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Data on the diet of *Lepilemur mittermeieri*, a sportive lemur endemic to the north-west of Madagascar

Leslie Wilmet[1,2,*], Pierre Devillers[2], Cédric Vermeulen[1], Roseline C. Beudels-Jamar[2]
[1]TERRA Research Center, Forest is Life, Gembloux Agro-Bio Tech, University of Liège. Passage des Déportés, 2. B.5030 Gembloux, Belgium
[2]Conservation Biology Unit, OD Nature, Royal Belgian Institute of Natural Sciences, 11 Rue Vautier, 29, 1000 Bruxelles. Belgium.
*corresponding author: **leslie.wilmet@hotmail.com**

Key words
Sportive lemur, feeding ecology, Madagascar

Abstract
Mittermeier's sportive lemur (*Lepilemur mittermeieri*) is an endangered primate endemic to the Ampasindava peninsula, in north-west Madagascar. *Lepilemur* are known to be folivores with a low metabolic rate, but no specific investigation of the diet of Mittermeier's sportive lemur has been reported. In 2015 and 2016, we conducted a field study of the species in two areas of the Ampasindava peninsula, involving direct observation of individuals equipped with radio-collars. We verified that Mittermeier's sportive lemur is a solitary forager. We identified a total of 77 tree species consumed and a large variation in the spectrum of species used within the two studied sites. Most of the plant material consumed was made of leaves, with few fruits.

Introduction
For small-bodied folivores, gaining enough energy and nutrients from a diet dominated by plant structural tissues may be challenging due to their high energy requirement (Kleiber, 1961; Martin, 1990; Eppley *et al*., 2010). The lower limit of body mass for folivorous primates was predicted to be about 700g due to energetic constraints (Kay, 1984; Richard, 1985; Schmid and Ganzhorn, 1996). *Lepilemurs,* with their small adult body size and a diet high in leaves, are therefore at the lower limit of body size for folivorous primates (Nash, 1998). Their metabolic rate is among the lowest of most mammalian folivores recorded (Schmid and Ganzhorn, 1996). Müller (1985) suggested that the low metabolic rate of prosimians could represent a mechanism to cope with environmental constraints (Schmid and Ganzhorn, 1996).
Mittermeier's sportive lemur (*Lepilemur mittermeieri*) is one of 26 species of sportive lemurs, family Lepilemuridae (Mittermeier *et al*., 2010). This Endangered (Andriaholinirina *et al*., 2012), small-sized, nocturnal primate is endemic of the Ampasindava peninsula, in northwest Madagascar and although no previous investigation have been conducted into its diet it is thought to be mostly folivorous (Mittermeier, 2013; Schwitzer *et al*., 2013). The species inhabits two vegetation types of the Ampasindava peninsula: dense humid forests with low perturbation and older secondary forests. In the current context of forest degradation and habitat loss, a better understanding of the feeding ecology of Mittermeier's sportive lemur will help identify appropriate conservation measures.
The aim of this short note is to gain a preliminary understanding of the diet of Mittermeier's sportive lemur. Specifically, we identified which plant species are consumed at the scale of forest patches, and we investigated food selection at the scale of micro-habitat.

Methods
Study area, study sites and study period
This study was carried out in the Ampasindava peninsula, in northwest Madagascar (Fig. 1). Altitude ranges from 0-720 m with a rough, hilly terrain. The peninsula has a hot, humid/sub-humid climate and is part of the Sambirano Domain (sensu Humbert, 1951). Because of the topography of the area, the climate of this region is more similar to that of the east coast of Madagascar than to that of other areas of the west coast (MBG, 2015; Rasoanaivo *et al*., 2015; Tahinarivony *et al*., 2017). There are four main vegetation types on the Ampasindava peninsula: dense humid forest with low perturbation, older secondary forests, young secondary forests and degraded areas. Mangroves also exist on the peninsula (Tahinarivony *et al*., 2017).
We conducted this study on two different sites. Site A is located on the Andranomatavy Mountain and is covered by dense humid forests with low disturbance. Site B is characterized by older secondary forests (Fig. 1). The study was carried out during three months (April-June) of two con-

