AZA Nutrition Advisory Group
TAG/SSP Husbandry Notebook
Nutrition Section
Lemur catta (Ring-tailed lemur)

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Literature Review

The ring-tailed lemur *(Lemur catt*a) is a patchily distributed diurnal primate native to southern Madagascar. Adult body weight is approximately 2.3 - 3.5 kg (IUCN, 1990). Habitat type varies from closed canopy gallery forests to open brush/scrub forests, but also includes transition zones between the two (Bunditz and Dainis, 1975). Goodman and Langrand (1996) described an atypical population of *L. catta* living above the tree line on the Andringitra Massif. Home range size appears to be directly related to the abundance and distribution of resources, including water, within the various habitat types. While ring-tailed lemurs spend more time on the ground than any other lemur species, they are also active throughout all forest strata (Sussman, 1977). Ring-tailed lemurs live in female-bonded groups with an average size of 14 individuals. Females are dominant over males and juveniles (Jolly, 1966; Nakamichi and Koyama, 1997). *L. catt*a's conservation status is listed as High Priority by Mittermeier *et a*l. (1994).

The digestive anatomy of the genus *Lemur* is described in Hill (1953) and includes parotid, submandibular, greater and lesser sublingual salivary glands. The parotid gland is well developed, but the submandibular is the primary salivary gland. The stomach is elongated and pyriform, with long pyloric segments and well-separated pylorica and esophageal openings. Long, well-marked rugae radiate from the cardia of the stomach. The capacity of the duodenum in *Lemur* is great, rivaling that of the stomach. There is a long (~ 1 ft.) and voluminous cecum that is somewhat spiraled in the distal part. Campbell *et a*l. (2000) also found the *L. catta* cecum to be large and well vascularized with distinct teniae. The transverse colon is relatively long and has a looping ansa coli. The ansa is long but in a single loop (Hill, 1953). Descriptions of *L. catt*a's digestive anatomy, combined with feeding ecology data on seasonal leaf consumption indicate that the ring-tailed lemur is capable of at least some degree of ceco-colic fermentation. For instance, Sheine (1979) found that *L. catta* was able to digest 29.9% of ingested cellulose when food particle size was small, supporting the idea that *L. catta* is capable of processing moderately high fiber diets. Recorded transit times are short, from 1.5 to 6.5 hours, depending on the food offered and the marker administrated (Ganzhorn 1986; Cabre-Vert and Feistner, 1995), however marker studies utilizing more accurate media have not been conducted.

The dental formula for *L. catta* includes two pairs of incisors, one pair of canines, three pairs of premolars, and three pairs of molars for both the upper and lower jaws. Hill (1953) provides a detailed description of each of these teeth (pp. 380-381; p. 392). Yamashita (1996) described *L. catta's* teeth as well designed for consumption of fruits and seeds as well as capable of moderate levels of leaf processing. Thus, *L. catta* can be classified as more folivorous than other Lemurids while not as folivorous as the Indriids.

Data on the ring-tailed lemur's natural diet comes primarily from three sites: the Berenty Reserve in southern Madagascar (Sussman, 1977; Rasamimanana and Rafidinarivo, 1993), and Antserananomby and Tongobato in southwestern Madagascar (Sussman, 1977). The natural diet is generally a mixture of frugivory and folivory, depending upon availability and habitat. Whenever possible, feeding on one food item (e.g., fruit) is usually followed by a feeding bout on the other item (e.g., leaves) (Rasamimanana and Rafidinarivo, 1993). Some

flowers, bark, dead wood and sap are also eaten, and soil consumption is reported to comprise about 1% of total feeding time (Sussman, 1977; Rasamimanana and Rafidinarivo, 1993). Ring-tailed lemurs at Berenty were seen preying upon a chameleon, as well as several types of invertebrates (cicadas, grasshoppers, caterpillars) (Oda, 1996).

