ASSOCIATION OF ZOOS & AQUARIUMS

EULEMUR
(*Eulemur* spp.)
CARE MANUAL

CREATED BY
AZA PROSIMIAN TAXON ADVISORY GROUP
IN ASSOCIATION WITH
AZA ANIMAL WELFARE COMMITTEE

Eulemur Care Manual

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Disclaimer: This manual presents a compilation of knowledge provided by recognized animal experts based on the current science, practice, and technology of animal management. The manual assembles basic requirements, best practices, and animal care recommendations to maximize capacity for excellence in animal care and welfare. The manual should be considered a work in progress, since practices continue to evolve through advances in scientific knowledge. The use of information within this manual should be in accordance with all local, state, and federal laws and regulations concerning the care of animals. While some government laws and regulations may be referenced in this manual, these are not all-inclusive nor is this manual intended to serve as an evaluation tool for those agencies. The recommendations included are not meant to be exclusive management approaches, diets, medical treatments, or procedures, and may require adaptation to meet the specific needs of individual animals and particular circumstances in each institution. Commercial entities and media identified are not necessarily endorsed by AZA. The statements presented throughout the body of the manual do not represent AZA standards of care unless specifically identified as such in clearly marked sidebar boxes.

This nutrition chapter is an excerpt from the complete Animal Care Manual available at the

Association of Zoos and Aquariums (AZA)'s website:

http://www.aza.org/animal-care-manuals/

Further information about diets and the nutrition of this and other species can be found at the

AZA's Nutrition Advisory Group (NAG)'s website:

http://nagonline.net

Chapter 5. Nutrition

5.1 Nutritional Requirements

A formal nutrition program is recommended to meet the nutritional and behavioral needs of all *Eulemur* (AZA Accreditation Standard 2.6.2). Diets should be developed using the recommendations of nutritionists, the Nutrition Scientific Advisory Group (NAG) feeding guidelines: (http://www.nagonline.net/Feeding%20Guidelines/feeding_guidelines.htm), and veterinarians as well as AZA Taxon Advisory Groups (TAGs), and Species Survival Plan® (SSP) Programs. Diet formulation criteria should address the animal's nutritional needs, feeding ecology, as well as individual and natural histories to ensure that species-specific feeding patterns and behaviors are stimulated.

> **AZA Accreditation Standard**
>
> **(2.6.2)** The institution should have a written nutrition program that meets the behavioral and nutritional needs of all species, individuals, and colonies/groups in the institution. Animal diets must be of a quality and quantity suitable for each animal's nutritional and psychological needs.

In general, *Eulemur* species select diets rich in leaves and fruit; although seasonal, environmental and species-specific differences exist. Across all species, it is clear that no species restricts intake to a single food type; folivorous lemurs often consume some fruit, and frugivorous lemurs often consume some leaves. Additional food items such as fungi, small invertebrates and vertebrates, eggs, and nectar have been reported to be consumed in the wild (Godfrey et al., 2004; Vasey, 2000; Curtis, 2004; Vasey, 2004).

Fruit consumed by *Eulemur* are moderately high in fiber. For example, 26% crude fiber in the fruit consumed by mongoose lemurs, 9% crude fiber in fruits consumed by black lemurs, and not excessively high in sugars (<20% total glucose, fructose, and sucrose in fruit consumed by mongoose lemurs) (Curtis, 2004). Leaves consumed by *Eulemur* are generally higher in essential amino acids and total protein, although most wild-type food items are limiting in methionine and cysteine (Curtis, 2004; Simmen et al., 2007). The composition of the wild-type diet varies dramatically from that of domesticated fruits that are often provided to animals in zoos (Willis, 2008). Also of note, the consumption of fruit by many *Eulemur* spp. plays an ecological role in addition to a nutritional role; for example, *E. macaco* consume a number of fruits for which seeds are not digested but are excreted intact and subsequently germinate (Birkinshaw, 2001).

Fruits and leaves consumed by *Eulemur* are generally low in phenolics, tannins, and alkaloids (Simmen et al., 1999; Simmen et al., 2007), and lemurs in zoos avoided alkaloids in preference trials (Glander & Rabin, 1983). However, tannin-rich foods may be consumed in the wild including *Tamarindus indica*, *Terminalia*, *Haronga madagascariense* (Spelman et al., 1989). The consumption of tannin-rich food items is a subject of discussion relative to the concern about hemosiderosis (iron-storage disorder) in lemurs.

Table 5. Wild-type dietary items consumed by Eulemur spp.

Species	Reported food items consumed by free-ranging animals	Source
Eulemur fulvus albifrons (White fronted brown lemur)	Primarily fruit, some leaves, occasionally insects	(Vasey, 2000; 2004)
Eulemur rubriventer (Red bellied lemur)	≥ 50% fruits, some flowers, some insects and millipedes in winter (12% of diet at peak)	(Overdorff, 1993)
Eulemur macaco (Black lemur)	>65% fruit, some flowers and leaves, small amounts of bark, gum, and earth (all data from dry season)	(Simmen et al., 2007)
Eulemur mongoz (Mongoose lemur)	Primarily fruit (~50–60%; mature and immature), leaves (~8–21%; mature and immature), seeds (9% in wet season); flowers (3–6%), nectar (24% in wet season), ants (13% in dry season); occasional bird-nest predation	(Curtis, 2004)
Eulemur coronatus (Crowned lemur)	Primarily fruit, some flowers and leaves	Reviewed by (Godfrey et al., 2004)
Eulemur fulvus (Brown lemur)	>70% fruit (ripe and unripe) in all seasons; <30% leaves (mature and immature) in all seasons; some reported animal matter	(Simmen et al., 2003)
Eulemur collaris (Collared lemur)	>75% fruit (predominantly ripe), flowers, leaves, invertebrates	(Donati, Bollen et al. 2007)

The gastrointestinal tract of lemurs (Figures 1–5) consists of a simple stomach and an expanded cecum and/or colon (with or without sacculation or haustration), which would be the primary site of microbial fermentation (Godfrey et al., 2004). *E. rubriventer* and *E. m. flavifrons* are reported to have similar GI anatomy to *E. fulvus* and *E. coronatus* (Gomis et al., 2009). This type of GI anatomy indicates ability for some alloenzymatic fiber digestion, although this capacity in *Eulemur* spp. is generally lower than other prosimian species; digestibility of fiber by *E. fulvus* was lower than that of *Propithecus* sp. or *H. griseus* fed similar diets.

