Final Evaluation Report

Your Details	
Full Name	Meredith Semel
Project Title	A Division of the Crown: using novel tracking collars to examine behavioral and physiological responses to fragmentation in golden-crowned sifakas
Application ID	29332-B
Grant Amount	£ 9970
Email Address	merak91@vt.edu
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1. Indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achieved	Partially achieved	Fully achieved	Comments
Identify differences in group cohesion and space use between sifakas in edge habitat and interior habitat				From January-March 2020 more than 600 observation hours were collected on six groups (36 individuals in total) of golden-crowned sifakas (*Propithecus tattersalli*). Data concerning proximity between individuals, group geometry measurements, and daily ranging behaviour were recorded. A manuscript of the work is being submitted to the journal Biological Conservation in the coming months.
Apply novel tracking devices to the study of golden-crowned sifakas				We constructed the final version of our tracking devices and will test them on captive sifakas at the Duke Lemur Centre (North Carolina, USA) to ensure they are safe and effective for use on wild sifaka. Then they will be deployed on wildlife lemurs.
Determine differences in forest structure between dry, moderate, and wet forest fragments in the Daraina region				We completed thorough vegetation surveys of all six lemur group habitats during this rainy field season. My research team and I visited two rainforest fragments, two moderate forests, and two dry forests. We have quantified habitat differences between the various fragments and microhabitats that are most important to the lemurs.
Determine differences in stress hormone (faecal cortisol metabolite) levels between different groups of lemurs				I spent March-August 2020 initiating faecal hormone analysis. Over 500 samples were analysed but due to COVID-19, I was unable to complete the 1000 samples I had planned to analyse. By March 2021 I plan to finish running the hormonal assays to quantify faecal glucocorticoid metabolite levels among lemurs across all forest fragments. Once these analyses are complete, I will be able to examine correlations between group size, social cohesion,

				habitat type, degree of fragmentation, season, and stress hormone levels.
Collaborate with Madagascar National Parks (MNP) to establish an Eco-Schools program in Daraina and complete outreach initiatives in the region				Based on community requests, during the 2019-2020 field season we continued focusing our environmental education on sustainability in the region, the importance of forests to prevent erosion, taking students into the forest to teach about the biodiversity in the area, etc. We have also continued to teach biweekly English lessons in Daraina and used creative activities to educate primary school students about the value of the biodiversity in their backyards.
Construct an outreach centre facility to be used in the Daraina community				The outreach centre is in the final stages of construction and will function as a space for: 1) student environmental education, 2) guide training, and 3) foreign and local researchers to gather.
Collaborate with local NGO Fanamby and work with local guides from the Daraina community				Fanamby's overarching goal is to better understand how biological, social and economic factors influence threatened ecosystems and how integration of these ideals can lead to successful regional conservation plans. By working alongside Fanamby, I am sharing my results to aid in conservation managements plans in the region. By training and employing local individuals, we bolstered the economy of Daraina and provide jobs that utilised the environment in a non-detrimental manner. By involving local guides in every facet of our research we connected them with nature in ways that enable them to benefit from its protection.
Determine diet composition and nutrient levels of lemur resources in humid, moderate, and dry forest types in the Loky-manambato region				I spent November 2019 at the City University (New York City) primate nutrition laboratory to analyse over 100 plant samples for nutrient and metabolite levels (including carbohydrates, lipids, tannins, protein, starch, minerals, water content, etc.).

				These data provided us with information concerning the most vital plant species/parts for golden-crowned sifaka in each of the three main forest types.

***Note: Some objectives are still listed as partially achieved because this work will hopefully continue. A future field season(s) will allow us the additional time needed to fully achieve these objectives and continue our conservation efforts in the region.**