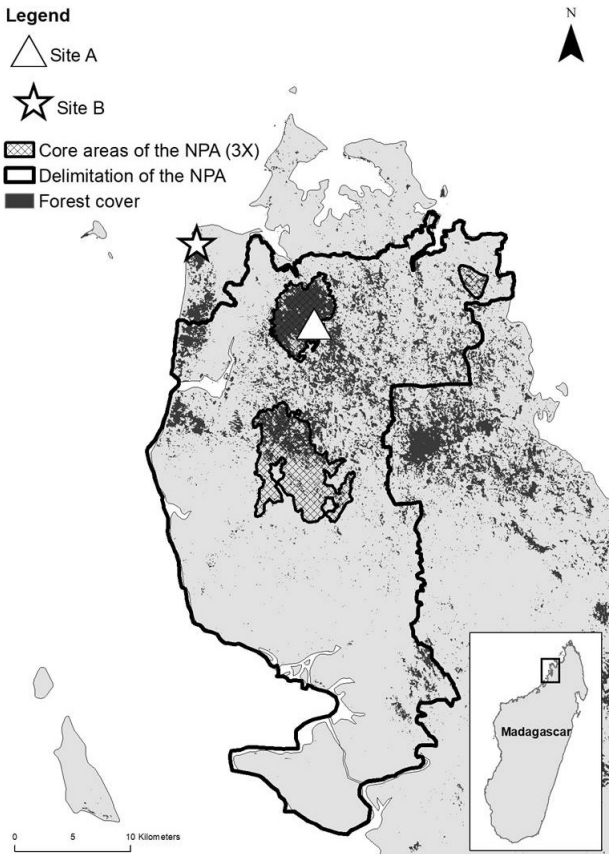

Fig. 1: Map of the Ampasindava peninsula in north-west Madagascar with representation of the two study sites, forest cover, the New Protected Area (NPA) and the 3 core areas of the New Protected Area.

secutive years (2015 and 2016) corresponding to the end of the rainy season.

Individuals studied

To allow continuous focal observation on known individuals, we studied 15 individuals equipped with radio-tracking transmitters (Biotrack-Dorset-UK PIP3 Tag-cable tie collar; weight < 4.5g) (for the detailed method see Wilmet *et al*., 2019).

Micro-habitat characterisation

We collected floristic data for four home ranges of the 15 Mittermeier's sportive lemurs studied. Within site A, sizes of home range 1 and home range 2 were 2.97ha and 0.77ha respectively (Wilmet *et al*., 2019). Within site B, sizes of home range 3 and 4 were 1.15ha and 1.96ha respectively (Wilmet *et al*., 2019). We conducted an exhaustive sampling of every tree with a circumference above 15cm in these home ranges. Herbarium material was collected for the different tree species and identified to genus by botanists at Tsimbazaza Botanical Garden in Antananarivo (Parc Botanique et Zoologique Tsimbazaza).

Feeding observation

Data on plants consumed by Mittermeier's sportive lemurs were obtained by direct observation on 15 individuals using the focal sampling method (Altmann, 1974) during radio-tracking nights. Records were made every time an individual was observed feeding. Systematic observations were difficult due to limited visibility at night. The feeding frequency of different dietary items was taken to estimate their prevalence in the diet. The number of times a focal individual was observed feeding on each item was recorded but the duration of each event was not considered. Once an individual was observed eating, the part of the plant consumed was recorded (leaf or fruit) and a sample of the tree was taken as a herbarium specimen. Plant identification at genus level was undertaken by botanists at Tsimbazaza Botanical Garden in Antananarivo.

Data analysis

To characterize the micro-habitat of four Mittermeier's sportive lemurs, we evaluated the distribution of species abundance. As diversity indexes (such as Shannon index, etc.) underestimate the species richness in tropical forests (Walter and Moore, 2005), we used non-parametric estimators to compare the species diversity of four home ranges. We computed estimated species richness using three non-parametric estimators: the bias-corrected Chao1, Chao2 (based on incidence) and Jackknife1 (based on abundance) (Chiarucci *et al*., 2003; Dove and Cribb, 2006; Poulin, 1998; Walther and Martin, 2001) using Estimates S9.1.0 (Colwell, 2013). It is best to use multiple estimators as concurrence between their individual values can lend support to results.

