LEMUR NEWS

The Newsletter of the Madagascar Section
of the IUCN SSC Primate Specialist Group

Volume 22, 2019/20

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Front cover: Female blue-eyed black lemur (*Eulemur flavifrons*), Sahamalaza – Iles Radama National Park, northwest Madagascar. This species is classified as Critically Endangered on the IUCN Red List. © Inaki Relanzon / naturepl.com

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Editorial

This volume of Lemur News was supposed to come out in late 2019, but for various reasons within and outside my control it was delayed until after year-end. And then came Covid-19, and everything changed. As Julio Vincent Gambuto (a US-based writer and film director) put it: Our way of life "has been brought to its knees by one pangolin".

The world is understandably focused on the tragically high death tolls caused by this novel coronavirus in many countries, and on the economic hardship that millions of people find themselves in as a result of widespread lockdowns imposed by governments to halt the spread of the disease. Perhaps of less immediacy while this outbreak continues, but of high long-term significance to our community of conservationists, are the financial and operational challenges that lie ahead for many conservation projects that ensure the survival of species, be it in Madagascar or elsewhere on the planet. Governments are spending vast amounts of money on supporting businesses in the face of closure forced upon them by lockdown – money that won't be available for statutory funding of conservation projects for some time. Similarly, businesses are suffering huge losses as they had to halt production and are unable to trade, and many face bankruptcy and permanent closure, which will impact on the availability of corporate conservation funding this year and next, and perhaps even beyond that. Zoos and aquariums, which as a community have become the third-largest funder of global species conservation, have had to close throughout Europe, the Americas, Australia, Africa and Asia as social distancing measures are implemented by governments. Many are already struggling for survival, as they are heavily reliant on income from their visitors. Since a substantial number of conservation projects and local NGOs count at least one zoo or aquarium among their funders, there will be a ripple effect that will be felt by many projects in 2020 and 2021.

And then there are the as yet mostly unknown threats to wild primate health potentially posed by SARS-CoV-2. Particularly apes and old-world monkeys, which share a set of 12 key amino acid residues on their host cell receptor with humans, are likely highly susceptible to the virus, and indeed experimentally infected rhesus macaques have developed symptoms similar to those exhibited by humans. Luckily, protein modelling seems to predict that Neotropical and strepsirrhine primates should have greatly reduced binding affinity for SARS-CoV-2 and should thus have lower susceptibility. As yet, I am not aware of any cases of wild or captive non-human primates that have contracted the virus, and I hope it will stay this way. The conservation community has reacted quickly and developed guidance for project leaders, governments and tour operators. The near total halt of international tourism has of course also helped.

While this is all rather gloomy, and the outlook is uncertain as I write this, there are also some interesting developments that should not go unmentioned. Only some months ago, had anybody suggested that the world economy could simply be stopped, they would at best have been smiled at. Driven by the spread of a novel pathogen with a relatively high fatality rate and a high basic reproduction number, things that had always been deemed impossible became the new normal in a matter of weeks. International and domestic travel has virtually ground to a complete halt in many parts of the world. Roads are empty – road travel has reduced by more than 70% here in the UK, and in many other parts of Europe, to levels last seen in the mid-1950s. Consequently, we have seen significant drops in air pollution, and carbon emissions have decreased by double-digit percentages in some countries, including China. The skies seem bluer, the birds are much louder as there is almost no background noise from traffic, and animals appear in places where they have never appeared before in the last two centuries or so, such as in the middle of city centres. We can suddenly provide 90% of our homeless people with beds in hotels, and feeding millions of children while their schools are closed has also become possible literally over night.

Significantly for conservation, in response to the Covid-19 outbreak the Standing Committee of China's National People's Congress adopted a decision on temporarily banning the illegal trade in wildlife and eliminating the consumption of terrestrial wild animals, including those bred or reared in captivity. The decision, which will be signed into law later this year, imposes heavy fines on those who violate it. While this decree was adopted in order to prevent major public health risks rather than to protect threatened wildlife, it is nevertheless an important first step for China on the way towards ending the trade.

Now I have written an entire editorial about a virus and haven't even mentioned lemurs once. But I won't apologise, as the remainder of this volume is, as always, full of fascinating articles, short reports and news items about lemurs. I hope you will enjoy reading it. Stay safe!

Christoph Schwitzer

News and Announcements

Obituary Prof. Dr. Elke Zimmermann

Prof. Dr. rer. nat. Elke Zimmermann, director of the Institute of Zoology of the University of Veterinary Medicine Hannover, Germany, died on 25th July 2019 at the age of 61.

She grew up in Stuttgart, Germany. Early on she discovered her love for nature, and as a young adult she had already begun developing her scientific skills, particularly in breeding frogs in her parent's house! She won the prestigious German scientific competition "Jugend forscht".

She studied Biology from 1977 to 1982 and completed her PhD in 1985 at the University Stuttgart-Hohenheim, supported by a highly competitive stipend of the *Studienstiftung des Deutschen Volkes*. Although her PhD was still focused on neotropical frogs (the behavioural physiology of acoustic communication in poison dart frogs), she soon broadened her scientific scope and completed her habilitation in 1990 on "Acoustic communication of animals".

It was during this time that she established one of the very few successful breeding colonies of grey mouse lemurs (*Microcebus murinus*) which she was able to maintain for the remainder of her academic life. It profoundly shaped her professional career, and the grey mouse lemur and subsequently other nocturnal lemurs became her most important study species for the subsequent two decades.

After two years of working as senior scientist in the working group of Prof. Markl at the University of Konstanz, in 1992 she moved to the German Primate Center (DPZ), while being financially independent thanks to a Heisenberg-Stipend of the *Deutsche Forschungsgemeinschaft*. She set up the *Biocommunication* working group at the DPZ, and in 1994 established a long-term field project on nocturnal lemurs in Madagascar based at the Ankarafantsika National Park. This project is ongoing and was directed for more than 10 years by her together with one of her first PhD students, Ute Radespiel. Twenty doctoral students (six Malagasy among them) and more than 10 Masters students (including five Malagasy) completed their field work in Madagascar under the supervision of Elke over the last 25 years. They worked on a wide range of topics, from socioecology to reproduction, seasonality, and health to the communication and evolution of mouse lemurs, sportive lemurs and woolly lemurs. The resulting publications from members of the Zimmermann working group have contributed substantially to our present understanding of the species diversity, lifestyles, communication, and adaptations of nocturnal lemurs on Madagascar.

Prof. Dr. Elke Zimmermann

After only a few years of working in Ankarafantsika, she was the lead author on the description of a new mouse lemur, *Microcebus ravelobensis* (Zimmermann *et al*., 1998), and contributed substantially in subsequent species descriptions of mouse lemurs and sportive lemurs. Her contributions of species-specific acoustic repertoires, in particular our growing understanding of loud calls (sportive lemurs) and advertisement calls (mouse lemurs), pointed to the importance of vocalisations in the context of searching for mates, and ultimately in the speciation of cryptic species. She was also one of the first to analyse the vast ultrasonic acoustic repertoires of mouse lemurs obtained through the various generations of highly sensitive acoustic recording technologies.

In 1996, she established a second breeding colony of mouse lemurs at the DPZ, this time one for Goodman's mouse lemur (*M. lehilahytsara*), with founders coming from the region of Andasibe. This species served as a comparative model to the grey mouse lemur and allowed us to better understand phylogenetic constraints and behavioural plasticity in these two small primate species. A breeding colony of *Tupaia belangeri*, a closely related outgroup to primates, complemented the research opportunities available in the Zimmermann working group.

Elke Zimmermann was recognised as a C4 professor at the Institute of Zoology in Hannover from 1996 until her death. The three breeding colonies were transferred to Hannover, and have been the subject of a multitude of studies over the last 22 years. Topics ranged from aspects of reproductive biology, female dominance, health and lateralization, to her main academic interest, the evolution of acoustic communication, communication of emotions, hearing and the dynamics of cognitive performance across different life stages. Over the years she obtained a series of competitive grants, both national (e.g., DFG and VolkswagenStiftung) and international (e.g., European Union), resulting in more than 12 doctoral dissertations and 30 Masters and Bachelor theses. However, Elke Zimmermann also supervised other primate projects, e.g., in continental Africa or on Borneo, on apes, galagos or proboscis monkeys. Her scientific legacy consists of more than 170 scientific publications. She will, however, be particularly remembered as an expert on the communication of nocturnal lemurs.

Elke Zimmermann was a member of many scientific societies, notably the IUCN Species Survival Commission (SSC) and the Malagasy NGO Groupe d'étude et de recherche sur les primates – GERP, and, over the last 25 years, was constantly engaged in capacity building in Madagascar. She advised the University of Mahajanga on the establishment of a doctoral program in primatology and, together with Ute Radespiel, she conducted biannual field courses on methods in tropical ecology in the Ankarafantsika National Park – for German and Malagasy students alike. She was highly esteemed by her international and national collaborators and colleagues, just as she was by the members of her working group.

We will miss a consummate scientist with a deep love and concern for Madagascar, Malagasy forests and lemurs in particular. Elke Zimmermann was an ever-helpful teacher and mentor, and a supporting pillar of the Institute of Zoology. She left us too early and will not be forgotten.

Ute Radespiel, Marina Scheumann

Obituary Dr. Martin Nicoll

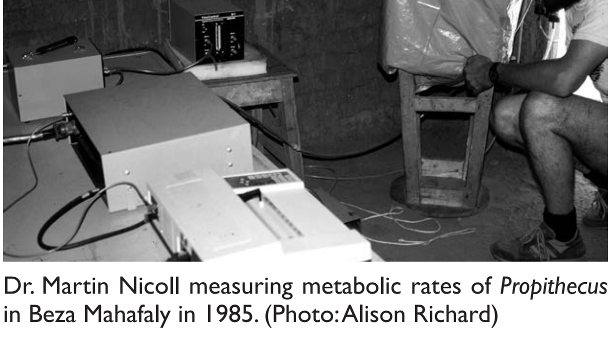
Martin Edward Nicoll, a leading biologist and conservationist died at the age of 65 on 1 January 2020 at his home in south-west Madagascar. He was buried in Ankilibe, Toliara, thus coming to rest and finding peace in the place he loved most.

With Martin's death we have lost a truly influential protagonist in conservation. Martin was not only an excellent naturalist and scientist, but also an exceptionally farsighted politician, becoming the architect of some of Madagascar's conservation pillars, ranging from student projects and the design of field stations to the establishment of the Madagascar Biodiversity Fund and the Durban Vision. Martin did not like being in the spotlight and preferred to work behind the scenes

Martin was born in Devizes, Wiltshire, UK, on 17 April 1954. After gaining a PhD from the University of Aberdeen, he went on to conduct postdoctoral research with the universities of Aberdeen and Kent and the Smithsonian Institution in the US. While much of his work focused on tenrecs, he also explored the energetics of lemurs. In 1986 Martin joined WWF, an organisation that he would work for most of his life and that became like a family to him. He led the WWF protected areas programme in Madagascar before joining WWF International to support projects throughout Africa. But he never forgot Madagascar and returned there in the mid 1990s. He was honoured by the organization with a memorial service in Antananarivo, celebrating his legacy for the conservation of Madagascar's biodiversity, and for each and every one of us who knew him. WWF established a website where people can post messages, photos and videos at https://tributetomartin.natiora.mg/. From people's own words and memories on the site, it's clear Martin was a much loved and respected friend and colleague to many biologists and conservationists in Madagascar, his intelligence, charm and wit appreciated by many he worked with and mentored.

Writing an obituary for Martin that does him justice is impossible. The WWF website summarizes many facets of his skills and personality better than a single text can do. Here we summarize and honour his achievements through the words of Dr Paul Racey, his long-time teacher, mentor and friend, Philip Boyle, the UK Ambassador to Madagascar, and Nanie Ratsifandrihamanana on behalf of the WWF-Madagascar team - "his" organization.

As an undergraduate, Martin revealed himself as a keen observer – and during his honours research project distinguished between red squirrels that worked their way around pine cones sinistrally or dextrally to extract the seeds. What distinguished Martin from the other students I taught at the time was an original mind. In the mid-seventies, he had enrolled in an undergraduate expedition to Malawi which was cancelled because a previous expedition had not respected the dress code! The expedition was diverted to the Seychelles where Martin became fascinated by the fruit bats Pteropus seychellensis and tenrecs Tenrec ecaudatus. He had difficulty in deciding what to work on for his PhD and although I was a 'batman', I didn't influence him and he eventually decided on tenrecs. He secured a highly competitive Leverhulme overseas studentship and a NATO studentship and worked on Praslin island for a couple of years on reproductive ecology of tenrecs – radiotracking individuals with implanted temperature transmitters. On completion of his PhD he was awarded a prestigious Harkness Fellowship to the USA where he became involved in reproductive energetics and took an oxygen analyser to Madagascar which he installed at Tsimbazaza.



Dr. Martin Nicoll measuring metabolic rates of *Propithecus* in Beza Mahafaly in 1985. (Photo: Alison Richard)

I would always try to see Martin during my visits to Madagascar. His knowledge and advice were invaluable but he would never do dinner. Breakfast meetings at the Colbert were OK or a late afternoon drink, until my last visit in 2018 when – for the first time – Martin joined Richard Lewis and I for dinner in the Buffet – so my last memories of him are happy and convivial ones. I am deeply saddened and greatly affected by his passing.

Professor Paul Racey, Centre for Ecology and
Conservation, University of Exeter in Cornwall, UK

Dr Nicoll was a conservationist of the very highest renown in Madagascar and elsewhere. His tireless work over many decades had an enormous positive effect on the outlook for threatened species in this jewel of global biodiversity, both directly and through influencing and inspiring generations of new conservationists. He had the rare talent of combining an encyclopaedic knowledge of the tiniest details of the species and habitats he studied with the big picture thinking needed to develop major programmes, protected areas and national strategies.

He represented the very best of British with his patience, humour, expertise and kind-heartedness: the UK had no better ambassador for conservation here. Our loss is profound, but Martin's legacy on this island will undoubtedly endure for a very long time.

Dr Phil Boyle, UK Ambassador to Madagascar

It is with great sadness that we announce the death of our long-time colleague, Dr Martin Nicoll. Martin had joined WWF in Madagascar in 1986. During these years, he did not stop devoting his time, his energy, to share his passion, his experience and his expertise to us, his colleagues at WWF, but also to all those passionate about nature, who have had the chance to cross paths. We are indebted to him today for who we are, as an organization and as conservationists. But Martin was also, above all, a generous, humble and humorous person, and he will be missed as a friend.

On behalf of the entire WWF-Madagascar team,
Nanie Ratsifandrihamanana, Country Director WWF

Some of the friends and colleagues of Martin Nicoll

Book release: The Terrestrial Protected Areas of Madagascar: their history, description and biota

In 1989, a book written by Nicoll and Langrand was published on the protected areas of Madagascar, which heralded in a new era of conservation for this island nation. In the subsequent three decades, there was an important increase in inventories and studies on Madagascar's terrestrial biota. This work led to significant changes in the systematics of Malagasy plants and animals, a large percentage unique to the island, and a notable augmentation in knowledge on Malagasy biodiversity. In addition, the considerable expansion of the protected area network, reinforcement of legal tools, and the development of new modes and management tools have contributed to a modernization of the protected area network. We have now released a bilingual book (French and English), *The Terrestrial Protected Areas of Madagascar: their history, description and biota* (Edited by Goodman, Raherilalo & Wohlhauser). The purpose of this three-volume and 1716 pp. book is to present a large-scale update of information available from 98 terrestrial protected areas, various analyses to understand general trends in the conservation of these sites, and a synthesis to assess the needs for future scientific programs. This book is intended as an important reference for students, researchers, protected area managers, conservationists, and visiting ecotourists.

In Madagascar copies of the book can be purchased from Association Vahatra, across the street from the Domaine d'Ankatso, and close to the Université d'Antananarivo (Map available at **www.vahatra.mg/planfr.html**). Outside Madagascar it is recommended to order the book from The University of Chicago Press on-line site (**www.press.uchicago.edu/ucp/books/book/distributed/T/bo46243442.html**).

The PSG Section for Human-Primate interactions

Siân Waters, Susan Cheyne
Vice chairs, PSG Section for Human-Primate Interactions

Non-human primates are geographically widespread, and many primate species are at risk of extinction due to anthropogenic activities including the pet trade, and persecution by people for crop foraging behaviour (commonly referred to as human-primate conflict). Human-primate interactions are complex, vary widely, occur in many different contexts and are often poorly understood. Human-primate interactions depend on social and cultural, as well as economic factors and can vary from a primate being worshipped as a deity in one place and the same species persecuted and killed in another. Currently most resources surrounding the human-primate interface focus on human-primate conflict in agro-ecosystems, but other interactions occur between people and primates and their study will benefit from a coordinated interdisciplinary approach.

An interdisciplinary approach is essential to understand the human dimension of human-primate interactions be they positive or negative. The PSG Section for Human-Primate interactions is composed of specialists with expertise in human-primate relations in various contexts coming from a wide range of disciplines across natural and social sciences and the humanities.

We are currently seeking members from habitat countries with experience of human-primate interactions at the academic or practical level in these topics:

a) Primate tourism
b) Primate hunting (subsistence and sport)
c) Primates in agroecosystems
d) Primate trade
e) The changing role of primates in human culture (religion; history, media etc)

Activities of the group will include

1) **Coordinating a reference library of human-primate interactions**. This would be wider ranging than the existing primate resource page of the IUCN/SSC Human-Wildlife Taskforce group, which focuses on human-primate conflict in agro-ecosystems. Members of each sub-group would be responsible for developing and updating the HPI reference library (which will eventually be available on our website*).
3) **Provide interdisciplinary advice and expertise**on problematic human-primate interactions.
4) **Build capacity** where needed, particularly in the study of the human dimension of human-primate interactions by providing training workshops in the application of social science methods and ethics in primate range countries.
5) **Add to existing IUCN/SSC Primate Specialist Group technical guidance materials**, resources and tools as and when appropriate.

Please contact Siân on (**psg.hpi@gmail.com**) and Susan (**section.small.apes@gmail.com**) if you would like more information about the section or are interested in becoming involved.

You can follow the activities of the group via our Facebook group:**www.facebook.com/groups/187157948858667/**

Lemur genetics workshop on Nanopore technology in Antananarivo, Madagascar

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We are entering an exciting time in which genetic analysis can be deployed in the field. Madagascar is a top priority for leveraging this power in the service of biodiversity conservation, and molecular techniques including DNA and RNA sequencing, are now commonly used to address questions about lemur evolution, ecology, health, and conservation, to great effect. Molecular-based workflow has previously involved researchers traveling to Madagascar to collect biological samples that are then exported to western universities or laboratories for analysis. There is now a growing interest among Malagasy and foreign researchers to perform molecular work in Madagascar. A number of emerging technologies are becoming increasingly miniaturized, more affordable, and relatively easy-to-operate. These advances in technology are making all phases of molecular analysis possible to perform in Madagascar, from sample extraction, to PCR and gel electrophoresis, to sequencing and bioinformatics. In particular, miniaturized sequencing technology developed by Oxford Nanopore Technology (ONT; the MinION sequencer) is allowing for a wide range of *in situ* molecular research in Madagascar. A new laboratory, Mahaliana (www.mahaliana.org), will open in 2019 in Antananarivo and will provide space, equipment, and expertise for a number of analytical options, including genetic sequencing using the ONT MinION sequencing platform. The Institut Pasteur in Antananarivo also appears to be using the ONT MinION to study human disease (as shown on their Twitter account @pasteurMG). Among the many benefits of performing sample analysis in Madagascar, perhaps the most exciting is the clear potential for Malagasy students to gain training, experience, and skills in conservation genetics and laboratory methods.

Fig. 1: Participants practice their pipetting skills, overseen by LKG, while loading amplicons on an agarose gel.

To explore this potential in Madagascar, our team deployed a mobile laboratory in 2018 with two main goals: (1) to demonstrate that real-time DNA sequencing in Madagascar is possible and reliable; and (2) to provide interested college students with hands-on training for our analytical pipeline. Our mobile laboratory, designed and outfitted by PAL, RCW, and ADY, and operated by LKG and MBB, includes all components necessary to extract genomic DNA from biological samples, amplify target genes using technology developed by miniPCR (www.minipcr.com), prepare amplicons for sequencing, and sequence using ONT's MinION. The entire laboratory fits into two pelican cases. The success of our mobile laboratory as a research tool is the subject of an upcoming publication (Blanco *et al*., in prep), whereas here we outline its use as a training tool.

Using our mobile lab, we created a two-day, genetics workshop that we held in Antananarivo in September 2018. Professor Achille Raselimanana (Faculty of Sciences, University of Antananarivo) helped advertise the workshop widely across the university and broader research community and, along with Dr. Steven Goodman, generously provided physical space at the Association Vahatra office in Ankatso to run the workshop. Held entirely in English, we originally wondered if students would signup, show up, or get anything useful out of the workshop, but minimally we were confident that there would be ample opportunities for conversation and networking over coffee breaks.

When we learned that 25 participants had signed up, our maximal capacity, we were delighted. The participants stemmed from diverse fields, including the Faculty of Sciences, Department of Veterinary Sciences and Medicine, the Institut Pasteur, and Durrell Wildlife Conservation Trust. There was a wide range of molecular experience, from students eager to improve their understanding of the basics, to those wanting to apply new techniques to their current projects, to junior university faculty staff who had already conquered genetic techniques and were supervising their own laboratories. While somewhat intimidating from a teaching perspective, this incredible diversity of attendees further underscored the great interest among Malagasy researchers and conservationists to learn and master new molecular approaches, thereby facilitating research on samples that could be collected, analysed, and interpreted in Madagascar.

The plan for the workshop was ambitious: On day 1, we began with a presentation to cover basic genetic principles and the theory behind ONT sequencing (i.e., how do nanopores actually work?). As a group, we began by taking a tissue sample from a mouse lemur, extracting genomic DNA, amplifying a mitochondrial marker gene for species diagnosis, and checking that our PCR had worked via gel electrophoresis. On day 2, we prepared amplicons for sequencing (i.e., library preparation), sequenced, and used a simple bioinformatics pipeline to confirm species identity by comparing sequences against a master database. Wonderfully, everything worked with no major problems, and by the end of day 2, we had confirmed that our mouse lemur was a Danfoss' mouse lemur (*Microcebus danfossi*).

Beyond the laboratory techniques comprising the workshop, we built in other critical components as well. Throughout the workshop, we offered participants hands-on experience with the lab work, from the basics of pipetting and proper lab techniques for those with minimal experience, up through sequencing and bioinformatic analysis for more advanced participants. In general, participants practiced on a suite of 'blank' and 'dummy' samples, whereas we demonstrated on the real sample. We purposefully did not prepare our workshop like a 'cookery show', where success is swift and guaranteed. When our protocol required samples to incubate for an hour, the participants experienced that hour, rather than having us bring out previously processed samples and quickly moving on. This real-time method served to demonstrate the tedious and time-consuming nature of laboratory work. We wanted our participants to emerge from the workshop with an honest appreciation for the challenges (and occasional downtime) that are intrinsic to molecular science. Moreover, by using a real sample, we had no idea if each successive step would work, and the participants got to experience both the anxiety of potential failure as well as the thrill of success.

Fig. 2: LKG leads a session on bioinformatics.

Fig. 3: The workshop participants after the end of a successful second day. MBB and LKG in the front row.

Finally, we cultivated an open, easy, and active learning environment such that participants felt free to ask questions and together deliberate as colleagues in pursuit of a unified goal. At the workshop's onset, we observed that though all appeared curious, many were too shy to speak. As the hours went by, however, this dynamic changed markedly. More and more students volunteered to help with laboratory work, raised their hands to ask questions, and even pressed us for more details in follow-up questions. When language became a barrier, we welcomed the participants with more genetics experience to help explain harder concepts. During coffee breaks, as we had hoped, many students approached us to talk about their research, to ask about other applications of our laboratory, and to seek advice regarding bioinformatic analysis. At the conclusion of the workshop, we had exchanged contact information and formed a community of scholars, and subsequently, have stayed in touch with several participants over the past months, continuing to answer questions via email. Fundamentally, we have progressed well beyond sequencing logistics and are now engaged as a community focused on building greater technical and human capacity for molecular work in Madagascar. The enthusiasm, energy, and desire among the participants to perform genetic analysis on the ground in Madagascar is inspiring. Ultimately, we hope to follow up this inaugural workshop with future workshops on an array of topics, from basic laboratory skills to more sophisticated bioinformatics, so that our new colleagues can carry this knowledge with them in their future scientific endeavours.

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Blue eyed black lemur ant-ics

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Formic acid is a substance produced by some ants for defense, trail marking, and recruitment. Some animals are known to rub ants or other arthropods on parts of their plumage or fur to anoint themselves with released substances. Functions of this behaviour are thought to involve detoxifying a rich food source, communication between conspecifics and protection against ectoparasites. For example, feather-wiping with ants has been documented in several bird species (Morozov, 2015). In primates, capuchin monkeys (*Cebus apella*) show "anting" with carpenter ants (*Camponotus rufipes*) (Hymenoptera: Formicidae), especially during the occurrence of the tick species *Amblyomma cajennense*, subadult season (Falotico *et al*., 2007). Formic acid is also shown to repel ticks in laboratory settings (Falotico *et al*., 2007). While anointing has been documented in black lemurs (*Eulemur macaco*: Birkinshaw, 1999) and red-fronted lemurs previously (*Eulemur rufifrons*: Peckre *et al*., 2018), this has been with the use of millipedes which secrete a different substance, a type of benzoquinone (Peckre *et al*., 2018).

The population of the Critically Endangered blue-eyed black lemur (*Eulemur flavifrons*) found in the Ankarafa Forest in northwestern Madagascar has been well-studied (Volampeno *et al*., 2011). Working with AEECL programme director Guy Randriatahina, the BBC Natural History Unit visited Ankarafa forest to film *E. flavifrons* in October 2018. On multiple occasions during this period, several individuals from one troop performed anointing behaviour with carpenter ants from an ant colony residing inside a dead tree within their home range (Fig. 1, Fig 2).

Both male and females, some with infants, let carpenter ants crawl all over their bodies. The presence of the lemurs caused a surge in activity from the ants. As the ants attacked *E. flavifrons*, they rubbed them all over their bodies, even putting the insects in their mouths and salivating as they did so. *E. flavifrons* stayed for up to thirty minutes performing this behaviour, sometimes alone, sometimes with several individuals engaging in the anointing at any one time. Evidence suggests that the formic acid could help protect against

Fig. 1: Blue-eyed black lemur *Eulemur flavifrons* males and females anointing with ants.

Fig. 2: Blue-eyed black lemur *Eulemur flavifrons* female eyes up ant for anointing.

ticks, although other explanations as a more general insecticide and gastrointestinal parasite could not be excluded. This is believed to be the first time this behaviour has been reported in blue-eyed black lemurs.

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Fig. 3: Carpenter ants in Ankarafa Forest.

Short Communications

Adaptability of *Hapalemur griseus griseus* to a diet containing cyanogenic heteroside

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Introduction
The feeding ecology of primates depends on the morphological adaptations of the dentition and digestive tract and on physiological adaptations (Hladik, 2006). The eastern lesser bamboo lemur (*Hapalemur griseus griseus*) is a folivorous bamboo lemur (Wright, 1986; Tan, 1999; Grassi, 2002; Mittermeier *et al.,* 2014), classified as Vulnerable (Andriaholinirina, 2014). The aim of this work was to enhance our understanding of feeding preferences of eastern lesser bamboo lemurs; specifically, foods consumed per season, habitat types and diets of the species.

Methods
Data collection
An ecological survey of foods consumed by two groups of eastern lesser bamboo lemurs was undertaken in the Maromizaha rainforest during 2016. The study spanned two

seasons: one wet and hot season (November to April) and one dry and cool season (May to October). Data was gathered over 12 days per month; observations were equally split between study groups (6 days per month ~ 1346.25hrs per group total).

Analysis of foodstuffs
In order to understand more about the cyanogenic properties of plant species consumed by eastern bamboo lemurs, phytochemical screening was undertaken to determine the presence or absence of cyanogenic glycosides. This analysis was undertaken using a Grignard test. Cyanogenic glycosides release toxic hydrocyanic acid (HCN) after hydrolysis. The Grignard test involves the use of an indicator paper (Whatman filter paper). Samples were impregnated with an aqueous solution of sodium picrate. The filter paper taking on a red hue is indicative of the presence of cyanogenic glycosides. Although this method is qualitative, it served to provide more information about the presence (or absence) of cyanogenic glycosides in the eastern bamboo lemur diet.

Results and Discussion

The eastern lesser bamboo lemurs in this study predominantly consumed plants belonging to the Poaceae family (Fig. 1), a type of bamboo including *Cephalostachyum* sp., *Panicum* sp1, and *Panicum* sp2 (64.52%). Preference was shown for young shoots and leaves of these plants. However, they also exploited other plants such as *Hypoestes* sp. (Acanthaceae).

Tab. 1: Food sources of eastern lesser bamboo lemur (*H. g. griseus*) containing cyanogenic glycosides

Samples	**% of consumption**	**Observation during tests**	**Results**
Cephalostachyum sp (POACEAE)	24,05 %	No reaction	(-): Absence of cyanogenic glycosides
Panicum sp1 (POACEAE)	38,10 %	Orange red colouring	(+): Presence of cyanogenic glycosides in small quantities
Hypoestes sp (ACANTHACEAE)	1.19 %	No reaction	(-): Absence of cyanogenic glycosides

Cyanogenic glycosides release toxins when hydrolysed. The catabolism of cyanogenic glycosides is therefore initiated upon tissue disruption, due to mechanical damage or ingestion by herbivores (Wajant *et al.*, 1994; Jarrige *et al.*, 1995; Patton *et al.*, 1997). Results of the phytochemical screening of cyanogenic glycosides in the three plant samples found in the eastern bamboo lemur diet demonstrate a small quantity of these chemicals, in particular within the *Panicum* sp1 (Poaceae) (Tab. 1). This species is a widespread plant found in the valleys of the Maromizaha rainforest. It is consumed to an even greater extent by eastern bamboo lemurs during the dry season (52.63%). The excessive consumption of this plant thus has the potential to poison the lemurs. Throughout the study period, irrespective of season, animals descended near to the ground to eat a small amount (1.19%) of soil a few hours post feeding or resting (Fig. 2). In all instances the consumption of soil only occurred after ingestion of cyanide-containing plants. This geophageous behavior may be attributed to the soil helping to neutralize the effects of ingested hydrocyanic acid, a theory which remains a hypothesis (Hladik, 2002; Hladik *et al.*, 2011). This suggests that soil consumption in these eastern bamboo lemurs is helping to offset any harmful effects from the vegetation.

Fig. 1: Male eastern lesser bamboo lemur (*H. g. griseus*) feeding on *Panicum* sp1 (Poaceae). (Photo: Andrianandrasana, Z.A.)

Feeding on soil is commonly observed in primates and is thought to resolve nutritional requirements (Izawa, 1993; Mahaney *et al.*, 1999; Krishnamani and Mahaney, 2000; Blake *et al.*, 2010; Hladik and Gueguen, 2011). Studies by Glander *et al.* (1989), Tan (1999) and Jeannoda *et al.* (2003) on foods eaten by golden bamboo lemurs (*Hapalemur aureus*) indicate that bamboos have toxic substances: tannins or glycoalkaloids, with varying toxicities. Tannins (as polyphenols) are abundant yet not very toxic, even at high doses (Hladik *et al.*, 2000). Research indicates there is no means of animals removing these toxic substances from the plant itself; rather, consumers must process them internally (Hladik *et al.*, 2000). Jeannoda *et al.* (2003) recommends consideration of physiological adaptations of lemurs when trying to understand how they process particularly toxic bamboo species. In eastern bamboo lemurs we hypothesise that individuals may have physiological adaptations to the cyanide contain-

Fig. 2: *Hapalemur g. griseus* feeding on soil. (Photo: Andrianandrasana, Z.A.)

ing diet. Tan (2006) suggested that processing cyanogens to avoid the toxic effects may involve a specific enzymatic pathway that is unique to the lemur and may yield insights into *Hapalemur*-bamboo coevolution.

The phytoanalysis undertaken in this study indicated that the level of toxic substances in the diet of the eastern bamboo lemurs studied may not be particularly high. However, after excessive consumption of bamboo, especially the young bamboo leaves, the eastern bamboo lemurs were observed to either consume a small quantity of soil or to drink water. Lemurs were even observed descending to the valley level in Maromizaha rainforest to drink at streams in high temperatures. Taken together these findings suggest that eastern bamboo lemurs are showing behavioural adaptations to their potentially toxic diet, but physiological adaptations must not be ruled out. This research contributes to our understanding of how eastern bamboo lemurs are adapted to their specialised diet.

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The elusive *Allocebus trichotis:* new records of hairy-eared dwarf lemurs in the northwest of Marojejy National Park

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A short paper published in *Lemur News* more than two decades ago by Anne Yoder (1996) started by saying "… The Malagasy primate *Allocebus trichotis*, the hairy-eared dwarf lemur, is undoubtedly the least studied and possibly the rarest of all living primates…". Here, we report new sightings of this elusive primate from the NW Marojejy area, during our expedition in October 2018.

To put things in perspective, at the time that Yoder's report was published, only three mouse lemur species (brown mouse lemur, *Microcebus rufus;* grey mouse lemur, *M. murinus*; pygmy mouse lemur, *M. myoxinus*) and 2 dwarf lemur species (fat-tailed dwarf lemur, *Cheirogaleus medius;* greater dwarf lemur, *C. major*) had been described. Today, those numbers rose to 24 and 9 respectively with more species pending description (Lei *et al*., 2014; Hotaling *et al*., 2016). Yet, hairy-eared dwarf lemurs (*Allocebus trichotis*), their biological "cousin", remains the single species within its genus, and one has to wonder whether this singularity is due to sampling bias or true biological "stasis" (Yoder *et al*., 2016). Until more sampling is accomplished, this will remain a mystery.

Around the time of the Yoder expedition to Mananara, north-eastern Madagascar in 1989, hairy-eared dwarf lemurs had been recently 're-discovered' in the region, bringing hope that the species was not extinct in the wild (Meier and Albignac, 1989). In the next decades, multiple sightings of hairy-eared dwarf lemurs were reported at several sites in Madagascar, perhaps because researchers, made aware of its rarity, began to target this lemur more specifically and/or, possibly because researchers were better able to discriminate this species from sympatric dwarf and mouse lemurs, which could be mistaken as hairy-eared dwarf lemurs due to some similarities in size and coloration. Identification of small-bodied nocturnal lemur species is additionally hindered in the rainforest, where visibility is diminished by thick forest cover and frequent rains.

By the early 2000s, hairy-eared dwarf lemurs had been sighted in several north-eastern and central-eastern rainforests: e.g. Anjanaharibe Sud, Marojejy, Masoala, Mananara, Zahamena, Andasibe region (Rakotoarison *et al*., 1997; Schütz and Goodman, 1998; Sterling and Rakotoarison, 1998; Goodman and Raselimanana, 2002). And though there was a growing sense of 'relief; that this species was more common than previously thought (Goodman and Raselimanana, 2002), hairy-eared dwarf lemurs were still difficult to see and only found at low densities. Moreover, little else was known about its biology, behavior or ecology.

We had learned from Yoder's early account (1996) that local Malagasy people thought hairy-eared dwarf lemurs nested inside tree holes and hibernated for half a year underground or deeply inside trees. Later data from two captive individuals suggested that this species could employ torpor based on occasional observations of body temperature drops below 30 °C during the winter season, though no obvious body mass gain -or prolonged lethargy- was observed (Rakotoarison *et al*., 1997). The most detailed study on behavioral ecology of hairy-eared dwarf lemurs was conducted by Biebouw and colleagues in the Andasibe region, central eastern Madagascar (Biebouw, 2009, 2013; Biebouw *et al*., 2009). Biebouw et al. (2009) confirmed the use and selective preference for tree holes as sleeping sites, observed an individual 'inactive' inside a tree hole for a whole night, suggesting torpor use similar to that employed by mouse lemurs, but reported that most hairy-eared dwarf lemurs remained active throughout the year, disputing the claim they hibernated (several weeks of inactivity at a time) at this forest (Biebouw *et al*., 2009). Surprisingly, hairy-eared dwarf lemurs displayed much larger home ranges than other cheirogaleids (e.g.; ranges more than three times larger than those of mouse lemurs) and ate a variety of foods, preferentially, insects and gum, but also fruits and flowers to a lesser degree (Biebouw, 2009, 2013). As far as we know, no additional hairy-eared dwarf lemur populations have been studied to date.

More than 20 years after Yoder's account, we do not question the existence of hairy-eared dwarf lemurs in the wild but continue to be captivated by its elusive nature. We are back to questioning the actual distribution of this species, as few reports have (re-)confirmed the presence of hairy-eared dwarf lemurs within the original estimated broad eastern distribution (Miller *et al*., 2018). During the last IUCN species assessment workshop in May 2018, no new data were available for this species, leaving the status unchanged as Vulnerable.

Between 1996 and 2002 Steven Goodman's research team surveyed different locations at Marojejy National Park, including southeast and northwest sites. Hairy-eared dwarf lemurs were only found in the northwest region (NW Marojejy) (Goodman and Wilmé, 2003). We conducted our expedition to NW Marojejy between October 12-29, 2018 which included lemur surveys on pre-set transects. During night walks, hairy-eared dwarf lemurs were observed on four occasions, twice at each campsite (Fig. 1). Although this report does not expand the known range of this species, nor document novel habits or biological facts, we wanted to re-confirm its presence in NW Marojejy, hoping this finding will stir some renewed interest within the scientific and conservation community to study hairy-eared dwarf lemurs. Finally, we would like to echo the closing words by Goodman and Raselimanana in their *Lemur News* article (2002), that states "…The density of this species [*Allocebus trichotis*] in the park [NW Marojejy] is notable and our two transect sites, particularly the second one, might be excellent places to conduct a detailed study of the ecology and natural history of this species…" We agree that these sites are promising and hope someone takes on the challenge to more fully explore the distribution and natural history of one of the most elusive lemurs in Madagascar.

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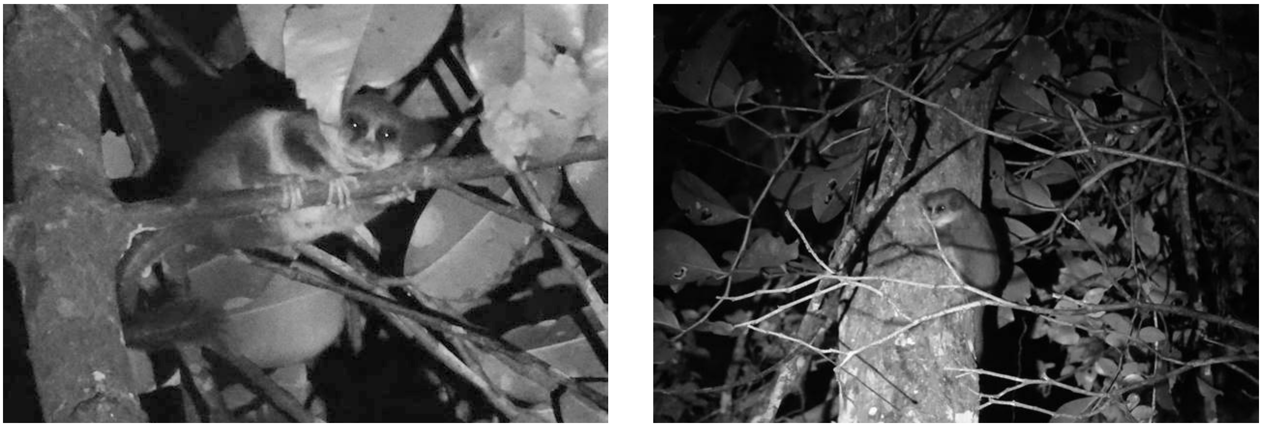

Fig. 1: *Allocebus trichotis* near Camp1 (left) and Camp 2 (right) at NW Marojejy. Photos taken by MBB and JET, October 2018.

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Observation préliminaire de l'écologie du lémur à ventre rouge *Eulemur rubriventer* dans la forêt de Maromizaha

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Introduction

Plusieurs espèces de lémuriens sont menacées par la déforestation et la dégradation d'habitat qui sont majoritairement dues aux activités humaines (Harper *et al.,* 2007; Irwin *et al.,* 2010; Herrera *et al.,* 2011). Le changement d'habitat ainsi que la variabilité du climat affectent la phénologie des arbres, et par conséquent la disponibilité des ressources pour les lémuriens (Wright, 1999; Ganzhorn *et al.,* 2003; Bollen and Donati, 2005; Arrigo-Nelson, 2006). Les espèces du genre *Eulemur* sont souvent perçus comme flexibles et tolérantes aux habitats perturbés du fait de leur adaptation à différents types d'environnements (Sussman and Tattersall, 1976; Mittermeier *et al.*, 2006). Ainsi, durant la saison de la raréfaction de nourriture, les espèces *Eulemur sp.* ont différentes stratégies de survies. Certaines espèces augmentent la durée de consommation de nourriture pendant la journée (*E. rubriventer*, Overdorff, 1996); d'autres se déplacent en dehors de leur territoire (*E. rufifrons,* Overdorff, 1993a), ou consomment des aliments nouveaux ou inhabituels (*E. cinereiceps*, Ralainasolo *et al.,* 2008).

Le lémur à ventre rouge ou *Eulemur rubriventer* qui est distribué du Nord au Sud-est de Madagascar est classé comme Vulnérable (Andriaholinirina *et al.,* 2014) et sa population est en déclin continu dans toute sa répartition géographique. Cette espèce a été bien étudiée dans son aire de répartition. Cependant, très peu de données sont disponibles concernant cette espèce dans la Nouvelle Aire Protégée (NAP) de Maromizaha et où elle n'est pas encore très habituée à la présence humaine. Dans cette étude, nous examinons l'écologie d'*Eulemur rubriventer* dans la forêt de Maromizaha afin de fournir des éléments utiles pour sa conservation (Ralison *et al.,* 2015).

Méthode

Cette étude a été menée dans la Nouvelle Aire Protégée de Maromizaha (18° 56' S – 48° 27' E), une forêt dense humide de 1880 ha située dans le District de Moramanga de la Région Alaotra-Mangoro au Centre-Est de Madagascar. La NAP a une altitude qui varie de 896 à 1213 m, reçoit une précipitation moyenne annuelle supérieure à 1600 mm. L'Aire Protégée abrite 13 espèces de lémurien comprenant l'espèce en danger critique *Indri indri*. Du 03 au 22 décembre 2017, nous avons suivi deux groupes (groupes 1 et 2) d'*Eulemur rubriventer* pour étudier leur comportement et écologie. Selon les guides locaux, trois groupes d'*E.rubriventer* existent dans le site d'étude et ils ont été déjà suivis par un guide local pendant un mois avant le commencement de notre étude pour être habitués à la présence humaine; mais nous n'avons pas pu voir l'un de ces groupes au cours de notre étude. Le groupe 1 composé de 4 individus comprenait 1 mâle adulte, 1 femelle adulte, 1 femelle subadulte et 1 femelle juvénile. Le groupe 2 composé de 4 individus comprenait 1 mâle adulte, 1 femelle adulte, 1 mâle juvénile et 1 petit de sexe indéterminé encore accroché au ventre de sa mère (Fig. 1). Le groupe 3 (que nous n'avons pas pu voir) composé de 3 individus comprendrait 1 mâle adulte, 1 femelle adulte et 1 femelle juvénile.

Les groupes ont été quotidiennement cherchés dans leur territoire et suivis de 06h00 à 13h00. Une fois qu'un groupe est trouvé, nous avons adopté la méthode «focal continuous sampling» pour connaître les activités du groupe. Dans ce cas, un individu a été choisi comme animal focal et le comportement de ce focal a été enregistré aussi longtemps que possible ou jusqu'à ce que le groupe soit perdu de vue. Dans cette étude, le mâle et la femelle adultes du groupe 1 et aussi le mâle adulte du groupe 2 étaient les individus focaux. Nous avons uniquement choisi les adultes parce qu'ils sont faciles à distinguer morphologiquement. A chaque changement d'activité du focal, les paramètres suivants ont été notés: heure, type d'activité (consommation de nourriture, marquage génital/tête, déplacement, repos, activité sociale ou «allogrooming», autres comme miction, défécation, grattage, «self grooming», vocalisation, vomissement), hauteur de l'animal sur l'arbre, nom vernaculaire de l'arbre que l'on identifiera le nom scientifique selon Ramanahadray (2009), hauteur et diamètre à hauteur de poitrine (DHP) de l'arbre utilisé au cours de chaque activité et distance de l'observateur à l'animal.

Résultats

Pendant les 20 jours sur terrain, seules les données de cinq jours ont été récoltées parce qu'il y avait des jours où les groupes n'ont pas été trouvés dans leur territoire habituel. Le groupe 2 n'a été rencontré qu'une seule fois et le groupe 1 quatre fois. Un total de 374 observations provenant de trois individus focaux (le mâle et la femelle adultes du groupe 1 et aussi le mâle adulte du groupe 2) ont été collectées pendant 12 heures d'observations soit environ 2h30 d'observation par jour. Les groupes d'*Eulemur rubriventer* ont été observés à une distance moyenne de 8.46±2.62m (moyenne±SD, n=326). Ils ont utilisé 45 espèces potentielles d'arbres appartenant à 26 familles connues: Anacardiaceae, Aquifoliaceae, Clusiaceae, Cyatheaceae, Elaeocarpaceae, Euphorbiaceae, Lamiaceae, Lauraceae, Liliaceae, Loganiaceae, Malvaceae, Melanophyllaceae, Monimiaceae, Moraceae, Myrsinaceae, Myrtaceae, Oleaceae, Orchidaceae, Pandanaceae, Passifloraceae, Proteaceae, Rubiaceae, Sapindaceae, Sapotaceae, Thymelaeaceae, Ulmaceae. Ces arbres ont une hauteur moyenne 10.63±3.40m (n=265) avec un DHP moyen de 24.35±15.97cm (n=256) pour effectuer leurs activités. Les arbres les plus utilisés sont présentés dans la Fig. 2. Les individus se trouvaient à une hauteur moyenne de 8.05±2.70m (n=265) sur l'arbre utilisé.

Fig. 1: Mâle juvénile (à gauche) et mâle adulte (à droite) du groupe 2 d'*Eulemur rubriventer* dans la NAP de Maromizaha. (Photo: Zo S.E. Fenosoa)

La consommation de nourriture constituait 13,4% des activités d'*E. rubriventer*. Les arbres servant comme nourriture sont listés dans le Tab. 1. Les groupes consommaient de fruits de *Coffea* sp.1, *Cryptocaria* sp.; *Danais* sp.; *Eugenia bernieri, Ficus* sp.; *Gaertnera* sp.1, *Gallenia sclerophylla, Pandanus hildebrandtii, Passiflora incarnata, Uapaca densifolia,* et jeunes feuilles de *Passiflora incarnata* et d'une orchidée de genre inconnu. Toutefois, *Ficus* sp.; *Gallenia sclerophylla* et *Passiflora incarnata* ont été les espèces d'arbres fréquemment consommées par le lémur à ventre rouge. Le marquage (génital pour les deux sexes mais marquage tête uniquement pour les mâles) constituait 10.7% de leurs activités, le déplacement 16.8%, le repos 14.7%, l'allogrooming 5.6%, et les 38.8% restant étaient composées de combinaisons d'autres activités comme miction, défécation, grattage, «self grooming», vocalisation, vomissement.

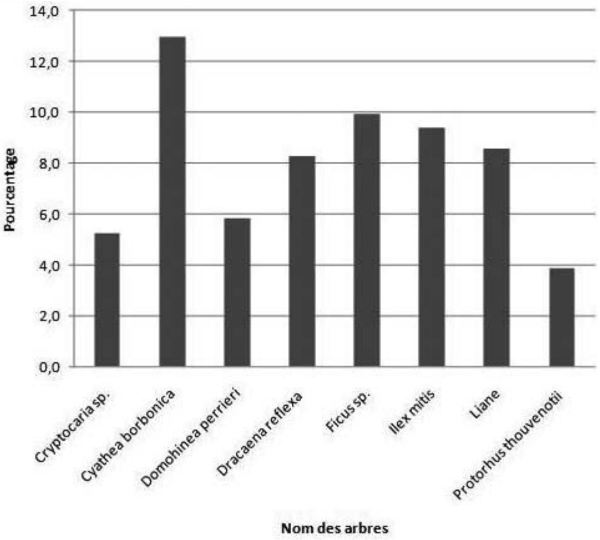

Fig. 2: Pourcentage des arbres fréquemment utilisés pour les activités d'*E. rubriventer* à Maromizaha.

