EAZA Best Practice Guidelines

Crowned sifaka (*Propithecus coronatus*)
Coquerel's sifaka (*Propithecus coquereli*)

1st Edition, June 2022

Edited by: Björn Unger

Prosimian TAG

TAG Chair: Achim Johann, NaturZoo Rheine

EEP-Coordinators:

P. coronatus Luca Morino, Muséum national d'Histoire naturelle

Sylvie Laidebeure, Parc zoologique de Paris

P. coquereli Andreas Pauly, Tierpark Berlin

Contributing authors

Björn Unger	Van Hall Larenstein University of Applied Sciences
Delphine Roullet	Prosimian TAG Vice-Chair
Andreas Pauly	Tierpark Berlin (Coordinator and vet. advisor Coquerel's Sifaka EEP)
Sylvie Laidebeure	Paris Zoo (Coordinator and vet. advisor Crowned sifaka EEP)
Alexis Lécu	Paris Zoo (vet. advisor Crowned sifaka EEP)
Luca Morino	Muséum national d'histoire naturelle (Vice Coordinator Crowned sifaka EEP)

Citation

Unger, B., Roullet, D., Pauly, A., Laidebeure, S., Lécu A., Morino, L. (2023). EAZA Best Practice Guidelines for Crowned sifaka (*Propithecus coronatus*) and Coquerel's sifaka (*Propithecus coquereli*) - 1st Edition. European Association of Zoos and Aquariums EAZA, Amsterdam, The Netherlands.

DOI: 10.61024/BPG2023SifakaEN

Cover photo

Coquerel's sifaka (*Propithecus coquereli*) at Tierpark Berlin. ©Tierpark Berlin.

EAZA Best Practice Guidelines disclaimer

Preamble

Right from the very beginning it has been the concern of EAZA and the EEPs to encourage and promote the highest possible standards for husbandry of zoo and aquarium animals. For this reason, quite early on, EAZA developed the “Minimum Standards for the Accommodation and Care of Animals in Zoos and Aquaria”. These standards lay down general principles of animal keeping, to which the members of EAZA feel themselves committed. Above and beyond this, some countries have defined regulatory minimum standards for the keeping of individual species regarding the size and furnishings of enclosures etc., which, according to the opinion of authors, should definitely be fulfilled before allowing such animals to be kept within the area of the jurisdiction of those countries. These minimum standards are intended to determine the borderline of acceptable animal welfare. It is not permitted to fall short of these standards. How difficult it is to determine the standards, however, can be seen in the fact that minimum standards vary from country to country.

Above and beyond this, specialists of the EEPs and TAGs have undertaken the considerable task of laying down guidelines for keeping individual animal species. Whilst some aspects of husbandry reported in the guidelines will define minimum standards, in general, these guidelines are not to be understood as minimum requirements; they represent best practice. As such the EAZA Best Practice Guidelines for keeping animals intend rather to describe the desirable design of enclosures and prerequisites for animal keeping that are, according to the present state of knowledge, considered as being optimal for each species. They intend above all to indicate how enclosures should be designed and what conditions should be fulfilled for the optimal care of individual species.

Abstract

The genus *Propithecus* (sifakas) has a well-deserved reputation of being delicate and difficult to manage in captivity. Only few zoological institutions have been successful in managing and breeding this delicate species consistently, which is why knowledge about the best practice for keeping sifakas is limited.
This document contains the guidelines for Crowned sifaka (*Propithecus coronatus*) and Coquerel’s sifaka (*Propithecus coquereli*) and is divided in two sections. The first one presents data on the biology of the species, as well as data from the wild, while the second one focuses on management in zoos. Essential aspects to the successful captive care of these highly specialized primates are the development of a captive diet, which takes into account the specialized nutritional needs of these browsing species, the determination of optimal housing conditions and the reduction of infant and juvenile mortality.
The aim of this document is to ensure that sifakas in captivity will get the best possible care, according to the latest knowledge of sifaka husbandry. It is also intended to serve as a reference when encountering problems with the maintenance and management of these primates. Holders are advised to contact TAG members with any concerns or queries about sifaka husbandry.

We thank all institutions who contributed to this document by answering the survey about sifaka husbandry in 2021. Furthermore, we thank the Duke Lemur Center for their support by sharing experience and knowledge in successfully keeping Coquerel’s sifakas.

Content

Section 1: Biology and field data

1.1 Biology

1.1.1 Taxonomy

Order: Primates
Suborder: Strepsirrhini
Infraorder: Lemuriformes
Family: Indriidae
Genus: *Propithecus*
Species: *Propithecus coronatus* / *Propithecus coquereli*

Common names of *Propithecus coronatus* and *Propithecus coquereli* are listed in **Table 1**.

Table 1 - Common names of P. coronatus *and* P. coquereli *in several languages*

Language	*P. coronatus*	*P. coquereli*
English	Crowned sifaka	Coquerel´s sifaka
German	Kronensifaka	Coquerel-Sifaka
French	Propithèque couronné	Propithèque de Coquerel
Spanish	Sifaca coronado	Sifaca de Coquerel

In 1994, it was estimated that the genus *Propithecus* had 3 species: *P. diadema* (4 subspecies), *P. tattersalli* (no subspecies) and *P. verreauxi* (4 subspecies) (Tattersall, 1986). Groves, in 2001, raised all sifakas at rank of species and considers *P. deckenii* as a species with 2 subspecies (*deckenii* and *coronatus*). Thalmann et al. (2002) showed that the 2 alleged subspecies of *P. deckenii* should be considered as different species. Recent taxonomic revisions (Mittermeier et al., 2008) have promoted all 4 subspecies *of P. verreauxi* to species status based on the review of craniodental characters. However, there is considerable debate about the validity of *P. coronatus*, and especially its relationship with *P. deckenii* (Mittermeier et al., 2008), due to the physical similarities and close geographical distributions of these taxa, including apparent sympatry at some sites (Roullet, 2011; Thalmann et al., 2002). The taxonomic status of Crowned sifakas has long been debated, but the combination of morphological and biogeographical evidence supports considering it as a valid species (Thalmann et al., 2002; Groves and Helgen, 2007; Mittermeier et al., 2008).

Members of genus *Propithecus* are listed in **Table 2**.

Table 2 - Members of the genus Propithecus

Scientific name	Common name
Propithecus candidus	Silky sifaka
Propithecus coquereli	Coquerel's sifaka
Propithecus coronatus	Crowned sifaka
Propithecus deckenii	Von der Decken's sifaka
Propithecus diadema	Diademed sifaka
Propithecus edwardsi	Milne-Edwards's sifaka
Propithecus perrieri	Perrier's sifaka
Propithecus tattersalli	Golden-crowned sifaka
Propithecus verreauxi	Verreaux's sifaka

1.1.2 Morphology

Weight

The average body weight of adult Crowned sifakas (captive) ranges from 3.5 to 4.5kg for males, and from 3.5 to 5.0kg for females. The weight of a newborn Crowned sifaka ranges from 67 to 116g for males and from 70 to 105g for females (Roullet, 2014).

The average body weight of adult Coquerel's sifakas (captive) ranges from 3.4 to 4.5kg. The weight of a newborn Coquerel's sifaka ranges from 90 to 120g (Haring, 2018).

Length

Both species are medium-sized indriids. The overall length of adult Crowned sifakas ranges from 95 to 113cm. The head plus body length ranges from 45 to 58 cm, their tail length is about 46-57cm.

The overall length of adult Coquerel's sifakas ranges from 92 to 110cm. The head plus body length ranges from 42 to 50 cm, their tail length is about 50-60cm (Andriantomopohavana et al., 2006; Mittermeier et al., 2010).

For both sifaka species, there is no sexual dimorphism in size.

Coloration

The Crowned sifaka has a mainly white colour. The coat is cream and white in contrast to the head, neck and throat that go from black to chocolate brown. The coat has varying shades ranging from yellow-gold to silver-brown on the upper part of the chest, shoulders, and upper forelegs. The hind limbs and tail are also white. Males and females are in similar coloration (Mittermeier et al., 2010; Harpet et al., 2008). The muzzle is prominent, rounded, and bulbous, and the face is hairless and black. The bulbous nose is quite unusual and can easily distinguish this sifaka of all others. Some individuals show an area of white fur along the ridge of the nose, as well as fine white tufts around the ears. Their eyes range from yellow gold to blue tints shade (Mittermeier et al., 2014; Harpet et al., 2008). **Figure 1** shows the typical coloration of *P. coronatus*.

About 44% of the wild *P. coronatus* population shows melanistic tendencies. 2 melanistic forms are recognized:

- a "very dark" form characterized by dark brown to blackish colouration on the forearms and upper back
- and an "intermediate" form with dull rufous or light brown forearms and upper back.

There appears to be a continuum in chromatic variation from the typically coloured individuals, through the intermediate melanistic form to the very dark form (Rakotonirina and *al.*, 2013). **Figure 2** shows melanistic forms of *P. coronatus.*

Figure 1 – Typical coloration of P. coronatus *© Björn Unger*

Figure 2 – melanistic forms of P. coronatus*. © Delphine Roullet*

The Coquerel's sifaka has a white dorsal coat. Maroon patches cover the chest and the anterior and interior aspects of the forelimbs and hindlimbs. The head and the tail are white. Occasionally, silver patches occur on the base of the back. The skin of the face as well as the muzzle is black, except for a distinctive patch of white fur along the back of the nose. The ears are black, naked, and visible. The bottom of hands and feet are black. The eyes are yellow. Males and females have similar coloration (Mittermeier et al., 2013). **Figure 3** shows the typical coloration of *P. coquereli*.

Figure 3 – typical coloration of P. coquereli*. © Andreas Pauly*

Description

Anatomical information

All sifakas have short arms and hips, hands and feet specially adapted for vertical clinging and leaping. Their legs are extremely long and powerful in relation to their trunk and arms. This enables them to cling and to leap between vertical trunks and branches (Haring, 2007). They have large feet, and the first toe is a widely divergent, pseudo-opposable grasping digit (Mittermeier et al., 2013). A common feature of the family Indriidae is that they only have four teeth in the toothcomb, instead of six like lemurs usually have. The dental formula is I2/1-C1/1-P2/2-M3/3, so Indriidae have 30 teeth (Mittermeier et al., 2013).

Senses

Like many mammals, sifakas use scent-marking as a common mean of communication. Scent glands are sexually dimorphic in sifakas: males are active in scent marking via both anogenital and sternal secretions, while the latter are abortive in females. Moreover, adult males also differ in their scent marking activity and chest appearance: the most actives exhibit a pronounced brown staining around their sternal gland, whereas the others have clean, whiter chest.

Different hypotheses are proposed to explain scent-marking behaviour: territorial demarcation, ownership of resources, mate attraction and advertisement. Males and females use scent marking very differently. Females use scent markings to indicate their presence. The chemical composition of marks can indicate female reproductive state (Pochron et al., 2005). Males attempt to guard females by limiting female communication and to communicate their presence to extra group members. Scent marking is a crucial component of male-female relationships in prosimians (Lewis, 2005).

Vocalisations

Sifakas use a wide set of vocalisations to communicate. Several types of vocalisations were recognised (Mittermeier et al., 2013):

- **« Hum call »:** low-frequency contact vocalizations occurring mainly during resting phases but also in other contexts.
- **« Mum call »:** low-frequency vocalizations, shorter than « Hum call», usually produced at the end of the periods of rest and just before the locomotion phases.
- **« Roars call »**: high amplitude cries, typically produced in the presence of predators. These vocalizations can be produced by several individuals at the same time and by several groups.
- **« Chatter-Squeal call »:** usually made as a sign of submission when an individual is disturbed by another.
- **« Shee-faak call »** = tchi-faks: These explosive vocalizations are often produced when an individual is separated from the rest of the group. The vocalisations are often accompanied by forward movements of the head. When hearing this vocalization, other group members can respond with the same type of vocalization. The Malagasy name “sifaka” comes from this behaviour issued during a threat. This behaviour is typical of the smaller species of sifaka such as *P. coronatus*.

Although, wild and captive Coquerel's sifakas exhibit the same alarm call system and use the same alarm call types, differences in the usage and perception of some of the alarm calls were found (Fichtel and van Schaik, 2006).

1.1.3 Physiology

Lemurs are commonly characterized by low basal metabolic rate (BMR). Energy input increases in the early wet season which is likely related to male-male mating competition. In addition, females must reach a physical condition sufficient for reproduction before the dry season (Pichon and Simmen, 2015).

A study, conducted by Rasambainarivo et al. (2014), determined physiological information in 18 adult and 15 immature *Propithecus verreauxi* from the Kirindy Mitea National Park in Madagascar. The study resulted in a mean body temperature of 36.87 °C for adults, and 36.12 °C for immature individuals. The mean pulse rate was 120 beats per minute for adults and 121.4 beats per minute for immature individuals. The respiratory rate was located at 45.11 breaths per minute for adults and 43.07 breaths per minute for immature individuals.

1.1.4 Longevity

The knowledge of typical longevity in wild sifaka species is limited. Wright et al. (2008) estimated, that the maximum longevity of female Milne-Edwards's sifaka (*Propithecus edwardsi*) is 32 years. According to Cassady et al. (2018), Coquerel's sifakas have a lifespan of approximately 30 years.

The oldest male in the international Studbook (ISB) population of *P. coquereli* is 32 years and 2 months (still alive), the oldest female 26 years and 5 months (Byrnes, 2021; March 2022).

The oldest male *P. coronatus* in the EEP was 25 years, the oldest female was 30 years (*P. coronatus* Studbook, 2021).

1.2 Field data

1.2.1 Conservation status/ Zoogeography/ Ecology

Distribution

The Crowned sifaka is found in a small area in the northwestern part of Madagascar just south of the city Mahajanga (=Majunga) where its range adjoins *P. deckeni* to the southwest and *P. coquereli* to the northeast (**Figure 4**). *P. coronatus* appears to be restricted to forests on the eastern side of Mahavavy River and the southeast side of the Betsiboka River (Haring, 2009). Others small populations have been discovered recently in various unprotected sites along the central highlands of Madagascar (GERP, 2011, 2012). The discovery of a population in the south of the central highlands sub region, confirms the hypothesis that the historical range of this species might have spread along the central highlands of Madagascar (Roullet, 2011).

The Coquerel´s sifaka is distributed in forested areas of north-western Madagascar. Its range adjoins *P. coronatus* in the southwest at the Betsiboka river, and spreads northeast near the town Bealalana. The southern limit is the region of Ambato Boeni, the eastern boundary is near Antetemasy, just in the west of Befandriana Nord (Mittermeier et al., 2013) (**Figure 4**). Although the distribution is highly fragmented, a field survey conducted in 2014, confirmed the presence of *P. coquereli* in many of the remaining forest fragments within the species range (Salmona, Jan, et al. 2014).

Figure 4 – Distribution of P. coronatus *and* P. coquereli *(taken from: Razafindramanana et al., 2020; Louis et al., 2020)*

Habitat

The Crowned sifaka is typically found on high tree crowns. It is located from sea level up to 700m of altitude. The largest known populations are surviving in fragmented dry deciduous forest patches between the Betsiboka and Mahavavy rivers in northwest of Madagascar (Majunga). Its habitat is also composed by riparian forests, savannahs, and mangroves (GERP, 2012; Petters and Andriatsarafara, 1978; Pichon et al., 2010). Mangroves are used as sleeping and feeding sites. Occasionally, *P. coronatus* also makes inroads in savannah areas. The presence of this species in the mangrove, which is an unusual habitat, might be a recent adaptation linked to high anthropic pressures. They are sympatric with *Eulemur rufus* and *Eulemur mongoz* (Gauthier et al., 2000; Mittermeier et al., 2014). Sometimes, the range of *P. coronatus* can overlap that of other sifaka species. **Figure 5** shows a typical forest habitat of *P. coronatus*.

Figure 5 – Natural habitat of P. coronatus. *© Sylvie Laidebeure*

The Coquerel`s sifaka lives in mixed deciduous dry and semi-evergreen lowland forests from sea level up to 300m of altitude. The habitat consists of isolated pockets of dry forests, which are separated by wide- open landscapes (Kun-Rodrigues et al., 2014). Additionally, it is present in brush-and-scrub, and secondary forest areas, adjacent to primary forest. Coquerel´s sifakas have also been observed in costal mangroves in the Bay of Mahajamba (Mittermeier et al., 2013).

Population

Exact population numbers of the Crowned sifaka are not known, but they are thought to be low due to the animal's very restricted range (Haring, 2009). Most of the wild population is located northwest of Madagascar whereas the centre of the island is home to smaller populations in small fragments of highly degraded forests (Roullet, 2014). Although the exact number is difficult to estimate with certainty, another study, conducted in 2014, estimates that it probably ranges around 10 000 in the northern part of its distribution and probably around 100 000 across the entire range of *P. coronatus* (Salmona et al., 2014). Field observations suggest that populations continue to decline at a high rate. Salmona et al. (2014) found the density of *P. coronatus* to vary among fragments, from a low 46 individuals/km² to a high 309 individuals/km². Such high population densities could be due to the

small suitable habitat fragments being enclosed within a matrix of open habitats that are not easily crossed by the species (Pichon, 2012).