We established a list of species identified as feeding plants, we then calculated the frequency of their consumption and the number of different individuals feeding on each species.

Results

Micro-habitat characterization

The diversity of tree species for each home range varied from 45 to 74 species. The largest home range (located in site A) is characterized by a lower species richness than the others (Fig. 2).

Among the most abundant species, only one species (*Garcinia decipiens*) is shared between the four nocturnal home ranges (Tab. 1). Some species, such as *Calandia cerasifolia*, are present at high density (among the 10 most abundant) in only one nocturnal home range (home range 1) (Tab. 1). Moreover, a species abundant in one home range of site A may not be abundant in another nocturnal home range of site A. When comparing this data set with the observations of species consumed by Mittermeier's sportive lemurs (Appendix 1 & 2), it appears that 9 of those species consumed (*Garcinia decipiens, Trilepsium madagascariensis, Throphis montana, Ixora mocquerysii, Rinorea angustifolia, Ochna pervilleana, Mammea punctata, Kaya madagascariensis and Coptosperma* sp.) are among the 24 most abundant species in the four home ranges (Tab. 1).

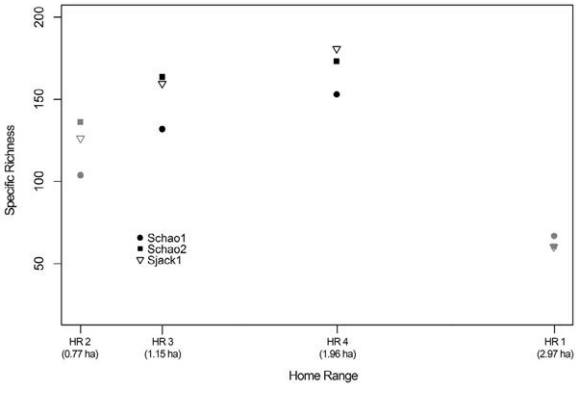

Fig. 2: Species richness of four home ranges (HR) calculated through three non-parametric indicators. Indicators Chao1(Schao1) and Chao2 (Schao2) are based on incidence and indicator Jackknife1 (Sjack1) is based on abundance. Size of each home range (HR) is given in bracket.

Tab. 1: Ten most abundant tree species within each of the four home ranges investigated. Species in bold correspond to consumed species. Home ranges (HR) 1 and 2 are located in site A and home ranges 3 and 4 in site B.

Ranking	HR 1 (2.97ha)	HR 2 (0.77ha)	HR 3 (1.15ha)	HR 4 (1.96ha)
1	*Garcinia decipiens*	*Rinorea angustifolia*	***Mammea punctata***	*Garcinia decipiens*
2	*Grangeria porosa*	*Grangeria porosa*	*Memecylon perditum*	*Memecyclon perditum*
3	***Trilepisium madagascariensis***	***Garcinia decipiens***	***Rinorea angustifolia***	***Mammea punctata***
4	*Calantica cerasifolia*	*Gaertnera* NA	*Suregada boiviniana*	*Grangeria porosa*
5	*Macarisia ellipticifolia*	***Trilepisium madagascariensis***	***Ochna pervilleana***	*Rinorea angustifolia*
6	*Treculia madagascariensis*	*Treculia madagascariensis*	*Cleistanthus suarezensis*	*Cleistanthus suarezensis*
7	*Breonia c apuronii*	*Broenia capuronii*	*Thecacoris cometia*	***Ochna pervilleana***
8	*Homalium* sp.	*Ixora mocquerysii*	*Xylopia buxifolia*	***Kaya madagascariensis***
9	***Trophis montana***	*Burasaia madagascariensis*	***Garcinia decipiens***	*Xylopia buxifolia*
10	***Ixora mocquerysii***	*Garcinia commersonii*	*Lasiodiscus pervillei*	***Coptosperma* sp.**

Feeding ecology

Individuals always foraged alone. In total, 77 tree species were identified as food resources: 49 species in the coastal site, 32 species in the inland sites, with only two species shared between site A (dense humid forests with low disturbance) and site B (older secondary forests) (Appendix 1 & 2). Typically, it was the leaves that were most frequently consumed, but fruits were also eaten from four species (*Coptosperma* sp.; *Dypsis* sp.; and two unknown) (Appendix 1 & 2).