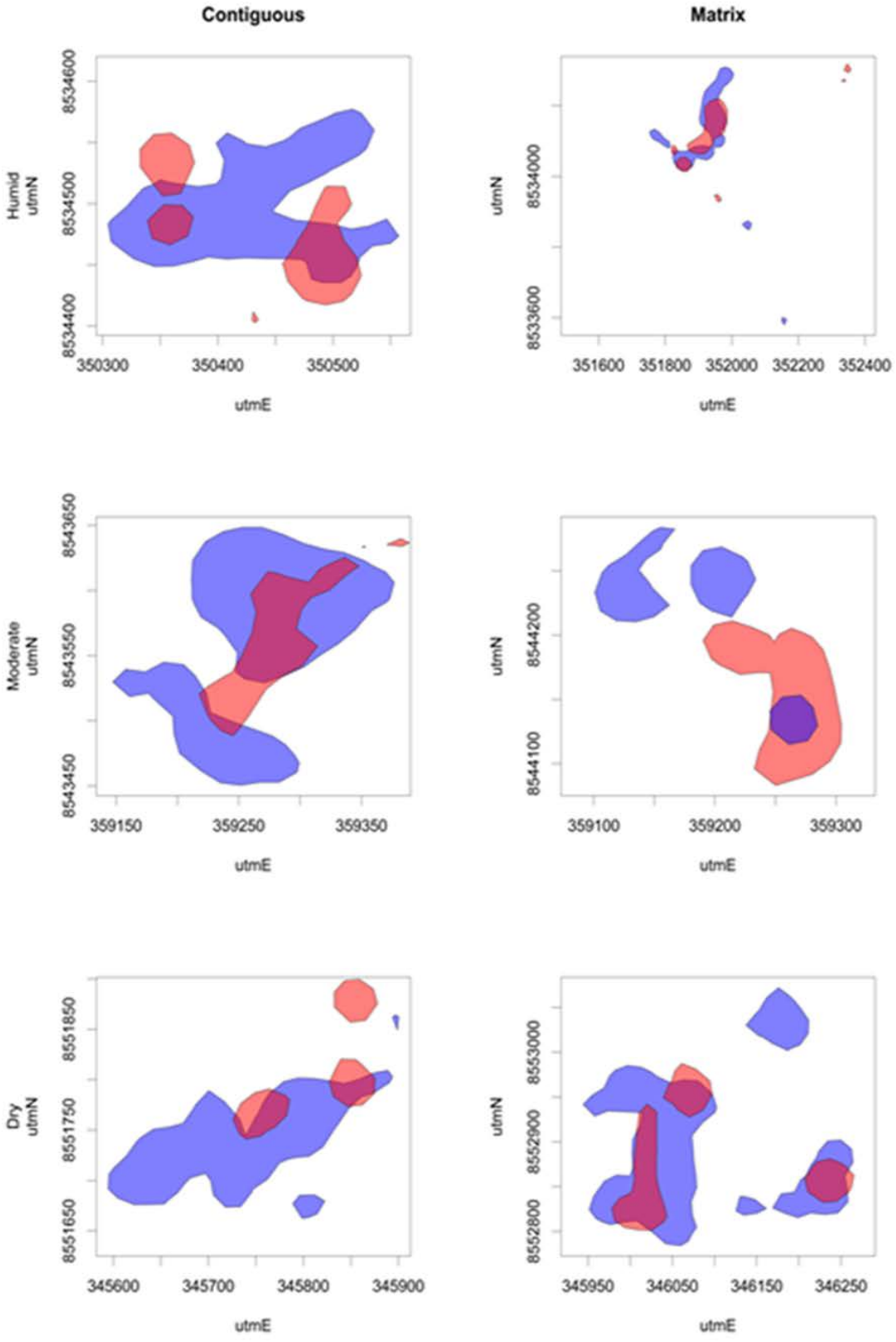
2. Please explain any unforeseen difficulties that arose during the project and how these were tackled.

The largest unforeseen difficulty during my third field season/year of improving local environmental education was the difficulty of traveling, securing permits, and constructing the outreach centre due to COVID-19. The government placed a ban on all cross-country travel in March 2020 (restrictions have only just now decreased as of October 2020) which made travel between regions nearly impossible. This made it very difficult to obtain necessary field supplies such as fresh vegetables (which come from the central region of Madagascar), ethanol to store faecal samples, and materials (cement, iron, windows, tiles, etc.) needed to construct the outreach centre. Additionally, due to government building closures, obtaining building and research permits as well as purchasing land for the outreach centre took roughly twice as long to obtain.