Discussion

Cette étude a montré que les groupes d'*Eulemur rubriventer* se trouvaient à une hauteur moyenne de 8.05±2.70m sur des arbres de hauteur moyenne 10.63±3.40m et de DHP 24.35±15.97cm. Bien que nous n'ayons pas caractérisé l'habitat à la NAP de Maromizaha à cause de la brièveté de l'étude, nous pouvons affirmer que l'espèce *E. rubriventer* dans ce site se trouve dans la strate supérieure de la forêt pour effectuer ses activités, en se basant sur la différence entre l'hauteur de l'arbre et celle de l'animal qui et de 2.5 m environ. Ce résultat est similaire à celui de Rafidimanana et *al.;* 2017 qui rapportent qu'*E.rubriventer* utilise les strates moyenne et supérieure de la forêt classée de Kianjavato.

En Novembre 2017, Randrianarison (données non publiées) a observé le même groupe d'*E. rubriventer* étudié pendant notre étude, et ses résultats présentent quelques différences sur les espèces d'arbres entrant dans l'alimentation des lémurs à ventre rouge. Certaines espèces d'Anacardiaceae, Lauraceae et Rubiaceae que les groupes d'*E. rubriventer* consommaient en Novembre ne portaient plus de fruits en Décembre dans le site d'étude. La présence de fruits sur certaines espèces s'est étalée de Novembre à Décembre (*Cryptocaria* sp.; *Ficus* sp. et *Pandanus hildebrandtii*) tandis que les fruits d'autres arbres n'apparaissaient qu'en Décembre (Myrtaceae, Euphorbiaceae, Passifloraceae et Rubiaceae) (Tab. 1). Les fruits de *Passiflora incarnata* que les groupes consommaient, par exemple, étaient encore non mûrs durant notre collecte de données en Décembre.

Tab. 1: Liste des arbres servant comme nourriture et arbres communs pour les activités aux mois de Novembre et Décembre par *Eulemur rubriventer* à Maromizaha. (Source des noms scientifiques: Ramanahadray, 2009)

Famille	Nom scientifique	Nom vernaculaire	Nourriture	Espèce commune
Anacardiaceae	*Protorhus ditimena*	Ditimena	Nov.	X
	Protorhus sp.1	Ditimena kr	Nov.	
	Protorhus thouvenotii	Menavahitra	Nov.	X
Cyatheaceae	*Cyathea borbonica*	Fanjana	Nov.	X
Elaeocarpaceae	*Sloanea rodentha*	Vanana fotsy		X
Euphorbiaceae	*Domohinea perrieri*	Hazondomoina beravina		X
	Uapaca densifolia	Voapaka/ Voapaka beravina	Déc.	
Lauraceae	*Beilschmiedia grandiflora*	Voankoromanga	Nov.	X
	Cryptocaria sp.	Tavolo malama/ Tavolo vanana	Déc.	X
	Ocotea sp.	Varongy		X
Moraceae	*Ficus* sp.	Nonoka beravina/Nonoka keliravina	Nov.; Déc.	X
Myrtaceae	*Eugenia acumenae*	Rotra mena/ Rotra mamilava		X
	Eugenia bernieri	Rotra fotsy	Déc.	
Oleaceae	*Steganthus lanceus*	Vazanahomby		X
Orchidaceae	*Inconnu*	Orchidée	Déc.	
Pandanaceae	*Pandanus hildebrandtii*	Vakoana	Nov.; Déc.	X
Passifloraceae	*Passiflora incarnata*	Garana	Déc.	
Rubiaceae	*Coffea* sp.1	Kafeala	Déc.	
	Danais sp.	Lengoala/Lengoala keliravina	Déc.	
	Gaertnera sp.1	Tsikafekafe mboeza	Déc.	
	Gallenia sclerophylla	Pitsikahitra potaka	Déc.	
	Bremeria perrieri	Pitsikahitra Kr br	Nov.	
	Bremeria sp.2	Pitsikahitra Kr	Nov.	

Cet asynchronisme sur la période de fructification des arbres à Maromizaha pourrait être lié à la disparition des groupes d'*E. rubriventer* dans leur territoire pendant presque deux semaines (du 30 novembre au 12 décembre 2017). Les déplacements de primates liés à la rareté de la nourriture, ou lorsque celle-ci est inégalement distribuée dans la forêt, sont communs (Strier, 1987; Chapman, 1988; Barton *et al.*, 1992; Isbell and Young, 1993). Par exemple, le congénérique d'*E. rubriventer, E. rufifrons*, est connue pour changer de zone d'habitat en suivant les saisonnalités de fructification (Overdorff, 1993a). Il serait possible que les groupes d'*E. rubriventer* se déplacent en dehors de leur territoire pour rechercher les arbres disponibles qui peuvent leur fournir des fruits parce que c'est une espèce frugivore dont plus de 80% de son régime alimentaire est composé de fruits (Overdorff, 1993b).

Conclusion

Bien que nos résultats sur l'écologie d'*Eulemur rubriventer* aient été obtenus sur une période de courte durée, ils vont servir a alimenter la base de données pour la conservation de l'espèce dans la NAP de Maromizaha. Une étude approfondie effectuée pendant la période d'abondance fruitière serait nécessaire pour obtenir des données plus complètes sur cette espèce cathémérale.

Remerciements

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Anecdotal report on mouse lemur survival following forest fires in Ankarafantsika National Park

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Fires can cause severe ecological damage and negatively impact biodiversity by decreasing available habitat and via direct mortality (Fisher *et al.*, 2009). Fires are particularly concerning to forest-dwelling lemurs in Madagascar where the *tavy* system of slash and burn agriculture and the burning of savannah for zebu pasture are widely practiced across the island (Bloesch, 1999). These anthropogenic fires and subsequent habitat destruction are one of the major causes of lemur population declines (Schwitzer *et al.*, 2014). Anthropogenic fires, as opposed to naturally occurring fires, are particularly destructive as they often burn larger areas at greater intensity and can be exacerbated by poor fire management regimes and climate change (Wheelan, 1995). Despite the widespread destructive potential of fires, many organisms have developed defences to forest fires that mitigate their negative impact (Hoffmann *et al.*, 2003). Here we report on two cases in which we observed mouse lemurs (*Microcebus* spp.) inhabiting small forest fragments before and after large fires and suggest possible mechanisms for surviving fires in Ankarafantsika National Park.

Our research took place at Ambanjabe, a fragmented landscape of tropical dry forest fragments within the Ankarafantsika National Park approximately 10 km west of *Route Nationale #4*. Multiple large fires occur during the dry season in the savannah of Ambanjabe, with some fires occasionally penetrating the forest edge and altering plant structure. For this reason, fragments like those found across Ambanjabe, are particularly vulnerable (Steffens and Lehman, 2018). Large trees in the interior of fragments usually remain intact during these fires, although branches and leaves were often observed burnt 2-3m high. Smaller trees, seedlings, and saplings as well as undergrowth were often completely destroyed throughout the fragments (Fig. 1). Six species of lemur have been recorded at Ambanjabe, although only small nocturnal species are able to survive outside of the largest fragments (Steffens and Lehman, 2018).


Fig. 1: Image of F35 after a fire. All underbrush and small trees are burnt, but larger trees can be seen remaining with fire damage on the trunks and branches.

We studied lemur populations in the fragments of Ambanjabe from May to October 2017 and September to October 2018. We observed two large forest fires in 2017 and 2018 which entered and burnt certain fragments (Fig. 2). We previously had recorded the size of fragments using the area calculation function on a handheld Garmin GPS. After the fires occurred, we walked around the edge of unburnt areas with a GPS to calculate the area of forest remaining and to assess the damage done to the fragments. Areas were considered burnt if the undergrowth had been completely burnt and only ash was left on the ground. We surveyed for nocturnal lemurs in fragments using standard line-transect methods and we used baited Sherman traps to capture small nocturnal lemurs (See Radespiel *et al.*, 2003 and Steffens and Lehman, 2018 for general description of these methods).

In May 2017, we captured (and subsequently released after marking) a female gray mouse lemur (*M. murinus*) in a small forest fragment. In June 2017 a large fire burnt 100% of the surface area of this fragment (F44, Fig. 2). In September and October 2017, the same mouse lemur was recaptured. There were no obvious signs of injury and body weight remained consistent over this period.

In September of 2018 another large fire occurred in the Western portion of Ambanjabe and burnt large sections of three fragments (Fig. 3, F32: 95% surface area burnt, F33:

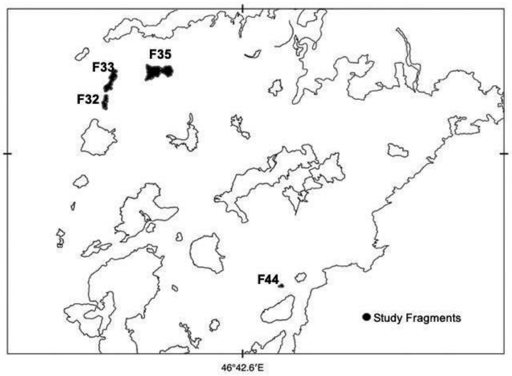

Fig. 2: Map of our study region Ambanjabe with the four fragments (F32, F33, F35, F44) impacted by the fires described.

100% surface area burnt, F35: 91% surface area burnt). While we did not capture mouse lemurs in F35, we observed several mouse lemurs on nocturnal surveys both before (n=2) and within one week following the fires (n=3). In F32 and F33 we observed mouse lemurs of an undetermined species (n=3) and captured gray mouse lemurs (n=3) within one week of the fire subsiding. In the captured animals there were no signs of injury.

These observations suggest that gray mouse lemurs in Ankarafantsika National Park may be relatively tolerant to habitat destruction via fires. While we cannot rule out that mouse lemurs fled fires to neighbouring forests and then returned, this is unlikely because the surrounding savannah matrix would also be burning at the same time as the fragment making it difficult to cross. Given the high amount (91-100%) of surface area burnt we observed, it is unclear how mouse lemurs survived in these fragments during fires although it is possible that the fire intensity is concentrated only at the ground level of the fragments and not in the trees where the mouse lemurs are primarily residing. Of the animals we identified, all (n=4) were gray mouse lemurs. Gray mouse lemurs are known to preferentially nest in the holes of large trees (Radespiel *et al.,* 2003). These large trees may provide a degree of protection from heat, smoke, and flames. Thus, mouse lemur habitat usage and preference for large trees, and the nesting cavities they provide, may be allowing for persistence in landscapes dominated by intermittent fires. If so, these large trees are of critical importance to the ability of mouse lemurs to survive forest fires and should therefore be prioritised for preservation.

In conclusion, at least some lemur species possess behavioural traits that allow them to withstand destructive forest fires. While it is difficult to determine exactly when forest fires will occur, we suggest further research should quantitatively measure the impacts of forest fires on lemur species across Madagascar.

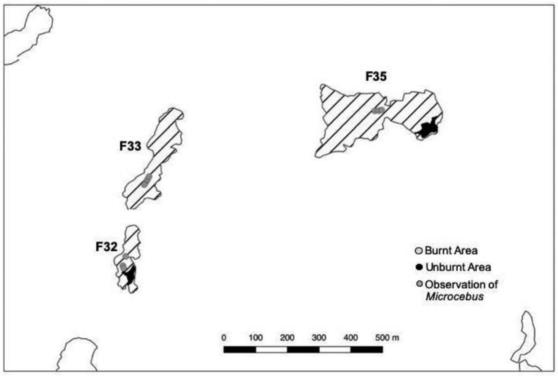

Fig. 3: Extent of the damage caused by one fire on a selection of fragments (F32, F33, F35). Fire damage is represented with diagonal lines, unburnt areas are displayed in black, and observations of mouse lemurs as gray dots.

Acknowledgements

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Etudes comparatives de la taille du domaine vital saisonnier d'*Hapalemur griseus griseus* dans la forêt de Maromizaha et les conséquences pour sa conservation

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Le domaine vital d'un animal est une aire de vie défendue qui suffit à répondre à ces besoins primaires (Burt, 1943; Powell, 2000). Au-delà de la dégradation par conversion de terre en champ de culture, le défrichement suivi de la culture sur brûlis ou «*Tavy*» et l'extraction des produits forestiers engendrant des perturbations qui diminue l'espace occupé par une espèce(Randrianarimanana *et al.,* 2012; Andrianandrasana *et al.,* 2013), les effets néfastes dus au changement climatique érodent les écosystèmes (Unesco, 1983; Spiral, 2012) et peuvent affecter l'habitat d'un animal.

Fig. 1: Femelle *H. g. griseus*

Hapalemur griseus griseus (Fig. 1) est classé comme Vulnérable par l'Union Internationale pour la Conservation de la Nature (Mittermeier *et al.,* 2010; UICN, 2014). Ce travail concerne l'étude du domaine vital de deux groupes d'*H. g. griseus* à l'état sauvage durant la saison humide et la saison sèche dans la forêt tropicale humide de Maromizaha (Fig. 2) en 2016.Chaque groupe était généralement formé par des adultes femelles et mâles, un juvénile et un petit. Déterminer la taille du domaine vital saisonnier d'*H. g. griseus* est l'objectif principal de cette étude afin d'identifier les facteurs écologiques déterminant la dynamique spatiale de l'animal selon la saisonnalité et le type d'habitat d'une part et de comprendre les conséquences pour sa conservation d'autre part. Pour cela, la méthode de d'observation focale (Altmann, 1974) a été utilisée en considérant les paramètres écologiques tels que la saisonnalité, la disponibilité des ressources naturelles et notamment alimentaires, afin de mieux analyser la potentielle relation des individus avec leur domaine vital. A cet effet, nous avons suivi au total deux groupes avec six jours d'observation pour chaque groupe (trois jours pour chaque adulte femelles et mâles). Au total, nous avons collectées 1346.25heures au suivi d'*H. g. griseus*. En outre, les coordonnées géographiques des observations directes, en vue de la délimitation la taille du domaine vital de chaque groupe ont été collectées. Avec le logiciel ArcGIS version 9.3, nous avons réalisé des cartes de la zone d'étude et de la distribution spatiale saisonnière des deux groupes étudiés d'*H. g. griseus*. Nous avons utilisé deux méthodes pour estimer la taille du domaine vital d'*H. g. griseus*: la première qui consiste à créer le plus petit polygone convexe englobant la totalité des localisations de l'animal focal est le Minimum Convex Polygon notée «MCP» (Mohr, 1947; Southwood, 1996) et la deuxième est la Densité de Kernel Estimator notée «DKE» (Worton, 1989). Cette dernière permet de mettre en évidence l'hétérogénéité des activités des animaux au sein de ses domaines vitaux. Pour définir les contours du domaine vital via la fonction kernel, nous avons choisi deux seuils critiques: un seuil de 95%, habituellement utilisé pour estimer la taille du domaine vital général et un seuil de 50%, utilisé pour estimer le centre ou le cœur du domaine vital. Le centre du domaine vital est donc défini fonctionnellement comme une zone d'occupation maximale, où l'espèce étudiée concentre l'essentiel de leur activité (Powell, 2000). Nous avons pu produire une carte des mouvements d'*H. g. griseus* et de leur habitat. En effet, la représentation s'appuie sur une échelle de couleurs allant du rouge au vert (échelle chaud-froid) pour l'affichage de la zone d'occupation. La couleur rouge correspond à la zone la plus fréquentée ou la zone d'occupation permanente. Elle est définie comme une zone réservée au cœur du domaine vital. La couleur jaune-verte correspond à une zone moins fréquentée ou la zone d'occurrence.

En utilisant la méthode du Polygone Convex Minimum de 100% (Mohr, 1947), le test de Wilcoxon (Z=-3.87, *P=0.018*, n=2) montre que la taille du domaine vital saisonnier des deux groupes étudiés varie en fonction de la saison. Elle est respectivement 8.61±0.58ha (±ES, n=2) pendant la saison humide et 12.48±0.26ha (±ES, n=2) pendant la saison sèche. De même, la taille du domaine vital des animaux étudiés varie également selon le type d'habitat (Z=-2.41, *P=0.031*, n=2), elle est de l'ordre de 9.43±0.20ha (±ES, n=2) au niveau des vallées et 11.84±0.88ha (±ES, n=2) au versant.

S'agissant du domaine vital des deux groupes étudiés d'*H. g. griseus* dans la forêt tropicale humide de Maromizaha, l'analyse spatiale de la taille du domaine vital saisonnier en utilisant l'Estimateur de Densité de Kernel (Worton, 1989) de 95 et de 50% de ces deux groupes montre qu'ils occupent une superficie apparemment différente entre les deux saisons. Cette différence est statistiquement significative (*Z*=-2.125; *P=0.004*, n=2). Le domaine vital des

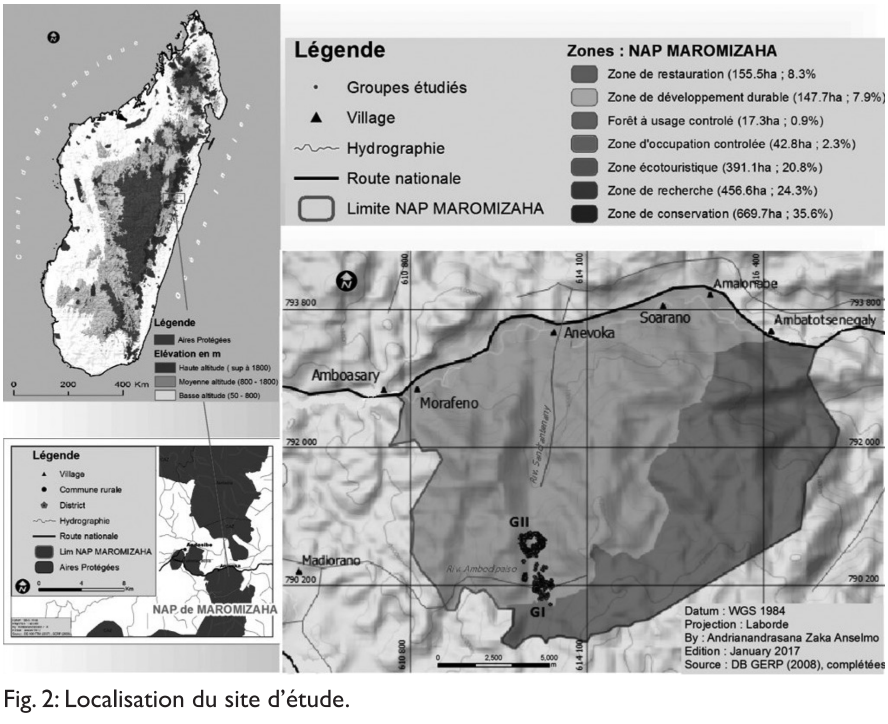

Fig. 2: Localisation du site d'étude.

individus étudiés est plus grand pendant la saison sèche que la saison humide. Il est respectivement de 4.78±0.73ha (±ES, n=2) et 2.93±0.17ha (±ES,n=2) pour le groupe I et celui de *Z*=-1.849; *P=0.013*; n=2, il est 5.70±0.40ha (±ES,n=2) et 3.58±0.63ha (±ES, n=2) pour le groupe II. Cette différence est potentiellement due à la disponibilité alimentaire dans la forêt tropicale humide de Maromizaha. En outre, durant cette étude, une corrélation entre la taille du domaine vital d'*H. g. griseus* et la disponibilité alimentaire qui est estimée par rapport à la fréquence générale de consommation des plantes sources de nourriture apparaît (r_s=0.995, *P<0.0001*, n=4). Pendant la saison humide et sèche, ces fréquences de consommation sont respectivement 53.91 et 46.09% pour le groupe I tandis que 54.45 et 45.55% pour le groupe II. Par ailleurs, cette disponibilité alimentaire en fonction du type d'habitat (vallée-versant) est de l'ordre de 14.06 et 85.94% pour le groupe I ainsi que 35.9 et 64.04% pour le groupe II.

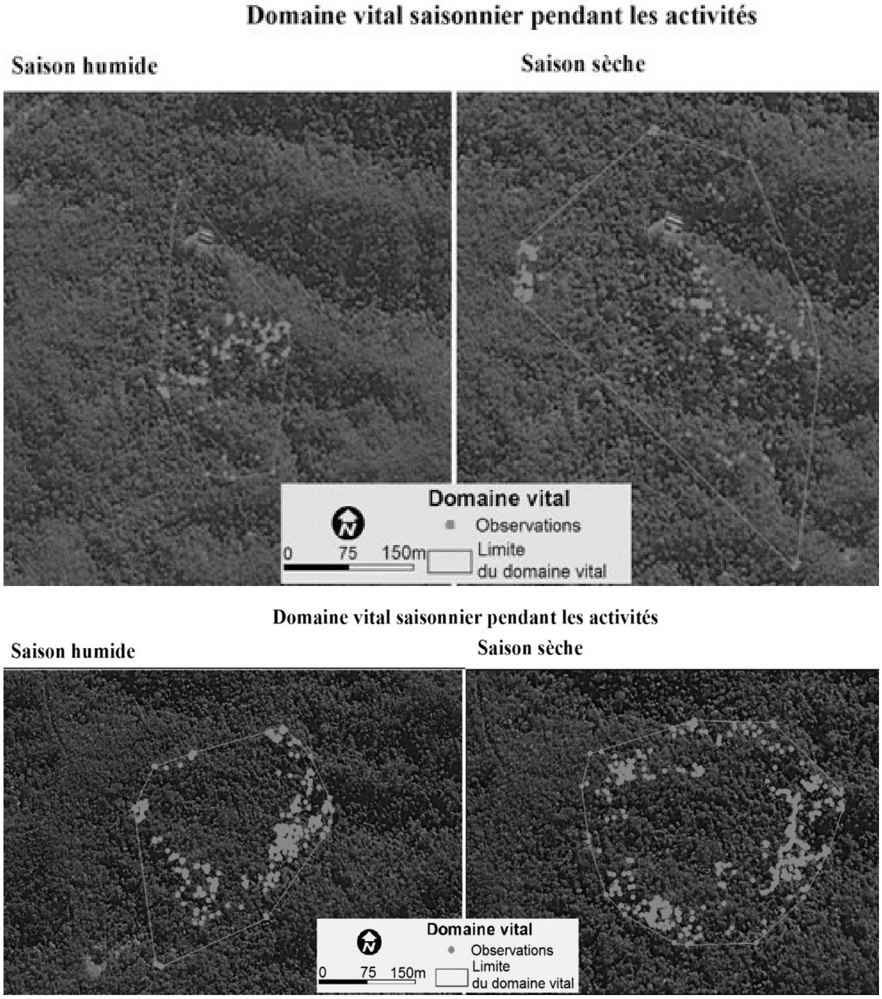

Fig. 3: Représentation du domaine vital saisonnier des groupes par Polygone Convex Minimum; a: groupe I, b: groupe II.

Par conséquent, les individus étudiés ne paraissent pas se déplacer beaucoup pendant la saison humide (Fig. 3). Durant le suivi, les deux groupes de *H. g. griseus* suivi se trouve fréquemment dans un même endroit qui constitue alors le cœur ou le centre de son domaine vital dont il représente sa zone d'occupation permanente, là où ses besoins sont potentiellement satisfaits. Du fait de la topographie accidentée et pentue de la forêt tropicale humide de Maromizaha, cette dernière présente des vallées assez étroites où l'animal est souvent rencontré au versant. Par ailleurs, l'étude de la structure spatio-temporelle du domaine vital d'*H.g.griseus* a permis d'identifier ses zones d'activité plus intense.

Deux zones bien distinctes ont été observées. La première, qui est la zone la plus fréquentée par *H.g. griseus* est appelée cœur du domaine vital (ou encore centre du domaine vital). Elle est considérée comme sa zone d'occupation permanente; c'est une zone prioritaire pour la conservation des individus, et qui nécessite une surveillance permanente et une protection stricte. En outre, elle présente également un intérêt de conservation pour le gestionnaire de la forêt d'autre part. La deuxième, qui est la zone la moins fréquentée n'est qu'une zone d'occurrence, où l'animal se retrouve plus rarement que dans le cœur de son domaine vital.

L'estimation sur la taille du domaine vital d'*H. g. griseus* par la fonction Kernel est considérablement précise parce qu'elle montre les zones fréquemment occupées et exclut les zones qui ne sont pas exploitées par l'animal. Ces derniers sont également considérés comme des habitats refuges d'*H. g. griseus* lors d'une perturbation (Andrianandrasana *et al.,* 2018). Une question découle de notre étude: est-ce que la population reste encore viable, si sa zone d'occupation permanente est isolée, ou si les zones aux alentours de celle-ci sont exploitées? Faces aux menaces majeures qui pèsent sur la biodiversité de l'île, Ganzhorn *et al.* (2000) dans leurs travaux sur les lémuriens de Madagascar ont évoqué que les fragments de forêts restant sont parfois trop petits pour maintenir des populations viables, ce qui entraîne la disparition de la biodiversité. Dans ce sens, en raison de la dégradation de la forêt sèche de l'ouest et de la forêt littorale de l'est, si le taux actuel de perte d'habitat n'est pas interrompu, les fragments restants ne pourront pas maintenir des populations viables d'ici 2040 (Ganzhorn *et al.,* 2001).

En conclusion, pour identifier une zone occupée par *H. g. griseus* dans la forêt tropicale humide de Maromizaha ou dans d'autres parcs, le Polygon Convex Minimum démontre le zonage global. Mais, un aménagement passant par cette zone, une installation des circuits écotouristiques, une translocation ou une introduction de l'espèce seraient envisagé nécessite une analyse Kernel, afin de déterminer exactement le cœur ou le centre du domaine vital qui est définit par le noyau Kernel et qui demande une surveillance permanente ainsi qu'une protection stricte. La méthode d'Estimation de la Densité de Kernel apporte donc une information complémentaire à celle du Polygon Convex Minimum en déterminant les zones préférentiellement fréquentées par *H. g. griseus* dans son habitat et est

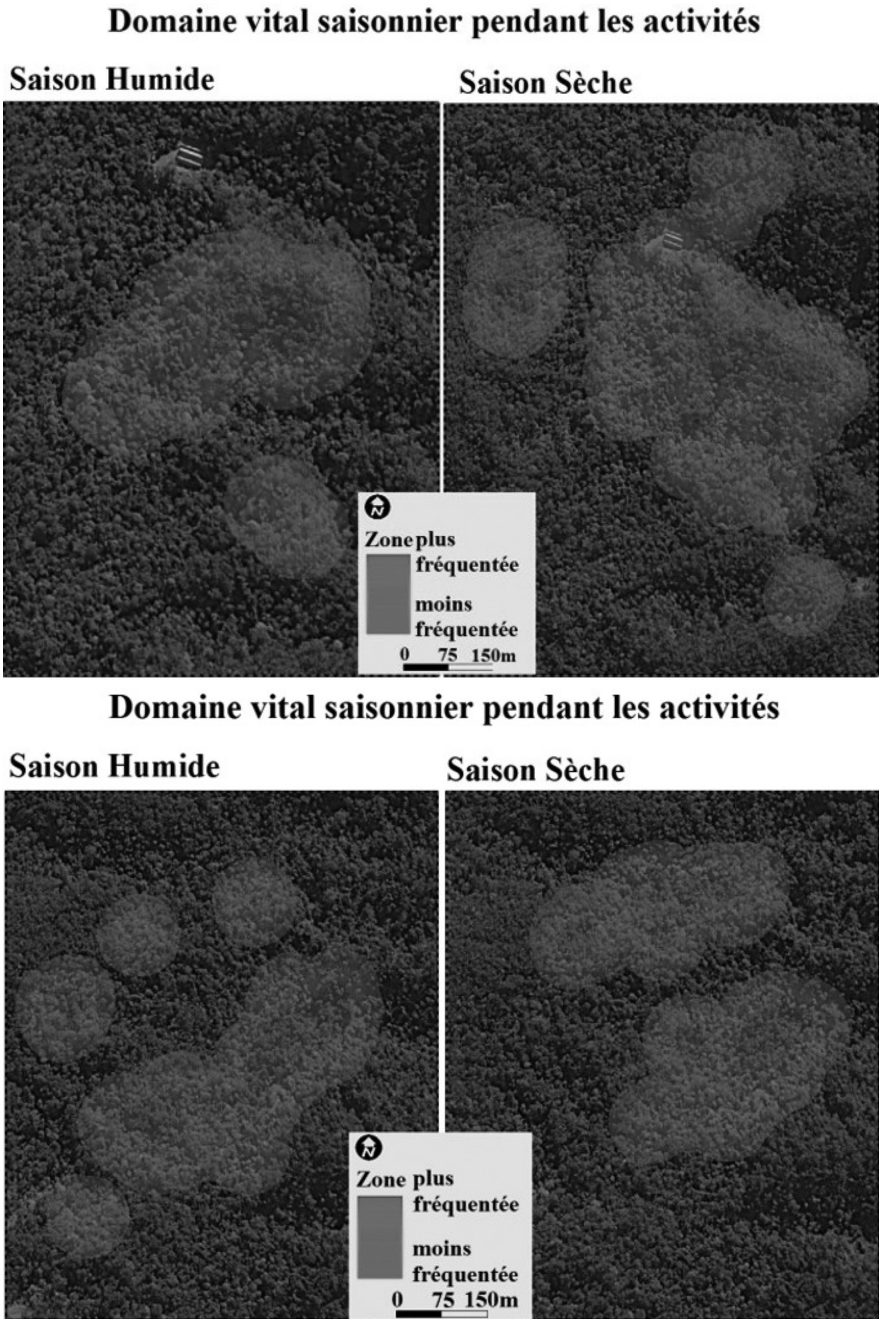

Fig. 4: Domaine vital saisonnier du groupe I en utilisant la méthode de l'Estimation de la Densité de Kernel; a: au niveau des vallées, b: au versant.

aussi un outil potentiel pour faire une meilleure estimation des aires occupées. En outre, ces résultats obtenus par le traitement SIG constitue un outil incontournable à la gestion des données spatio-temporelles concernant les domaines vitaux d'*H. g. griseus* de Maromizaha, d'aide à la prise de décision pour les gestionnaires de la forêt ainsi que pour les acteurs de la conservation.

H.g. griseus classé Vulnérable selon l'Union Internationale pour la Conservation de la Nature mérite d'être protégé et conservé à l'état sauvage en collaboration avec des communautés locales, des acteurs de la conservation, des gestionnaires des ressources naturelles. La diminution de la zone d'occupation et de la zone d'occurrence d'*H. g. griseus* et des autres lémuriens reste un débat pour les acteurs de la conservation tels que les chercheurs, afin de diminuer au moins les pressions d'origine anthropique qui pèsent sur leur survie.

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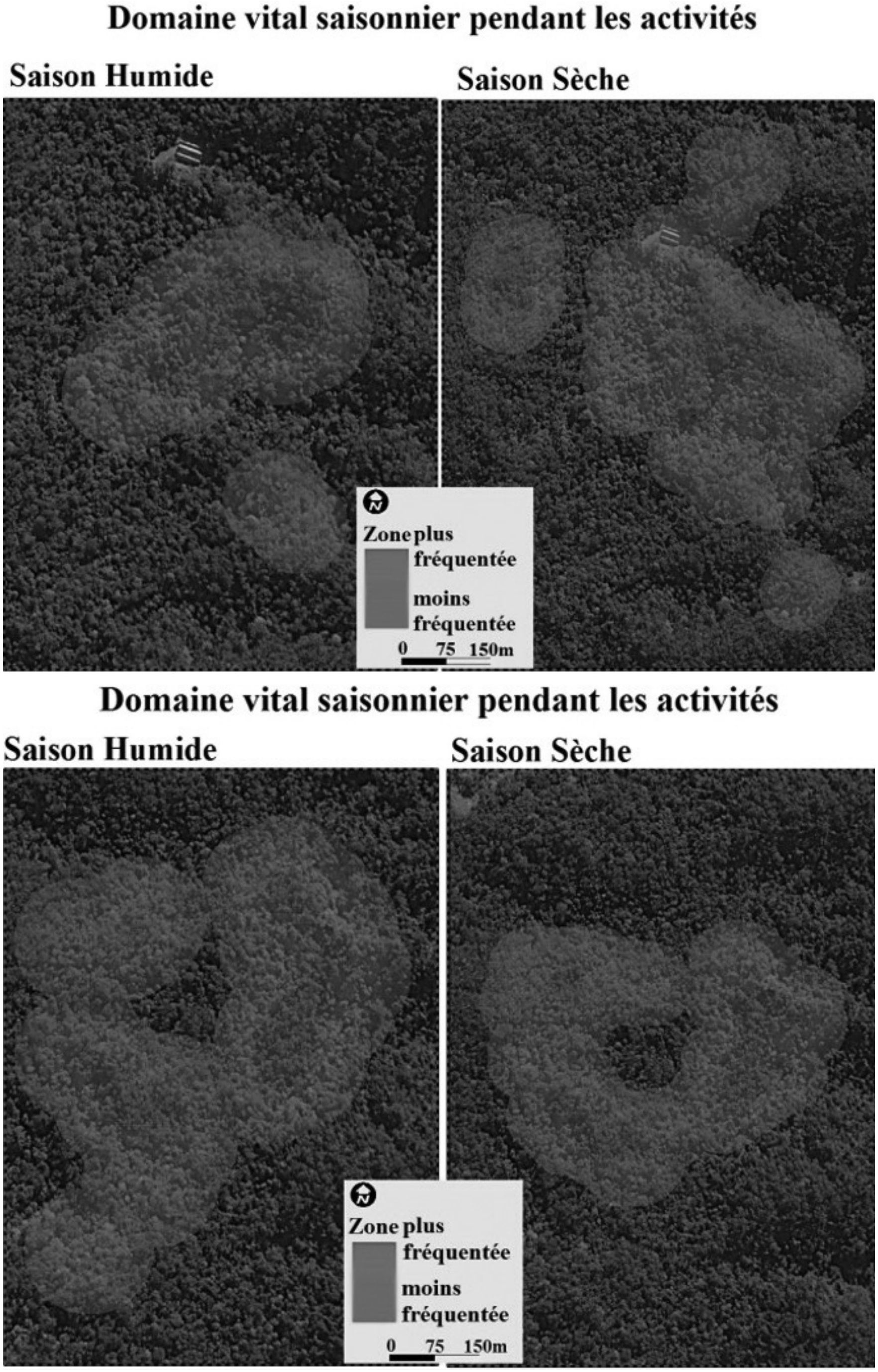

Fig. 5: Domaine vital saisonnier du groupe II par en utilisant la méthode de l'Estimation de la Densité de Kernel; a: au niveau des vallées, b: au versant.

Observations on the mating behavior of *Mirza coquereli* in Kirindy Forest, Western Madagascar

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Direct observations of sexual iteractions among nocturnal solitary lemurs in the wild are not only difficult because of the practical challenges of observing small, arboreal animals at night, but also because female receptivity is often limited to a single night of the year (Rasmussen, 1985; Sterling, 1994; Andrès and Solignac, 2003; Randrianambinina *et al.*, 2003; Kappeler, 2012). As a result, most of our knowledge on mating behavior and reproduction in cheirogaleids, which represent the best-studied nocturnal lemurs, is derived from a few field studies of *Microcebus* (e.g. Fietz, 1999; Fietz *et al.* 2000; Radespiel, 2000; Eberle and Kappeler, 2004a,b; Schülke *et al.*, 2004; Blanco, 2015) and studies of captive populations (e.g. Petter-Rousseaux, 1980; Foerg, 1982; Perret, 1992; Stanger *et al*., 1995; Andrès *et al*., 2003; Eberle *et al*., 2007). These studies confirmed the pronounced seasonal pattern of reproduction, the short duration of oestrus and either monogamous or promiscuous mating patterns.

The mating system of Coquerel's giant dwarf lemur (*Mirza coquereli*), was studied by Kappeler (1997a; 2002) in Kirindy Forest and is best described as scramble competition polygyny. These studies revealed that social interactions between males and females are rare outside the mating season, and that males increase their home range size during this period, presumably to obtain access to more females despite the associated potential costs (see Kraus *et al*., 2008). The annual mating season in Coquerel's giant dwarf lemur seems to be restricted to a few weeks between September and November during which oestrus of individual females is limited to a few hours of a single night (Stanger *et al*., 1995). Although mixed paternities revealed polyandrous mating behavior in females (Kappeler *et al*., 2002), no direct field observations of female mating behavior have been published. Below, we offer the first description of an observation of an oestrous female wild Coquerel's giant dwarf lemur.

The observations were made by MM on the 18 October 2006 in Kirindy Forest. All observations were recorded on a mobile voice recorder. During the location of nesting sites of radio-collared individuals on the morning of October 18, an individually marked male (Male 1) was observed sitting on top of a nest occupied by a known female at 10:38h and subsequently tried to enter it. Subsequently, the female left her nest and entered another one about 100m away. The male rapidly locomoted from one tree to another, only interrupted by effusive scent marking behavior, and visited at least three different nests in the area without entering them. The male subsequently entered a tree hole in approximately 2m height at 11:47h.

This unusual observation of Coquerel's giant dwarf lemur activity in broad daylight and the fact that the female in question had a distinctly swollen, reddish but closed vulva when captured 11 days earlier indicated that the female was close to oestrus. Both individuals were relocated in the late afternoon of the same day. The male was found awake on a tree approximately 75m away from the female's sleeping place at 18:03h. The female emerged from her nest at 18:07h and engaged in self-grooming. A few minutes after the female left her nest, MM heard a call that was described as "sexual call sequence" by Pages (1980) or as "trill" or "advertisement call" by Stanger (1993, 1995). This call starts with a downward modulated pulse ("zek"), followed by a rapid succession of up and down frequency modulations (Fig. 1).

It took MM 2-3 minutes to relocate the calling female visually. Upon locating her, she was found copulating, and the mating continued for another 2 minutes. Throughout mating, the female was hanging on a branch with her back facing towards the ground. The male was clutching the female so that the female seemed to hold the weight of both (Fig. 2) during mating.

After separation the male groomed himself for about 5 minutes 2m further down on the same tree (18:41h). Subsequently, the male groomed the female for about 25 minutes (Fig. 3); first on the head and neck, and later other parts of the body, including the anogenital region. Grooming was not reciprocated by the female. At 19:08h, the female struck the male twice and moved away. The male followed her, and 3 minutes later, they were observed mating once again. However, no further details of the mating itself could be observed due to the dense vegetation. Over the next couple of minutes, MM had no visual contact to the female but heard two more of the calls mentioned above. Male 1 was again observed following the oestrous female at 19:34h.

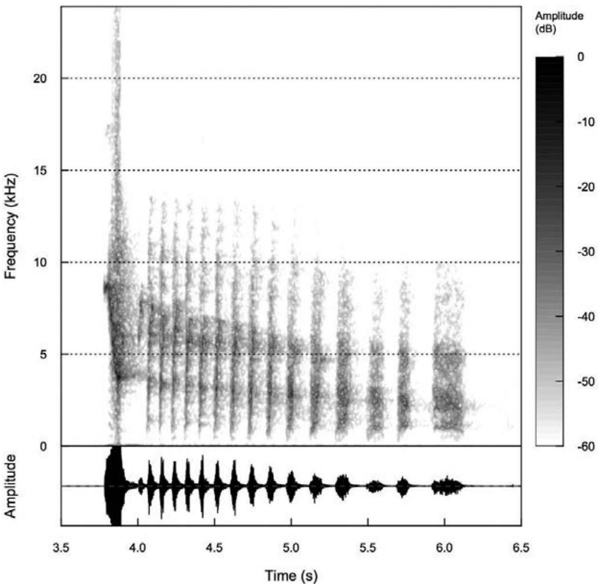

Fig. 1: Spectrogram of "advertisement call" of Coquerel's giant dwarf lemur (*Mirza coquereli*).

At 19:49h, the female was observed mating with another unmarked male (Male 2) at about 8 m for approximately 3 minutes (Fig. 4). As previously, Male 2 groomed the female afterwards, but only for about 5 minutes. The male tried to maintain proximity to the female by pulling her tail. After she managed to escape, Male 2 tried to follow her. However, yet another, rather small unmarked male (Male 3) appeared and produced an advertisement call. The female responded with the same call type and they approached each other. Before they managed to copulate, an unmarked male (presumably Male 2) interfered and chased Male 3 away. At 20:12h, the female was observed mating with an unmarked and unidentified male.

After approximately 4 minutes of mating, the male also groomed the female for a couple of minutes. At 20:19h, an unmarked male (presumably the same) approached the female, which escaped. This male continued to follow the female, which allowed the male to groom her again shortly thereafter, but she rejected another mating. At 20:43h, a large unmarked male was also rejected by the female, which escaped thereafter. The female was observed to feed at another location at 21:11h. An unmarked male was within 10m of the female and subsequently tried to mount her,

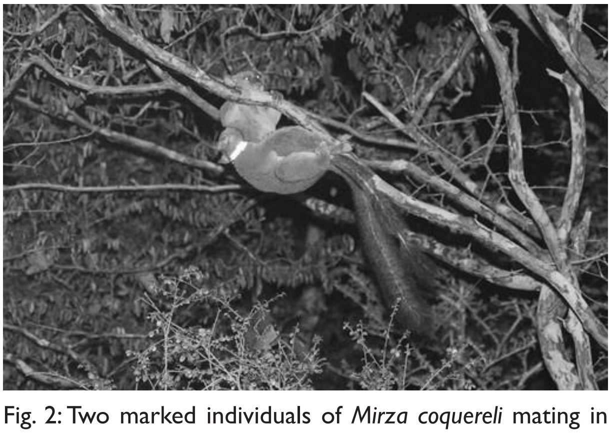

Fig. 2: Two marked individuals of *Mirza coquereli* mating in Kirindy Forest.

Fig. 3: The male grooming the female for 25 minutes after mating.

Fig. 4: The same female mating with an unmarked male.

but she hit and rejected the male. This male kept a distance of about 2m to the female and wagged his tail, while facing away from her. The female left and continued to forage but emitted three more advertisement calls at different localities within the following 25 minutes without any sign of a potential mating partner or event. The female was still observed foraging at 22:00h.

On October 31, another female with an open vagina was located while being groomed by a male but no mating behavior was observed. During this and the previous night, aggressive interactions between males were observed, which ended two times in at least one of the males falling from a tree. The oestrous female was also observed being aggressive to her sub-adult female offspring during previous nights.

Although this report provides a qualitative description based upon observations of a single oestrous female, they advance our knowledge of mating behavior of Coquerel's giant dwarf lemur and other cheirogaleids. At least one male was present near the oestrous female long before the onset of the night, indicating that he seemed to be aware of the reproductive status of the female without direct vocal advertisement of her reproductive status. Thus, female Coquerel's giant dwarf lemurs are presumably signaling changes in their reproductive status via olfactory communication to potential mating partners as suggested by Stanger *et al.* (1995) in captivity. Increased female olfactory communication behavior via urine markings during the period of oestrus has also been reported in grey mouse lemurs in captivity (Buesching *et al.*, 1998).

The observed female mated with 2-5 different males within approximately two hours and rejected additional mating attempts of at least two different males afterwards. Unfortunately, the exact number of males could not be determined as only one male was individually marked. However, one male could be clearly distinguished by his small size from the others. This male was chased away by a larger unmarked male just after mounting the female. Four matings could be directly observed, but it is possible that two to three more matings occurred during periods without visual contact with the female. The female mated at least two times with the first male. This male showed mate guarding behavior between the two mating events by following and extensively grooming the female. This male also showed pre-copulatory mate guarding behavior by staying in proximity to the female already during the day. Similar patterns of repeated matings with the same male and fights among males during mate guarding have also been reported for wild grey mouse lemurs in Kirindy forest (Eberle and Kappeler, 2004a,b). Male grey mouse lemurs were occasionally observed to wait at the sleeping site of an oestrous female before dusk as described here for one of the males (Radespiel *et al.,* 2000, Eberle and Kappeler 2004a).

Previous studies in captivity also reported that Coquerel's giant dwarf lemurs and others cheirogaleids (e.g. grey mouse lemurs, Buesching *et al.*, 1998) emit characteristic oestrus advertisement calls (Pages, 1978, 1980; Stanger *et al.*, 1993, 1995), and Kappeler (1997a,b) suggested that these calls may reflect the interest of females to attract more than one male. However, the study of Stanger *et al.* (1993, 1995) was conducted on captive individuals of northern giant mouse lemurs (*Mirza zaza*: Kappeler *et al.*, 2005) from northern Madagascar. The observations described here therefore represent the first evidence of the use of vocalizations in the mating context in wild Coquerel's giant dwarf lemurs. The locations of the female during the observations reported here were restricted to an area of less than 1.75ha. This area is considerably smaller than the average size of the home range of a female in October (Kappeler, 1997a), suggesting that females might call and wait for mates. However, it is unclear whether the call is really and exclusively used to attract mates.

Increased aggressive or affiliative social interactions between the sexes during the mating season in Kirindy could also explain increased usage of this particular call during this time of the year. Unfortunately, behavioural observations of this species are still relatively limited, and vocalizations are generally difficult to be reliably assigned to a specific individual or behavior in nocturnal lemurs. This type of call was recognized several times in northern parts of the island during various surveys of MM at different times of the year. In Sahalamaza and Ambato in October 2007, in Beanka in August 2010, in the Town of Ambanja and in the Reserve Speciale de Manongarivo in October 2011. With the exception of Beanka all these sites are today known to be occupied by northern giant mouse lemurs, which seems to be generally more vocal than Coquerel's giant dwarf lemurs (Dammhahn *et al.*, 2013).

In contrast to Coquerel's giant dwarf lemurs, northern giant mouse lemurs show aseasonal reproduction (Stanger *et al.* 1995; Kappeler *et al.*, 2005), and females share sleeping sites with unrelated males (Rode-Margono *et al.*, 2015). Rode (2010) observed the same couple of northern giant mouse lemurs in Ankarafa Forest mating three times during different nights in June. No details of the mating could be observed and only quiet "Hn" calls ("Hon" after Stanger *et al.*, 1993) were associated with these mating events. Given the differences in social organization and reproduction between Coquerel's giant dwarf lemurs and northern giant mouse lemurs, the above mentioned "advertisement call" might therefore have different functions in both species.

These differences in social behavior and reproduction between the two *Mirza* species underline the variability in social organization and behavior among closely related cheirogaleids (Schülke and Ostner, 2005) and highlight the still limited knowledge about the biology of most of the 32 species of Cheirogaleidae. The observations confirm previous suggestions that mate competition in Coquerel's giant dwarf lemurs is mainly of the scramble type, but observations also revealed the presence of aggressive interactions between males and (precopulatory) mate guarding behavior. The observations presented in this article may therefore hopefully stimulate additional research on the social systems of giant mouse lemurs.

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Tombeau Royale de la forêt d'Anora: Un refuge potentiel pour les *Lemur catta*

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Lemur catta était representé dans la liste des 25 primates les plus menacés de 2016-2018 (Schwitzer *et al.,* 2017), et se retrouve dans une zone limitée au sud et sud-ouest de Madagascar (Goodman *et al.*, 2006). Cette espèce est l'un des rares lémuriens diurnes appréciant cette région aride et vit dans le tapis végétal continu composé de hauts tamariniers (*Tamarindus indica*) (Sussman et Rakotozafy, 1994). Elle y joue un rôle primordial dans la dissémination des espèces végétales (Mertl-Millhollen *et al.,* 2011).

Sur la route national numéro 7 vers le sud, la zone où *Lemur catta* est le plus facilement observable est la Reserve Communautaire d'Anja (Gould et Andrianomena, 2015). Au nord-ouest de cette réserve se trouve une forêt fragmentée appelée Anora (Fokontany Anora, Commune Iarintsena, District Ambalavao). Anora est gérée par le VOI FIMIVA (gestionnaire du reliquat forestier d'Anora), et est susceptible d'abriter des lémuriens (Fig. 1).

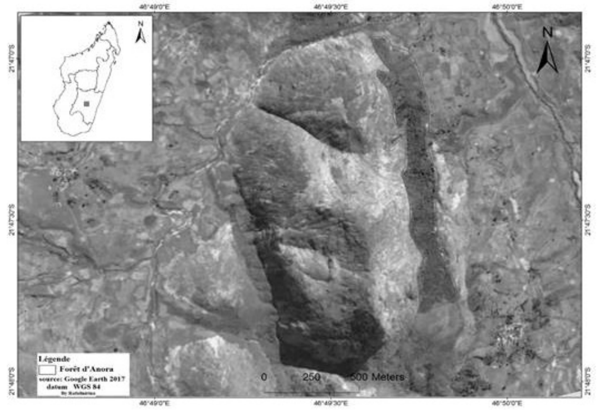

Fig. 1: Carte de localisation du fragment forêstier d'Anora (source: Google Earth 2017).

Durant le mois de décembre 2017, nous avons, avec l'aide financière de Mikea Lodge, effectué un inventaire rapide de la faune et de la flore d'Anora. Nous avons appliqué la méthode d'inventaire avec comptage directe des espèces sur une ligne transect de 2km (Fig. 2).

Fig. 2: Mise en place de la ligne transect.

D'après nos résultats, le site d'Anora abrite à la fois des espèces végétales caractéristiques de la forêt de l'est (*Phyllarthron madagascariensis*, *Tambourissa thouvenotii*, *Weinmannia rutembergii*), et des espèces caractéristiques des fourrés xérophytiques du sud-ouest malgache (*Euphorbia oncoclada*, *Pachypodium* sp, *Xerophyta* sp, *Aloe* sp, *Calanchoe* sp). Nous avons pu identifier 32 espèces d'arbre. Du point de vue de la faune, la forêt héberge 27 espèces d'ornitho faunes avec encore une fois beaucoup d'espèces d'oiseaux typiquement forestiers tels que *Copsychus albospecularis*, *Otus rutilus* et *Monticola sharpei*, 11 espèces d'herpeto faunes, deux espèces de micromammifères et une espèce de carnivores. Ainsi, on a constaté une richesse spécifique très important dans ce site.

