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Adult Female Activity Time Budgets in Red-Bellied Lemurs (*Eulemur Rubriventer*) and Infant Survival: Ranomafana National Park

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**Adult Female Activity Time Budgets in
Red-bellied Lemurs (*Eulemur rubriventer*) and Infant Survival:
Ranomafana National Park**

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Spring 2011

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Misoatra Betsaka!

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Abstract

My research during the independent study period focuses on the relationship between activity time budgets of adult female red-bellied lemurs (*Eulemur rubriventer*) and infant survival. I conducted my research under the guidance of Centre ValBio in Ranomafana National Park. Red-bellied lemurs have a clear three month birth peak from Aug-Oct, but up to 30% of infants in a single year can be born outside of this birth peak, however, survival for out-of-season infants is strikingly low compared to in-season infants, 100% (n=4) of out-of-season infants died in one study conducted in 2009, whereas only 11% (n=18) of in-season infants died within their first year. I collected data on adult female activity time budgets as a way to compare adult females with out-of-season infants and those without, to see if mother ATBs may be a factor in infant survival. I found that all female ATBs are strikingly similar, with only small adjustments, such as increased feeding and decreased moving in the adult female with an out-of-season infant. Infants born outside of the birth season may be at a disadvantage because the mother's activity time budget cannot sufficiently adjust to ensure adequate energy to support the stresses, like lactation, of rearing an infant. I suggest that this preliminary research be used to design a longer term study, to assess different factors affecting relaxed birth seasonality and infant survival in red-bellied lemurs.

Introduction

The Red-bellied lemur, *Eulemur rubriventer*, is one of twelve lemur species found in Ranomafana National Park. As an independent study project, with duration of roughly three weeks of data collection, I decided to devote my time to studying activity time budgets of red-bellied lemurs. The impetus for this research was derived from the oddity that red-bellied lemurs have a clear three month birth peak, from late August through October (Tecot, 2010), but infants in this species, at least in Ranomafana National Park, are often born outside of the normal birth season. However, past studies have shown that infant survival is greatly compromised for individuals born outside of the peak birth season (Tecot, 2010). The goal of this research was to assess the role of adult female activity time budgets and infant survival.

Ranomafana National Park

I conducted my research in Ranomafana National Park, located in southeastern Madagascar (47° 18' - 47° 37' E and 21° 02' - 21° 25' S). The national park lies 400 kilometers south of the country's capital, Antananarivo, and 90 kilometers inland of the Indian Ocean on the east side of the central High Plateau (ICTE website). Ranomafana National Park began in 1991, owing a great deal of credit to Dr. Patricia Wright who rediscovered the greater Bamboo lemur, *Prolemur simus*, in 1985, when it had been thought to be extinct for over 85 year, while also discovered during this year the golden bamboo lemur, *Hapalemur aureus* (Page, 1999). The park covers 43,500 hectares ranging from 600 to 1513 meters in altitude (Tecot, 2010). The park is managed by MNP, Madagascar National Parks, and is also home to Centre ValBio (Centre pour la Valorisation de la Biodiversité).

Centre ValBio, an impressive research station located on RN45 just outside of the entrance to Ranomafana National Park, who helped facilitate my research. The center is staffed

almost entirely by local Malagasy research technicians, chefs, administrators, guards, etc. The Institute for the Conservation of Tropical Environments at Stony Brook University created and manages Centre ValBio. Centre ValBio's aims are manyfold, including projects focusing on biodiversity conservation, youth education, scientific research, family planning and hygiene education, for example.

The richness of biodiversity is impressive within the park. The national park is home to over 100 tree species, high land snail biodiversity, a vast array of frog species, impressive insect and reptile species diversity, 110 bird species, and incredibly high primate diversity. Five lemur families, a total of 12 species, of which all are endemic to Madagascar, inhabit Ranomafana National Park. Of the twelve species, there are 3 species of bamboo lemur: Greater bamboo lemur (*Prolemur simus*), Eastern lesser bamboo lemur (*Hapalemur griseus*) and the Golden Bamboo lemur (*Hapalemur aureus*), 2 *Eulemur* species: the red-bellied lemur (*Eulemur rubriventer*) and the red-fronted brown lemur (*Eulemur rufus*), the black-and-white ruffed lemur (*Varecia variegata variegata*), Milne-Edward's sifaka (*Propithecus edwardsi*), the Eastern woolly lemur (*Avahi laniger*), the small-tooth sportive lemur (*Lepilemur microdron*), the greater dwarf lemur (*Chreirogaleus major*), the brown mouse lemur (*Microcebus rufus*), and the aye-aye (*Daubentonia madagascariensis*) (Mittermeier *et al.*, 2006 & WildMadagascar Website).

The Namorana River runs through the subtropical rain forest of Ranomafana National Park, with many streams that feed the river. Energy generated from the river is used to power all of Ranomafana and some of the energy needs of the nearest city, Fianarantsoa, located about 60 kilometers from the park (Dina, pers. comm.). Annual rainfall in the park ranges from 1500-4000 mm per year, with an average of 3090mm of rain per year (Tecot, 2010). The rainy season begins in November and continues until March. The dry season picks up in April and ends in December, however Ranomafana National Park has no weeks that are completely devoid of rainfall (ICTE

website). Cyclones can greatly affect the park and the surrounding villages in the months of January, February and March. During the cyclone season, access to the park is often cut off due to the flooding of the Namorana River.