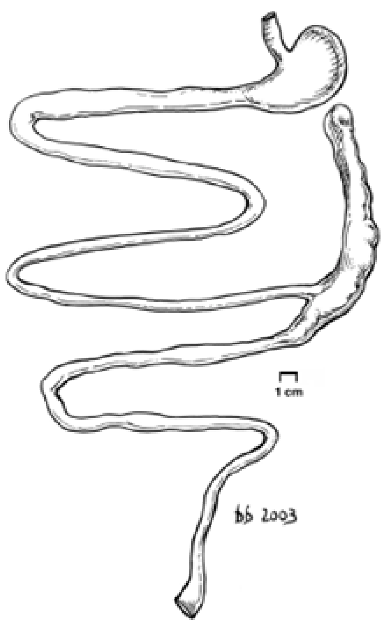

Figure 1. Drawing, to scale, of the gastrointestinal tract of a brown lemur (*Eulemur fulvus*). From Campbell, 2003.

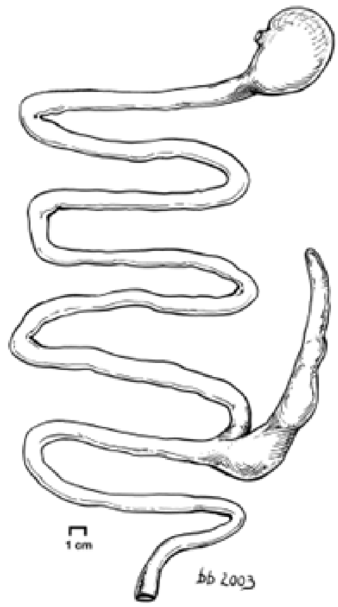

Figure 2. Drawing, to scale, of the gastrointestinal tract of a crowned lemur (*Eulemur coronatus*). From Campbell, 2003.

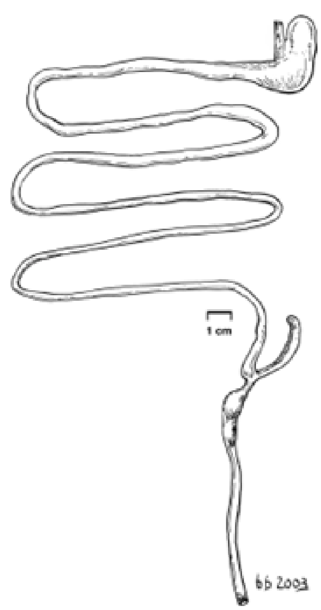

Figure 3. Drawing, to scale, of the gastrointestinal tract of a dwarf lemur (*Cheirogaleus medius*). From Campbell, 2003.

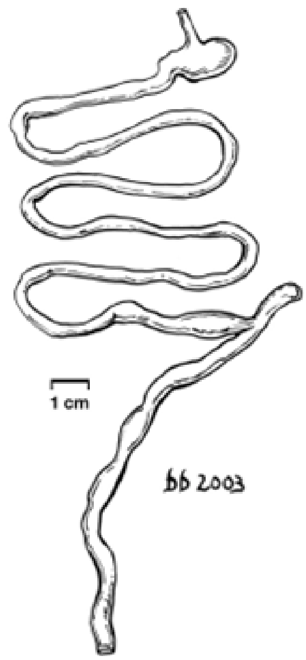

Figure 4. Drawing, to scale, of the gastrointestinal tract of a mouse lemur (*Microcebus murinus*). From Campbell, 2003.

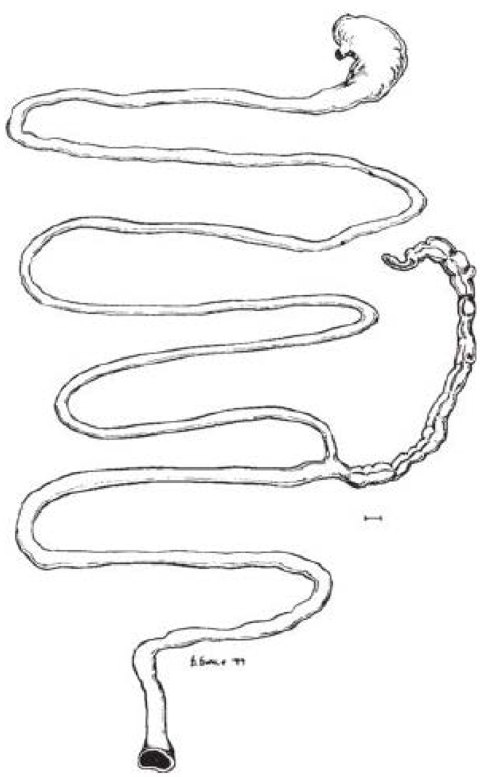

Figure 5. Drawing, to scale, of a red ruffed lemur (*Varecia rubra*).
Scale equals 1cm. From Campbell et al., 2000)

Transit time through the stomach of *E. fulvus* was 1–8 hours (longer for larger particles), while transit through the intestine was ~1 hour regardless of particle size (Campbell et al., 2004). Mean retention time in this species was 7.9–10.4 hours (Campbell et al., 2004). Again, this indicates some capacity for alloenzymatic digestion, but the retention of food in the GI tract is shorter than for more folivorous prosimians such as Propithecus and Hapalemur (Campbell et al., 2004).

Food-related behaviors including regurgitation and coprophogy have been noted in *Eulemur* spp. For example, *E. fulvus rufus* were observed in the wild regurgitating and re-swallowing their food during resting bouts after feeding on unripe fruit and occasionally mature leaves (Overdorff, 1993). Similarly, *E. fulvus rufus* and *E. rubriventer* were observed practicing coprophagy in the wild (Overdorff, 1993). Owing to their dietary flexibility, *Eulemur* species have been successfully housed in zoos and aquariums for centuries. Thus their nutritional management can be straightforward, provided that a few key issues are carefully addressed. The main issues are: (1) provision of a palatable and nutritionally complete diet; and (2) prevention of obesity.

Without exception, all managed *Eulemur* species have been successfully maintained on a diet consisting of a nutritionally complete, commercially available biscuit designed for feeding omnivorous primates, in combination with a mixture of locally available produce. Most commercially available produce is safe to feed; however, the quantities offered should not affect the adequate consumption of the nutritionally complete biscuit provided. The U.S. Food and Drug Administration recommends washing fresh produce thoroughly with tap water before eating. When appropriate, produce should be scrubbed with a brush to remove microorganisms that might be present. The surfaces of firm fruits and vegetables, such as apples, melons, and cucumbers, can withstand scrubbing with a brush. However, fragile produce, such as berries and lettuce, cannot be scrubbed and should be rinsed thoroughly with clean tap water before eating. It is important to remember that the Food and Drug Administration does not recommend using anything other than clean tap water to wash fresh produce (FDA, 2010).

More recently, locally available browse species have been used as a dietary enrichment item (Campbell et al., 2001). While all browse species offered should be documented as safe for consumption, browse can provide animals with a novel and challenging food item and can be good for maintaining dental health. Recommended nutrient intake is provided in Table 6, based on minimum estimated nutrient requirements as published in the NRC Nutrient Requirements of Nonhuman Primates, 2nd edition (NRC, 2003).