Exact population numbers of Coquerel's sifaka are also not provided. Mittermeier et al. (2010) estimated 200 000 remaining individuals, but there was also a severe fragmentation and habitat loss during the last years in the protected areas of Ankaranfantsika National Park, Anjiamangirana and Bora. According to Kun-Rodrigues et al. (2014) the population of Ankaranfantsika consist of estimated 47 000 individuals. The estimated population density in Ankaranfantsika National Park is 60 individuals/km² (Mittermeier et al., 2013). A study, conducted by Salmona et al. (2014) concluded that although *P. coquereli* was observed at almost all the visited sites during the study, it remains unclear how viable the populations of a significant proportion of these sites actually are, as the distribution range is highly fragmented.

Conservation status and threats

In the most recent IUCN Red List assessment conducted in 2020, the Crowned sifaka has been moved from the category "Endangered" to "Critically Endangered" (Razafindramanana et al., 2020). This was justified as the species has undergone a population decline of ≥80% over a period of 30 years (three generations). Reasons for the decline are "the continuing decline in area, extent and quality of habitat from burning of forests to provide pasture for livestock and logging for charcoal production, in addition to exploitation through unsustainable hunting pressure." According to Eppley et al. (2020), these causes will not be easily reversible and *P. coronatus* is negatively impacted by this habitat fragmentation. The current population trend is decreasing (Razafindramanana et al., 2020).

During the IUCN Red List assessment in 2020, the Coquerel's sifaka has also been moved from the category "Endangered" to "Critically Endangered" (Louis et al., 2020). The species also faced a population decline ≥ 80% over a period of 30 years due to severe fragmentation and habitat loss. The major threats are slash-and-burn agriculture and burning to generate new pasture for livestock, agricultural shift, forests logging to produce charcoal, unsustainable hunting pressure, and increased human population pressure. These causes have not ceased and will to a large extent not be easily reversible (Eppley et al., 2020).

Sifaka populations remaining in fragmented forests are highly endangered due to anthropogenic threats like habitat degradation, demographic and genetic effects related to small population sizes and isolation from other populations (Rakotonirina et al., 2013). These species are very sensitive to habitat loss and food scarcity (Haring, 1988). Forest degradation affects the general biology of lemurs as forests serve as support for locomotion for example. The forests within the range of these species have decreased dramatically since decades and local communities continue to burn forests to produce charcoal. The slash-and-burn agriculture (locally named "tavy") creates space for pasture for livestock (Louis et al., 2020). Human intrusion into the forest for various reasons (gathering honey, presence of human habitation or temporary camps in or around the forest) also negatively impact sifaka populations.

Predation threats

Apart from anthropogenic threats, sifakas have multiple potential predators. the Madagascar harrier hawk (*Polyboroides radiata*), the Madagascar ground boa (*Acrantophis madagascariensis*), Fossas (*Cryptoprocta ferox*), feral dogs (*Canis lupus familiaris*), and feral cats (*Felis catus*) can all be

considered potential predators of dry forest's sifakas (Burney, 2002; Pichon, 2012). Though no direct observations of predation on sifakas have yet been made for *P. coronatus*, the behavioural and vocal responses (visual scanning, avoidance, mobbing and predatory roars) to most of these potential predators suggest that they do indeed play a role in regulating sifaka populations. *P. coquereli* expressed anti-terrestrial predator responses when exposed to playbacks of "Shee-faak call" vocalisations. (Fichtel and Kappeler, 2010).

Both the Crowned sifaka and the Coquerel's sifaka are listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). CITES prohibits commercial international trade in wild specimens of these species. Sifakas occasionally get captured alive for illegal pet traffic (Mittermeier et al., 2014; Harpet et al., 2008). In certain regions, hunting does not occur as sifakas are considered sacred by the local communities (Razafindramanana and Rasamimanana, 2010).

The conservation of *P. coronatus* is a great example of EAZA's One Plan Approach, integrating the needs of the wild populations, the captive population in Madagascar, and the captive population in Europe. Research and experience on wild animals are used to inform and improve husbandry practices, and vice versa, what is learned on captive animals can be used to fine-tune in situ conservation efforts. The captive population can act as an insurance population, while suitable wild individuals may serve as valuable founders to improve the genetic variability of such captive population. A multidisciplinary field project is in place, researching population density in each site, habitat structure assessments, ecological monitoring (like forest carrying capacity of each site, feeding behaviour of the animals, home range of the groups, social behaviour), environmental education, genetic, conservation activities for the newly discovered populations in each site by involving local communities and *ex situ* conservation. *In situ* and *ex situ* actions are complementary and may serve as a model for the implementation of metapopulation management for endangered species in isolated forest fragments of Madagascar (Razafindramanana and Roullet, 2011). An awareness campaign was organized to sensitize local people about conservation, biodiversity and living in harmony with nature. Other conservation activities like forest restoration and tree planting are organised. Every year, a tree planting programme is conducted to help with habitat restoration. The creation of green corridors ensured the connection between fragments and the control of bushfires. Educational materials for local people are brought and regular meeting are organized to train and sensitize them about environmental actions and conservation issues (GERP, 2012). Numerous educational events on the Crowned sifaka are organized in Europe by members of the EEP: collecting funds for the conservation of the species, informing people about the situation of the species in the wild and collecting French books to improve education. These activities improve awareness of the species and contribute to its protection (Roullet, 2014). The experience of the EEP helps to arrange translocations of Crowned sifakas between forest fragments that are included in the metapopulation conservation project (Roullet, 2014).

Members of the Coquerel's sifaka EEP are financially supporting the organisation IMPACT Madagascar (Sifaka-Conservation), which is going to execute a comparative study on the ecology of *P. coronatus and P. coquereli* in the wild in 2022. A metapopulation management approach for the conservation of *P. coquereli* is planned for the upcoming years.

1.2.2 Diet and feeding behaviour

Food preference

Both *P. coronatus* and *P. coquereli* are primarily folivores and have a highly diversified diet (Mittermeier et al., 2013). The majority of their diet is composed by leaves. They are highly folivorous during both seasons, supplementing their diet with flowers, fruits, vegetative buds, young stems, shoots, earth and dead wood as commonly occurs in other *Propithecus* species (Mittermeier et al., 2013). Crowned sifakas feed primarily on mature leaves from a few trees, liana, and vine species. In the wild, leaves comprise about 40-60% of the Crowned sifaka diet with seasonally available fruits seeds and flowers making up the rest (Haring, 2009). *P. coronatus* is known to consume more than 50 plant species. For example, in Antrema, sifakas consume at least 60 plant species belonging to 32 families (like Euphorbiaceae, Fabaceae, Apocynaceae and Rubiaceae). McGoogan (2013) studied groups of *P. coquereli* in Ankarafantsika National Park and found that they feed on at least 79 different plant species. The preferred feeding species in this study included *Drypetes* sp., *Cedrelopsis* sp., *Terminalia* sp., and *Mimosa* sp.

The relative proportion of these different food items in the sifakas' diet depend on their availability, in relation to season and location. The contribution of items changes qualitatively (consumed plant parts) but also quantitatively (ingested matter). In the wild, adult sifakas ingests an average of 240g of plant material per day. Variations in food intake and energy expenditure indicate that these lemurs depend on the rainy season to build up body reserves and achieve a body condition favourable for reproduction. (Pichon, 2012).

Feeding

In the wild, Sifakas have feeding bouts throughout the day. Sifakas forage essentially in trees, but they are also found on the ground when they are consuming earth, fruits, flowers, or leaves. They rarely split branches carrying food items but use their hands to bring branches within the reach of their mouth. The most common feeding posture is sitting on or clinging vertically to branches. Leaves are consumed by mouthfuls, generally leaving petioles and sometimes rachis on branches. Small fruits like drupes are consumed directly on branches whereas bigger fruits are generally taken down to manipulate and peel them more easily (Roullet, 2011).

Associated with their largely folivorous diet, sifakas present digestive specializations (molars with very pronounced crests, salivary glands, elongated intestines, a cecum, and a lengthy spiralled colon both well vascularised). In particular, their cecum hosts a particular microbiome allowing *Propithecus* species to obtain energy by fermentation of cellulosic fibres, while detoxifying secondary compounds present in ingested foliage. Although the plants consumed provide important nutrients for *Propithecus* sp. (proteins, carbohydrates, and lipids), they also produce hard-to digest or even toxic secondary compounds. Among these metabolites, tannins are the most widespread secondary compounds. They are active in high doses and some of them precipitate proteins, making the digestion of plant proteins difficult and reducing the efficiency of the sifakas' digestive enzymes. Hindgut fermenters like sifakas should be able to produce protein and amino acids through their microbial colon activity. Wild sifakas are known to have poorer protein consumption, sometimes as low as 3% dry matter (Lecu et al., 2006). Facing this problem, sifakas are sometimes observed

consuming small quantities of earth to benefit from absorbent properties of clay (Roullet, 2011; Pichon, 2012).

1.2.3 Reproduction

The social system of *Propithecus* show remarkable flexibility, with individuals living in monogamous, polygynous, polyandrous or polygynandrous groups. The mating system is reported as promiscuous (Brockman, 1999).

Developmental stages to sexual maturity

Immediately after birth, the infants are able to grab onto their mother's fur. Right after birth, the female spends about an hour cleaning her infant and consuming the afterbirth (Haring, 2018). On the first day, the infants' movements are limited to crawling up their mother's ventral surface and either cling at her lower abdomen in a horizontal position or upright to suckle at one of the mother's two nipples (Haring, 2018).

On the third day, the infant become noticeably more active, moving freely on the mother and the first vocalisations can be heard. Infants are first observed "tasting" solid foods when they are about one/ two weeks old. Young are carried ventrally until the third/ fourth week and then begin to be carried dorsally. The transition from transverse ventral to sagittal dorsal clinging is gradual. Infants up to 7 weeks old are periodically seen riding in the ventral position on the mother and on other group members. Parental investment is low in sifakas and often limited to the mother. Mothers become less responsive towards their infants when they are about one month old. Up to this point, a single call from the infant is usually enough to cause the mother to approach and fetch it immediately. In fact, females often retrieve their infants when they are more than 0.5 to 1 m away, regardless of whether the infant makes a "distress" call or not. By the beginning of the fifth week, mothers begin to move away from their infants more frequently, often ignoring their "distress" calls. Other group members often appear to act as surrogate mothers. Play behaviour is first seen three to four weeks after birth. Weaning starts at around four to five months.

Infants grow relatively slowly. High infant mortality (40-70%) is caused by predation, disease, environmental stress, and infanticide (Wright, 1999).

Age of sexual maturity

In captivity female *P. coronatus* become mature at the age of 2.5 years when they develop their first oestrus and begin to have conflicts with their mothers. Males also become mature at the age of 2.5 years (Roullet, 2010). Female *P. coquereli* in captivity have been mating at the age of 2.6 years, whereas males became mature at the age of 2 years (Haring, 2018). Age at first reproduction is 3 years, in captivity for both females and males, age at last reproduction in captivity is 25 years for males and 28 for females (Roullet, 2014)

Seasonality of cycling

Sifaka reproduction is strictly seasonal (Pichon, 2012). Reproduction is dependent on females' physical condition (Pichon and Simmen, 2015), and compared to other lemurs, the reproductive rate is very slow, making recovery of small populations' problematic (GERP, 2012). The breeding season

spans the austral summer months of January-March (although some post-partum oestrus could be possible after a baby loss), during which they experience up to 2 oestrus periods. Sifakas have 0.5 to 96 hour periods of receptivity. Oestrus' periods are characterized by 10 to 15 days of elevations in faecal oestradiol and the absence of vulvas indicators of ovulation. Unlike the vulvas of most prosimian females, those of sifaka are not sealed (Brockman, 1999; Brockman and Whitten, 1996). The receptivity doesn't always coincide with periovulatory events and is associated with male immigration. In captivity, sifaka are seasonal breeders as well. The breeding season is running from July to October (in the northern hemisphere), and births occur between December and March (Haring, 2018). Up to three estruses per breeding season are observed in captivity (Roullet, 2010).

Gestation period

The gestation length of *P. coronatus* is 169-170 days (Roullet, 2011). For *P. coquereli*, the typical gestation ranges between 155-165 days, and the infants nurse for about six months (Haring, 2018). Abortion in sifakas is reportedly rare and may be associated with translocation stress (Brockman and Whitten, 1996).

Offspring size

In the wild, females usually have one young every 2-3 years (Roullet, 2014). The inter birth interval is 24 months, although interval can be reduced to 12 months following the death of a neonate (Brockman, 1999). In captivity, females can give birth to one offspring every year (Roullet, 2014). Two babies in the same year have been reported in captivity but such an event remains exceptionally rare (Roullet, 2010).

Birth details and seasons

The birth peak occurs in the dry months from July to September (Brockman, 1999). Sifaka infants are born fully furred with eyes open (Haring, 2018).

1.2.4 Behaviour

Activity

P. coronatus and *P. coquereli* follow the typical activity pattern of other sifaka species. Whatever the period, sifakas follow a diurnal, bimodal activity pattern (Mittermeier et al., 2014). Individuals are less active in the morning than in the second part of the day, with a feeding peak in the late afternoon, just before getting back to their resting site. Activities vary with the season, with no significant differences between sexes. Their activity phase is more spread in the wet season when photoperiod is the longest (Haring, 1988).

Crowned sifakas adopt different behavioural strategies in function of the seasons, reducing their activity level (i.e. energy expenditure) during the food- scares dry season. Animals consume the equivalent of 5-6% of their body weight in the dry season (against 10-11% in early wet season) (Haring, 1988).

Depending on the group, individuals, and seasons, sifakas can sleep in contact, in close proximity or on different branches (Pichon et al., 2010). Typical sleeping sites are tall trees, optimally exposed to sunlight (Haring, 2009).

Locomotion

Sifakas locomotion comprises leaping, climbing, walking (bipedal, quadrupedal), and skipping. Unlike gibbon and siamang, brachiation is not often used by sifakas. As vertical clingers and leapers, sifakas travel mainly via powerful leaps from vertical to vertical, propelled by the power of the long hind limbs (**Figure 6**). Facing the trunk, sifaka use the deep cleft between their big toe and other digits to push off the vertical trunk and then rotate in mid-air to face the oncoming vertical trunk, with the tail aiding towards the rotation of the body (Lawler et al., 2005; Mittermeier et al., 2014).

Figure 6 - P. coronatus *leaping pose. © Sylvie Laidebeure*

When foraging in the canopy, sifakas often hop and walk quadrupedally before adopting suspensory postures. At rest, they prefer to grab to vertical trunks, legs bent and knees against the abdomen (Haring, 2009). On the ground, locomotion is mainly limited to the typical bipedal sideways hopping which allow sifakas to rapidly cover several dozens of meters to join a forest fragment nearby.

Social behaviour

P. coronatus forms relatively small social groups of 2-8 individuals, including adult males and females, juveniles, and infants. The average group size is 4.8 without variation between forest blocks (Roullet, 2011).

P. coquereli group size ranges from 3 to 10 individuals that occupy home ranges of 4-9ha (Ramilison et al., 2021). Structure and composition of sifaka groups are quite variable between seasons and years due to regular dispersal events (Richard, 1976).

Madagascar's harsh and unpredictable environment may pressure sifakas to keep groups small, to reduce local feeding competition. Moreover, high predation rates may also pressure sifakas to live in groups. Infanticide may influence group size through dispersal patterns (Pochron and Wright, 2003). Infanticides are shared by a wide range of lemur species. This behaviour is commonly used as a sexual strategy by males to increase their reproductive success (Pichon, 2012).

Sifakas live in matriarchal social systems, where a reproductive alpha female exists in each group (Salmona et al., 2013). Female dominance in lemurs is expressed in terms of food priority or access to mates (Razanaparany et al., 2014). Some female sifakas are very dominant and very aggressive towards males. Group size and composition have significant effects on feeding competition and reproduction, demographic parameters such as residency and emigration are actively influenced via targeted aggression (Pichon, 2012; Pochron et al., 2003).

Allogrooming plays an important social function in Sifaka groups (Lewis, 2009). Dominant females receive significantly more grooming than males. Grooming may be performed to reduce or avoid aggressive behaviour from dominant individuals. Additionally, subordinate sub adults groomed mothers with infants, perhaps with the aim of interacting with the infant. It may be a strategy to handle infants and thereby contribute to indirect fitness (Razanaparany et al., 2014).

Sifaka males frequently move between social groups, with most moves taking place over short distances. Age differences among males and differences in their previous history contribute to differing patterns of movement. All males leave their natal groups and transferred into neighbouring or nearby groups. Dispersal by males aged 3-6 years appeared to be voluntary, whereas dispersal of older males occurred through eviction (Richard et al., 1993).

Sexual behaviour

The sexual behaviour of sifakas is complex and can be influenced by numerous factors such as female-female mate competition, oestrus asynchronicity, presence of subordinated males or newly-immigrated ones, potentially infanticidal males, and the availability of extra group males. Both sexes can seek multiple mating opportunities in their own and neighbouring groups (Richard et al., 1993; Brockman, 1999). Although females generally come into oestrus asynchronously within groups and dominant males could thus be able to mate guard each female during their brief annual receptivity, females often mate with multiple partners, possibly to confuse paternity and therefore to avoid infanticide (Brockman and Whitten, 1996).