There are four trail systems within the park, each of which is 5-7 square kilometers. The Talatakely Trail System is located in low montane eastern rain forest and was selectively logged from 1986-1987. This trail system is the most heavily used by guides and tourists, and is also the trail system that I most frequented during my research. I also used the Vatoharanana Trail System which is an area of minimum disturbance, classified as primary forest at a higher altitude of 1200 meters that is 4 kilometers south of the Talatakely area. The Talatakely Trail System is well-maintained whereas the Vatoharanana Trail System is overgrown in many areas. The two remaining trail systems are the Valohoaka Trail System, located located 8 kilometers south of Talatakely and the Vohiparara Tail System of the high plateau (ICTE website). According to my research technician from Centre ValBio, there are no current maps of all trail systems of Ranomafana National Park.

It is forbidden to enter the park boundaries without a guide, with good reason as the trail systems are rarely marked and even after three weeks of frequenting the park I still managed to get lost when I strayed too far from my research technician, Dina. Unfortunately no concrete tourist statistics are available for Ranomafana National Park. Even during the month of April the park was well frequented by both international and Malagasy visitors. Tourist groups in the park are supposed to be capped at six individuals per guide, to ensure no extra stress is put on lemur species in their natural habitat. Several times while in the field Dina and I encountered groups of visitors numbering up to twenty.

Eulemur rubriventer, Red-bellied lemur (Include phylogenetic tree)

The red-bellied lemur is a medium sized lemur part of the genus *Eulemurs* or "true lemurs". The red-bellied lemur weighs between 1.6-2.4 kilograms and an adult individual is between 78-93 cm in total length (head-body: 35-40cm; tail length: 43-53 cm) (Mittermeier *et al.*, 2006). The species is sexually dichromatic. Males have a long, dense coat that is a dark red to brown color and a black tail. Males also have white skin underneath the eyes that form teardrop shapes that allows them to be easily distinguished from females. Males typically have a square shaped head. Females, on the other hand, have a similarly colored pelage, of dark red to brown, but their underside is creamy white. The tail appears black, similar to that of a male's. Female's have a noticeably rounder head and have absent or significantly reduced white skin under the eyes. The female's crown is not darkened and the lower cheeks and beard are also creamy white like the underbelly (Garbutt, 2007).

The red-bellied lemur lives in lowland, mid-altitude and high altitude rainforest and is sometimes found in secondary growth at the edge of primary forest. The species has been recorded at altitudes ranging from 70-2400 meters, but likely prefers mid to high forest elevations. Within Ranomafana National Park species population density ranges from 5-30 individuals/kilometers squared (Garbutt, 2007). Throughout their range in Madagascar, red-bellied lemurs are sympatric with four other *Eulemur species*: *E. albifrons*, *E. fulvus*, *E. rufus*, and *E. albocollaris* (Mittermeier *et al.*, 2006). Within Ranomafana National Park, red-bellied lemur groups have territory overlaps with red-fronted brown lemurs (*Eulemur rufus*).

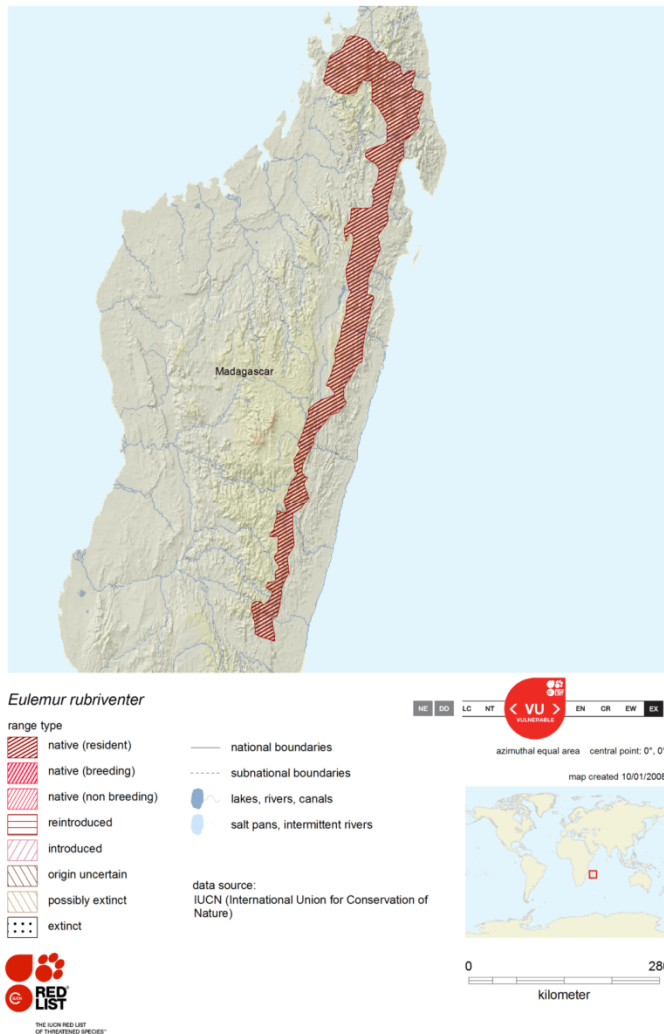


Fig. 1. Map showing the distribution of the red-bellied lemur (IUCN website)