Many of the local individuals in Daraina also have a deep distrust in the Government of Madagascar (due to corruption at many levels) and often believe that government-declared health issues are a hoax. We witnessed this distrust when the bubonic plague became pneumonic during our 2018 field season. As a result of this distrust, many local individuals that we collaborate with, including local guides, believe that COVID-19 is a conspiracy. This has made our outreach efforts more difficult and we have had to change procedures in order to be both safe and culturally sensitive. Luckily, a respected local doctor has helped to alleviate some of the distrust from locals and has helped with allowing us to continue to safely conduct outreach despite health concerns.

We also faced challenges due to delays constructing the outreach centre. The centre was originally scheduled to be fully completed by May 2020, but the pandemic prolonged that date. From January-March 2020 we continued conducting outreach programmes in the secondary and primary school classrooms. By April 2020, we conducted all outreach activities outside to allow for social distancing and limited the activities to 10 students at a time. The outreach centre, while still within the town limits, is on a large piece of land that allows us to maintain distance and has a covered outdoor area allowing for outreach outdoors. We also hired a full-time outreach coordinator whose main responsibilities are planning, leading, and assessing the success of the educational outreach.

3. Briefly describe the three most important outcomes of your project.



a). One of the most important outcomes of my third field season was being able to understand seasonal range shifts and resource needs of sifaka in both the rainy and dry seasons (pictured to the left). Our results revealed that golden-crowned sifaka core home range areas varied as a function of season ($p = 0.003$, $F=14.65$, $df=1$) with home ranges being substantially larger in the wet season. We also found that lemur home range overlap between seasons is less than 50% in all six groups, indicating substantial location shifts throughout the year. This information is vital because previous studies have only examined behaviour and ranging in the dry season. Now that we have an increased understanding of their resource and space needs during both seasons and the most common tree species utilised during each season, we can more effectively protect and reforest their habitat.

We also identified the impact of anthropogenic factors (roads, villages, edge effects, etc.) on sifaka resource selection and habitat use. By tracking lemur movements every 15 minutes and identifying all consumed resources, we found that human disturbance influenced lemur spatial ecology with lemurs preferentially selecting foraging locations where larger trees were present. We also detected variation in behavioural responses that individual lemur groups display in regard to villages and road networks. Lemurs in humid and dry forest fragments specifically avoided locations near road networks in both the dry and rainy seasons, but lemurs in the moderate forest fragment selected locations near roads in the dry season. Lemurs in the moderate and dry forests also preferentially avoided feeding near villages while lemurs in humid forest selected for feeding location near villages. In sum, although groups of sifaka show marked variation in behavioural responses to human disturbance, higher-use zones consist of locations closer to large trees and generally in locations distant from roads. This is particularly informative as the region population is increasing and the road network is being both paved and expanded. We are currently using these findings to inform Malagasy infrastructure and road development plans by working with local conservation NGOs, government officials, and construction teams to limit construction nearby lemur home ranges that are most impacted by human activity. Specifically, we are advising that the national road not be re-routed towards Binara, the humid forest fragment, due to the strong avoidance lemurs display towards existing road networks.

b). The second important outcome was being invited to present our findings of golden-crowned sifaka behaviour, physiology, and conservation and take part in the reassessment of the species with the International Union for Conservation. Based on our thorough assessment, the species is unfortunately still listed as critically endangered. We also worked together to identify the main threats to the species and the Daraina Outreach Centre is working on developing curriculum to help mitigate those threats.
https://www.iucnredlist.org/species/18352/115571806

c). The third, and arguably most important, outcomes were the construction of the Daraina Outreach Centre facility and continued development a self-sustaining field team composed of all Malagasy locals, students, and researchers.

The main scaffolding of the building is complete and the windows, doors, tile, painting, etc. will be complete in the next month (delays have continued to occur due to

difficulties withdrawing funds, purchasing materials, and transporting material on poor quality roads/closures due to COVID-19). This building is going to function as a space for: 1) increased environmental education, 2) local guide training, and 3) accommodation for long term researchers. This is the first piece of infrastructure in the region that is dedicated to conservation and education.