Table 6. Recommended nutrient intake of *Eulemur* spp.*

Nutrient		Recommended nutrient level*	Species based on (from NRC)
Protein	%	8; 14 growth	Macaque; growth=chimp
Fat	%	n/a	
Crude Fiber	%	n/a	
NDF	%	20	Lemur
ADF	%	10	Lemur
Calcium	%	0.55	Macaque
Phosphorus	%	0.33	Macaque
Sodium	%	0.25	Baboon
Magnesium	%	0.04	Macaque
Potassium	%	0.24	Baboon
Omega-3 fatty acids	%	0.5	Macaque, squirrel monkey, *Cebus* spp., chimp
Omega-6 fatty acids	%	2	Macaque, squirrel monkey, *Cebus* spp., chimp
Chloride	%	0.27	Baboon
Chromium	ppm	>0.09	Squirrel monkey
Copper	ppm	15	Macaque
Iodine	ppm	0.65	Marmoset, tamarin
Iron	ppm	100	Macaque
Manganese	ppm	44	Macaque
Selenium	ppm	0.11	Macaque, squirrel monkey
Zinc	ppm	13; mtnc 20; growth	Macaque
Ascorbic Acid	ppm	110	Macaque
Biotin	ppm	2–4	*Cebus* spp.
Choline	ppm	1,000	Overall species
Folic acid	ppm	1.5; growth 3.3; repro	Squirrel monkey, *Cebus* spp.
Niacin	ppm	16	Macaque
Pantothenate	ppm	20	Macaque, *Cebus* spp.
Pyridoxine	ppm	3.1	Baboon
Riboflavin	ppm	1.7	Macaque, *Cebus* spp.
Thiamin	ppm	1.1	Macaque
Vitamin A	IU/kg	12,000	Squirrel monkey
Vitamin D3	IU/kg	1,000	Macaque, *Cebus* spp.
Vitamin E	IU/lb	68	Macaque
Vitamin B12	mcg/kg	11	Macaque
Vitamin K	ppm	>0.06–3	Macaque

Based on Nutrient Requirements of Nonhuman Primates, 2nd edition (NRC, 2003).

Commercial diets commonly offered, and which provide minimum estimated requirements when fed at recommended dietary inclusion level provided by the manufacturer include:

- Purina Monkey Diet (5038): www.purina-mills.com
- Marion Leaf Eater Diet: www.marionzoological.com
- Mazuri Leaf Eater Diet (5M02): www.mazuri.com
- Mazuri High Fiber Sticks (5MA3): www.mazuri.com
- Mazuri Primate Maintenance (5MA2): www.mazuri.com
- Mazuri High Fiber Geriatric Gel (5S2R): www.mazuri.com
- Mazuri Primate L/S Biscuit (5M1G): www.mazuri.com

Additionally, a recent survey examined the diets of black & white ruffed lemurs (*V. variegata*) at 33 US Zoological institutions found that majority of institutions fed either Marion Leaf Eater Diet (10 institutions), Mazuri Leaf Eater Diet (14 institutions), or Mazuri Primate Browse Biscuit (10 institutions). In addition to commercial diets, apples, bananas and browse were offered (although 33% of institutions reported little to no consumption of browse offered (Donadeo, 2013). The estimated chemical composition (dry matter basis) of the diets showed a median crude protein content of 17%, median crude fat content of 4.7%, and median energy density of 3.2 kcal ME/g. In comparison to nutrient composition of plant parts from Madagascar (Schmidt et al., 2010; Donadeo, 2013), zoo diets were estimated to contain higher crude protein and digestible carbohydrates and lower fat and fiber levels. Compared to plant parts from

Madagascar, managed diets were estimated to have higher CP and NFE, and lower fat and fiber concentrations. Reducing the amount of fruit included in diets for black-and-white ruffed lemurs would decrease digestible carbohydrate content and increase fiber content of these diets, which could reduce the prevalence of obesity and diabetes in *V. variegata*.

For successful dietary management, the produce portion of the diet should not be considered a significant contributor to the animals' nutritional needs. In fact, overconsumption of produce that is particularly high in sugar and starch can contribute to diarrheal episodes, obesity, dental decay, and diabetes. However, produce possessing a low glycemic load (i.e., less than or equal to 10) can be viewed as a key enrichment item, providing daily variety in the dietary protocol. Glycemic load (GL) is a grading system designed to describe the relationship between the carbohydrate content of a particular food and its effect on blood sugar and insulin response (Ludwig, 2002). In human subjects, research has demonstrated that sustained elevations in blood sugar and the associated spikes in insulin level may lead to an increased risk of diabetes and insulin resistance (Ludwig, 2002). Low glycemic load commercial produce that is commonly included in *Eulemur* diets:

- Leafy greens: no limit
- Cucumbers, carrots, celery: no limit
- Cruciferous vegetables (broccoli, cauliflower, kale, cabbage): limit amounts daily
- Starchy vegetables (sweet potatoes, corn): limit amounts daily
- Fruits (apples, blueberries, plums, cherries, pears, raspberries, blackberries, cantaloupe, honeydew melon, bananas): limit amounts daily

Food intake of wild *Eulemur* spp. is ~16–34% of body weight (BW) on an as-fed basis, varying due to species. *E. mongoz* consumed 19% of BW (3.2% DMB) (Curtis, 2004). *E. fulvus* consumed 16% of BW as is basis, and *E. macaco* consumed 28–34% of BW as is basis (6–7.5% DMB) (Simmen et al., 2003; Simmen et al., 2007). However, in zoo-managed animals, food intake is generally lower. Managed adult lemurs at maintenance typically consume around 2–2.5% of their bodyweight in dry matter daily. This corresponds to 20–25 g of dry matter per kilogram of body weight. Diets should be formulated so that 80–90% of total dry matter (DM) intake is composed of commercially available complete feed and 10–20% of the remaining diet is produce. At this level, all minimum estimated requirements would be met by the intake of biscuit, while produce levels will be high enough to provide dietary variety.

The rate of passage of ingesta may be far more rapid in *Eulemur* than in other lemur species. As mentioned previously, transit time through the stomach of *E. fulvus* was 1–8 hours (longer for larger particles), while transit through the intestine was ~1 hour regardless of particle size (Campbell et al., 2004). Mean retention time in this species was 7.9–10.4 hours (Campbell et al., 2004). Again, this indicates some capacity for alloenzymatic digestion, but the retention of food in the GI tract is shorter than for more folivorous prosimians such as *Propithecus* spp. and *Hapalemur* spp. (Campbell et al., 2004). Although the number of animals included in the research is not high enough to constitute statistical significance, it does suggest the potential importance of considering nutrient passage rate when formulating diets for *E. fulvus*. Measures should be taken to avoid feeding an inappropriate diet in this species and all *Eulemur* species.