The geographic distribution of *Eulemur rubriventer* is restricted to intact forests, occurring naturally only along the thin band of eastern rain forest beginning in the north from the Tsaratanana Massif to the Pic d'Ivohibe Special Reserve and the Manampatrana River (Mittermeier *et al.*, 2006). The red-bellied lemur's distribution extends almost from the north of to the far south of the island, but is restricted to a thin belt, as mentioned above. The largest population of red-bellied lemurs known to date lives in Ranomafana National Park, which makes the conservation and study of this species vital in this particular protected area.

Eulemur rubriventer lives in small family groups of 2-6 individuals, including an adult pair, male and female, and any dependent offspring. Occasionally, offspring that has already reached adulthood may still live with the parental group if the individual has not yet separated to

form its own pair-bonded group. Red-bellied lemurs defend a home range of 10-20 hectares, but are rarely aggressive during inter-group encounters. Red-bellied lemur groups travel 400-500 meters per day on average, but will displace up to 1000 meters per day during periods of low food abundance. Traveling in red-bellied lemur groups is usually dictated by the adult female. (Garbutt, 2007). Red-bellied lemurs are vertical clingers and leapers, jumping in a vertical posture from tree to tree.

Red-bellied lemurs are cathemeral, meaning that they are neither diurnal nor nocturnal, but rather are active both day and night. The species' activity patterns vary by season, temperature, moonlight, and food availability (Garbutt, 2007 and pers. comm. with Dina). During full moons, when visibility is high at night and temperature is cooler, red-bellied lemurs are often more active once the sun sets. As I found out while observing the red-bellied lemurs, they favor conserving energy rather than expending energy to acquire more calories. In other words, red-bellied lemurs are skilled at being extremely lazy during the hot part of the day, and only becoming active once the temperature drops when the sundown begins.

This phenomenon is also known as optimal foraging theory, which states that feeding and traveling times fluctuate relative to one another. In order to maximize energy an individual can either spend more time traveling to find higher quality food, but spend less time feeding, or one can spend more time feeding on lower quality foods, but expend less energy by traveling minimally (Tecom, 2007).

Fruit, including the introduced and invasive Chinese Guava (*Psidium cattleianum*), makes up the majority of red-bellied lemur diets. Fortunately, Chinese Guava fruit in late April and May, facilitating my research by making it easier to locate the infamously mysterious red-bellied lemur groups and providing a tasty snack to hungry researchers like myself, while in the field. Red-bellied lemurs also feed on flowers and leaves when fruit is unavailable, using roughly

70 plant species per year. (Garbutt, 2007). Occasionally, red-bellied lemurs also feed on invertebrates such as millipedes, as well as eat soil, which I observed personally (Dina, pers. comm.). The red-bellied lemur is occasionally predated on by the Fosa, *Cryptoprocta ferox*, and large raptors.

The red-bellied lemur is listed according to IUCN Red List's last assessment in 2008 as vulnerable with a decreasing population trend (IUCN website). The main threats to *E. rubriventer* survival all center on habitat loss caused by various human activities such as slash-and-burn agriculture, illegal logging and hunting (Mittermeier *et al.*, 2006).

The reproductive behavior of red-bellied lemurs is of interest to me as it is at the heart of my research of out-of-season infant survival. Information regarding reproductive behavior of *E. rubriventer* varies depending on the source. For example, interbirth interval is often cited as one year for the species in general, but it has been found in Ranomafana National Park interbirth interval is on the scale one infant per two years (Tecot, 2010). Secondly, several sources state that the mother does not carry an infant past 35 days and infants carried by the father occurs up to 100 days, however I observed during my time out in the field a 2 month old infant being carried by the adult female any time that the group travelled beyond their current tree and the infant never travelled with the adult male (Garbutt, 2007). These contradictions coupled with the inexplicable prevalence of out-of-season infants with high mortality rates make studying aspects of red-bellied lemur reproductive behavior crucial for their conservation.

In Ranomafana National Park single young are born from late August through October, the peak birth season, but infant births have been recorded in every month except for May, June and July (Tecot, 2010). Breeding is synched with maximum fruit availability during peak lactation (Garbutt, 2007 and Tecot, 2010). Mothers carry newborn infants on their bellies, but infants quickly move to ride jockey style.