Both sexes evaluate potential partners and express mating preferences through increased approaches or aggression. In most cases, females choose their multiple partners based on residence, age and dominance rank. Males may mate guard in order to prevent females from mating with other males (Brockman, 1999).

Male sifakas visit and sometimes transfer to other groups during the brief mating season. The reasons for transfers are unclear but visits may be advantageous because females mate with the most dominant males present, regardless of their group affiliation. Dominance may have been

established previously: there is some evidence of a social network transcending the group. Dominance may also be established just prior to mating through fierce fights between males. Females mate with the winners of these fights (Richard, 1985).

Mating behaviour has rarely been observed. At the time of oestrus, the behaviours of the animals change, and they become more active. Especially, a lot of markings can be observed: the male systematically covers the marks of the female and follows her when she moves. Simultaneously, the female becomes more aggressive towards the male. Brockman (1999) describes her observations in *Propithecus verreauxi*: "Copulations occurred on arboreal substrates, typically in trees. Males clasped females with their forelimbs, with one or both feet gripping her ankles or legs. A mating was composed of 2 to 10 shallow intromissions having rapid and intermittent thrusts followed by a single prolonged intromission with 36 to 156 slow rhythmic thrusts culminating in ejaculation, suggesting that sifaka may be multiple-mount ejaculators." (Brockmann, 1999: p388).

Section 2: Management in Zoos and Aquariums

The recommendations below are based on combined experience and research on *Propithecus coronatus* and *Propithecus coquereli* in all 10 EAZA institutions, holding sifakas in January 2022. All institutions participated to a survey in order to facilitate this document. The experience, gained through many years of successful husbandry and management of *P. coquereli* at the Duke Lemur Center (Durham, North Carolina, USA), has also been integrated to the recommendations below.

2.1 Enclosure

A good sifaka enclosure should offer an environment that supports the expression of their behavioural repertoire. Space is measured in three dimensions (width, length, and height). The vertical dimension is very important as sifakas spend the majority of their time, high above the ground. While it is generally assumed that a large enclosure means better animal welfare, qualitative aspects of an enclosure and careful consideration of space and furniture use is as important as enclosure size.

Sifakas, that do not have access to outdoor enclosures, may become much less active (especially adults, healthy youngsters are active in both environments: indoor and outdoor). There is also some evidence to suggest that outdoor housing (either large outdoor cages or forested enclosures) increase activity levels in captive sifakas and improves breeding activities (Haring, 2018). However, having indoor/outdoor cages is probably the best housing situation to manage weather extremes (Haring, 2009).

In all temperate countries, a combination of indoor and outdoor enclosures is a basic requirement. In summer, when weather conditions are good (dry and sunny), it is possible to confine sifakas outdoors during the day, but in general most facilities prefer to always give them access to enter their indoor enclosure, so that the animals have the opportunity to choose which climate they prefer. It is recommended to keep sifakas indoor when outdoor temperatures are lower than 5 °C.

Social structure in sifaka groups can be complex (see section **2.3** Social structure). Therefore, enclosures should be designed to allow shifting or separating animals for observation, feeding, weighing, or capturing if necessary. It is essential to have several smaller and larger indoor holding areas so that animals can be separated in different constellations dependent of the specific situation. Especially for breeding or medication, it might be relevant to have indoor holding areas which allow visual contact between individuals when they are separated, but also to have indoor cages where individuals can be fully isolated. If it is desired to keep sifakas in mixed species exhibits, being able to separate individuals or animal groups is even more important. Most institutions provide one large outdoor enclosure for the entire group, but an extra outdoor holding area, with its own independent access, can be beneficial if an individual must be separated from the group for a longer period of time.

In the section below the recommendations for indoor and outdoor enclosures will be discussed separately.

2.1.1 Boundary

Outdoor enclosure

Outdoor enclosures can be built with different materials. Often the outdoor enclosures are built adjacent to the indoor enclosures, which is why at least one side of the enclosure can be covered by a (concrete) wall. Walls can easily be disguised as a natural barrier by covering them in artificial rocks, which improves the aesthetic for visitors, and the complexity of the environment for the sifakas. In European facilities, outdoor enclosures for sifakas are built from chain link fence or weldmesh. The fence should be buried about 1 meter below the substrate or anchored to a solid foundation to prevent native predators and rodents from getting inside. The barrier should be regularly checked for holes and weak spots. Glass walls can be used for public viewing areas. These windows allow visitors to get close to the animals, have a good sight into the enclosure and prevent visitors from illegal feeding. A roof on top of the visitor area can reduce reflections due to sunlight, improving visibility for visitors. When a fence is used as barrier for the visitor viewing areas, it is important to erect a second barrier like a railing or a planted green strip, to make sure that visitors cannot feed or touch the animals.

It is recommended to build closed outdoor enclosures with chain link fence, weld mesh, or netting on top, to ensure that animals cannot escape, and to provide extra surface which the sifakas can use for climbing. Most institutions use mesh sizes of 3x3, 4x4, or 5x5 cm. For the construction of outdoor enclosures with open top, the Duke Lemur Centre recommends fences at least 1.8 meters high, with 1 meter of electrified net with a voltage of at least 2000 volts and at most 5000 volts AC. In enclosures with tall vegetation, fence lines should be cleared 4.5 meters on either side of the barrier to prevent sifakas from leaping over the barrier. Water moats are not recommended barriers as sifakas are highly susceptible for systemic infections with pathogens found in shallow water (see section **2.7.5** Infectious diseases) (Haring, 2018; Cassady et al., 2018).

Indoor enclosure

In all European facilities, glass windows are used to separate the sifaka's indoor enclosures from visitors. The enclosures are built mainly of solid concrete or brick walls, which provide an enclosed shelter where climate can easily be controlled. Not more than one side should be visible to visitors through glass, to ensure that the animals have enough space to hide and reduce stress due to visitors. Multiple indoor enclosures are recommended to separate animals if necessary. Behind the scenes, indoor holding areas contain larger and smaller cages, which are built from stainless steel weldmesh. Most institutions use mesh sizes of 3x3, 4x4, or 5x5 cm.

2.1.2 Substrate

Outdoor enclosure

It is recommended to use different types of substrates for sifaka outdoor enclosures. In European facilities, the majority of outdoor enclosures are covered with grass or natural soil like earth, wood bark, sand, and rocks/ gravel. It is important that the substrate absorbs water well and that there is a good drainage to prevent puddles in the enclosure after rain. It is recommended to use natural vegetation as it provides the animals with cover, shade, and a more interesting and complex

environment. Abundant plants can also make the enclosure more aesthetically pleasing to visitors. As sifakas are folivorous species, plants must be carefully selected. It is essential to non-poisonous/ toxic plants and advantageous to choose plant species not eaten by the sifakas. **APPENDIX I** – Enclosure plant listprovides an overview of different plant species, successfully used in European sifaka enclosures.

Indoor enclosure

Most indoor enclosures for sifakas consist of a concrete floor, covered with a thin layer of sawdust/ wood shavings. It is important that the wood shavings are of high quality, are not too dusty, and do not contain any kind of foreign objects. Wood shavings can soak urine and are easy to remove without exchanging the entire floor cover. One institution also covers the concrete floor with sand. It is important that the indoor substrate is easy to remove for cleaning purpose, to prevent health problem. Bright coloured substrates are practical to control stool consistency.
To keep the level of pathogens low inside the indoor enclosure, the species can also be kept on concrete floor without any type of substrate. Cleaning the enclosure by spraying the concrete floor and furniture with a water hose can result in very high humidity. Therefore, if a concrete floor without substrate is preferred, it is recommended to wipe out the enclosure with water and disinfectant and then swipe the excess water to avoid excessive humidity.

2.1.3 Furnishing and maintenance

Outdoor enclosure

The outdoor enclosure must be large enough and designed in a way, that allows the animals to perform their typical leaping form of locomotion. A high enclosure with numerous vertical and horizontal branches at different heights, ensures that the animals can efficiently use the entire space. The diameter of the climbing structures should range between 7 and 20 centimetres. As vertical clingers and leapers, sifakas move mainly by jumping from vertical to vertical. Horizontal climbing structures are used by the animals for resting and as supports when feeding and playing. In addition, infants and juveniles also use horizontal branches for locomotion when the distance between vertical branches is too great to be jumped (Haring, 2018). Care must be taken that large vertical branches and other permanent types of structures are firmly fixed in the ground. Various temporary structures like ropes, vines, and thin branches can also be used to connect climbing structures. Sifakas use these to swing, play, and for locomotion. Branches can also be hung on ropes, to make locomotion more challenging and to environmentally enrich the animals. A mix of permanent and temporary fixtures is ideal. Changing around the furniture allows the sifakas to explore their environment. Horizontal platforms are used by the sifakas to sit on. They can also be beneficial as feeding platforms in the outdoor enclosure. It is important that platforms are easy to clean and not too high, so that they can easily be reached by staff. A pulley can be used to raise platforms higher. Experience from different institutions shows, that sifakas enjoy using platforms to play and rest on. Some institutions offer outdoor nest boxes, which are open on at least one side, so that visitors can easily see the animals, but still offer shelter from bad weather. Two institutions made good experience with outdoor shelter boxes, heated through electric radiant heaters.

The outdoor exhibit at Heidelberg Zoo (**Figure 7**) consists of multiple vertical and horizontal branches at different heights, ropes, vines, and a hammock as well as vertical platforms. The yellow ball serves as an enrichment tool and the wooden box on the right is a heated shelter, which is regularly used by the sifaka.

Figure 7 - Outdoor enclosure for P.coronatus *at Heidelberg Zoo. © Björn Unger*

All furnishing should be made from non-toxic materials and should be resistant to rain and other weatherly conditions. Branches with and without bark can be used, but especially in the outdoor enclosure it is recommended to use unprocessed natural hard wood branches with bark. Robinia branches are particularly well suited as this is a very long-lasting wood with a great structured bark. Sifakas should have access to fresh and clean drinking water, but it is not recommended to build water basins in the outdoor enclosures as sifakas are sensitive to pathogens (see section **2.7.5** Infectious diseases) (Haring, 2018).

Large natural outdoor enclosures do not require much maintenance as substrates and climbing structures remain in hygienical condition due to climatic conditions (rain, sun). Faeces and food leftovers must be removed on a daily basis. Vertical platforms should be cleaned before food is distributed and areas, which are less exposed to the weather especially when parts of the outdoor enclosure do have a roof, might require special attention in terms of maintenance. Enrichment tools like ropes and hammocks should be replaced on a regular base.

Indoor enclosure

Just like the outdoor enclosure, the indoor enclosure must provide a great variety of vertical and horizontal climbing structures. Some institutions prefer to use manufactured wood poles to construct climbing structures, but natural branches can also be used (and should be preferred). High enclosures are beneficial as sifakas are arboreal and survey results indicate they use higher "canopy" levels more commonly than lower ones. An artificial rock wall can be used to make the enclosure more visually appealing for visitors, while providing extra climbing area for the animals, but regular concrete walls with some climbing structures attached are also fine and easier to clean. Various horizontal platforms should be present at different heights and locations. These can be used by the sifakas to sit and rest on but are also useful to distribute food. Several feeding stations help to avoid intra-species aggression.

Some institutions offer nest boxes to rest in (**Figure 8**Figure 8). These boxes should be placed high in the indoor areas, and there should be as many boxes as animals in the enclosure.

Figure 8 - Nest box for sifaka at Mulhouse Zoo. © Björn Unger

Just like in the outdoor enclosure, a variety of temporary fixtures like ropes, vines, and thin branches should be used. Such an enriched environment will promote exploratory and locomotive behaviour of the animals, which will use the opportunity to swing, play, and explore their indoor enclosures. These temporary fixtures should be repositioned from time to time.

The indoor enclosure at Paris Zoo (**Figure 9**) consists of multiple vertical and horizontal branches. A combination of manufactured wood poles and natural branches is used. Ropes are used to connect climbing structures. In the background, a Crowned sifaka is resting on a horizontal feeding platform.

Figure 9 – Indoor enclosure for sifaka at Paris Zoo. © B. Unger

Indoor enclosures should be cleaned on a daily basis. The bare floor should be wiped out with water once a day and disinfected 2-3 times per week. In enclosures with substrate (wood shavings/ sawdust), the soiled substrate should be removed, the floor underneath wiped out, and then new substrate scattered over. Food leftovers should be removed. Feeding platforms should be wiped out and disinfected on a daily basis. Other furniture must be cleaned only if it has come into contact with faeces. Enrichment tools like ropes and hammocks should be replaced on a regular base. Wooden poles and other furniture in indoor enclosures are bolted together to ensure the stability of the structure. The connections should be checked regularly to ensure they do not pose a hazard to the animals and promptly replaced or repaired as necessary.

2.1.4 Environment

Outdoor enclosure

Most institutions always allow sifakas access to their outdoor enclosures as long as temperature is above 5 °C and weather conditions are good. If a facility decides to confine the animals outdoors, it is important that there are sufficient outdoor shelters where the animals are protected from rain or high winds. Below 10 °C sifakas should always have access to their indoor enclosures. Most institutions give the animals access to their indoor enclosures whenever they want so that they can choose their preferred temperature and climate. An outdoor basking spot can allow sifakas to use their outdoor enclosure even when temperatures are low. A weldmesh box around the heater is essential to keep the animals at a safe distance from the lamp to avoid burn injuries. The outdoor temperature should be monitored daily, and the weather forecast should be taken into account when deciding whether sifakas do get access to their outdoor enclosure overnight.

Indoor enclosure

Across EAZA institutions, the median time which sifakas spend inside their indoor enclosures is 12 hours during summer and 15 hours in the winter (Survey among Sifaka holders, 2022). Indoor temperature should range between 20 and 25 °C, and most institutions made good experience with an indoor humidity ranging around 70%. It is recommended to regularly monitor the indoor temperature and humidity. The temperature can be controlled by a thermostat. Typical heating systems include electronic heaters, central heaters, underfloor heating, radiators, and decentralized heating systems. Keep in mind that hot pipes or other heating devices must be placed out of reach of the animals. Some institutions use air circulation systems (like vents/vans or electrically operated skylights), but no facility has experience with humidity control systems. When humidity is too low, it can simply be raised by lightly spraying the floor with water on a daily base. Too high humidity sometimes occurs after cleaning the enclosure by spraying the floor and furniture with a water hose. Wiping out the enclosure with water and swipe excess water afterwards, can avoid excessive humidity.

2.1.5 Dimensions

Outdoor enclosure

Survey results indicate that most institutions do have one large outdoor enclosure for their sifaka group. Some institutions additionally provide a second small outdoor holding area for separation of individuals. One institution uses multiple smaller outdoor cages, which are connected but can also be separated whenever necessary. The median volume of sifaka outdoor enclosure in Europe is 553m³.

Table 3 provides information on the dimensions of Sifaka outdoor enclosures in Europe. Both, the enclosure surface, and the enclosure volume are relevant for planning an enclosure which fulfils the specific needs for good husbandry of sifakas.

Table 3 - Outdoor enclosure dimensions

Outdoor enclosure dimensions	Smallest (in surface)	Largest enclosure	Average	Median
Outdoor enclosure **length**	7.1m	35m	20.7m	**21,6m**
Outdoor enclosure **width**	6.2m	22m	8.8m	**6,4m**
Outdoor enclosure **height**	5.9m	12m	5.4m²	**5m**
Outdoor enclosure **surface**	44m²	895m²	212.3m²	**140m²**
Outdoor enclosure **volume**	260m³	10740m³	1812m³	**553m³**

Indoor enclosure

A large indoor enclosure is beneficial as sifakas spend a lot of time in indoor enclosures in European climate. All European institutions provide at least one larger indoor exhibit, which is in some cases visible by the public, and a second smaller indoor holding area, which can be used to separate individuals from the group. Some institutions provide three or more separated indoor holding areas. This is beneficial because it creates more flexibility for shifting or separating animals for observation, feeding, weighing, medication, crate training or capturing when necessary. Separation areas can also be beneficial for hand-rearing sifaka infants in visual contact with the group. It is recommended to have separation areas where separated individuals can still see and interact with the group to make reintroduction easier, but also to have a separation area where an individual which is susceptible to stress, can be isolated from the group to allow it to rest without disturbance. The median volume of sifaka indoor enclosure in Europe is 87m³.

Table 4 provides information on the dimensions of Sifaka indoor enclosures in Europe. Both, the enclosure surface, and the enclosure volume are relevant for planning an enclosure which fulfils the specific needs for good husbandry of sifakas.

