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Examining Visual Measures of Coat and Body Condition in Wild Ring-Tailed Lemurs at the Bezà Mahafaly Special Reserve, Madagascar

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Key Words

Lemur catta · Noninvasive methods · Body mass · Coat status · Visual methods · Health status

Abstract

Coat and body mass status provide a potential noninvasive way to assess primate health status as well as the effects of seasonality, resource use and reproductive state. Coat and body condition were scored visually for 36 wild *Lemur catta* at the Bezà Mahafaly Special Reserve, Madagascar, from July 2012 to March 2013. Coat quality generally increased during the wet season when resource availability increased, in contrast to that observed during the resource-depleted dry season. Alopecia frequency increased from June to December and declined between January and March. Sex differences for coat condition were only observed in January, when males had superior coat scores. Body condition did not vary by month or sex except in February, when males were larger than females. Females that birthed infants were of lower body size than individuals who did not for November and from January to March. Our results indicate visual methods effectively detect variability in coat and body condition related to seasonality and reproductive status. Such methods present a noninvasive means for assessing the impact of seasonal resource availability, stresses of infant care and reproductive state on ring-tailed lemurs, and may be useful for assessing the impacts of these factors on general health status.

Introduction

Measures of coat condition and body mass present an avenue for assessing general health status among nonhuman primates, but also reflect a variety of factors including individual reproductive state, social ecology, resource use and availability,

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and seasonality. Poor coat condition and/or hair loss may result from a number of potential sources including seasonality and aging, reproductive condition, nutritional and hormonal imbalances, social stress, parasites and infections, and diet. Although a range of variables may impact coat quality and/or result in hair loss, coat condition indices can present a valuable noninvasive measure of general health status, but may also provide insights into aspects of social and feeding ecology as well as reproductive state [Isbell, 1995; Pride, 2003; Beisner and Isbell, 2009; Jolly, 2009a, b; Novak and Meyer, 2009; Zhang, 2011; Borg et al., 2014]. Similarly, measures of body mass can provide information about resource availability, nutritional and health status, and insight into reproductive condition. For example, body mass has been positively associated with increased access to resources [Eley et al., 1989; Altmann et al., 1993; Olupot, 1999; Borg et al., 2014] and is also positively associated with reproductive outcomes [Bercovitch, 1987; Richard et al., 2000]. Likewise, body condition may also vary seasonally due to reproductive condition (e.g. pregnancy and lactational status, seasonal timing of reproduction) and/or seasonal variation in food availability [Sauther, 1998; Richard et al., 2000; Lewis and Kappeler, 2005].

Among ring-tailed lemurs *(Lemur catta),* coat condition has been associated with seasonality, resource use, reproductive state, physiological stress and health status [Pereira et al., 1999; Pride, 2003; Crawford et al., 2006a, b; Junge and Sauther, 2006; Miller et al., 2007; Jolly, 2009a, b; LaFleur, 2012; Ichino et al., 2013b]. Variation in body mass that is related to resource availability, seasonality and lactational status has also been reported for *L. catta* in both wild and captive settings [Pereira, 1993; Sauther, 1998; Ichino et al., 2013a]. While these measures may be evaluated through direct veterinary examinations, visual scoring systems for body mass and coat condition provide a cost-effective and less time-consuming alternative. In this paper we present data using remote visual measures of coat condition and body condition related to body mass in ring-tailed lemurs from the Bezà Mahafaly Special Reserve (BMSR). Although visual measures of coat condition have been presented for *L. catta* from Berenty and Tsimanampesotse [Pride, 2003; Jolly, 2009a, b; LaFleur, 2012], to date no such data have been presented for BMSR ring-tailed lemurs. Likewise, to our knowledge, no researchers have published quantitative visual indices of body mass condition for wild ring-tailed lemurs, or for any other wild strepsirrhine primate. As such, in this paper we examine month-to-month variation for body size, coat condition and alopecia (hair loss). We also provide information on sex differences for each of these measures on a within-month basis, as well as data examining variability in monthly body condition between individuals with and without infants.