Fig. 3: Des individus de *Lemur catta*.

Quant aux espèces des lémuriens, la forêt d'Anora abrite une seule espèce diurne: le *Lemur catta* (Fig. 3). On en compte une trentaine d'individus, qui se subdivisent en 3 groupes.

Malgré la taille de la forêt d'une superficie de 100 ha, le VOI FIMIVA est optimiste sur l'avenir de ce fragment forestier et la biodiversité qu'il contient. A environ 30min seulement en voiture de la ville d'Ambalavao, la diversité du paysage (chaine de montagne, champ de culture typique de l'ethnie Betsileo) et sa diversité faunique font du site d'Anora une attraction écotouristique exceptionnelle. En plus de cela, le reliquat forestier d'Anora possède une valeur culturelle importante, notamment due aux vestiges d'un tombeau royal (Fig. 4). Le respect des valeurs spirituelles et culturelles de ce vestige par l'ethnie Bara Bory locale pourrait être un atout pour la préservation de la biodiversité d'Anora.

Fig. 4: Tombeau royale (Tranomena), les *Lemur catta* dorment à l'intérieur.

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Observation of the natural re-colonisation of a littoral forest fragment by the Endangered red-collared brown lemur (*Eulemur collaris*) in southeast Madagascar

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Keywords: conservation, habitat loss, hunting, migration, primate, Sainte Luce

Abstract

The biologically rich littoral forests of Sainte Luce support an isolated sub-population of Endangered red-collared brown lemur (*Eulemur collaris*). The area encompasses 17 disconnected forest fragments, separated by a matrix of ericaceous heath, grasslands, swamps and watercourses. Since the earliest faunal studies in the late 1980s, this species has only been recorded within four forest patches. We detail this lemur's recent re-colonisation of a protected fragment and consider its broader implications for future conservation initiatives. This observation highlights the value of small, seemingly unimportant patches of forest and the importance of maintaining functional habitat connectivity. Our observations also provide insight into the conditions that likely led to the current distribution of this species in Sainte Luce.

Introduction

Habitat loss and fragmentation are widely recognised as the main threat to the survival of lemurs (Ganzhorn *et al.*, 2001; Schwitzer *et al.*, 2014), and indeed to that of primates worldwide (Estrada *et al.*, 2017). The littoral forests of Madagascar represent one of the island's most impacted and threatened ecosystems, and the remaining habitat is severely fragmented and limited in extent (de Gouvenain and Silander, 2003; Bollen and Donati, 2006; Consiglio *et al.*, 2006). Despite this, these forests support an exceptional biodiversity (Lewis Environmental Consultants, 1992; Dumetz, 1999). The Sainte Luce littoral forest comprises 17 disconnected fragments (Fig. 1), which have been in there current arrangement since at least the 1950s (Green and Sussman, 1990). Recent studies indicate the area has had a highly dynamic history (Burney *et al.*, 2004; Virah-Sawmy, 2009; Bertoncini *et al.*, 2017) and the initial break up of continuous forest likely occurred centuries ago.

The resulting genetic bottlenecking and increased risk from inbreeding depression is a serious concern in Sainte Luce, with the sub-population of red-collared brown lemur (*Eulemur collaris*) (Fig. 2) exhibiting very low levels of genetic diversity (Bertoncini *et al.*, 2017). The species' absence from several major fragments calls into question the underlying cause of its current distributional pattern and threshold dispersal capabilities. The earliest faunal studies conducted in Sainte Luce show that for the past few decades at least, this species inhabited only four of the seventeen fragments (Lewis Environmental Consultants, 1992). However, anecdotal evidence from community elders indicates that several currently uninhabited fragments supported this lemur until as recently as three decades ago (L.S. Johnarson pers. comm.).

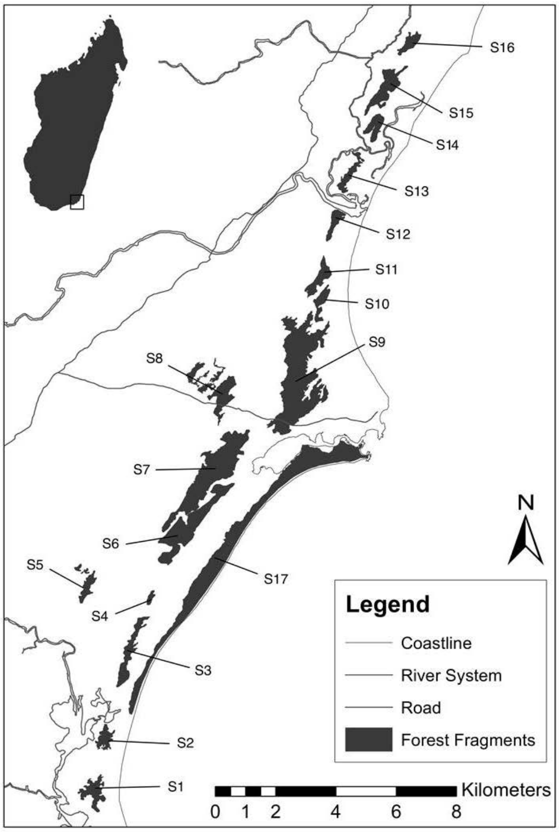

Fig. 1: The littoral forest fragments of Sainte Luce; *Eulemur collaris* groups now inhabit the forest fragments S1, S2, S8, S9, S12* and S17. The authors report a group within the S12 fragment here for the first time.

A series of observations made in one such fragment (S8) provides evidence of a recent re-colonisation event. We observed three adult lemurs (one male, two females) in the southern parcel of S8, on the 07 April 2017 at 09.30am (GPS: UTM-38J 717337.45 E; 7257904.68 S). Local forest police made a second observation of the group, now with an additional four babies (two males, two females), crossing between the southern and the northern sections of the fragment (GPS: UTM-38J 717534.49 E; 7258223.93 S) at 10.05am on the 15 April 2018. Finally, ONG SEED Madagascar researchers observed three adults of undetermined sex and a single juvenile at 10.00am on 06 November 2018. The group was seen crossing 50m of open matrix between this fragment's northern portion and a satellite remnant located to the northwest (GPS: UTM-38J 717263.00 E; 7258708.00 S). It is unclear if the missing lemurs were merely out of sight, if the group had split, or perhaps had not survived. Although the group has travelled extensively throughout the fragment, it has remained in the forest for over 18 months.

This natural re-colonization event represents a significant development for the Sainte Luce sub-population, with the species, an important seed disperser (Bollen and Donati, 2006), now inhabiting each of the five newly protected forest fragments. According to a dozen local guides and elders from the nearby village of Ambandrika, these lemurs disappeared from S8 between 1970 and the late 1980s. Assuming this is the first dispersal event between the fragments in recent times, this observation roughly matches with genetic data concluding that such events occur once every three to four generations (Bertoncini *et al.*, 2017; Andriaholinirina *et al.*, 2018).

The origin of the migrant group can be traced to the nearby fragment of S9, where one of the observed adult females was fitted with a collar during a 2011 study (Campera *et al.*, 2014). Our observations provide insight into the dispersal capacity of the species: the two fragments are currently 1.4km apart at the closest point, with the vast majority of the distance dominated by open savannah habitat. While this lemur is known to use open ground for travel and foraging (Donati *et al.*, 2007a, 2011), the causal factor behind this long-distance migration is unknown.

This observation has wider implications for nationwide conservation strategy planning. *Eulemur* species are widespread in Madagascar, occupying almost all forested areas (Mittermeier *et al.*, 2010). It is plausible that other *Eulemur* species, experiencing a similar array of threats, including habitat loss and fragmentation (Schwitzer *et al.*, 2013), have similar dispersal capabilities. Furthermore, this observation highlights the value of small, seemingly unimportant patches of forest, to act as stepping-stones, and underlines the importance of conserving and maintaining functional habitat connectivity.

Red-collared brown lemurs face significant conservation challenges in Sainte Luce and the prospect of genetic bottlenecking and inbreeding constitutes a considerable long-term threat (Ranaivoarisoa *et al.*, 2010; Brenneman *et al.*, 2012). The sub-population already shows the genetic signature of restricted gene flow (Bertoncini *et al.*, 2017), confirming that although the species is less vulnerable to forest fragmentation than other strictly arboreal lemurs, long-distance migration is rare.

The historic disappearance of red-collared brown lemurs across Sainte Luce is locally attributed to hunting (M. Aimé pers. comm.). In recent times, hunting has greatly impacted this species in other nearby forests (Ralison, 2001; Donati *et al.*, 2007b), and is cited as a major contributor to the species overall decline (Andriaholinirina *et al.*, 2018). Given the testimony of village elders, the impact of hunting on proximal lemur populations and their dispersal capability, we conclude that historic hunting pressure is the most parsimonious explanation for the current distribution of red-collared brown lemurs in Sainte Luce.

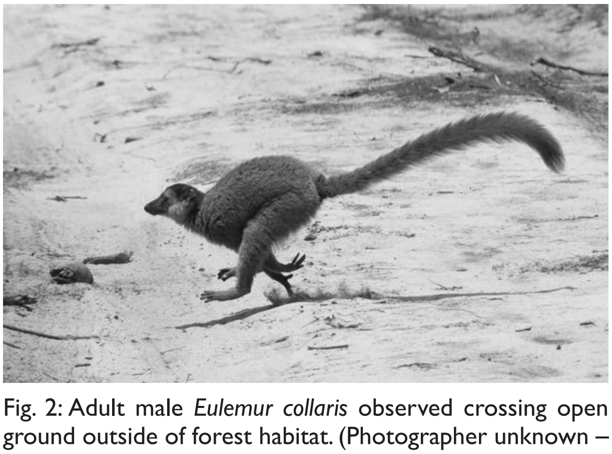

Fig. 2: Adult male *Eulemur collaris* observed crossing open ground outside of forest habitat. (Photographer unknown – photo credit ONG SEED Madagascar).

In addition, the proposed mining plan of QMM (a Rio Tinto subsidiary; Vincelette *et al.*, 2003; Temple *et al.*, 2012) to clear many of the smaller forest fragments and connecting habitats may further limit future dispersal opportunities. Whilst this natural re-colonization event demonstrates that red-collared brown lemurs, and perhaps other *Eulemur* species, have the capacity to disperse across relatively large distances and utilise highly fragmented landscapes, such migrations appear uncommon. Well-designed habitat management and restoration projects should take into account this inherent dispersal capability, to facilitate migration and gene flow within lemurid populations.

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

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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-

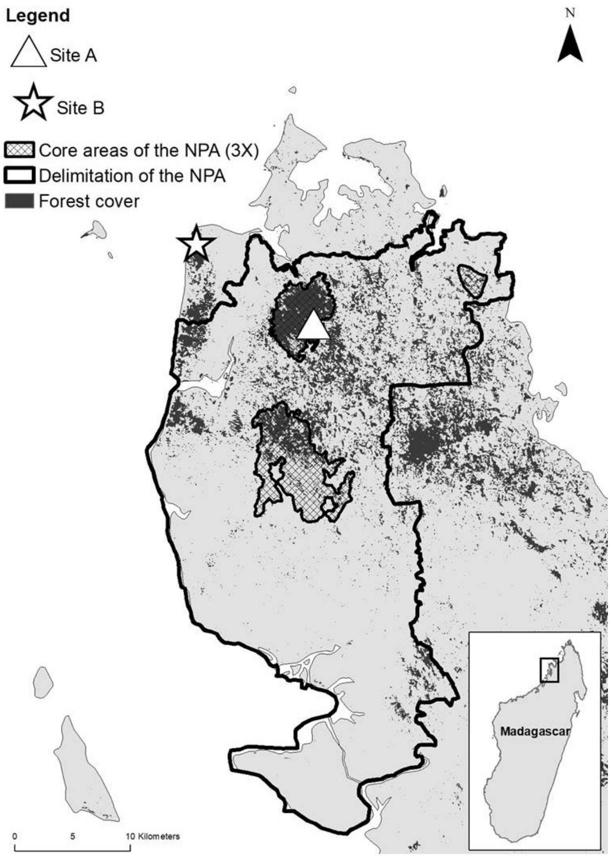

Fig. 1: Map of the Ampasindava peninsula in north-west Madagascar with representation of the two study sites, forest cover, the New Protected Area (NPA) and the 3 core areas of the New Protected Area.

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).

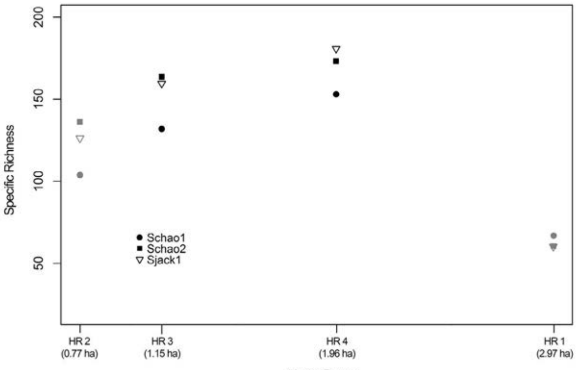

Fig. 2: Species richness of four home ranges (HR) calculated through three non-parametric indicators. Indicators Chao1(Schao1) and Chao2 (Schao2) are based on incidence and indicator Jackknife1 (Sjack1) is based on abundance. Size of each home range (HR) is given in bracket.

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
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

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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

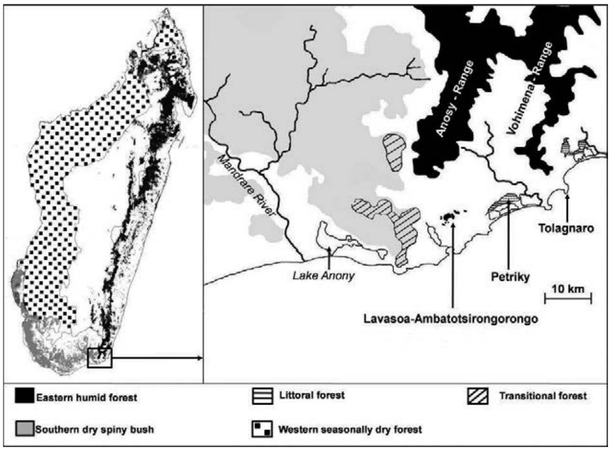

Fig. 1: Location of the forest fragments of Lavasoa-Ambatotsirongorongo Mountains in southeast Madagascar. Map is adapted from Andrianjaka and Hapke (2015).

six fragments (at that time) had a total size of 135.6ha, with Grand Lavasoa (54.7ha), Lavasoa F1 (17.8ha), Andranotsikoza (18ha), Ankaroa (5.9ha), Petit Lavasoa (also known as Bemanasa, 31.1ha) and Ambatotsirongorongo (8.1ha).

These fragments are formally protected as the Special Reserve of Ambatotsirongorongo (a Nouvelle Aire Protégée, NAP). Floristically, their composition has been characterized as a predominantly humid, transitional mixture (Andrianarimisa et *al*., 2009, Ramanamanjato et *al.* 2002), likely due to the mountains' position within the steep ecological gradient between spiny forest to the west and humid forest to the north and east. Though the humid section of Andohahela National Park (parcel 1) lies immediately to the north, historical land cover maps indicate that there has not been a direct connection between these forests for more than 40 years (Foiben-Taosarintanin'i Madagasikara, 1979).

The importance of this site is such that it is one of only a few known locations where both dry, spiny forest species live in sympatry with humid forest lemur species (Tab. 1). This includes four nocturnal, three cathemeral, and one diurnal lemur species, all of which were recommended as Endangered or worse by the IUCN Red List assessment meeting in 2018. While the majority of these lemur species exist within other geographic areas of southern Madagascar, Nosey Be mouse lemur (*Microcebus manitatra*) (Hotaling *et al*., 2016) is endemic to Lavasoa-Ambatotsirongorongo, while the Lavasoa dwarf lemur (*Cheirogaleus lavasoensis*) (Thiele *et al*., 2013) is only known from this site and Kalambatritra-Sahalava, 170km to the north (Lei *et al*., 2014). This isolation within shrinking habitats presents increasingly long odds for their survival, so much so, that both recently described species have been or will soon be included on the list of the World's 25 Most Endangered Primates.

Previously reported threats to these forest fragments and its unique lemur species assemblage include timber extraction, shifting cultivation and subsequent fires (Ramanamanjato *et al*., 2002; Hapke *et al*., 2012; Andrianjaka and Hapke, 2015). In July 2019, we visited each of these remaining forest fragments, accessible from the village of Amboavola to the immediate south of the mountains. The fields cultivated by this small village in the valley were quite extensive. These forests play a key role as sources of irrigation and drinking water (Andrianjaka and Hapke, 2015), and in fact, many of the local trails we used were irrigation ditches redirecting stream water from the forest fragments towards the rice terraces below.

Tab. 1: Lemur species present (or formerly present) within the Lavasoa-Ambatotsirongorongo forest fragments. Not all species were observed or heard, but their presence was confirmed by local guides.

Family	**Species**	**Ob-served**	**Heard**	Recommended IUCN Red List status (2018)
Lemuridae				
	Lemur catta	+	+	EN A4cd
	Eulemur collaris		+	EN A2cd+4cd
	Hapalemur meridionalis	+	+	EN A4acd
Indriidae				
	Propithecus verreauxi			CR A3cde
	Avahi meridionalis			EN B1ab(iii,v)
Cheirogalidae				
	Microcebus manitatra	+		CR B2ab(ii,iii)
	*Cheirogaleus lavasoensis**			CR A2c+B2ab(ii,iii)
Daubentoniidae				
	Daubentonia madagascariensis			EN A2cd+4cd

*We did not observe *C. lavasoensis* as our visit took place in mid-July, when this species is typically hibernating.

We noted mostly timber extraction from the Grand Lavasoa forest fragments, with multiple locals creating wooden planks for construction materials. Locals had constructed multiple rigs, referred to as "*Sovaly*" where they could create planks more efficiently (Fig. 2). Only one charcoal pit was recorded in this area, but it is likely that this will intensify as smaller logs are unable to be used for plank making.

Within Ambatotsirongorongo, the situation was far more dire. As we are writing this in haste to alert the conservation community as to what is occurring here, our GPS points indicated the newly logged area within the center of the fragment according to GoogleEarth. This was already an extremely small fragment, but this new information suggests that at least 50% of it may have been illegally logged within the last few months. Intense charcoal production was occurring during our visit, and we recorded 26 charcoal pits (Fig. 3), ten of which were actively smoking the wood. The locals that had been maintaining these fled upon our arrival at the site. *Sovaly* were also recorded here, but this stage of activity likely ended prior to the charcoal production.

In their unpublished technical report, Andrianjaka and Hapke (2015) identified where immediate reforestation efforts should be focused within this fragmented forest

Fig. 2: *Sovaly* were often encountered in areas where large trees had recently been felled.

Fig. 3. Charcoal pits were recorded in all fragments. This one had already been used, but many that we observed were still covered and smoking.

system, specifically between Bemanasa and Grand Lavasoa. These appear to be the closest in proximity, and still maintain the largest lemur populations remaining here. Though our time was severely limited in the Ambatotsirongorongo fragment, it was unlikely that many individuals of any lemur species are still there. Therefore, if tough decisions need to be made, we would recommend that future actions (e.g. reduction of timber extraction, forest edge stabilization, and corridor creation) focus on the Bemanasa and Grand Lavasoa fragments.

It is due to our recent findings that we are urging immediate conservation actions to take place here. At the very least, the local community management and patrolling system should be supported and reorganised. Many organisations have been interested in protecting this site in the past, but for various reasons have ultimately pulled out. The incredible biodiversity of this site coupled with the unrestrained rate at which the forest is being lost should inspire both conservation actors and funding organizations to help protect this unique site.

Acknowledgements

We thank the local guides from Amboavola who assisted us.

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Short-term impact of conference scholarships on Malagasy tropical biology researchers

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Background

It is widely recognized that increasing diversity in science - and ensuring the inclusion of under-represented groups in science - is critical for the production of better research (Nature Editorial, 2018). At the same time, achieving diversity in science is difficult because of the dominance of the English language, lack of accommodations to parents (particularly mothers), subconscious bias, and various other factors (Nature Collection, 2019). Research from developing countries is underrepresented in high-impact journals (e.g. Sumathipala *et al.*, 2004), and when papers are published from these areas of the world, the vast majority are produced in collaboration with a partner from outside the region (Nelius, 2009). In addition, non-English speaking researchers from developing countries often do not get appropriate credit for their work because: 1) many international journals are written in English, 2) authorship guidance does not mitigate the power differences between researchers in high and low-middle income countries, 3) there can be real (or perceived) editorial bias in favor of western authorship, and 4) there can be cultural differences between researchers from low-middle and high income countries on approaches to authorship and publications (Smith *et al.*, 2014).

In Madagascar, in addition to the issues noted above, there are many hurdles facing Malagasy researchers and scientists, aiming to build successful careers in the STEM fields. A study conducted with science and math teachers in 2012 in primary, secondary, and university-level institutions, found that, "crowded classes, limited resources (pedagogical and infrastructural), an average student range in age of seven years per classroom (suggestive of grade repetition and/or late school starting age), and discontinuities in the language of instruction explain why teachers estimated that almost

25% of their students would not finish school" (Wills *et al.*, 2014). Even at the university level, there are significant financial, administrative, and language barriers to student success (Venart and Reuter, 2014), with university teachers estimating that "just one-third of students could fully understand" French, the language of instruction (Wills *et al.*, 2014). Female university students also face discrimination and sexual harassment (reviewed by Vernart and Reuter, 2014).

After Malagasy scientists and researchers graduate from university, they continue to face hurdles in their journeys to building careers in STEM. As one example, as of mid-2019, there is not a single Ethical Review Board for human studies in the entire country (in contrast to the hundreds that are constituted in North America alone); this is problematic given that it is a standard requirement for peer-reviewed journals, and for many funders as well, that research with human subjects be signed-off by an independent Ethical Review Board before the onset of data collection. In practice, this means that any Malagasy person undertaking research involving people – be it biomedical or social science research – either needs to seek an affiliation with a non-Malagasy research institution, or collaborate with a non-Malagasy researcher. Hurdles faced by Malagasy researchers are also evidenced in the scientific literature: a survey of 4000 publications on Madagascar's biodiversity found that more than 90% had first authors affiliated with institutions outside of Madagascar (Waeber *et al.*, 2016).

The 56th Annual Association for Tropical Biology and Conservation (ATBC) meeting took place in Antananarivo, Madagascar from July 30th to August 4th 2019. ATCB 2019 brought 712 delegates from 55 countries together to discuss biodiversity conservation and sustainable development. This annual conference is held in different countries throughout the world. Prior to the start of the conference, it became clear that the costs of registration even for those paying non-high income country (as per World Bank classifications) fees were prohibitively high. Fees for developing country non-ATBC members were USD$475 and for non-students USD$280. For context, the monthly minimum wage in 2018 was USD$45 for non-agricultural workers (168,019 MGA; Ernst and Young, 2018). Becoming an ATBC member for developing country nationals is USD$25, which reduced the costs of registration by USD$50, but even this amount was prohibitively high for many (although these fees were waived for a small number of Malagasy applicants). As a result, weeks before the conference, there were 55 Malagasy students and professionals with accepted presentation abstracts without the means to pay for their conference registration.

In order to improve Malagasy representation at the conference, a number of organizations mobilized - particularly in the final two months before the conference took place - to raise additional funds that could cover the registration costs for Malagasy attendees with accepted presentation abstracts. Here, we discuss the short-term impact of these scholarships on 29 Malagasy environmental scientists whose participation was subsidized by Lemur Love (a small US registered non-profit, www.lemurlove.org) and Global Wildlife Conservation (GWC; via a small grant to KR). It is worth noting that a number of other entities in Madagascar, such as Association Vahatra sponsored the attendance of a significant but unknown number of Malagasy delegates. Moreover, several other organizations such as Centre ValBio, sponsored the participation of their own Malagasy researchers and staff. These other sponsored participants, however, are not the subject of this report.

Methods

Post-conference survey

In the days immediately after the completion of the conference, we sent out a short 10-question survey to all 29 individuals whose ATCB participation was sponsored by Lemur Love or GWC.

Results

Survey respondents

17 people responded to our survey within three weeks of the conference, of which 65% were female and 35% were male. Regarding their employment status, one-third (35%) did not have a paying job, 24% had a full-time job, 18% were a consultant with a contract, 18% were students, and 5% were in some kind of temporary employment.

Of the 11 respondents who indicated they were either in school or in some kind of employment (whether temporary or permanent), 73% were working/studying in areas related to environmental conservation, 36% were working/studying in STEM subjects, and 36% were working/studying in areas related to sustainable development (respondents could indicate more than one area of study/work focus).

Type of respondent participation in the conference

Of the 17 respondents, 16 confirmed they had presented at the conference (with most indicating they presented a poster).

Previous experience in a similar conference: 65% had previously participated in a similar conference (though we did not ask for more information as to what kind of conferences they had participated in) and 35% had not participated in a similar conference before.

Short-term impact of the conference on sponsored participations

Before the conference, respondents ranked themselves a 2.82±1.07 (mean±SD) on a scale of 1 to 5 on their knowledge of career opportunities in STEM. This increased significantly to 4.18±0.95 after the conference (Z=10.7940, p=0.001; Fig. 1a).

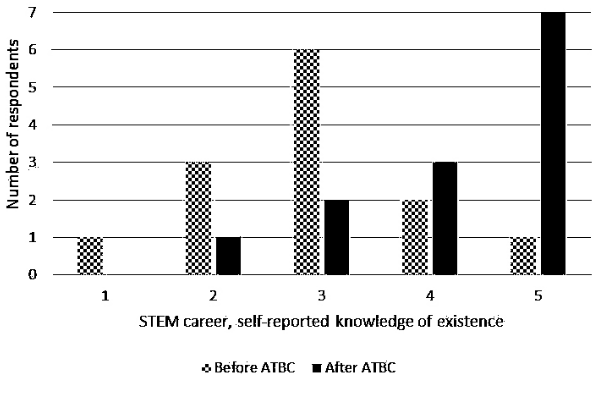

Fig. 1a: Self-reported knowledge of the existence of STEM career opportunities in Madagascar before and after the conference.

Before the conference, respondents ranked themselves a 3.11±1.32 on a scale of 1 to 5 on their perceived ability to have a career in STEM. This increased significantly to 4.24±0.90 after the conference (Z=6.5031, p = 0.011; Fig. 1b).

Finally, before the conference, only 24% of respondents reported knowing seven or more people that they felt would be able to help them in their career progression. After the conference, this number increased significantly to 65% of respondents, of which 18% said they knew more than 15

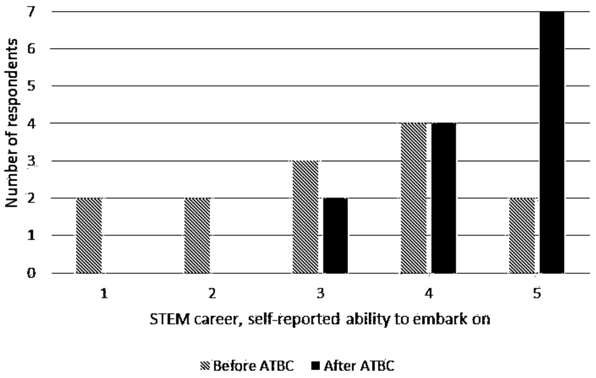

Fig. 1b: Self-reported rating of respondents' ability to embark on a career in STEM before and after the conference.

people who could help them (($\chi^2(1)=5.846$, $p=0.016$); respondents grouped into those who knew 6 or less people and those who knew 7 or more people; Fig. 1c).

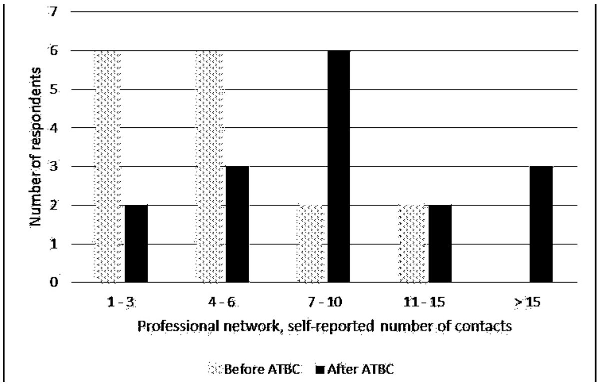

Fig. 1c: Self-reported number of professional relationships (people) that respondents thought could help them in their career search before and after the conference.

Discussion

While attendance to the ATCB conference was not going to single-handedly launch or turbo-charge the careers of Malagasy scientists, this six-day event presented a unique opportunity for career and research training at a price point unlikely to be matched by any other conference in the coming years (as so few international conferences on this subject are held in Madagascar). At a cost of USD$71/day and USD$38/day for Malagasy professionals and students, respectively, the short-term return-on-investment on the 29 sponsored students is substantial. As a result of the conference, sponsored participants were more aware of STEM career opportunities, felt more capable of launching a career in STEM fields, and substantially increased the number of professional relationships that they felt could help them in their careers. One of the participants sponsored by Lemur Love, Miatrana Rasamoelina (a veterinary student at the University of Antananarivo), won the 2019 Alwyn Gentry Award for Best Poster Presentation for her presentation on West Nile Virus in Malagasy birds all award winners can be found here. All of these delegates were supported with a relatively small amount of funding (USD$5000 from Global Wildlife Conservation and USD$3555 from Lemur Love) that was fundraised last-minute by individuals who were not part of the conference organizational team.

While it is true that a substantial number of the conference participants were Malagasy (about one month before the conference was due to start, one-third of conference registrations were Malagasy people). Nevertheless, with a planning lead time of at least one year, more could have been done to ensure that no Malagasy person was dissuaded from submitting a presentation abstract because of the cost of registration. For context, the ATCB conference itself was sponsored by some of the world's biggest conservation and development agencies in the world including the World Resources Institute, WWF, and Conservation International. Other notable sponsors included Ambatovy (one of the world's largest nickel mines), the French Embassy in Madagascar, and numerous smaller international and national foundations and conservation organizations.

Looking forward, and specific to the Malagasy conservation and environmental sector, we urge the following:

1) any international conferences taking place in Madagascar should seek to maximize Malagasy participation, offering, at a minimum, highly discounted registration options to qualified Malagasy applicants. It is not unusual for other events and opportunities in Africa to price tickets based on ability to pay (e.g. in Kenya, national park fees are ten times higher for non-residents compared to Kenyan citizens). Alternatively, fees from researchers from high-income countries could be increased to cover the cost of Malagasy delegates. A similar model is used in Madagascar for research, wherein foreign researchers are legally obligated to include, train, and pay Malagasy students as part of their studies.
2) entities funding conservation programming in Madagascar, should take note of the need to support individual capacity building within the country, so that Malagasy researchers can continue to grow and share the international research stage as equals to their foreign counterparts. Few entities are willing to fund individual bursaries, scholarships, and conference fees. We understand that conservation funding is limited, but we contend that targeted support of talented Malagasy researchers is a cost-effective and impactful way to improve the long-term sustainability of conservation programming in the country. Moreover, lasting effects of *not including* these talented Malagasy scholars are certain to negatively impact conservation and relationships between foreign and domestic researchers.

Conclusion

In sum, ATBC 2019 was successful in Madagascar in that over 300 Malagasy students and scholars were able to present their research, highlight their abilities, and network with an international audience. We encourage organizers of this and other international conferences to consider the needs of local scholars (including the cost of attendance in relation local income) into their planning, and how inclusion (or lack-thereof), may impact conservation and development in these locations in the years following conferences.

Acknowledgements

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Articles

Introducing the Lemur Portal: a tool to improve research and conservation in Madagascar

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Introduction

Madagascar is a global treasure chest of biodiversity with extremely high levels of species and higher order endemism among terrestrial taxa (Goodman and Benstead, 2005; Crottini *et al.,* 2012). Madagascar is known as one of the world's poorest countries, which has resulted from decades of weak governance, declining rule of law, political crises (mainly between 2009 – 2013), networks of corruption and a lack of commitment of the government at several levels (Jones *et al.,* 2019; Ratsimbazafy *et al.,* 2019). These challenges contribute to driving the loss of Madagascar's biodiversity and a continuing increase in threats for protected areas and species, leaving only 10 - 15% of the country's original natural forests standing, with the remaining forested areas highly fragmented and at the brink of extinction (Kull, 2000; Vieilledent *et al.,* 2018). The biodiversity resources found in Madagascar are under extreme pressure from activities generated by a predominantly rural, natural resource dependent population. The most significant impacts arise from habitat loss through slash-and-burn agriculture, however hunting and fuelwood extraction also have significant impacts in many locations throughout Madagascar. A 2014 study concluded that the Central Menabe dry forest may disappear completely before 2050 if the current rate of deforestation holds. Indeed, between 2008 and 2010, the average annual deforestation rate in the Menabe-Antimena was estimated at 1820ha or 2.55% (Zinner *et al.,* 2014). More recently, it has been reported that Madagascar has lost 44% of its natural forest between 1953 and 2014, primarily resulting from the deforestation attributable to human activities (Vieilledent *et al.,* 2018).

The most emblematic species, the 113 lemur species found in Madagascar represent a clear and well-known example of the high diversity and endemism affected by dynamic threats across the island (Mittermeier *et al.,* 2014). Madagascar's lemurs have the dubious honor of representing 20% of the species listed on the World's 25 Most Endangered Primates List. As a result of a recent Red-Listing workshop in Antananarivo in 2018, 34% of lemur species are now listed as Critically Endangered on the IUCN Red List, while 40% are Endangered and 21% Vulnerable (C. Schwitzer, pers. comm.). It is estimated that a large number of species will face extinction in coming decades if significant steps are not taken to reverse current trends (Allnut *et al.,* 2008). Many species have extremely small distribution areas and are restricted to fragmented and threatened forest remnants. In addition, the life history characteristics of lemurs, including highly specific habitat niches and feeding behavior, mean that they are amongst the species in Madagascar that will potentially be the most affected by the manifestations of climate change including changes to wet season precipitation, higher intensity cyclones, and more frequent droughts in coastal zones. Such climate related threats will exacerbate the prevailing anthropological threats faced by these species (McAllister *et al.,* 2017).

Despite awareness in conservation and research circles of the growing threats experienced by lemur species, in addition to a passionate international and national conservation community that has leveraged significant support for investment in research and field-based conservation actions, efforts to date have failed to reverse negative trends in lemur conservation statuses (Schwitzer *et al.,* 2013; Schwitzer *et al.,* 2014). The increasing incidences of illegal wildlife trafficking and capture of lemurs as pets are a clear illustration of the increasing gravity of threats these animals are facing in Madagascar (Reuter *et al.,* 2016). Between 2010 and 2015, more than 28,000 lemurs were estimated to have been illegally kept not only in various villages near protected areas but also in cities (Reuter *et al.,* 2015). A prominent example of poaching occurred in 2018 in the Andasibe region near the Antavolobe Forest, where 11 lemurs were killed (Lemur Conservation Network, February 2018). Conservation experts have confirmed that restaurants serve lemur meat across multiple regions, despite ongoing efforts to end the illegal bushmeat trade and protect these emblematic species (LaFleur *et al.,* 2019).

While concrete efforts remain underway, such as various community-based conservation programmes, there exists a strong need for capacity building for local communities, especially those living near protected areas. It is clear that individuals, communities and organizations must acquire a diverse set of skills, knowledge and attitudes in order to achieve biodiversity conservation goals. Enhancing local capacity will increase biodiversity stewardship and ownership, thereby positively impacting local conservation and development.

In accordance with these observations and recommendations, a technical workshop with over 40 representatives of lemur conservation organizations launched the development of the "Madagascar Lemur Portal" in 2016. The workshop highlighted the urgent need to work together to ensure long-term conservation of lemurs through the use of tools that promote collaboration, exchanges, and sharing of expertise and data. With support from JRS Biodiversity Foundation, the creation of the Lemur Portal involved collaboration between: Madagascar Biodiversity Foundation (Fondation pour les Aires Protégées et la Biodiversité de Madagascar - FAPBM); Wildlife Conservation Society (WCS); REBIOMA (Réseau de la Biodiversité de Madagascar); Groupe d'Etude et de Recherche sur les Primates de Madagascar (GERP); and the IUCN SSC Primate Specialist Group. The portal is one of the most sophisticated tools in Africa that allows for the sharing of primate data and knowledge, and it enables a wide range of users to access information on every kind of lemur in Madagascar. Various stakeholders are able to access real time and continuously updated information, a comprehensive species database, ready-made and tailored visualizations, and a mobile application for citizen science. These opportunities have inspired the Lemur Portal project to move towards a dedicated vision, specifically aiming to (1) increase local communities' spirit of ownership of lemurs and (2) build the capacity of future potential conservation leaders at the local and regional scale.

The Lemur Portal is intended to reach nationals, local communities and institutions and engage them in lemur conservation. This will decrease the gaps between decision making processes, conservation actions, and research. Conversely, without an active effort to capitalize and share lemur information with a wide range of users, public awareness on the ongoing situation of lemurs in Madagascar would lack severely. Only a select few people would understand how lemurs can be useful for communities and why they are valuable for conservation and development. To ensure ubiquitous understanding and enthusiasm for lemur conservation, the Lemur Portal will connect everyone around the world.

Identifying needs and gaps in lemur research and conservation

A contributing factor to the current failure to implement effective lemur conservation is weak biodiversity information and access to knowledge on the part of stakeholders involved in conservation activities (Holmes *et al.,* 2019). Specifically, the lack of a robust mechanism to create positive feedback loops between research and researchers and policy decisions and on the ground conservation actions carried out by communities and NGO conservation practitioners creates significant obstacles to effective conservation. A workshop held in February 2016 that assembled stakeholders from a number of different groups (NGOs, researchers, government, private sector, tourism industry, and students) identified a range of challenges in lemur conservation:

> (i) Lack of research reaching, and being used by, field-based conservation practitioners: The results of research are dispersed, but they are often difficult to access and are not available in forms or developed in tools that can be readily applied by community managers or NGOs carrying out field-based conservation.
>
> (ii) Incoherence between research activities and field-based data needs for conservation success: Researchers have little information on the most pressing field-based research questions that would allow them to tailor research priorities to the needs of conservation practitioners.
>
> (iii) Lack of influence of data and research on policy and decision-making: Governmental and non-governmental decision and policy makers have little direct contact with researchers and difficulty accessing reliable and comprehensive data sources meaning that both government strategies (e.g. National Biodiversity Strategy and Action Plan) and technical strategies and policies (e.g. IUCN Red List assessments or the Madagascar Lemur Conservation Action Plan) suffer in terms of the completeness of the data sources used to compile them.
>
> (iv) Lack of data in suitable formats for existing or potential conservation partners outside academic or NGO circles: Other partners including donors, private sector partners and tourists who have the potential not only to provide direct support to lemur conservation actions, but also to raise awareness more broadly in international circles on the crisis facing Madagascar's biodiversity struggle to find accurate, and robust information in a format that meets their specific needs.
>
> (v) Lack of data to evaluate effects of development on lemur conservation: Developers of projects that have the potential to have negative effects on lemurs or their habitat or to valorize lemurs (for example through tourism developments) only have limited data at their disposal to enable them to assess project impacts and develop appropriate mitigation measures.
>
> (vi) Failure to foster capacity for lemur conservation among young national scientists and practitioners: The next generation of national researchers and conservation practitioners has limited access to current specialists in lemur conservation and there is a lack of professional networking and exchange opportunities to allow skills transfer and capacity building among young scientists.

To date, networks and data exchanges around lemur conservation have remained informal and based largely on historic personal and professional relationships among individuals or groups (e.g. Lemur Conservation Network.org; IUCN Primate Specialists Group). In recent years, three initiatives have attempted to redress this and develop a more structured data framework for lemur conservation data but they have only achieved a partial resolution of the issue. While each of these initiatives – REBIOMA, Lemur Atlas and the Lemur Conservation Network – all have significant strengths, none of them has been designed specifically to address the goal of creating positive feedback loops between research and researchers and policy decisions and on the ground conservation actions.

Existing biodiversity information portals that have links to lemur conservation in Madagascar

REBIOMA includes extensive lemur data as part of its overall data portal and currently includes 7,300 lemur records. The datasets and products included in REBIOMA form an important technical dataset but REBIOMA does not aim to focus specifically on lemurs, nor does it integrate the tools needed to create a community of practice for lemur conservation by facilitating exchanges of information and improved networking and linkages between data users in relation to this one group of species. The Lemur Atlas, developed by ONE, attempted to develop an interactive lemur database but the Atlas has suffered from a lack of features for user interactivity, data sharing, and progressive evolution of the platform. Finally, the Lemur Conservation Network (LCN) is a popular and user-friendly website that provides general information on lemur conservation issues to a wide audience. The objective of LCN is fully complementary to that of the Portal and significant cross-promotion between the two initiatives is anticipated. LCN was established to serve as a guide to the work being done in Madagascar and is designed for organization membership. The LCN does not present any technical information/database about lemur species and is limited in terms of the networking functions it provides as it only helps people to find appropriate organizations for their research program and perhaps some ideas of funding. It does not guide lemur researchers to ask questions on specific topics or specific problems as they are looking for specific solutions from experts or professionals. The forum page is entirely managed by the web-designer and focused on their specific interest, but does not capture the on-the-ground news or events that should be posted by the researchers or conservationists working onsite.

With regards to the IUCN Red List website where all species are listed with rich information on several criteria, categories and definitions, the access remains for high level people such as masters and doctoral students, established researchers and conservationists, and particularly those who can read and understand English. However, the IUCN Red List can be complementary with the Lemur Portal, where exchange and possibly 'real-time' information could be seen as well.

Lemur Portal: a technological tool for research, capacity building and Conservation:

The Lemur Portal (http://www.lemursportal.org) addresses the limitations of the existing initiatives by (i) being based on an open access platform and with a user interface that encourages user interaction and engagement across the different functions of the Portal; (ii) focusing solely on lemur conservation and containing comprehensive technical information on lemur species that is updated regularly, including through interactive user driven tools; and (iii) developing a community of practice amongst different stakeholders and allowing for information exchange both at the non-technical informative level and at a more comprehensive technical level between researchers and professionals.

The main goal of this portal is to close the networking loop between research, policy decisions, and on the ground conservation actions. This leads to the following prioritization of user groups: (i) academic users (researchers and students) and conservation practitioners: they are priority user groups for this portal as they have the most concrete and immediate ability to impact the success or failure of on the ground conservation outcomes; (ii) policy and decision makers: In the short term this user group has a lower ability to impact conservation outcomes because of the low capacity and weak governance that currently prevails in the Madagascar conservation sector. However, one of the desired outcomes of the proposed Portal is to contribute to raising the capacity and interest of these stakeholders in lemur conservation so that their influence and impact grows over time; (iii) the rest of the user groups (tourists and tourism operators, private sector and the general public) are predominantly recipients of data and do not contribute directly in a substantial way to lemur conservation outcomes. Providing them with the information may however encourage them to be more empathetic to the plight of lemurs and thus to support conservation actions.

The functions of the proposed Portal will be developed in a staged fashion that responds to the prioritization of user groups. A technical annex has been prepared that describes the technical features of each of the functions and a summary is provided below:

Online Forum: A key objective of the Portal is to facilitate exchanges, data sharing, mentoring/networking and capacity building. This can be achieved through a forum function on the Portal, which will allow for real-time contact between Portal community members, facilitate networking and contact between members to develop joint initiatives or mentoring/partnership relationships, and sharing of data outside of the species database and visualization functions such as grey literature, peer-reviewed publications, and training or conservation tools.

Species Database: The species database collates information on individual species in relation to taxonomy, ecology, recorded locations, status, threats, population trends, photos, vernacular names, occurrence in protected areas, and the identification of specialists with expertise in species ecology. Data are available for download and the database will be the entry point for data upload by Portal users. Data are classified as private data (confidential or sensitive data) or public data. Both private and public data are used to generate visualizations but with restrictions on access to private raw datasets, which are subject to prior validation by lemur experts.

Visualizations: Users are able to download a range of visualizations of species distribution, threat data, relevant environmental layers, and conservation action interventions. These visualizations are available both in terms of pre-developed documents that can be accessed by all levels of users (including distribution maps for commonly queried species and species lists for protected areas) and tailored products that can be developed by registered users based on the results of individual queries (e.g. distribution maps of a group of species, overlay of distribution and threats, combination of different environmental layers with distribution maps, species database for a defined geographic area).

Mobile application for citizen science: A key feature of the lemur Portal is that information is kept current and up to date by ongoing user entry of data. To this end, a Madagascar Lemur Portal mobile application for data upload will be adapted based on existing ones to be as simple and intuitive as possible, such as iNaturalist. In addition, the site will be linked to existing citizen science sites including iNaturalist or the lemur observation application that is currently being developed by Mittermeier and his team, to facilitate data sharing.

Progress and way forward

Currently, the Lemur Portal is available for public use at http://www.lemursportal.org. This tool responds to the needs of users and is available in three languages (Malagasy, English, and French). It stores comprehensive information on 110 lemur species, more than 12,000 occurrences of lemur data, 150 users, and 30 experts for forum moderation and data validation. Over 15 collaborators from public institutions, NGOs, universities, and protected areas have agreed to officially partner with the Lemur Portal project, providing input from their specialties and localities. In terms of capacity building, more than 300 local technicians, including academic students and local managers of protected areas in five regions of Madagascar (Ranomafana, Toamasina, Morondava, Antananarivo, and Mahajanga), have benefited from training on biodiversity data management, biodiversity informatics, and Geographical Information System (GIS) since 2016.

Reaching local communities and primary data holders will be one aspect which the Lemur Portal considers as a critical path for the future. Therefore, every researcher, practitioner, conservationist, student and citizen, working on lemur research, lemur and habitat conservation is invited to contribute to the Lemur Portal by providing new data and occurrences, relevant information, grants and opportunities, news and recent publications; as well as by making use of the tool for lemur conservation in Madagascar.

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Inventory of the lemur community in the Vohimana reserve, eastern Madagascar

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Abstract

Faunal inventories are essential to understanding distribution patterns, as well as informing and prioritizing conservation actions. Lemurs are charismatic taxa, used not only as umbrella and flagship species but also as predictors of community richness and models of the diversification processes in Madagascar. The Vohimana Reserve is located in the heart of the Ankeniheny-Zahamena corridor, one of Madagascar's conservation priorities, and hosts a mid-altitude rainforest. The forest has long faced strong anthropogenic disturbances, such as slash-and-burn agriculture, logging, and poaching. Prior to this study no long-term study on the lemur community in Vohimana had been conducted and no updated information was available. We aimed to provide a lemur inventory and a description of threats that could be used by forest managers in order to inform and optimize future conservation plans. Between April and December 2018, we surveyed the forest using line-transect distance sampling. Our results show that Vohimana is home to 11 lemur species, including two critically endangered species (*Indri indri* and *Propithecus diadema*). We found no evidence of the presence of the black-and-white ruffed lemur (*Varecia variegata*), which was once reported to inhabit the forest. The possible disappearance of this species, the low frequency of Lemuridae species observations, and the observation of snares, selective logging, and charcoal production suggest actions and long-term monitoring are urgently needed in order to protect this fragile but strategic ecosystem.

Résumé

Les inventaires fauniques sont essentiels pour comprendre les schémas de distribution, informer et prioriser les actions de conservation. Les lémuriens sont des espèces charismatiques jouant le rôle non seulement d'espèces parapluies et drapeaux, mais aussi utilisés comme prédicteurs de la richesse des communautés et comme modèles de diversification à Madagascar. La Réserve de Vohimana est située au cœur du corridor Ankeniheny-Zahamena, l'une des priorités de Madagascar en matière de conservation, et héberge une forêt pluviale de moyenne altitude. La forêt a longtemps été soumise à de fortes pressions résultant d'activités humaines telles que l'agriculture sur brûlis, l'exploitation forestière et le braconnage. Aucune étude à long terme de la communauté de lémuriens n'a été menée à Vohimana et aucune information actualisée n'est disponible. Notre objectif était de fournir un inventaire des lémuriens et une description des menaces, utilisables pour informer et optimiser la conservation de la réserve. Entre avril et décembre 2018, nous avons inventorié les lémuriens en utilisant la méthode de «line-transect distance sampling». Nos résultats montrent que Vohimana abrite 11 espèces de lémuriens, dont deux espèces en danger critique d'extinction (*Indri indri* et *Propithecus diadema*). Nous n'avons trouvé aucune évidence de la présence du vari noir et blanc (*Varecia variegata*), autrefois reportée dans la réserve. La possible disparition de cette espèce et les rares observations des espèces de la famille des Lemuridae ainsi que la découverte de collets, l'abattage sélectif et la production de charbon de bois dans la réserve souligne l'urgence d'actions de conservation et une surveillance à long terme, cruciales pour protéger cet écosystème fragile mais néanmoins stratégique.