Table 4 - Indoor enclosure dimensions

Indoor enclosure dimensions	Smallest enclosure	Largest enclosure	Average	Median
Indoor enclosure **length**	4m	9.5m	7.7m	**8m**
Indoor enclosure **width**	3m	6.5m	3.7m	**3.5m**
Indoor enclosure **height**	2m	3.5m	3.5m	**3.5m**
Indoor enclosure **surface**	15m²	72m²	31m²	**24m²**
Indoor enclosure **volume**	30m³	252m³	114m³	**87m³**

2.2 Feeding

As folivorous primate species, the digestive system of sifakas is highly specialized. Diet in captivity should resemble as much as possible the natural diet in terms of nutritional composition and feeding strategy. The specialized nutritional needs of sifakas were considered when developing a captive diet that ensures that individuals remain healthy, receive sufficient dietary fibre, and avoid obesity. The feeding ecology, dentition, gastrointestinal morphology, and physiology of sifakas confirm that these primates in captivity require a diet similar to that of other leaf-eating primate species (Campbell, 2003). Food items, high in simple sugars and starches should be avoided as they are known to cause loose stools. Diarrohea occurs, when bacterial populations in the digestive tract shift toward those species that preferentially use sugar as a food source over those species that ferment fibrous substrates. When animals have a wide range of food choices, they do not always select the most appropriate food. For example, they will routinely prefer ripe, high-sugar fruits such as oranges or bananas, or high-fat foods such as avocados, to other foods whose characteristics are more similar to their diet in the wild (Campbell, 2003). As other folivorous primates, sifakas have a fairly slow digestion rate. Their digestive tract is longer, and the stomach is larger than the ones of more frugivorous *Lemur* spp. The digestion time for food leaving the stomach is 10-24 hours, and the time for food leaving the intestines is similar. To ensure that the food contains the correct nutrients and especially the correct amount of fibre, it is important that sifakas get access to foliage browse year-round.

2.2.1 Basic diet

Captive sifaka diet mainly consists of fresh browse of different European plants, commercially available folivore primate pellet, vegetables, and nuts/ legumes.

Most institutions use “leaf eater primate pellet” by the company Mazuri as commercial folivore primate food. The pellets can be fed dry or soaked in water or tea. Some European institutions choose to soak leaf eater pellets in black tea. This is done, because the tea is high in tannins and enhanced tannin levels can prevent iron intestinal absorption (Lecu et. al, 2016).

Suitable vegetables include carrot, green beans, cabbage, broccoli, onion, and cucumber. Leavy greens like kale, collards, cabbage or romaine lettuce are provided in addition to fresh browse. Legumes/ nuts can include garbanzo beans or other unsweetened canned or cooked beans, bean sprouts, or unsalted nut mixtures.

Coquerels sifaka (*P. coquereli*) - amounts of food per animal per day

The following should be provided for each adult *P. coquereli* per day in addition to browse (**Table 5**):

Table 5 – Coquerel´s sifaka: food items per animal per day (Haring, 2018)

Amount	Food item	Example
75g	Folivore pellet	Mazuri leaf eater primate diet – Mini Bisquit
30g	Vegetable mix	carrot, green beans, cabbage, broccoli, onion, cucumber
10g	Legumes/ Nuts	bean sprouts, or unsalted nut mixtures
30g	Leavy greens	kale, collards, cabbage, romaine lettuce
Ad libitum	Browse	Several different species at a time

Crowned sifaka (*P. coronatus*) - amounts of food per animal per day

The following should be provided for each adult *P. coronatus* per day in addition to browse (**Table 6**).

Table 6- Crowned sifaka: food items per animal per day (median survey data)

Amount	Food item	Example
60g	Folivore pellet	Mazuri leaf eater primate diet – Mini Bisquit
300g	Vegetable mix	carrot, green beans, cabbage, broccoli, onion, cucumber
70g	fruit	Apple, Pear
10g	Legumes/ Nuts	bean sprouts, or unsalted nut mixtures
30g	Leavy greens	kale, collards, cabbage, romaine lettuce
Ad libitum	Browse	Several different species at a time

Browse summer and winter

As sifakas are a folivorous species, leaves are an important part of sifakas diet in captivity, and it is recommended to offer fresh browse *ad libitum*. A sufficient quantity is about 200-250g per animal per day. The false acacia (*Robinia pseudoacacia*) is a plant species, which is often fed in European institutions, because leaf structure remains stable after freezing and thawing in the winter, and the acceptance of the plant as food for *P. coronatus* is very high; it is then recommended as the main browse species for Crowned sifakas. In contrast, acceptance of false acacia as a food item for *P. coquereli* is low.

In the wild, sifakas are known to feed on about 60-70 different plant species. Therefore, it is highly recommended to always offer sifakas several different species of browse at a time. Many common European tree species are suitable and well accepted, and variation in food stimulates natural behaviour and suits the specific needs of sifakas digestive system. It is recommended to feed browse in the form of 1m to 1.5m-long whole branches, rather than just loose leaves.

In the winter, sifakas should also be fed with a variety of different browse every day. Therefore, fresh browse must be collected in summer, and frozen for use in winter. In spring and autumn, a transition phase between fresh and frozen browse is recommended for at least one to two weeks. Not every plant species is suitable for freezing as leaves can dry out or get soft and squishy, which results in reduced acceptance by the animals. Nevertheless, there is a wide selection of different plant species, that are very well suited for winter feeding (see APPENDIX II – Suitable browse for sifakas). Just like in summer, browse should be served in the form of 1- to 1.5-meter-long whole branches with leaves on them, rather than bare leaves, collected in plastic bags. Branches with leaves are advantageous because sifaka typical feeding behaviour includes grabbing branches with their hands and pulling them within the reach of their mouth. Also, sifakas do not only consume foliage but also feed on bark and thin branches. Willow branches (*Salix* sp.) should be fed carefully as they are high in long fibres, which cannot always be fully digested. This could lead to an ileus due to phytobezoars. Note that it is best to collect, and freeze browse in late spring and early summer, when the quality of foliage is at its peak. About 200-250g of browse of different species per animal per day should be prepared for the winter months when not enough fresh browse is available. Additionally, to frozen browse, fresh branches of evergreen plant species: *Elaeagnus*, *Cotoneaster* and *Rubus* should be offered whenever available.

APPENDIX II – Suitable browse for sifakas provides an overview of different suitable browse, acceptance per plant species, and the suitability to freeze the specific browse for the winter.

2.2.2 Special dietary requirements and food disinfection

The above diet works well for all sifaka over 2000g (see section **1.1.2** Morphology). As soon as a female is in the second half of pregnancy, the amount of food should be increased by 30 % to fulfil the extra needs of the mother. At birth of the infant, the amount should be increased by 50 to 100 % depending of the weight and appetite of the mother. As soon as the infant is eating on its own (3- 4 weeks), a full adult amount of diet should be added (Laidebeure, pers. comm. September 15, 2022).

Food disinfection

Sifakas are very susceptible to diseases. To decrease the risk of exposure to food-borne pathogens such as *Listeria*, *Giardia*, and pathogenic enteric bacteria such as *Escherichia coli* or *Salmonella*, it is recommended to disinfect all food items before feeding it to sifakas.

For disinfection, a dilute chloride bleach solution with a concentration of **0.38-0.4g/L of active CL (=0.12° chlorometric degree)** should be prepared
Do disinfect browse, spread branches with foliage on a clean surface. Rinse of the browse with cold water on both sides. Use a pressure spray bottle to distribute chloride bleach solution on both sides of the foliage. After a reaction time of 5 minutes, spray down the foliage with cold water again, to rinse off any remaining bleach solution.

To disinfect other food items, first rinse the items thoroughly with water to remove gross contaminants. Then place the uncut food items with intact peel in a bath of chloride bleach solution for five minutes, then rinse very thoroughly with cold water, to remove remaining bleach solution. Afterwards, the food is safe to be fed to the sifakas.

2.2.3 Feeding Schedule

In the wild, sifakas have feeding bouts throughout the day. Therefore, multiple feedings mimic their wild feeding strategy, keeping the sifaka's gastrointestinal tracts operating at a level of fill similar to that of wild populations (Campbell, 2003). Fresh browse can be offered *ad libitum* so that sifakas are able to feed on it whenever they want, and to reduce intraspecific aggressions during feeding times. The branches with leaves can be fixed in different places in the outdoor or indoor enclosures. It is important to offer at least as many feeding stations as there are animals in the group (Haring, 2018). Feeding baskets can be used as enriching tool to offer browse in the enclosures (**Figure 10**).

Figure 10 – Basket to feed browse at Tierpark Berlin. © Andreas Pauly

It is recommended to feed sifakas at least three times throughout the day. In European institutions, sifakas are fed between two and four times, with the majority of institutions, offering three meals. The first meal is offered between 8 and 10 am, the last meal is offered around 3 pm. Feeding times are dependent on staff work schedules. Leaf eater pellets should be offered in bowls, fresh vegetables can be distributed on different feeding platforms within the indoor or outdoor enclosures. The animals will consume a large portion of their vegetable ration and their browse immediately after delivery, but they will not consume everything, and smaller feeding bouts will continue throughout the day until the next feeding time.

2.2.4 Water

In nature, sifakas obtain the majority of required water from foraging on browse and licking dew from leaves. In captivity, diet can be lower in moisture, so the animals might drink more frequently.

Sifakas should have access to fresh water at all times. Most institutions use simple water bowls, which are distributed in the indoor enclosures. When sifakas are locked outdoors, a clean water bowl should be present in the outdoor enclosures as well. The bowls can be placed on horizontal platforms within the climbing structures, as sifakas prefer to eat and drink in elevated locations. Some institutions prefer to use water bottles, which can be hung outside the indoor enclosure to the weldmesh, so that sifakas can drink from inside the enclosure. Advantages of water bottles are that they cannot be contaminated by rodents, urine or other hazards, can be replaced without entering the enclosure. An automatic watering system/ nipple drinker is another suitable water source for sifakas (Haring, 2018).

More than one source of water should be provided to allow all members of the troop to drink if they want to. The bowls or bottles should be cleaned and refilled on a daily basis.

2.3 Social structure

2.3.1 Basic social structure

Sifakas live in matriarchal social systems, where a reproductive alpha female exists in each group. Groups usually consist of a dominant female, a breeding male, and their offspring. Group size varies from 2 to 10 individuals. (see section **1.2.4** Behaviour).

In captivity, sifakas should be housed in natural social groupings whenever possible. Groups generally consist of a breeding pair and their immature offspring. Sifakas are very territorial, and adult animals of the same sex are very aggressive towards each other. In the past, several attempts to keep more than one unrelated breeding male or breeding female in a group were unsuccessful (Roullet, 2014). The largest group size of *P. coronatus* in captivity was eight individuals, the largest group size of *P. coquereli* was six individuals (Roullet, 2014; Haring, 2018).

2.3.2 Changing group structure

Generally, a breeding couple can be kept together year-round. Most institutions separate the female from the male shortly before, or directly after birth, to reduce stress. During these temporary separations, visual contact should be maintained (adjust depending on individual behaviours) (see section **2.4.4** Birth).

The first introduction, but also reintroduction of individuals which have not been kept in physical contact for a long period of time, must be done very carefully and gradually. First animals should be kept in adjacent enclosures with visual and olfactory contact. Afterwards, and if no negative reactions were noted, introduction should be monitored by staff, who can immediately interfere if aggressive behaviour occurs. In the beginning, reintroduction should only be done during the day, when staff is present. Only if no agonistic behaviour has been observed in a longer period of time, animals can be kept together over night.

Young females are rejected when they reach sexual maturity. Therefore, it is necessary to remove young females from their group at sexual maturity, at about 2.5 years old when they develop their first oestrus. The change in behaviour 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 from the keepers. Unlike female offspring, young males are generally tolerated longer by the group (only one was rejected in 5 years) (Roullet, 2010). In nature, young males begin to voluntarily disperse to other groups at an age of 3-6 years. Therefore, they can be kept in family groups longer until a suitable new facility is found for continued husbandry. Adult males seem to be more tolerant with their sons than the females are with their daughters (Roullet, 2013).

Even though it is recommended to keep sifakas in family groups, a small population size and skewed sex ratio caused some institutions to keep their male *P. coronatus* in single sex groups or individually without conspecifics. If for example the female of a breeding couple dies, it can be possible to keep the remaining male and its male offspring together until a new breeding female is found. The success of gender-based groups depends on the character of the individuals, and even those groups that work well initially can break down over time (Craig, pers. comm., June 7, 2022). Therefore, single-sex

groups are recommended only for experienced keepers of the species, and there must always be the possibility of separating the animals.

2.3.3 Sharing enclosure with other species

It is possible- but delicate- to mix sifakas with other species of lemurs. Before deciding to mix different species, it is always important to carefully analyse the costs and benefits of the projected exhibit. Mixed species exhibits can be beneficial to optimize resources (especially space for bigger enclosures) and to behaviourally enrich different species. However, there are various potential risks and disadvantages like undesirable behaviours, aggression, stress, and especially issues in management and diet. Sifaka can be dominant over certain lemur species, but strong individual variation in personality is an important determinant of the success of a mix. Generally, sifakas are very laid back with other species but can displace them at feeds if they want to (Craig, pers. comm., April 26, 2022). Until now, no successfully breeding couple has ever been kept in a mixed- species exhibit. For institutions keeping individual sifakas (surplus males) without conspecifics it is recommended to establish a mixed enclosure with other lemur species.

If sifakas are kept in mixed species exhibits, there must be plenty of options to separate individuals, and groups of species within the indoor enclosure. At all times there should be the possibility to provide sufficient indoor and outdoor space to each species separately if needed. Remember that dynamics can change and alterations to groups may be required (Craig, pers. comm., April 26, 2022). Sifakas have specific dietary requirements, some of which differ significantly from those of other lemur species. Therefore, it is recommended to feed different species separately to allow them access to their varied and specialized diet without any competition. This is the only way to ensure that the sifakas consume sufficient amounts of their diet. Leftover food of other lemur species must be removed before the species are reintroduced to ensure that sifakas will not consume leftovers that are too high in sugars and starch.

Various lemur species have been successfully kept together with *P. coronatus* (**Table 7**). Note that any mixing attempt is strongly dependent on the character of the individuals involved, and it cannot be assumed that a mix of different species will work (or not), just based on previous experience elsewhere.

Table 7 - Species kept in mixed exhibits with P.coronatus

Species mixed with *P. coronatus*	Stable combination	Duration
Eulemur collaris	Yes	6 years
Eulemur coronatus	Yes (in two institutions)	4 month, 2 years
Eulemur macaco	Yes	5 years
Eulemur rubriventer	Yes (in two institutions)	1 year; 10 years +
Eulemur mongoz	Yes (in one institution)	2 months
Hapalemur alaotrensis	Yes	around one year
Hapalemur occidentalis	Yes	1 year
Lemur catta	Yes (in three institutions)	6 months; 10 years +; 4months

2.4 Breeding

Sifakas are well known for being difficult to manage in captivity. Especially the process of breeding poses several challenges and only few institutions managed to breed this delicate species successfully and consistently. The time of birth and the first few days of life are highly precarious for sifakas. Mortality records from the Duke Lemur Center indicate that death during parturition and in the first 3 days of life accounts for just over 30% of all deaths in this species in captivity (Haring, 2018).

2.4.1 Mating

As in the wild, there is a defined breeding season in captivity (Roullet, 2014). Mating between sifakas is very rarely observed. It can last from a few seconds to a few minutes. After copulation, sifakas frequently scent mark on the poles with their genitals and obsessively clean their own genitals. **Figure 11** shows the copulation of *P. coronatus*.

Figure 11 - Copulation of P. coronatus*. © F.-G. Grandin, MNHN.*

Oestrus can be observed due to behavioural changes. Sifakas become more active and increased marking can be observed. The male systematically covers the female's markings. Also, the male follows the female when she moves, and the female becomes more aggressive toward the male. Oestrus is usually observed from July to September, with most oestrus occurring in July. Some oestrus episodes have also been recorded in February. They occurred 20 days after the loss of a baby (death of the baby or hand rearing of the baby). Usually there are 3 oestrus periods per reproductive season. Often, female oestrus is not very regular, with one oestrus lasting about 10 days and the next oestrus occurring about one month apart (Roullet, 2011, 2013).

2.4.2 Pregnancy

For *P. coquereli*, a typical gestation ranges between 155 and 165 days. Typical gestation period for *P. coronatus* is between 165 and 170 days. To monitor pregnancy, some institutions have trained their females to voluntarily participate in regular ultrasound examination. More details on this kind of training are outlined in chapter **2.5** Training **and behavioural enrichment**

Nearly two thirds of all neonatal deaths are due to stillbirth of full-term foetuses. Especially in the last weeks before the expected birth, the female should be observed regularly by the staff to early detect problems during the birth process and for instituting early intervention (Haring, 2018). The installation of a camera system can help to monitor the animals as much as possible without disturbing them. Possible problematic situations are as follows:

1. The foetus dies in utero before birth and without significant impact on the health of the mother. The only way to definitely determine this is by performing regular ultrasound scans. Surgical interventions should be avoided as far as possible. Veterinarians should hand medications to induce the expulsion of the dead foetus.
2. The foetus is lively but large (can be detect with an x-ray or ultrasound exam). It is very unlikely that a foetus gets locked in the pelvis (it always finally goes through), but however, it is good to have a vet to assist the parturition if it is particularly long (it would normally last around 1h-1h30, 2h max) and that the female is getting too tired.
3. The parturition can be too long even though the foetus is normal-sized. Assistance of a vet may be required to help parturition or to reanimate the infant.

2.4.3 Contraception possibilities

Contraception is not recommended for both Sifaka species in the EAZA region.

Hormone implants (Deslorelin) have been tested to curb testosterone production. This implant has been used – unsuccessfully - to limit aggressions in male groups (Roullet, 2010). Therefore they are not recommended.