The diet regimen of *L. catta* contains a wide variety of plants, but the majority of the diet comes from a relatively few species. Sussman (1977) found that eight species made up over 70% of the diet at Antserananomby, while the same number made up over 80% of the diet at Berenty. Important species included the fruits of *Rinorea greveana* and *Pithecelobium dulce* and the mature leaves and fruits of the tamarind or kily tree, *Tamarindus indica* (Sussman, 1977; Rasamimanana and Rafidinarivo, 1993; Sauther, 1998). *T. indic*a, a nitrogen-fixing leguminous species, is found in the diet of other African primates, and its phytochemical profile includes relatively high nitrogen (3.46% dry weight) and acid detergent fiber (43.10% dry weight) values, as well as a strong protein-precipitating ability and high condensed tannin concentrations (8.82% quebracho tannin equivalents) (Mowry *et a*l., 1996; Mowry, unpublished data). Ring-tailed lemurs at Berenty consume bananas from tourists, as well as plant parts from introduced species such as *Eucalyptus* flowers (Rasamimanana and Rafidinarivo, 1993). Melons, sweet potato leaves and other raided crops have also been reported in the diet (IUCN, 1990). Most water needs are thought to be met through the diet, but drinking from tree hollows, puddles and rivers has been observed (Sussman, 1977).

The feeding ecology of semi-free-ranging ring-tailed lemurs has been studied at the Duke University Primate Center (Ganzhorn, 1986;1987 a,b) and on St. Catherines Island, Georgia (Mowry *et a*l. 1997; Dierenfeld and McCann, 1999) Ganzhorn (1986) reported that ring-tailed lemurs at Duke fed on thirty different local plant species (mainly leaves), but found no effect of measured plant secondary compounds on food choice. Animals were provisioned and only obtaining 5% of daily protein from selected plant materials, so he suspected that choice was of little consequence.

On St. Catherines Island, ring-tailed lemurs selected a wide variety of native vegetation in addition to their provisioned diet. Items eaten included live oak *(Quercus virginian*a) leaves and acorns, assorted mushrooms and unripe Muscadine grapes *(Vitis rotundifoi*a). Some levels of ingested phenolics and tannins (both hydrolyzable and condensed) were quite high. These animals did not, however, appear to be selecting foods based on sugar and/or protein, and the free-range diet was often higher in fiber than diets currently fed in captivity. For example, neutral detergent fiber values were nearly 40% (on a dry matter basis) for many of the free-choice items (Dierenfeld and McCann, 1999). Secondary compounds were not having an effect on food choice (Mowry *et a*l., 1997).

Zoo Diet Summary

Ring-tailed lemurs are relatively common in captivity and are generally fed a combination of commercial primate biscuit, fresh produce and locally available browse. Some institutions offer recently available high fiber biscuits (e.g., HMS hi-fiber primate biscuits, Marion high fiber monkey biscuits, Mazuri Leafeater Biscuit), while others utilize biscuits intended for omnivorous primates (Mazuri Old-World Primate, Mazuri High Protein Primate).

All are designed to be nutritionally complete for non-human primates when fed as the total diet, however some are more concentrated for use in combination with produce, which when fed in large quantities tends to have a dilution effect on the nutrient density of the biscuit. Neutral detergent fiber (NDF) values for the high-fiber biscuits are generally 30% on a dry matter basis and less than 10% for the other biscuits. Both of these values are lower than levels recorded for items chosen by free-ranging animals. Crude protein values range between 15% - 20% for most of these products, with those on the high end coming from the commercially formulated high-protein biscuits. Fat values generally fall between 4% - 5 %, while ash values are between 4% - 6%.