Introduction

Deep knowledge of the biota of a given area is crucial not only to investigate biodiversity distribution patterns and diversification processes (Wilmé *et al.,* 2006) but also to inform and prioritize conservation actions (Goodman, 2010). The potential for assessing a forests' biological value, detecting local patterns of micro-endemism, and identifying sources of anthropogenic pressures makes inventories essential tools, which conservation actions are based on at a local and regional scale (Goodman, 2010; Silveira *et al*., 2010). Lemurs constitute charismatic species commonly used as flagship and umbrella species (Schwitzer *et al.,* 2014) as well as predictors of faunal community richness (Muldoon and Goodman, 2015).

Due to the accessibility of the highway linking Antananarivo and Toamasina, the forests in the extended Andasibe region have been amongst the most intensively studied in Madagascar. Several new species from that region have been described over the last decades (Goodman, 2010). In this context, faunal data of the lesser known forests outside the Andasibe protected block (Andasibe-Mantadia National Park and Analamazaotra Special Reserve) and information about their threats are essential to evaluate the eligibility of new protected areas, plans for the creation of forest corridors, and the development of conservation programs that would include an efficient rural development.

The Vohimana Experimental Reserve (18° 54'S/18° 56'S; 48° 28'E/48° 31'E) is located in the rainforest belt in the Alaotra-Mangoro region, district of Moramanga, eastern Madagascar. The reserve ranges in altitude from 600 to 1044m and covers a surface of 2190ha, of which 554ha are covered by rainforest (L'Homme et l'Environnement, unp. report). The reserve is in the south-eastern portion of the Ankeniheny-Zahamena forest Corridor (CAZ), one of the largest remaining rainforest swaths in Madagascar. Vohimana has the potential to serve as a corridor between the Analamazaotra Special Reserve, the Andasibe-Mantadia National Park (west and north of Vohimana), the Maromizaha Protected Area, and the Vohidrazana forest (south of Vohimana). The forest is home to endangered, endemic, and rare animals, such as the lance-nosed chameleon (*Calumma gallus*). The reserve has been managed by the Malagasy NGO "L'Homme et l'Environnement" (henceforth "MATE") since 2002, under a 25-year management agreement with the Province of Toamasina.

Vohimana has long been subjected to strong anthropogenic disturbance and continues to be under environmental pressure due to human activities. The traditional practice of slash-and-burn agriculture (*tavy*), illegal logging for firewood, and production of charcoal have severely fragmented and impacted the forest and are all serious threats: 90ha were reforested from 2007 to 2017 and 235ha were destroyed from 2013 to 2017 (L'Homme et l'Environnement, unp. report). Between 2009 and 2010, the reserve was impacted by the creation of the road and the embankment for the installation of the pipeline of the "Ambatovy" mining project, carrying nickel, cobalt, and ammonium sulphate from Ambatovy (30km west of Vohimana) to Toamasina harbour (Dickinson and Berner, 2010), which left clear marks in the landscape.

Vohimana is known to host the indri (*Indri indri*)*,* the diademed sifaka (*Propithecus diadema*), the eastern lesser bamboo lemur (*Hapalemur griseus griseus*), the weasel sportive lemur (*Lepilemur mustelinus*)*,* the furry-eared dwarf lemur (*Cheirogaleus crossleyi*)*,* the Goodman's mouse lemur (*Microcebus lehilahytsara*) (Mittermeier *et al.,* 2010), and the hairy-eared dwarf lemur (*Allocebus trichotis*) (Rakotoarison *et al*., 1997; Garbutt, 2007). In 2005, the black-and-white ruffed lemur (*Varecia variegata*) was acoustically detected during diurnal surveys (S. Westra, *pers. comm.*) but its presence was not recorded during the diurnal surveys conducted in April-July 2011 (Deguette, 2011). The presence of brown lemur (*Eulemur fulvus*) and red-bellied lemur (*Eulemur rubriventer*) was also reported (Westra, 2005; Deguette, 2011), augmenting the total number of lemur species detected in this forest to 10.

Nocturnal lemurs have never been systematically surveyed in Vohimana and no updated lemur inventory is available. This study aims to 1) provide the inventory of the lemur community in the Vohimana Reserve and 2) collect information of the anthropogenic threats to lemur survival, in order to provide indications to the forest managers for future and optimized conservation plans.

Methods

Study area

The Vohimana reserve extends over two *fokontany* administrative units: Anevoka (Commune rurale d'Andasibe) and Ambavaniasy (Commune rurale d'Ambatovola). In the reserve, a matrix of primary and secondary forest patches of different sizes are surrounded by degraded and anthropic zones such as *Eucalyptus* plantations, exploited forest, recolonized bush (*savoka*), herbaceous fallow, cultivated and residential areas (Klanderud *et al*., 2010; Reeb *et al*., 2011). The native forest is constituted by mid-altitude humid and dense evergreen vegetation. The climate is hot, humid, and strongly influenced by moist winds from the east. The average annual temperature is 20.4°C and the average annual precipitation is 1850mm, with the absence of dry season (Klanderud *et al*., 2010). The reserve is bounded by the Sahatandra river and the railway to the north and the east, by the Iasina river to the west and the south and the Route Nationale 2 to the south (Fig. 1). Several small rivers flow within the forest: Antsahatsana, Sandratanana, Sity, Vohimana, and Sandrasoa.

Eleven villages are located on the border of the reserve perimeter, including Ambavaniasy, 6km south of the forest core, with an estimated population of 720 inhabitants in 2018 (L.Razafindravelo, *pers. comm.*). The Vohimana village is located within the reserve and three more villages are in the nearby area. Two train stations are present on the northern border of the reserve: An'ala (nearby the Andasifahadimy village) and Fanovana. In the area, most people belong to the Betsimisaraka ethnic group and other minorities are present (L. Razafindravelo, *pers. comm.*). The majority of the villagers rely on agriculture and small-scale poultry breeding. Part of the community is also involved inessential oil distilling in Ambodikijy and Andasifahadimy, railway mainte-

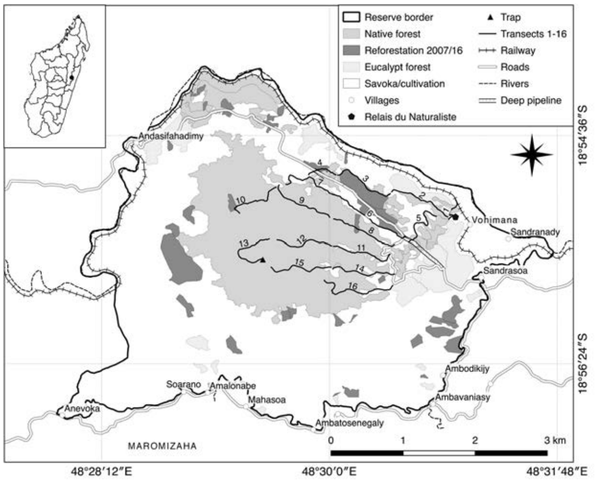

Fig. 1: Map of the Vohimana Reserve. The researchers' accommodation facilities are located at the "Relais du Naturaliste" site. Forest layers provided by "L'Homme et l'Environnement". Eucalypt forest layer created by Basile Marchais and Camille Dobler.

nance, trade, charcoal production, pig breeding, bee-keeping, nursery, and forest conservation. In the last 15 years, the community of the Vohimana-Maromizaha area has benefitted from the actions of conservation and rural development by two Malagasy NGOs: MATE and the "Groupe d'Etude et de Recherche sur les Primates de Madagascar" (Randrianarison *et al.,* 2015).

Lemur survey and threats information collection

The Vohimana Experimental Reserve was surveyed from 19 April to 23 June and from 22 July to 11 December 2018. The survey was timed to encompass periods at which all species were active and detectable. For instance, dwarf lemurs (genus *Cheirogaleus*) from eastern Madagascar hibernate in tree holes or nest-like structures from May to September (Wright and Martin, 1995; Blanco *et al.,* 2010).

The survey teams were composed of a researcher or a trained field assistant (AA, TG, MM, LS) and one local guide from the association "MERCIE Vohimana". In some cases, one or two guide apprentices joined the team. Lemur presence was investigated using diurnal and nocturnal visual line-transect distance sampling surveys (Buckland, 2001). Sixteen independent transects from existing and renovated trails of 0.45 to 1.3km for a total of 15.6km were used. Transects were created to ensure they crossed most vegetation types including well-preserved forest, secondary forest, herbaceous fallow, shrubby fallow, *Eucalyptus* and pine plantations, banana plantations, riverside vegetation, forest clearing, railway, and pipeline. Transects were flagged with 25m intervals. Transects were walked between 07:25 and 14:00 or, less frequently, between 14:55 and 16:30 for diurnal sampling and between 17:55 and 21:30 for nocturnal sampling. Transects were surveyed at a mean pace of 1.2km/h during daylight and 0.9km/h at night.

At every sighting, the following data were collected: GPS location, group size, and perpendicular distance from the transect. Survey time and transect starting point were varied to ensure that these variables would not affect estimates. At night, lemurs were located with head-torches thanks to the eyeshine of their *tapetum lucidum,* a reflecting structure present in nocturnal lemurs and eastern lesser bamboo lemur (Pariente, 1979). Species were identified using a powerful spotlight hand-held torch. A camera equipped with flash and a sound recorder was occasionally used to confirm species identification and create a photographic inventory.

Acoustic observations and occasionally recorded lemur calls were also documented. In addition, three off trail expeditions were undertaken to search for the gnaw marks and nests of the elusive aye-aye (*Daubentonia madagascariensis*), extremely difficult to locate with classic survey techniques (Sterling and McCreless, 2006). *Lepilemur* species sightings were identified according to the latest taxonomy (Andriaholinirina *et al.,* 2006). Forms of forest exploitation were identified from direct observations and informal conversations with local guides.

Tab. 1: Local names and presence-absence of lemur species in Vohimana

Family	Species	Common name	Local name	IUCN status	N obs	N ind	G. S. range	G. S. mean	G. S. st dev	P/A
Cheirogaleidae	*Allocebus trichotis*	Hairy-eared Dwarf Lemur	Antsidiala, Antsidy	VU	1	1	1	1.0	-	+
	Cheirogaleus cf. crossleyi	Furry-eared Dwarf Lemur, Crossley's Dwarf Lemur	Matavirambo, Tsitsihy	DD	33	40	1 - 3	1.3	0.6	+
	Microcebus lehilahytsara	Goodman's mouse lemur	Antsidy	VU	37	37	1	1	0	+
Daubentoniidae	*Daubentonia madagascariensis*	Aye-aye	Hay-hay	EN	0	0	-	-	-	*
Indriidae	*Avahi laniger*	Eastern Woolly Lemur	Avahina, Fotsife, Fotsiefaka	VU	42	59	1 - 3	1.5	0.6	+
	Indri indri	Indri	Babakoto, Endrina	CR	33	73	1 - 5	2.2	0.9	+
	Propithecus diadema	Diademed sifaka	Simpona	CR	3	12	2 - 7	4.0	2.6	+
Lemuridae	*Eulemur fulvus*	Brown Lemur	Lokosy, Varikamavo	NT	4	10	1 - 5	2.5	1.9	+
	Eulemur rubriventer	Red-bellied lemur	Varikamena	VU	4	10	1 - 4	2.5	1.7	+
	Hapalemur griseus griseus	Eastern Lesser Bamboo Lemur	Kotrika	VU	4	6	1 - 2	1.5	0.6	+
	Varecia variegata editorum	Black-and-white Ruffed Lemur	Varikandana	CR	0	0	-	-	-	-
Lepilemuridae	*Lepilemur mustelinus*	Weasel Sportive Lemur	Hataka, Matoriandro	NT	15	16	1 - 2	1.1	0.3	+

The group size range of the indri is calculated on a larger sample including observations made out of distance sampling surveys. The number of observations (N obs) and the number of observed individuals (N ind) include also diurnal lemurs observed at night and nocturnal lemurs detected during daylight. Abbreviations: GS: Group size; st dev: standard deviation; P/A: presence/absence; CR: Critically Endangered, EN: Endangered, VU: vulnerable, NT: Near Threatened, DD: Data Deficient; +: presence, -: absence, *: gnaw mark.

Results

Lemur inventory and ecological notes

Overall, a total of 210 surveys were conducted (111 diurnal and 99 nocturnal surveys) and 292 lemurs were observed for a total of 286.5km and ~203h of survey effort. Ten lemur species (Tab. 1) from four families (Cheirogaleidae, Lepilemuridae, Lemuridae, Indriidae) were directly observed. Of these observed species, two are diurnal (*I. indri, P. diadema*), three are cathemeral (*Eulemur rubriventer*, *Eulemur fulvus, H. griseus*) and five are nocturnal (*Avahi laniger, L. mustelinus, Cheirogaleus* sp.; *M. lehilahytsara, A. trichotis*) (Tab. 1). Photographs, which were made of all observed species, are available at https://drive.google.com/drive/folders/1A2URcr6_JvwPAcC3wWaYS0rPL74X2GLB.

The fur pattern of the indri was similar to the variants from the Analamazoatra Special Reserve, Mantadia, and Maromizaha (Brenneman *et al.,* 2016), with a white patch on the top of the head connected to a white lateral collar of variable size, absent or very light face ring, white outer side of forearms and hindlimbs, and dorsal white triangle. A few individuals lacked the white patch on the top of the head.

Two marks were found on tree trunks that we interpreted as the gnaw marks of the aye-aye. The first one (Fig. 2a), found in May 2018, measured 7x7.5cm (length x height) and was at 0.8m on a bowed tree trunk. The second one (Fig. 2b), found in December 2018, measured 1x2cm and was at 1.7m on a *Chrysophillum boivinianum*tree (L. Razafindravelo, *pers. comm.*).

The elder local guide reported finding one group of three black-and-white ruffed lemurs in the early 2000s in Vohimana but there have been no further sightings since 2008. Although another guide reported that he heard loud calls of black and white ruffed lemurs once during the last year, we found no evidence of its presence.

During diurnal sampling, the indri was the most frequently detected species (visually and acoustically), while observations of *Eulemur* species, the eastern lesser bamboo lemur and the diademed sifaka were rare (Tab. 1). The eastern woolly lemur (*A. laniger*) and the Goodman's mouse lemur were the most frequently observed nocturnal lemur species. A hairy-eared dwarf lemur was observed only once on 10 December 2018.

Cheirogaleus was observed from 20 to 27 April and from 10 August until the end of the study. We note that *Cheirogaleus* from Vohimana have a clear white stripe on the mid-facial zone and distinct black eye rings. Because of the morphometrical similarity between the furry-eared dwarf lemur and the greater dwarf lemur (*Cheirogaleus major*), both found in eastern Madagascar (Louis, *pers. comm.*), it was not possible to determine the taxonomic status of the observed individuals. Interestingly, in April 2018, AA observed an individual of *Cheirogaleus* moving quadrupedally on the ground along the 90-m high railway bridge that runs parallel to the Sahatandra river. To our knowledge, that was the first time that an individual from this genus has been observed using a bridge to reach a separated forest fragment.

The presence of the largest lemur terrestrial predator, the fossa (*Cryptoprocta ferox*) has been reported by local guides and other villagers and we observed the presence of diurnal raptors.

Threats

Locals exploit the forest in different fashions and with different impacts. Slash-and-burn agriculture still represents one of the major threats in Vohimana as it entails forest clearing. Although tavy has negatively affected the forest in the last few years, its impact is decreasing due to MATE's rule enforcement and patrolling by locals.


Fig. 2 a,b: The two tree traces interpreted as gnaw marks of the aye-aye. Photos by A. Anania (a) and L. Sauvadet (b).

In the area, logging is traditionally practised to produce firewood and charcoal. Evidence of selective logging was observed during forest surveys. Most charcoal used in the area comes from the heavily exploited forest located on the northern side of the Sahatandra river, between Vohimana and Mantadia (an area called 821-IT), but charcoal production was also witnessed in two areas on the border of the Vohimana forest core.

Tree wood (i.e. *Ravenala madagascariensis,* known locally as *ravinala*) and leaves (i.e. *Pandanus* sp.; known as *vakona,* and ravinala) are also used for the construction of permanent and temporary houses. Tree bark of *fatraina* (*Melicope* sp.) is used to produce local fermented alcohol (*betsabetsa*). Several plants are used for traditional medicine practices (*fanafody*) and parts of the ravinala plant are also a source of food and hydration. Mats and handicraft are created by weaving together leaves of *Pandanus* sp.

In Vohimana, people traditionally hunted birds, tenrecs (family: Tenrecidae), wild boars, and lemurs as a source of food. Lemur poaching was common before 2002 when MATE started conservation actions in the area. Among lemurs, the indri is *fady* (taboo) for the local Betsimisaraka community and the only other lemur species, which is traditionally not hunted and consumed is the aye-aye. The fossa is mostly killed to prevent poultry predation. Blowpipes and slingshots were used to hunt birds and lemurs and snares to trap lemurs, boars, wild cats, fossas, and fanalokas (*Fossa fossana*). Dogs were used to hunt boars and tenrecs. Dogs are present in the Vohimana village, the closest village to the forest core, but they were not observed inside the forest during this study. Villagers also consume insect larvae, grilled or fried, of *andretra* (the clove leaf miner, lepidoptera *Chrysotypus mabilianum*) and *olipohy*. According to locals, these larvae are typically found in dead trees, and palm trees were normally cut and left on the ground to extract larvae afterwards. These larvae are said to have become increasingly rare, together with palm trees. On 6 July 2018, three snares were found on a log bridge connecting trees along an existing forest trail (Fig. 3). Snares and runways were placed at 73-82cm above the ground. Each snare was set with a noose made from bicycle brake cables. In the center of the three-headed trap, guava (*Psidium* sp.) fruits were set as a lure. Medium-size species from the Lemuridae family were possibly the targets of these traps and feathers of the blue coua (*Coua caerulea*) were found nearby.

Fig. 3: The three-headed trap found in the Vohimana forest. Photo: A. Anania

Discussion

Lemur inventory

Vohimana appears to be home to 11 lemur species, one more than previously reported in the literature (Westra, 2005; Garbutt, 2007; Mittermeier *et al.,* 2010; Deguette, 2011). Vohimana lemur richness is typical of the center of endemism No. 2 (per Wilmé *et al*., 2006), located north of the Mangoro river and south of the Bemarivo river. The forest has similar species richness to Mantadia (11 species) and lower than Analamazaotra-Andasibe forests, Maromizaha, Ambatovy-Analamay (12 species) and Torotorofotsy (13 species) (Mittermeier *et al.,* 2010; Ralison, 2010; Rakotondratsimba *et al.,* 2013; Ralison *et al.,* 2015).

Despite one local guide's report, we found no evidence of the black-and-white ruffed lemur presence. This species, an obligate frugivore, is particularly sensitive to fruit availability and habitat degradation (Balko and Underwood, 2005) and is among the first lemur species to become locally extinct due to habitat degradation (White *et al.,* 1995). Black and white ruffed lemurs still occur in the nearby Maromizaha and Mantadia forests and they were reintroduced in the Analamazaotra Special Reserve after their extirpation by the mid-1970s (Day *et al.,* 2009; Ralison *et al.,* 2015). In the Andasibe area, this species is particularly threatened by tavy and other forest exploitation activities (Rasoamanarivo *et al.,* 2015). Despite ruffed lemur call rate peaking around 7am.; the survey timing was compatible with their loud call choruses evenly distributed during the day (Geissmann and Mutschler, 2006). Therefore, ruffed lemurs are likely to be locally extinct in Vohimana. We also found no evidence of the presence of the greater bamboo lemur (*Prolemur simus*), which is present in the area close to Torotorofotsy wetlands, in the Andasibe area (Dolch *et al.,* 2008), and whose presence in Maromizaha was reported (Rakotosamimanana *et al*., 2003) and then controverted (Ralison *et al.,* 2015).

The presence of the rare and little studied hairy-eared dwarf lemur was confirmed in Vohimana (Garbutt, 2007), also present in the Analamazaotra Special Reserve and Forest Station, in Ambatovy-Analamay, Torotorofotsy, Mantadia, and Maromizaha (Ralison, 2010; Biebouw, 2012; Rakotondratsimba *et al.;* 2013; Ralison *et al.,* 2015). The only observation of this species may be due to the fact that this species is hard to distinguish from *Microcebus* in night field conditions (Mittermeier *et al.,* 2010).

Our indirect evidence suggests that in Vohimana, *Cheirogaleus* apparently hibernates earlier (early May) and emerges earlier (early August) than in Tsinjoarivo forest (males hibernate from late May to mid-September, females from mid-late June to mid-September; Blanco *et al.,* 2010) and in Ranomafana National Park (from May to late September; Wright and Martin, 1995). Recent molecular analysis revealed the presence of furry-eared dwarf lemurs in most forests sites around Vohimana (Andasibe, Mantadia, Torotorofotsy, Maromizaha; McLain *et al.,* 2017), but as in the nearby Torotorofotsy area the presence of both greater dwarf lemurs and hairy-eared dwarf lemurs was reported based on field surveys (Rakotondratsimba *et al.,* 2013), further morphological and genetic analyses may help to confirm the taxonomic identity of the observed *Cheirogaleus* species in Vohimana.

The presence of the elusive aye-aye was only indirectly detected through the observation of bite marks. As teeth marks or the staggered cutting that normally comes from the gnawing are not evident, the identification of the second mark is doubtful and it may be from a burrowing insect (M. Aylward, *pers. comm.*). However, we note that aye-aye foraging on the deadwood of *Chrysophyllum* sp. from eastern Madagascar is reported in the literature (Thompson *et al.,* 2016).

Threats

The observations of all cathemeral and diurnal species (except the indri) were scarce. We suggest that these species may be threatened by hunting. In Vohimana, a brown lemur was observed with a cord tied to its foot in 2011 (Deguette, 2011). The report of a trap confirms that hunting is still an ongoing phenomenon in the area. Similarly, traps have been found in the Bevoloto forest, north of Mantadia, in 2018 (A. Massagli, *pers. comm.*) and in Maromizaha in 2014 (A. Anania, *pers. obs.*) and 2015 (V. Torti, *pers. comm.*). In Maromizaha, hunting is probably a major factor affecting the populations of black and white ruffed lemurs, brown lemurs and red-bellied lemurs (Ralison *et al.,* 2015). According to a survey in the Andasibe area (Jenkins *et al.,* 2011), *Eulemur* species, diademed sifakas, *Microcebus* sp.; *Cheirogaleus* sp.; *Lepilemur* sp. and eastern lesser bamboo lemurs have been consumed by more than 40% of respondents in their lifetime and black-and-white ruffed lemurs and greater bamboo lemurs have been consumed by more than 20% of respondents. The brown lemur was ranked one of the top five most preferred meat by 19% of respondents to the interview. The fact that the indri was the most frequently observed lemur may be linked to the traditional taboo, which is likely to ensure the protection of this species amongst the Betsimisaraka and Tsimihety communities (Thalmann *et al.,* 1993; Britt *et al.,* 1999). However, there is evidence that adherence to this taboo is eroding in the Andasibe area (Jenkins *et al.,* 2011). In that area, hunting is practised for family subsistence, but one should not forget that only in February 2018 in a forest in the Andasibe region, nine indris and one diademed sifaka had been killed allegedly to be sold in a restaurant in Toamasina (Schwitzer, 2018).

In eastern Madagascar, slash-and-burn agriculture is a traditional and deeply rooted practice, being bound to spiritual meanings (Hume, 2006), and represents the major cause of deforestation and ecosystem degradation (Styger *et al.,* 2007). In Vohimana, a recent study (Klanderud *et al.,* 2010) showed that tavy decreased plant species richness and affected species abundance and composition. Its intensity was demonstrated to influence the natural succession and recovery of the forest ecosystem, which is overall very slow, taking much more than 30 years to recover towards secondary forest formations (Styger *et al.,* 2007; Klanderud *et al.,* 2010). Tavy, charcoal production, and hard-wood logging likely constitute the major threats faced by the Vohimana forest. However, habitat loss and degradation are presently contained, and recovering forests have the potential for supporting lemur communities (Knoop *et al.,* 2018; Miller *et al.,* 2018).

Conclusion

Vohimana is home to two critically endangered (the indri and the diademed sifaka), one endangered (the aye-aye) (IUCN, 2014), and two poorly known (the hairy-eared dwarf lemur and *Cheirogaleus* sp.) species. The forest has good potential for ecotourism and research thanks to its easy accessibility, the opportunity of night walks, and the fact that the indri, the eastern woolly lemur and the Goodman's mouse lemur are relatively easy to observe. Despite the efforts developed by forest managers to enhance rural development and ecotourism and their actions of reforestation and rule enforcement, the forest still faces a certain number of threats. The absence of black-and-white ruffed lemurs and the rarity of diademed sifakas and of all Lemuridae species are clues that the lemur communities likely suffer from anthropogenic pressure. The observations of snares, timber extraction, and charcoal production within the reserve recall that urgent actions such as long-term monitoring, increased patrolling, environmental education programs, and further reforestation efforts are required to protect this ecologically strategic ecosystem. It would further benefit from the reintroduction of the recently disappeared species, from close localities (translocation) or through the creation and maintenance of forest corridors between Vohimana, Maromizaha and Mantadia. Although the last point seems challenging, it represents the key to the long-term flora and fauna conservation of the area.

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Evaluating the behaviour of captive lemurs in a mixed-species enclosure as an indicator of welfare

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Abstract

Mixed-species enclosures have been increasingly adopted by zoos and animal parks as a means to improve both the welfare of captive animals and the experience of visitors. A larger and more stimulating environment is expected to benefit the welfare of its inhabitants. However, unnatural species associations and/or interactions with human visitors risks inducing stress likely to manifest as an increase in negative behaviour such as aggression, stereotypy or reclusiveness. Here we investigated the intra- and inter-specific behaviour of lemurs living in a mixed-species enclosure at Howletts Wild Animal Park, UK. The enclosure housed three species: black-and-white ruffed lemur (*Varecia variegata*), red-bellied lemur (*Eulemur rubriventer*) and crowned lemur (*Eulemur coronatus*). The wild distributions of black-and-white ruffed lemur and red-bellied lemur broadly overlap in the eastern rainforests of Madagascar while the crowned lemur does not occur sympatrically with either species, being restricted to forests in the north-west of Madagascar. We recorded the behaviour and location of each individual over a period of 35 days using both continuous and scan sampling methods. Negative interactions such as aggression were rarely observed, but when they did occur were more likely to occur between individuals of the same species. Since the general lack of negative behaviours does not appear to be dependent upon species segregation within the enclosure, we conclude that the welfare benefits of the enclosure in

this particular case appear to outweigh any potential risks of housing multiple species together.

Introduction

Due to the challenges associated with conserving many rapidly declining species through *in situ* conservation methods, zoos have been established as a form of *ex situ* conservation with the aim of breeding and reintroducing species back into the wild (Lees and Wilcken, 2008; Brown, 2014; Attard *et al*., 2016), although there are significant limitations to the effectiveness of captive-breeding as a conservation tool (Snyder *et al*., 1996; Pastorini *et al*., 2015). A major issue for captive-breeding programmes is that keeping animals in captivity causes welfare concerns (Hosey, 2004). Spruijt *et al*. (2001) defined welfare as the balance between positive (reward, satisfaction) and negative (stress) experiences or affective states. However, welfare cannot be directly measured. This balance of positive and negative states can only be inferred. Therefore, to infer the welfare of captive primates one tool is to measure the positive and negative behaviours presented.

The use of mixed-species enclosures for holding primates in captivity attempts to outweigh any potential negative effects with the positive effects of shared enclosures. The mixing of species within an enclosure can increase activity levels and the social complexity can provide behavioural enrichment; however, this can also be a cause of stressful dominance relationships and competition which would have a negative effect on their welfare (Moberg and Mench, 2000; Kleiman *et al.,* 2010). Previous studies have shown that creating a mixed-species enclosure for three lemur species, black-and-white ruffed lemur (*Varecia variegata*), red-bellied lemur (*Eulemur rubriventer*), and red-fronted lemur (*Eulemur rufus*), resulted in an increase in diversity of play behaviours presented compared to when living in a single-species exhibit (Veasey, 2005; Kleiman *et al.,* 2010), suggesting that mixed lemur enclosures are beneficial for positive welfare. Another study found that by providing a carefully designed large mixed-species enclosure for capuchin monkeys (*Cebus apella*) and squirrel monkeys (*Saimiri sciureus*), which naturally co-occur for foraging benefits and to reduce predation risks in the wild, mildly aggressive interactions were reduced between species (Leonardi *et al.,* 2009). Daoudi *et al.* (2017) later found that creating this mixed-species enclosure may not be cognitively enriching for the individuals, but provided cognitive challenges that otherwise would not be available in captivity, enhancing individual welfare. These beneficial cases arose from housing species which naturally co-occur together. Housing species which do not naturally co-occur could conceivably have negative welfare impacts.

The current study was undertaken in a relatively large, open-top, mixed-species walk-through enclosure with three lemur species, two of which naturally occur together, black-and-white ruffed lemur and red-bellied lemur, and one that does not, crowned lemur (*Eulemur coronatus*). The enclosure may be considered advantageous over a traditional zoo cage in that it provides greater space for individuals to roam around a more complex and natural, and therefore stimulating, environment; for example a previous study showed that stereotypic behaviours of red ruffed lemurs, were reduced following introduction to a larger enclosure (Garrison and White, 1993). However, the mix of species in a multi-species enclosure could potentially cause some welfare problems. Conversely, the relative complexity of the mixed-species enclosure may provide substantial behavioural opportunities for the species within, and thus improve welfare (Kleiman *et al.,* 2010). This study therefore aimed to infer the welfare state of the lemurs within the mixed-species enclosure by measuring the positive and negative behaviours presented.

Methods

Our study of a mixed-species lemur walk-through enclosure was undertaken at Howletts Wild Animal Park, Kent, UK. The enclosure comprised a large outside enclosure of 50m x 45m and four inside rooms (Fig. 1). One of the inside rooms was a large 8m x 4m room with a window to the public viewing area, the other three inside rooms were 8m x 2m. During the first round of observations (July-August 2015), the lemurs were excluded from entering the three smaller inside rooms, whilst during the second round of observations (December 2015-January 2016), they were able to access all four of the inside rooms.

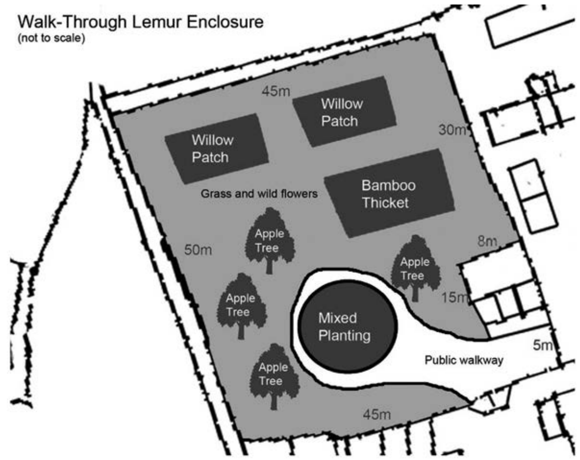

Fig. 1: Layout of the lemur walk-through enclosure at Howletts Wild Animal Park.

Within the enclosure there was one male black-and-white ruffed lemur, three male red-bellied lemurs and five crowned lemurs, comprising a monogamous pair and their offspring (two males and one female). The youngest crowned lemur was only three days old when observations started and was in constant contact with his mother throughout the study so was not included in the sample. Eight individual lemurs were used as the focal animals in this study. The unnatural group sizes and sex ratio for the black-and-white ruffed lemur and the red-bellied lemurs was thought to be a potential cause of stress and aggression within the enclosure.

Based on an initial 8-hour behavioural observation an ethogram was developed to define six mutually exclusive lemur behaviours (Tab. 1). Using instantaneous scan sampling (Martin and Bateson, 2007) the behaviour of every individual was recorded by a single observer (EB) every minute over a 30 minute interval, on six occasions a day between 9am and 4pm. These data were used to calculate time budgets for each individual. For social interactions the identity of the other individual(s) were recorded to assess the frequency of inter- vs intra-specific interactions.

During the first phase of the study behavioural observations were repeated for a total of 26.5 non-consecutive days between July 20th and August 31st 2015, totalling 80 hours of behaviour based data collection, 10 hours per lemur (n=13). To assess whether species segregate or associate in space initial behavioural observations were followed up with with a second study of eight non-consecutive days over the period of 20th December 2015- 8th January 2016. Using scan sampling the spatial position of every individual was recorded every 5 minutes over 30-minute periods, where position was defined as one of 19 defined quadrants within the enclosure.

Tab. 1: Ethogram of observed behaviours

Behaviour	Type of interaction	Definition
Grooming*	Positive	Licking, biting or picking at fur
Sitting in proximity	Positive	Sitting on the same branch or parallel branch with another individual
Sitting in isolation	Negative	Sitting alone
Aggression*	Negative	Presentation of aggressive sounds or physical interactions
Huddling	Positive	Sitting, lying or sleeping pressed up against another individual
Playing	Positive	Running around the enclosure
Interacting with enrichment	Positive	Smelling, touching or playing with any enrichment provided in the enclosure

*Observed between species and genders, **Observed between species and individuals

Statistical analyses were conducted in MiniTab 17 Statistical Software. Two-sample *t* tests were used to compare samples among two groups (e.g. within and among species) and one-way ANOVA was used to compare samples within three groups or more (e.g. quadrants). Chi Square tests were used to compare expected vs. observed total number of observations for aggressive acts, and species co-occurrence in quadrants in the enclosure.

Results

In total 620 observations were made of each individual lemur, making a total of 4,960 observations of behaviours across the study period. For the crowned and red-bellied lemurs the majority of interactions occurred within their own species. The highest number of inter-species interactions occurred between the black-and-white ruffed and crowned lemurs (Fig. 2).

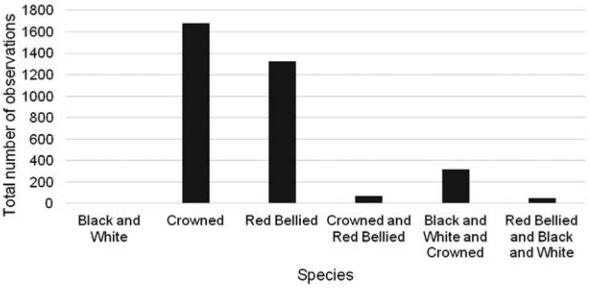

Fig. 2: The total number of interactions that occurred within and between each species. An interaction is any behaviour or activity that involves another individual.

Positive Behaviours

Positive behaviours occurred more frequently than negative behaviours and for longer durations for the red-bellied and crowned lemurs, whilst the single black-and-white ruffed lemur spent most of his time sitting in isolation (Fig. 3). Positive social interactions were more frequent among individuals of the same vs. different species in four out of five behaviours (Fig. 4); grooming (t=4.72, *p*<0.001, DF=13), sitting in proximity (*t*=3.14, *p*<0.001, DF=11), huddling (*t* =9.72, P<0.001, DF=6) and interacting with enrichment (t=10.3, *p*<0.001, DF=8). However, playing occurred at similar rates within and between species (Fig. 4), and was not statistically different (t=0.29, *p*>0.1, DF=10).

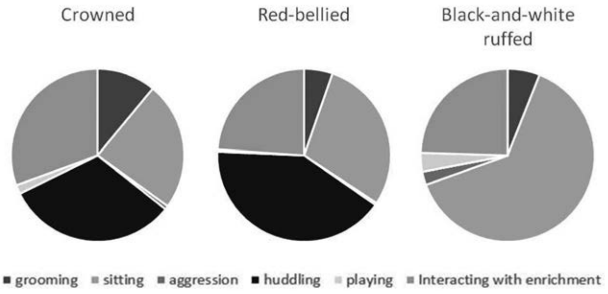

Fig. 3: The percentage of time spent on each behaviour during observation. Positive behaviour includes grooming, sitting in proximity, huddling, playing, interacting with enrichment. Negative behaviours include sitting in isolation and aggression.

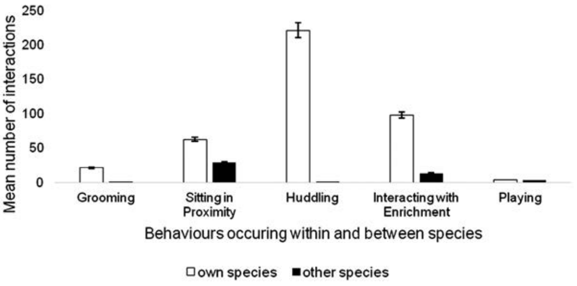

Fig. 4: Mean number of overall positive social interactions occurring within and between species over the whole observation period. The error bars plotted on this graph are demonstrating the 95% confidence intervals.

Negative Behaviours

The black-and-white ruffed lemur spent a significantly greater proportion of his time sitting in isolation (43.5%), than the red-bellied (15.6%), or the crowned (10.2%) lemurs (*F*=5.96, *p*=0.047). Lemurs over seven years old spent more time sitting in isolation than young lemurs (*F* = 11.26, *p*<0.001). The two crowned lemur females were the only females within the enclosure, and spent little time in isolation.

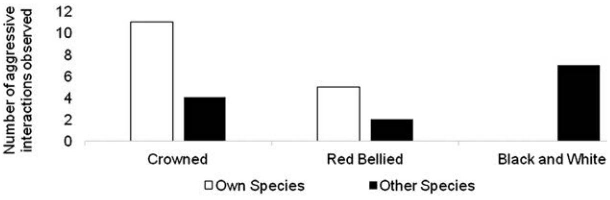

Fig. 5: Total number of aggressive interactions observed

There were very few acts of aggression observed throughout the study period (n=29; Fig. 5) and of those that occurred among just the crowned and red-bellied lemurs the majority were between members of the same species (16 of 21), although this was not significantly different to the null expectation of random interactions based on the numbers of individuals for each species (χ^2=0.267; p>0.1).

Spatial association between species

There was a statistically significant effect of quadrant in the mean percentage of time spent within each quadrant, showing that utilisation of space in the enclosure was not random (*F*=8.79; *p*<0.001). Moreover we found that individuals of different species occurred together in the same quadrant re often that we would expect by random chance (Fig. 6; χ^2 =159.406, *p*<0.001).

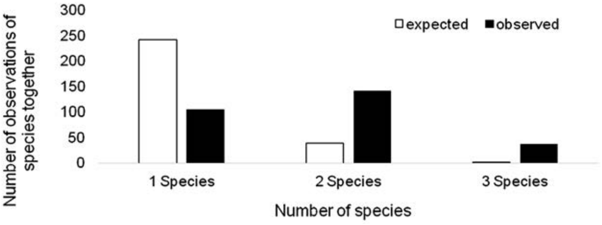

Fig. 6: Expected and observed number of observations of species co-occurrence in different quadrants of the enclosure.

Discussion

Generally, interactions occurred more within a species than between species. This reflects observations in the wild that suggest polyspecific interactions are naturally rare between lemurs (Freed, 2007; Eppley *et al.,* 2015). Interspecies interactions did occur in this study, most frequently between the black-and-white ruffed lemur and the crowned lemurs. This may be due to the crowned lemur juveniles being captive-born into that environment, and to the black-and-white ruffed lemur being alone, therefore seeking the company of others. It is thought that due to the red-bellied lemurs being an all-male group, they were more submissive than other species due to the presence of two females within the crowned lemur group. Interspecific interactions were the lowest for this species, occurring mainly with the black-and-white ruffed. In the wild, male lemurs consistently express submissive behaviours toward the females for all behavioural traits (Pochron *et al.,* 2003). Interactions between adults occurred at a higher rate, closely followed by both adults and juveniles, demonstrating that all ages interacted together. This is vital for juveniles as they learn from conspecifics within their groups, and from non-maternal adults to learn gender-appropriate behaviour from the same sexed adults (Pereira and Fairbanks, 2002). This also benefits the non-maternal adults within the group as alloparenting has been seen across primates to increase the success rate for their first live-born infants (Fairbanks, 1990; Förster and Cords, 2005).

Positive Interactions

All individuals demonstrated positive behaviours most of the time, showing that the lemurs' welfare did not appear to be compromised during this study because animal welfare is assessed on the balance of positive and negative states (Spruijt *et al.,* 2001). Positive behaviours occurred most frequently within species, with grooming occurring almost exclusively intra-specifically. This is to be expected as grooming is used to reaffirm bonds within social groups (McPherson, 2013). However, there was one anomaly for interspecific grooming which occurred between the juvenile female crowned lemur and one of the red-bellied lemurs, suggesting a potential polyspecific bond which has been noted in the wild between crowned lemurs and Sanford's lemur (*Eulemur sanfordi*) (Freed, 2007). There was no interspecific huddling witnessed, however intra-specific huddling is highly beneficial for maintaining thermoregulation and to reaffirm family groups and social bonding (Gilbert *et al.,* 2009).

The only behaviour to occur at similar rates within and between species was playing, demonstrating that individuals are positively interacting with one another which can increase the individuals' mental and physical health (Kleiman *et al.,* 2012). There was a high level of group playing, with play behaviours most frequently occurring towards both males and females, and adults and juveniles, at the same time. This is a good sign as it shows that playing occurs through all the ages and genders, therefore demonstrating that individuals are mentally stimulated within the enclosure. Other studies suggest play can lead to a reduction in aggression between captive individuals, promoting a more positive interaction environment (Palagi, 2009). In contrast, adults playing in their natural environment is a rare observation, suggesting that this could be a learnt behaviour for coping mechanisms to captivity (Pochron *et al.,* 2003).

Overall, the lemurs were seen to seek out company with one another, and this was not due to the enrichment provided. This is a positive interaction as it demonstrates interspecies tolerance without any negative signs of stress to the other species within the enclosure. It is common for captive primates to seek the company of other captive primate species, however it is rarer for species that do not naturally cohabit to do so; social aggregation in lemurs could be due to their close taxonomic relationship and being social species (Visalberghi and Anderson 1993; Pearson *et al.,* 2010; Macdonald and Whiten, 2011; Kleiman *et al.,* 2012).

Negative Interactions

Aggressive interactions occurred more within a species than between species, which was perhaps surprising. However, aggression between species is more likely to happen with very distantly related species, as such species may not understand the submissive and antagonistic behaviours presented (Kleiman *et al.,* 2012). Therefore, the close taxonomic relationship of the species in this enclosure could be a beneficial factor when considering the low level of aggressive interactions between them. Aggression was directed more towards males than females, perhaps unsurprisingly as female-dominance is a feature of most lemur species (Pochron *et al.,* 2003). However, the unnatural sex ratio and species group sizes may have affected this during our study. Furthermore, the aggressive occurrences observed were only minor aggression; no individual drew blood or had a serious aggressive interaction, they were mostly interpreted as warning signals. Some aggressive encounters were due to competition for food, despite enough food being provided. This is to be expected of species with the same mixed diet and has been witnessed across all lemur species (Dammhahn and Kappeler, 2009). All aggressive encounters were followed by immediate reconciliation, as seen in other captive lemur species, therefore were not considered to be a cause for concern (Kappeler, 1993; Palagi *et al.,* 2005).

The single black-and-white ruffed lemur spent the majority of his time sitting in isolation, and was the only lemur in the enclosure to spend more time exhibiting negative than positive behaviours. Due to lemurs social behaviours and the importance of group sizes on their individual fitness, isolation can be considered a welfare concern and therefore as a negative behaviour (Baden *et al.,* 2016). In our study this is an individual-specific case due to the presence of just one individual of this species during our study; previous work has shown that a group of captive black-and-white ruffed lemurs at Woburn Safari Park expressed more play behaviours once moved into a mixed species enclosure with red-bellied and red-fronted lemurs (Kleiman *et al.,* 2012). It should be noted that the male black-and-white ruffed lemur in our study was to be subsequently paired with an incoming female from another zoo.

Conclusion

Most behaviours observed during this study were considered to be positive behaviours. This, coupled with the general lack of negative behaviours observed, despite the three species showing a tendency to associate spatially, suggests that the welfare benefits of this mixed-species enclosure outweigh the potential risks of housing multiple species together.

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Birthing behavior of Verreaux's sifaka (*Propithecus verreauxi*): Accounts of two births at Bezà Mahafaly Special Reserve, southwest Madagascar

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Keywords: sifaka, *Propithecus verrauxi*, birthing behaviour, parturition

Abstract

Verreaux's sifaka (*Propithecus verreauxi*) is a well-studied species of lemur, yet there is very little published information on behavior during parturition. During our focal observations of sifakas at Bezà Mahafaly Special Reserve (BMSR) in July 2017 we witnessed two births, both strikingly similar in terms of the mother's behavior, physical position during labour and birth, and time of day. We recorded behavioral data for each mother during the birthing period using a combination of continuous and *ad libitum* sampling. The two females, belonging to two different social groups in the sustainable use zone of BMSR, had each given birth to surviving infants the previous year (2016). Both births occurred about 8-9 m above the ground in a tamarind tree (*Tamarindus indica*) in the afternoon (between 14:30 and 16:00hrs) as the other individuals in the group were settling into their sleeping tree for the night. The mothers showed visible signs of discomfort pre-partum lasting between 20 and 30 minutes, ending when the mother pulled the neonate from the birth canal. Each mother then spent about three minutes cleaning the neonate before it moved up her chest to nurse. While the infant nursed, the mothers consumed the placenta and umbilical cord – a process which lasted approximately 38 minutes. These data increase our knowledge of sifaka natural history and may also be of assistance to conservation practitioners seeking to protect critical resources for this endangered species.

Résumé

Propithecus verreauxi ou sifaka est une espèce de lémurien bien connue, cependant peu d'informations sont publiées sur le comportement de mise bas. Pendant les "*focal observation*" de *P. verreauxi* dans la Réserve Spéciale de Bezà Mahafaly (RSBM) en Juillet 2017, deux naissances ont été observé lesquelles étaient remarquablement similaire en termes de comportement de la mère, position physique pendant le travail et la mise bas ainsi que l'heure. Les données comportementaux ont été enregistré pour chacune des mères pendant l'accouchement en utilisant la combinaison de la "*continuous*" et "*ad libitum sampling*". Les deux femelles appartenant à deux groupes sociaux différents de *P. verreauxi* dans la zone à utilisation durable de la RSBM ont déjà chacune données naissance à des enfants qui ont survécu l'année précédente (2016). Les deux naissances ont été observés aux alentours de 8 et 9 m au dessus du sol sur les branches de *Tamarindus indica* vers l'après-midi (entre 14:30 et 16:00h) quand les autres individus du groups s'installaient pour dormir. Avant l'accouchement, les deux mères ont montré des signes de malaise durant à peu près 19 et 30 minutes respectivement qui se terminait après avoir expulsés les nouveaux nées. Chacune des mères ont alors passé à peu près trois minutes pour les laver avant qu'ils montent pour téter. Pendant que l'enfant tétait, leurs mères ont consommés le placenta et le cord ombilical-un processus qui dure près de 38 minutes. Ces données enrichissent la connaissance sur l'histoire naturelle de sifaka et fournissent des informations qui seraient nécessaires en vu de la protection des ressources critiques pour cette espèce en danger d'extinction.

Introduction

Accounts of wild primate births are rare and knowledge of Strepsirhine birthing behavior is especially lacking. It has long been thought that most wild primates give birth at night or early in the morning (Jolly, 1973), but a growing literature details observations of births during the day, especially in Old World monkeys (e.g. Gorzitze, 1996; Brogan and Cords, 2010; Turner *et al.,* 2010; Pan *et al.,* 2014; Yang *et al.,* 2016) and apes (e.g. Douglas, 2014; Fujisawa *et al.,* 2016). Verreaux' sifaka (*Propithecus verreauxi*), an endangered lemur species, is iconic to southwest Madagascar. Despite extensive studies at several long-term research sites (Jolly, 2012; Kappeler and Fichtel, 2012; Richard *et al.,* 2016; Leimberger and Lewis, 2017), only one published record of parturition behavior exists (Richard, 1976). This article is an account of two sifaka births observed during a large study of sifaka behavioural ecology at Bezà Mahafaly Special Reserve (BMSR).

Methods

We collected data on sifaka birthing behavior as part of a larger study of sifaka behavioural ecology at BMSR (Fig. 1). During observations, in 2017, we observed two females giving birth. The mothers, "Mama" and "Atody", are both multiparous females of unknown age living in the recently protected sustainable use zone of BMSR. Both Mama and Atody gave birth to surviving infants in 2016 and also had offspring in 2018, suggesting that they are relatively experienced and successful females (Richard *et al.,* 2002).