While concern about hemosiderosis has been discussed with respect to managed lemurs, its actual prevalence and clinical significance is unclear. Recent studies suggest that different lemur species have varying propensities for accumulating excess iron in tissues and that the incidence of the condition is likely much lower than previously thought (Williams et al., 2006; Glenn et al., 2006). While some authors have recommended adding tea, beans, or tannins to managed lemur diets in an effort to reduce dietary iron absorption there is currently insufficient evidence to support these recommendations (Wood et al., 2003). Thus, with the exception of avoiding giving iron-containing supplements to lemurs, diet modifications to decrease iron absorption are not currently recommended (Hemosiderosis statement, AZA).

Body size and energy requirements: In general, *Eulemur* spp. have a relatively low basal metabolic rate (BMR) compared to haplorrhine primates and other mammals (Daniels, 1984). Actual BMR has been calculated at 28–70% of that predicted by Kleiber's equation (BMR (ml O_2/h) = 3.42 x BW^0.75) (Genoud, 2002; Harcourt, 2008). This low BMR coupled with relatively lower activity level in the zoo environment likely predisposes these animals to obesity; care should be taken to monitor body condition and caloric intake to maintain healthy body weights. Smaller species typically exhibit higher BMR and lowered energy costs of locomotion (Warren & Crompton, 1998). Smaller body mass also tends to be accompanied by selection for more nutrient dense dietary items (Pough, 1973). However, folivory, which is common to many lemur species, is often linked with slower basal metabolic rates possibly due to the low bioavailability of leaf biomass (McNab, 1978; Ganzhorn, 1992). When formulating diets for the more folivorous prosimian species, it may be prudent to consider a slower rate of metabolism in addition to body size. Calculated energy intake of black lemurs in the wild (using Atwater factors) was 230–260 kcal/day (~92–104 kcal/kg BW*d) (Simmen et al., 2007). A mixed *Eulemur* group (brown x collared) was reported to have total energy expenditure of 314–349 kJ/kg BW*day (~75–83 kcal/kg BW*d) (Simmen et al., 2010).

Age and activity: For brown lemurs, young are generally weaned at approximately 4–5 months of age, but females may reduce nursing when young are 3–5 months, encouraging the young to consume solid foods at this time (Tarnaud, 2006b). Managed infants at one zoological institution have been observed sampling food items at as early as 4–6 weeks of age. The institution typically begins including food rations for the juvenile at 50% of an adult portion, at approximately 3 months of age. Further diet increases are implemented based on changes in body weight and hunger. In general, animals are offered a full adult portion by 1 year of age. As infants are weaned they tend to consume more solid foods with high sugar content (fruit) than protein content (e.g., flowers, young leaves), while lactating females consume more protein-rich foods (e.g., flowers) (Tarnaud, 2006b). Adult male white-fronted brown lemurs will also consume more insect material (Vasey, 2004).

Older animals' diets are not dramatically altered unless a medical condition necessitates a diet change; however, animals with severely worn molars may require biscuits be softened by spritzing with water or dilute fruit juice in an effort to encourage consumption. Terranova & Coffman (1997) compared the body weights of wild and managed lemurs and found that overall, the animals were heavier in zoos. Additionally, they found that crowned lemurs (*E. coronatus*) and Sclater's black lemurs (*E. m. macaco*) in zoos and aquariums weighed significantly more than their wild counterparts and proposed that the high occurrence of obesity in managed Sclater's black lemurs may be problematic for this species. Activity levels are typically lower for *ex situ* lemurs relative to free ranging animals.

They further suggest that obesity in managed lemurs may be a function of the elements of a managed environment, such as physical limitations, a steady and highly palatable food supply, and dominance hierarchies which may lead to overconsumption of food by some individuals. Given that they are prone to obesity, body weights and dietary intakes should be monitored on a regular basis. Increasing activity when possible, using multiple feeding sites in group-housed animals, and avoiding overfeeding are all helpful measures that can help reduce obesity in managed *Eulemur* species. If a change in diet is necessary, changes should be implemented slowly, be carefully documented, and body weights monitored frequently. Recommended healthy weight ranges for *Eulemur* housed at one zoological institution are:

- *Eulemur collaris, E. fulvus, E. rufus, E. macaco, E. rubriventer*: 2–2.4 kg
- *Eulemur mongoz, E. coronatus*: 1.4–1.7 kg

Unlike most other primates, all *Eulemur* species have been reported to exhibit some level of both nocturnal and diurnal activity (i.e., cathemerality), including feeding behavior (Tattersal, 1987; Overdorff 1998; Overdorff & Rasmussen, 1995; Wright, 1999). There are species differences in the time spent feeding (in addition to seasonal differences), but most species spent reasonable time during day and night on feeding activities (Andrews & Birkinshaw, 1998). The total time spent feeding and foraging in the wild is reported to be 12–20% of the time budgets of *E. mongoz*, *E. fulvus*, *E. rubriventer*, and *E. fulvus rufus* (Overdorff, 1993; Curtis, 2004; Tarnaud, 2006a and 2006b). Research performed by Sussman and Tattersal first documented nocturnal feeding behavior of the normally diurnal *Eulemur mongoz* in 1976 (Wright, 1999). Research conducted by Overdorff (1998), reported an average of 6 hours of nocturnal activity that was balanced by 6 hours of sleep during midday for *Eulemur rubriventer*. It has been suggested that adaptations towards energy conservation and a high level of metabolic efficiency have developed in order to maximize the utilization of scarce resources (Wright, 1999).

Reproductive factors: There are nutritional considerations for reproductive *Eulemur* females. Food consumption by wild female brown lemurs increases during lactation and is also greater during the early lactation period compared to the subsequent weaning period (Tarnaud, 2006b). Managed females that are lactating may receive an increased daily ration; however, care should be taken not to overfeed. Increases (or decreases) in the diet should be implemented in no more than 10% increments, and intake and weight should be carefully monitored. Diets should return to baseline when the female is no longer lactating. Female white-fronted brown lemurs will consume more low-fiber protein than males during gestation and lactation (Vasey, 2000b).

Seasonal variation: Managed *Eulemur* do not experience large seasonal changes in dietary intake. At most, animals consume somewhat less food during hot or inclement weather. The decrease is typically not enough to necessitate a decrease in amounts offered. At this time there is no recommendation to implement dietary increases or decreases based on season. Thus, dietary requirements do not vary greatly with seasonal changes. Seasonal changes in body condition have not been noted in *Eulemur* species.

Health status: One indicator of a change in health status is a change in stool consistency. Most zoo diets are lower in both the amount and variety of fiber types than are wild diets. As a result, stool consistency in managed lemurs tends to be looser than in wild lemurs. If loose stool is a problem in managed lemurs and pathogens have been ruled out as a cause, it is possible that diet modifications are warranted. Changes to the diet that may improve stool consistency include limiting fruits and starchy vegetables, increasing the amount of fiber in the diet, and feeding fresh browse if available.