Produce offered to *L. catta* generally falls into the following categories: fruit, starchy vegetables, leafy greens and vegetables. These are offered daily, along with a nutritionally complete biscuit, in some combination. Year-round available fruits are most often offered (e.g., oranges, bananas, grapes and apples), while a variety of other fruits are provided when in season. Starchy vegetables include sweet potatoes, turnips, potatoes and corn; greens include kale, collard greens, alfalfa, cabbage and lettuce. Other vegetables include broccoli, celery, cucumbers and green beans. Many facilities also offer leaves, fruits and flowers from local browse, although its use is governed by staff time and knowledge of safe species, availability and season. Animals are fed either once or twice daily, and produce rotation provides diet variety. Sample diets fed to ring-tailed lemurs at several institutions follow this general pattern (Table 1).

Hand-Rearing Protocols

• Refer to Infant Diet Care Notebook

• Based on one sample collected for *L. catt*a, milk composition is probably similar to *Eulemur* – dilute like other anthropoids. Composition: (n=1) at 62 days postpartum, 10.9% DM, 1.8% fat, 2.0% protein, 8.1% sugar, .60kcal/g (Tilden and Oftedal, 1997).

Special Considerations

• Spelman *et a*l. (1989) found that captive lemurs were extremely susceptible to excess iron deposition (hemosiderosis) in the duodenum, liver and spleen, and they attributed this disease to a diet high in iron and ascorbic acid, and low in tannins. The tannins consumed by wild lemurs, as well as other herbivorous mammals, may help to control iron metabolism (Roy and Mukherjee, 1979). Lemurs on a commercial biscuit diet do not need any additional supplementation with vitamins and minerals, which might increase the iron overload problem.

• female physiological state - Leaf consumption of *T. indica* plant parts by wild ring-tailed lemurs doubled during pregnancy (Rasamimanana and Rafidinarivo, 1993).

• dental calculi - Sauther *et a*l. (1999) found little plaque and few dental calculi in 7 groups of wild ring-tailed lemurs from the Beza Mahafaly Reserve in southern Madagascar. Dental abscesses were mostly periapical and located on the molars. Extensive staining of the teeth, ranging from a dark brown to black, was found in nearly a quarter of the population, and more

so in females than in males. As expected, older individuals exhibited more tooth wear (Sauther *et a*l., 1999). Eight *L. catta* and six *E. fulvus* were utilized in a single reversal experiment to determine the effectiveness of a sodium hexametaphosphate (HMP) coating on their commercial biscuit in control of dental calculus or periodontal disease. The project was conducted at Indianapolis Zoo, and the diet other than the HMP was similar to most captive diets (Willis *et a*l., 1999). Animals given the experimental diet (0.6% HMP) had significantly lower dental calculus formation (scores were 62% lower) than they did on their normal diet regimen.

Recommendations

Most institutions that house *L. catta* provide them with a nutritionally complete biscuit and locally available produce on daily basis. Table 2 illustrates the nutrient composition of this type of diet presently offered by one institution (St. Catherines Island, Georgia). Use of daily targeted nutrient values, based on NRC requirements for non-human primates (NRC, 1978), RDA's (NRC, 1989), and recent research provides a guideline by which to judge a potential diet for use in a captive colony (see Table 3). Chronic overfeeding can result in diet selectivity by the animals and obesity; therefore diets should be fed such that no more than 10-15% of the offered diet will be left uneaten. Large groups should be fed in multiple sites to prevent competition for choice items.

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Table 1: Sample *Lemur catta* diets fed to captive/semi free-ranging individuals.

Duke University Primate Center (per animal/~30-35 animals):
60g Mazuri Old World Primate Diet (#5667)
120g Fruit/vegetable mix (specific items vary daily and include bananas, apples, oranges, melon, grapes, sweet potatoes, carrots) with browse for enrichment (avg. is probably not even once a week & less in off season obviously).