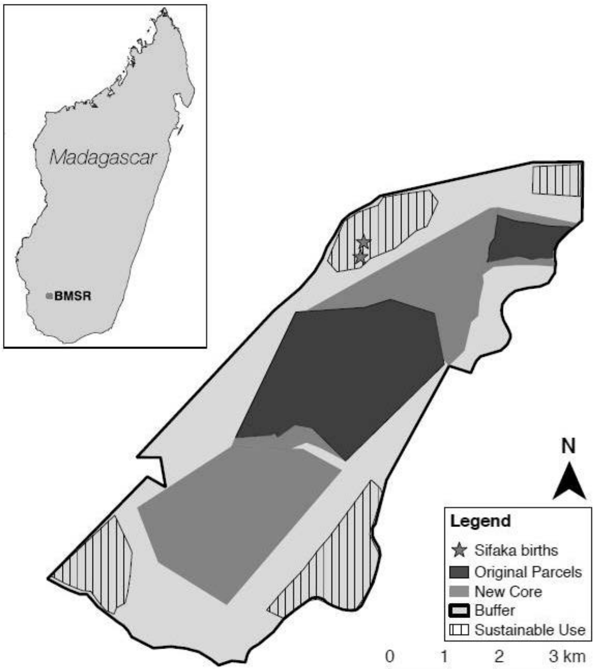

Fig. 1: Map of Bezà Mahafaly Special Reserve (BMSR) zonation with the locations of the two observed sifaka births marked by a star.

Normally, we recorded continuous data on an individual for 20 minutes and rotated through group members throughout the day. We started collecting focal data for Mama during a regular 20-minute focal, but continued data collection past this period because she was acting 'strangely', leading us to suspect she was in labour. We began collecting data on Atody when she started behaving in a similar way to that which had been observed with Mama. In both cases, we continued collecting data throughout labour and birth, stopping only after the mother finished consuming the afterbirth. We recorded data using the Animal Observer application on iPads following our continuous behavioral data protocol, supplemented by written notes on behaviors not included in our regular protocol.

Results

Both births were similar in terms of the mother's behavior pre- and post-partum, time of day, duration, and physical position (Fig. 2). Both births occurred in mid-July during the afternoon (between 14:30 and 16:00hrs) as the other individuals in the group were settling into their sleeping tree for the night. Both females remained approximately 8-9 m high in a tamarind tree (*Tamarindus indica*), where their group was sleeping, during labor and birth.

Pre-partum stage

The pre-partum stage was characterized by the female frequently changing position, licking her vaginal area, rubbing her ano-genital region on a tree branch, and head tossing (a behaviour indicative of distress or disturbance where

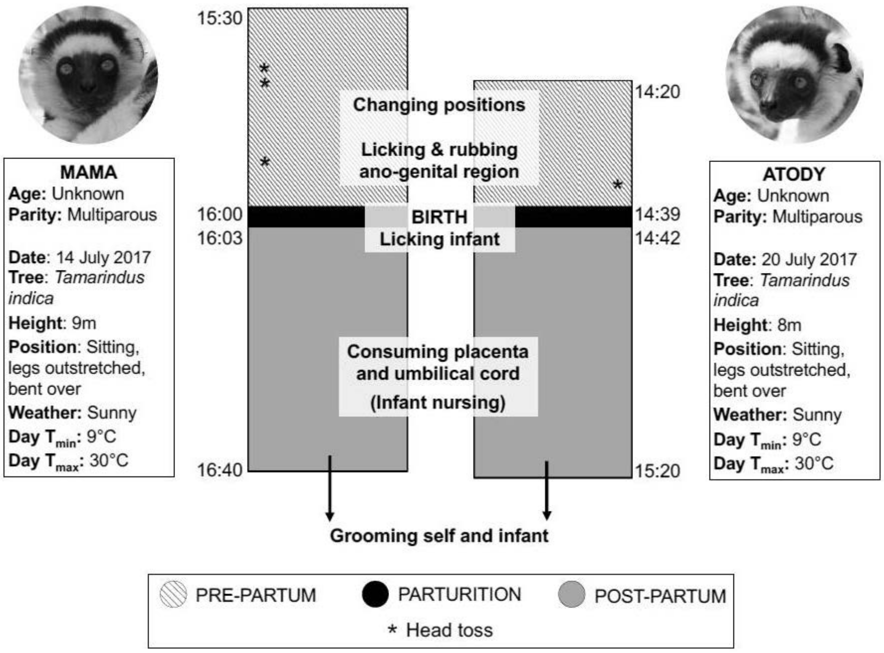

Fig. 2: Overview of the timing and conditions of the two sifaka births observed.

the sifaka throws its head back quickly and then returns to a neutral position). During the pre-partum stage, there were no visible signs of contractions and no audible vocalizations, except for one loud exhalation by Mama several minutes prior to parturition. Both females remained in the same tree as other group members during this phase, but were 2-3m removed from the nearest conspecific. None of the individuals in Mama's group approached her or seemed to acknowledge her unusual behaviour. In Atody's case, her one-year-old daughter approached during the pre-partum stage, seeming very curious, but Atody cuffed her and she retreated several meters away. After 20-30 minutes, the females positioned themselves on a forked branch with their legs outstretched.

Parturition

In both cases, the birth happened very quickly. It was a matter of minutes from when we observed the first signs of clear viscous liquid (presumably amniotic fluid) coming out of the female's vagina to when the neonate was pulled out of the vaginal canal by the mother. There were no visible signs of blood and no audible sounds were made by the mother or neonate.

Post-partum stage

After being licked by the mother for several minutes, the newborn climbed up to her nipple and began nursing. While the infant nursed, the mother delivered the placenta, which she held and kept carefully balanced in her lap as she consumed it. The process of consuming the afterbirth lasted nearly forty minutes in each case. As far as we could tell, both mothers consumed the entire placenta, followed by the umbilical cord, as there were no remains on the ground or in the tree following the birth. After the female finished consuming the afterbirth, she carefully groomed herself and the infant. Once Atody finished this process and was grooming herself and her new infant, her young daughter approached again and this time was allowed to look at and smell the neonate for several minutes. No group members were observed approaching Mama following the birth of her infant.

Discussion

Both births observed were very similar in terms of the mothers' behavior pre- and post-partum, the amount of time they were observed in each of the phases, and their physical position during birth. These observations are similar to the other published record of a sifaka birth, in which the female gave birth on a wide horizontal branch about 15m from the ground in the mid-afternoon after approximately 40 minutes of licking her ano-genital region (Richard, 1976). It has long been assumed that diurnal lemurs give birth primarily at night (Jolly, 1973), but daytime births may in fact be common: our team has now observed multiple day-time births (including six noted by Bezà Mahafaly monitoring team members on which no systematic behavioural data was collected). The mothers' behavior during the process is relatively inconspicuous, and day-time births may simply have been overlooked in the past.

These compiled observations also suggest that tall trees, like tamarinds, with significant canopy cover are important locations where females are relatively safe giving birth. Tamarind trees stand out amongst other dry forest tree species because they sustain thick canopy cover through the dry sifaka birth season (July-August), providing females with protection from aerial predators during parturition as well as the structural support necessary to give birth safely off the ground. While observations of lemur birthing behaviour are likely to remain rare, parturition is a key event in primate life histories and it is important to consider the data available, even though these are very limited, in our efforts to improve lemur research and conservation. For example, prioritizing protection of old growth trees that provide sifakas (and likely other lemurs) with relatively safe spaces in which to give birth could play a significant role in safeguarding lemur survival and reproduction.

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Indications of a potential alarming population decline in the golden-brown mouse lemur (*Microcebus ravelobensis*) in a long-term study site in the Ankarafantsika National Park

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Key words: *Microcebus ravelobensis,* Ankarafantsika National Park, abundance, population decline

Abstract

Recent capture-recaptures of the endangered mouse lemur species (*Microcebus ravelobensis*), at the long-term study site Jardin Botanique B in the Ankarafantsika National Park (about 1km away from the park headquarters in Ampijoroa), point to a decline in population size. In order to assess long-term fluctuations of mouse lemur abundance in more depth and to determine the potential beginning of the decline, capture data of the golden brown mouse lemur were analysed over a period of 20 years from 1996 – 2016. Monthly population sizes were estimated by the Jolly-Seber method, and absolute capture results per trapping night were taken as another proxy of abundance. Both the nightly capture frequencies and the calculated population sizes, show monthly and yearly variations but suggest a relatively constant number of animals until 2010 with high capture success (>40 animals/night) in August/September 2010, and a decreasing capture success down to less than ten animals/night in September 2016. The same applies to the calculated population size that declined from 52 in September 2010 to 13 in September 2016. No obvious relationship could be identified between the population size and rainfall or temperature dynamics, although a temporal effect of a severe cyclone in 2011 cannot be excluded. Intensified human use of the forest, e.g. for wood exploitation or hunting during times of political instability, or reduced monitoring activities are further likely explanatory variables. This potential decline of an endangered Malagasy mouse lemur calls for immediate attention, and we suggest the implementation of a long-term monthly population monitoring program in addition to protective measures such as routine patrolling activities. These should, if necessary, lead to law enforcement actions in the area to prevent further illegal human activities in the forest.

Introduction

The endangered golden-brown mouse lemur (*Microcebus ravelobensis)*, was described for the first time 20 years ago (Zimmermann *et al.,* 1998) and is limited to the dry deciduous forests between the large rivers Betsiboka and Mahajamba in northwestern Madagascar (Olivieri *et al.,* 2007). The largest remaining forest block in this region is the Ankarafantsika National Park. Since the beginning of a long-term study in Ampijoroa (Zimmermann *et al.,* 1998; Kappeler *et al.,* 2017), population dynamics of golden-brown mouse lemurs in the Ankarafantsika National Park were assessed at two study sites, Jardin Botanique A (JBA) and Jardin Botanique B (JBB). Recently, routine capture procedures suggested a decline of golden-brown mouse lemurs at one of these sites, JBB. The aim of this study is to investigate the population fluctuations of GBML at this site over the last 20 years and to explore some potential determinants for the observed fluctuations.

Methods

Study site

The data for this study were collected at the long-term study site Jardin Botanique B (JBB) in the Ankarafantsika National Park in northwestern Madagascar (16°15'S 46°48'E, 89m asl). JBB is located next to Lake Ravelobe close to the National Route 4 and is accessible via a 5.1ha large rectangular grid of small trails intersecting every 25m. Based on long-term records from the Durrell Wildlife Conservation Trust, the average yearly rainfall of about 1500mm is mostly limited to the rainy season between November and April. Minimum temperatures can drop to about 13°C at night in June and can increase to about 40°C during the daytime in October/November.

The vegetation of JBB has been categorized as a mix of dry deciduous forest and gallery forest which can be partly flooded during the rainy season (Sehen *et al.,* 2010). The forest is partially degraded due to past and present anthropogenic activities including a bushfire in 1983. The forest contains several introduced tree species, such as *Tectona grandis* and *Mangifera indica* (Sehen *et al.*; 2010). In addition to golden-brown mouse lemurs, larger species (e.g. fat-tailed dwarf lemur, *Cheirogaleus medius;* Milne Edwards' sportive lemur, *Lepilemur edwardsi*; western woolly lemur, *Avahi occidentalis*; Coquerel's sifaka, *Propithecus coquereli*;

brown lemur, *Eulemur fulvus* and mongoose lemur, *Eulemur mongoz)* have also been regularly observed at this site in former years (Zimmermann *et al*., 1998; Mittermeier *et al*., 2010) and the grey mouse lemur (*M. murinus)* has been occasionally captured in recent years (Klein, Radespiel, Zimmermann, unpubl. results).

Trapping mouse lemurs

Golden-brown mouse lemurs were trapped in JBB according to the routines described in Rendigs *et al*. (2003) with about 90 Sherman Live Traps (© Sherman, Tallahassee, FL, USA) per night baited with banana. Trapping took place during most dry seasons between 1996 and 2016 with a variable number of trapping months (n) across years (Tab. 1) and typically with three trapping nights per trapping month (mean 3.3 ± 0.8 SD, min: 2, max: 6).

Tab. 1: Number of trapping months (n) per year.

n = 0	n = 1	n = 2	n = 3	n = 4	n = 5	n = 6
2004	2013	2002	1996	1997	2001	1998
2012		2009	1999		2003	2000
2014		2016	2006		2008	2005
						2007
						2010
						2011
						2015

A total of 197 trapping nights were included for the analyses of population sizes between 1996 and 2015, and a total of 125 trapping nights were available to calculate the number of captured golden-brown mouse lemurs per night within the last 10 years, i.e.; between 2006 and 2016. Newly captured animals were marked subcutaneously with a transponder (Trovan ID-100 ©Telinject, Römerberg, Germany) and recaptures were thereby identified and noted on each capture day.

Data analyses

Capture-recapture data were used first to calculate population sizes per capture day for each year separately by means of the Jolly-Seber method that is suitable for open populations (Krebs, 1989). From this number we calculated the mean (±SE) monthly population sizes which were compared qualitatively across the years. The calculation is possible for all months except the first and the last in each year, i.e.; for June to September. As an additional indicator for population size fluctuations on a finer scale and applicable even in years with insufficient data for density calculations, absolute capture frequencies are presented and compared qualitatively for each capture night across the period between 2006 and 2016.

Results

The estimated population size of *M. ravelobensis* in JBB was relatively constant until 2008 ranging from 30-60 individuals in any given month despite some variations in the first four years (1996-1999) (Fig. 1). It reached its maximum in August 2010 with 63 individuals, after which the yearly minimum and maximum values decreased successively until 2015 (marked by arrows in Fig. 1). Whereas the population dynamics within each year probably reflect demographic changes driven by immigration, emigration and death, the yearly dynamics in maximum and minimum values are most likely the result of true population size changes. Another general result concerns the size of the standard error. Whereas it was relatively stable and small until 2003, it was substantially larger in some of the later years, in particular in June 2007 and in most of 2011.

The absolute capture results per capture night across the last 10 years revealed considerable fluctuations between zero and 45 animals (Fig. 2). Within a given year, capture numbers tended to increase from May to July/August and decreased towards October/November. The period of increase can most likely be explained by an increased attractiveness of traps with decreasing food availability in the environment in the course of the progressing dry season and by the arrival of new immigrants on site. Conversely, the period of decrease most likely reflects losses due to mortality and emigration across the dry season and a decreasing attractiveness of traps after the start of the first rain. The overall maximum number of individuals captured in one night (n = 45) was recorded in August 2010 (Fig. 2) which was also the month with the largest population size according to the Jolly-Seber method (Fig. 1). After this time point, trapping numbers per night decreased over the following years, illustrated best by comparable numbers from each subsequent September (Fig. 2). The maximum trapping number in September decreased from 44 in 2010 to 29 in 2011, 26 in 2015 and only seven in 2016 (all marked by arrows in Fig. 2). Moreover, there were almost no animals in the traps in the month May since 2011, which never happened to that extent in previous years.

Discussion

Our analyses of long-term capture data at one study site in the Ankarafantsika National Park revealed signals of a potential decline of golden-brown mouse lemurs in this forest part after 2010, with the daily maximum number of individuals trapped per night between 2010 and 2016 decreasing from 44 animals (September 2010) to 7 (September 2016). There are several explanations for these changing population dynamics.

Firstly, the population decline may be the consequence of changes in temperature and/or rainfall that may have changed food availability in the area. An inspection of the yearly fluctuations in the amount of rainfall and the average minimum and maximum temperature variations, however, revealed no clear directional trend between the years 2010 and 2016 (results not shown). We therefore deem this explanation to be unlikely but would like to point out that data on the yearly variations in resource availability across this period are not available.

Secondly, the forest may have been severely damaged locally by one or more cyclones transforming parts of JBB into unsuitable habitats for mouse lemurs. Indeed, an online cyclone database that is based on the analyses of satellite images, provides support for one severe cyclone in the area in 2011 (cyclone 'Bingiza') (US Navy, 2018). However, other cyclones touched the region in previous years and comparable long-term effects have never been observed before in this forest area. Moreover, no such decline in trapping numbers could be detected across the same time period at the second long-term study site (JBA) that is only 3km away from JBB (results not shown).

Thirdly, it is possible that the population decline is the result of increased human intervention in JBB that started shortly after the period of political instability in 2009. Since then, signs of human presence and traffic in the forest, e.g. in form of new and more holes dug to collect maciba (*Dioscoreaceae maciba*), enlarged trails, cut trees, cattle faeces, and even plastic waste have increased considerably (UR, AK, EZ pers. obs.). Furthermore, Illegal hunting is likely to

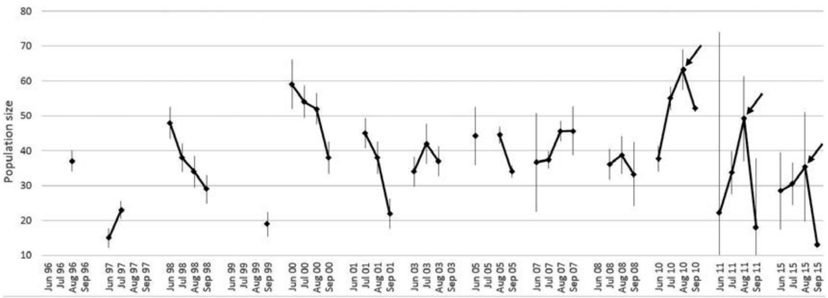

Fig. 1: Monthly mean (±SE) population sizes in JBB from 1996 – 2015 estimated by the Jolly-Seber method. The four possible months are displayed for all study years, although not all monthly data points are available for all years (see methods). A total of 197 trapping nights were included in this analysis. No population size data are available for the years 2002, 2004, 2006, 2009, 2012-2014, and 2016. Arrows point towards the maximum population size that was calculated for the month September between 2010 – 2015 (see text for explanation).

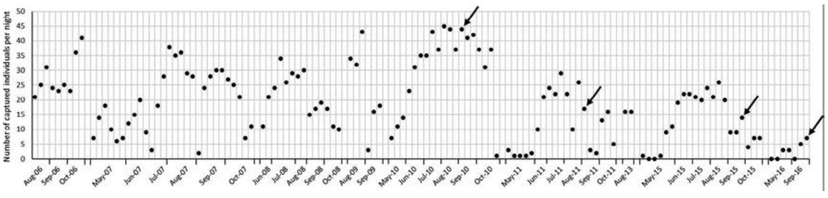

Fig. 2: Absolute number of individual M. ravelobensis captured per capture night in JBB from 2006 – 2016. Each dot represents the results of one trapping night. The number of dots per month varies due to variable capture effort across months and years. A total of 125 capture nights were included in this analysis. Arrows point towards the maximum number of captures that were made in the month September between the years 2010 – 2016 (see text for explanation).

have happened, since the larger lemur species seem also to have mostly disappeared from the site as well (UR, AK, EZ pers. obs.). Increased human presence could also be the result of illegal nocturnal fishing activities that were more frequent around Lake Ravelobe in recent years (AK, UR, EZ pers. obs.). The increased presence of humans in the forest and the associated safety risks even prompted Madagascar National Parks at the park level to prohibit any research work at night time in JBB in 2009 and this regulation was still in effect in 2016. In 2017 increased patrolling around Lake Ravelobe was initiated and facilitated by the local Durrell Wildlife Conservation Trust in order to monitor and thereby prevent illegal activities around Lake Ravelobe which is next to the study site (Durrell Wildlife Conservation Trust, pers. communication). Possible positive effects of this program on the lemur populations in JBB remain to be seen in the future.

Further activities to counteract the observed potential negative population trend are recommended. Firstly, it would be beneficial to install a monthly diurnal and nocturnal lemur survey program in JBB and possibly other highly frequented sites. This would benefit conservation purposes in two ways; based on our experience, the presence of a surveying team in the forest alone should lead to a reduction of illegal activities in the forest and the surveys will deliver actual population size estimates that can guide and inform further intervention strategies. Secondly, the forest should be regularly monitored by a group of rangers (e.g. 2-4 times per week) and/or by hidden camera traps to collect data on human traffic and illegal activities in JBB and surrounding stretches of forest. Those datasets could then be used by the National Park to plan law enforcement activities together with the police in the area.

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Tourism and lemurs: the fate of diurnal indriids at popular tourist destinations

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Keywords: dirunal indriids, indri, sifaka, tourism, captive facilities, best practice tourism

Abstract

The diurnal indriids are charismatic species which both foreign and domestic tourists visiting Madagascar enjoy seeing and photographing. Several popular tourist facilities in Madagascar have government permits to keep translocated indriids on premises. Our aims include understanding, broadly, how many indriids are translocated and kept at tourist facilities, how tourists interact with the animals, and what foods these folivorous lemurs may be provisioned with. We used photo sharing websites (Flickr, TripAdvisor, Instagram) to view publicly-shared photographs of indri and sifaka kept in captivity at eight tourist facilities in Madagascar. We also conducted site visits to four of these facilities between 2016-2018. We found 391 photographs of translocated indri and sifaka at tourist facilities, spanning the years 2004-2018, that included the following species: *Indri indri*, *Propithecus diadema*, *P. coronatus*, *P. verreauxi*, *P. deckenii*. With one exception, legal captive facilities are badly failing, as recently as 2018, to meet best practice standards for captive care of lemurs, and are in some cases wild-capturing lemurs to replace individuals that have died in their care. We also note that one facility is apparently able to keep indri in captivity for some period of time. We state unequivocally the importance for legal captive facilities to immediately begin implementing best practice standards, which include prohibiting human-lemur contact, ceasing the use of bananas to feed lemurs, and accurately reporting to the Government the number of lemurs in their care.

Introduction

The diurnal indriid primates (indri, sifaka) of Madagascar are extraordinarily charismatic and draw tourists from around the globe. However, the most recent IUCN Red List assessment elevated all diurnal indriids to Critically Endangered (not yet published). These animals have limited ability to survive captivity, likely resulting from intolerance to captive diet, and the associated changes that occur within gut microbiome (GMB) assemblages (see Zehr *et al.*, 2014).

Of the facilities within Madagascar that have legal permission to keep wild-captured lemurs (approximately 12 to 14 facilities across the country), eight have translocated indriids in captive and semi-captive conditions, or in small forest parcels (these are highly modified when compared to the animals' natural habitats). The lemurs kept at permitted facilities often interact with humans, even though human-lemur contact is not considered best practice for lemur captive care (Reuter and Schaefer, 2016), and the facilities' contracts with the Ministry of the Environment specifies that they prohibit direct contact between lemurs and tourists. Moreover, at some facilities, these folivorous lemurs consume significant proportions of non-natural dietary items, such as bananas. In the absence of a permit, it is illegal to extract from the wild, keep in captivity, and/or trade live lemurs (Reuter *et al.*, 2016). Permits for legal captive facilities typically specify the number of individuals, and species of lemur, that a facility is allowed to keep.

Very little information is known about the indriids being kept in legal captive facilities in Madagascar. Therefore, we aimed to understand the species and number of individuals living in legal captive facilities, the interactions they have with humans (including provisioning), and more about their captive care conditions.

Methods

We examined publicly-available photographs of indri and sifaka posted online in 2018 on Flickr, Trip Advisor and Instagram at eight facilities in Madagascar (Tab. 1). All of these facilities target international tourists as their primary clientele and have been given legal permission by the Madagascar national government to keep lemurs on premises. We only included photos that were geotagged to the locations of the eight facilities or clearly described as being taken there. Of note: for the Palmarium, we looked at photos posted online dated from 2004 to present-day. We visited the Palmarium and Lemurs Park in 2018 in person in the capacity as a researcher (ML) and as a tourist (KR), respectively. We report information gathered from these in-person visits, here.

Tab. 1: Eight legal captive facilities included within the scope of this study.

Name	**Location**	**Type of Facility**	**Price/Cost for Entry and or accommodation (€)**	**Author site visit**
Croc Farm	Ivato	Crocodile farm and restaurant	c. €3 entry fee	No
Kimony Resort	Morondava	Hotel with zoological park	€66/night for cheapest bungalow, c. €3 entry fee	May 2016
Lemuria Land	Nosy Be	Zoological and botanical garden	c. €11 entry fee for non-Malagasy visitor	No
Lemurs' Park	Imerintsiatosika	Zoological and botanical garden	c. €7 entry fee for non-Malagasy visitor	May 2016 Jan 2017May 2018
Nahampoana Reserve	Fort Dauphin	Reserve/nature park	c. €4 per person for entry and tour	No
Palmarium Hotel	Ankanin' Nofy	Hotel with reserve/nature park	c. €36/night for cheapest room (boat transport required) c. €12 entry fee to Aye-Aye island	July 2018
Peyrieras Reptile Reserve	Marozevo	Reserve/ nature park	c. €4 per person for entry and tour	No
Vakona Forest Lodge	Andasibe	Hotel with reserve/ nature park	€90/night for standard bungalow €6 entry fee for all visitors	May 2018

Results

Species kept in legal captive facilities

We viewed a total of 221 photos posted in 2018 by 130 unique social media users of indri and sifaka at eight legal captive facilities in Madagascar. The species pictured in tourism photographs can be found in Tab. 11. We list the species, and number of individuals, that each resort reported having in captivity to the *Ministère de l'Environnement, de l'Ecologie et des Forêts* (MEEF) in 2016 in Tab. 2.

Captive conditions

Infants were seen in photos taken at three of the locations, but juveniles and sub-adults were only seen in photos at two of the locations.

From the photos viewed, Lemuria Land appears to be the only location with caged sifaka; all other facilities have free ranging animals. Photographs evidenced that several resorts (Lemuria Land, Peyrieras, Palmarium) allow direct human contact with the animals and feed the animals bananas, presumably to entice them to interact with tourists; several photos from the Palmarium show tourists feeding indri bananas from their mouths (Fig. 1). Lemurs Park appears to be the only destination where tourists/guides do not directly interact with the sifaka, and also display signage noting that touching the animals is not allowed. Our visit to Lemurs Park in May 2018, in the capacity as a tourist, confirmed no human-lemur contact was condoned and tourists were escorted by a guide.

The Palmarium Reserve

We were able to view: 1) 37 photos of sifaka (*P. coquereli*), posted by 12 people between April of 2004 and December of 2016; and 2) 133 photos of indri posted by 46 people, from the Palmarium between April 2004 and June of 2019.

We visited the Palmarium in July 2018 in the capacity as researchers and were told by staff that all sifaka (Coquerel's) had died. Last photographs of these animals appeared online in December 2016. Seven indri (3 adult male/female pairs and one infant) were present, and staff noted a 2015 translocation of four adults from Ambalarondra, to replace animals that had died. At least one indri pair is able to reproduce at the Palmarium, but infant survivorship is unknown.

Tab. 2: Lemur species pictured in photographs taken by tourists at eight legal captive facilities in Madagascar. Notes on captive conditions are included, as well as the number of individuals that the facility reported having in captivity to the Ministère de l'Environnement, de l'Ecologie et des Forêts (MEEF) in 2016.

Location	**Social Media photos 2018**	**Human contact**	**Fed bananas**	**Number reported to MEEF in 2016**
Croc Farm (Ivato)	*Propithecus coquereli*	No*	No*	5
Kimony (Morondava)	*P. verreauxi*	Yes	Yes	0
Lemuria Land (Nosy Be)	*P. coquereli,* *P. coronatus,* *P. deckenii*	Yes	Yes	11 0 6
Lemurs' Park (Imerintsiatosika)	*P. coquereli,* *P. coronatus*	No	No	15 3
Nahampoana (Fort Dauphin)	*P. verreauxi*	No*	No*	0
Palmarium (Ankanin'Nofy)	*Indri indri*	Yes	Yes	4 1 (*P. coquereli*)**
Peyrieras (Marozevo)	*P. coquereli*	Yes	Yes	13
Vakona Lodge (Andasibe)	*P. diadema*	No	Yes	0

*Only one photo appeared from these locations in 2018. There was no direct contact, or bananas in the photo. **In 2014, four *P. coquereli* appear in together in one photograph at the Palmarium.

Fig. 1: Publicly available photographs posted on TripAdvisor and Instagram of human-lemur interactions at the Palmarium. Clockwise from top left: woman grabbing a sifaka, men feeding indri bananas from their mouths, and man with a sifaka eating a banana.

Discussion

In this study, we demonstrate that, with the singular exception of Lemurs' Park, legal captive facilities in Madagascar are not maintaining minimum best practices in the captive care of indri and sifaka as recently as the end of 2018. Specifically, dozens of photos posted online showed that at least half of the facilities allowed human-lemur contact, and most facilities appear to feed bananas to their captive indri and sifaka. We also received information that at least one legal captive facility - the Palmarium - had wild-captured lemurs to replace lemurs that died in captivity.

The facilities studied here, are listed in tourist guides and are popular with international visitors. At the prices charged to international tourists for use of the facilities, and especially because they are among the rare entities who have been permitted by the government to keep lemurs on their premises, it is unacceptable that legal captive facilities continue to promote inappropriate human-lemur contact and feeding regimes. It is also unacceptable that they be allowed to extract lemurs from the wild, when there are thousands of illegally captured pet lemurs across the country that cannot be returned to the wild, and that could instead be taken in by these facilities. Several other concerns are detailed below.

Captive survival of indriid lemurs

Indriid lemur health is notoriously difficult to maintain in captivity (Charles-Smith *et al*., 2010; Schwitzer *et al*., 2013; Roullet, 2014; Zehr *et al*., 2014). Currently only two species of sifaka, Coquerel's (*P. coquereli*) and crowned (*P. coronatus*) sifakas, are kept under captive conditions outside of Madagascar, and these animals cope with frequent gastrointestinal upset and diarrheal diseases, decreased longevity, low infant survivorship, and decreased reproductive success (Roullet, 2014; Zehr *et al*., 2014). This is probably also why they are rarely kept as illegal pet lemurs in the country (less than 3% of lemurs are kept as pets, Reuter *et al*., 2019).

We expect that the indri and sifaka living at legal captive facilities in Madagascar also suffer from poor health, survivorship and reproductive success, when compared to wild counterparts, despite having access to adequate calories and likely reduced exposure to predators. Nation-wide standardized health monitoring and care would be beneficial to the wellbeing and survival of these Critically Endangered animals, but to-date these have not been implemented. Additionally, transparency on the number of legally permitted captures would be beneficial in understanding the scope of this legal trade, but to date these are not available.

Infant survivorship in captivity

We found little evidence regarding infant survival rates across the eight facilities, but, for the Palmarium, we were unable to establish clear photographic records of infant survival into adulthood and the staff confirmed the death of infant lemurs. At the same time, it is notable that the Palmarium has been able to keep indri in captivity successfully (e.g. able to survive for some period of time and reproduce). This is despite the lemurs living within a small (50 hectare) highly-degraded secondary growth parcel, a diet that is upwards of 50% banana, and frequent direct contact with humans. We do not know of another successful attempt at keeping indri in captivity, even as it is not clear if any indri infants born at the Palmarium have survived to adulthood. This could be important in future if breeding in translocated areas became essential for repopulation or to otherwise ensure the survival of the species.

Future studies

We were unable to determine the total number of indriids at each resort, but in future we recommend the use of facial recognition software to understand the number of animals present and captured over time. Some individual animals were recognizable over time due to unique characteristics, such as ear notches or scars, but in most cases we could not identify the individual.

'Best practice' tourism

To minimize the number of wild-captures, translocations, morbidity, and mortality in Critically Endangered indriids, we suggest that tourists should prioritize seeing lemurs in their natural forest habitats, where no food or sound 'bait' are used to attract animals. For those who choose to see lemurs in captive or semi-captive conditions, we suggest avoiding locations that allow direct interactions with animals or 'bait' animals with food or recorded calls, as these likely induce significant psychological and physiological stress. In sum, we recommend the following 'best practices' for wildlife tourism within Madagascar: 1) visit wildlife in the wild; 2) do not directly touch or feed animals; and 3) do not post, like, or share photos of humans directly touching or feeding endangered animals. Adhering to these best practice guidelines will reduce the demand for wild capture of Malagasy fauna (including lemurs, reptiles, amphibians, and fossa), increase the wellbeing of the wildlife exposed to tourists, and set appropriate expectations for engagement with wild animals.

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Lemur inventory of the Analabe forest, SAVA region, and observation of an albino *Eulemur*

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Keywords: *Eulemur*, species diversity, albinism, isolation, Analabe, conservation

Abstract

Analabe is a fragment (1064ha) of a dry forest located in northern Madagascar where we observed five lemur species and an adult albino *Eulemur* holding an infant accompanied by a male crowned lemur (*Eulemur coronatus*) in that forest. These observations suggest that small forests are still able to harbour diversity in Madagascar today. However, even when they are located close to larger protected forests, they may suffer from increasing isolation. We thus urge the community to increase the effort to identify and survey isolated forests before their unique diversity is gone.

Résumé

Analabe (1064ha) est un fragment de forêt sèche du Nord de Madagascar où nous avons observé jusqu'à cinq espèces de lémuriens. Nous rapportons aussi la présence, dans cette forêt, d'un *Eulemur* albino tenant un bébé, et accompagné par un *Eulemur coronatus* mâle. Ces observations suggèrent que les petits fragments forestiers peuvent présenter de la biodiversité à Madagascar aujourd'hui. Cependant, même

lorsqu'ils sont proches de grandes forêts protégées, ces fragments pourraient subir les conséquences de leur isolement. Nous pensons donc que la communauté scientifique devrait intensifier ses efforts pour identifier et étudier ces forêts isolées avant que leur biodiversité ne disparaisse.

Introduction

The lemurs of northern Madagascar are well-known thanks to inventories carried out in the dry and humid forests over many decades (Capuron, 1952; Tattersall, 1977; Hawkins *et al.*, 1990; Ganzhorn *et al.*, 1997; Goodman, 2006; Louis *et al.*, 2006; Louis *et al.*, 2008; Sabel *et al.*, 2009). The dry forests include the Ankarana National Park, the Loky Manambato region, the Analamerana and Andrafiamena areas, and the Montagne des Français. The most important humid forest is the Montagne d'Ambre. However, limited data is available for the surrounding and often unprotected small forest fragments. Note that 'unprotected' is used throughout the manuscript to describe forests that are not included in the Protected Area national network. Given the small size of these fragments and the strong anthropogenic pressures (Harper *et al.*, 2007) threatening the persistence of forested habitat in many unprotected areas of Madagascar, it is of utmost importance to undertake surveys which could provide information on present biodiversity before it is lost. Species inventories from these under-studied forests may also contribute to conservation and complete our understanding of the natural history of northern Madagascar (Nusbaumer *et al.*, 2010).

More than 35 years ago, Arbelot-Tracqui (1983) mentioned the observation of three white female crowned lemurs, one with an infant. These individuals were not strictly albino because of the presence of grey and red hairs on their head and dark hair on their tail. These observations took place in the Matakasary forest, located 35km away from Analabe, on the eastern slopes of the Montagne d'Ambre. The reason for the presence of albinism in this species is unknown; it could be the result of loss of genetic diversity leading to a general increase in homozygosity, as has been documented for the clawed toad (Hoperskaya, 1975), and in several mammals (Guillery, 1986) including gorillas (Prado-Martinez *et al.*, 2013). Alternatively, it could be a rare genetic variant that can occur naturally in a population with an estimated rate of one albino individual per 10,000 births (Miller, 2005). Such rare individuals have indeed been observed in several species such as gorillas (Prado-Martinez *et al.*, 2013), whales (Filatova *et al.*, 2016) or harbour porpoises (Gil *et al.*, 2019). The presence of such rare phenotypes (white and albino) in the wild should lead to further studies in order to understand whether they are connected and whether they can inform us on the possible isolation of these forests. This study sought to increase our understanding of lemur species in the Analabe forest, Madagascar.

Method

Study site and data collection

The study site was Analabe, one of the largest unprotected forest fragments of northern Madagascar. The Analabe forest is located at approximately 13 km from the Mozambique Channel, less than 10 km southwest of the National Park of Montagne d'Ambre and 10 km northwest from the Ankarana National Park. It is located between two permanent rivers, Andromantsy and Tsimahalahy, flowing towards the Mozambique Channel (Fig. 1).

Analabe is the largest patch of a set of three small (1ha, 11ha, and 136ha) and one large (1064ha) forest fragments.

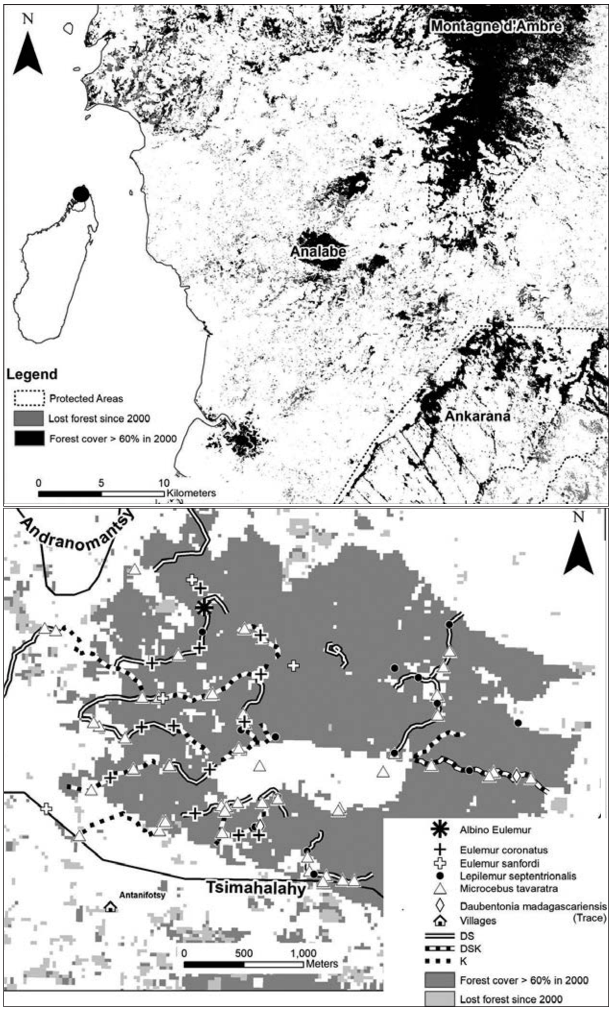

Fig. 1: Analabe forest and lemur observations.

It is an unprotected but still well preserved forest and it is currently managed by a COmité de GEstion (COGE), a local management committee that depends on the council of Misorolava (7 km north-west from Antanifotsy).

Data collection to assess lemur species richness in the forest was undertaken from 11 to 15 October 2017; five survey days at the end of the dry season. Four approaches were used to undertake the survey:

(I) Diurnal visits conducted by four teams of two to three persons along existing trails in Analabe during five days. These opportunistic visits were organised to identify sporting lemur (*Lepilemur* sp.) resting sites, aye-aye (*Daubentonia*) tree marks, *Eulemur* groups and to prepare night transects. These diurnal visits should thus not be used for quantitative approaches. Observations were made between 10:00 and 17:45 across the five days.

(II) Nocturnal line transects surveys were conducted along the same existing trails as Buckland et al. (2001), Meyler et al. (2012) and Salmona et al. (2014) (Fig. 1). Transect surveys were undertaken during four nights from 11 to 14 October. Four teams went through covered 11.85km divided into 14 transects. This represented 15hours 26minutes of nocturnal line transects surveys.

(III) Mouse lemurs (*Microcebus murinus*) were captured using 500 Sherman traps distributed along 11 trails totalling 8.26km (Fig. 1). Four teams worked on 11 and 12 October and two teams worked on 14 October.

(IV) Hand capture of sportive lemurs (genus *Lepilemur*) that had been detected during the diurnal visits. When possible, faecal or tissue samples of the trapped or captured animals were also taken for future genetic analyses, including measures of genetic diversity and reconstruction of their demographic history.

788 observational points were used to estimate the forest canopy height. Observational points were located 10 to 20 meters from each other along the trails presented in Fig. 1. Canopy height was estimated by one member of each of the four team. Climatic data of the study region was sourced from www.worldclim.org and used to produce an ombrothermal diagram, which describes the monthly precipitation and temperature.

Results and Discussion

Forest canopy height and climatic data

Canopy height showed a wide variation ranging from 3 to 30 m but with a midspread between 8 and 15m (Fig. 2). Variation in rainfall and temperature across the year is provided in Fig. 3.

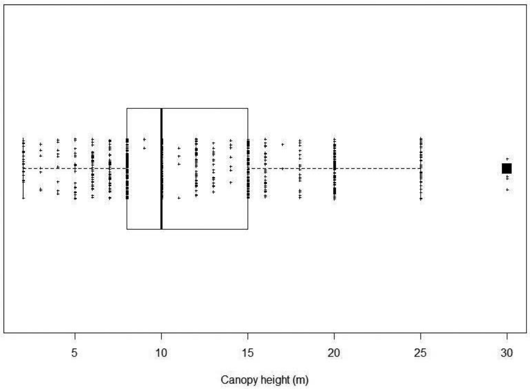

Fig. 2: Analabe canopy height.

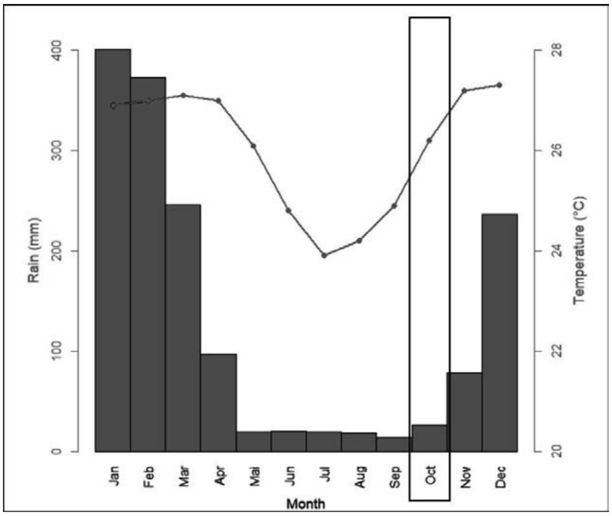

Fig. 3: Analabe ombrothermic diagram where the histogram represents the precipitations and the line represents temperature.

Species diversity

During the surveys, evidence was found of the occurrence of five lemur species from four genera of nocturnal or diurnal/cathemeral lemurs: crowned lemurs, Sanford's brown lemur (*Eulemur sanfordi*), Northern sportive lemur (*Lepilemur septentrionalis*), Northern rufous mouse lemur (*Microcebus tavaratra*) and aye-aye (identified from fresh tree marks) (Tab. 1 & Fig. 4). We did not observe dwarf lemurs (*Cheirogaleus* sp.) individuals, although the genus is known to occur in several dry forests of northern Madagascar (Mittermeier *et al.*, 2010). At this stage, we cannot exclude the presence of *Cheirogaleus* individuals in the Analabe forest given that they were expected to emerge from hibernation in November (Fietz, 1999) and that our data collection period may have thus been a few weeks too early.

Tab. 1: Lemurs diversity and sampling method in Analabe.

Species	***E. coronatus***	***E. sanfordi***	***L. septentrionalis***	***M. tavaratra***	***D. madagascariensis* (Traces)**	**Total**
Trapped			3	10		13
Fecal sampling	23	4				27
Nocturnal observations	1		8	28	3	40
Diurnal observations	77	29	8	18	1	133
Total observations	78	29	19	56	4	186

Northern rufous mouse lemur and northern sportive lemur were observed across the whole forest fragment. Similarly, evidence of aye-aye activity were also found across Analabe. This was not the case of the two *Eulemur* species as groups were only observed in the western part. Even though the sampling effort was biased towards the western part which we had to cross every day, the absence of *Eulemur* observations in the east when other species were regularly observed is worth stressing here and may require further investigation.

Albino Eulemur: observation, parental and species status

On two occasions (14 and 15 October), an adult albino *Eulemur* holding an infant was observed (Fig. 5), accompanied by a male crowned lemur. Due to the albino phenotype, it was not possible to identify the sex and the species of this individual visually.

Studies on other lemur species (including red ruffed lemur (*Varecia rubra*); black and white ruffed lemur (*V. variegata*); grey mouse lemur (*Microcebus murinus*); ring-tailed lemur (*Lemur catta*); mongoose lemur (*Eulemur mongoz*); red-bellied lemur (*E. rubriventer*); silky sifaka (*Propithecus candidus*); diademed sifaka (*P. diadema*) and the eastern lesser bamboo lemur (*Hapalemur griseus*) have reported alloparenting, which means that other adults independent of their age, sex or relatedness to infants may be caregivers in these species (Overdorff, 1996; Eberle and Kappeler, 2006; Patel, 2007; Vasey, 2007).

Two *Eulemur* species occur in the Analabe forest; crowned lemur and Sanford's brown lemur. The co-occurrence of these two species have also been reported in Ankarana and Montagne d'Ambre, northern Madagascar (Mittermeier *et al.*, 2010). Females of the two species can typically be distinguished by the typical V-shaped crown they exhibit (Mittermeier *et al.*, 2010). However due to albinism in this individual, this V-shaped crown could not be distinguished here. Observations of both crowned lemurs and Sanford's brown lemurs suggest individuals usually give birth between mid-September and October (Kappeler, 1987; Freed, 2006). So both species would be expected to have similar-aged infants. However, some behavioural differences have been observed between the species which may help to identify the species observed. Wilson *et al.* (1989) observed aggressive behaviours in the Ankarana NP between crowned lemurs and Sanford's brown lemurs when crowned lemurs were carrying infants. The presence of the male crowned lemur

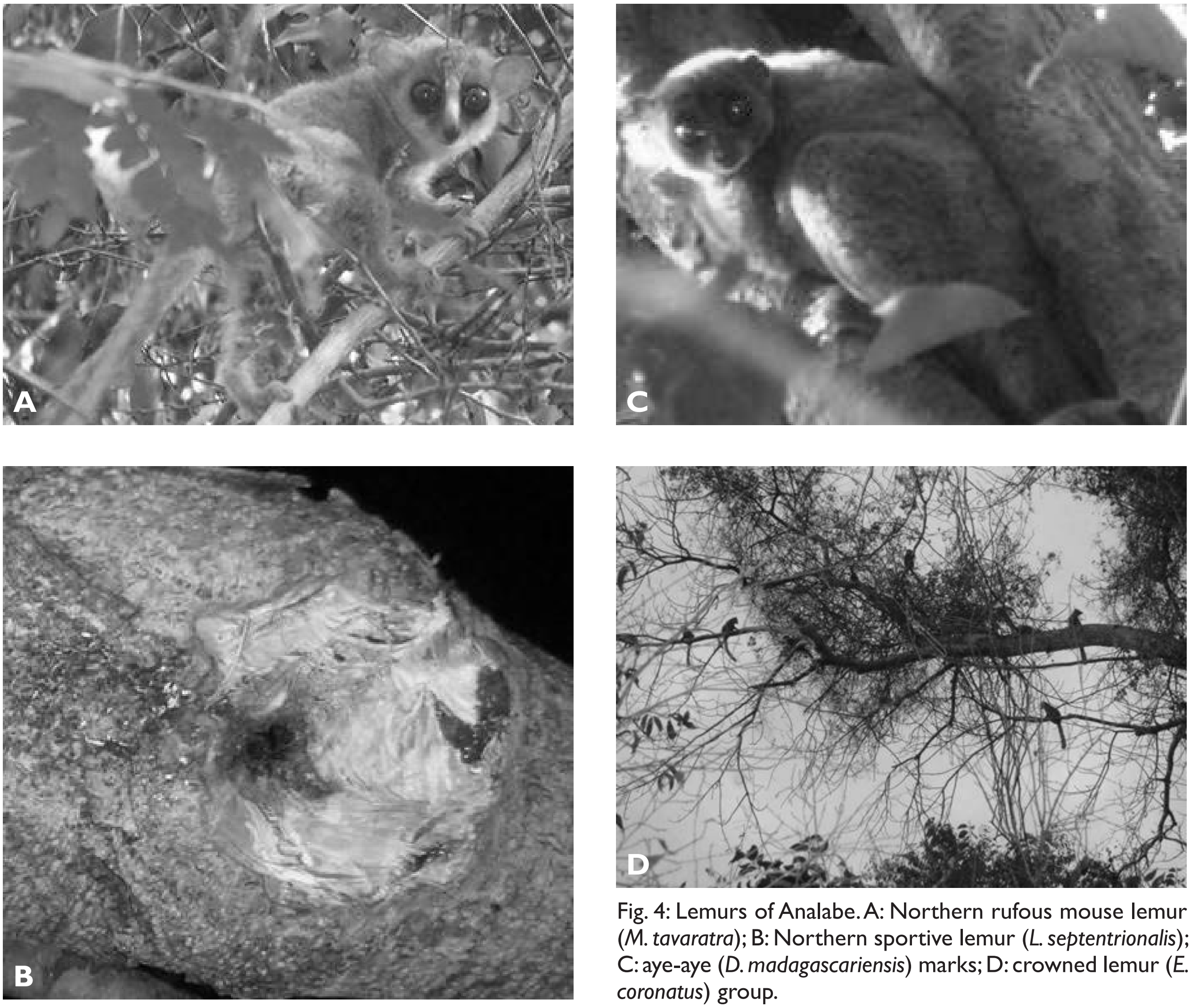

Fig. 4: Lemurs of Analabe. A: Northern rufous mouse lemur (*M. tavaratra*); B: Northern sportive lemur (*L. septentrionalis*); C: aye-aye (*D. madagascariensis*) marks; D: crowned lemur (*E. coronatus*) group.

with the albino individual and her infant thus suggests that the albino female is a crowned lemur. It is also important to note that this observation shows that, regardless of species, an albino *Eulemur* was able to mate and raise an infant despite a marked phenotypic difference.