Materials and Methods

Coat and body condition evaluations were conducted for 36 (23 female, 13 male) adult ring-tailed lemurs *(L. catta)* at the BMSR, in southwestern Madagascar (23.6667° S, 44.6000° E) from July 2012 to March 2013 as part of an ongoing long-term study (since 2003) of *L. catta* dental and general health. Individuals were drawn from 7 initial study groups, with observations being recorded in 9 groups following migration of 4 male study subjects over the course of observations. All individuals were identified using a numerical collar system [Cuozzo and Sauther, 2006; Sauther and Cuozzo, 2008]. There were more females in the study sample than males due to male immigration. J.B.M. assessed coat condition, body condition and the presence of alopecia for each study animal ideally on a twice-monthly basis from July 2012 to February 2013. Bezà Mahafaly

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Fig. 1. Coat condition scores for BMSR *L. catta.* 0 = Good; 1 = rough; 2 = holes; 3 = ragged. Individuals in images 2 and 3 demonstrate alopecia.

Table 1. Coat condition scoring system definitions (based on Berg et al. [2009])

Coat score	Defining characteristics of coat condition score	
0 (good)	(1)	Animal has excellent coat with no or few imperfections
	(2)	Little to no hair creasing present
	(3)	Hair is unidirectional in cranial-caudal direction
	(4)	Little to no visible coat shagginess; coat is uniform
	(5)	One or 2 small, coin-sized holes permissible
1 (rough)	(1)	Coat has slight to significant shagginess and/or unevenness
	(2)	Creasing of the hair frequently present
	(3)	Hair may have 1 or 2 small holes up to coin size
	(4)	Score may be assigned when 1 larger hole present, but small sized (e.g. 2 or 3 coins)
2 (holes)	(1)	Animal demonstrates >2 coin-sized holes in hair
	(2)	Holes are typically surrounded by rough hair
	(3)	<25% of hair missing in total
	(4)	Hair may be partially grown back in the hole, but not predominantly filled with presence of hole still clear
3 (ragged)	(1)	Hair shows holes over >25% but <50% of body or limbs
	(2)	Hair is <1/2 normal length in affected areas
4 (sheared)	(1)	Hair less than half depth on >50% of body. *Not observed*
5 (bald)	(1)	More than 50% of hair on body or limbs absent. *Not observed*

demonstrates a highly seasonal pattern of rainfall with the majority of precipitation falling during the wet season from between October–November to the end of March [Sauther, 1998]. Therefore, data presented herein were collected from the height of the dry season until the end of the wet season. At BMSR, food resources available to *L. catta* track patterns of rainfall with reduced food availability occurring during the height of the dry season and increased resource availability occurring during the wet season [Sauther, 1998; Millette, pers. observation]. BMSR *L. catta* demonstrate a seasonal pattern of reproduction with the majority of births occurring during the months of September and October [Sauther 1998; Millette, pers. observation], and infant weaning commencing by March before the subsequent mating season (May–June [Sauther, 1998]).

Observations for study animals were occasionally, but rarely, made more than twice monthly. Likewise, on several occasions animals were only observed once during a month (e.g. the animal was too far away to be observed adequately or could not be located), although this occurred infrequently from July to February. A smaller subset of individuals (n = 29) was scored by J.B.M. once during March 2013.

Coat condition was scored using a 0–5 ordinal system (table 1, fig. 1) derived from that of Berg et al. [2009], and which has been used for assessing *L. catta* at Berenty Private Reserve and Tsimanampesotse National Park [Berg et al., 2009; Jolly, 2009a, b; LaFleur, 2012]. Alopecia was documented using a Yes/No system, and was recorded if holes with missing hair were present in the coat. If hair regrowth had started where hair had been previously missing, alopecia was recorded if these patches were not predominantly filled by new growth. Body condition for each subject was recorded using a 0–4 ordinal system based on that designed for quantifying relative body fat in *Macaca mulatta* by Berman and Schwartz [1988] and adapted for use in *L. catta* (table 2, fig. 2). Our system represents a general measure of relative body mass (e.g. from extremely thin to obese), although we use the term 'body condition' as study animals were not weighed directly. While we did not directly compare body condition scores between BMSR lemurs and rhesus macaques, Pereira and Pond [1995] found patterns of fat deposition to be similar between both taxa.

All scores were preferably collected when subjects were on the ground and at a close range to the observer. While observation distance was not recorded, observations were typically conducted less than 3 m from the animal. To account for multiple monthly observations, each animal's status was assessed using the highest recorded monthly value for coat and body condition, while alopecia was reported if observed during at least 1 monthly assessment.