Research Topic & Previous Research

My main objective in conducting field work on red-bellied lemurs was to weigh the effects of adult female activity time budgets on infant survival. In gathering data on adult female behavioral profiles, I hoped to compare activity time budgets of mothers with out-of-season infants to adult females without. Unfortunately there were no red-bellied lemur groups with in-season infants of this year that I observed in the Talatakely or Vatoharanana forests of Ranomafana National Park during the month of April 2011. My original intention was to compare activity time budgets for mothers with out-of-season vs. in-season infants, to see if any differences could be attributed to mothering behavior that may account for decreased infant survival in out-of-season infants. Because red-bellied lemur groups consist of only a single pair-bonded adult female and male and their dependent offspring, infant(s), juvenile(s) and subadult(s), I knew I could not collect data under the impression that mothering behavior might be swayed by neighboring mothers, suggesting an imitation or copycat phenomenon. I hypothesized that at any given time, for example the three weeks in April that I observed five different lemur groups, food abundance and other environmental conditions would be similar for all groups, but I suspected that energy needs should be variable between a lactating female with an infant and adult females without the burden of an infant. Red-bellied lemur reproductive behavior is a complicated phenomenon as it is responsive to both endogenous, internal chemical factors like nutrient quotas, and exogenous cues, environmental factors such as photoperiod (Tecot, 2010). Infants born out-of-season and infants born in-season are at crucially different life stages--an in-season infant being up to 9 months old and an out-of-season infant being as young as 0 months old. If mother activity time budgets do not adjust to match the infant's energetic requirements for lactation, instead reflecting the current levels of food abundance, the infant born

out of the adaptive birth peak will have lowered survival because the caloric requirement and calories available are not synched as they are when an infant is born in the peak birth season.

Methods

In order to collect data on the activity time budgets of adult females I used an ethogram. The ethogram consisted of six main categories with subdivisions for one category 'social'. The six categories were: resting, moving, feeding, social, marking, out of sight. 'Social' was broken up into the following subdivisions: autogrooming, allogrooming, playing, vocalization and aggression. Each category was mutually exclusive, so that at each time observed only one behavior could be accounted for in the ethogram. To avoid confusion I made clear definitions for each category.

Resting: The individual is inactive, staying in the same location, but may adjust posture.

This category also includes sleeping.

Moving: The individual is displacing within the same tree, translocating between trees or traveling on the ground.

Feeding: The individual is putting food into its mouth and/or processing food already in its mouth. This category does not include foraging.

Social: The individual's behavior has a purposeful effect on another individual.

Marking: The individual rubs scent glands onto a tree or another individual.

Out of Sight: The individuals behavior cannot be recorded by the observer because the individual cannot be seen. (This category is not represented in the results section. Any minutes recorded as 'out of sight' were deleted from the total minutes observed and disregarded as a behavioral category.)

'Social' Category Subdivisions:

Autogrooming: The individual is grooming themselves. If the individual is self-grooming and also being groomed by another individual (allogrooming) simultaneously, it is recorded as auto grooming.

Allogrooming: The individual is either grooming another individual or being groomed by another individual. While recording, I indicated whether this was 'mutual grooming' or in which direction the grooming was taking place (which individual was the receiver and which was the recipient). For the sake of this study all grooming with another individual has been presented as 'allogrooming.'

Playing: Two or more individuals are interacting together, not grooming, in a way that is solely for amusement.

Vocalizing: The individual produces an audible call.

Aggression: The individual is ready or likely to confront another individual with hostile or violent behavior or is a hostile encounter.

In order to systematize data collection I observed a particular individual in 15 minutes bouts. At each minute, indicated by a beep with my stopwatch, I recorded the behavior, one of the listed categories above, of the adult female and distance from infant if applicable. The sound of the stopwatch never seemed to affect the behavior of the Red-bellied lemurs. With the data collected I was able to create an activity time budget for adult females that is presented in the results section.

Ranomafana National Park has several forest partitions, of which I studied in two: Talatakely and Vatoharanana. Talatakely, a previously selectively logged forest, had a total of

six Red-bellied lemur groups of which I collected data on four groups. Vatoharanana also had several groups of lemurs, although we only encountered one of these group and we were unable to collect any behavioral data. Each group observed was labeled A-F, and my research technician, Dina, and I tried to find groups on a rotating basis to get an equal number of minutes observed for each group. Unfortunately the red-bellied lemur is notoriously difficult to find, due to their small group size, minimal vocalizations and rather large territories. It usually took between 2-2.5 hours to find a group to observe.

Each group composition and territory range was particular to each group, facilitating group identification. Table 1 includes the group composition and total time observed.

Group	Individuals (w/ individual characteristics)	Forest Territory	Total Minutes Observed (1080 minutes total)
Group A	1 adult female, 1 adult male, 1 subadult female	Talatakely	165 minutes
Group B	1 adult female, 1 adult male (w/ radio-collar)	Talatakely	540 minutes
Group C	1 adult female, 1 adult male, 1 subadult male, 1 female infant (~ 2 months old)	Taltakely	225 minutes
Group D	1 adult female (left eye blue), 1 adult male, 1 subadult female, 1 juvenile female ~ 1.5 years old	Talatakely	150 minutes

Group E	1 adult female, 1 adult male	Talatakely	0 minutes
Group F	1 adult female, 1 adult male, 1 infant ~ 2 months old	Vatoharanana	0 minutes

Table 1. Group Compositions of red-bellied lemurs in Talatakely and Vatoharanana, Ranomafana National Park.