It was also difficult to accurately age this individual. However, based on observations made of the blue-eyed black lemur (*Eulemur flavifrons*), a closely related species (Markolf and Kappeler, 2013), the uniform fur colour down to the end of the tail, and the ventral and hidden posture of the infant suggests that this individual was younger than 50 days. Indeed, in blue-eyed black lemur such phenotypic data correspond to an infant that would be less than three weeks of age. Volampeno *et al*. (2011) observed predominantly maternal care when infants are very young. This suggests that this albino individual could be the mother of this young infant.

Isolation, Habitat dimension & Habitat loss

Albinism in mammals is usually due to a mutation leading to the absence of melanin and alteration of various important functions including vision and hearing (Grønskov *et al*., 2007). White phenotypes are also more conspicuous and thus easily detected by predators (Galván *et al*., 2018). In primates such as western lowland gorillas (*Gorilla gorilla gorilla*) an albino individual has been observed in the wild (Prado-Martinez *et al*., 2013), and genetic analyses suggested that it was due to inbreeding. In our case, we have no evidence to

Fig. 5: Albino *Eulemur* from Analabe.

say if the albino phenotype observed was due to inbreeding as a consequence of population isolation (Bergl *et al*., 2008; Oklander *et al*., 2010) because no genetic data were available for the albino individual. However, the distance to the large forests such as the Ankarana or Montagne d'Ambre (which are 10km away) and the nature of the habitat (rice crops, Katy plantations) suggest that it is unlikely for lemurs to maintain gene flow with populations to which they were likely connected in the past.

Conclusion

During this study we observed lemur species at Analabe, including an albino individual. The presence of an albino individual cannot be taken as evidence of inbreeding but might still suggest that a genetic study on that forest is needed. *Eulemurs* are hunted in many regions of Madagascar but this does not seem to be the case in Analabe where human populations appear to respect local taboos or *fady* that protect *Eulemurs*. However, the movement or migrations of human populations within Madagascar might lead to a decreasing application of the *fady* that still protects some lemurs. During our fieldwork we noted that the forest habitat was under pressure as a consequence of timber exploitation for local home building. Today, the forest remains isolated from neighbouring forests to which it was likely connected in the past (Ankarana and Montagne d'Ambre). It is unlikely that the lemurs present in Analabe could traverse the 13km of open habitats regularly burnt (a consequence of the practice of *tavy*) and the many rice fields and villages scattered in the Malagasy landscape. It is thus urgent to protect this and other similar forests. Analabe is located between two well-studied national parks, the strongest protection status in Madagascar. We suggest integrating Analabe as a valuable island for biodiversity into existing national conservation programs and connecting or reconnecting it to Montagne d'Ambre or Ankarana through reforestation or installation of habitat corridors.

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Updated population density estimation and distribution range of the Critically Endangered Sahamalaza sportive lemur, *Lepilemur sahamalaza*

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Abstract
Accurate population density estimates are important for effective conservation measures of endangered species. For the Critically Endangered Sahalamaza sportive lemur (*Lepilemur sahamalaza*), no recent or robust population estimates are available, complicating conservation management of this species. This study examined the species distribution range as well as assessing population density in the range of occurrence with standardized methodology (transect walks and home range calculations) between 2013 and 2016. The results suggest that Sahamalaza sportive lemurs are confined to the Sahamalaza Peninsula. Population density ranges between 1.49 to 1.87 individuals/ha depending on the methodology used to estimate density. Population size estimates consequently vary between 3800 and 4700 remaining individuals of this species, subject to a re-evaluation of the remaining habitat.

Introduction

The nocturnal and arboreal Sahamalaza sportive lemur (*Lepilemur sahamalaza*) (the name was changed recently from *L. sahamalazensis*, Andriaholinirina *et al.,* 2017), remains comparatively unstudied despite facing pressing conservation issues, the most prominent issue being loss of habitat from anthropogenic pressure (Schwitzer *et al.,* 2006; Seiler *et al.,* 2010, 2013a; Volampeno *et al.*, 2013). This species occurs only in the northwest of Madagascar and is believed to be confined to the forests on the Sahamalaza Peninsula which was proclaimed a National Park in 2007 (Schwitzer *et al*., 2010; Seiler *et al*., 2013a). Despite official protection through government agencies, habitat destruction has continued over the past decade: human-induced forest fires and logging worsened after the 2009 political crisis, severely affecting remaining forests (Seiler, 2012). The Ankarafa Forest in the west of the peninsula (totalling around 300ha in size, Volampeno *et al*., 2010) remained relatively protected due to the placement of a research site and ongoing presence of researchers, guides and non-governmental organisation (NGO) members (Seiler *et al.,* 2013b). The biggest connected forest in the east of the Peninsula, Analavory, however, has been decimated within the last decade and the remaining unconnected fragments effectively total around 100ha in size (Randriatahina and Schwitzer, personal communication).

In addition to habitat loss, sportive lemurs are hunted for food (Schwitzer *et al*., 2006; Seiler *et al*., 2010). Although hunting events were recorded only sporadically (Volampeno *et al*., 2010), their sessile nature during daylight hours makes sportive lemurs easy prey for opportunistic hunters. These threats call for conservation measures that include long-term population monitoring to assess the effects of habitat loss and hunting on the last Sahamalaza sportive lemur populations. To date, however, the exact range of Sahamalaza sportive lemurs has not been investigated: there remains the possibility that populations exist on the mainland. After initial surveys in 2004, found no evidence of this species on the mainland (Olivieri *et al.,* 2005) it was generally assumed that this species was not represented off the peninsula, but this has not been confirmed since. Given the uncertainty of the species' distribution, it has been difficult to produce a robust population size estimation. Only two population density estimations studies have been conducted to date with a highly variable result: Ruperti (2007) conducted *ad libitum* surveys in one-hectare plots during the daytime over four months, estimating a mean density of 280 individuals/km^2. Seiler (2013a) counted all individuals encountered during three field seasons (totalling up to 12 months between 2009 and 2011), estimating a density of 7 to 23 individuals/km^2. Despite differences in estimations (attributed to habitat alterations and different methodologies; IUCN, 2018) these population density estimations have contributed to the decision of classifying Sahamalaza sportive lemurs as Critically Endangered by the IUCN Red List (IUCN, 2018).

While important for baseline assessments, these highly dissimilar estimations of the remaining populations fail to inform effective conservation-based monitoring. This study therefore aims to 1) determine the exact distribution range of Sahamalaza sportive lemurs off the peninsula, and 2) produce a robust population density estimate using standardised and repeatable methodology.

Methods

Study Sites

Presence/absence surveys were conducted in five forest fragments in the northwest of Madagascar, on the mainland east of the Sahamalaza Peninsula (Fig. 1; Tab. 1). The fragments were chosen as they were located between the rivers Maevarano (in the south) and Andranomalaza (in the north) (Fig. 1), which are presumed to be natural barriers for sportive lemur speciation (Craul *et al*., 2007). Data were collected between April and May 2013.

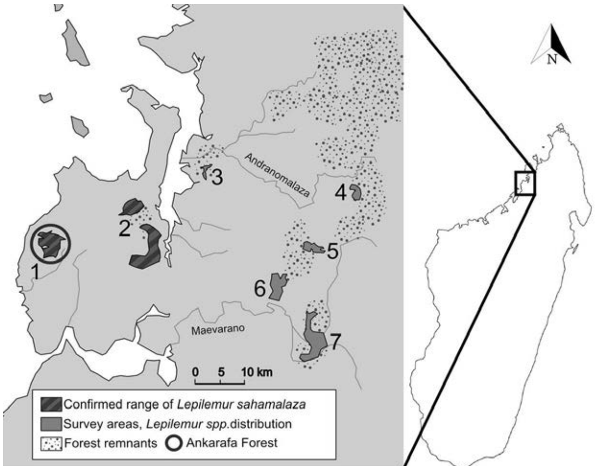

Fig. 1: Location of study sites on the Sahamalaza Peninsula in north-western Madagascar. Study site 1: Ankarafa forest; site 2: Analavory and Anabohazo (sites 1 and 2 make up the Sahamalaza-Iles Radama National Park); site 3: Marovato Sud; site 4: Anefitrabe; site 5: Betolongo; site 6: Andrafiabe; site 7: Sasindro. Transect counts and population density estimations were performed with data collected at site 1. Surveys for absence/presence of sportive lemurs were performed in the mainland areas between the rivers Maevarano (south) and Andranomalaza (north) (sites 3 to 7).

Tab. 1: Names and GPS waypoints of survey areas where presence/absence surveys were conducted in 2013. Location ID numbers correspond with numbers in Fig. 1.

Location ID	**Name**	**Southing**	**Easting**	**Survey duration**
1	Ankarafa	-14.38019	47.76057	N/A
2	Analavory and Anabohazo	-14.32253	47.91427	N/A
3	Marovato Sud	-14.14397	48.02204	2 days
4	Anefitrabe	-14.1727	48.21424	4 days
5	Betolongo	-14.24404	48.14404	4 days
6	Andrafiabe	-14.29546	48.12187	4 days
7	Sasindro	-14.32394	48.17336	4 days

Data on population density were collected in the Ankarafa Forest within the Sahamalaza – Iles Radama National Park (Fig. 1). The Ankarafa Forest, the most western forest patch within the protected area located between 13°52'S and 14°27'S and 45°38'E and 47°46'E, is characterized by a mix of dry deciduous and Sambirano rainforest vegetation structures with a canopy height of 25m, as is typical for Malagasy lowland forests (Dumetz, 1999; de Gouvenain and Silander, 2003; Grubb, 2003; Volampeno *et al*., 2013). The climate on the Sahamalaza Peninsula is highly seasonal with a hot and wet period between November and March and a colder dry period between April and October. Data collection took place between March 2015 and August 2016.

Sahamalaza sportive lemur distribution range

Each study location on the mainland was visited for 2-4 days. Surveys were conducted during daytime and night-time. During daytime surveys, we conducted reconnaissance walks, looking for sleeping trees. Night-time surveys were then conducted to detect the nocturnal sportive lemurs, whose presence was identified by movement, vocalization and eye shine. Local villagers were also asked to provide information on known sleeping sites for nocturnal sportive lemurs.

Density Evaluation

For population counts we walked a total of 26.7km across three line-transects situated in three parts of the Ankarafa Forest (Fig. 2). Transect lengths and number of repeats were variable due to weather conditions and accessibility issues during fieldwork: FRAG1 = 2.2km (surveyed 9 times), FRAG2 = 1.3km (surveyed 3 times) and FRAG3 = 1km (surveyed 3 times). As it was not possible to establish parallel and linear transects through the vegetation, non-linear, pre-existing trails that led through each forest fragment were used. Transect walks were conducted between 6:30pm and 10:00pm, when the lemurs were active. Three to five people walked at an approximate speed of 2km/h using torches to detect lemurs. Communication was held at a minimum so as to not disturb the lemurs. Each time a sportive lemur was spotted, and the species confirmed, the following data were recorded at the location the lemur was first seen: time, number of individuals, perpendicular distance from the transect (measured using a laser distance meter: GLM 30, BOSCH Professional) and the coordinates (using a handheld GPSMAP Garmin 60 CSx,). If independence of the sighting was uncertain, it was not recorded again (N = 3). Data were analysed using the software DISTANCE (Thomas *et al*., 2010).

Home range-based estimation

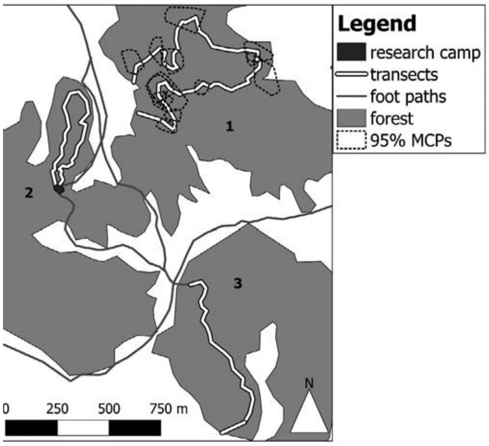

Fig. 2: Line transects surveyed in the Ankarafa Forest (location 1) between 2015 and 2016. FRAG1 = 2.2km, FRAG2 = 1.3km, FRAG 3 = 1km. Dotted lines represent 95% Minimum Convex Polygon (MCP) home ranges of all tagged Sahamalaza sportive lemur individuals.

We fitted 14 Sahamalaza sportive lemurs, inhabiting FRAG1 of the Ankarafa Forest (Fig. 2) with cable-tie VHF radio-collars (3.5g; Biotrack). From October 2015 until August 2016 behavioural observations of these focal individuals were conducted between 6:00pm and midnight. The location of each tree visited by focal individuals was marked by taking a GPS fixture. Fixtures for each focal animal were collated and used to estimate annual home ranges (number/individual mean±SD: 333±134, range = 106 – 587 points). Home range size was calculated for each individual as 95% Minimum Convex Polygons (MCP). Overlap between home ranges of the study individuals was calculated according to the degree of overlap in QuantumGIS (Version 2.18). The area of overlap was expressed as percentage of home range area.

Results

Sahamalaza sportive lemur distribution range
No populations of Sahamalaza sportive lemurs were found outside of the confirmed distribution range on the Sahamalaza Peninsula. Local villagers admitted to knowing of nocturnal lemurs but claimed they were 'very difficult to find'. No *Lepilemur* spp were sighted at any of the survey sites during the survey period.

Density Evaluation
We recorded 200 independent sightings of sportive lemurs throughout the study (FRAG1: 156 sightings; FRAG2: 24 sightings; FRAG3: 20 sightings). The most sightings recorded for one survey night was 27 individuals in FRAG1. Encounter rates varied across survey nights and forest fragments: on average 8.2±2.7 (mean±SD) individuals per kilometre were encountered in FRAG1, 6.4±1.9 individuals per kilometre in FRAG2 and 6.6±1.2 individual per kilometre in FRAG3. Across all forest fragments the population density was estimated to be 1.52 individuals/ha (% coefficient of variation: 21.7).

Home range-based estimation
Home range sizes differed between individuals with variable overlap between direct neighbours (Tab. 2). Based on the average home range size of 0.67ha, population density was calculated as 1.49 individuals/ha. However, home ranges were not exclusive: the average overlap measured between collared individuals in this study was 20.6% (Tab. 2). Adapting the calculation to account for the average overlap between individuals, and assuming the remaining home range was used exclusively, the population density was estimated to be 1.87 individuals/ha.

Tab. 2: Home range sizes (95% MCPs) and overlap of ranges with direct neighbours of all collared study individuals in the Ankarafa Forest. F = female, M = male.

Individual	Home range size (ha)	Percentage overlap (mean±SD)	Number of tagged individuals overlapped with
F1	0.87	35.4±41.5	3
F2	0.31	10.7±7.2	1
F3	0.29	N/A	0
M4	0.93	N/A	0
F5	0.27	12.6±6.7	3
F6	0.25	69.5±0	1
F7	0.79	1.3±0	1
M8	0.40	2.6±0	1
F9	0.57	N/A	0
M10	0.34	2.4±0	1
M11	1.88	14.1±19.8	5
M12	0.73	29.6±0	2
F13	0.18	27.7±14.2	3
M14	1.60	N/A	0
mean±SD	0.67±0.50	20.6±12.7	

Abundance
The total forested area in which Sahamalaza sportive lemurs are reported to occur on the Sahamalaza Peninsula is estimated to be 2,500ha (Schwitzer and Randriatahina, personal communication). Given a population density estimation of 1.52 individuals/ha we estimate the remaining population to be around 3,800 individuals. The slightly higher population density estimation using the home range and overlap data (1.87 individuals/ha) would result in a total population of 4,675 individuals on the Sahamalaza Peninsula.

Discussion

The results of this study support previous reports (Olivieri *et al.,* 2005) that Sahamalaza sportive lemurs do not occur outside of the Sahamalaza Pensinsula, their assumed distribution range. We estimate here that the remaining populations, which are limited to the forested areas on the peninsula, are comprised of 3,800 to 4,700 individuals. The actual size of the remaining forest on the peninsula has not been assessed and needs ground-truthing. The population estimate can then be adapted using the results presented here for population density.

While the population density estimated in this study is higher than that estimated by Seiler *et al.* (2013) who estimated 0.27 individuals/ha, we suggest this is likely due to differences in methodology rather than a genuine increase in population size. Seiler *et al.* (2013) conducted opportunistic searches and recorded all individuals encountered during behavioural observations in 2009 to 2011, rather than using a standardised methodology. The population density estimated in 2007 by Ruperti (2007) was based on a more systematic approach (resting site searches in 1-hectare plots during the day) resulting in similar estimates to those of the present study with 2.8 individuals/ha. Both studies were conducted in the same three forest parts of the Ankarafa Forest as the present study. It is unlikely that the big differences in estimates stem from population fluctuations alone as no major habitat loss occurred in the Ankarafa Forest from 2006 to 2011 and as sportive lemur females give birth to a single young per year (Mittermeier *et al.*, 2010; Hilgartner *et al.*, 2012), rapid population recovery is unlikely. The more systematic approach in this study, which spanned both the wet and the dry season, gives similar results to the study of Ruperti (2007); it is likely that standardised methods give a more robust estimate (Peres, 1999) and that the results of the present study represent a plausible estimate of the population density at Ankarafa Forest

Forest area in Ankarafa has been relatively stable over the past five years and disturbances have been kept to a minimum by the continuing presence of researchers and field guides. As our surveys took place only in Ankarafa, our density estimates are not likely to be representative of the sportive lemurs' entire range. Population estimations produced in this area may therefore be positively biased. Future studies should estimate population sizes in different parts of the Peninsula, such as the Anabohazo Forest where a research site is currently being completed (Randriatahina, 2017).

When comparing home range sizes of the studied population to those of *Lepilemur* spp. populations living in large connected forests, differences are apparent (Campera, pers. comm.). The home ranges we report here are among the smallest home ranges reported for this genus and present an unusually high degree of overlap (see Ganzhorn *et al.*, 2004; Rasoloharijaona *et al.,* 2006; Hilgartener *et al.*, 2012; Dröscher and Kappeler, 2013; Zinner *et al.*, 2013; Seiler *et al.,* 2015; Dinsmore *et al.*, 2016; Wilmet, 2018).

Limited dispersal possibilities, due to the increasingly fragmented nature of the Sahamalaza forests, may have induced high overlap between individuals (Bondrup-Nielsen, 1985) as the habitat may reach carrying capacity. In addition, unusual pelage colorations increased in the studied populations between 2013 and 2016 (Mandl, personal observation). White tail tips, reportedly found in small, genetically isolated lemur populations, may be a sign of increased inbreeding (Eppley and Donati, 2017), and were found on at least seven different individuals during the study period. The spatial isolation and limited dispersal options, and associated genetic and demographic consequences, make the last populations of Sahamalaza sportive lemurs especially vulnerable to extinction. A genetic study that assesses the viability of sportive lemurs and evaluates their tolerance to isolation would greatly inform future conservation efforts as the species becomes restricted to ever smaller forest fragments.

Based on the results we present, we make the following recommendations for long-term conservation planning:

1. Conducting population density estimations based on the numbers of individuals found in Anabohazo and Analavory is necessary. A systematic approach in both the wet and the dry season is important to establish robust numbers. This will allow assessment of the effect of fragmentation and fragment size on population densities.
2. Focussing reforestation efforts on enlarging the available habitat, starting at fragments that may be quickly connected with (comparatively) little effort.
3. Consideration of implementation of translocation schemes for individuals to improve genetic exchange. The Ankarafa population is genetically, and physically, isolated. A study on the genetic status of the last remaining populations would be an important precursor for translocation activities.
4. Ongoing protection of remaining habitat is imperative. Establishing research stations has proven effective in protection forests (e.g. N'goran *et al*., 2012) and close contact with local government authorities is needed to improve infrastructure in the north-west area.

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Ontogenesis of behaviour in greater bamboo lemurs (*Prolemur simus*) at Ambalafary, eastern Madagascar: a preliminary study during the first four months of life

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Abstract

Before reaching maturity, young greater bamboo lemurs (*Prolemur simus*) undergo a developmental period characterized by different phases. The objective of this study was to be able to highlight the initial developmental phases of the lives of young greater bamboo lemurs inhabiting the site of Ambalafary in the Brickaville District, eastern Madagascar, during the first four months of their lives. Focal animal sampling was used between October 2015 and January 2016 to record behaviours of the mother and infants simultaneously. We found that during the first month of their lives, the infant greater bamboo lemurs had complete dependence on their mothers and that regardless of the activities undertaken by the infants, direct body contact with the mothers was almost constant. From the second month of life the mother-infant direct body contact was reduced, as the infants began to venture away from their mothers, and manipulation of non-consumable and consumable objects began. Manipulation of non-consumable objects, such as sticks, decreased during the third month and was not observed during the fourth month. Conversely exploration of consumable objects, such as young bamboo leaves or the bamboo stalk, increased each month. Direct body contact with the mothers decreased during the third and fourth months, and some activities, such as feeding and travelling, occurred up to 4m away from the mothers. A greater understanding of behavioural development in young greater bamboo lemurs is paramount in conservation decision-making and population management for this Critically Endangered species moving forwards.

Résume

Avant d'atteindre la maturité, les jeunes *Prolemur simus* présentent une phase de développement caractérisée par différentes phases. L'objectif de cette étude était de pouvoir mettre en évidence les premières phases de développement de la vie des jeunes *P. simus* habitant le site d'Ambalafary, dans le District de Brickaville à l'est de Madagascar, au cours de leurs quatre premiers mois de vie. La méthode utilisée entre octobre 2015 et janvier 2016 était celle de «Focal animal sampling» pour enregistrer simultanément les comportements de la mère et des jeunes. Nous avons constaté que, pendant le premier mois de leur vie, les jeunes *P. simus* était totalement dépendants de leur mère et que, quelles que soient les activités du jeune, le contact physique direct avec les mères était presque constant. À partir du deuxième mois de vie, le contact corporel direct mère-jeune a été réduit, car les jeunes ont commencé à s'éloigner un peu de leur mère et à manipuler des objets non-consommables et consommables. La manipulation d'objets non-consommables, tels que des bâtons, a diminué au cours du troisième mois et n'a pas été observée au cours du quatrième mois. Au contraire, la manipulation d'objets consommables, tels que les jeunes feuilles de bambou ou la tige de bambou, augmentait chaque mois. Les contacts corporels directs avec les mères ont diminué au cours des troisième et quatrième mois et certaines activités, telles que l'alimentation et les déplacements, ont été pratiquées jusqu'à une distance de 4 m de la mère.

Introduction

Compared with other mammals, young primates have a long period of immaturity (Walters, 1987; Pereira *et al*., 2002; Lonsdorf *et al*., 2012) characterized by a period of high dependence (MacKinnon, 2014). Indeed, non-human primates have few innate (or instinctive) behaviours and therefore must learn behaviours in order to master their physical or social environment in order to survive (Nash *et al*., 1982; MacKinnon, 2014). This learning takes place within the protected framework of a social group and is usually through the mother-offspring link because in most cases in primates it is primarily the mothers who provide their offspring with food, heat, transportation and protection (Nash *et al*., 1982). The development of an individual from birth to maturity is gradual and occurs by stage. This is referred to as the ontogenetic trajectory, during which the young primate acquires various learnt behaviours and preferences (Hinde *et al.,* 1976). Ontogenesis is defined as the psycho-physiological construction of the individual as it develops. The study of behavioural development is therefore called ontogenesis of behaviour (Bateson, 1987). An ontogenetic study helps to understand how young primates learn and develop within their environment to ensure their survival (MacKinnon, 2014).

Understanding the mother-offspring relationship in primates is complicated by the fact that the majority of the research on mother-offspring interaction (undertaken in the mid-1980s) involved only 5% of 186 primate species and 3 of 11 non-human primate families (Nash *et al.*, 1982), and research in the natural habitats of the study species is rare (Fragaszy and Mitchell, 1974; McKenna, 1979; Altmann, 2001). Even now, few studies currently relate to the development of this mother-offspring relationship for higher primates (Bezanson, 2006; MacKinnon, 2006; Bezanson and Morbeck, 2012) or for prosimians such as lemurs (Tarnaud, 2002; Fichtel, 2008; Hohenbrink *et al.*, 2015).

For greater bamboo lemurs (*Prolemur simus*), the focus of this research, studies concerning the ontogeny of this species in the wild are limited (Tan, 2000). However those that have investigated its ontogeny have identified variations between the different stages of the young lemur's development from birth, with feeding on solid food observed from eight weeks of age, travelling with group members at four months of age, and weaning at 7.5 months (Tan, 2000). This species is considered Critically Endangered by the IUCN (2012), and it is thus important to develop a greater understanding of its behavioural development. Understanding behaviour of threatened species helps improve conservation planning, especially when some form of population management might be necessary to improve the viability of small isolated populations.

The aim of this study was to investigate the initial developmental phases of greater bamboo lemurs during the first four months of life, to quantify the evolution of the relationship of the mother-infant dyad, the development of social interactions with group members other than the mother, and to understand if certain learning is acquired during this period.

Methods

Study site

Ambalafary is an isolated site in the Rural Commune of Fanasana-Gare in the Brickaville District of eastern Madagascar (Fig. 1). It is one of a complex of sites supporting greater bamboo lemurs that surround the Andriantantely lowland rainforest (King *et al.*, 2013b). Ambalafary has geographical coordinates S18.8008°, E48.8092°, and is located on the north bank of the river Ivohitra between the chief town of the Rural Commune of Fanasana-Gare to the west and the fokontany of Mangabe to the east.

The greater bamboo lemur population at Ambalafary was only recently discovered, as part of The Aspinall Foundation's "Saving *Prolemur simus* Project" in 2009 (Ravaloharimaitra *et al.,* 2011). The site is managed by the VOI Ainga Vao II, created by the local population when the presence of greater bamboo lemurs was confirmed in the region (Ravaloharimanitra and King, 2012), and supported through a long-term collaboration with The Aspinall Foundation (Ravaloharimanitra *et al.,* 2013a, 2013b). It is a bamboo-dominated site with two large-culmed bamboo species, *Bambusa vulgaris* and *Valiha diffusa*, providing the majority of the greater bamboo lemur diet at the site (Mihaminekena *et al.,* 2012, 2018; King *et al.,* 2013a). Ambalafary is one of the few sites where greater bamboo lemurs can be followed without much difficulty therefore regular monitoring can be undertaken without radio-tracking equipment.

Observation methods

Focal animal sampling (Altmann, 1974) was used to record the activity, behaviour and locations of the mother-young dyads simultaneously, which provided the opportunity to monitor social relationships in the dyads. The study was undertaken between October 2015 and January 2016 (Tab. 1) when the group consisted of 48 individuals, including 8 males, 13 lactating females, 6 non-lactating females, 8 sub-adults, and 13 juveniles. Data was collected on all 13 mother-infant dyads. During each observation period one lactating female and her offspring was randomly selected to monitor their activities for at least 30 minutes or until the focal dyad disappeared from view.

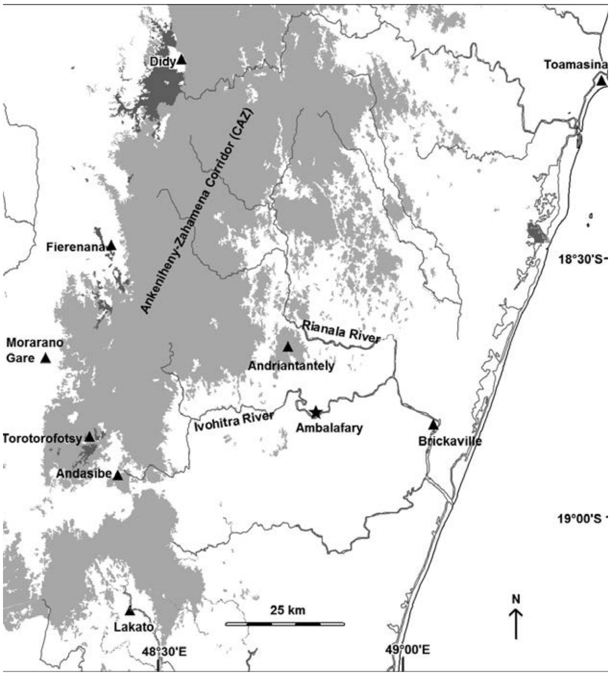

Fig. 1: Location of the study site, Ambalafary (black star), situated to the south-east of the Ankeniheny-Zahamena Corridor, eastern Madagascar. Approximate forest cover is shown in light grey, major water courses in dark grey, and other locations as black triangles.

The main activities of the infant greater bamboo lemurs were categorised as follows: manipulation (of consumable or non-consumable objects), solitary behaviour (when the infant is not in the company of its mother or other individuals of the group), and socialization (relationship that the infant maintains mainly with its mother or other members of the group during the activities of rest, movement, or grooming).

Tab. 1: Hours of observation during each month of the study.

Month	Total hours of observation
October 2015	96 h
November 2015	96 h
December 2015	96 h
January 2016	84 h

Index of association

The index of association (L) reflects the relationship between two individuals A and B by the number of times these two individuals are observed together (at less than one meter distance) compared to that where they are observed alone or in the company of other individuals who are neither A nor B (Martin & Bateson, 1995). In this study, we calculated this index to investigate the evolution of the mother-infant relationship over the course of the study.

The index of association (L) is calculated as follows:

$$L = \frac{nAB}{[(nA+nB)+nAB]}$$

Where nAB= number of occasions when A and B are observed together, nA = number of occasions when A is observed without B, nB = number of occasions when B is observed without A. Association was considered strong if L is close to 1, medium if L is close to 0.5, and weak or absent if L is close to 0.

Results

Mother-infant socialisation and other activities

Tab. 2: Activities undertaken by infant greater bamboo lemurs during the first four months of their lives at Ambalafary, October 2015 to January 2016.

	Oct	Nov	Dec	Jan
Socialisation with mother	99.1	81.5	80.7	79.1
Socialisation with other group members	0	0.8	1.2	0
Solitary behaviour	0.9	0	0	10.3
Manipulation of non-consumable objects	0	13.8	10.8	0
Manipulation of consumable objects	0	3.9	7.2	10.6

Tab. 2 shows the main activities of the infant greater bamboo lemurs during each of the first four months of their lives. During the first month of its life, the socialisation of the infant greater bamboo lemurs with their mothers was the highest (99.1%). A decrease in contact or socialisation with the mothers was observed from the second month onwards (81.5, 80.7 and 79.1% respectively in the second, third and fourth months), a statistically significant change in socialisation behaviour during the study ($\chi^2_3 = 20.845$, $P < 0.01$).

Throughout the study the socialisation of the infant greater bamboo lemurs with the other members of the group was limited, at or close to 0% of activities recorded (Tab. 2). Solitary behaviour of the infants during the first three months of their lives was virtually non-existent, but started during the fourth month (Tab. 2).

Object manipulation began during the second month of life; non-consumable objects were manipulated more frequently (13.8%) than consumable objects (3.9%). Manipulation of non-consumable objects decreased during the third month and was not observed during the fourth month. Conversely manipulation of consumable objects, such as young bamboo leaves or the bamboo stalk, increased each month (Tab. 2). Manipulation behaviour changed over time from non-consumable to consumable objects during the study period ($\chi^2_2 = 16.741$, $P < 0.01$).

Mother-infant association

From birth to the second month of life, the mother-infant index of association was between 0.99 and 1, indicating an extremely strong association. The value decreased slightly during the third and fourth month nevertheless the association between the mother and the young was still high (0.96 and 0.97 respectively).

Distance between infant and mother

Whatever the activities performed by the infant greater bamboo lemurs during the first two months, infants were always or almost always in direct bodily contact with their mothers: 100% during feeding (which is still maternal milk), 99.3% during resting, 91.7% during travelling, and 100% during other activities such as grooming (Fig. 2). Direct body contact with the mother decreased during the third and fourth months, and some activities, such as feeding and travelling, occurred up to 4m away from the mother (Fig. 3).

Fig. 2: A young *Prolemur simus* aged approximately 1 to 2 months, with its mother. (Photo: T. H. Mihaminekena)

Fig. 3: A young *Prolemur simus* aged approximately 3 to 4 months. (Photo: T. H. Mihaminekena)

Discussion

Socialisation of the infant greater bamboo lemurs

From birth until the first month of the infants' lives, the mother-infant relationship was strong, with the infant greater bamboo lemurs showing complete dependence on their mothers. From the second month the infants began to take an interest in the environment independent of their mothers, and started to engage in socialisation with other group members. Solitary behaviour increased in frequency as the infants started to break away from their mothers. Similar patterns of development have been observed in brown lemurs (*Eulemur fulvus*) in the Comoros Archipelago, with the infants starting to move away from their mothers in the third month of their lives, especially during feeding, and spending just 28.4% of time within a metre of their mothers by months four and five (Tarnaud, 2002). Similarly, young white-faced capuchin monkeys (*Cebus capucinus*) begin to be independent of their mothers after three months of age; travelling alone at larger distances from their mother and are often transported by other members of the group (MacKinnon, 2002).

Exploratory behaviour of the infant greater bamboo lemurs

The manipulation of different types of objects by the infant greater bamboo lemurs began in the second month of their lives. Initially the manipulation of non-consumable objects was the most frequently observed object manipulation behaviour, but by the fourth month only consumable objects, such as parts of plants, were manipulated. A similar study of young brown lemurs (*Eulemur fulvus*) also found that infants explored their environment during the first four months of life, with non-consumable objects manipulated more frequently than consumable objects initially (Tarnaud, 2002). A study by Byrne *et al*. (1995) reported that the handling of consumable and non-consumable items by capuchin monkeys (*Cebus apella*) starts from the 3rd and 4th month of life, becoming stable in the second half of the first year of life.

Conclusion

This study of the ontogenesis of the behaviour of infant greater bamboo lemurs has shown that during the first month of their lives, the infants have complete dependence on their mothers. The distance between the infants and their mothers is very small and does not exceed 2m. It is during this phase that the bodily contact between mother and young is most frequent, and socialisation with the other members of the group is rare. During the second month of the infants' lives the manipulation of non-consumable objects and socialisation with other group members begins. Between the second and fourth month mother-to-young contact is reduced and exploration of other environments is increased. By the fourth month consumable objects (parts consumed as young leaves, stems) are the most manipulated while the handling of non-consumables becomes less frequent. Our study of the ontogenesis of the behaviour of greater bamboo lemurs in the Ambalafary site has illustrated that infants pass at least two main stages of development before reaching maturity. However, in order to have more complete data concerning this ontogenesis it is important to follow the other phases of development of the infants for subsequent months, until their behaviour is similar to that of older animals. Understanding the ontogenesis of behaviours in greater bamboo lemurs will aid conservation decision-making for this Critically Endangered species, especially in regards to planning for population management interventions for small isolated populations.

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Preliminary study of gastrointestinal parasites in different species in Bandro and around Park Bandro, Madagascar

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Abstract

The introduction of domestic animals into the fragmented habitat of Aloatran gentle lemurs (*Hapalemur alaotrensis*) poses a serious threat for the conservation of the species in terms of increased risk of disease transmission and spread of epidemics. This study aimed to investigate gastrointestinal parasites in Alaotran gentle lemurs, domestic animals and other wild species living in and around Bandro Park in the Alaotra-Madagascar region. 3g of fecal samples were collected from each individual that was encountered. The floatation technique using Sheather solution was used to analyze endoparasites. Species of parasite were observed during coprological analysis: three species of *Ascaris*; two species of *Ankylostoma*, *Coccidia*, *Hymenolepis*, *Schistosoma* and one species of *Dyplidium*, *Strongyloididae*, *Trichostrongylus*, *Trichuris*. The faeces of domestic cattle (*Bos taurus indicus*) had the most parasites, followed by the Alaotran gentle lemur and mallard ducks (*Anas platyrhynchos*). Each host species carried at least one parasite species that was not found in other species. The results of this study are not only significant for our understanding of the health and parasites in Aloatran gentle lemurs in and around Bandro Park; but they are also useful to consider during conservation planning for this Malagasy flagship species.

Résumé

L'introduction d'animaux domestiques dans l'habitat fragmenté d'*Hapalemur alaotrensis* est une menace pour la conservation de cette espèce et pourrait entrainer la transmission de maladies et la propagation d'épidémies. Ainsi, cette étude a pour but d'examiner les parasites gastro-intestinaux de la population d'*Hapalemur alaotrensis*, des animaux domestiques ainsi que d'autres espèces sauvages vivant dans et autour du parc Bandro dans la région d'Alaotra-Madagascar. Pour cela, nous avons collecté 3g d'échantillon de matière fécale de chaque individu rencontré. La technique de flottaison en utilisant la solution de Sheather a ensuite été utilisée pour analyser les endoparasites. Les parasites observés lors de l'analyse coprologique sont : trois espèces d'*Ascaris;* deux espèces d'*Ankylostoma*, de *Coccidia*, d'*Hymenolepis,* de *Schistosoma* et une espèce de *Dyplidium*, de *Strongyloididae*, de *Trichostrongylus*, et de *Trichuris*. Les matières fécales de *Bostaurus indicus* hébergeaient les parasites les plus identifiés, suivies d'*Hapalemur alaotraensis* et *Anas platyrhynchos*. Chaque espèce hôte possède au moins un parasite qu'elle ne partage pas avec d'autres espèces. Par conséquent, les résultats de cette étude ne sont pas seulement significatifs pour notre compréhension sur la santé et les parasites vivant chez les *Hapalemur alaotrensis* et autour du parc Bandro, mais ils sont également utiles pour envisager le plan de conservation de cette espèce phare malgache.

Introduction

In 2004, the regional branch of the Madagascar Ministry of Environment, Ecology, and Forests, with the support of Durrell Wildlife Conservation Trust, designated 85 hectares of intact and dense marshland vegetation as a protected area in the village of Andreba. Park Bandro hosts the biggest Alaotran gentle lemur (*Hapalemur alaotrensis*) sub-population with an estimated 170 individuals (Ratsimbazafy *et al.*, 2013a). The greatest threats to Alaotran gentle lemurs are human pressures (including marsh burning, draining, converting marshland to rice fields), and siltation from erosion of topsoil (Guillera-Arroita *et al.,* 2010a; Guillera-Arroita *et al.,* 2010b; Ratsimbazafy *et al.*, 2013a). All of these activities have significantly reduced their habitat. Habitat loss incurred by anthropogenic activities is therefore considered one of the main threats to the overall viability of the Alaotran gentle lemur population and its conservation. The effects of anthropogenic activities do not stop there, however, as a reduced habitat and a more frequent rate of entrance by humans and domestic animals to the area may increase incidences of contact with the lemur population and therefore increase the possibility of disease transmissions and spread of epidemics.

Groupe d'Etude et de Recherche sur les Primates de Madagascar (GERP) aimed to investigate the gastrointestinal parasite of the lemur population in Park Bandro in order to identify the types of parasite interplay between domestic animals and Alaotran gentle lemur and other wild fauna in the park. This will inform and improve conservation management plans in the park, the area holding the largest known number of Alaotran gentle lemurs and biggest tourist attraction at Lake Alaotra. The project is the result of a collaboration between field biologists and veterinarians involved in conservation projects in the area.

Methods

Study site
Park Bandro is situated in the marshes of the village Andreba Gare (17°38'S; 048°30'E) (Ralainasolo, 2004) and is classified as a priority zone for conservation (Zone de Priorité de Conservation, ZPC), which is the highest conservation category within the Nouvelle Aires Protégées (NAP) (Fig. 1). With an area of 85 hectares, it shelters the highest density of Alaotran gentle lemurs found in the Alaotra region (Ratsimbazafy *et al.*, 2013).

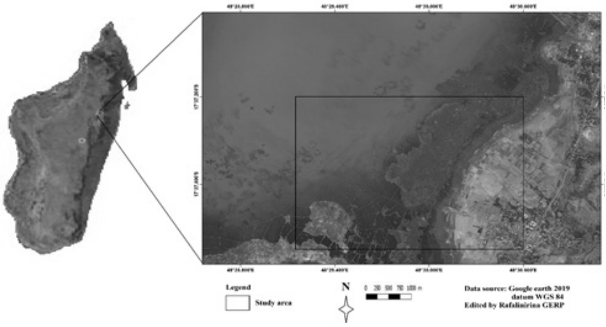

Fig. 1: Study site and site for collection of the faeces.

Data collection
No animals were captured during the study. Instead a non-invasive data collection approach, collection of faecal samples, was taken to study the state of health of Alaotran gentle lemurs, comparing results with those of other wildlife (including rodents and birds) and livestock. Alaotran gentle lemur faecal samples were obtained opportunistically: a sample of about 3g of faeces from each individual was collected from tree branches or leaves and placed in a 15ml tube containing 10ml of 10% buffered formalin solution. Samples were collected daily at dawn beginning at 4am when the lemurs were feeding.

Faecal samples from livestock at Andreba Gare were obtained non-invasively immediately after defecation and collected in a pre-identified sterile plastic tube. The collection was done every afternoon in the neighbourhoods of Andreba. Each sample was examined macroscopically immediately after collection to note the consistency and presence of mucus or parasites. A maximum of 3 g of the sample was placed in a 15 ml tube containing 10 ml of 10% buffered formalin solution.

Data analysis

Parasite analysis
Samples were analysed by a double centrifugation and floatation method using a sheather's solution of density 1.2 as described by Foreyt (2001) for the detection of helminth eggs and protists. A maximum of 3g of faeces was briefly homogenized in 10ml of water before being poured into a 15ml centrifuge tube. The tube was centrifuged for 10 minutes at 1500 rpm and the supernatant was removed. The sample was triturated with 3ml of sheather solution in a tube before being filtered in a fine mesh sieve. It was rinsed with 42ml of the same solution for a total volume of 45ml. A few drops are transferred to both of the Mac Master counting chambers with a pipette. The preparation was left to stand for 5 minutes before being examined under a microscope.

Using the x40 objective lens of the microscope, the number of each type of parasite egg and larva present in both cells were counted. Parasite identification is based on morphology, size, internal structure of eggs, and oocysts. Parasitic eggs and larvae were identified by morphological measurements and characteristics of parasites as described in humans (Foreyt, 2001), domestic animals, peri-domestic rodents and lemurs (Chabaud and Petter, 1959; Chabaud *et al.,* 1961a; Chabaud et *al.,* 1965; Raharivololona, 2006; Clough, 2009; Irwin and Raharison, 2009).

Parasite infestation was determined using parasite species richness (PSR) and parasite prevalence:
- Parasite species richness (PSR) = number of species or types of parasites encountered in a host individual. This index reflects the degree of polyparasitism in a host.

$$\text{- Parasite prevalence} = \frac{\text{No. of hosts infected by a particular parasite}}{\text{Number of hosts examined}} \times 100$$

Statistical analysis
Statistical analysis was undertaken in SPSS version 22.0 (SPSS Inc.; IBM, Chicago Illinois). A Mann Whitney and a Kruskal-Wallis test were used for the prevalence comparison and for the analysis of PSR. All statistical analyses were two tailed and $p<0.05$ was considered statistically significant.

For the ethics, the study was carried out with regard for the well-being of all animals included and with the consent of the owners of the farm animals.

Results

Faecal collection
146 faecal samples were collected in total:
- 41 from Alaotran gentle lemurs
- 41 from wild animals cohabiting with the lemurs in the Park;
    - o 14 from rats (*Rattus rattus*)
    - o 27 from wild birds (striated heron (*Butoridess striatus*), Madagascan swamp warbler (*Acrocephalus newtoni*), white-throated rail (*Dryolimnas cuvieri*), squacco heron (*Ardeola ralloides*), white-faced whistling duck (*Dendrocygna viduata*) and common moorhen (*Gallinula chloropus*))
- 64 from livestock in Andreba Gara
    - o 18 from common mallard
    - o 11 from geese (*Anser* sp.)
    - o 22 from domestic cattle
    - o 8 from domestic sheep (*Ovis aries*)
    - o 3 from domestic dogs (*Canis familiar*)
    - o 1 from domestic pigs (*Sus scrofa domesticus*)
    - o 1 from Muscovy duck (*Anas moschata*)

Identification of the gastro-intestinal parasites of Alaotran gentle lemurs, wild animals in the Park and livestock with access to the Park
After laboratory analysis, 57 of the 146 samples (39.04%) responded positively to the presence of parasites and 88 samples (60.27%) responded negatively. Observed parasites are detailed in Tab. 1. Domestic cattle faecal samples had the most identified parasites, followed by Alaotran gentle lemur, mallard ducks and rats. Each host species has at least one

parasite that it does not share with other species: *Coccidia* sp1, *Ascaris* sp2, and *Schistosoma* sp2 for domestic cattle; *Trichuris* sp1 for mallard ducks; and *Trichostrongylus* sp1 for the Alaotran gentle lemur.

Tab. 1: Gastrointestinal parasites identified and percentage of samples infected (prevalence) by host species.

Species Host	**Parasites identified**	**Infected individual**	**Prevalence (%)**
Alaotran gentle lemur (*Hapalemur alaotraensis*)	*Ankylostoma* sp1	7/41	17.07
	Ankylostoma sp2	2/41	4.88
	Trichostrongylus sp2	2/41	4.88
	Ascaris sp1	2/41	4.88
	Strongyloididae sp1	1/41	2.44
Domestic cattle (*Bos taurus indicus*)	*Ascaris* sp1	1/22	4.55
	Ascaris sp2	1/22	4.55
	Ascaris sp3	2/22	9.09
	Coccidia sp1	2/22	9.09
	Schistosoma sp2	1/22	4.55
	Strongyloididae sp1	1/22	4.55
	Ankylostoma sp1	1/22	4.55
Mallard duck (*Anas platyrhynchos*)	*Ascaris* sp1	2/18	11.11
	Ascaris sp3	1/18	1.56
	Trichuris sp1	1/18	1.56
Rats (*Rattus rattus*)	*Hymenolepis* sp1	3/14	21.43
	Hymenolepis sp2	1/14	7.14
	Schistosoma sp1	1/14	7.14
Domestic pig (*Sus scrofa domesticus*)	*Dyplidium* sp1	1/1	100
Domestic sheep (*Ovis aries*)	*Strongyloididae* sp1	1/8	12.50
	Ankylostoma sp2	1/8	12.50
Common moorhen (*Gallinula chloropus*)	*Ascaris* sp1	2/5	40.00
Geese (*Anser* sp.)	*Ascaris* sp1	1/11	9.09

Degree of infestation of gastrointestinal parasites in and around the Park Bandro

Prevalence of *Ascaris* sp1

From the 146 samples, 8 (5.48%) responded positively to the presence of *Ascaris* sp1 after coprological analysis. The species hosting these types of parasites are: Alaotran gentle lemur, common moorhen (in park Bandro), domestic cattle, geese and mallard ducks. The prevalence of *Ascaris* sp1 is much higher in moorhens (40.00%) than mallard ducks (11.11%), geese (9.09%), domestic cattle (4.55%), and Alaotran gentle lemurs (4.88%). However, despite apparent higher prevalence within park Brando there was no significant difference between the rate of infestation of *Ascaris* sp1 within or around Park Brando (U=2.000, p=0.564).

Prevalence of *Ankylostoma* sp1

From the 146 samples, eight (5.48%) were positive for the presence of *Ankylostoma* sp1. These were all Alaotran gentle lemur and domestic cattle samples. The prevalence of *Ankylostoma* sp1 is greater in Alaotran gentle lemurs (17.10%) than domestic cattle (4.50%). However there is again no difference between infestation rates in or around Park Brando (U=0.000, p=1.000).

Prevalence of *Ankylostoma* sp2

Three (2.05%) of the 146 samples were positive for the presence of *Ankylostoma* sp2. These samples were from Alaotran gentle lemurs and domestic sheep. Prevalence was higher in domestic sheep (12.50%) than Alaotran gentle lemurs (4.90%), which may be indicative of infestations outside of the park. However, there is no significant difference between the rate of *Ankylostoma* sp2 infestation inside and outside of Park Brando (U=1.000, p=1.000).

Prevalence of *Strongyloididae* sp1

Three (2.05%) of the 146 samples were positive for the presence of *Strongyloididae* sp1. Samples containing *Strongyloididae* sp1 came from: domestic cattle, domestic sheep and Alaotran gentle lemurs. The proportion of individuals infected is greater in domestic sheep (12.50%) than either cattle (4.50%) or Alaotran gentle lemurs (2.40%). Despite these species differences there is no difference in the prevalence of *Strongyloididae* sp1 between the animal hosts inside and outside of the Park Bandro (U=2.000, p=1.000).

Polyparasitism analysis according to the host species and collection site of the samples

Parasites Specific Richness according to the host species

The PSR of the host species is used to determine which host animal species may be a parasite reservoir. Domestic cattle, Alaotran gentle lemurs, mallard ducks and rats all host more than two parasite species (Fig. 2). However there was no significant variation in species richness by host species ($H_{(14)}$=16.939, p=0.259). Therefore, regardless of the host species, each of the species studied holds the potential to be a vector of transmission or gastrointestinal parasite reservoir.