5.2 Diets

The formulation, preparation, and delivery of all diets must be of a quality and quantity suitable to meet the animal's psychological and behavioral needs (AZA Accreditation Standard 2.6.2). Food should be purchased from reliable, sustainable and well-managed sources. The nutritional analysis of the food should be regularly tested and recorded.

Sample diets: Feeding practices can contrast greatly between institutions. Care should be taken when utilizing domestically harvested fruit products in *Eulemur* diets. Domesticated fruits are cultivated to contain high levels of soluble and low levels of structural carbohydrate and thus carry the potential to contribute to obesity and diabetes (Schwitzer et. al., 2008). The nutritional profile of wild fruits native to Madagascar more closely resembles that of domestically grown vegetables than fruits (Schwitzer et al., 2008). The utilization of low glycemic load produce should also be considered. The feeding of browse has been suggested as a means of increasing structural carbohydrate (fiber) levels in the diet. However, prior to incorporating browse into a feeding program, both a nutrient analysis and an assessment of secondary metabolites should be conducted (Campbell et al., 2001). The feeding of browse can contribute significantly to the total nutrients supplied in the diet, and secondary plant compounds can potentially affect palatability as well as impose additional energetic costs for detoxification (Campbell et al., 2001; Ganzhorn, 1992; McNab, 1978).

Example 1

Species: *E. coronatus*
Age: Adult male
Health status: Clinically healthy
Diet/Ration provided daily:

- Mazuri Primate L/S Biscuit (5M1G) (30% AF)
- Carrots (20% AF)
- Blackberries (30% AF)
- Dandelion greens (20% AF)

Selected nutrient analysis:

- ME (3.2 kcal/g DM)
- Protein (18.1% DM)
- Fat (5.3% DM)
- NDF (27.9% DM)
- ADF (13.7% DM)
- Calcium (0.8% DM)
- Phosphorus (0.4% DM)
- Iron (153 ppm DM)
- Ascorbic acid (410 ppm DM)

Example 2

Species: *E. collaris*
Age: Geriatric female
Health status: Hyperglycemic/Insulin resistant
Diet/Ration provided daily:

- Fresh cherries (30% AF)
- Greens (20% AF)
- Mazuri High Fiber Sticks (5MA3) (30% AF)
- Soluble fiber supplement (*Amorphophallus konjac*) (20% AF)

Selected nutrient analysis:

- ME (2.9 kcal/g DM)
- Protein (17.6% DM)
- Fat (4.5% DM), NDF (27.4% DM)
- ADF (14.9% DM), Calcium (1.0% DM)
- Phosphorus (0.5% DM), Iron (216 ppm DM)
- Ascorbic acid (495 ppm DM)

Abbreviation key:
ME = Metabolizable Energy
NDF = Neutral Detergent Fiber
ADF = Acid Detergent Fiber
AF = As Fed
DM = Dry Matter

Food variety and presentation: *Eulemur* should be provided a variety of foods including produce; approved browse and a protein source (see Table 6 for more detailed dietary requirements). In the wild, brown lemurs naturally spend 13–20% of their time searching for and consuming their diet (Tarnaud, 2006b). They forage opportunistically on both ripe and unripe fruits, flowers, and young and mature leaves; females tend to prefer fruit to leaves (Tarnaud, 2006b). Food should be provided at least twice daily, and more often as necessary for specific individuals' requirements. More complex foraging opportunities, including browse, puzzle feeders, multiple feedings, and scatter feedings allow for increased foraging activity.

Feeding: Food should be provided early in the day in multiple locations within the enclosure to promote foraging. USDA regulations require that appropriate feeding containers be present in all holding areas. Care should be taken to ensure that each individual has access to their appropriate diet, and that one individual does not monopolize resources. When possible, the scattering of food may help to reduce or prevent dominant animals from monopolizing a particular feeding position. Multiple bowls/feeding stations should be spaced as far apart as possible. Individuals may be separated during feedings if necessary to prevent food aggression.

Eulemur species may also prefer arboreal feeding stations. This is extremely important for lemurs that are candidates for reintroduction. In most cases, animals will relocate to the ground to feed if necessary. Food should be spaced throughout an exhibit or holding area to avoid social conflict through food competition as well as prevent a dominant animal from monopolizing a food source. Steps should be taken to increase foraging time through the use of enrichment devices when possible.

Various mechanisms can be used to present *Eulemur* species with opportunities to work for food. Enrichment items, browse, and food chopped into different sizes are all techniques used to present food items. For example, Sommerfield et al. (2006) utilized self-operated feeder boxes to increase locomotion and overall activity in *E. albifrons* to levels that approximated activity levels in the wild. Other examples include giving foods whole, cut very small, or leaving in husk/rind/shell. Food can also be hung, skewered, or mixed with substrate to increase foraging time. Commonly utilized commercial laboratories that routinely perform analysis on animal feeds include: Dairy One Forage Lab, Ithaca, NY; Michigan State Diagnostic Center for Population and Animal Health, Lansing, MI; BASF Corporation: Animal Nutrition Technical Services Laboratory, Wyandotte, MI; Eurofins Scientific, Inc. Des Moines, IA; Central Analytical Laboratories, Metairie, LA; Midwest Laboratories, Inc. Omaha, NE; and Barrow-Agee Laboratories, Memphis, TN. It is recommended that zoo professionals not familiar with the interpretation of nutritional analysis request assistance from SSP nutrition advisors and or the AZA Nutrition Advisory Group (NAG) prior to incorporating dietary changes based on analytical data.

Food preparation must be performed in accordance with all relevant federal, state, or local laws and/or regulations (AZA Accreditation Standard 2.6.1). Meat processed on site must be processed following all USDA standards. The appropriate hazard analysis and critical control points (HACCP) food safety protocols for the diet ingredients, diet preparation, and diet administration should be established for the taxa or species specified. Diet preparation staff should remain current on food recalls, updates, and regulations per USDA/FDA. Remove food within a maximum of 24 hours of being offered unless state or federal regulations specify otherwise and dispose of per USDA guidelines.

AZA Accreditation Standard

(2.6.1) Animal food preparation and storage must meet all applicable laws and/or regulations.

If browse plants are used within the animal's diet or for enrichment, all plants should be identified and assessed for safety. The responsibility for approval of plants and oversight of the program should be assigned to at least one qualified individual (AZA Accreditation Standard 2.6.3). The program should identify if the plants have been treated with any chemicals or near any point sources of pollution and if the plants are safe for the *Eulemur*. If animals have access to plants in and around their exhibits, there should be a staff member responsible for ensuring that toxic plants are not available.