Concerning the frequency of consumption for the plant species, six species comprised 45% of all feeding observations (Tab. 2). Out of those most frequently consumed species, only two (*Trilepsium madagascariensis* and *Coptosperma* sp.), are among the ten most abundant species (Tab. 1). Another four species (*Secamone* sp.; *Sorendeia madagascariensis, Dypsis* sp.; *Dichapetalum pachypus*) were frequently observed as food species but were not among the most abundant species (Tab. 1).

Discussion

The study confirms that Mittermeier's sportive lemur is a solitary forager. As expected, leaves are the part of the tree most frequently consumed, but fruits are also eaten (Appendix 1&2). This has also been observed for other *Lepilemur* species such as Hawks' sportive lemur (*L. tymerlachsoni*) (Sawyer *et al*., 2015), northern sportive lemur (*L. septentrionalis*) (Dinsmore *et al*., 2016), white-footed sportive lemur (*L. leucopus*), weasel sportive lemur (*L. mustelinus*), red-tailed sportive lemur (*L. ruficaudatus*), Gray's sportive lemur (*L. dorsalis*) and Sahamalaza sportive lemur (*L. sahamalazensis*) (Hladik and Charles-Dominique, 1974; Nash, 1998; Thalmann, 2001; Ganzhorn *et al*., 2004; Seiler, 2012). In the case of Mittermeier's sportive lemur we do not have sufficient data to investigate seasonality or correlation with local phenology.

The specific diversity of leaves consumed is high. Individuals observed were feeding on 77 species of trees. A similarly varied diet was observed for Sahamalaza sportive lemur for which Seiler (2012) found that at least 42 tree species were consumed. We found no correlation between tree species use and their relative frequency within the home ranges investigated. Nor could differences in choice of species between patches be correlated to local forest composition. This suggests adaptability to local conditions, but no true opportunism, as most numerous species were not significantly favoured. In contrast, the white-footed sportive lemur, which feeds mainly on a small number (three) of plant species (Nash, 1998), uses the most abundant plant species (Dröscher and Kappeler, 2013), a clear opportunist behaviour.

Our findings have significant implications for the conservation of Mittermeier's sportive lemurs. They appear to have a high potential of adaptation to local conditions but nevertheless depend on a variety of trees providing the needed resources at the right time. Preservation of the forest climate and diversity is thus probably the key to its survival.

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Tab. 2: List of the plant species most frequently consumed during observation time: site location, plant family, genus, part of the plant consumed number of observations, percentage of total number of observations (196), number of individuals observed eating the plant. The species name is in bold when the tree is among the most abundant species in the home ranges studied.

Site	Family	Genus species	Part of the plant	# observed	%	Number of individuals observed eating
A&B	Apocynacea	*Secamone* sp.	leaf	33	17	9
A&B	Moraceae	*Trilepsium madagascariensis*	leaf	17	9	5
A&B	Anacardiaceae	***Sorendeia madagascariensis***	leaf	12	6	5
A	Arecaceae	*Dypsis* sp.	fruit	10	5	3
A	Dichapetalaceae	*Dichapetalum pachypus*	leaf	10	5	4
A	Rubiaceae	***Coptosperma* sp.**	fruit	7	4	3

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Appendix 1: List of plant species consumed by *L. mittermeieri* in site A. The two species marked by an asterix are shared with site B.