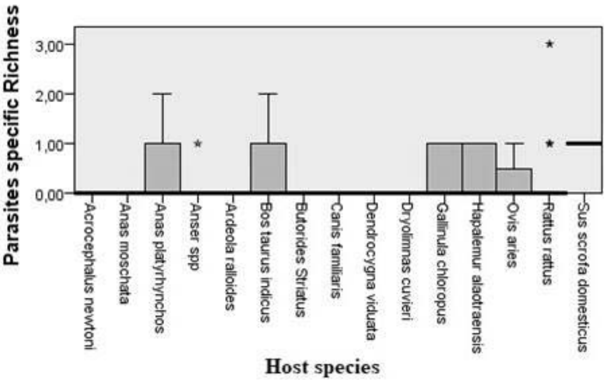

Fig. 2: Variation of Parasites Specific Richness according to species host.

Parasites Specific Richness according to the collection site

The number of parasite species varies significantly depending on the collection site of the samples ($H_{(2)}$=9.525, p=0.009); the number of parasite species observed in the village neigh-

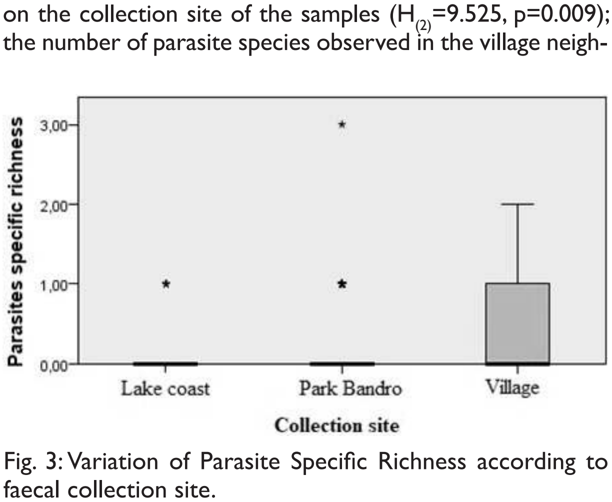

Fig. 3: Variation of Parasite Specific Richness according to faecal collection site.

bourhood is greater than in Bandro Park or at the lake. Most parasites were found in the village neighbourhood, followed by Park Bandro, and then the lake coast (Fig. 3).

Discussion

According to the coprological analysis of wild fauna and domestic animals in Andreba, fifteen species of gastro-intestinal parasites were identified: fourteen helminths and one species of protozoa. Helminthofauna comprises eight nematodes, three *Ascaris* species, two species of *Ankylostoma*, one species of *Strongyloididae*, one species of *Trichuris*, and one species of *Trichostrongylus*; three cestodes comprising one species of *Dyplidium* and two species of *Hymenolepis*; two trematodes of *Schistosoma* species; and two *Coccidia*.

Based on the measure of parasites and the degree of infestation, we found that the Alaotran gentle lemurs and other wild species are more infected by the *Ascaris* sp1 and *Ankylostoma* sp1 than the species belonging to the livestock. A different infection has been observed for the *Ankylostoma* sp2 and *Strongyloididae* sp1. However, we found that the proportion of Alaotran gentle lemurs infested by different parasites did not differ significantly from that of other host species (domestic animals or wildlife). It seems then that the degree of parasite infestation in and around Bandro Park is the same.

Domestic animals in the village neighbourhood are the most polyparasitic. Therefore, it could be the case that Alaotran gentle lemurs were infected via domestic animals that graze inside the Park and thereby spread infectious eggs or larvae upon defecation. The number of species of parasite is highest in domestic animals (cattle and mallard ducks). However, the Alaotran gentle lemurs in Park Bandro still have five nematode species, one of which was found only in the lemurs (*Trichostrongylus* sp1). It shares other species of parasite with 4 species of domestic animals (cattle, mallard ducks, geese and domestic sheep) and one wild bird (common moorhen). So where do these parasites come from and what are the dynamics of these parasites in the area? Local people and their domestic animals enter the park, especially during the time when water is decreasing. People convert the marshland into rice field and other plantations (Ralainasolo, 2006; Antje *et al.,* 2015). The park is therefore potentially contaminated by defecation of the people and their domesticated animals, such as cattle, sheep, and dogs. The Alaotran gentle lemurs within Park Brando may have been infected with parasites either orally (ingestion of food or water contaminated with L3 larvae) or through a cutaneous transmission (penetration of larvae through pores of the skin, as is the case with *Strongyloididae sp.*) (Irwin and Raharison, 2009). A similar case has been reported in and around Ranomafana National Park where lemurs residing in forests altered or frequented by people, livestock, or peridomestic rodents, are at risk of infections and other similarly transmitted pathogens (Bublitz *et al.,* 2015).

Conclusion

In conclusion, this study contributes important scientific knowledge on parasites in Alaotran gentle lemurs, wild animals cohabiting with Alaotran gentle lemurs, and domestic animals living in the villages surrounding Park Bandro. This data will contribute to the preventive and curative measures implemented to protect Alaotran gentle lemurs from parasites while at the same time guide future research on the ecology of potentially zoonotic parasites that infect lemurs and pose an additional threat to endemic species at risk of extinction in Park Brando. To avoid the risk of epidemics, it is highly recommended that managers carry out systematic control and monitoring of all domestic animals in the villages of Andreba and in the surrounding areas, including regular deworming.

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Perception of High School students on lemurs

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Abstract

Madagascar is the habitat of 5% of the world's flora and fauna; more than 80% of which are endemic, including 113 lemurs species. Despite the endemism of lemurs, few Malagasy people living in cities (especially younger generations) have heard about lemurs or are even aware of their threat to the survival of lemurs. To address this issue, we conducted an educational project in high schools in order to increase awareness of the importance of lemurs. During two months in 2015, we provided 6 lectures about lemurs to students in two high schools in the capital of Madagascar. Each lecture per class lasted approximately 2 hours, including questionnaires. A total of 236 students (aged 14 to 15 years) took part in the survey. Before the lectures, the majority of students (92%) knew lemurs as mammals and only 29% of them were able to draw an accurate picture of a lemur. After the lectures, 80% of the students could concisely define what lemurs were. Major threats to lemurs were understood by approximately 92% of students and 51% of students knew that lemurs are forest dwellers. All students reported that they enjoyed the lesson and were motivated to contribute to the protection of Madagascar's biodiversity such as participation in reforestation and attending lemur festivals. These findings highlight the success of such an approach in increasing the awareness of young people with respect to the importance of lemurs. We advocate the use of lectures and involvement of students in discussions about lemurs to help protect lemur populations in the future.

Introduction

Madagascar is the fourth largest island in the world and possesses a high diversity of both plants and animals. This island is among the 12 top priority countries for biodiversity conservation (Myers, 1988) and the third highest on the world list of primate species diversity (Mittermeier *et al.*, 2010). All 113 registered lemur species are endemic to the country and about 94% are threatened with extinction (Schwitzer *et al.*, 2013).

People living in Antananarivo, the capital of Madagascar call lemurs 'Maki'. This is a Malagasy term which is used generically for lemurs, regardless of species. The word Maki is popular in Antananarivo and is used in a variety of contexts: for instance a T-shirt company is named "Maki Company"; the national rugby team called "Maki de Madagascar"; a stadium for rugby is named "Kianja Maki"; a public transport station that was inaugurated recently called "Gare Routière Maki" and a supermarket named "Supermaki" is present throughout the capital. Despite the popularity of the word 'maki', it has been reported that the majority of the Malagasy people are still unaware of the biodiversity richness and conservation values of their country (Reibelt *et al.*, 2017).

Ratsimbazafy (2003) noted that at school students are not taught about native wildlife or the science of conservation. They are more familiar with giraffes, lions and tigers, despite these animals not being found in Madagascar (Ratsimbazafy, 2003). During the first day of the celebration of the first lemur festival in Antananarivo in 2014, we conducted street interviews with approximately 50 people, composed mostly of 15 to 30 year olds. The people interviewed during this festival replied that they had not heard of lemurs and did not know the threats they face. Therefore, the Mikajy Natiora Association, a Madagascar-based non-profit association decided to carry out an educational project in high schools in the capital of Madagascar. In 2002, the Malagasy government issued a decree that environmental education should be integrated in the national curriculum in schools at all levels throughout the country (Rakotomamonjy *et al.*, 2014). Environmental education aims to provide people with the knowledge they need to protect and manage their environment and also to help encourage attitude change (Palmer, 1998; Kaiser, Oerke and Bogner, 2007; van der Ploeg *et al.*, 2011). Education within schools was chosen as the most efficient means of increasing environmental awareness in the community because younger people have the ability to learn quickly and in future they may go on to become policy makers and thus have responsibilities relating to ongoing lemur protection. The aim of this work was to increase awareness in young people, about the role of lemurs in Malagasy biodiversity. The following report describes the successes of the methods employed to reach this aim.

Methods

Several high schools within the capital were contacted in October 2015. Two schools (Ecole Sacré Coeur Antanimena (ESCA) and Lycée Jean Joseph Rabearivelo (LJJR)) accepted the invitation to be part of the programme. The high school students (n=236) were 10th grade and 11th grade (age range 14 to 15 years). A breakdown of the number of students involved in the projects is detailed in Tab. 1.

Tab. 1: Number of students per class in each school

ESCA			**LJJR**		
Class Seconde I	Class Seconde II	Class Seconde III	Class Première VI	Class Première VIII	Club Vintsy
46	45	47	39	41	18

Prior to the onset of the study a meeting was held with the headmaster to finalize an appropriate method. The project was undertaken from November to December 2015. Presentations were created which were no more than two hours long and focused on local lemur species, three presentations were given to each school. Presentations were delivered in Malagasy and contained the following information: basic detailed information on flagship species of lemurs including definition, diet, habitat and examples of conservation efforts.

In order to evaluate the effectiveness of the sessions, students were asked to complete questionnaires before and after the presentation (Appendix 1 and 2). Before the presentation students were asked to provide the following information: definition of a lemur which has mammal's character; habitat, lifestyle and diet. They were also asked to draw a lemur. Lemur pictures were scored from 1 to 3 (1: poor; 2: fair; 3: good). A 'poor' picture was an incomplete picture without the body and tail (Fig. 2), a picture with an entire body was classed as 'fair' and a complete drawing that shows the body and the tail was defined as 'good' (Fig. 3). The aim of this exercise was to ascertain the ability of the students to distinguish the lemur from other animals. The questionnaires after the presentation were related to the presentation and included description of a lemur, social life, threats and conservation effort. The questionnaire was in multiple-choice format. During the presentation, aptitude of the students was evaluated by asking oral questions about the basic knowledge on lemurs and its habitat. Notes were taken of students' answers.

Statistical analyses were undertaken in Excel. Chi-square tests were used to test the difference in knowledge before and after the lectures and between schools. Significance levels were set at $p<0.05$.

Fig. 1: Sharing of the evaluation form.

Results

Student knowledge before the presentation

Before the presentation on lemurs, the majority of the high school students (95%, n=219) knew lemurs were mammals; 89% of the students responded that lemurs are endemic to Madagascar while 11% of them 'did not know'. Sixty-seven percent of the students stated that lemurs were not a pet, the remaining 33% viewed lemurs as domestic animals. Of the students who drew a lemur (n=232), 29% drew a 'good' picture, 31% drew a 'fair' picture 40% drew a 'poor' picture. The knowledge on lemurs between the two schools ESCA and LJJR did not differ significantly ($\chi^2=1.37$; $p>0.05$).

Student perception during the presentation

Students took notes during the presentation (Fig. 4), which was taken as an indicator of their interest in the subject. Engagement levels (figures 5 and 6) in students at the two schools differed significantly ($\chi^2=179.12$, $p<0.05$). Students at ESCA participated actively in the discussion with 90% asking for information and responding to questions (n=124). At LJJR interaction was lower but 36% of the class (n=35) still asked and answered questions during presentations.

Fig. 2: A 'poor' picture of a lemur.

Fig. 3: A 'poor' picture of a lemur.

Student perception after the presentation

After the lecture, 80% of the students could provide an accurate definition of what a lemur is. All students (100%) knew the origin of lemurs. Knowledge on lemur habitat was mixed; 51% of the students said that lemurs inhabit forest while 49% suggested lemurs live in zoos. The majority of the students (92%) were familiar with the major threats to lemurs including deforestation from slash and burn agriculture, illegal logging and mining exploitation but few (13%) could identify lemur predators. Lemur knowledge after the presentation differed between the two schools ($\chi^2=12.13$, $p<0.05$).

Fig. 4: Students taking notes.

Discussion

The results showed that before the lecture, the majority of the students knew lemurs as mammals. After the presentation, most of them could concisely define what lemurs were and understood the main threats to lemurs.

Engagement with schools

Attempts were made to contact a number of local schools but only two participated in the project. Prior to the presentation's meetings were held with the two headmasters. During these meetings it was difficult to fully convince them the importance of the work. Their main concern was that the time taken to engage in the project would take away from the syllabus which students needed to cover in their school day. The discussions in the meetings led us to believe that the headmasters were not fully aware of the importance of the work. It appeared difficult for the headmasters to find time to include our activity; they had to negotiate with the teachers and ask them to include our activity during their classes. The teachers however were supportive of our request. This research has indicated that environmental education can be integrated within school in national level, but it seems that many teachers do not have the capacity to effectively include environmental education in their teaching (Dollins et al., 2010). Despite of a decree about the

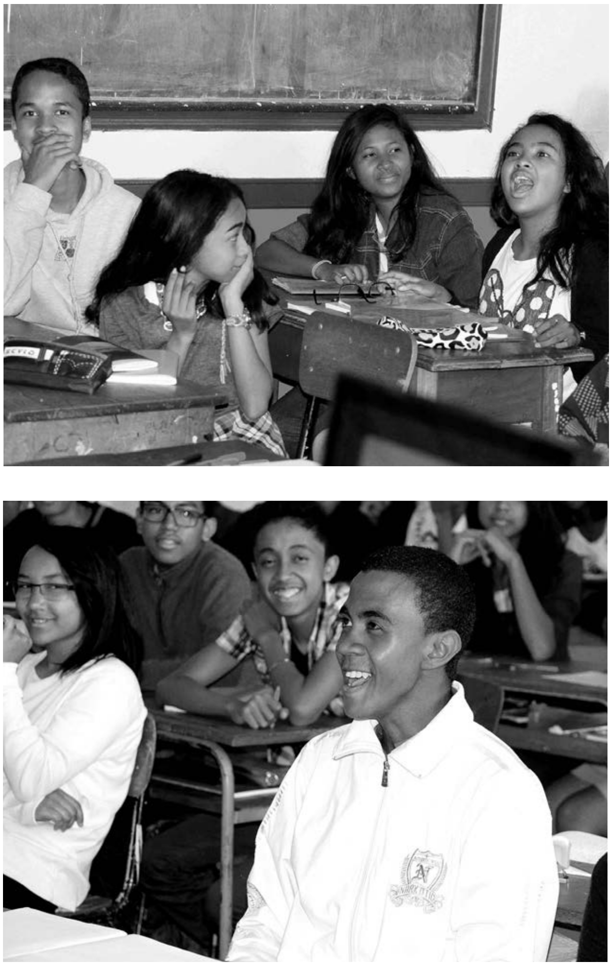

Fig. 5: Students engaging in sessions.

Fig. 6: Students raising hands to reply to questions.

integration of the environmental education into education in schools across the country by the Malagasy government, this initiative is not yet well practiced in schools (Rakotomamony *et al*., 2014).

Lemur knowledge

High school students in both schools did not know about the activity in advance; it was a surprise for them when the Mikajy Natiora team entered their classes and their teachers introduced the project. The evaluation before the presentation showed that both schools had basic knowledge on lemurs and this knowledge did not differ between the two schools. However, the majority of the students drew relatively poor lemur pictures. The reason for this could be lack of familiarity with lemurs or just a lack of ability to accurately draw what they perceived lemurs to be. In addition, during our presentations the majority of students stated they had not visited any national park and only had visited the zoos in Antananarivo that keep several species of lemur. It has been reported that only few Malagasy's have seen lemurs out of captivity and approximately 90% of the population of Madagascar do not live close to forests (Dollins *et al*., 2010).

Dynamism of the students

Students from ESCA were more dynamic (active in terms of responding to questions and sharing information during the presentation) than those from LJJR. ESCA is a private catholic school while LJJR is a government high school. ESCA is very strict in terms of discipline and students were taught in active and dynamic ways during classes (e.g. to ask questions without hesitation if they did not understand an explanation; answer questions and share information). In addition, the teacher was present during the presentation and encouraged the students to ask questions during and after the lemur presentation. Students from LJJR were more reserved; the team had to encourage them to be more participative during the presentation.

Following on from this work, we recommend the following actions, in order to further increase Malagasy's awareness on lemur conservation and habitat protection:

- Malagasy Television channels should broadcast films or documentaries on biodiversity including lemurs
- Schools should organise day-excursions to the national zoo or field visit within national parks
- All conservation NGOs working in Madagascar should provide environmental education to people living in the villages and cities surrounding their work sites wherever possible
- The Malagasy government should reinforce environmental education from primary schools upwards in order to improve the knowledge and aptitude of the Malagasy population towards their nation's unique biodiversity

Conclusion

This environmental education project was a basic step to improve young people's knowledge of lemurs. The project successfully helped increase lemur knowledge in high school students. Students enjoyed and understood the activity on lemurs and were aware of the current threats to lemurs. At the end of the presentation, students were to contribute to the lemur conservation, and they responded positively. Students stated that they would like to be involved in several forms of environmental action events such as reforestation activities and lemur festivals. We can conclude that environmental education programs such as the one undertaken as part of this work have positive impacts on young people. Knowledge of lemurs and their natural habitat was improved in young people following the sessions. Further work should seek to involve more schools within the capital in order to maximize the impact of this initiative.

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Observations of fission-fusion dynamics in diademed sifakas (*Propithecus diadema*) at Tsinjoarivo, eastern Madagascar

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Abstract

As with other primate clades, many lemur species form social groups and coordinate their activities and travel. However, some primate species exhibit 'fission-fusion dynamics', meaning that the larger social unit breaks into two or more subgroups for hours or days, and those subgroups travel and forage independently for hours or days. This behavior serves to alleviate the effects of within-group feeding competition while preserving the overall social organisation. This behavior had previously been reported in lemurs, but only within Lemuridae (genera *Varecia* and *Eulemur*). Here we report fission-fusion behaviors in diademed sifaka (*Propithecus diadema*, Indriidae) at Tsinjoarivo. Three of four groups studied exhibited fission-fusion dynamics, splitting on more than 50% of days studied, with splits lasting up to 48 hours and subgroups reaching up to 690 meters apart (greater than half the home range diameter). Further research is needed, both to understand the factors causing this behavior at Tsinjoarivo, to determine if other Indriids also exhibit this behavior, and finally to examine its impacts on social behavior and fitness (for example, through facilitating extra-group paternities).

Résumé

Comme d'autres clades de primate, beaucoup d'espèces de lémuriens mènent une vie sociale en groupe et synchronisent leurs activités et leur déplacement. Cependant, certaines de ces espèces montrent la «dynamique de fission-fusion», définissant la division d'un large groupe en deux ou plusieurs sous-groupes qui se déplacent et recherchent de la nourriture indépendamment, durant des heures ou des jours. Ce comportement sert à alléger les effets de la compétition alimentaire intra-groupe, tout en préservant l'organisation sociale en général. Celui-ci avait été précédemment observé sur les lémuriens, mais seulement chez la famille des Lemuridae (genres *Varecia* et *Eulemur*). Ici nous rapportons le comportement de fission-fusion chez le sifaka à diadème (*Propithecus diadema*, Indriidae) à Tsinjoarivo. Trois des quatre groupes étudiés ont montré la dynamique de fission-fusion, se séparant plus de 50% des jours étudiés, avec des fissions qui durent 48 heures et des sous-groupes atteignant une distance de 690 mètres (plus grand que la moitié du diamètre du territoire). Compte tenu de ces faits, d'autres recherches sont nécessaires pour comprendre les origines de ces facteurs à Tsinjoarivo; pour déterminer si d'autres Indriidae le pratiquent également; et finalement, pour examiner leurs impacts sur le comportement social et l'état de santé (par exemple, en facilitant les paternités de groupe supplémentaire).

Introduction

Primates exhibit great inter- and intra-species variation in the size, composition and cohesiveness of social groups. The term 'fission-fusion dynamics' describes the extent of variation in cohesion (Aureli *et al*., 2008; Carnes *et al*., 2011). Groups with high fission-fusion dynamics exhibit high temporal variation in spatial size, spatial cohesion and party size while those with low fission-fusion dynamics exhibit low temporal variation in spatial size, spatial cohesion and party size (Aureli *et al*., 2008). Fission-fusion dynamics can be adaptive when optimal group size varies over short time periods (Lehmann and Boesch, 2004) as well as regulating intragroup scramble competition by decreasing feeding competition (Leighton and Leighton, 1982; Chapman *et al*., 1995; Stevenson et *al.,* 1998; Chapman and Chapman, 2000) and allowing greater efficiency in exploiting food resources that tend to be heterogeneously clumped within the landscape (Asensio et *al.*, 2009).

Studies on fission-fusion dynamics in primates have largely focused on chimpanzees (Goodall, 1968; Nishida, 1968; Sugiyama, 1968; Itoh and Nishida, 2007) and spider monkeys (Robbins et *al.*, 1991; Asensio et *al.*, 2009), but fission-fusion dynamics have been reported in several other monkey and ape species (van Schaik, 1999; Delgado and van Schaik, 2000; Ren et *al.*, 2002; Aureli et *al.*, 2008; Snaith and Chapman, 2008). Some species of strepsirrhines have also exhibited fission-fusion dynamics, including red ruffed lemurs (*Varecia rubra*: Vasey, 1997; Vasey, 2006; Vasey, 2007), black and white ruffed lemurs (*Varecia variegata*: Morland 1991a, Morland 1991b; Baden et *al.*, 2015; Holmes et *al.*, 2016), white-fronted brown lemurs (*Eulemur albifrons*: Toborowsky 2008), white-collared brown lemurs (*Eulemur cinereiceps*: Johnson, 2002), black lemurs (*Eulemur macaco*: Colquhoun, 1997), common brown lemurs (*Eulemur fulvus*: Tattersall, 1977), crowned lemurs (*Eulemur coronatus*: Freed, 1996) and red-fronted brown lemurs (*Eulemur rufifrons*: Overdorff et *al.*, 2003; Pyritz et *al.,* 2013).

Baden et *al.* (2015) found, unlike other groups that exhibit high fission-fusion dynamics, black and white ruffed lemurs appear to exhibit this type of social structure due to communal breeding; forming small and cohesive groups during early lactation and high infant dependency. Other factors impacting their fission-fusion dynamics included fruit availability and climate. This is similar to haplorhines, although, unlike haplorhines, they exhibited small subgroup sizes, lower rates of association and a more female-centered social organization (Baden et *al.*, 2015). According to Holmes et *al.* (2016), fission fusion dynamics of black and white ruffed lemurs were largely predicted by fruit availability, season and presence of infants. However, unlike other studies of fission-fusion dynamics, they exhibit smaller subgroup sizes during periods of site-wide fruit availability. This may be due to the impact of fragmentation on fruit abundance, diversity or predictability (Holmes et *al.*, 2016). Vasey (2006) reports similar findings concerning the fission-fusion dynamics of red ruffed lemurs. They were largely impacted by their reproductive biology and patchy fruit-based diet (Vasey, 2006). Within Lemuriformes, fission-fusion dynamics have only been described in *Eulemur sp.* and *Varecia sp.* Here we report the occurrence of fission-fusion dynamics in diademed sifakas (*Propithecus diadema*) in Tsinjoarivo, Madagascar.

Methods

Tsinjoarivo forest is located about 80km SSE of Antananarivo and 45km SE of Ambatolampy, in the region of Vakinankaratra, with an altitude of 1400–1650m. Data were collected at two sites: Mahatsinjo (19°40'56"S, 47°45'28"E, altitude 1475-1625m, 10km SE of Tsinjoarivo), and Ankadivory (19°42'59"S, 47°49'18"E, altitude 1350-1575m, 17km SE of Tsinjoarivo (Irwin et *al.*, 2015; Rakotomalala et *al.,* 2017). Ankadivory is a relatively continuous, intact forest, while Mahatsinjo has been subjected to considerably more tree extraction and has fewer trees >5cm DBH per hectare, less basal area per hectare and a shorter, more discontinuous canopy (Irwin and Raharison, in press). These sites belong to the future protected area of Tsinjoarivo-Ambalaomby, which includes several forest blocks from Mahatsinjo to Ambalaomby along the Onive river.

The diademed sifaka is the largest lemur at Tsinjoarivo and classified as critically endangered (Andriaholinirina et *al.*, 2014). They live in small groups (2-10 individuals) including a dominant female (sometimes accompanied by a second breeding female), a single adult male and offspring (Mittermeier et *al.,* 2014). Their diet is composed primarily of foliage (53% of feeding time), fruit, seeds and flowers (Irwin, 2008). Four groups were followed: CONT4 and CONT5 at Ankadivory and FRAG4 and FRAG5 at Mahatsinjo with seven, six, seven and three individuals, respectively (excluding infants born during the study; Tab. 1). All individuals in the group were collared during the study except 1-year-olds; all were identifiable.

Tab. 1: Composition of Tsinjoarivo diademed sifaka (*Propithecus diadema*) study groups, sampling time, and prevalence of fission-fusion behaviors.

Group	**Composition (immatures' age in years)**[1]	**# Data Collection Days**	**# Days with**	**% Time in**
			Fission-Fusion Activity	
CONT4	2 Adult Female (RAD, GB) 1 Adult Male (RG) 4 immatures: PR (3), BP (2), JUV1 (1), JUV1 (1)	11 (2-7 July, 24-28 July)	10 (91%)	74%
CONT5	2 Adult Females (RAD, PS) 1 Adult Male (BR) 3 immatures: BG (approx. 4), TO (approx. 3), JUV (approx. 1)	11 (26-30 June, 30 July–4 Aug)	7 (64%)	52%
FRAG4	2 Adult Females (RAD, PB) 1 Adult Male (BG) 4 immatures: GS (5), PO (4), BR (3), JUV (1)	11 (11-16 June, 10-14 July)	8 (73%)	42%
FRAG5	1 Adult Female (RAD) 1 Adult Male (BP) 1 immature: JUV (1)	11 (18-23 June, 16-21 July)	0 (0%)	0%
Total		**44**	**25 (57%)**	**42%**

[1] CONT5: RAD, CONT5:PS and FRAG4:PB gave birth during the study but these infants are not recorded in the table.

Data were collected between 11 June and 04 August 2018; each group was subjected to all-day focal animal follows for 11 days. Data were collected on one adult female and one adult male simultaneously; for three groups with two adult females each, observations were focused on the dominant, older adult female (CONT4: RAD, CONT5: RAD, FRAG4: RAD, Tab. 1) rather than the younger breeding adult female. Activity data (feeding, traveling, resting, social) were collected using instantaneous sampling with a 5-minute inter-scan interval for each focal animal. Additionally, a team of 2-3 research assistants monitored the position of all group members and estimated distances between each pair of animals (distances above 20 meters were recorded as ">20"). With few exceptions, the focal animals were followed daily from their wakening until their dormitory tree.

A 'fission event' was defined as when subgroups became >250 meters from each other and a 'fusion event' was defined as when subgroups converged into visual and vocal contact (usually <20 meters). Thus, subgroups were sometimes considered as fissioned when less than 250 meters apart (when they had previously been >250 meters apart). Additionally, it was noted when the group stayed in a fissioned state, but the composition of subgroups changed. GPS points were recorded on all data collection days; when the group was cohesive, a single GPS unit was used, but a second GPS unit was deployed during certain days with fission-fusion events so that both the adult male and adult female's paths were recorded. Points were recorded at

5-minute intervals throughout the day (except if the animal had not moved during the last 5 minutes).

Data collected from GPS waypoints were mapped in ArcGIS Version 10.6 (ESRI, Redlands, California, USA) and used to measure selected distances between subgroups. Using times of fission and fusion events, cumulative times spent in fission situations were calculated and expressed this as a proportion of total observation time. This calculation included time passing overnight between consecutive days of data collection (this population almost never moved at night).

Results

Three of the four study groups exhibited fission-fusion dynamics (Tab. 1 - 4). Among those three groups, 64-73% of days sampled exhibited fission-fusion dynamics and 42-74% of overall time sampled was in a state of fission.

Tab. 2: Fission-fusion events for diademed sifaka (*Propithecus diadema*) study group CONT4.

Date/Time	Fission/Fusion Event	No. of Subgroups	Notes
2 July, 07:25	Start Data Collection: RAD, GB, RG, PR, BP, JUV1, JUV2	1	
2 July, 8:15	Fission: RAD, PR/ GB, RG, BP, JUV1, JUV2	2	
2 July, 10:15	Fission: RAD, PR/ GB, RG, BP, JUV1/ JUV2	3	
2 July, 13:00	Fusion: RAD, GB, RG, PR, BP, JUV1/ JUV2	2	
4 July, 12:30	Fission: RAD, GB, BP, JUV 1/RG, PR/ JUV2	3	
5 July, 10:50	Fusion: RAD, GB, RG, PR, BP, JUV1/ JUV2	2	
7 July, 16:00	End Data Collection: RAD, GB, RG, PR, BP, JUV1/JUV2	2	JUV2 was seen by a plant collection team, roughly 500 m from the group (7 July, 13:24)
24 July, 06:45	Start Data Collection: RAD, PR, BP, JUV/GB, RG, JUV	2	
24 July, 8:15	Fusion: RAD, BG, RG, PR, BP, JUV1, JUV2	1	
26 July, 14:45	Fission: RAD, GB, BP, JUV1, JUV2/ RG, PR	2	
27 July, 12:10	Subgroup composition change: RAD, BP, JUV1, JUV2/GB, RG, PR	2	
28 July, 11:08	Fusion: RAD, GB, RG, PR, BP, JUV1, JUV2	1	
28 July, 16:05	End Data Collection	1	

Tab. 3: Fission-fusion events for diademed sifaka (*Propithecus diadema*) study group CONT5.

Date/Time	Fission/Fusion Event	No. of Subgroups	Notes
26 June, 08:00	Start Data Collection: RAD, PS, TO, JUV, BR, BG	1	
26 June, 13:40	Fission: RAD, PS, TO, JUV/BR, BG	2	BR, BG lost until next fusion
27 June, 09:40	Fission: RAD, PS / TO, JUV/BR, BG	3	
27 June, 10:35	Fusion: RAD, PS, TO, JUV/BR, BG	2	
28 June, 12:45	Fission: RAD, JUV / PS, TO/BR, BG	3	
28 June, 13:50	Fusion: RAD, PS, TO, JUV, BR, BG	1	BR, BG relocated by research team at time of fusion
28 June, 14:40	Fission: RAD, PS, TO, JUV/BR, BG	2	
30 June, 13:12	Fusion: RAD, BR, BG, PS, TO, JUV	1	BR+BG had been stationary for 1h40 minutes when another subgroup arrived
30 June, 15:06	Fission: RAD, PS, TO, JUV/BR, BG	2	
30 June, 17:45	End of Data Collection Cycle: RAD, PS, TO, JUV/BR, BG	2	
30 July, 07:30	Start Data Collection: RAD, PS, TO, JUV, BR, BG	1	
3 August, 16:20	Fission: RAD, PS, TO, JUV/BR, BG	2	
4 August, 08:15	Fission: RAD, PS/BR, TO, BG/JUV	3	
4 August, 08:50	Fusion: RAD, PS/BR, TO, BG, JUV	2	
4 August, 16:35	End of Data Collection Cycle: RAD, PS/ BR, TO, BG, JUV	2	

Tab. 4: Fission-fusion events for diademed sifaka (*Propithecus diadema*) study group FRAG4.

Date/Time	Fission/Fusion Event	No. of Subgroups	Notes
11 June, 7:40	Start of Data Collection: RAD, BG, GS, JUV/PB, PO, BR	2	PB, PO, BR missing but not within 250 m
12 June, 14:50	Fusion: RAD, BG, PB, PO, GS, BR, JUV	1	PB, PO, BR relocated at time of fusion
14 June, 13:05	Fission: RAD, BG, GS, PO/PB, JUV, BR	2	
15 June, 13:10	Fusion: RAD, BG, PB, PO, GS, BR, JUV	1	
16 June, 16:20	End of Data Collection: RAD, BG, PB, PO, GS, BR, JUV	1	
10 July, 08:35	Start of Data Collection: RAD, BG, PB, JUV/GS, PO, BR	2	GS, PO, BR missing but not within 250 m
11 July, 11:15	Subgroup Composition Change: RAD, PB, PO, GS, BR, JUV/BG	2	BG falls behind while remainder of group joins
11 July, 15:30	Fusion: RAD, BG, PB, PO, GS, BR, JUV	1	
12 July, 7:50	Fission: RAD, BG, GS, JUV/PB, TO, BR in rear	2	
12 July, 15:20	Fusion: RAD, BG, PB, PO, GS, BR, JUV	1	
14 July, 12:55	Fission: RAD, PB, PO, GS, BR, JUV/BG	2	
14 July, 16:00	End of Data Collection: RAD, PB, PO, GS, BR, JUV/BG	2	

During fission events, the number of subgroups varied between two and three for groups CONT4 and CONT5, but only reached two for group FRAG4. The composition of subgroups varied (Tab. 2 - 4). Among the three adults in CONT4, 'fissioning' involved either the older adult female (RAD) separating from the other two (younger female GB and adult male RG) or the adult male separating from both adult females. Further variations in subgroup composition were caused by different arrangements of the immature animals. In CONT5, the most common arrangement was the adult male (BR) and an older immature (BG) separating from the remaining four animals, but those four animals would also fission into two subgroups of two individuals each. At the end of the second data collection cycle, the older and younger adult females (RAD and PS) were together, with the adult male (BR) with the three immatures (except for a short time when JUV was alone). In FRAG4, the most common 'fissioning' involved the younger adult female PB (who was born in this group in 2012 and reproduced for the first time in 2018) splitting from the older adult female (RAD) and adult male (BG). PB often had some immatures accompanying her. On another occasion, three immatures separated from the group, and on two occasions the adult male (BG) separated from the group alone.

Subgroups often remained separated for extended periods, including overnights (using separate, distant sleep trees). The longest consecutive time spent in fission (including overnight time) was >127.75h (CONT4: 2-7 July), which included the separation of JUV2 (a 1-year-old) from the remainder of group CONT4 for >125.75h. The next longest consecutive time spent in fission (including overnight time) was 48.2h (CONT5: 26-28 June), followed closely by 46.5h (CONT5: 28-30 June) and 44.4h (CONT4: 26-28 July).

The distances among subgroups were considerable (Fig. 1). CONT5's subgroups on 28 June were 690m apart at 16:50 and slept 580m apart. On 29 June, the subgroups were 490m apart at 10:40 and slept 190m apart. On 30 June, they slept 265m apart. For reference, CONT5's home range is 62.9ha and measures roughly 1230m north to south and 1030m west to east (Irwin and Raharison, in press). CONT4's subgroups were 340m apart at the beginning of the day on 28 July. For reference, CONT4's home range is 90.2ha and measures roughly 945m north to south and 1630m west to east (Irwin and Raharison, in press).

Discussion

Our observations show an extremely high prevalence of fission-fusion behavior in diademed sifakas, at least during this short study during the lean season. The fact that three of four groups exhibited the behavior means it is not an idiosyncrasy of a single group, and further, the fact that it was observed in two groups in relatively intact forest (CONT4 and CONT5) and another group in more disturbed forest (FRAG4) suggests that this behavior is not expressed only in more degraded habitat, as was suggested for spider monkeys (Rodrigues, 2017). It is notable that the two CONT groups exhibited higher percentages of time in fission (52-74%), and a higher number of simultaneous subgroups (2-3) relative to FRAG4 (42% and 2, respectively). This may be due to the CONT habitat's larger groups and larger home ranges, or the nature of the food resources (Irwin, 2008; Irwin and Raharison, in press). The lack of fission-fusion in FRAG5 may be due to its small group size (3). However, the observed differences may also be artifacts of the relatively small sample size.

Although this is the first published report, fission-fusion behavior has been observed previously (but not quantified) by research teams studying this diademed sifaka population. In particular, in FRAG4, the adult male BG has been seen for several years now to separate from groupmates, often with one or more immatures. In CONT4, similar splits between the three adults were observed in 2016-17. Thus, this behaviour is not a rare occurrence driven by an unusual year in terms of resource availability.

The implications of fission-fusion behaviour on daily life are potentially meaningful. In terms of feeding competition, it could be crucial in alleviating within-group feeding competition and maximizing foraging efficiency. However, it is curious that this behaviour would be expressed in the lean season. This season sees a switch to lower-quality fallback foods, greatly reduced feeding times and lower aggression rates compared to other seasons, suggesting an 'energy minimizer' strategy, during which feeding competi-

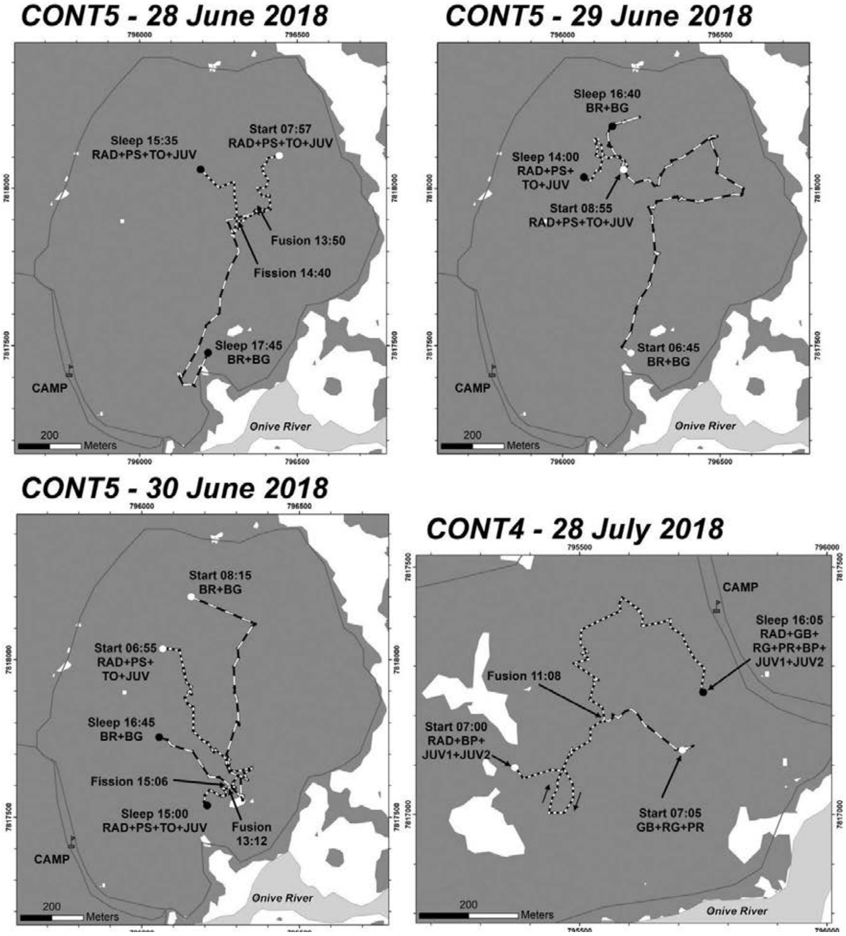

Fig. 1: Daily paths of subgroups during fission-fusion events of diademed sifaka (*Propithecus diadema*) at Tsinjoarivo. White dots indicate starting points (waking up); black dots indicate ending points (sleep trees). Lines with short dashes represent the subgroups containing the adult female(s) or the whole group; lines with long dashes represent the subgroups containing the adult male. The first three panels are three consecutive days of fission-fusion events in CONT5; on the first day BR+BG were not located until fusion at 13:50 (their early morning path is therefore not shown); on the second day the subgroups never joined up, and on the third day they joined and then split again. Group CONT4 on 28 July (fourth panel) woke up in two subgroups but joined and slept together.

tion should be lessened (Irwin, 2006; Irwin *et al.*, 2015; Irwin and Raharison, *in press*). Further study is needed to quantify seasonal variation in the tendency to fission-fusion and to explore links between this behavior and feeding competition. If conducted across multiple groups, the linkages with habitat disturbance could also be explored.

If occurring during the mating season, fission-fusion could affect mating access and mate choice and may facilitate extra-group paternities (which have not yet been detected in this population). We do not have evidence that this has occurred, but it is interesting to note that PB in FRAG4 gave birth during our study, despite being a natal female (born in FRAG4 in 2012) and her presumed father (BG) being the sole resident male since at least 2006. Although it is possible she bred with her father, it is also possible that PB's infant was sired by an extra-group male, or that she herself was sired by an extra-group male rather than by BG. Further paternity sampling would be necessary to explore this possibility.

Finally, we were surprised by the long separation of a 1-year-old (CONT4: JUV2) from its group (2-7 July; Tab. 2). 1-year-olds are noticeably smaller than adults (approximately 2.9 vs 5.0 kg), meaning they should be more vulnerable to predation, and typically maintain closer distances to adults (particularly their mother) during both resting and active times (Irwin, *unpublished data*). It is possible this was an unintentional separation.

Conclusion

In sum, fission-fusion dynamics in lemurs do not seem to be restricted to two genera (*Eulemur* and *Varecia*) within a single family (Lemuridae). This report is the first we are aware of outside the Lemurids. It is possible that the true occurrence in nature is even more widespread; further research efforts should seek to document this behavior, and explore its causes, in this population and in lemurs more broadly.

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Utilisation verticale de l'habitat par *Hapalemur griseus griseus* dans la forêt tropicale humide de Maromizaha (Andasibe)

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Résumé

Lorsqu'on parle de l'espèce *Hapalemur griseus*, c'est le Parc National de Ranomafana qui est considéré comme un site de référence. L'étude sur l'utilisation verticale de l'habitat par *Hapalemur g. griseus* a été effectuée dans la forêt humide tropicale de Maromizaha pendant la saison humide et sèche en 2016. *Hapalemur g. griseus,* un lémurien folivore, se trouve dans cette forêt mais les informations scientifiques sur ce taxon restent méconnues, notamment sur cette utilisation verticale et les facteurs qui peuvent l'influencer, voire les enjeux environnementaux qui peuvent également modifier l'habitat de l'animal. A cet effet, la présente étude a fait l'objet d'identifier les facteurs bioécologiques dans l'utilisation verticale de l'habitat d'*Hapalemur g. griseus*. Des données sur cette utilisation ont été obtenues par la méthode de l'observation focal. En effet, *Hapalemur g. griseus* occupe toutes les strates forestières disponibles de son habitat (basses, moyennes et supérieures), mais avec différentes fréquences. Quand l'animal occupe la strate basse (0.1-3m), il récupère les pousses, les jeunes feuilles de bambou et les jeunes feuilles d'autres plantes ainsi qu'il se repose dans un endroit sécurisé. Pour les autres strates, l'animal l'utilise pour surveiller leur environnement. Dans cette utilisation de l'habitat verticale, la hauteur d'*Hapalemur g. griseus*, dépend de la hauteur des arbres utilisés comme support (R_s=0.712; $P<0.0001$). En outre, *Hapalemur g. griseus* exploite les supports de deux façons pour récupérer les aliments. Pour la première méthode, il se nourrit sur un support, l'animal récupère les feuilles du bambou sur cette même plante (*Cephalostachyum* sp), il exploite les fruits de *Canthium* sp les feuilles et les fruits de *Ficus sorocoides et* de *Ficus reflexa* sur ce même arbre. Pour la deuxième méthode, l'animal collecte son aliment en s'appuyant sur un autre support. Dans l'organisation sociale d'*Hapalemur g. griseus*, l'animal se regroupe pendant leur activité et parfois il se disperse. Il y a une distance du voisin moyenne minimale et maximale par rapport à l'animal focal qui est respectivement 1.3m±0.0m et

3.21m±0.0m (n=1039). En cas de perturbation, il lance un cri d'alerte pour avertir les autres membres. *Hapalemur g. griseus* est considérablement vigilant en adoptant une stratégie adéquate pour sa structure sociale. En conclusion, dans l'utilisation verticale de l'habitat par *Hapalemur g. griseus,* les facteurs déterminants de cette utilisation sont la disponibilité des ressources notamment la hauteur des arbres utilisés comme support, la luminosité, la saisonnalité, le sexe ainsi que les comportements.

Introduction

Le genre *Hapalemur* qui est un lémurien mangeur de bambou présente des groupes très diversifiés (Mittermeier *et al.,* 2010), auquel appartient l'espèce d'*Hapalemur g. griseus*. Dans la dernière décennie, ce taxon occupe presque toutes les zones éco floristiques orientales (Mittermeier *et al.,* 2006). La révision systématique de la génétique de la population de cet animal montre que l'aire de sa répartition diminue par rapport à 2006 (Rabarivola *et al.,* 2007). En effet, il se trouve dans deux Réserves Spéciales (Analamazaotra et Mangerivola), dans la Réserve Naturelle Intégrale de Betampona et dans le Parc National de Mantadia (Mittermeier *et al.,* 2010). Selon Rabarivola *et al.* (2007), *Hapalemur g. griseus* est actuellement limité au centre-est de Madagascar, il s'étend probablement de la rivière Onive jusqu'à la rivière de Nosivolo au sud. Cette dernière le sépare d'*Hapalemur g. gilberti*. Par contre, au nord, l'aire de sa répartition ne dépasse pas la rivière d'Onibe.

Geoffroy (1851) a décrit pour la première fois que le genre *Hapalemur* est répandu dans la forêt tropicale humide primaire ou dans la forêt secondaire dans laquelle poussent les bambous. Plusieurs auteurs qui ont effectué des recherches sur *Hapalemur g. griseus* (Petter *et al.,* 1975; Tattersall, 1982; Wright, 1986; Tan, 1999; Grassi, 2002, 2006; Rabarivola *et al.,* 2007; Mittermeier *et al.,* 2014) ont montré que cet animal se focalise dans la forêt primaire et secondaire, dans la plaine tropicale mosaïque, dans les habitats où poussent des bambous.

Un habitat peut être défini comme l'ensemble des ressources (abris, nourritures) et des conditions environnementales (facteurs abiotiques et biotiques) qui déterminent la présence, la survie et la reproduction d'une espèce (Hall *et al.,* 1997; Gaillard *et al.,* 2010). *Hapalemur g. griseus,* un petit lémurien folivore (Wright, 1986, 1990; Tan, 1999; Grassi, 2002), est classé Vulnérable par l'Union Internationale pour la Conservation de la Nature (Mittermeier *et al.,* 2010; IUCN, 2014). Dans la forêt de Maromizaha, l'espèce occupe tous les niveaux forestiers disponibles de son habitat pendant ses activités comportementales. Mais, les informations sur sa fréquentation verticale restent mé connues. L'utilisation verticale de l'habitat dans cette forêt permettrait d'identifier les facteurs bioécologiques qu'exige *Hapalemur g. griseus*, afin de connaître et d'éclaircir au moins une partie de son mode de vie à l'état sauvage. Par ailleurs, les objectifs spécifiques sont (1) déterminer les niveaux de fréquentation verticale, (2) faire une étude des corrélations entre les niveaux de fréquentation verticale et la hauteur des arbres utilisés comme support et (3) comparer les niveaux de fréquentation saisonnière par *Hapalemur g. griseus* en fonction des activités comportementales. Pour ce faire, les hypothèses à vérifier sont: (a) la hauteur des arbres utilisés comme support car la saison peut l'influencer; (b)il existe une variation saisonnière de la hauteur des individus du groupe et (c) la hauteur d'*Hapalemur g. griseus* varie également en fonction des activités comportementales.

Méthodes

Site d'étude

Le site d'étude se trouve dans la forêt humide tropicale de Maromizaha, au sud-est de la commune rurale d'Andasibe, au PK 142 du village d'Anevoka (Fig. 1). Il Se situe aux coordonnées géographiques suivantes: S18.9760° de la latitude et E48.4648° de la longitude, dont les groupes d'*Hapalemur g. griseus* étudiés pendant la saison humide et sèche d'août à septembre 2016 setrouvant dans cette forêt, à une altitude de 870à 1100m.

Observation focale

Etant donné que *Hapalemur g. griseus* est diurne (Wright, 1986; Tan, 2000) et vit en groupe (Petter *et al.,* 1970), les observations se font toute la journée. L'identification des groupes étudiés est facile grâce à l'assistance des guides locaux. Pour éviter la confusion entre les groupes, nous avons considéré l'endroit et les environs ou le mem groupé d'*Hapalemur g. griseus* a été rencontré. Un guide local a aidé techniquement et a permis facilement le suivi du groupe étudié. Toutes les coordonnées géographiques obtenues à partir d'un GPS sont traités sur le Système d'Information Géographique (SIG), car ce dernier facilite l'identification de la répartition spatiale de ces groupes (Fig. 1).