AZA Accreditation Standard

(2.6.3) The institution should assign at least one person to oversee appropriate browse material for the animals.

Nutritional analysis of browse species can be difficult to locate and interpret. Nijboer & Dierenfeld (1996) list analyses of browse species common to the diets of managed nonhuman primates. Although browse is a valuable enrichment tool, fatalities have been reported in certain species of primates as a direct result of browse consumption (Ensley et al., 1982; Janssen, 1994; Robinson et al., 1982). Some species of browse found safe for hoof stock have caused illness and death in some species of primates (Ensley et. al., 1982). It is critical for any institution that utilizes browse in their dietary protocols to have qualified staff officially designated to the identification of primate specific edible browse. Individuals are encouraged to contact the AZA *Eulemur* SSPs, the AZA Prosimian Taxon Advisory Group nutrition advisor, or the AZA Nutrition Advisory Group as reference prior to initiating a browse-feeding program (Toddes et al., 1997). Commonly utilized browse species include, but are not limited to *Cornus* sp. (Dogwood), *Salix* sp. (Willow), *Morus* sp. (Mulberry), *Phyllostachys* sp. (Bamboo), and *Cercis* sp. (Redbud). If husbandry staff are not familiar with a particular browse species and subsequently how that feed source may react with their animals they should seek advice from qualified individuals.

5.3 Nutritional Evaluations

Nutrition related health concerns with the potential to affect *Eulemur* species include obesity, diabetes, and both vitamin and mineral imbalances. Obesity can be significant for *Eulemur* species of all ages, and should be monitored closely. Although hemosiderosis has classically been considered an associated condition with *ex situ Eulemur* populations, research suggests that this disorder is not as pervasive as has been previously reported (Williams et al., 2006; Glenn et al., 2006). However, if iron storage pathologies are present and hemochromatosis is suspected, the levels of dietary iron and ascorbic acid (vitamin C) should be considered.

Assessments of nutritional status should be routinely administered as a direct function of preventative animal health care. Evaluations commonly utilized for this purpose include: body condition scoring by properly trained nutrition veterinary and or husbandry staff; fecal scoring based upon current established literature; and blood vitamin and mineral panels analyzed via commercial laboratories (Nijboer et al., 2001; 2006). If zoo professionals are unfamiliar with the interpretation of hematologic nutritional analyses they should seek advice from appropriate SSP Nutrition and Veterinary Advisors or the AZA Nutrition Advisory Group. Physical evaluation, through both visual and routine body weights and morphometric measurements, can be a valuable tool in addressing animal health. Although a sanctioned body condition scoring system does not currently exist for *Eulemur*, basic parameters can be utilized to implement a visual and or palpation based scoring system.

Developing an index of body condition requires a visual assessment of mass (i.e., fat to lean tissue that can be correlated with species specific skeletal reference points including spinous, rib cage, abdomen, etc.). To be effective, the establishment of these reference points should be undertaken by staff with an excellent working knowledge of the structural parameters of the species in question. Typical body condition scoring systems rely upon either a 1–5 or 1–9 point numeric scale. A score of 1 designates an emaciated individual with severe depletion of total body energy reserves and is often accompanied by extreme angularity due to skeletal protrusions and a lack of subcutaneous fat. Depending on the scale used, a score of 5 or 9 will designate an obese individual with extreme fat deposition and greatly reduced structural angularity due to excess subcutaneous fat stores. It is often helpful to utilize photography when establishing a scoring system as this allows for reference to be made specific to score, health status and age of individuals. These practices when combined with routine body weight determinations can play an important role within preventative health care programs.

7.4 Birthing Facilities

As parturition approaches, animal care staff should ensure that the mother is comfortable in the area where the birth will take place, and that this area is "baby-proofed."

Housing: Housing of the female should be evaluated once a breeding recommendation is received, or in the case of an unplanned birth, as soon as the female is confirmed pregnant. In many cases, births and the rearing of offspring in mixed-species groups or groups containing multiple adult males and females and/or the previous year's offspring have not been successful. Successful reproduction has been seen in mixed-species groups or groups with older offspring. Institutions should contact the AZA Prosimian TAG and the AZA *Eulemur* SSP coordinator prior to the birth to evaluate the situation. Also, exhibit construction should be examined to ensure a safe environment for infants. It is recommended that enclosure wire measure 2.54 cm x 2.54 cm (1 in. x 1 in.) or smaller when infants are present (see Chapter 2.2).

Institutions should consider moving the breeding pair out of the group and into a separate enclosure once the recommendation is received. This separation may reduce social stress and encourage maternal behavior (Meyer, 1982). This may be very important for first time mothers. Complete visual isolation from the social group should be avoided as this may result in permanent group fractioning.

If the decision is made to leave the pair in the group, institutions should closely monitor the behavior of the female within the group to ensure other group members are not harassing her.

If separation is warranted late in pregnancy, consider plans that would minimize stress to the female. Determine if other members of the group be can moved or separated. If not, keeping the pair together during the move may help reduce stress from the move/separation. In some cases, particularly when a female has had problematic birth, it may be advisable to house a pregnant female alone during the late stages of pregnancy. In this case she could be housed in visual and olfactory contact with the sire and/or other group members.

A separate enclosure would preferably be a small area that can be provided with additional heat sources. By providing external heat, the time that infants can be off the mother without having to intervene will be extended. This may allow new mothers the time to adjust to the infant. As *Eulemur* infants are not found off of their mothers unless they are extremely weak or have been removed by the mother (see Chapter 4.5), careful observation should be conducted to determine the reason the infant is off the female.

The *Eulemur* infant should be found clinging to its mother after birth; when this occurs, additional birthing materials are not necessary. There is the possibility that the infant will be weak and unable to cling, and may fall to the floor after birth. If the floor of the birthing enclosure is concrete, cement, or a very hard surface, a layer of wood shavings may be appropriate to cushion a fall.

If it becomes necessary to remove an infant from the mother for some reason, the use of a small kennel has been recommended to immediately reintroduce an infant to its mother. The enclosed space may trigger maternal behaviors (see Chapter 4.5).

Management: Institutions should evaluate any other factors that may encourage or discourage maternal care and make appropriate management changes. Examples of factors that may impact maternal care include:

- Loud noises
- High traffic areas
- Proximity to other groups
- Number of training sessions
- Exposure (visual or auditory) to other infants
- Exposure to conspecifics other than parents
- Removal of the infant in the first 24 hours following birth, and perhaps in the first 72 hours
- The majority of *Eulemur* dams acclimate immediately to birth, particularly in that most females give birth in their home enclosure

7.5 Assisted Rearing

Although mothers may successfully give birth, there are times when they are not able to properly care for their offspring, both in the wild and in *ex-situ* populations. Fortunately, animal care staff in AZA-accredited institutions are able to assist with the rearing of these offspring if necessary.