Plant Species – feeding observation – Site A				
No.	**Family**	**Genus species**	**Part of the plant eaten**	**Year of observation**
1	Anacardiaceae	*Sorindeia madagascariensis*	Leaf	2015
2	Apocynaceae	*Mascarenhasia arborescens*	Leaf	2015
3	Apocynaceae *	*Secamone* sp.*	Leaf	2015
4	Apocynaceae	*Landolphia myrtifolia*	Leaf	2016
5	Apocynaceae	*Landolphia* sp.	Leaf	2016
6	Arecaceae	*Dypsis* sp.	Fruit	2015 + 2016
7	Celastraceae	*Mystroxylon aethiopicum*	Leaf	2015
8	Convolvulaceae	*Merremia myriantha*	Leaf	2016
9	Convolvulaceae	*Merremia peltata*	Leaf	2016
10	Dichapetalaceae	*Dichapetalum madagascariense*	Leaf	2015
11	Dichapetalaceae	*Dichapetalum pachypus*	Leaf	2015
12	Euphorbiaceae	*Drypetes* sp.	Leaf	2015
13	Euphorbiaceae	*Securinega seyrigii*	Leaf	2015
14	Fabaceae	*Abrus precatorius*	Leaf	2015
15	Fabaceae	*Entada pervillei*	Leaf	2015
16	Fabaceae	*Clitoria lasciva*	Leaf	2016
17	Fabaceae	*Dalbergia* sp.	Leaf	2016
18	Icacinaceae	*Demostachys* sp.	Leaf	2015

Plant Species – feeding observation – Site A				
No.	**Family**	**Genus species**	**Part of the plant eaten**	**Year of observation**
19	Malvaceae	*Grewia cuneifolia*	Leaf	2015
20	Malvaceae	*Grewia* sp.	Leaf	2015
21	Melicaeae	*Malleastrum boivinianum*	Leaf	2015
22	Moraceae	*Trophis montana*	Leaf	2015
23	Moraceae *	*Trilepisium madagascariensis* *	Leaf	2016
24	Ochnaceae	*Ochna greveanum*	Leaf	2015
25	Oleaceae	*Noronhia candicans*	Leaf	2015
26	Rubiaceae	*Coptosperma* sp.	Fruit + Leaf	2015
27	Rubiaceae	*Peponidium* sp.	Leaf	2015
28	Rubiaceae	*Ixora mocquerysii*	Leaf	2015
29	Sapindaceae	*Macphersonia gracilis*	Leaf	2016
30	Vebenaceae	*Clerodendron* sp.	Leaf	2016
31	Violaceae	*Rinorea angustifolia*	Leaf	2015
32	NA	*NA*	Fruit	2016

Appendix 2: List of plant species consumed by *L. mittermeieri* in site B. The two species marked by an asterix are shared with site A.

Plant Species – feeding observation – Site B				
No.	**Family**	**Genus species**	**Part of the plant eaten**	**Year of observation**
1	Anacardiaceae	*Abrahamia sambiranensis*	Leaf	2015
2	Aphloiaceae	*Aphloia theiformis*	Leaf	2016
3	Apocynaceae	*Petchia madagascariensis*	Leaf	2015
4	Apocynaceae *	*Secamone* sp. *	Leaf	2015 + 2016
5	Apocynaceae	*Carissa septentrionalis*	Leaf	2015
6	Apocynaceae	*Uvaria decaryana*	Leaf	2015
7	Bignoniaceae	*Phyllarthron* sp.	Leaf	2016
8	Buxaceae	*Buxus macrocarpa*	Leaf	2015
9	Capparidaceae	*Tylachium umangii*	Leaf	2015
10	Capparidaceae	*Crateva excelsa*	Leaf	2016
11	Celastraceae	*Salacia madagascariensis*	Leaf	2015
12	Clusiaceae	*Garcinia decipiens*	Leaf	2015
13	Clusiaceae	*Mammea punctata*	Leaf	2015
14	Dichapetalaceae	*Dichapetalum leucosia*	Leaf	2016
15	Dilleniaceae	*Tetracera madagascariensis*	Leaf	2015
16	Ebenaceae	*Diospyros impressinervis*	Leaf	2015
17	Erythroxylaceae	*Erythroxylum retusum*	Leaf	2015
18	Erythroxylaceae	*Erythroxylum nitidulum*	Leaf	2016
19	Euphorbiaceae	*Wielandia bojeriana*	Leaf	2015
20	Euphorbiaceae	*Dryptes thouarsii*	Leaf	2015
21	Euphorbiaceae	*Wielandia platyrachis*	Leaf	2015
22	Euphorbiaceae	*Euphorbia* sp.	Leaf	2016
23	Euphorbiaceae	*Claoxylon* sp.	Leaf	2016
24	Euphorbiaceae	*Thecacoris* sp.	Leaf	2016
25	Fabaceae	*Viguieranthus ambongensis*	Leaf	2015
26	Achariaceae	*Prockiopsis calcicola*	Leaf	2016
27	Melastomataceae	*Memecylon perditum*	Leaf	2016