Coat, body condition and alopecia scores were evaluated for month-to-month differences and for within-month sex differences using nonparametric methods (Wilcoxon Mann-Whitney and Wilcoxon signed-rank tests). Between-month differences for alopecia were determined using McNemar's exact test. Within-month sex differences for alopecia were determined using Fisher's exact test. To examine the effect of reproductive status on within-month variation in body condition, females who were never observed with a new infant and males were compared to females who had infants using a Wilcoxon Mann-Whitney test. For all tests, significance was set at the $\alpha \leq 0.05$ level using a 2-tailed distribution with values approaching p = 0.05 (e.g. p = 0.052) being rounded down [Weiss, 2011].

Results

Coat Scores

Significant differences for coat scores were observed between the months of December and January (p = 0.008, S = –40.05, n = 34, December mean = 1.294, January mean = 0.912) as well as between February and March (p = 0.002, S = –40.00, n = 29, February mean = 0.794, March mean = 0.345). Coat scores improved several months after the transition from the dry season to the wet season (November), during which poor coat scores (e.g. 2 = holes and 3 = ragged) became less common and/or disappeared. While females generally had better coats than males during the late dry season, males generally demonstrated better coats when compared with females for the months following infant birth and subsequent lactation (e.g. September/October onward). However, significant within-month coat differences between sexes were not observed except when males had lower (better) coat scores in January (Wilcoxon Mann-Whitney test: p = 0.052, S = 159.5, Z = –1.95; males: n = 11, rank mean = 14.5; females: n = 23, rank mean = 18.9; table 3). Although individual coat scores ranged from 0 (good) to 3 (ragged), no animals were observed to have coats in the categories 4 (sheared) or 5 (bald).

Table 2. Body condition scoring system definitions

Score	Defining characteristics of body score
1	(1) Animal is extremely thin (2) Underlying skeletal structure clearly visible (3) Score 1 was not observed during this study
1.5	(1) Animal shows low body mass and appears visibly thin (2) Body rail-like; hips are exposed with flanks depressed (3) Animal has taut skin with no excess fat (4) Eye orbits exaggerated and face appears thin (5) No bones or ribs visible through skin
2	(1) Animal is of average size, neither thin nor fat; animal is lean (2) No excess fat apparent; animal is 'sleek' in appearance (3) Face appears full; eye orbits do not protrude (4) Hips and flanks are not concave or only slightly so
2.5	(1) Animal of slightly higher body mass than in score 2 (2) Hips often rounded; fat often on hips and lower back (3) Body rounded; slight to moderate belly fat may be present (4) Face full; head may appear small in relation to body
3	(1) Animal is of high body mass (2) Girth >2.5 with belly fat present; wide at hips and midsection (3) Sides bulge when sitting, fat may be present over legs (4) Head small in relation to body; animal is 'light bulb' shape (5) Animal appears very full or 'overstuffed'
3.5–4	(1) Animal is of extremely high body mass (2) Extreme amounts of fat present (3) Scores 3.5 and 4 were not observed during this study

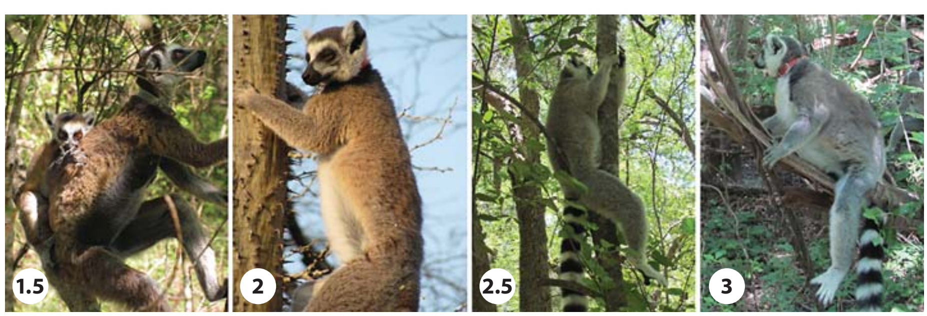

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Fig. 2. Body condition scores for BMSR *L. catta.* 1.5 = Reduced body condition; 2 = moderate body condition; 2.5 = slightly high body condition; 3 = high body condition.