St. Catherines Island (per animal):
130 g HMS hi-fiber primate biscuits
175 g fruit
75 g vegetables
150 g greens

Indianapolis Zoo (for 10 animals, 2 of whom are *L. fulvus collaris*):
AM:
24 pieces Mazuri High Protein Primate bisquits (#5668)
2 oranges - peeled and sliced
1 1/4 apple - sliced
1 lb. greens
1 cup Marion Leaf Eater food (lemur size)

PM:
24 pieces Mazuri High Protein Primate bisquits (#5668)
2 1/2 bananas - sliced
4 carrots - sliced
1 cup Marion Leaf Eater food (lemur size)
1/2 lb. greens
During winter the 1 cup of leaf eater food is deleted.
Occasional treats include browse, seasonally available produce (1 cup per feeding berries, melon, tomatoes, zucchini), apple fiber bisquits, bread, hay, nuts, 1/4 cup sunflower seeds, frozen juice blocks.

San Diego Zoo:
AM:
3/4 c Leafeater, dry/lemur (Marion Zool.) daily
Vegetables, mixed assorted, feed 1-2 times daily
PM:
1/2 c Leafeater, dry/lemur (Marion Zool.) daily
6 leaves kale twice weekly
3 1/2 leaves greens, collard twice weekly
4 1/2 bunches spinach once weekly
3 1/2 leaves greens, dandelion once weekly
1/6 head cabbage once weekly
1/2 whole turnip, raw twice weekly
Feed strictly as indicated. Do not alter diet. If change is required, provide details in diet request form.
Instructions: Note any item refusals. Browse should not exceed 1-3 foot sections / animal, no *Acacia spp*.

Table 2: Nutrient composition (dry matter basis) of the diet fed to *Lemur catta* on St. Catherines Island, Georgia [a]

Nutrient	Concentration In Diet
Water (%)	62.5
Energy (kcal/g)	3.2
Protein (%)	19.2
Fat (%)	3.9
NDF (%)	5.1
ADF (%)	2.8
Ash (%)	5.9
Vit A (IU/g)	68+
Vit D (IU/g)	1
Vit E (IU/g)	116
Ca (%)	0.7
P (%)	0.5
Ca:P ratio	1.4:1.0

[a] Based on a caloric requirement of 480 kcal/day/animal (E. Dierenfeld, personal communication).
The diet actually provides 635 kcal/day/animal.

Table 3: Daily Target Nutrient Levels for *Lemur catta* diets [a]

Nutrient	Concentration in diet
Energy (kcal/KgBW)	not less than 100
Crude Protein (%)	not less than 16.7
Fat (%)	-
Fiber (% NDF)	10-20 [b]
Linoleic Acid (%)	1
Vitamin A (IU/g)	14
Vitamin D (IU/g)	2.2 [c]
Vitamin E (mg/kg)	56
Riboflavin (mg/kg)	5.6
Niacin (mg/kg)	55.6
Pyridoxine (mg/kg)	2.8
Folacin (mg/kg)	0.2
Vitamin B-12 (mg/kg)	0.6
Pantothenic Acid (mg/kg)	16.7
Thiamin (mg/kg)	5.6
Choline (mg/kg)	-
Biotin (mg/kg)	0.1
Vitamin C (mg/kg)	111
Calcium (%)	0.6
Phosphorus (%)	0.4
Magnesium (%)	0.2
Potassium (%)	0.9
Sodium (%)	0.3
Iron (mg/kg)	80-200
Zinc (mg/kg)	11.1
Copper (mg/kg)	1.5
Manganese (mg/kg)	44.4
Selenium (mg/kg)	-
Iodine (mg/kg)	2 [d]

[a] Based on NRC requirements for Old World primates (1978) and human RDA values (1989).
[b] Based on suggested guidelines from Oftedal and Allen (1996).
[c] If animals are not housed where they have access to appropriate amounts of the correct spectrum of UV light, it is essential to provide adequate Vitamin D in the diet.
[d] NRC may have overestimated the quantity needed. For most other animals, the requirement is approximately 0.1 ppm.
-Information on this nutrient is not present in NRC (1978).