Dina and I would set out twice a day in the mornings and afternoons, from 7h30-11h30 and 13h30-14h30. Often in passing other guides within the forest we would get information about where certain red-bellied lemurs had been recently. Once a group was located I would begin the one minute intervals for fifteen minutes at a time and record data. If the group began to move, we would follow them off the trails. Often times it would prove difficult for both Dina and I to get through the dense forest where no trails had been made. (In reality I did not have the graceful steps, sure footing, or fitness to follow the red-bellied lemurs as well as Dina). I would make an effort to follow, but once I could not see the adult female anymore, Dina would yell to me the behavior that I would note down from a distance.

The last week at Centre ValBio I went on an excursion for three days to the primary forest, Vatoharanana, about a two hour hike from the research station. Centre ValBio helped us arrange for a cook and porters so that we could spend three days looking for different red-bellied groups living in this more pristine part of Ranomafana National Park. Unfortunately, we had an unlucky three days and I was not able to collect any data while there. Dina and I did see on the first day a group of three individuals, including a two month old out-of-season infant that was at the border between the Talatakely and Vatoharnana fragments.

In order to draw conclusions from the data, I computed the total minutes for each behavior category and then calculated the percentage of time for each behavior to create an activity time budget for adult female red-bellied lemurs. The single group with an out of season infant (Group C) from this year was calculated separately, (225 minutes observed) from the groups with no current out of season infants (Groups A/B/D/E). Groups A/B/D/E were calculated together giving a total time observed (855 minutes) for all of these groups with percentages representing all behavior observations from the four groups.

Results

While the goal of this research was to either eliminate or pinpoint maternal activity time budgets as a factor contributing to the disparity between out-of-season and in-season infant survival, one can also extract general results pertaining to activity time budgets for adult female red-bellied lemurs.

Ideally I would have liked to compare Group C (one adult female, one adult male, one sub-adult male, ~2 mo. female infant) to a group with an in-season infant born between late August-October of 2010, however I encountered no such groups. Alternatively, it may have been interesting to compare Group C directly with Group D (one adult female, one adult male, one sub-adult female and one ~1.5 year old juvenile). Comparing the activity time budgets of these two particular adult females may have revealed interesting results, given that their two infants are at significantly different life stages. Unfortunately I was only able to observe Group D once, for 120 minutes one morning, which is not adequate data to analyze in comparison to the 225 minutes of Group C observation during both morning and afternoon sessions in the field.

The behavioral repertoire of the adult female with an infant consists of only 5 behaviors, whereas the behavioral repertoire of the adult females without infants is made up of 9 behaviors. This can be attributed to two main factors--the group with an infant was only observed for 225 minutes and the groups without infants were observed for a total of 855 minutes. In addition, I only followed one group with an infant vs. 3 groups without infants, which gives a more accurate representation of behavioral diversity in red-bellied lemurs. In total, adult female red-bellied lemurs were observed from April 6-22, 2011 for 1080 minutes. It may be worth noting here that observation time is very scant in comparison to time spent in the field. Usually 2-2.5 hours were spent looking for a red-bellied lemur group to study each morning and afternoon. Of roughly

5040 minutes spent in the field, only 1080 were spent collecting data (a mere 21% of the time); in other words a lot of effort for just a little bit of data.

Activity Time Budget: Adult Female with 2 mo. infant

■ Resting ■ Moving ■ Feeding ■ Autogrooming ■ Allogrooming

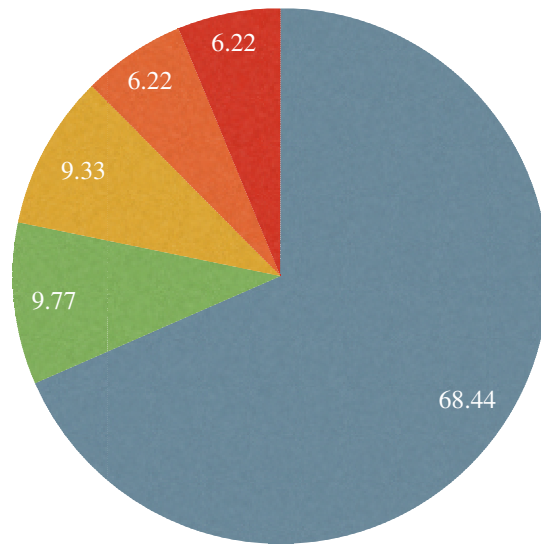


Fig. 1. Adult female with a 2 month infant activity time budget.

Behavior	Minutes Observed (225 Total minutes)	% of Activity Time Budget
Resting	154 minutes	68.44%
Moving	22 minutes	9.77%
Feeding	21 minutes	9.33%
Autogrooming	14 minutes	6.22%
Allogrooming	14 minutes	6.22%

Table 2. Ethogram with behavior categories with percentages of total activity time budget for the adult female with an out-of-season infant.