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Table 3. Monthly coat condition by sex (Wilcoxon Mann-Whitney test)

	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Males									
Number	13	13	13	12	12	11	11	11	10
Score sum	267	256	235.5	222	200.5	152	159.5	163	129
Expected sum	240.5	240.5	240.5	216	216	192.5	192.5	192.5	150
Rank mean	20.5	19.7	18.1	18.5	16.7	13.8	14.5	14.8	12.9
Females									
Number	23	23	23	23	23	23	23	23	19
Score sum	399	410	430.5	408	429.5	443	435.5	432	306
Expected sum	425.5	425.5	425.5	414	414	402.5	402.5	402.5	285
Rank mean	17.4	17.8	18.7	17.7	18.7	19.3	18.9	18.8	16.1
Statistical values									
S score	267	256	235.5	222	200.5	152	159.5	163	129
Z	1.05	0.58	–0.19	0.27	–0.66	–1.64	–1.95	–1.52	–1.14
p	0.292	0.563	0.851	0.784	0.512	0.102	0.052	0.128	0.254

Alopecia Scores

No significant within-month differences were observed between males and females. Exact McNemar's tests indicate that alopecia became more common during the height of the dry season from July to August ($p = 0.031$, July: no alopecia $n = 28$, alopecia $n = 8$; August: no alopecia $n = 22$, alopecia $n = 14$), along with a similar trend between November and December ($p = 0.070$, November: no alopecia $n = 14$, alopecia $n = 21$; December: no alopecia $n = 8$, alopecia $n = 26$). Individuals demonstrated alopecia with decreased frequency from December to January ($p = 0.0002$, December: no alopecia $n = 8$, alopecia $n = 26$; January: no alopecia $n = 21$, alopecia $n = 13$) approximately a month after the start of the wet season, with a trend towards reduced alopecia between January and February ($p = 0.070$, January: no alopecia $n = 21$, alopecia, $n = 13$; February: no alopecia $n = 27$, alopecia $n = 7$; fig. 3).

Body Condition Scores

Body condition scores did not differ significantly between months. Likewise, body condition did not differ by sex except for February when males had higher body condition scores than did females (Wilcoxon Mann-Whitney test: $p = 0.049$, $S = 226$, $Z = 1.97$; males: $n = 11$, rank mean = 20.6; females: $n = 23$, rank mean = 16.0). When males and non-infant-bearing females were compared to females that gave birth, however, significantly higher body condition scores were recorded for males and non-infant-bearing females for November, January, February and March (Wilcoxon Mann-Whitney test: November: $p = 0.052$, $S = 339$, $Z = 1.94$; males and females without infant: $n = 17$, rank mean = 19.9; females with infant: $n = 18$, rank mean = 16.2; January: $p = 0.027$, $S = 320$, $Z = 2.21$; males and females without infant: $n = 16$, rank mean = 20.0; females with infant: $n = 18$, rank mean = 15.3; February: $p = 0.020$, $S = 322$, $Z = 2.33$; males and females without infant: $n = 16$, rank mean = 20.1; females with infant: $n = 18$, rank mean = 15.2; March: $p = 0.004$, $S = 263$, $Z = 2.92$; males and

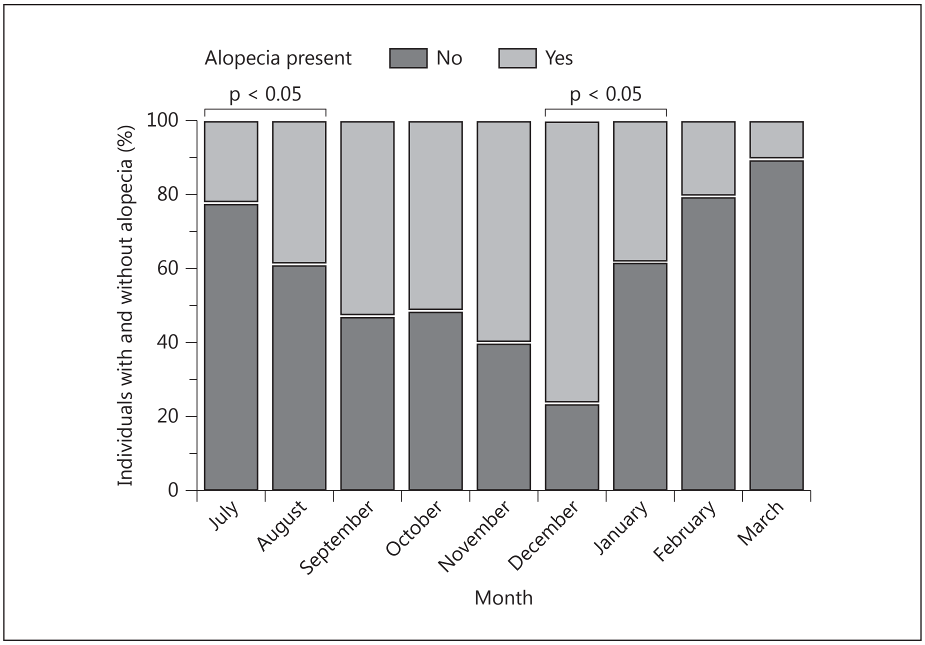

Fig. 3. Presence of alopecia for BMSR *L. catta*. Alopecia increased in frequency from July to December, before becoming less common from January to March.