In the Coquerel's sifaka AZA population, nearly two thirds of adult sifaka females are currently being contracepted due to a shortage of space for this species (Haring, 2018). The main contraceptive method is with Depo-Provera injections (5mg/kg) which are administered three times during the breeding season starting 1st of June and continuing every 60 days (i.e. on 1st August and on 1st October) (see section **2.7.9** Gestation and contraception).

2.4.4 Birth

Births occur from November to April, with a peak in December and January (Roullet, 2014). It is recommended to anticipate the date of birth in order to separate the female from the group before giving birth. Otherwise, it should be separated right after birth to prevent accidental injury to the infant by overly zealous group mates. Mother and child should remain separated for 7 days after birth, with visual contact to the group to facilitate reintroduction. Staff must observe mother and child almost continuously during the activity time of the mother to make sure that no nursing times

or signs of weakness are missed (Laidebeure, pers. comm., September 16, 2022). Healthy infants are calm, and either cling to the dam's lower abdomen in a horizontal position or are positioned upright when nursing (see **Figure 12**). If several hours after birth the infant seems restless, moves a lot on the mother's back, neck or legs, vocalizes frequently, and the mother is also moving around and handling it frequently, it means that the infant cannot find and attach to the nipple.

Since there is little experience with the successful rearing of *P. coquereli* in European zoos, the following section recommends the experiences of sifaka keepers from the USA as best practice. The method, developed by the Duke Lemur Center includes a very hands-on approach with a lot of interfering which might appear stressful for the animals (Haring, 2018). However, the Duke Lemur Center made very good experience with it, which is why it is also recommended for *P. coquereli* holders in Europe.

The infant and mother of *P. coquereli* should be physically examinated several hours after birth. Therefore, the infant is separated from the mother and the veterinarian should check the mother for vaginal discharge and perform an abdominal palpation to ensure uterine involution is occurring normally (Haring, 2018). It is also important to check the dam for milk: empty mammary glands indicate that the infant is nursing. Some infants may nurse only on one side for the first few days, so it is not uncommon for the nursed gland to be empty and the un-nursed gland to have milk (Haring, 2009).

This practice is not recommended for *P. coronatus*, as experienced mothers without signs of problems would be unnecessarily stressed. In *P. coronatus*, infants should only be physically checked within the first 36 hours after birth, if surveillance by the staff indicates a problem. This surveillance should last several days as most problems occur between 24 and 72 hours.

It is important to know the birth weight on the first day to determine whether the infant is nursing on the following days. The infant of *P. coquereli* should weigh between 100 and 120g, an infant *of P. coronatus* should weigh between 90 and 100g. Rectal temperature should be 35.5 – 37.2°C (Haring, 2018). If temperature is below 35.5°C, the infant must be warmed up slowly (heat lamp or incubator) in the presence of the mother (in box next to it). The infant should be alert, vocalize when removed from the mother, and eyelids should be fully open. Droopy eyelids are a bad sign and indicate a weak or cold infant (Haring, 2018).

Figure 12 - P. coronatus *infant, clinging to the mother's lower abdomen (Mulhouse Zoo). © Benoît Quintard*

2.4.5 Development and care of young

Most weak or sick infants die on day two or three. Therefore, it is crucial to observe the mother and infant almost continuously by an experienced observer (Laidebeure, pers. comm., September 16, 2022). The infant should always be either in transversal position in the lower abdomen (with the head sometimes on the left side, sometimes on the right side), sleeping most of the day, or in vertical position on the belly when it accesses to the nipples. In a quiet environment, one might hear the suction noises. The mother should regularly, but not excessively, manipulate the infant for grooming or anogenital stimulation. The infant usually vocalizes when she does this, but should remain silent at almost any other time. If the infant is found on the back, on the tail, on the thigh of the mother, if it vocalizes a lot, or if it looks to grasp "loose" or only with one arm, then there is a problem and the infant should be examined immediately. Probably it must be removed for hand rearing. If the infant falls from the mother, don't put it back on the mother, but immediately remove it for hand rearing (Laidebeure, pers. comm., September 16, 2022).

According to the experience of *P. coquereli* holders in the USA the infant should be weighed again on day two, three, five and seven. In the best case, it should weight the same or more as the birthweight on day two. A loss of more than four grams indicates that the infant is not getting enough milk and might be dehydrated, in which case subcutaneous fluids, additional warmth and nutrition are necessary (Haring, 2018). On the 3rd, 5th, and 7th day, examinations of the infant should be repeated for *P. coquereli*. The weight at day three should at least be as much as the birth weight. Again, if this is not the case, subcutaneous fluids, supplemental warmth, and supplemental nutrition may be

necessary (Haring, 2018). From week two to twelve, the infant of *P. coquereli* should be weighted once a week.

According to experience of *P. coronatus*, this invasive technique is not recommended. If hand rearing is not necessary until day three, there are no alert signals and the mother is behaving normal, *P. coronatus* should not be disturbed by regular investigation. Experience showed that most infants were growing well until weaning, if the first three days went successful (Laidebeure, pers. comm., September 16, 2022).

Data from hand-reared P. coronatus infants showed, that the mean daily weight gain is about 3-5g/day for the first 2 months (Laidebeure et. al, 2010). If the infant is stable and gaining weight, the male can be reintroduced from day 7 (if not, a couple of days later). Before reintroduction, both adults should be fed separately. Observe the couple closely for a few hours after reintroduction. If no aggression occurs, continue to observe for a few minutes every hour. Due to the separation, it might occur that the male does not recognize the infant as its own and becomes aggressive or tries to kill it. Therefore, observing staff must be prepared to intervene quickly if necessary (Haring, 2018). In *P. coquereli*, it is observed that the male might take the infant from the female and keep it for extended periods. If the male and female are both calm, the infant can remain on the male for about one hour. If the female does not retrieve it, staff must intervene and return the infant to the mother. In *P. coronatus*, this behaviour is not typically observed. In one case, it was necessary to isolate a father who kidnapped infants from the group, until infants were able to get back to the mother by their own (after 4-5 weeks). During the first week of reintroduction, separate the male at night. The reintroduction of other group members (older siblings) should be started after week 4. If the group contains only one young sibling, reintroductions could take place earlier (Week 3-4). Introductions are best done slowly, an hour or two the first day, then increasing each day until group dynamics are stable (Haring, 2018). Staff must intensively observe the group during reintroduction. Additional enrichments can distract older siblings from focusing all of their attention on the new infant.

From the 3rd to the 6th month after birth, the infant should be weighed every other week; from the 6th month, weighing can be repeated once a month. As other large-bodied lemurs, infants grow relatively slowly. In captivity, infant *P. coronatus* reach 50% of adult body mass at the end of their first year when becoming juveniles and go over 90% of mean adult body mass at 3 years.

2.4.6 Hand-Rearing

Because the European population of Crowned sifaka is very small and vulnerable, the EEP recommends to hand-rear the babies in case of maternal failure. This section contains a hand rearing protocol for sifakas, which is compiled from the information of multiple sifaka keeping institutions. A natural rearing of the young by the mother is always preferable but nevertheless, the necessary equipment and preparations for hand rearing should be in place before the infant is born, and all adult females should be trained to accept cooperative rearing protocol. When hand-rearing sifakas, care should be taken to raise the infants in close contact to the mother, so that they can later be integrated into a group and reproduce. Because it is often impossible to feed the infant while it stays on his mother, the protocol includes training mothers to readily accept the removal of the infant. Infants of cooperative mothers can be fed on the mother after 2-3 months but even then, the infants should be put back in the incubator at night.

During the first weeks of life, the infants stay in an incubator with a foster plush as surrogate to cling to (**Figure 13**). The temperature for the first week is 34°C and decreases slowly (1 to 2°C every week). From birth, they are returned to their mother once or twice a day and eventually fed on her throughout the day to promote their psychological and behavioural development and reducing the risk of rejection/aggression from the mother.

Figure 13 - Incubator for hand-rearing sifaka infants in Besançon Zoo. © Björn Unger

The infants are fed with a milk formula consisting of a mix of kitten/puppy milk and human milk. The usual challenge while crafting the recipe for sifaka milk is to get a high Fat (8-20%) target while keeping dry matter and carbohydrate (3-6%) low, and proteins between 6 and 14%. It is therefore recommended to call EEP vet advisors for help on proportion and choice of adapted ingredients. Lipid and caloric content should always be increased slowly over several days/weeks and first meals are usually fed with diluted formula. **Figure 14** shows an infant of *P. coronatus*, which is fed with artificial milk in an incubator. Animals are weighted every morning. On day one and two, the infants are left with their mother to strengthen maternal bound, and only supplemented with colostrum (milked from the mother) and oral rehydration product based on dextrose, glycine and electrolytes (e.g. Biodiet®). The infant remains in visual contact with its parents when it is in the incubator. Introduction of solid food starts around day 15. Infants are fed ad libitum until 2 months old. Afterwards, the volume of each meal is limited to 10 ml to stimulate solid food intake. Full weaning is achieved between 5 and 5.5 months old. A long period of diarrhoea is encountered in every infant, which might be related to the composition of formula and to its stability over the whole hand-rearing period (Laidebeure et. al, 2010).

Figure 14 – P. coronatus *infant fed with milk in an incubator. © Benoît Quintard*

2.4.7 Population management

The population of Crowned sifakas in Europe is very small and unstable. Only a few zoos succeed in breeding the animals successfully and regularly. Another problem is the skewed sex ratio, with only very few breeding females. Every successful juvenile rearing is therefore crucial to ensure *ex situ* species conservation. Due to the surplus of males, it is recommended to keep the young males in the family groups as long as possible. This is also essential for them to acquire the social skills necessary to be a good breeder.

The population of Coquerel's sifakas in Europe is also very small, with the difference that the population is derived from the larger American SSP population. All couples have a breeding recommendation to enlarge the European population, and to build up a second self-sustaining *ex situ* population.

For details on sifaka contraception, see section **2.7.9** Gestation and contraception.

2.5 Training and behavioural enrichment

2.5.1 Training

It is highly recommended to train sifakas not only because the training is essential for the management of the species, but also because it serves as cognitive enrichment for the animals. Every sifaka should be trained to voluntarily hop on a scale for regular weight control (**Figure 15**).

Figure 15 – P. coquereli *scale training at Tierpark Berlin. © Andreas Pauly*

Furthermore, sifakas should be trained to voluntarily enter crates for transport and separation areas or small extra training areas within the indoor enclosure. It is important to train sifakas individually within a training cage so that they are not disturbed by other group members. Typical training cages are generally connected with the main enclosure through a sliding door, which remains closed when the animals are not trained (**Figure 16**). Sifakas should associate entering the cage with the start of the training process. The cages contain a small door on the front, which can be opened during the process of training. The size of the training cage should allow the sifaka to sit or stand on the ground while clinging on the cage roof (or an extra bar) with their uplifted hands.

Figure 16 - Sifaka training cages at Mulhouse Zoo (left) and Paris Zoo (right). © Björn Unger

Sifakas should be trained to remain in an upright position and clinging on to a pole or the training cage roof, while staff is opening the front door. As soon as the animals have learned to remain in this position, which allows access to their belly, the next steps are to slowly open the front door and touch the sifaka's belly. Once the animal is not scared of being touched on the belly, trainers can simulate the use of an ultrasound scanner (for pregnancy or health checks), or the removal of a clinging baby (see section **2.4** Breeding) (**Figure 17**).

Figure 17 - Sifaka training at Tierpark Berlin. © Andreas Pauly

Figure 18 shows some more sifaka training in Mulhouse Zoo. On the left, the sifaka is trained to voluntarily open its mouth after staff performs a specific gesture with the hand. This is useful for regular teeth control. In the right the sifaka stands in the training cage and grabs a bar on the top of its head. This ensures that the belly is stretched and facing forward. The front opening of the training cage can be replaced by an acrylic panel and a flat panel detector is attached on the back side of the cage. This structure makes it possible to use a portable radiography system.

Figure 18 - Sifaka training to open mouth (left) and for radiography (right) at Mulhouse Zoo. © Benoît Quintard

Regular training allows for good training results, and time and resources should be allocated to allow it. While short training sessions such as regular weight monitoring can be done more frequently, most facilities in Europe conduct longer training sessions once or twice a week. Training sessions should not be too long, so as not to overtax the animals, and should be adjusted to the character and the mood of the individuals. As reinforcement, good experience was made with Mazuri treats, which are fruit flavoured, very low caloric content, but great acceptance in sifakas. Nuts can be used as final rewards after training. The treats which are used for training, should be subtracted from the daily diet. Institutions that have no experience with training sifakas should contact the coordinators for detailed training protocols and advice.

2.5.2 Behavioural enrichment

Enrichment has become a standard tool for improving the welfare of animals in zoos. Advantages of enrichment can include the promotion of more naturalistic behaviours, reducing stereotyped and aberrant behaviours, and improving the general health of a species. For example, active behaviours of different lemur species significantly increase when they got access to environmental enrichment (Fernandez and Timberlake, 2019).

Most sifaka holders in Europe offer different types of enrichment to the animals. The most common types are scattering food and regular cognitive enrichment through training. Other common types of enrichment are habitat alterations (new logs, ropes, shelters) and toys, which can be filled with food items (**Figure 19**). Such toys should be filled using the food that is already part of the animal's daily

diet. It is also not recommended to use rubber toys, as some sifakas have been observed chewing on rubber toys and may swallow parts. Toys from hard plastic on the other hand are safe to use.

Figure 19 - Hard plastic toys which are used as sifaka enrichment tools at Mulhouse Zoo. © Björn Unger

Figure 20 shows an enrichment wall which is hung up at the indoor enclosure wall. This enrichment tool can also be filled with food items which are then collected by the sifakas.

Figure 20 - Enrichment wall which can be filled with food at Heidelberg Zoo. © Björn Unger

Sifakas should only be handled if there is an absolutely necessary reason to do so. Handling sifakas should therefore not be part of any routine management and the capture of an animal should only be carried out by experienced staff.

2.6 Handling

2.6.1 Individual identification and sexing

In order to visually identify each individual, it is possible to look at morphological and anatomical characteristics like the sex of the individual with visual inspection of the genitalia, the morphology, presence of scars/ cuts or details of colouration (different coloured fur on some parts, dark spots on the back or on the neck, facial mask, eye colour) (Pichon et. al, 2010; Pichon et. al, 2012; Pichon and Simmen, 2015; Razanaparany et. al, 2014).

Microchip transponders are mandatory for permanent identification. They are usually placed subcutaneously in the sifaka's shoulder or between the shoulders.

2.6.2 General handling

Well-trained sifakas require less handling, as many reasons for handling (separation, relocation, medication) can be achieved by training individuals to participate voluntarily, which also results in much less stress for the animals.

Half of the sifaka keeping institutions in Europe are training their sifakas specifically for voluntary participation in handling the animals.

2.6.3 Catching/ Restraining

Catching sifakas is only necessary for major veterinary interventions for example after a fight when animals have wounds, which need to be treated, or for pre-shipment examination.

The majority of institutions in Europe is using a net to catch sifakas. Sifakas should be used to enter smaller separation holding areas within the indoor enclosure. This is easily trained by regularly feeding the animals in the separation cage. In the event that an animal needs to be caught, they can be trapped inside the smaller holding area, where a net is utilized to make the final catch (Haring, 2018). More details on physical restraint are highlighted in section **2.7.2** Restraint.

Some institutions prefer to use a squeeze cage to catch/ restrain sifakas. Ideally enclosures are built with a crush tunnel system in which the animals can be captured (**Figure 21**). Sifakas are used to enter this tunnel. In case that an animal needs to be caught, solid sliding doors are used to trap the animal in the tunnel. Afterwards a transport crate can be positioned on a platform next to the tunnel, which is connected by opening another sliding door. If necessary, the solid wall opposite of the crate can be moved to squeeze the sifaka into the crate.

Figure 21 - Passage with crush tunnel system for catching sifakas at Paris Zoo. © Björn Unger

2.6.4 Transportation

Sifakas are best transported in plastic or wooden crates or carriers designed for dogs. A suitable crate is stable, well ventilated, in good condition, and large enough to safely enclose the animal and prevent people from approaching the animal during transport. Within the crate, the sifaka should be able to stand up, turn around and lay down. The crate must have air vents located at least on three sides to avoid blocking the ventilation during the storage of the crates. It is important, that there are no sharp edges (nails, for example) that could cause injury to the animal. Wood chips can be used as bedding material to absorb urine produced during transport. Food and water containers should be affixed inside the crate and possibility to fill them (from outside) should be available for long transports. The crate should always be labelled with the following information: Live animal; Up/Bottom; Feeding/watering instructions.

Before an animal can be transported, it should always be checked by a veterinarian. Pregnant females in their last trimester, diseased and too young animals are not allowed to be transported. Sifakas should generally be transported individually. Any necessary pre-shipment medical testing should be completed, and the health certificate, the medical record, and copies of test results should be included with the shipment.

When travelling by plane, compliance with shipping regulations of the International Air Transport Association (IATA), local and national regulatory agencies, and those of the airline are required. The crate must meet all IATA design requirements. The transport must be planned well, prepared well, and executed effectively. Measures should be taken to minimize the degree of stress for the animal and to make sure the animal cannot injure itself in the crate. To reduce stress, the shortest route must be selected. For long distance, air transport should be the preferred option. Food and water should be provided in transit when the shipment is delayed.