Activity Time Budget: Adult Females without infants

■ Resting
■ Moving
■ Feeding
■ Autogrooming
■ Allogrooming
■ Playing
■ Vocalizing
■ Marking
■ Aggression

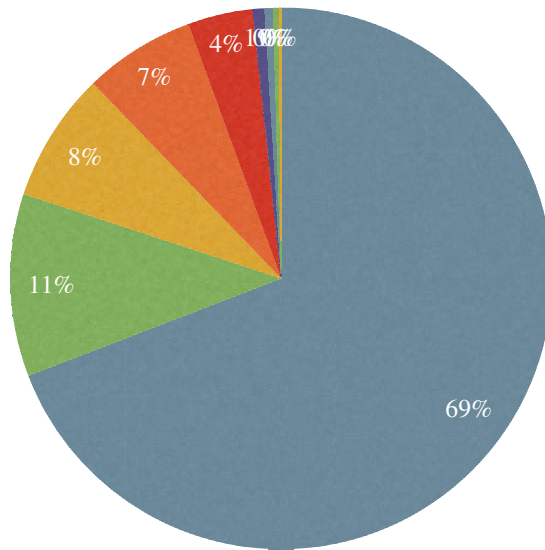


Fig. 2. Adult females without infants activity time budgets.

Behavior	Minutes Observed (855 Total Minutes)	% of Activity Time Budget
Resting	572 minutes	69.17%
Moving	90 minutes	10.88%
Feeding	64 minutes	7.74%
Autogrooming	55 minutes	6.65%
Allogrooming	32 minutes	3.87%
Playing	6 minutes	0.73%
Vocalizing	4 minutes	0.48%
Marking	3 minutes	0.36%
Aggression	1 minute	0.12%

Table 3. Ethogram of behavior categories with percentages of total activity time budget for adult females without infants.

The results, as shown above in Figure 1 and 2, reveal a striking similarity in the activity time budgets of adult female red-bellied lemurs, regardless of the presence of an infant. For instance, resting took up 69.17% of activity time budgets for females without infants and 68.44% for the adult female rearing a 2 month old infant. The percent of time spent moving is also comparable between the adult female with an infant and the adult females without--9.77% and 10.88% respectively.

One behavioral category in which adult females without infants and the adult female with an infant differ is feeding. Adult females without infants fed 7.74% of the time, whereas the adult female with an infant fed for 9.33%.

The two grooming behaviors recorded, allogrooming and autogrooming, make up important components of adult female red-bellied lemur's activity time budgets, after resting, moving and feeding. Interestingly, the adult female's activity time budget with an infant reveals an equal amount of time spent autogrooming and allogrooming. In contrast, adult females without infants spent almost twice as much time autogrooming (6.65%) than allogrooming (3.87%). Autogrooming in both females without infants and the female with an infant are comparable at 6.65% and 6.22% respectively.

While the last four categories--playing, vocalizing, marking and aggression--are present only in adult females without infants and make up a meager 2.69% of their activity time budgets, these are important behaviors that represent subdivisions of social comportment (as detailed above in 'methods'). As mentioned previously, the behavioral repertoire of adult females with infants is most likely insufficient as I spent significantly less time observing the one group with an infant compared to the three groups without infants. The behaviors playing, vocalizing, marking and aggression are probably exhibited by the adult female without an infant, but she was not observed often or long enough to record these activities.