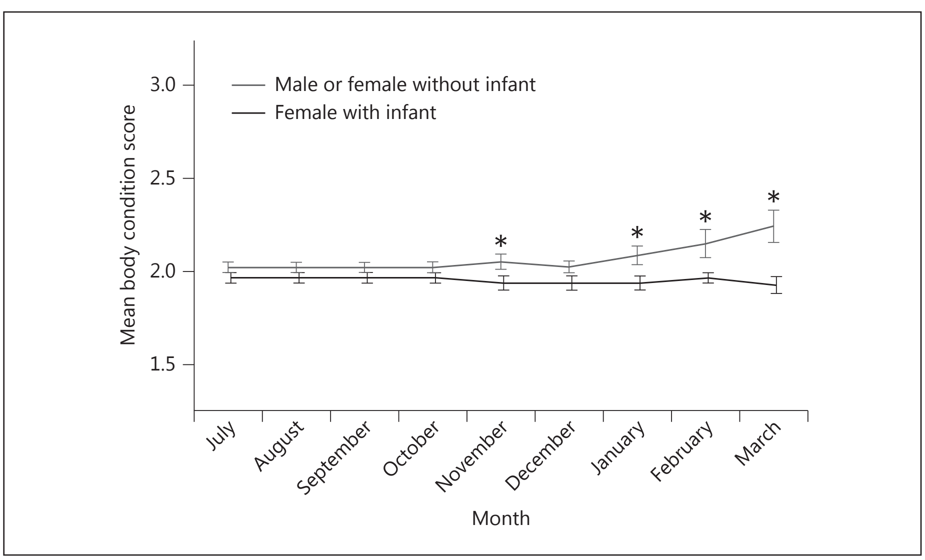

Fig. 4. Body condition scores for BMSR *L. catta* by reproductive status. Males and females who were not observed to give birth demonstrated higher body condition scores than females who had infants for November, January, February and March. * $p \leq 0.05$. Each error bar is constructed using 1 standard error from the mean.

females without infant: n = 14, rank mean = 18.8; females with infant: n = 15, rank mean = 11.5; fig. 4). Individuals with exceptionally low (e.g. score 1) or high (scores 3.5 and 4) body condition scores were not observed.

Discussion

Coat Condition

Our data show that coat condition varies seasonally among BMSR *L. catta*. Coat condition generally improved following the transition from the dry season to the wet season (late October to early November [Sauther, 1998; Millette, pers. observation]) when resource availability increases [Sauther, 1998]. Coat scores do not improve immediately, indicating a delay occurs before hair growth and/or replacement. While the observational method used in this study may not be of high enough resolution to determine fine differences in coat condition between the sexes, from October through March, when females give birth (September to October), nurse (birth to March) and wean their infants (March [Sauther, 1998; Millette, pers. observation]), males generally had better average coat scores than did females, although this only reached significance during late lactation (January). Similar patterns of coat condition have also been documented among ring-tailed lemurs at Tsimanampesotse, where females demonstrated poorer-quality coats than males overall, but also showed a more rapid deterioration of coat condition during the dry season and slower recovery of coat condition during the wet season [LaFleur, 2012]. Seasonal variation in coat condition has also been observed at Berenty, where Jolly [2009a] found coat status declined from September to November for males and for females with infants. Likewise, females with infants showed reduced coat condition in contrast to those without infants in October and November, although no overall male-female differences in coat condition were found.

When compared to data collected for Berenty *L. catta* from September to November [Jolly, 2009a, b], our data demonstrate a restricted range of scores as BMSR lemurs do not show categories 4 (sheared) or 5 (bald). This reduced range of variation likely reflects the absence of *Leucaena leucocephala* at BMSR, an introduced food species which has been implicated in the occurrence of bald lemur syndrome among Berenty *L. catta* [Crawford et al., 2006a; Jolly, 2009b; Ichino et al., 2013b]. The frequency of alopecia also varied seasonally, generally increasing from July to December, before declining until the end of the study. These alopecia data roughly correspond with our ordinal measures of coat condition across the study period, suggesting that alopecia frequency may provide a general proxy for overall coat condition. As with coat condition scores, no significant differences were noted between males and females, although informal observations suggest that females and males demonstrate divergent patterns of alopecia. BMSR mothers often appear to lose hair in large (5–10 cm) patches where their infants consistently grasp (e.g. the flanks and back) when being carried. Similar hair loss has been reported for Berenty mothers, and has also been reported among Japanese macaques *(Macaca fuscata)*, suggesting such patterns are not unique to BMSR lemurs [Crawford et al., 2006a, b; Jolly, 2009a; Zhang, 2011]. Additionally, observed patterns of alopecia may also reflect seasonal variation in the rate of hair growth. Captive ring-tailed lemurs have been observed to grow tail hair primarily between the spring and fall equinoxes [Pereira et al., 1999], and similar cessations in body hair growth could possibly impact the occurrence and duration of