Detailed transportation legislation can be obtained from IATA Live Animal Regulations; 28th Ed.

2.7 Veterinary: Considerations for health and welfare

Compiled by Andreas Pauly, veterinarian at Tierpark Berlin (vet. advisor Coquerel´s sifaka EEP), Sylvie Laidebeure and Alexis Lécu, veterinarians at Paris Zoo (vet. advisors Crowned sifaka EEP)

2.7.1 General remarks about the health status

A sick sifaka can be recognized by:

- Loss of appetite and rejection of preferred food, e.g. nuts.
- Looking sleepy (eyelids half closed) is a severe sign of illness. Please do not wait and inform your responsible veterinarian immediately to examine and treat the sifaka. This is very urgent because sifakas can die very quickly.
- Changes in stool consistency. Please assess the consistency of the faeces on a daily basis with the stool scale (see diseases of the digestive tract).
- Gradual weight loss. Please weigh the sifakas on a regular basis (minimum once a week). The healthy weight range of an adult sifaka is 3.4 - 4.5 kg.

2.7.2 Restraint

a) Safety

Sifakas are generally not aggressive animals, but they have sharp teeth. Moreover, as all prosimians and primates, a specific attention should be paid to pathogens, transmissible to humans (or from humans to sifakas), so the wear of gloves is always recommended, as well as facial mask in case of respiratory disease.

b) Physical restraint

Direct manual restraint is possible by grasping the neck from the ventral side, either from a crate, or even in the enclosure when the animal is attracted to keepers. The wear of Kevlar sleeves is highly recommended. This manipulation is rather straightforward with this species but it should only be done by an experienced keeper (**Figure 22**). It is useful for a close examination of eye, fore-teeth, nostrils, integument, perineal area, masking. It is not recommended but can be used for blood sampling, in which case two restrainers are required for a femoral venipuncture. It is not suitable for abdominal palpation, and obviously not convenient for painful procedures.

Figure 22 - Physical restraint of an adult sifaka. The safe posture is to secure the neck ventrally with one hand and let the sifaka grasp on your forearm like a log. © Paris Zoo-MNHN

c) Chemical restraint

Injectable anaesthesia: Sifakas can be completely immobilised with 0.02 mg/kg BW dexmedetomidine, 0.4 mg/kg BW butorphanol and 0.2 mg/kg BW midazolam i.m. for around 30 minutes. If you plan a longer immobilisation, please give 0.02 mg/kg BW dexmedetomidine and 0.2 mg/kg BW midazolam i.m. as premedication and prolong the anaesthesia with an inhalant agent via mask (isoflurane or sevoflurane: 4-5% induction, 1-2% maintenance). Please note that these inhalant agents have a hypotensive effect in sifakas. It is therefore recommended to monitor blood pressure during anaesthesia (Williams, 2014). Generally, it is recommended to put the lemur on a heating blanket during anaesthesia and to give pre-warmed fluids (e.g. 10 ml/kg BW NaCl (0.9%) s.c.) after it. Dexmedetomidine can be antagonised with 0.2 mg/kg BW atipamezole i.m.

Gaseous anaesthesia: Gaseous anaesthesia is preferred to injectable when the lemurs' facilities allow it. Sifakas can be easily trained to enter a crate and transported to the vet facilities for sevoflurane or isoflurane induction through mask under manual restraint. The induction is done through mask with 8% sevoflurane or 5% isoflurane, then maintenance through tracheal probe (d2.5-3.5) is advised for a long-lasting procedure or after only short fasting with 4-5% sevoflurane or 2-3% isoflurane. Depending on the procedure, adequate analgesic agents should be used (e.g. buprenorphine, meloxicam).

2.7.3 Blood collection

Blood samples can be easily collected from the saphenous or the femoral vein. The saphenous vein is directly located under the skin in the middle of the calf. The femoral vein can be punctured in the

femoral triangle at the inner side of the leg (**Figure 23**). References of blood values are listed in the Species 360 database (https://zims.species360.org).

Figure 23 - Blood sampling on the femoral vein in an adult sifaka. © Paris Zoo-MNHN

2.7.4 Diseases of the digestive tract

a **Diarrhoea**

Sifakas are specialized hindgut fermenter. Bacteria in the enlarged caecum and the spiral colon break down the cellulose in the fibrous diet. The products of this fermentation are volatile fatty acids, which are absorbed through the wall of the large intestine and metabolised in the liver. Therefore, a high fibre diet is essential for an effective gut microbiome. If the diet contains too much carbohydrate (e.g. simple sugars or starch), the microbiome changes and the intestinal pH decreases. This acidic environment leads finally to diarrhoea (Haring, 2018).

A "high fibre – low carb" diet is essential for a good health status.

Diarrhoea can also be caused by pathogenic bacteria and parasites (see infectious diseases), by using antibiotics or by seasonal changes in browse.

The stool consistency should be assessed on a daily base according to the following **stool scale** (Haring, 2018) (**Figure 24**):

0 = pelleted stool (like faeces of rabbits)
1= stool in shape of a log
2 = thick pudding ("cow patty")
3 = thin pudding ("splats")
4 = watery

*Figure 24 - stool consistency 0-1 (**left**), stool consistency 2 (**middle**), stool consistency 3 (**right**), © A. Pauly*

0–1 are normal stool consistencies. Faeces with the consistency 2 are seen often after changing the browse species in the diet. If you find faeces with splats, you should offer at first coconut water. Sifakas like to drink coconut water. It is a very good source to rehydrate the animals. Oral rehydration fluids such as the ones intended for calves are also to consider as primary treatment in case of diarrhoea. If a sifaka reject coconut water or other oral rehydration fluids, or if the faeces are watery, you have to give fluids (25-50 ml/ kg BW NaCl (0.9%) s.c. twice a day (BID)). Rehydration in a sick sifaka is very important, because sifakas are developing quickly an intestinal ileus with subsequent bloating. Giving fluids helps to resolve an ileus.

Beside the fluid therapy you should immediately start with the examination of stool samples, if a sifaka is suffering from diarrhoea. This should include antigen quick tests on *Cryptosporidium*, *Giardia* and *Entamoeba histolytica* as well as a flotation and sedimentation and cultures for the following pathogenic bacteria: *Salmonella*, *Shigella*, *Yersinia*, *Campylobacter, Klebsiella*. Furthermore, the determination of *Clostridium perfringens*- and *Clostridium difficile*- toxins in the faeces can be helpful. First intention antibacterial treatment if a bacterial diarrhoea is suspected should be done with injectable amoxicillin, associated or not with fluoroquinolone (if the animal is in bad condition) or oral azythromycin if you suspect a campylobacteriosis, while waiting for antibiogram. Additional symptomatic treatments include pain killers (meloxicam, 0.2mg/kg p.o. or s.c.), antispasmodics (metamizole), mucosa protectors (smectite) and probiotics (prosoluble for instance).

b **Intestinal ileus**

An intestinal ileus is seen very often in sick sifakas. In most of the cases, it is a paralytic ileus. An obstructive ileus is uncommon in sifakas. The visible signs range from low appetite, decreased amount of stools to complete constipation and apathy. The clinical exam shows a very painful and swollen abdomen, with a digestive tract full of gas. In abdominal radiographs, gas accumulation in the stomach and the intestines indicates an ileus. Please note, that gas in the spiral colon (cranial right quadrant of the abdomen) is often seen in healthy sifaka (Haring, 2018). It is very important to try to resolve immediately an ileus by giving fluids (see section **2.7.4** Diseases of the digestive tract). According to initial images, first action could be to empty stomach (metoclopramide, see below) and the release cranial abdomen pressure.

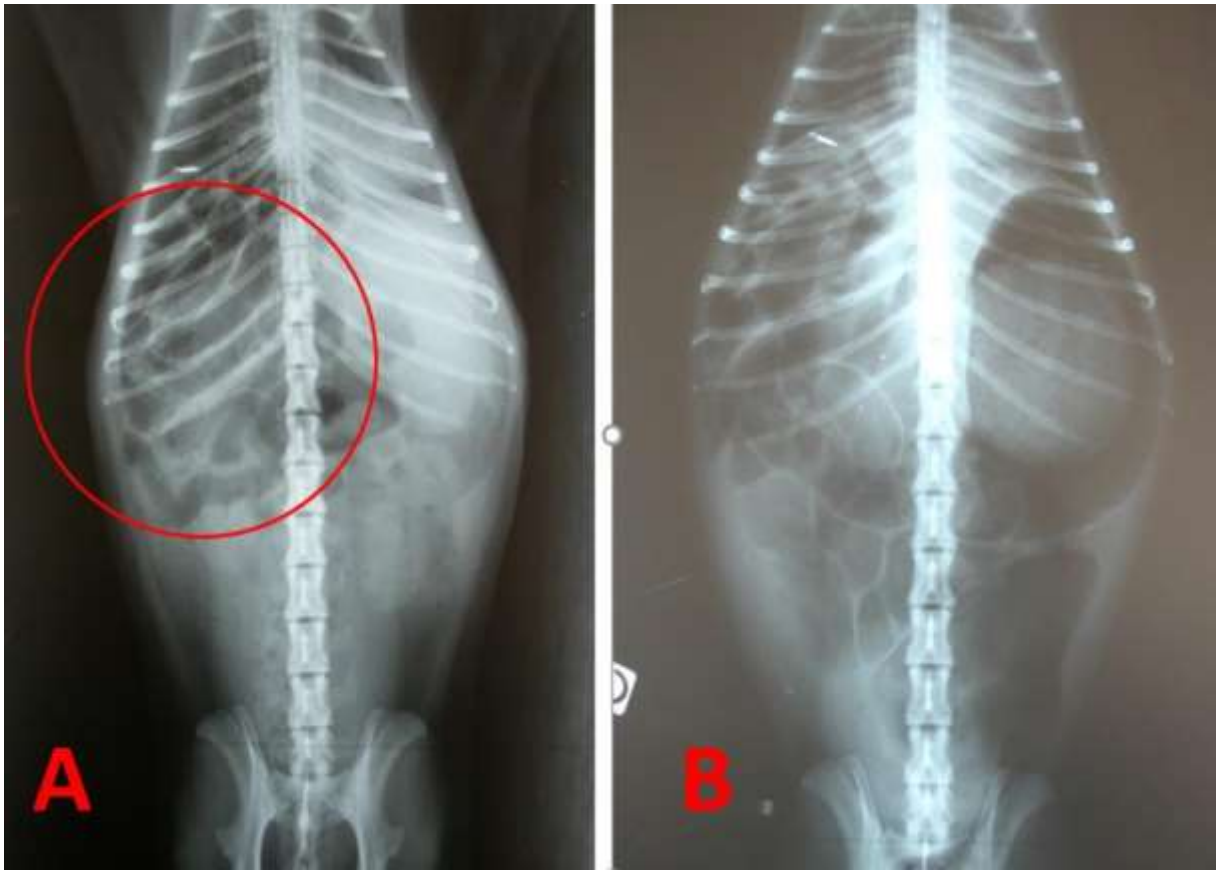

*Figure 25 - Abdominal x-ray image of a healthy Crowned sifaka (Red circle: topographic area of the spiral colon) (**A**). and abdominal x-ray image of a Crowned sifaka with paralytic ileus (**B**). © Paris Zoo-MNHN*

2.7.5 Infectious diseases

Please note that hyperthermia in Sifakas may start over 37.5°C while their usual rectal temperature remains between 35.5°C and 37°C according to their low basal metabolic rate

a **Bacteria**

As with all other lemur species, sifakas can suffer from diarrhoea caused by pathogenic bacteria such as *Campylobacter, Yersinia*, *Salmonella*, *Shigella*, *Klebsiella* and *Clostridium perfringens* and *Clostridium difficile* (see 4.a.). Lethal Tyzzer's disease (*Clostridium piliformis*) has been diagnosed in a 3 months-old young Crowned sifaka (Laidebeure, pers. comm.). If a lemur shows clinical symptoms of an intestinal disease, stool samples should be tested for the above-mentioned bacteria and endoparasites (see parasites). These examinations should also be done before any transfer to another institution. Enteritis caused by pathogen bacteria should be treated with antibiotics according to an antibiogram (see **Table 8**). In severe cases, e.g. watery or bloody diarrhoea, an initial therapy with 25 – 30 mg/kg BW metronidazole p.o. q24h and 25 – 50 ml/kg BW NaCl (0.9%) s.c. BID should be started to prevent enterotoxaemia caused by clostridia, dehydration and ileus with subsequent bloating. Reports of Tuberculosis (TB) are rare in lemurs (Williams, 2014), however they're susceptible to mycobacterial disease, whether from tuberculosis complex or from Non-Tuberculous Mycobacteria. Therefore, intradermal TB tests with Mammalian Old Tuberculin (MOT) (0.1ml i.d. in the upper eyelid) should be done before any transfer between institutions.

b **Bacterial septicaemia**

Systemic infections within 24-48h after detection of the first symptoms are common in sifakas. Therefore, it is very important to react immediately, if a sifaka shows signs of lethargy or anorexia (see section **2.7.1** General remarks about the health status). If a systemic infection is suspected, fluid should be given and therapy with antibiotics should be started (see list of antibiotics). Furthermore, blood should be drawn for a Complete Blood cell Count (CBC) and serum chemistries and additionally for blood cultures (anaerobic and aerobic). Blood cultures help to detect the pathogen bacteria, like at the origin of the septicaemia and are important to choose the right antibiotics for further treatment. Please do not use only antibiotics, effective against gram negative bacteria, because these have a negative impact on the microbiome and can lead to severe diarrhoea. If broad-spectrum antibiotics are given, an oral treatment with metronidazole should be started at the same time to prevent an overgrowth of the gut microbiome with *Clostridium difficile* (Williams, 2002). Please avoid refrain from drug formulations with clavulanic acid in sifakas, unless justified by antibiogram, because this can lead to a disruption of the normal gut microflora and to an overgrowth with *Clostridium difficile* (Williams and Schopler, pers. comm.).

Sifakas are highly susceptible to systemic infections caused by *Listeria monocytogenes* (Cassady et al., 2018). This pathogenic bacterium is found in shallow water, on plants and in silage with faulty fermentation. To prevent severe *Listeria* infections, please note the following recommendations:

- Disinfect the browse and the vegetables before feeding. It is strictly recommended to use the disinfection protocol (see section **2.2.2** Special dietary requirements and food disinfection)
- Avoid stagnant, shallow water in the enclosures
- Do not feed silage, because you cannot ensure that the silage is not contaminated with *Listeria*

c **Parasites**

Endoparasites found in *Propithecus* species in zoological institutions are protozoa, e.g. *Cryptosporidium*, *Giardia* or *Entamoeba histolytica* and nematodes, e.g. *Enterobius* or *Strongyloides*. It is possible to detect protozoal organisms with special antigen quick tests, such as *Giardia-Cryptosporidium* quick tests, but not all brands work equally well, so please contact the veterinary advisors for more details if needed. A negative test should be confirmed by direct examination if the suspicion is strong.

Symptoms: The first sign of a *Giardia* infection in sifakas is mucus covering normal stools or a diarrhoea, but usually no blood. Any production of mucoid stool should be evocative of this pathogen and tested accordingly. Abdominal pain could lead to dysorexia, ileus and rapid dehydration with change in cellulolytic flora of colon. Real problems start when *Giardia* cysts are invading the colon and decreasing the regular protozoans harbored there.

Diagnosis: The diagnosis of a *Giardia* infection is difficult, as the trophozoites can be seen only in very fresh stools (<2-3h), else cysts will be found. This exam requires an experienced technician to notice the cysts or trophozoites. A negative antigenic quick test cannot rule out this disease and direct examination is mandatory to confirm the result.

Management:

- Treatment: if the symptoms appear, the very first thing is to keep the animals well hydrated with an oral rehydration solution (ex. BIODIET®, Elanco, which is highly palatable for lemurs) to slow down the lesions and the disbalance of regular colonic flora. The treatment of choice is albendazole at 50 mg/kg orally for 2 days. Weekly coproscopic checks should be done for the subsequent 3-4 weeks, followed by a 2nd treatment. Tiliquinol/tibroquinol (2.5mg/kg tiliquinol + 5 mg/kg tibroquinol p.o. BID 7 days) is another option. Metronidazole is also effective (25-50 mg/kg p.o. SID 5 days or 12.5-25 mg/kg p.o. BID), but due to its possible side effects on regular flora, should only be used in case of proven *Giardia* infection.
- Prophylaxis: as the infection may pop up following a stressful event such as transfer or introduction of a new animal in a group, it is advised to check stools weekly in these sensitive periods, and to preventively treat with albendazole (50mg/kg, 2 days) if a coproscopic exam is positive, even without clinical signs.