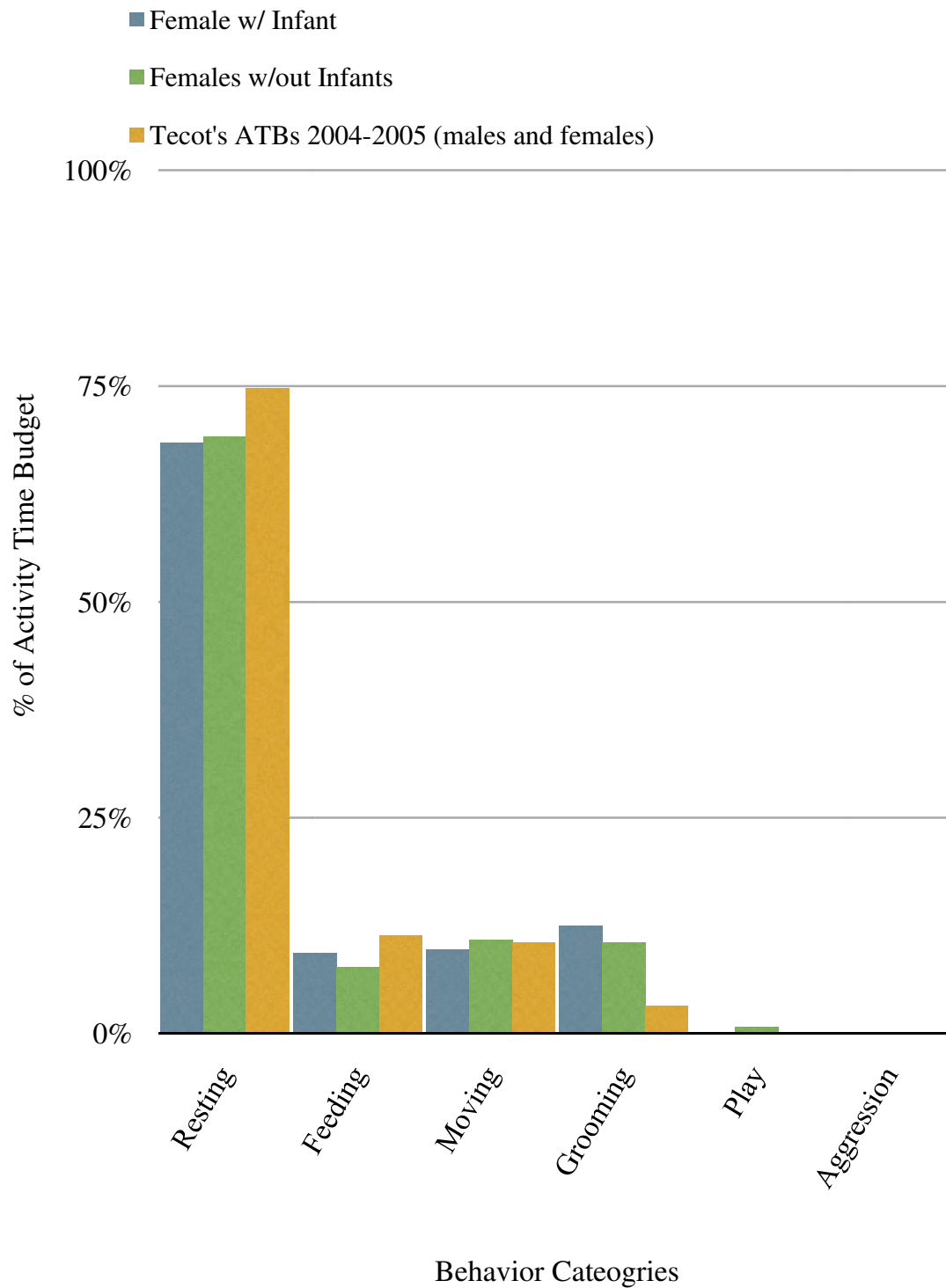


Fig. 3. Comparison of activity time budgets: female with out-of-season infant (Hardy, 2011) females without infants (Hardy, 2011), adult males, adult females and juveniles (Tecot, 2010).

Discussion

While studying activity time budgets of a species generally is not the most enthralling behavioral study, interesting correlations and similarities come to light once ATB results are compared using differing variables. Comparisons can be performed using variables such as sex, age, caloric needs, season, food availability, time of day and photoperiod. To ensure some level of reliability for such a short research period, I compared my data on activity time budgets of female red-bellied lemurs to data from January 2004- March 2005 collected by Stacey Tecot for her dissertation (see Fig. 3).

Tecot's data uses slightly different behavior categories, such as 'feeding and drinking' whereas I only used the category 'feeding' and she did not use the behavioral category 'marking', as I did. A second important consideration is that Tecot's data, as presented above, is the average activity time budget for 17 individuals (adults and juveniles of both sexes). She found, however, no significant differences between male and female activity time budgets, allowing data from both sexes to be presented together. The minute discrepancy between male and female activity time budgets can most likely be attributed to the fact that there is no marked sexual dimorphism in red-bellied lemurs (Tecot, 2007).

The three most prominent behaviors--resting, feeding and moving--differed by <6%, <3%, <1%, respectively when Tecot's data is compared to my own. This can be partially attributed to the fact that Tecot's data spans 15 months, including months of decreased or increased food abundance, and differing day lengths compared to the three weeks in April during which I conducted my study.

The overall similarity in the activity time budgets of the adult female with an infant vs. adult females without infants indicates to a certain degree that activity time budgets are largely influenced by exogenous cues. These external factors, such as fruit availability and photoperiod,

primarily dictate the behavior of red-bellied lemurs. As mentioned in the introduction, optimal foraging theory posits that an individual lemur will maximize energy by either seeking out high quality food by travelling more or that an individual will spend more time feeding on lower quality foods and travel less, thereby conserving energy (Tecot, 2007). Another factor that may be related to lower infant survival is the fact that if a forest is depleted of high quality or high abundance food resources, little adjustment can be made to maximize energy. For example, if a female red-bellied lemur were pregnant or lactating, and there was not a choice between high quality or high abundance of food resources, her activity time budget would be in large part dictated by the current environment.

It is important to take note of small differences between activity time budgets of females without infants and the female with an infant, as these differences may reflect endogenous factors. For example, the female with an infant exhibited increased feeding time in comparison to the adult females without infants. This discrepancy may be indicative of increased caloric needs for a lactating female who is rearing a 2 month infant. A second example of maximizing energy strategies for the adult female with an infant is the decreased moving time for the adult female with the infant. This decreased moving time may be a strategy to conserve energy in an energy-taxing time for her.