The goal of the AZA *Eulemur* SSP is to encourage the rearing of infants by their mothers or lemur surrogates as often as possible. Care should be taken to avoid the premature removal of infants due to anticipated or perceived maternal incompetence. Hand rearing has been implicated in later behavioral deficits in a number of species, and there is some evidence that hand rearing could have a negative impact on copulatory behavior in male *E. macaco* (Niebruegge & Porton, 2006). If hand-rearing is deemed necessary and all other possible solutions have been exhausted, infants should be housed singularly to avoid suckling on one another, and a soft stuffed toy or rolled towel should be provided as a surrogate for the infant to cling to (Gage, 2002). When hand rearing, keeping the neonate warm is critical and an incubator is recommended. For neonates, ambient temperature should be 35.5–36.7 °C (96–98 °F), with humidity at 50–65% (Gage, 2002). As the infant ages and is able to thermoregulate, temperature can gradually be decreased. Infants that are at least 1 month of age may be kept under a heat lamp or with a warm water circulating blanket (Gage, 2002). See Williams (2002) for additional information on hand rearing lemurs.

As the social and reproductive situation varies greatly between individuals and institutions, the AZA *Eulemur* SSP encourages individual institutions to consult with the AZA Prosimian TAG Chair and the AZA *Eulemur* SSP Coordinator as soon as a female is confirmed pregnant. The following generalized guidelines are suggested to maximize the likelihood of successful parent rearing.

Birth plan: An institutional birth plan should be developed as soon as a breeding recommendation is received or as soon as a female is determined to be pregnant. This birth plan provides guidelines whereby senior staff, animal managers, veterinarians, and keepers are all clear on contingency plans for addressing a female's failure to provide appropriate maternal care.

This birth plan should include a review of the social, reproductive, and medical history of the pregnant female, staff assignments, determination of due date, pre-partum plan, birthday plan, and other considerations relating to the birth. It should also include history of the expectant female, discussion of intervention types, record keeping or documentation, housing situations, previous maternal skills, labor and delivery, problems associated with birth and delivery, physical appearance of the newborn, postpartum behavior, diet and supplementation during lactation. Each birth event and neonate/mother relationship should be evaluated on a case-by-case basis.

Pre-birth training: If not already in place, institutions should incorporate a training program with pregnant animals to ensure females come to the mesh, fencing, or exhibit perimeter for food or a training session. These sessions will allow closer examination of the infant and increase the ability to conduct supplemental feedings without removing the infant from the female. In addition to rewarding for coming to the mesh or wire, training sessions should focus on desensitizing the female to having her back and stomach touched. This may increase a new female's tolerance to having an infant cling to her.

Nutritional supplementation vs. hand-rearing: Nutritional support is necessary when infants are weak, fail to gain weight, become ill or orphaned, or in the event of maternal illness, neglect, or abuse. Low birth weight by itself is not a reason to intervene as long as the mother is attentive and the infant is vigorous and gains weight steadily. See Table 9 for a range of birth weights in *Eulemur* infants, taken on day of birth or day after birth. All infant weights included in this range were from infants born at one zoological institution and survived more than 2 weeks.

Table 9. Summary of *Eulemur* reproductive data from one zoological institution over approximately 30 years of reproduction and management

Species	**Peak breeding season (N. America)**	**Peak birth season (N. America)**	**Length of receptivity (days)**	**Time between cycles (days)**	**Typical # of cycles per season**	**Sperm plugs?**	**Gestation (days)**
E. fulvus	Nov–Jan	Mar–May	1	30	2–3		120–128
E. collaris	Nov–Jan	Mar–May	1	30	2–3		120–128
E. rufus	Oct–Dec	Feb–Apr	1	30	2–3		120–128
E. albifrons	Dec–Jan	Apr–May	1	30	2–3		120–128
E. sanfordi	Dec–Jan	Apr–May	1	30	2–3		120–128
E. macaco	Oct–Jan	Mar–May	1	33	2–3	Y	120–129
E. flavifrons	Nov–Dec	Mar–Apr	1	33	2–3	Y	120–129
E. rubriventer	Nov–feb	Mar–Jun	1		2–3		120–127
E. mongoz	Nov–feb	Mar–Jun	1	30–38	2–3	Y	120–128
E. coronatus	Dec–Jan	Apr–May	1	34	2–3	Y	120–126

Table 9 cont'd.

Species	**# of infants**	**Infant weight ranges @ DLC (grams)**	**Lowest birth weight to survive @ DLC (grams)**	**Average weaning age**	**Youngest dam age at conception (months)**	**Oldest dam age at conception (years)**	**Youngest sire age at conception (months)**	**Oldest sire age at conception (years)**	**Ideal adult weight ranges (kg)**
E. fulvus	1–2	60–90		3–4 m	16	23	15	28	2.0–2.4
E. collaris	1–2	60–90		3–4 m	19	23	21	22	2.0–2.4
E. rufus	1–2	60–90		3–4 m	18	23	9	25	2.0–2.4
E. albifrons	1–2	60–90		3–4 m	18	21	19	16	2.0–2.4
E. sanfordi	1–2	60–90		3–4 m	19	19	24	8	2.0–2.4
E. macaco	**1–3	60–90		3–4 m	9	25	8	29	2.0–2.4
E. flavifrons	**1–2	60–90	55	3–4 m	18	17	20	21	2.0–2.4
E. rubriventer	1–2	60–90		3–4 m	16	14	34	14	2.0–2.4
E. mongoz	1–2	55–60	51.5	3–4 m	19	24	18	20	1.4–1.6
E. coronatus	1–2	40–50		3–4 m	16	19	20	16	1.4–1.8

**singletons are most common

If an infant is not able to nurse or is prevented from nursing by the dam, milk can be manually expressed from the mother and fed by syringe. Alternately, many dams will allow infants to be manually placed on the nipple to suckle if lightly sedated and gently restrained. Keeping a dam's mammary glands emptied also encourages continued milk production, which is important if infants are to be reunited with their mothers.

The term "supplementation" is used in this document to indicate nutritional support given while an infant is housed with its dam or other members of its own species. Hand-rearing is used to refer rearing infants in a nursery environment away from members of its own species. Although the AZA Prosimian Taxon Advisory Group has not formally developed a policy on hand-rearing, there are several reasons supplementing infants is preferred over hand-rearing. Hand-reared infants are more likely to exhibit abnormal social or behavioral traits making it difficult to reintegrate them with members of their own species after weaning. Hand-reared infants are more likely to develop human directed aggression, and infants that nurse from their dams, even on a limited basis, are less likely to develop nutritional deficiencies that may occur in fully formula-reared infants.