Il est à noter que les lémuriens de la forêt de Maromizaha sont exemptés de colliers radio. Par conséquent, on prend plus de temps pour le suivi du groupe d'*Hapalemur g. gri-*

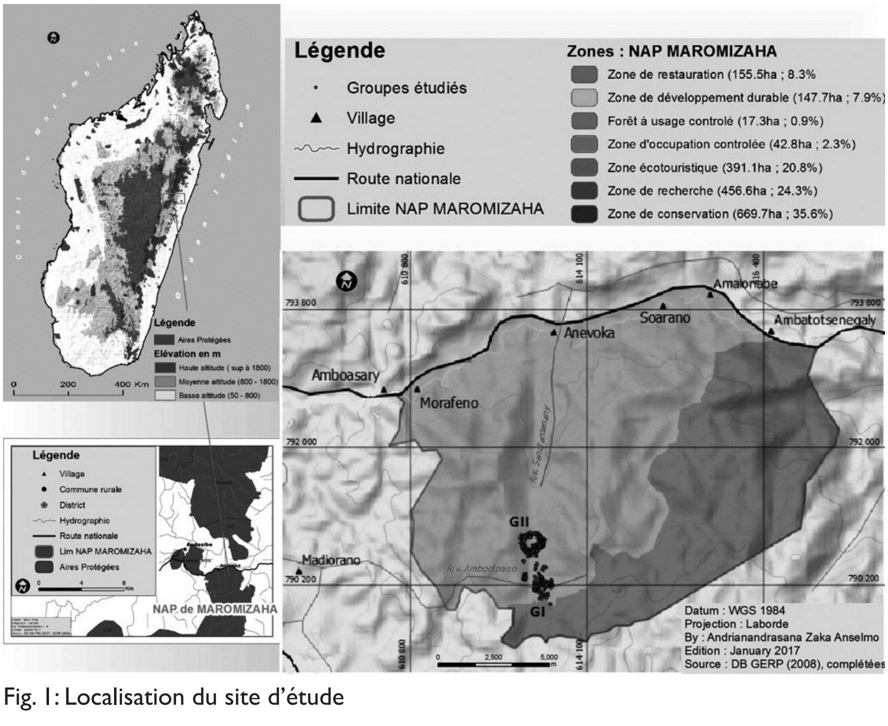

Fig. 1: Localisation du site d'étude

seus. Ainsi, lors de cette étude, quatre groupes d'*Hapalemur g. griseus* ont été rencontré. Mais, deux groupes ont été seulement choisis et suivis dans leur habitat durant la saison humide et sèche, car ils sont presque habitués. Chaque groupe est formé d'individus adultes, de juvéniles et de petits (Tab.1). A cet effet, la méthode de l'observation focale (Altmann, 1974) a été adoptée. Elle permet de collecter des données sur les activités comportementales sur un individu spécifique pour une durée donnée, ici pendant les cinq minutes. Les observations ont été fait durant la journée de 5h30mn à 12h et de 14h à 17h30mn. Au total, 1346 observation focale de 5 minutes, pour un total de 25 heures d'observation allouées au suivi de l'espèce. De ce fait, nous avons suivi pendant 6 jours par mois chacun des deux groupes de *H. g. griseus* étudiés, avec trois jours par individu femelle et mâle. A chaque rencontre avec l'animal focal, la terminologie servit par Andrianandrasana *et al.* (2018) a été adoptée. A cet effet, des données concernant les points suivants ont été collectées et enregistrées dans une fiche préétablie:

Comportement alimentaire: c'est l'ensemble des activités de l'animal qui s'étendent à la recherche de la nourriture jusqu'à sa consommation,

Repos: l'animal focal cesse toute activité,

Vigilance: l'animal surveille en permanence l'environnement de façon attentive,

Marquage: l'animal le fait en frottant ou en urinant une branche ou un tronc d'arbre,

Activités sociales: ce sont des activités menées par un individu impliquant les autres membres de la collectivité (toilettages, jeux, allaitement).

Afin d'étudier l'interaction entre l'utilisation verticale par *Hapalemur g. griseus* et les facteurs écologiques, une estimation des niveaux de fréquentation verticale a été faite, basée sur la classification élaborée par Andrianandrasana *et al.* (2018):

Sol: 0m,
Niveau bas: compris entre 0.1 et 3m,
Niveau moyen: compris entre 3.1 et 6m,
Niveau supérieur: supérieur à 6m.

De ce fait, les facteurs écologiques tels que la hauteur des arbres utilisés comme support, l'individu du groupe, les comportements, la température, l'humidité, l'indice de chaleur, la pression et la luminosité sont prises en comptes.

Tab. 1: Nombre d'individus aperçus par groupe.

Groupe	G1*	G2*	G3	G4	Total
Adulte	2	3	2	2	9
Juvénile	1	1	1	1	4
Petit	1	1	-	-	2
Total	4	5	3	3	15
Latitude	S18.9774°	S18.9728°	S18.9699°	S18.9673°	
Longitude	E48.4657°	E48.4627°	E48.4655°	E48.4658°	
Altitude (m)	1055	1085	1058	1038	
Date	2015-09-3; 11:25:18	2015-09-19:43:58	2015-08-31;7:55:44	2015-09-3;14:49:01	

*Groupe d'*Hapalemur g. griseus étudié*

Analyse statistique et modélisation sur l'utilisation verticale de l'habitat par Hapalemur g. griseus

Cette partie consiste à faire une analyse statistique sur l'interaction entre l'utilisation verticale de l'habitat par *Hapalemur g. griseus* afin de dégager les facteurs qui peuvent influencer cette utilisation. La corrélation Rhôde Spearman (R_s) a été utilisée pour vérifier s'il existe une corrélation entre la hauteur d'*Hapalemur g. griseus* pendant ses activités comportementales et la hauteur des arbres comme support ainsi que les autres facteurs. De ce fait, les valeurs de probabilité *P* des résultats du test statistique ont été comparées au seuil de signification $\alpha = 0.05$ pour accepter ou rejeter l'hypothèse nulle.

De plus, une modélisation sur l'utilisation verticale de l'habitat par *Hapalemur g. griseus* a été effectuée, afin de visualiser et déterminer les facteurs les plus influençant cette utilisation. A cet effet, une analyse de modèle linéaire estimée par la fonction LM (analyse de variance et régression linéaire multiple) en utilisant le Critère d'Information d'Akaike (AIC)a été également adoptée. Ce Critère d'Information d'Akaike (AIC) qui consiste à déterminer le meilleur modèle en éliminant pas à pas les variables explicatives qui n'ont pas d'influence sur la matrice d'observation multivariées, ici la hauteur de l'animal focal, par la méthode descendante(Burnham and Anderson, 2002). En effet, les meilleur modèle est celui possédant une valeur d'AIC la plus faible. Dans ce cas, ce modèle est un modèle linéaire gaussien permettant ici de déterminer les facteurs influençant l'utilisation verticale de l'habitat par *Hapalemur g. griseus*. Dans la conception de modèle linéaire, toutes les variables explicatives ou prédicteurs et les effets de l'interaction entre les variables suivantes ont été considérées: la hauteur des arbres utilisés comme support, la fraicheur, la température, l'humidité, l'indice de chaleur, la pression, la luminosité, l'individu du groupe et les catégories des comportements collectés. L'équation du modèle linéaire est «hauteur de l'animal focale~ hauteur des arbres utilisés comme support + conditions climatiques * individu du groupe * activités comportementales de l'animal».

En effet, un meilleur modèle en éliminant pas à pas les variables explicatives ou indépendantes qui n'ont pas d'influence sur la hauteur de l'animal focale par la méthode descendante est celui possédant une valeur d'AIC la plus faible. Par ailleurs, la détermination de coefficient de détermination multiple ajusté (R^2) a été effectuée. Ce dernier est une mesure qui permet d'évaluer le degré d'adéquation du modèle ainsi obtenu. Dans ce sens, le test F permettra en plus de construire un test de signification globale vue la valeur de probabilité *P*. Et pour comparer les effets de l'interaction des variables explicatives, le test t a été également utilisé. Ainsi, si les valeurs de probabilité *P* est inférieure au seuil de signification α=0,05, l'hypothèse nulle est rejetée. Les analyses statistiques ont été réalisées avec le logiciel SPSS version 20 (IBM Corporation, 1989-2011) et R version 3.4 (R Core Team, 2016).

Résultats

Niveaux de fréquentation verticale générale

Selon les niveaux disponibles de l'habitat d'*Hapalemur g. griseus*, la Fig. 2 montre un aperçu de la fréquentation de ces différents niveaux. Au cours de ses activités, l'animal occupe tous les niveaux disponibles de son habitat, mais avec différentes fréquences. Il préfère le niveau bas compris entre 0.1-3m avec un taux 68.4% comparé au niveau moyen (3.1-6m) (25.6%). Durant le suivi écologique, *Hapalemur g. griseus* descend près du sol (2.3%), il se trouve rarement au niveau supérieur (>6m) avec un taux considérablement faible (3.7%).

Modélisation de l'utilisation verticale de l'habitat par Hapalemur g. griseus

Le Tab. 2 donnes le classement des modèles linéaires créé. Selon le Critère d'Information d'Aikake (AIC), le meilleur modèle fiable est celui qui possède une faible valeur d'AIC (en gras), dont le rapport entre la hauteur de l'animal focal et la hauteur des arbres utilisés comme support.

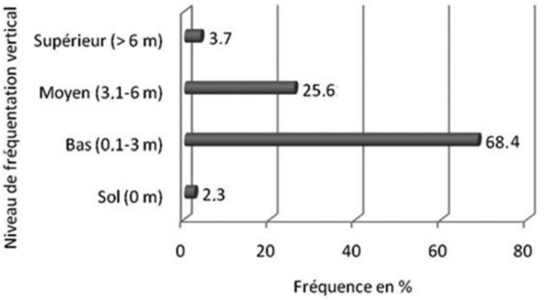

Fig. 2: Pourcentage de fréquence d'utilisation de l'habitat par catégorie de strates verticales d'*Hapalemur g. griseus*.

Tab.2: Classement des modèles selon le Critère d'Information d'Aikake (AIC).

Modèles	**ddl**	**AIC**
HF~HA	15	3108.48
HF~HA + T	11	3127.13
HF~HA + T + F	11	3127.13
HF~HA + T + F + H	10	3132.74
HF~HA + T + F + H + IC	9	3147.34
HF ~ HA + T + F + H + IC + P	8	3149.33
HF ~ HA + T + F + H + IC + P + L	7	3148.91
HF~HA + T + F + H + IC + P + L + IG	6	3147.69
HF~HA + T + F + H + IC + P + L + IG + C	5	3154.71
HF~HA + T + F + H + IC + P + L + IG + C	4	3153.04
HF~HA + T + F + H + IC + P + L + IG + C	3	3152.92

HF: hauteur de l'animal focal, HA: hauteur des arbres utilisés comme support, T: température, F: fraicheur, H: humidité, IC: indice de chaleur, P: pression, L: luminosité, IG: individu du groupe et C: Comportements

Le meilleur modèle (avec le plus bas AIC) sur l'utilisation verticale de l'habitat par l'animal focal est confirmé par l'analyse de variance ($F_{13, 1025}$=117.4; ddl=1025; *P<0.0001*). Autrement dit, la hauteur d'*Hapalemur g. griseus* qui est influencée par la hauteur des arbres utilisés comme support et les autres facteurs est confirmée par un taux de 59.3%. De ce fait, les résultats du test t(t=36.272; *P<0.0001*) indique une différence significative entre les hauteurs d'arbres utilisés comme support pendant les activités comportementales de l'espèce. De même pour les facteurs climatiques sauf la luminosité, cette dernière est considérée parmi les facteurs influençant la hauteur de l'animal par rapport au sol(t=-2.335; *P=0.019*) avec une moyenne de 934.8±37.1 lux(±ES, N=1039).Concernant la saisonnalité, il y a une différence significative (t=-4.397; *P<0.0001*) surtout pendant la saison sèche, c'est-à-dire la saison sèche influence la hauteur d'*Hapalemur g. griseus*, notamment la hauteur du mâle (t=3.213; *P= 0.001*). Le mâle atteint un niveau plus haut que la femelle.

Tab.3: Modèle linéaire entre les facteurs écologiques influençant la hauteur des adultes males de *Hapalemur g. griseus* pendant ses activités comportementales de la saison sèche.

Prédicteurs	**Estimation**	**Erreur standard**	**t**	**P**
Intersection	5.976	7.615	0.785	0.433
Hauteur des arbres utilisés comme support	2.178	0.221	36.272	0.000
Facteurs climatiques				
Température	0.606	0.919	0.660	0.510
Fraicheur	-0.427	0.843	-0.506	0.613
Humidité	0.158	0.183	0.862	0.389
Indice de chaleur	-0.675	0.154	-1.641	0.144
Pression	-0.263	0.403	-0.652	0.515
Luminosité	-0.044	0.019	-2.335	0.019
Période (Saison):Sèche	-1.403	1.174	-4.397	0.000
Sexe Mâle	0.849	0.972	3.231	0.001
Comportements				
Comportement alimentaire	-1.825	0.444	-4.106	0.000
Marquage	-1.196	1.212	-3.631	0.000
Repos	-0.951	0.463	-2.051	0.040
Vigilance	-1.462	0.477	-3.067	0.002

Corrélation entre les niveaux de fréquentations verticales et la hauteur des arbres utilisés comme support

D'après le test des corrélations de Rhô Spearman (R_s=0.712; *P<0.0001*; N=1039), la hauteur générale d'*Hapalemur g. griseus* est fortement corrélée avec la hauteur d'arbres utilisés comme support. Cette corrélation est illustrée par la Fig. ci-dessous (Fig. 3a). A propos du niveau de fréquentation des individus du groupe d'*Hapalemur g. griseus*, la Fig. 3b montre que la hauteur du mâle varie en fonction de la saison. Il fréquente une hauteur considérablement plus élevée pendant la saison humide que pendant la saison sèche avec une moyenne respectivement 3.1±0.2m des arbres de 4.7±0.2m (±ES, N=153) et 2.1±0.9m des arbres de 3.6±0.1m (±ES, N=192). Le mâle peut atteindre jusqu'à 15m de hauteur des arbres de 18m pendant la saison humide, tandis qu'il fréquente le niveau de 6 m des arbres de 8 m de hauteur pendant la saison sèche. Pour la femelle, le niveau de fréquentation est quasiment égal entre les saisons. Elle fréquente une hauteur moyenne de 2.7±0.1m de hauteur des arbres de 4.4m±0.1m (±ES, N=255) pendant la saison humide et 2.5±0.1m de hauteur des arbres de 4.5±0.1m (±ES, N=439) pendant la saison sèche. En général, la femelle ne dépasse pas la hauteur de 11m pendant les deux saisons durant cette étude.

Comparaison des niveaux de fréquentation saisonnière par Hapalemur g. griseus en fonction des activités comportementales

En se référant au modèle linéaire sur les facteurs écologiques influençant la hauteur de *Hapalemur g. griseus* pendant ses activités comportementales (Tab.3), la différence existe également au niveau de fréquentation en fonction de ces activités (Fig. 5) notamment le comportement alimentaire (t=-4.106; *P<0.0001*), le marquage (t=-3.631; *P<0.0001*), le repos (t=-2.051; *P=0.04*) et la vigilance (t =-2.051; *P=0.002*). Pour le comportement alimentaire, *Hapalemur g. griseus* fréquente une hauteur moyenne de 2.2m±0.1m sur des arbres de 3.8m±0.1m de hauteur. L'animal atteint le niveau supérieur jusqu'à 12m de hauteur des arbres de 14m pour récupérer les aliments. Pendant le comportement alimentaire, 46.3% de temps d'alimentation d'*Hapalemur g. griseus* sont généralement consacrés à la récupération des aliments sur une seule plante comme support : *Cephalostachyum* sp. (Poaceae); *Ficus sorocoides* (Moraceae); *Canthium* sp. (Rubiaceae); mais quand il récupère ses aliments en s'appuyant sur un autre support, le pourcentage atteint 53.6% (Sol/*Panicum* sp.1; Bois mort/*Panicum* sp.1; *Eugenia lokohensis*/*Cephalostachyum* sp.). Dans l'utilisation spatiale verticale, *Hapalemur g. griseus* exploite les supports de deux méthodes différentes pour récupérer les aliments. Pour la première méthode, il

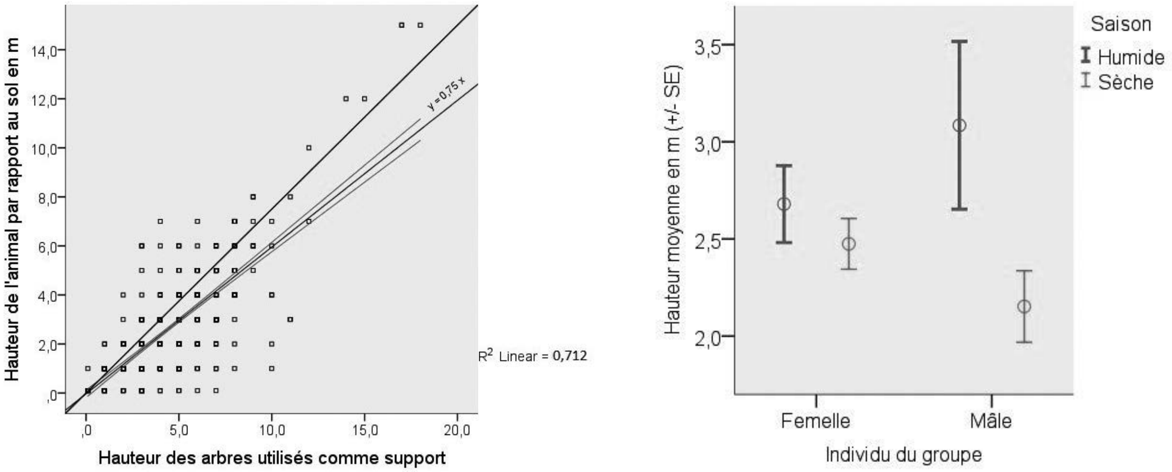

Fig. 3: Rapport entre la hauteur générale de l'animal et des arbres utilisés comme support. Gauche: Corrélation entre la hauteur générale de l'animal et la hauteur des arbres utilisés comme support; droite: Comparaison saisonnière des niveaux de fréquentation par les individus du groupe.

se nourrit sur un support, l'animal récupère les feuilles de bambou sur cette même plante (*Cephalostachyum* sp.), il exploite les fruits de *Canthium* sp, les feuilles et les fruits de *Ficus sorocoides et Ficus reflexa* sur ce même arbre (Fig. 4a). Pour la deuxième méthode, l'animal collecte son aliment en s'appuyant sur un autre support (Fig. 4b). Ce geste a été souvent observé pendant le suivi du comportement alimentaire durant cette étude, dont l'animal récupère les jeunes feuilles de *Panicum* sp.1 (Poaceae) près du sol ou sur un bois mort ou sur d'autres supports.

De plus, dans cette occupation spatiale verticale, *Hapalemur g. griseus* dispose d'une distance moyenne minimale du voisin le plus proche et de la distance moyenne maximale du voisin le plus éloigné par rapport à l'animal focal qui est respectivement 1.3±0.0 met 3.2±0.0m (N=1039). Durant le suivi écologique de l'animal, nous avons aperçu fréquemment que le mâle protège le petit (Fig. 5b).

Concernant le marquage, l'animal se trouve en moyenne à 1.9±0.2m de hauteur des arbres de 4.1±0.5m. Il fait des marquages sur des branches avec une hauteur maximale de 4m des arbres de 8m de hauteur. Quand l'animal se repose, il préfère une hauteur moyenne de 2.9m±0.1m sur des arbres de 4.9±0.1m de hauteur. Il atteint le niveau supérieur jusqu'à 15m de hauteur des arbres de 17m. Ainsi, pour la vigilance, *Hapalemur g. griseus* se situe en moyenne à 2.6±0.1m sur des arbres de 4.5±0.1m de hauteur. Il atteint le niveau de fréquentation maximal jusqu'à 15m de hauteur des arbres de 18m.

Discussion

L'étude sur l'utilisation verticale de l'habitat par *Hapalemur g. griseus* montre une interaction significative entre le mode de vie de l'animal et son habitat. Cette étude renseigne l'occupation spatiale de l'animal par rapport au plan vertical des masses végétales depuis la surface du sol jusqu'à la canopée. Cette dernière protège naturellement cette espèce. Étant quadrupède-arboricole, l'espèce préfère des arbres pendant ses activités comportementales. L'animal traverse et saute d'une branche à une autre lors de son déplacement. Il utilise les supports pour récupérer les jeunes feuilles et les fruits à l'extrémité des branches et les utilise également pour faire le marquage de son territoire et pour se reposer.

Quant à la fréquentation des niveaux forestiers, *Hapalemur g. griseus* fréquente tous les niveaux forestiers disponibles dans son habitat: bas, moyens et supérieurs, mais leurs fréquences diffèrent. Pendant cette étude, la fréquentation du niveau bas à un taux de 68.4%. Cette constatation semble être corroborée par Andrianandrasana *et al.* (2018) dans leurs travaux sur *Hapalemur g.griseus* pendant la saison humide dans la forêt de Maromizaha, où ils ont trouvé 57.8% d'utilisation du niveau bas de la forêt. Cette fréquentation peut être expliquer par le fait que la plupart des plantes sources de nourriture comme les bambous et les autres plantes consommées se trouvent à ce niveau. Andrianandrasana *et al.* (2018) dans ses travaux ont également confirmé cette observation. Ils ont révélé que l'animal se trouve à ce niveau bas pour s'alimenter surtout pendant la saison sèche. La plante *Panicum*s pest particulièrement abondante dans la forêt de Maromizaha et est répandue dans tout l'habitat d'*Hapalemur g. griseus* (de la vallée au versant). A cet effet, cette abondance oblige l'animal à descendre au niveau bas pour récupérer des aliments ce qui peut influencer sa hauteur. Des observations par Rakotoarinivo *et al.* (2017); Andrianandrasana *et al.* (2018); Rasolofoson *et al.* (2014); Grassi (2001) a également affirmé que les lémuriens descendent au niveau bas voire près du sol. Durant le suivi du comportement alimentaire dans la forêt de Maromizaha, *Hapalemur g. griseus* descend près du sol avec un faible taux (2.3%). L'animal assis récupère les jeunes feuilles de *Panicum* sp. En gardant sa position verticale ou mange une faible quantité de terre. En outre, en cas de perturbation, lorsque l'espèce entend des cris de *Buteobrachypterus* (rapace) vivant dans cette forêt (Woog, 2006; Gerp, 2008; Andrianandrasana *et al.,* 2018), il se disperse, s'enfuit et se camoufle dans l'endroit très serré de la strate basse. Cette dernière constatation a été fréquente durant nos observations. Il serait indispensable d'approfondir la plasticité de la réaction de *Hapalemur g. griseus* dans son habitat naturel face aux prédateurs aériens.

Hapalemur g. griseus utilise cette strate pendant le repos quand il se repose sur une touffe de plantes ou sur une branche horizontale. Pour le niveau moyen de la forêt, l'espèce l'utilise également pendant leur activité. En effet, l'animal peut repérer les situations imprévisibles: passage de chien, repérage d'humains. Ceciindique qu'*Hapalemur g. griseus* est considérablement vigilant. Cette constatation semble être corroborée par Andrianandrasana *et al.* (2018) dansées études sur cette même espèce dans la forêt de Maromizaha. De plus, les canopées des plantes utilisées

Fig. 4: *Hapalemur g. griseus* récupérant les fruits sur un support et les jeunes feuilles en s'appuyant sur un autre support: (a) fruits de *Ficus reflexe* gauche; (b) jeune feuille de *Panicum* sp1, (Photo: Andrianandrasana Z. A.)

Fig. 5: *Hapalemur g. griseus* durant ses activités comportementales. Gauche: l'animal récupérant les jeunes feuilles de *Panicum* sp1 en gardant sa position verticale au sol; au-dessus: Petit *Hapalemur g. griseus* protégé par le mâle adulte. (Photo: Andrianandrasana Z. A.)

comme support pendant ses activités comportementales sont fermées et semi-ouvertes et donc protègent l'animal. Bref, ces observations confirment que la fréquentation des niveaux forestiers par *Hapalemur g. griseus* est donc fortement corrélée avec la hauteur des arbres utilisés comme support.

Dans l'organisation sociale d'*Hapalemur g. griseus*, l'animal se regroupe et parfois il se disperse. Au repos, les individus du groupe d'*Hapalemur g. griseus* qui se mettent à l'ombre s'accolent. Les adultes mâles n'ont pas souvent les mêmes activités que les autres. Il s'alimente mais de temps en temp s'il reste immobile. Cet animal joue considérablement le rôle protecteur du groupe, car quand une perturbation apparaît, il lance un cri d'alerte pour avertir les autres membres. De plus, lors du repos, il reste en état inactif mais attentif.

Le mâle adulte joue également un rôle principal de protecteur du groupe, notamment des petits. Par ailleurs, il se met à un niveau plus élevé de la forêt pendant la saison humide que pendant la saison sèche, c'est-à-dire l'animal surveille attentivement de bas en haut son environnant pendant ses activités comportementales. Par contre, la femelle dominante dirige le groupe, dont les niveaux de fréquentation forestier au cours des deux saisons est quasiment les mêmes.Cela signifie que l'occupation spatiale par *Hapalemur g. griseus* présente une implication sociale qui joue un rôle capital dans la dynamique de groupe. Cette occupation verticale peut être liée au système de vigilance par l'animal durant ses activités. Par exemple, le mâle adulte joue le rôle de protecteur du groupe surtout de ses petits (Andrianandrasana *et al.,* 2018). En cas de danger ou d'une circonstance imprévisible, il lance un cri d'alerte pour avertir les autres membres du groupe. Andrianandrasana *et al.* (2018) l'ont constaté dans leurs études sur cette même espèce.

L'analyse du modèle linéaire sur l'utilisation verticale de l'habitat par *Hapalemur g. griseus* permet de vérifier les hypothèses énoncées dans l'introduction d'une part et de déterminer les facteurs bioécologiques qui peuvent l'influencer d'autre part. Pendant cette étude, c'est la hauteur des

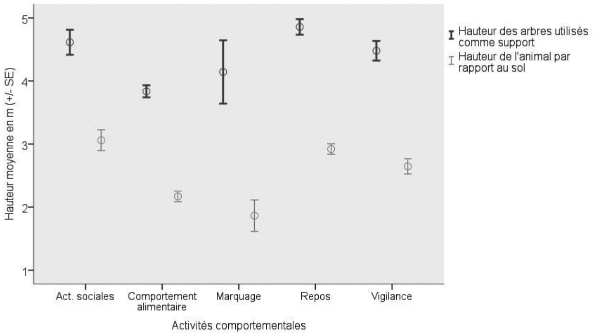

Fig. 6: Variation saisonnière des niveaux de fréquentation par *Hapalemur g. griseus* en fonction des activités comportementales.

arbres utilisés comme support qui est le premier facteur influent, suivi des conditions climatiques, notamment la luminosité, la saisonnalité, les individus du groupe ainsi que les comportements. Durant les activités comportementales, le mâle joue le rôle protecteur du groupe qui surveille attentif son environnement. Dans l'utilisation verticale de l'habitat par *Hapalemur g. griseus* vue le meilleur modèle linéaire obtenu, la hauteur de l'animal est fortement corrélée avec la hauteur des arbres utilisés comme support. De ce fait, plus la hauteur des arbres utilisés comme support est grande, plus l'animal fréquente un niveau forestier supérieur.

Conclusion

En conclusion, la vie d'*Hapalemur g. griseus* dans la forêt tropicale de Maromizaha dépend davantage des conditions environnementales telles que l'impact de la variation saisonnière sur la disponibilité des ressources, le changement climatique et la perturbation de l'habitat. Cette étude permet également d'apprendre que *Hapalemur g. griseus* dans la forêt de Maromizaha occupe un niveau forestier bas (0.1-3m). En effet, pour l'exploitation et la maîtrise de l'espace face aux enjeux écologiques, *Hapalemur g. griseus* utilise une stratégie adéquate dans sa structure sociale que nous venons d'expliquer précédemment. L'animal utilise également un système de vigilance face aux dangers où le mâle adulte joue le rôle de protecteur du groupe.

Remerciements

Nos vifs remerciements s'adressent au Ministère de l'Environnement, de l'Ecologie et des Forêts qui a délivré l'autorisation de recherche pour cette étude. Nous remercions également le Groupe d'Etude et de Recherche sur les Primates (GERP) qui a donné un avis favorable à la réalisation de cette étude dans la Nouvelle Aire Protégée de Maromizaha. Sans oublier Jean Ruffin Andriamiarison et Marolahy Ndrianasolo, guides locaux dans le village d'Anevoka, merci de votre assistance durant les travaux sur terrain.

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Funding and Training

AEECL Small Grants

Since 2009, AEECL awards two small grants of up to €1,000 each year to graduate students, qualified conservationists and/or researchers to study lemurs in their natural habitat. Priority is given to proposals covering conservation-relevant research on those species red-listed as Vulnerable, Endangered, Critically Endangered or Data Deficient by the IUCN. We support original research that helps with establishing conservation action plans for the studied species. Grants are normally given to recent graduates from Malagasy universities to help building local capacity.

AEECL
The Lemur Conservation Association

We may also, in special circumstances, support studies on Malagasy species other than lemurs if the proposal provides satisfactory information as to how lemurs or the respective habitat/ecosystem as a whole will benefit from the research. All proposals will be assessed by the Board of Directors of AEECL and/or by external referees. The deadline for applications is February 28th of each year. Successful applicants will be notified by June 1st. More information can be found on the AEECL website, **www.aeecl.org**.

The Mohamed bin Zayed Species Conservation Fund

Announced at the World Conservation Congress in Barcelona in 2008, The Mohamed bin Zayed Species Conservation Fund is a significant philanthropic endowment established to do the following:

- Provide targeted grants to individual species conservation initiatives;
- Recognize leaders in the field of species conservation; and
- Elevate the importance of species in the broader conservation debate.

صندوق محمد بن زايد
للمحافظة على الكائنات الحية
The Mohamed bin Zayed SPECIES CONSERVATION FUND

The fund's reach is truly global, and its species interest is non-discriminatory. It is open to applications for funding support from conservationists based in all parts of the world, and will potentially support projects focused on any and all kinds of plant and animal species, subject to the approval of an independent evaluation committee.
Details on this important source for species conservation initiatives and research can be found at
http://www.mbzspeciesconservation.org.

Lemur Conservation Action Fund

The principal objective of the Lemur Conservation Action Fund of Global Wildlife Conservation (GWC) is to contribute to global biodiversity conservation by providing strategically targeted, catalytic support for the conservation of endangered nonhuman primates and their natural habitats. The Lemur Conservation Action Fund is supported by the IUCN SOS [Save our Species] fund and managed by Global Wildlife Conservation.

Projects submitted to the foundation should have one or more of the following characteristics:

1. a focus on critically endangered and endangered lemurs (and most especially those included in the biennial listing the World's 25 Most Endangered Primates) living in their natural habitats;
2. direction and management by Malgasy, to help increase local capacity for implementing biodiversity conservation;
3. the ability to strengthen international networks of field-based lemur specialists and enhance their capacity to be successful conservationists; and
4. projects that result in publication of information on endangered lemurs in a format that is useful both to experts and the general public

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Projects should contribute to at least one, and preferably more, of the following themes:

1. enhancement of scientific understanding/knowledge of the target species/ecosystem;
2. improved protection of a key species, habitat, or reserved area;
3. demonstration of *economic* benefit achieved through conservation of a species and its habitat, as compared to loss thereof;
4. increased public awareness or educational impact resulting from the project in question;
5. improved local capacity to carry out future conservation efforts through training or practical experience obtained through project participation; and
6. modification of inappropriate policies or legislation that previously led to species or habitat decline.

The maximum award given is $5,000. Typical Lemur Conservation Action Fund grants range from US $1,000 to $5,000 and average around $3000.

Applications for support are considered throughout the year, with no deadlines for submitting. Proposals should be sent electronically to: Anthony B. Rylands, Lemur Conservation Action Fund, Global Wildlife Conservation,
arylands@globalwildlife.org.

Theses completed

Mandl, I. 2018. Nightly Encounters: The social, spatial and vocal ecology of the Sahamalaza sportive lemur, Lepilemur sahamalaza, in north-western Madagascar. PhD thesis, University of Bristol, UK.

The Critically Endangered Sahamalaza sportive lemur, *Lepilemur sahamalaza*, inhabits the remaining fragmented forests of the Sahamalaza Peninsula in north-west Madagascar, and is increasingly threatened by ongoing deforestation and anthropogenic pressures. To inform conservation measures that were suggested by the IUCN lemur conservation strategy "Lemurs of Madagascar – A Strategy for Their Conservation 2013-2016", the present PhD study aimed to provide conservation-relevant information on the behavioural ecology of this species. Through long-term continuous behavioural observations between 2015 and 2016, I collected data on seasonal influences on behaviour, the social system, individual habitat use and potential edge effects to forward the development of specific, targeted conservation actions that involve a captive breeding strategy and reforestation practices. In addition, I focussed on non-invasive monitoring methodology via bioacoustic analysis and described in detail the vocal repertoire and calling behaviour. Further I assessed the use of playbacks of loud calls as a conservation tool. The study individuals showed seasonal variations in activity levels and were seemingly truly solitary with indications for a promiscuous mating system, aspects that need to be carefully considered when attempting to establish captive breeding colonies to safeguard from extinction. They were not negatively impacted by forest edges, although the microclimate of the forest showed edge-related effects, calling for increased reforestation efforts to buffer any effects on the forest structure. The vocal repertoire of this species showed a high amount of gradation that complicates species-recognition but may allow for individual and population monitoring, and playbacks were not deemed feasible as a conservation tool due to the limited vocal responses recorded in this study. These results are the first to provide detailed insights into Sahamalaza sportive lemur behavioural ecology over multiple seasons. As such, they provide a basis to achieve the goals set in IUCN lemur conservation strategy and emphasize the need for behavioural data in conservation practices.

Eschmann, C. L. 2019. A Comparison of *Eulemur* Social Systems and Vocal Communication During the Mating Season: Implications for the Speciation and Conservation of Blue-Eyed Black Lemurs and Black Lemurs. PhD thesis, University of Bristol, UK.

Within the last ten years, two closely-related, parapatric species of lemurs, the blue-eyed black lemur (*Eulemur flavifrons*) and the black lemur (*E. macaco*), were classified as distinct taxa. Despite this, morphologically intermediate forms have been reported from an area of potential overlap in the two species' distributions. If hybridisation between *E. flavifrons* and *E. macaco* is, or was, ongoing in this region, pre-mating barriers reinforcing reproductive isolation between the two species may be incomplete. No published studies compare comprehensively their behavioural ecology. Therefore, the overall aims of this study were to identify an area of contact between the two species and to illuminate the role of species-specific behaviours as potential pre-mating isolation mechanisms. The social systems and vocal communication of three distinct populations of *E. flavifrons* (*Ef-1*, *Ef-2*, and *Ef-3*) and three distinct populations of *E. macaco* (*Em-1*, *Em-2*, and *Em-3*) were examined over three mating seasons (May-July 2015-2017). Each population, which could contain multiple groups, was selected to be representative of a unique allopatric (*Ef-1*, *Em-1*, and *Em-3*) or parapatric location (*Ef-2*, *Ef-3*, and *Em-2*) within the two taxa's geographic distributions. In addition, the two species' potential contact zone was surveyed. Although *E. flavifrons* was observed outside of its established range during this time, I was unable to conclusively determine whether the two species currently overlap. The comparisons of the social organisation, social structure, and mating systems of *E. flavifrons* populations and *E. macaco* populations did not reveal clear interspecific differences. Instead, one *E. macaco* population (*Em-1*) was found to differ from the others consistently. Preliminary findings suggest that social system plasticity in these species may be partially related to local ecological conditions. The comparison of the vocal repertoires and acoustic parameters of specific calls also revealed no clear interspecific differences. The lack of evidence supporting *E. flavifrons* and *E. macaco* social system and acoustic communication divergence suggests that it is unlikely that these characters serve as mate recognition mechanisms between the two species or prevent their interbreeding in natural settings. Based on these findings, possible modes of speciation for *E. flavifrons* and *E. macaco* are evaluated.

Narváez Torres, P. 2018. Effects of Disturbance and Forest Structure on the Functional Diversity and Abundance of Lemur Communities in a Fragmented Landscape. Masters thesis, Anthropology, University of Calgary, Canada.

Lemurs are strongly affected by forest loss, fragmentation and degradation because of their high dependence on tropical forest habitat. At the same time, these primates are critical for the functioning of forest ecosystems of Madagascar. While the effects of disturbance on biodiversity are often evaluated with measures of taxonomic diversity, functional diversity takes into account a variety of traits that define species' ecological roles, and thus more closely linked with ecosystem function. For this thesis, I analyzed the effects of direct anthropogenic disturbance, variation in forest structure, and edge effects on the functional diversity of lemur communities in five forest fragments in the Kianjavato-Vatovavy (KV) region. I found that forest structure, measured as mean tree diameter (DBH), was positively correlated with the functional diversity of the overall lemur community. However, the variables used for anthropogenic disturbance and edge effects did not seem to affect lemur functional diversity. In addition, I studied the effects of forest fires on the functional diversity of diurnal lemur communities, as well as on the relative abundance of individual species. Lemur surveys were conducted before and after three forest fragments were partially burned in 2015. While there was not a significant difference in functional diversity between the pre- and the post-fire periods, there was a significant decrease in abundance of two frugivores, Varecia variegata editorum and Eulemur rufifrons, and one omnivore, Microcebus jollyae. Severely reduced food supply and the loss of habitat connectivity could explain these decreases in abundance for individual species. The decline in abundance may put these species at risk of extirpation, likely affecting the functional diversity of the community, and, therefore, the functioning of the ecosystem. Individual species and functional diversity studies are useful in understanding the responses of lemur communities to habitat change and disturbance.

Aylward, M. 2017. Investigating dispersal through molecular genomics: Sex-biased dispersal and phylogeography in aye-ayes (*Daubentonia madagascariensis*) in Madagascar. PhD thesis. Anthropology, University of Calgary, Canada.

Dispersal patterns within species have profound consequences for population dynamics and species' evolutionary trajectories. Intraspecific interactions and habitat variability dictate dispersal trends. Given the rate at which habitat is altered globally by climatic and anthropogenic influences it is important to understand historic dispersal trends to assess the impact these changes may have on biodiversity. Madagascar is of particular interest as it harbours unique biodiversity. The lemurs on Madagascar represent a unique radiation of primates and make up 21% of the species in this order. Yet, the processes that have led to current species distributions across Madagascar remain unresolved. Aye-ayes have the widest geographic distribution of all lemurs and are found across multiple biomes on the island. However, their cryptic nature makes them especially elusive and therefore relatively little is known about their evolutionary history. I make use of innovations in the field of molecular genomics to sample genomic regions of this species to elucidate historic gene flow among populations. I developed a novel method of mitogenomic sampling from aye-ayes' distinct feeding traces to sample from two regions towards the extents of the aye-aye's distribution. These data supplemented sampling by Madagascar Biodiversity Partnership to provide the most geographically extensive genomic sampling of this species to date. Through application of target capture and enrichment I obtained genomic DNA to investigate the role of biogeographic processes and sex-biased dispersal in the evolutionary history of aye-ayes. I used markers across the mitochondria, autosome, and Y-chromosome to assess genomic diversity and to resolve mechanisms that have led to aye-aye population genomic structure. I revealed matrilineal structure on the maternally inherited markers, whereas male-specific Y-chromosome marker systems showed weak structure; indicating male-mediated gene flow. Analysis of diversity in a phylogeographic context indicated that geographic distance drives genomic structure, yet I show support for the watershed and western-rainforest refugia hypotheses. Therefore, changes to riparian vegetation during the Pleistocene likely impacted connectivity among aye-aye populations. I provide interesting avenues for future research to better understand lemur biogeography, and findings can be integrated into conservation planning, particularly initiatives with focus on protecting genomic diversity in this species.

Holmes, S. 2017. Sharing Space: Habitat Use and Spatial Relationships of Frugivorous Lemurs in Fragmented Forests. PhD thesis. Anthropology, University of Calgary, Canada.
I studied the habitat use and interspecific association patterns of red-bellied, red-fronted, and black-and-white ruffed lemurs at Kianjavato, Madagascar. I also investigated the flexible intraspecific association patterns of black-and-white ruffed lemurs. These studies took place in two forest patches of different sizes and disturbance levels within a largely-deforested landscape. Results sometimes differed across forest fragments, indicating potential impacts of fragment size and/or vegetation structure on habitat use and association patterns. All three species used trees with broader crowns more heavily, underscoring the importance of this limited resource. Fruit availability also influenced ruffed lemur habitat use and subgroup size. This species also showed some avoidance of the forest edge and tended to form larger groups of adults when offspring were present. Both red-bellied lemurs and red-fronted lemurs showed avoidance of ruffed lemur core use areas, though they did not avoid one another spatiotemporally. Red-fronted lemurs actually showed positive spatiotemporal associations with both ruffed lemurs and red-bellied lemurs. This was positively related to the amount of core area overlap between groups, and may have been related to the resources and predators shared by these three species. Currently, spatial avoidance of core areas and small differences in diet may facilitate the coexistence of these three species, though red-bellied lemurs may be limited to more marginal habitat in some cases. Future changes to the forest (i.e., deforestation or reforestation) should be monitored, as they may alter both habitat use and association patterns.

Houston, B. 2017. Functional Diversity and Abundances of the Lemur Community at Ranomafana National Park, Madagascar. Masters thesis. Anthropology, University of Calgary, Canada.
Lemurs in Madagascar have been facing losses to population and diversity across the country, potentially resulting in a loss of functional and ecosystem diversity. While species diversity has long been studied, functional diversity allows us to more closely examine how abundances and traits of species are distributed in the community. I use lemur surveys conducted in 2004 at eight sites within Ranomafana National Park (RNP) to test the effects of habitat characteristics and anthropogenic disturbance on lemur functional diversity. In addition, I examine whether functional redundancy is present in the lemur community of RNP – that is, do multiple species fill similar functional roles. Niche separation should affect the traits present in the lemur community such that I expected functional redundancy to be low in most locations. Disturbance, elevation, and vegetation characteristics were all important factors in explaining functional diversity metrics. I found that most communities have low functional redundancy across all measures. I also resampled the site Valohoaka in 2015 to examine lemur abundances over time. The results suggest abundances have remained generally stable, however, *Microcebus rufus* abundances appear to be rising. Used in conjunction with individual species studies, the information presented here can be useful in understanding what is shaping lemur community composition and the sensitivity of these communities to environmental change. It is important to continue monitoring for long-term population trends and responses to both natural and anthropogenic change.

Chell, C. 2019. Habitat utilisation of two sympatric diurnal lemur species in response to human disturbance: A comparison of Coquerel's sifaka (*Propithecus coquereli*) and Common brown lemur (*Eulemur fulvus*) in the Mahamavo region, northwest Madagascar. Masters thesis, Nottingham Trent University.
The lemurs of Madagascar make up 20% of the world's primate species and are considered one of the most threatened mammal taxa on earth with an estimated 95% of all species currently facing extinction. Species responses to increasing levels of anthropogenic disturbance are generally thought to be negative but remain poorly understood, particularly in regards to primate species and lemurs. This study aimed to assess and compare how two sympatric lemur species the Coquerel's sifaka (*Propithecus coquereli*) and the Common Brown lemur (*Eulemur fulvus*) are utilising their habitat in response to anthropogenic disturbance. Species distribution, habitat use and activity budgets were assessed across two forest fragments with differing levels of human disturbance in the remote dry forests of north western Madagascar. Predetermined survey routes were used to opportunistically search for both species, once in the morning and once in the afternoon. Data such as habitat type, tree species, canopy cover (%), tree height (m) and position in tree (m) were taken in order to assess habitat use. An additional 10-minute continuous focal sample on a selected *P. coquereli* individual was recorded to later assess activity budgets. Findings show that the distribution of each species does not appear to differ significantly across disturbed and undisturbed habitats, or in relation to distance from human disturbance (villages, roads and camps). However, a significantly larger amount of *P. coquereli* were observed compared with *E. fulvus*, 61 and 19 groups respectively. *P. coquereli* were found more often on introduced trees, such as mango (*Mangifera indica*), as well as in higher percentage canopy cover, taller trees and higher positions in the tree, compared with *E. fulvus*. Additionally, analysis of activity budgets found *P. coquereli* observed in disturbed habitats spent on average, increased time feeding and decreased time resting and in locomotion, compared with those in undisturbed forest habitats. Findings suggest *P. coquereli* appear to be responding more positively to increased human disturbance in the Mahamavo region, compared to *E. fulvus*. The ability to successfully determine and understand the responses of endangered primate species to anthropogenic disturbance is key to their conservation, and future survival in a world dominated by human activity.

Guidelines for authors

Lemur News publishes manuscripts that deal largely or exclusively with lemurs and their habitats. The aims of *Lemur News* are: 1) to provide a forum for exchange of information about all aspects of lemur biology and conservation, and 2) to alert interested parties to particular threats to lemurs as they arise. *Lemur News* is distributed free of charge to all interested individuals and institutions. To the extent that donations are sufficient to meet production and distribution costs, the policy of free distribution will continue. Manuscripts should be sent to one of the editors electronically (see addresses for contributions on the inside front cover). *Lemur News* welcomes the results of original research, field surveys, advances in field and laboratory techniques, book reviews, and informal status reports from research, conservation, and management programs with lemurs in Madagascar and from around the world. In addition, notes on public awareness programs, the availability of new educational materials (include the name and address of distributor and cost, if applicable), and notification of newly published scientific papers, technical reports and academic theses are all appropriate contributions. Readers are also encouraged to alert *Lemur News* to pertinent campaigns and other activities which may need the support of the lemur research and conservation community. Finally, *Lemur News* serves as a conduit for debate and discussion and welcomes contributions on any aspect of the legal or scientific status of lemurs, or on conservation philosophy.

Manuscripts should be in English or French, double spaced with generous margins, and should be submitted electronically in Word (*.doc or *.docx) or rich text format (*.rtf). They should generally be 1-8 pages long, including references and figures. Submissions to the "Articles" section should be divided into Introduction, Methods, Results and Discussion and should include a list of 4-6 key words. Short reports and other submissions do not need subheadings or key words. Ideally, English articles should include a French abstract and vice versa. Articles should include a map of the area discussed, including all major locations mentioned in the text. Macros, complex formatting (such as section breaks) and automatic numbering as provided by text processing software must be avoided. The corresponding author's affiliation and full address must be provided, including e-mail and telephone number. For all other authors, affiliation and address should be provided. Use superscript numerals for identification. Tables should include concise captions and should be numbered using roman numerals. Please give all measurements in metric units. Please accent all foreign words carefully.

Maps should always be made as concise as possible and should include an inset showing the location of the area discussed in relation to the whole of Madagascar.

Photographs: Black-and-white photographs are ideal. Color photographs are acceptable if they can be printed in greyscale without losing any of the information that they are supposed to convey. Please send only sharply-focused, high quality photographs. Please name each file with the photographer credit and the number of the identifying caption (e.g. "Schwitzer_Fig.1"). We are always interested in receiving high quality photographs for our covers, especially those of little known and rarely photographed lemurs, even if they do not accompany an article.

All figures should include concise captions. Captions should be listed on a separate sheet, or after the References section of the manuscript. Subtle differences in shading should be avoided as they will not show up in the final print. Maps, photographs and figures should be sent electronically in any one of the following formats: EMF, GIF, TIFF, JPG, BMP, XLS. Please name all files with the name of the first author of the manuscript to which they belong. Do not send figures embedded in the text of the manuscript.

References: In the text, references should be cited consecutively with the author's surname and year of publication in brackets (e.g. Schwitzer *et al.*, 2010; Kaumanns and Schwitzer, 2001). The reference list should be arranged alphabetically by first author's surname. Examples are given below.

Journal article

Ranaivoarisoa, J.F.; Ramanamahefa, R.; Louis, Jr., E.E.; Brenneman, R.A. 2006. Range extension of Perrier's sifaka, *Propithecus perrieri*, in the Andrafiamena Classified Forest. Lemur News 11: 17-21.

Book chapter

Ganzhorn, J.U. 1994. Les lémuriens. Pp. 70-72. In: S.M. Goodman; O. Langrand (eds.). Inventaire biologique; Forêt de Zombitse. Recherches pour le Développement, Série Sciences Biologiques, n° Spécial. Centre d'Information et de Documentation Scientifique et Technique, Antananarivo, Madagascar.

Book

Mittermeier, R.A.; Konstant, W.R.; Hawkins, A.F.; Louis, E.E.; Langrand, O.; Ratsimbazafy, H.J.; Rasoloarison, M.R.; Ganzhorn, J.U.; Rajaobelina, S.; Tattersall, I.; Meyers, D.M. 2006. Lemurs of Madagascar. Second edition. Conservation International, Washington, DC, USA.

Thesis

Freed, B.Z. 1996. Co-occurrence among crowned lemurs (*Lemur coronatus*) and Sanford's lemur (*Lemur fulvus sanfordi*) of Madagascar. Ph.D. thesis, Washington University, St. Louis, USA.

Website

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As most readers of Lemur News are certainly aware, fundraising has become more diffcult. We will continue to distribute *Lemur News* free of charge to all interested individuals and institutions. However, we would like to ask subscribers for voluntary contributions to cover production costs. Please contact one of the editors for information on how to make contributions.

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