Plant Species – feeding observation – Site B				
No.	**Family**	**Genus species**	**Part of the plant eaten**	**Year of observation**
28	Melastomataceae	*Memecylon bakerianum*	Leaf	2016
29	Meliaceae	*Khaya madagascariensis*	Leaf	2015
30	Moraceae	*Treculia madagascariensis*	Leaf	2015
31	Moraceae *	*Trilepisium madagascariensis* *	Leaf	2016
32	Myristicaceae	*Brochoneura acuminata*	Leaf	2015
33	Myrtaceae	*Syzygium cumini*	Leaf	2016
34	Ochnaceae	*Ochna pervilleana*	Leaf	2015
35	Olacaceae	*Anacolosa* sp.	Leaf	2016
36	Phyllanthaceae	*Meineckia* sp.	Leaf	2016
37	Pittosp.oraceae	*Pittosporum senacia*	Leaf	2016
38	Poaceae	*Nastus* sp.	Leaf	2015
39	Rubiaceae	*Polysphaera acuminata*	Leaf	2015
40	Rubiaceae	*Coffea tetragona*	Leaf	2016
41	Rubiaceae	*Coffea dubardii*	Leaf	2016
42	Rubiaceae	*Ixora* sp.	Leaf	2016
43	Rubiaceae	*Coffea* sp.	Leaf	2016
44	Rutaceae	*Melicope sp.*	Leaf	2016
45	Salicaceae	*Homalium nudiflorum*	Leaf	2015
46	Sapotaceae	*Capurodendron* sp.	Leaf	2016
47	Violaceae	*Rinorea angustifolia*	Leaf	2015
48	NA	NA	Fruit	2016

Urgent action needed: the forgotten forests of the Lavasoa-Ambatotsirongorongo Mountains, southeast Madagascar

Timothy M. Eppley[1,2,*], Ernest Refaly[3], Cedric Tsagnangara[3], Jean-Baptiste Ramanamanjato[3], Giuseppe Donati[4]

[1]Institute for Conservation Research, San Diego Zoo Global, PO Box 120551, San Diego, CA 92112, USA

[2]Department of Anthropology, Portland State University, PO Box 751, Portland, OR 97297, USA

[3]Tropical Biodiversity & Social Enterprise sarl., Immeuble CNAPS, premier étage, Fort-Dauphin 00614, Madagascar

[4]Department of Social Sciences, Oxford Brookes University, Oxford, OX3 0BP, UK

*Corresponding author: **eppleyti@gmail.com**

When we think of important areas of biodiversity within Madagascar, we tend to focus on the more well-known national parks and special reserves. The truth is, however, that there are many small fragments scattered across this island that hold a significant wealth of biodiversity that are in critical need of attention and immediate conservation actions. One such system is a group of six small forest fragments within the Lavasoa-Ambatotsirongorongo mountains in the extreme southeast of Madagascar. From east to west, these include Ambatotsirongorongo, Bemanasa, and Grand Lavasoa (Fig. 1). This last fragment is further divided into four fragments that are all in relatively close proximity.

Though this forest used to be continuous across the mountain range, the majority has disappeared and only these six small fragments remain on the southern side of the three main summits. According to Andrianjaka and Hapke (2015), these