Information on the composition of normal lemur milk is limited but available data indicates composition varies widely between species. In general, species that carry their young produce dilute milk low in energy, fat, and protein. True lemurs (*Eulemur* spp.) fall in this category. Infants nurse on demand and ingest small amounts of milk frequently. If the use of artificial formulas becomes necessary the formula should approximate as closely as possible the composition of normal mother's milk for the species being raised. While lemurs have been successfully raised on cow milk formulas, formulas using human infant formula or Zoologic® Milk Matrix (PetAg Inc., 261 Keyes Ave., Box 396, Hampshire, IL 60140, 1-800-323-0877; www.petag.com) as a base are preferable because the balance of vitamins, minerals, and micronutrients are likely to be more appropriate for young, growing primates. It is important to note that if human or Milk Matrix formulas are used, supplemental pediatric vitamins should be avoided, as the combination can lead to overdoses of certain vitamins and minerals, particularly iron. When human formulas are used, low iron varieties are preferred. More details on formulas and feeding protocols appropriate for lemurs can be found in the book "Hand-Rearing Wild and Domestic Mammals" (Gage, 2002).

Institutions should prepare for the need to supplementary feed an infant by having the proper formula materials and dosages available to all keeper staff. Williams (2002) recommended using one of two formulas:

- <u>Formula 1</u>: Mix 30 ml human infant formula prepared according to directions with 30 ml nonfat milk, and 3 ml 50% dextrose (total volume = 63 ml)
- <u>Formula 2</u>: Zoologic® Milk Matrix 20/14. Add 10 g powder to 100 ml water

Additionally, 5–10% dextrose in water has been used as a first feeding for infants that are not being nursed. This may provide infants some immediate fluid and allow for an immediate reintroduction attempt.

A source of supplementary heat may be used to warm up infants before giving them back to their mother. Easy access to this heat source may allow quicker reintroduction attempts. When providing supplementary heat, always provide areas where the infant, and dam if present, can get away from the heat source to prevent overheating.

Supplementation or assisted rearing is always preferable to hand-rearing. Hand-reared infants are more likely to exhibit abnormal social behaviors and be aggressive as adults. Infants that nurse on their dams, even on a limited basis are also less likely to develop nutritional deficiencies. Even complete supplemental nutrition can be provided while the infants remain with the dam or others in the family group.

If in an extreme case, if an infant has to be removed into a nursery setting, every attempt should be made to re-introduce the infant to the dam as soon as possible after infant is warmed, hydrated, and appears strong enough to cling to the dam. Maternal rejection might occur after even 24 hours of separation, but other females might accept the re-introduced infant after a longer separation. In general, longer separations are tolerated better for older infants than for younger. Housing the infant in close visual, olfactory and auditory proximity to the dam improves chances of a successful reintroduction. The rate at which reintroductions can be accomplished varies greatly, depending on the specific case. The method of placing an infant back on a dam also may vary, depending on the dam's temperament. One method that has been used successfully is to restrain the female, place the infant on her abdomen and wait a few seconds till the infant clings tightly. Then return dam with infant to a kennel or small cage (where her movement is restricted and the infant is less likely to fall off). A second method, often successful with assisted rearing when the infant is only removed from the dam for feeding, is to distract the dam with treats and then ease the infant back into position to cling on her abdomen.

After an infant has been reintroduced the dam, introductions of dam/infant to other group members should be done gradually and with close observation. Ideally if dam/infant are housed in an adjacent, connected enclosure, they can be introduced to one or multiple other groups members with continuous observation, gradually working up to all day together. Dam/infant may be separated in the adjacent enclosure overnight, until the social interaction is evaluated to be stable and affiliative.

7.6 Contraception

Many animals cared for in AZA-accredited institutions breed so successfully that contraception techniques are implemented to ensure that the population remains at a healthy size.

Mating behavior in *Eulemur* often goes unseen by human caretakers. In the majority of conceptions in *E. mongoz,* mating was never observed (T. Bettinger, personal communication, 2008). Therefore, a lack of apparent mating does not mean it is not occurring. It is strongly advised that contraception be used if an institution has no plans to breed a female. Furthermore, *Eulemur* species can interbreed, particularly those previously classified as brown lemurs (*E. fulvus.*) and black lemurs (*E. macaco*). Contraception should be used when housing males and females of two or more closely related species together to prevent interbreeding and birth of hybrids.

The AZA Mongoose Lemur SSP and *Eulemur* Studbook programs recommend permanent sterilization of all hybrid animals. Because the AZA Mongoose Lemur SSP and *Eulemur* Studbook programs are cooperatively managed, all individuals are part of the managed population. We therefore should provide hybrid individuals with the same standards of care we give other species, with the hope to eliminate hybrid animals through attrition so that their space can be turned over to other managed *Eulemur* species.

Separation of sexes: *Eulemur* species have been historically managed through separation of males and females if space allows during the breeding season. At one zoological institution, in order to prevent pregnancy in red-ruffed lemurs (*Varecia variegata rubra*) housed in a large mixed-sex group, signs of vaginal color (pinkness) were monitored (Kuhar et al., 2001). When a color change was observed, all females were separated from the males until no further signs of estrus were observed, after which the group was reunited. This management technique was successful in preventing pregnancies within this group, and could also be applied to *Eulemur* species, although it should be noted that estrus swellings are much more difficult to detect in many *Eulemur* species. Maintaining visual contact during periods of separation facilitates reintroduction of the animals once the breeding season is over.

Chemical contraception: The AZA Wildlife Contraception Center (WCC) recommends the use of MGA implants for *Eulemur* as a reversible contraception method. To minimize progestin exposure, implants should be inserted in October before the onset of breeding season and be removed in May after the breeding season. If the MGA implant is left in place, it has an expected effective period of a minimum of 2 years, but may in fact release hormone for much longer. If mating behavior in a female with an MGA implant is observed, this may indicate that the implant in not effective. Mating is not normally seen in *Eulemur* with MGA implants.

Another form of reversible female contraception used quite frequently is Depo-Provera injections. The AZA WCC recommended dose is 5 mg/kg body weight given every 30–45 days from November through March. One institution reported giving injections every 60 days with no unintended pregnancies in recent history (C. Williams, personal communication, 2008). However, there has been a confirmed pregnancy in a ruffed lemur during Depo-Provera treatment and care should be taken to give animals injections at regular intervals. Both MGA implants and Depo-Provera injections can cause weight gain, so diet should be monitored.

In males, gonadotropin releasing-hormone (GnRH) agonists are considered the safest reversible contraceptives but dosages and duration efficacy have not been well established for all *Eulemur* species. Side effects are similar to those following gonadectomy, especially weight gain. GnRH agonists are available as Suprelorin® (deslorelin) implants or Lupron® Depot injections. Please visit the Wildlife Contraception Center webpage for more information: http://www.stlzoo.org/contraception.

Contraception in females or males may lead to color change depending on the method used *(E. m. flavifrons* and *E. m. macaco*). For example, castration of males can lead to female coloration in sexually

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