An infestation with nematodes can be diagnosed using flotation and sedimentation in stool samples. *Giardia* or *Entamoeba* infections can be treated with 10mg/kg albendazole p.o. once (prophylaxis), or 50-60 mg/kg albendazole SID for 2 days (treatment), or 2.5 mg/kg tiliquinol + 5mg/kg tribroquinol q12h, 7days (treatment), or 25 – 30 mg/kg BW metronidazole p.o. q24h for 10 days. Nematodes can be treated with 0.2 mg/kg BW ivermectin or moxidectin s.c. Pyrantel, albendazole, mebendazole, or levamisole can also be used (see dosages table below). **Please be cautious to use fenbendazole in a dosage over 25 mg / Kg BW once a day in sifakas, because this can lead to bone marrow suppression with neutropenia. Sifakas with subclinical infections can die due to the depression of the immune system** (Williams and Schopler, pers. comm.).

In the last years many cases of a cysticercosis in lemurs caused by the tapeworm *Taenia crassiceps* were reported from different European zoos. Red foxes (*Vulpes vulpes*) and other European carnivore species are spreading the tapeworm eggs with their faeces. If you see any tumescence in a lemur, please think of the possibility of a cysticercosis. A surgery with radical removal of the cysts only makes sense if these are located under the skin or in the muscles. If inner organs are affected, euthanasia of the lemur is probably unavoidable.

Other protozoal infection such as Neosporosis and Toxoplasmosis are also an often severe parasitic disease in sifakas (Cassady et al, 2018). There are reports of lethal myocarditis due to toxoplasma in crowned sifaka: the *Propithecus* species are likely as susceptible to this protozoan as other prosimians, leading to acute clinical signs. Any sudden weakness associated to neurological signs should trigger toxoplasma/neospora exploration among diagnostic panel. Some individuals may overcome the disease, as antibody towards Toxoplasma can be found occasionally (Page-Karjian et al, 2021).

2.7.6 Other diseases

Urolithiasis: it is very common to find uroliths as “sand” in the bladder during routine ultrasound examination of healthy sifakas, and it should not be considered as pathological, as far as no urinary infection is diagnosed. Tricalcium phosphates, urates, ammonium urates, calcium oxalates and magnesium ammonium phosphates have been reported in healthy animals with urinary pH varying between 6.5 to 8, even in animals of the same group with the same diet.

Dental abscess and dental fracture: As most lemur species, sifakas are prone to develop dental abscesses. Main teeth involved are the canines. The symptoms are classical and, depending on the localization of the abscess, may include: distant and slow animal, swollen part of the maxilla or mandibula, headache (e.g. animal holding its head in its hands), anorexia, exophthalmia, nasal discharge. The diagnosis is based on clinical exam and x-rays. The treatment is classical: surgical removal or root canal treatment, antibacterial and anti-inflammatory treatment. In case of exophthalmia, it is necessary to pay a special attention to the cornea integrity. One case reports corneal ulcer following exophthalmia due to dental abscess of a premolar. The treatment included topical chloramphenicol ointment and transient surgery (tarsorrhaphy).

2.7.7 Vaccination

The use of vaccines is not generally recommended in sifakas. It depends on the pathogens in each institution. If there is a risk for rabies infections, the application of a killed vaccine is useful.

2.7.8 Zoonosis

Zoonotic pathogens can be transmitted between sifakas and humans as in all other primates. Please keep in mind that this is a big issue in walk-through enclosures as well. Examples of zoonoses are: *Giardia*, *Entamoeba histolytica*, *Campylobacter*, *Yersinia*, *Shigella*, *Klebsiella* and zoonotic *Escherichia coli* strains. Sifakas and humans do share a very similar genomic sequence of the cell receptor ACE2, which is also a key step in virus cell entrance. Therefore, they are predicted as being at high risk of cross infection by SARS-Cov-2, like some other prosimians or primates. However, since the start of the pandemic, there have been no reports of either sifaka or other lemurs that were found PCR or seropositive to SARS Cov2 (Melin et al., 2021). Nonetheless, an effective sanitary protocol is recommended. This should include the wearing of latex gloves during preparation of food and cleaning the enclosures and the wearing of face masks when in close contact to lemurs, e.g. during training sessions. Visitors should wear face masks in walk-through enclosures and should not be allowed to touch the animals. Moreover, veterinarians and their staff should also wear protective equipment, especially during key actions such as tracheal intubation or upper respiratory close exam.

2.7.9 Gestation and contraception

Oestrus occurs between July and September, and pregnancy can be assessed through ultrasound examination and regular weighing of the female. Females can be trained to accept ultrasound exam without anaesthesia, and references of foetal growth (measurement of biparietal diameter and femur length) throughout the gestation are available by contacting the veterinary advisors of the Crowned sifaka EEP (unpubl. data). Specific guidelines regarding Crowned sifaka training are described in section **2.5Training**), in order to be prepared to a hand-rearing protocol that maintains infant-mother contact if needed.

For chemical contraception, it is recommended to use medroxyprogesterone (e.g. Depo-Provera®): 5 mg/kg BW q60 days in the breeding season (total of 3 contraceptive shots, start: 1st of June) (Keith et al., 2020). Please note, that the use of medroxyprogesterone can lead to an increase in weight. The

use of contraception should be validated by the EEP and requires a close monitoring (regular uterine assessment) if used over several breeding seasons.

2.7.10 Formulary

Table 8 - Antibiotics and antifungal agents recommended for Propithecus

drug	dosage (mg/kg BW)	remarks
Amoxicillin	10-20 p.o. BID	10-20 mg/kg BW i.m. q48 h
Azithromycin	5-10 p.o. q24 h	20 mg/kg BW p.o. q24h 2 weeks for Campylobacteriosis (if resistant to other drugs)
Cefovecin	8 i.m. q14 days	-
Ceftiofur crystalline free acid	5 i.m. once	-
Cephalexin	30 i.m., p.o. SID or in 2pq	-
Ciprofloxacin	10 p.o. BID	-
Clindamycin	10 p.o. BID	-
Doxycycline	5-10 p.o. BID	-
Enrofloxacin	5 mg/kg i.m., p.o. SID	oral acceptance may be low
Ketoconazole	12.5 p.o. SID	2-4 weeks for Dermatophytosis
Lincomycin	20 i.m. once	-
Lufenuron	17 p.o. once a month	Dermatophytosis
Metronidazole	25-50 p.o. SID	anaerobic bacteria/protozoa
Penicillin G **Dihydrostreptomycin**	10000 UI/kg BW q48-72h 20 mg/kg BW q48-72h	-
Tetracycline	60 mg/animal genital oblet	abortion/genital infection

Table 9 - Antiparasitic drugs recommended for Propithecus

drug	dosage (mg/kg BW)	remarks
Albendazole	10 p.o. once 50-60 p.o. SID 2 days	*Giardia*/nematodes prophylaxis *Giardia*
Fenbendazole		to be used carefully as it may lead to aplastic anemia
Ivermectin	0.2 s.c. or p.o. once	nematodes, ectoparasites
Metronidazole	25-50 p.o. q24 h	Protozoa to be used carefully as it may lead to intestinal protozoan flora imbalance
Moxidectin	0.2 s.c.	nematodes, ectoparasites
Oxfendazole	11 p.o.SID 3 days	nematodes
Pyrantel pamoate	6 p.o. once	nematodes
Tiliquinol / Tibroquinol	2.5mg/kg Tiliquinol+ 5mg/kg Tibroquinol p.o. BID 7 days	*Giardia*

Table 10 - Miscellaneous drugs recommended for Propithecus

Drug	dosage (mg/kg BW)	remarks
Dipyrone (=metamizole = dipyrone) **+/- Butylscopolamine**	100 i.m. or s.c. SID 0.8 i.m. or s.c. SID	Antispasmodic (intestinal)
Domperidone	0.5 p.o. BID 3 days	ileus
Doxapram	2 i.m., i.v. or i.n.	respiratory stimulant
Furosemide	0.3 i.m. SID	diuretic
Gabapentin	8-10 BID	Arhtrosis-related pain.

Ibuprofen	10 p.o. BID 3-5 days	analgesic, antipyretic
Meloxicam	0.2 s.c. or p.o. SID	analgesia
Methionine	100mg/animal p.o. SID several weeks	hepatoprotective (hemosiderosis)
Methionine **Inositol** **Choline**	10 mg/animal p.o. BID 10 mg/animal p.o. BID 3.5 mg/animal p.o. BID	hepatoprotective (hemosiderosis), dosage for adult sifaka
Hydrochlorothiazide	2.5 mg/kg i.m., i.v. or s.c.	diuretic
Loperamide	0.03 p.o. SID or BID	Diarrhoea cautious use as repetition, as it slows peristaltic down
Metoclopramide	0.6 i.m.	Gastric discharge ileus
Ornithine **Citrulline** **Arginine** **Betaïne** **Sorbitol**	15 p.o. BID 10 p.o. BID 40 p.o. BID 15 p.o. BID 200 p.o. BID	hepatoprotective (hemosiderosis)
Paraffine oil	5-10 ml/animal p.o. SID or BID, 3-4 days	gastro-intestinal obstruction; no spontaneous intake recorded
Prifinium	5 p.o. SID 2 days	diarrhoea
Racecadotril	1.5 p.o. TID max 7 days	diarrhoea (especially useful in juveniles and hand-reared babies)
Sodium dioctylsulfosuccinate (Sorbicarax ND, Vetoquinol)	5 µg/kg p.o. once	laxative
Sorbitol **Sodium citrate** **Sodium laurylsulfoacetate**	1 baby dose, intra-rectal	laxative, used in adults and babies (0,2 ml/300g)
Tolfenamic acid	1-2 i.m. q48h (max 5 inj.)	analgesia

2.8 Recommended research

In 2022, the following research project will be conducted and supported by the Coquerel´s sifaka EEP: **Ecological niches of *Propithecus coronatus* and *Propithecus* coquereli in Madagascar and their conservation implications**

PRINCIPAL INVESTIGATOR: Josia Razafindramanana, IMPACT Madagascar, University of Antananarivo (Madagascar)

The projects' main goal is to describe the ecological niches of *P. coronatus* and *P. coronatus* and to update conservation planning accordingly.

Therefore, specific aims of the project are:

- To compare the forest structure, plant species diversity and phenology between continuous and fragmented forest and to evaluate edge effects in order to establish food availability and habitat suitability (including for locomotion and sleep sites) for *P. coronatus* and *P. coquereli*
- To determine the population density of both species in the study sites
- To compare diet (species and plant parts consumed) between continuous and fragmented forest
- To compare activity budgets and group cohesion between continuous and fragmented forest
- To compare home range size and daily path length between continuous and fragmented forest.
- To investigate impact of distance from the forest edge on ranging behaviour.

Another research project about the composition of the **Coquerel´s sifaka microbiome during wintertime and summertime in EAZA zoos**:

PRINCIPAL INVESTIGATOR: Franziska Zölzer (initiated by Dr. Andreas Pauly) from Goethe University Frankfurt/Main (Germany)

All institutions, keeping Coquerel´s sifakas in the EAZA region (Tierpark Berlin, Cologne Zoo, Chester Zoo) are participating in this study.

Currently a research on hormone analysis in female Coquerel's sifakas is executed in collaboration with Tierpark Berlin and Cologne Zoo to determine the exact sexual cycle.

PRINCIPAL INVESTIGATOR: Jella Wauters, Institute for Zoo and Wildlife Research

---

Study on the effects of stress on behavior of Coquerel's Sifaka

PRINCIPAL INVESTIGATOR: Kiran Mahli, University of Cologne

A study on the **gut microbiome of *P. coronatus*** has been started in 2021/22

PRINCIPAL INVESTIGATOR: Francis Cabana, Wildlife Nutritionist

The aim is to conduct proper intake study and medical reports of Sifakas in present and recent past.

For *P. coronatus*, it is recommended to conduct a study where the deviated birth sex ratio and neonatal deaths are investigated.

Section 3: References

Andriantomopohavana, R., Zoanarivelo, J., Randriamampionona, R., Razafindraibe, J., Brenneman, R., & Louis, E. J. (2006). A preliminary study on resident lemur populations in the Mariarano Classified Forest. *Lemur News*, *11*, 21–24.

Brockman, D. K. (1999). Reproductive Behavior of Female *Propithecus verreauxi* at Beza Mahafaly, Madagascar. *International Journal of Primatology*, *20*(3), 375–398. https://doi.org/10.1023/a:1020500804442

Brockman, D. K., & Whitten, P. L. (1996). Reproduction in free-ranging *Propithecus verreauxi*: Estrus and the relationship between multiple partner matings and fertilization. *American Journal of Physical Anthropology*, *100*(1), 57–69.

Cassady, K., Cullen, J. M., & Williams, C. V. (2018a). MORTALITY IN COQUEREL'S SIFAKAS (*PROPITHECUS COQUERELI*) UNDER HUMAN CARE: A RETROSPECTIVE SURVEY FROM THE DUKE LEMUR CENTER 1990–2015. *Journal of Zoo and Wildlife Medicine*, *49*(2), 315–323. https://doi.org/10.1638/2017-0242.1

Charles-Smith, L. E., Cowen, P., & Schopler, R. (2010). Environmental and Physiological Factors Contributing to Outbreaks of Cryptosporidium in Coquerel's Sifaka (*Propithecus coquereli*) at the Duke Lemur Center: 1999–2007. *Journal of Zoo and Wildlife Medicine*, *41*(3), 438–444. https://doi.org/10.1638/2009-0160.1

Eppley, T. M., Santini, L., Tinsman, J. C., & Donati, G. (2020). Do functional traits offset the effects of fragmentation? The case of large-bodied diurnal lemur species. *American Journal of Primatology*, *82*(4). https://doi.org/10.1002/ajp.23104

Fernandez, E. J., & Timberlake, W. (2019). Selecting and Testing Environmental Enrichment in Lemurs. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02119

Fichtel, C., & Kappeler, P. M. (2010). Variation in the Meaning of Alarm Calls in Verreaux's and Coquerel's Sifakas (*Propithecus verreauxi, P. coquereli*). *International Journal of Primatology*, *32*(2), 346–361. https://doi.org/10.1007/s10764-010-9472-9

Fichtel, C., & van Schaik, C. P. (2006). Semantic Differences in Sifaka (*Propithecus verreauxi*) Alarm Calls: A Reflection of Genetic or Cultural Variants? *Ethology*, *112*(9), 839–849. https://doi.org/10.1111/j.1439-0310.2006.01239.x

Gauthier, C. A., Deniaud, J. L., Leclerc-Cassan, M., Rakotomalala, M., & Razafindramanana, S. (2000). Biologie des Propithèques couronnés (*Propithecus coronatus*) in situ : résultats préliminaires. *Diversité et Endémisme à Madagascar*, 177–180.

Groves, C. P., & Helgen, K. M. (2007). Craniodental Characters in the Taxonomy of *Propithecus*. *International Journal of Primatology*, *28*(6), 1363–1383. https://doi.org/10.1007/s10764-007-9226-5

Haring, D. (2018). *International Propithecus coquereli (Coquerel´s sifaka) studbook.*

Haring, D. M. (1988). Natural history and captive management of Verreaux's sifaka. *International Zoo Yearbook*, *27*, 125–134.

Harpet, C., Navarro, L., & Ramanankirahina, R. (2008). Rôle et implications des croyances et des savoir-faire locaux dans les programmes de conservation : exemple d'un site à lémuriens sacrés au cœur de la station forestière à usages multiples d'Antrema (pays Sakalava, Madagascar). *Revue d'Ecologie, Terre et Vie, Société Nationale de Protection de La Nature*, *63*(3), 289–292.

Hartng, D. M. (2007). Natural history and captive management of Verreaux's sifaka *Propithecus verreauxi*. *International Zoo Yearbook*, *27*(1), 125–134. https://doi.org/10.1111/j.1748-1090.1988.tb03205.x

Irwin, M. T., Junge, R. E., Raharison, J. L., & Samonds, K. E. (2010). Variation in physiological health of diademed sifakas across intact and fragmented forest at Tsinjoarivo, eastern Madagascar. *American Journal of Primatology*, *72*(11), 1013–1025. https://doi.org/10.1002/ajp.20847

Junge, R. E., & Louis, E. E. (2005). BIOMEDICAL EVALUATION OF TWO SYMPATRIC LEMUR SPECIES (*PROPITHECUS VERREAUXI DECKENI* AND *EULEMUR FULVUS RUFUS*) IN TSIOMBOKIBO CLASSIFIED FOREST, MADAGASCAR. *Journal of Zoo and Wildlife Medicine*, *36*(4), 581–589. https://doi.org/10.1638/05-025.1

Keith, B., Byrnes, K., & Cara, G. B. (2020). *Coquerel´s sifaka (Propithecus coquereli) AZA Species Survival Plan – Yellow Program.*

Kun-Rodrigues, C., Salmona, J., Besolo, A., Rasolondraibe, E., Rabarivola, C., Marques, T. A., & Chikhi, L. (2014). New density estimates of a threatened sifaka species (*Propithecus coquereli*) in Ankarafantsika National Park. *American Journal of Primatology*, *76*(6), 515–528. https://doi.org/10.1002/ajp.22243

Laidebeure, S., Lécu, A., Quintard, B., Gomis, D., & Moisson, P. (2010). *Hand-rearing a Crowned sifaka (Propithecus coronatus): milk formulation, infant growth, comparison with mother-reared animals and previous protocols used in Propithecus sp.* 6 EUROPEAN ZOO NUTRITION CONFERENCE, Barcelona, Spain.

