by his father, at five years old. We did not observe fighting between him and his father, but one day the young male seemed very scared of his father. We heard a lot of "sifak" calls coming from him, and had to quickly remove him from the group.

Management of the European Captive Population

The size of the European captive population of crowned sifaka has been declining since 2005, especially in the number of females (Fig. 1), resulting in the youngest proven breeding female in the current population being an elderly 11 years old. Three major factors can explain this recent decline: 1) the death from old age of the best breeding female in the population in 2005, one of the original wild-born founders; 2) an increase in transfers between institutions, especially in 2008 with the closing of the Parc Zoologique de Paris for renovation, that led to an increase in deaths due to digestive problems and infectious diseases; and 3) the difficulty of other members of the program to breed this species successfully and even sometimes to keep it, illustrated by a high mortality of newborns and even of adults, especially females.

To counter this third factor, newborns are now closely monitored, comparable to what is done at the Duke University Primate Center in the USA for Coquerel's sifaka (Haring 2009), and following a unique hand-rearing protocol set up at Paris in 2005. In this protocol the females are trained to allow the keepers to take their baby from them to conduct regular check-ups (Fig. 6). This protocol, which was first initiated for a wild-born female showing abnormal nipples that prevented her from feeding her babies, allowed for the hand-raising of several of her babies whilst keeping the mother and baby in contact.

The main issue in the management of this captive population is the lack of females. The sex ratio is clearly biased towards males: about three males for each female. The management of surplus males is problematic due to the instability of single-sex groups comprising adult males. Two adult males are successfully kept together with the help of Deslorelin implants, which inhibit testosterone production (previously used with male Coquerel's sifaka; D. Haring, pers. comm.). However, while the implants probably reduced the aggressiveness of the animals at the time of the contact, it is the age difference between them that was probably the most important factor in the success of this group. Even with the implants, it was impossible to add a third male of the same age as the older one to this group. Consequently, several males are currently kept without conspecifics but share enclosures with other lemur species, often bamboo lemurs *Hapalemur* spp. and ring-tailed lemurs *Lemur catta*.

Conservation activities

Since 1998, several members of the EEP are actively involved in *in situ* conservation projects. The "Projet pilote bioculturel d'Antrema" concerns one of the largest populations of crowned sifaka in Madagascar. This project was initiated by the Parc Zoologique de Paris (Muséum national d'histoire naturelle) in 1998, and led, in 2000, to the creation of the "Station forestière à usage multiple d'Antrema". The first observations of crowned sifakas in mangroves were made in Antrema in the early days of the project (Gauthier *et al.* 1999). From 2008, another EEP member, Mulhouse Zoo, initiated a survey of crowned sifaka populations living in very degraded forests near Mahajanga (Boanamary), in collaboration with national partners Fanamby and Mahajanga University (P. Moisson and B. Lefaux, pers. comm.).

Since 2009, several EEP members support the "Dabolava project," which concerns the conservation of a group of seven crowned sifakas living in a fragment of forest at Dabolava, near Miandrivazo (Fig. 7; Razafindramanana and Rasamimanana 2010). The isolation of this site, and the discovery of additional small populations by the "Tsibahaka project" initiated and coordinated by The Aspinall Foundation (TAF 2009; King *et al.* 2012; Rakotonirina *et al.* 2014), led to the creation of a more global project of *ex situ* and *in situ* metapopulation management. Five members of the EEP (Cotswold Wildlife Park, Muséum de Besançon, Belfast Zoo, Parc Zoologique de Paris, and Port Lympne Wildlife Park through The Aspinall Foundation) and the SECAS (a French association close to Paris Zoo) are actively involved in this project. The *Association Européenne pour l'Etude et la Conservation des Lémuriens* (AEECL) opened a special account for the conservation of the crowned sifaka, which enabled the participation of public zoos in this project. The project "Conservation of the Crowned Sifaka," coordinated by Josia Razafindramanana, was awarded 17,801 Euros by the EAZA Madagascar Campaign fund in 2011.

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The first technical meeting for the conservation of the crowned sifaka was primarily funded by EAZA. During this meeting, the captive population, which is an important part of the metapopulation conservation project, especially in the management of the most isolated groups living in very small fragments of forest, was identified as one of the priorities for the conservation of the crowned sifaka (MEF/GERP/TAF 2011). As part of the crowned sifaka metapopulation project, once the most isolated groups without a chance to survive in the wild have been identified, some of them should be included in the captive population. Initially these animals would stay in Madagascar in order to implement a captive breeding program *in situ*. Lemurs Park, the only zoo in Madagascar that has, for many years, successfully maintained this species in captivity, has been identified as the most appropriate place to establish this Malagasy captive population. This captive population will be managed by the EEP, with Lemurs Park becoming a member. The objective is to set up an international management regime of the captive population, and exchange animals between Europe and Madagascar to increase the global genetic diversity of the captive population. This should lead to the development of a sustainable captive population able to reinforce, in the future, wild populations if necessary, especially those that are isolated. The experience of the EEP will also help to arrange translocations of crowned sifakas between forest fragments that are included in the metapopulation conservation project. These animals will be individually identified and added to the European studbook that will evolve to a global data base for the project.

Education Activities

Numerous educational events on the crowned sifaka are organized in Europe by members of the EEP. The primary objective is to collect funds for the conservation of the species, but zoos also contribute to informing people about the situation of the crowned sifaka in the wild. An educational project was developed in 2010 by the EEP in connection with the *in situ* metapopulation project. The aim is to encourage EEP members to support a joint educational project and to facilitate exchanges between Malagasy and European schools, but also between European schools. The project has three goals.

1. To create a teaching kit on the crowned sifaka. This tool, easy to move and to use, will help explain to Malagasy and European children what a sifaka is, where it lives, why it is threatened, and how and why to protect it.
2. To sponsor the crowned sifaka at Dabolava; funds for the conservation of the animals and for the publication of a comic on environmental education (created by Roots and Shoots), the first edition of which was tested with Malagasy children in 2011 (J. Razafindramanana, pers. comm.).
3. To collect French books, various school materials, and donate posters on the crowned sifaka for Malagasy schools to contribute to improving education (Fig. 8).



Figure 8. Poster about crowned sifaka (*Propithecus coronatus*) for the Davolava primary school, Madagascar. Photograph by F.-G. Grandin, MNHN.

Conclusion

The EEP captive population plays an important role in the conservation of the crowned sifaka. Despite the problems encountered in the management of this breeding program, the 25 years of captive management of the crowned sifaka have led to better knowledge of the species, including descriptions of many behaviors that would be difficult to observe in the wild—most especially concerning the reproduction of *P. coronatus* at Parc Zoologique de Paris—and a better understanding of the needs of the species and improvement of captive husbandry. The involvement of several members of the EEP in *in situ* projects, especially their fundraising activities, led to the proposition of the metapopulation conservation project in which the EEP will help with the management of the most isolated groups of crowned sifakas, including the implementation of a sustainable captive population. Finally, the educational activities conducted by the EEP and/or its members improve awareness of the species and contribute to its protection.

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