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missing hair patches among wild *L. catta.* Patterns of alopecia at BMSR may also be influenced by the presence of notable toothcomb wear among some lemurs in this population, as individuals with toothcomb wear/damage have been observed to demonstrate increased rates of hair loss [Sauther and Cuozzo, 2013].

Body Condition

While a nonsignificant trend towards greater body condition scores was observed following the new year, no significant monthly differences for body condition were found. Likewise, no sex differences for body condition were noted except for February, when males demonstrated higher body condition scores than did females. This lack of significant differences between months and sexes may reflect the relatively small size of our study sample and/or the coarse nature of our scoring system. Alternatively, a lack of month-to-month and sex differences during the dry season may relate to the relatively longer coats that animals possess during this time [Millette, pers. observation]. Dry-season coats may obscure individual differences in body status as lengthier hair not only makes animals appear visually larger, but may also hide diagnostic traits characterizing low body condition scores (e.g. exposed skeletal features, depressed flanks, etc.). Future studies may benefit from the use of coat and body condition scoring systems which account for seasonal variability in coat length.

Our results do suggest that the body condition scoring system employed is useful and effective following the onset of the wet season when coats become shorter and females with infants are undergoing lactation. When contrasting males and females who did not have infants against females who did, significant differences for body condition were observed in November, January, February and March. These data suggest that the energetic demands of infant care in terms of lactation and infant carriage may limit weight gain following resource increases during the wet season, while females without infants and males unencumbered by these demands proceed to gain weight. Likewise, all scores of 1.5 (the lowest recorded body condition score) were recorded for females who bore infants, further suggesting that female lactational status and/or infant carrying is associated with reduced body condition. These data are analogous to those reported by Sauther [1998] who noted that females became observably thin during lactation. Similarly, Pereira [1993] reported weight loss among captive lactating *L. catta* females, and lactation-related weight loss has also been reported among olive baboons [Bercovitch, 1987]. Our data showing that individuals without infants visually gain mass is also similar to Pereira's [1993] observations that captive males and females gain weight prior to the mating season, although reproductive status appears to have a mediating effect on weight gain. While we acknowledge that our study did not collect measured body weights with which to confirm our visual methods, the congruence of our findings with those of other studies suggests that our method represents a valid, useful measure of body condition in wild ring-tailed lemurs.

Conclusion

Our results provide support for the efficacy of visual methods for assessing coat and body condition among BMSR ring-tailed lemurs. Such methods provide a valuable tool permitting examination of individual condition and health status without requiring direct health assessments under veterinary care that are both time-consuming and expensive. Such examinations are also potentially disruptive to animals and also present a small, but not insignificant, risk of injury during capture. Our results also correspond with those by other ring-tailed lemur studies, in which poor coat and/or body condition may reflect female reproductive costs [Sauther, 1998; Pride, 2003; Jolly, 2009a; LaFleur, 2012]. Additionally, ring-tailed lemur health status may be impacted by factors such as seasonal variation in food availability or stochastic events resulting in reduced food availability, such as cyclones and/or droughts which occur commonly at BMSR [Sauther, 1998; Gould et al., 1999; LaFleur and Gould, 2009; Rasamimanana et al., 2012; Sauther et al., 2012]. Health status may also be impacted by factors that influence individual access to nutritional resources including social group size, habitat quality and/or severe dental impairment (a common occurrence among BMSR *L. catta* [Pride, 2005; Cuozzo and Sauther, 2006; Sauther et al., 2006]). The coat and body condition scoring methods presented here may be used to enhance studies investigating the impact of these factors on lemur health. While we do not directly address the impact of these factors here, we are currently assessing how the measures presented in this paper also interact with aspects of lemur behavior and health (e.g. tooth loss status, indicators of illness, etc.).

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