Lawler, R. R., Richard, A. F., & Riley, M. A. (2005). Intrasexual selection in Verreaux's sifaka (*Propithecus verreauxi verreauxi*). *Journal of Human Evolution*, *48*(3), 259–277. https://doi.org/10.1016/j.jhevol.2004.11.005

Lecu, A., Leidebeure, S., & Heissat, F. (2006, May). *Crowned verreaux's sifaka (Propithecus verreauxi coronatus) nutrition in captivity. First results.* 6th EAZWV scientific meeting, Budapest.

Lewis, R. J. (2005). Sex differences in scent-marking in sifaka: Mating conflict or male services? *American Journal of Physical Anthropology*, *128*(2), 389–398. https://doi.org/10.1002/ajpa.20206

Lewis, R. J. (2009). Grooming patterns in Verreaux's sifaka. *American Journal of Primatology*, *72*(3), 254–261. https://doi.org/10.1002/ajp.20776

Louis, E. E., Bailey, C. A., Sefczek, T. M., King, T., Radespiel, U., & Frasier, C. L. (2020). *Propithecus coquereli*, Coquerel's Sifaka. *The IUCN Red List of Threatened Species*, *2020: e.T18355A115572275.* https://dx.doi.org/10.2305/IUCN.UK.2020-2.RLTS.T18355A115572275.en.

McGoogan, K. C. (2013). *Edge Effects on the Behaviour and Ecology of Propithecus Coquereli in Northwest Madagascar*. Bibliothèque et Archives Canada.

Melin, A. D., Orkin, J. D., Janiak, M. C., Valenzuela, A., Kuderna, L., Marrone, F., Ramangason, H., Horvath, J. E., Roos, C., Kitchener, A. C., Khor, C. C., Lim, W. K., Lee, J. G. H., Tan, P., Umapathy, G., Raveendran, M., Alan Harris, R., Gut, I., Gut, M., . . . Higham, J. P. (2021). Variation in predicted COVID-19 risk among lemurs and lorises. *American Journal of Primatology*, *83*(6). https://doi.org/10.1002/ajp.23255

Mittermeier, R. A., Ganzhorn, J. U., Konstant, W. R., Glander, K., Tattersall, I., Groves, C. P., Rylands, A. B., Hapke, A., Ratsimbazafy, J., Mayor, M. I., Louis, E. E., Rumpler, Y., Schwitzer, C., & Rasoloarison, R. M. (2008). Lemur Diversity in Madagascar. *International Journal of Primatology*, *29*(6), 1607–1656.

Mittermeier, R. A., Louis, E. E., Richardson, M. J., Schwitzer, C., Langrand, O., Rylands, A. B., Hawkins, F., Rajaobelina, S., Ratsimbazafy, J., Rasoloarison, R., Roos, C., Kappeler, P. M., & MacKinnon, J. (2010). *Lemurs of Madagascar*. Conservation International.

Mittermeier, R. A., Rylands, A. B., & Wilson, D. E. (2013). *Handbook of the Mammals of the World: Vol. Volume 3 Primates*. Lynx Edicions.

Muehlenbein, M. P., Schwartz, M., & Richard, A. (2003). PARASITOLOGIC ANALYSES OF THE SIFAKA (*PROPITHECUS VERREAUXI VERREAUXI*) AT BEZA MAHAFALY, MADAGASCAR. *Journal of Zoo and Wildlife Medicine*, *34*(3), 274–277.

Page-Karjian A., Norton T.M., Louis E.E., Junge R.E (2021). Biomedical evaluation of the golden-crowned Sifaka (*Propithecus tattersalli*) in Daraina, Madagascar. J Zoo Wildl Med.52(2):726-731

Petters, J. J., & Andriatsarafara, F. (1978). Conservation status and distribution of lemurs in the west and northwest of Madagascar. *Primate Conservation*, *8*, 169–171.

Pichon, C. (2012). Contraintes écologiques et sociales sur l'acquisition alimentaire du propithèque couronné (*Propithecus coronatus*) dans une forêt sèche semi-caducifoliée du nord-ouest de Madagascar. *Thèse, Ecole Doctorale Sciences de La Nature et de l'Homme*, 179pp.

Pichon, C., Ramanamisata, R., Tarnaud, L., Bayrat, F., Hlandik, A., Hlandik, C. M., & Simmen, B. (2010). Feeding ecology of the Crowned sifaka (*Propithecus coronatus*) in a coastal dry forest in northwest Madagascar (SFUM, Antrema). *Lemur News*, *15*, 43–47.

Pichon, C., & Simmen, B. (2015). Energy management in Crowned sifakas (*Propithecus coronatus*) and the timing of reproduction in a seasonal environment. *American Journal of Physical Anthropology*, *158*(2), 269–278. https://doi.org/10.1002/ajpa.22786

Pochron, S. T., Fitzgerald, J., Gilbert, C. C., Lawrence, D., Grgas, M., Rakotonirina, G., Ratsimbazafy, R., Rakotosoa, R., & Wright, P. C. (2003). Patterns of female dominance in *Propithecus diadema* edwardsi of Ranomafana national park, Madagascar. *American Journal of Primatology*, *61*(4), 173–185. https://doi.org/10.1002/ajp.10119

Pochron, S. T., Morelli, T. L., Terranova, P., Scirbona, J., Cohen, J., Kunapareddy, G., Rakotonirina, G., Ratsimbazafy, R., Rakotosoa, R., & Wright, P. C. (2005). Patterns of male scent-marking in *Propithecus edwardsi* of Ranomafana National Park, Madagascar. *American Journal of Primatology*, *65*(2), 103–115. https://doi.org/10.1002/ajp.20102

Rakotonirina, L. H. F., Randriantsara, F., Rakotoarisoa, A. H., Rakotondrabe, R., Razafindramanana, J., Ratsimbazafy, J., & King, T. (2013). A Preliminary Assessment of Sifaka (*Propithecus)* Distribution, Chromatic Variation and Conservation in Western Central Madagascar. *Primate Conservation*, *28*(1), 43–53. https://doi.org/10.1896/052.028.0116

Ramilison, M. L., Andriatsitohaina, B., Chell, C., Rakotondravony, R., Radespiel, U., & Ramsay, M. S. (2021). Distribution of the critically endangered Coquerel's sifaka (*Propithecus coquereli*) across a fragmented landscape in NW Madagascar. *African Journal of Ecology*, *59*(2), 350–358. https://doi.org/10.1111/aje.12844

Rasambainarivo, F. T., Junge, R. E., & Lewis, R. J. (2014). BIOMEDICAL EVALUATION OF VERREAUX'S SIFAKA (*PROPITHECUS VERREAUXI*) FROM KIRINDY MITEA NATIONAL PARK IN MADAGASCAR. *Journal of Zoo and Wildlife Medicine*, *45*(2), 247–255.

Razafindramanana, J., & Rasamimanana, R. (2010). Discovery of Crowned sifaka (*Propithecus coronatus*) in Dabolava, Miandrivazo, Menabe Region. *Lemur News*, *15*, 23–25. https://scholar.google.com/scholar_lookup?title=Discovery+of+Crowned+sifaka+(*Propithecus+coronatus*)+in+Dabolava,+Miandrivazo,+Menabe+Region.&volume=15&publication_year=2010&pages=23-25

Razafindramanana, J., & Roullet, D. (2011). Gestion en métapopulation de *Propithecus coronatus*: une approche originale et multidisciplinaire pour la conservation d'une espèce en danger à Madagascar1. *Revue de Primatologie*, *3*. https://doi.org/10.4000/primatologie.721

Razafindramanana, J., Salmona, J., King, T., Roullet, D., Eppley, T. M., Sgarlata, G. M., & Schwitzer, C. (2020). *Propithecus coronatus*, Crowned Sifaka. *The IUCN Red List of Threatened Species*, *2020 e.T18356A115572495.* https://dx.doi.org/10.2305/IUCN.UK.2020-2.RLTS.T18356A115572495.en.

Razanaparany, P. T., Pichon, C., Rabetafika, L., Bayrat, F., & Ratsimbazafy, J. (2014). Female dominance in *Propithecus coronatus* over the dry season in the dry forest of Antrema, northwest Madagascar. *Lemur News*, *18*, 10–13.

Richard, A. F. (1976). Preliminary observations on the birth and development of *Propithecus verreauxi* to the age of six months. *Primates*, *17*(3), 357–366. https://doi.org/10.1007/bf02382791

Richard, A. F. (1985). Social boundaries in a Malagasy Prosimian, the Sifaka (*Propithecus verreauxi*). *International Journal of Primatology*, *6*(6), 553–568. https://doi.org/10.1007/bf02692288

Richard, A. F., Rakotomanga, P., & Schwartz, M. (1993). Dispersal by *Propithecus verreauxi* at Beza Mahafaly, Madagascar: 1984–1991. *American Journal of Primatology*, *30*(1), 1–20. https://doi.org/10.1002/ajp.1350300102

Roullet, D. (2014). The European Captive Population of Crowned Sifaka: 25 Years of Management. *Primate Conservation*, *28*(1), 99–107. https://doi.org/10.1896/052.028.0118

Salmona, J., Jan, F., Rasolondraibe, E., Besolo, A., Ousseni, D., Beck, A., Zaranaina, R., Rakotoarisoa, H., Rabarivola, C., & Chikhi, L. (2014). Extensive survey of the Endangered Coquerel's sifaka *Propithecus coquereli*. *Endangered Species Research*, *25*(2), 175–183. https://doi.org/10.3354/esr00622

Salmona, J., Rasolondraibe, E., Jan, F., Besolo, A., Rakotoarisoa, H., Meyler, S. V., Wohlhauser, S., Rabarivola, C., & Chikhi, L. (2014). Conservation Status and Abundance of the Crowned Sifaka (*Propithecus coronatus*). *Primate Conservation*, *28*(1), 73–83. https://doi.org/10.1896/052.028.0122

Tattersall, I. (1986). Notes on the Distribution and Taxonomic Status of Some Subspecies of *Propithecus* in Madagascar. *Folia Primatologica*, *46*(1), 51–63. https://doi.org/10.1159/000156236

Thalmann, U., Kummerli, R., & Zaramody, A. (2002). Why *Porpithecus verreauxi deckeni* and *P.v. coronatus* are valid taxa – quantitative and qualitative arguments. *Lemur News*, *7*, 11–16. https://www.dpz.eu/fileadmin/content/Bibliothek/Downloads/Lemur_News/Lemur%20News%207%20%282002%29.pdf

Williams, C. V. (2002). Spontaneous Clostridium difficile-associated diarrhea in lemurs. *Proceedings of the American Association of Zoo Veterinarians*, 359–364.

Williams, C. V. (2014). Prosimians. *Fowler´s Zoo and Wild Animal Medicine; Miller R. E., Fowler M. E.*, *8*, 291–301.

Wright, P. C. (1999). Lemur traits and Madagascar ecology: Coping with an island environment. *American Journal of Physical Anthropology*, *110*(S29), 31–72.

Wright, P. C., King, S. J., Baden, A., & Jernvall, J. (2008). Aging in Wild Female Lemurs: Sustained Fertility with Increased Infant Mortality. *Primate Reproductive Aging*, 17–28. https://doi.org/10.1159/000137677

APPENDIX I – Enclosure plant list

Table 11 shows different plant species used in sifaka enclosures in the left column. The right column informs whether the respective plant species is eaten by the sifakas.

Table 11 - Plant species in European sifaka enclosures

Plant species	Eaten by sifakas?
Achnatherum calamagrostis	No
Akebia quinata	Yes
Alyssum spinosum	/
Amorpha canescens	/
Anaphalis margaritacea	/
Arundo donax	No
Bamboo (different species)	Most sifaka do not eat it
***Buddleia* sp.**	No
Buddleia globosa	/
Caesalpina gilliesii	/
Caragana arborescens	No
Caragana arborescens (edge)	/
Cercis chinensis	/
Chitalpa tashkentensis	/
Cladastris lutea	/
Colutea arborescens	/
Convolvulus cneorum	/
***Coronilla emerus* (edge)**	/
Cotoneaster salicifolius floccosus	No
Dorycnium suffruticosum	/
Elaeagnus angustifolia	/
***Festuca* sp.**	No
Grass (different species)	No
Hipophae rhamnoides	/
Hydrangea petiolaris	No
Hydrangea petiolaris	No
***Kniphofia* sp.**	/
Koelreutheria paniculata	/
***Lycium barbarum* (edge)**	/
***Magnolia* sp.**	Yes
Magnolia grandiflora galonspiere	No
Magnolia tripetala	No
***Mahonia* sp.**	No
Paliurus spina-christi	/
Phyllostachys bisetti	No
***Platanus* sp. (edge)**	Yes
Poncirus trifoliata	/
Robinia hispida macrophylla	No
Stipa tenuissima	No
***Teucrium fruticans* (edge)**	/
***Yucca* sp.**	No

APPENDIX II – Suitable browse for sifakas

Table 12 provides an overview of different suitable browse, acceptance per plant species, and the suitability to freeze the specific browse for the winter.

Table 12 - suitability of different European browse for sifakas

browse species	scientific name	good acceptance	moderate acceptance	bad acceptance	remarks	Quality after freezing
Common maple	*Acer campestre*	**x**			favourite	excellent quality
Hornbeam	*Carpinus betulus*	**x**			favourite	
Loquat	*Eriobtrya japonica*	**x**				
Japanese snowbush	*Lonicera japonica*	**x**				
Magnolia	*Mognolia* sp.	**x**			outside exhibit, leaves	
Common oak	*Quercus robur*	**x**				
Red oak	*Quercus rubra*	**x**			outside exhibit, bark	
Sumac	*Rhus* sp.	**x**			favourite	good to excellent quality
Staghorn sumac	*Rhus typhina*	**x**			favourite	excellent quality
Rose	*Rosa* sp.	**x**			favourite	excellent quality
Lavender willow	*Salix eleagnos*	**x**				
Weeping willow	*Salix sepulcralis*	**x**				
Osier	*Salix viminalis*	**x**				
Viburnum	*Viburnum plicatum*	**x**				
Hazelnut	*Corylus avellana*	**x**	**x**			
Plane tree	*Platanus* sp.	**x**	**x**		outside exhibit, leaves	good to excellent quality
False acacia	*Robinia pseudoacacia*	**x**	**x**			excellent quality
Judas tree	*Cercis* sp.	**x**		**x**	favourite	
Firethorn	*Pyracantha coccinea*	**x**		**x**	favourite	
Blackberry	*Rubus fructicosus*	**x**		**x**	only flowers	
Norway maple	*Acer platanoides*		**x**			good to excellent quality
Gray alder	*Alnus incana*		**x**			
Silver birch	*Betula pendula*		**x**			
Quicksilver	*Elaeagnus "Quicksilver"*		**x**			
European beech	*Fagus sylvatica*		**x**			
Forsythia	*Forsythia* sp.		**x**			
White willow	*Salix alba*		**x**			
Goat willow	*Salix caprea*		**x**			excellent quality
Chinese willow	*Salix matsudana*		**x**			
Sea buckthorn	*Hippophae rhamnoides*		**x**			
Grape vine	*Vitis vinifera*		**x**	**x**		
Sycamore	*Acer pseudoplatanus*			**x**		

Silver maple	*Acer saccharinum*			**x**		
Buckeye	*Aesculus hippocastanum*			**x**		
Black poplar	*Alnus glutinosa*			**x**		
Downy birch	*Betula pubescens*			**x**		
Birch tree	*Betula sp.*			**x**		
Butterfly bush	*Buddleia cloudii*			**x**		
Hazelnut tree	*Corylus colurna*			**x**		
Cotoneaster	*Cotoneaster salicifolius*			**x**		
Hawthorn	*Crataegus laevigata*			**x**		
Hawthorn	*Crataegus monogyna*			**x**		
Fig	*Ficus carica*			**x**		
Forsythia	*Forsythia intermedia*			**x**		
Ash tree	*Fraxinus excelsior*			**x**		
Hibiscus	*Hibiscus syriacus*			**x**	only flowers	
Walnut	*Juglans regia*			**x**		
Tulip tree	*Liriodendron tulipifera*			**x**		
Apple tree	*Malus domestica*			**x**		
Mulberry	*Morus alba*			**x**		
Passion flower	*Passiflora* sp.			**x**		
Photinia	*Photinia fraseri*			**x**		
White poplar	*Populus alba*			**x**		
Poplar tree	Populus sp.			**x**		excellent quality
Aspen	*Populus tremula*			**x**		
Plum	*Prunus domestica*			**x**		
Sloe	*Prunus spinosa*			**x**		
Wingnut	*Pterocarya fraxinifolia*			**x**		
Knotweed	*Reynoutria japonica*			**x**		
Bramble	*Rubus fruticosus*			**x**		
Willow	*Salix* sp.			**x**		
Whitebeem	*Sorbus aria*			**x**		
Lilac	*Syringa vulgaris*			**x**		
Basswood	*Tilia americana*			**x**		
Broad leaved lime	*Tilia platyphyllos*			**x**		
Lime tree	*Tilia* sp.			**x**		good quality
Field elm	*Ulmus minor*			**x**		
Elm tree	*Ulmus* sp.			**x**		good quality
Honeysuckle	*Lonicera periclymenum*				unknown results	
Guelder rose	*Viburnum opulus*				unknown results	