Out-of-season infant survival may be negatively affected, as Tecot observed in her study of infant survival in 2009, because the mother's activity time budget cannot sufficiently adjust to meet the increased energy needs of each reproductive stage. Tecot found that the 3 month birth peak from August-October corresponds to maximum fruit abundance, implying that infants born outside of this birth peak are at an immediate disadvantage because fruit availability will be significantly lower during pregnancy, lactation and weaning. In other words the reproductive

stages during which an adult female is burdened by the energy requirements of an infant, must synch with maximum food availability in order to ensure maximum infant survival.

The oddity of the prevalence of out of season births, contradicts flexible birth seasonality as an adaptive reproductive strategy in red-bellied lemurs. Tecot presents four possible explanations for out-of-season births. First, social factors may affect group compositions, causing new pair bonds to reproduce at abnormal times during the year. This hypothesis is unlikely because red-bellied lemur groups are very stable, so this could not account for the high frequency of out-of-season births. A second suggestion is that food availability and food quality are constantly in flux from year to year and season to season. During a resource rich year, females may become pregnant earlier than normal, responding to both endogenous and exogenous cues. However, this hypothesis can also be questioned because all of the out-of-season births occurred in more disturbed, less fruit abundant sites. A third hypothesis proposes cyclones as a mechanism for disturbed birth seasonality. Cyclones drastically wipe out fruit availability and may affect caloric quotas needed for a female to cycle and become pregnant during the normal reproductive months. However, out-of-season births do not seem correlated with cyclones as they occur both before and after the cyclone period. Lastly, the timing of food availability overall may have an effect on birth seasonality in red-bellied lemurs. This last hypothesis appears the most promising as a possible explanation for births occurring outside of the birth peak, but it fails to explain why the births are so spread out over 9 months of the year. An interesting point that Tecot has alluded to in her analysis of relaxed birth seasonality is that all wild lemur species that have births that occur more than 4 months apart have either cathemeral or nocturnal activity patterns (Tecot, 2010).

There were several shortcomings of this project, that if I had the chance to replicate I would address these issues using altered methods. First, I was able to follow only one group with

an out-of-season infant. I know that there were at least two groups with out-of-season infants, having encountered a second on my hike into the primary forest. Unfortunately my research technician and I were unable to find this group again for observation. A longer research period would be necessary to ensure an adequate sampling of groups with out-of-season infants. Secondly, the comparisons I drew from the mother with an out-of-season infant and mothers without infants would have been strengthened had I observed mothers with infants from this year's birth peak, allowing comparison between mother's with infants of 0-9 months (born between the beginning of the birth peak in August 2010, up until my study that occurred in April of 2011). This issue may also be avoided by increasing time spent in the field. A general insufficiency in observation hours may have skewed data, as well as limited observation hours during the day. I only went into the field in the morning and afternoons, and never observed red-bellied lemurs after sundown when they often become more active than they are during the warmer days. Lastly, groups were observed one-by-one, meaning that I have no overlapping data of several groups during one particular period of a single day. This lends itself to the possibility of differing environmental conditions, such as weather, food abundance, or time of day that may have affected the activity time budgets of individual red-bellied lemur groups.

Conclusion

In conclusion, the study of activity time budgets is essential to the general understanding of any species. Red-bellied lemurs are of particular importance due to the vulnerable IUCN status (IUCN, 2008). Activity time budget comparisons using different variables, such as age, sex, group composition, photoperiod, food availability, etc., allows insight into odd phenomena, such as the decreased survival of out-of-season infants in red-bellied lemurs. The health of a population, such as red-bellied lemurs, is directly affected by the survival of all individuals in the group, especially those who have not yet reached reproductive maturity. Because out-of-season infants can make up to 30% of births in a year, it is vital to understand why their survival is particularly threatened (Tecot, 2010).

The findings of this particular study are important in light of decreased infant survival for out-of-season infants. Increased feeding time and decreased moving time for a mother with an infant, seem both adaptive and necessary for the survival of her infant through lactation, however the difference in time spent feeding and moving between females without infants and this particular female with an infant is minimal. This may indicate that activity time budgets are largely dependent on the environment (food availability and photoperiod), and less so on endogenous factors, such as nutrient requirements for lactation. An infant born outside of the adaptive birth peak will be disfavored due to lowered food availability during key infant stages, such as pregnancy and lactation, receiving lower quality nutrients from the mother due to decreased food availability, and during weaning, lowered food abundance when the infant begins to feed independently.

This project, if anything, provides preliminary research for future studies that can be conducted on red-bellied lemur birth seasonality. Clearly, longer term research is vital to understand the relaxed reproductive behavior in red-bellied lemurs. Infant survival for this

species is crucial to understand and ensure the health of the population and proper management and conservation strategies.

Lastly, I would like to highlight the importance of a research station like Centre ValBio. The center not only provides the local community with employment, for both men and women, but also takes an active role in educating the local community about the richness of biodiversity in Ranomafana National Park. Before working with Centre ValBio, the mission and activities of the center were unclear to me. One must work with the staff to understand the complexities behind such an impressive organization that reaches out in numerous ways to the community-- healthcare, family planning, youth education, women's weaving cooperative, just to name a few. I am truly appreciative of Centre ValBio's presence in the southeast region of Madagascar.

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