At the request of the guide association, we have also initiated a chicken coop project on the outreach center property. Fanamby has worked to help communities cultivate high value resources such as vanilla, spices, essential oils, and fish, however, these goods are difficult to produce across the Loky-Manambato protected area due to the arid climate. Chickens and eggs are very expensive in the region (three to five times more expensive than those in the capital region) due to a lack of proper avian vaccination and coops. Thus, our community-led programme aimed at breeding chickens is offering a sustainable income for off-duty guides and is starting to provide an alternative to bush meat hunting.

The success of our outreach center also extends beyond the infrastructure development itself by creating effective education and communication pathways in northern Madagascar. We are also working with psychologists and educators at Virginia Tech (e.g., Dr. Dana Hawley) and the University of Antananarivo to develop methods to evaluate the success of our science education in a culturally appropriate manner. We are creating an outcomes-based evaluation which will utilise surveys, interviews, and classroom observations during the first 6 months of the programme (once the building groundbreaking occurs). This will allow us to examine the impacts, benefits, and behavior changes of students and teachers as a result of the programme. We will use this information to make alterations to the curriculum as needed and ensure that the topics covered are relevant to the community. We also hope to publish our results in an education-based journal.

In regard to the self-sustaining field team, our guides are highly trained and able to collect high quality data without my presence in Daraina. This is important because: 1) the team can monitor the health and behaviour of the sifakas on a more regular basis, 2) spend more time in the forest which is a known method of protecting the landscape, 3) conduct community outreach year-round, and 4) local Malagasy individuals can now be the driving force working to protect Daraina's biodiversity. This autonomy will enable not only consistent monitoring of the sifaka population but will also allow other researchers to hire well trained guides to assist with their research (drawing foreign and Malagasy researchers to the area).

4. Briefly describe the involvement of local communities and how they have benefitted from the project.

I continued to work closely with Fanamby, the Daraina guide association, and the local schools during my 2019-2020 field season. Fanamby is an NGO in northern Madagascar that seeks to better understand how biological, social, and economic factors influence threatened ecosystems and how integration of these ideals can lead to successful regional conservation plans. By working with Fanamby to complete my research and build the outreach centre, we fostered community/stakeholder engagement and accountability to help Fanamby effectively accomplish their goals

as an NGO. It is my goal to continue to work closely with Fanamby to develop strategies to protect Daraina's lemurs and their habitat.

During my 2019-2020 field season I also continued to work closely with Amidou Souleimany, the head guide of the Daraina Guide Association (managed by NGO Fanamby). In addition to his research-based skills of coordinating the guide hiring and training process, Amidou is the president of Daraina's private primary school and his help is vital in organising outreach plans and implementing our outreach programme. He has an excellent rapport within the community and is highly respected as a guide, administrator, and community leader. With Amidou's knowledge of Daraina's educational structure and curriculum, we have been able to form relationships with teachers in the secondary and primary schools in Daraina and will be able to arrange field trips and educational programmes in a way that benefits the students most effectively.

This project also benefited the local community by employing 28 guides throughout the field season (for lemur follows and guide training) and an additional ~40 community members as porters. I purchased all food from local shops in Daraina and bought locally grown beans, rice, potatoes, corn, and fresh fruit whenever possible. The local community also benefited from the outreach activities we completed in the schools and the bi-weekly English lessons taught. The outreach programme, which has been designed to meet the needs specified by individuals in the Daraina community, is seeking to improve sanitation, food sustainability, and access to electricity in Daraina (and now disease prevention). Providing education and training in how to more sustainably produce food will increase intrinsic value of the habitats and lead to more effective resource management. Our hope is that the Daraina Outreach Centre will lead to continued infrastructure development and behavioural change of local communities.

5. Are there any plans to continue this work?

As a doctoral dissertation student, this on-going project will continue for one final field season. This was the third field season and I plan to continue conducting lemur behaviour follows and educational outreach within the community. In mid-2021 (pending COVID-19 travel restrictions), I plan to return to Daraina to work with Fanamby to implement my findings and focus on community education and reforestation.

6. How do you plan to share the results of your work with others?

As part of my dissertation, the results of this work will be shared with the scientific community through publishing peer-reviewed articles and presenting at professional conferences. I presented results from the 2019 field season at the Society for Integrative and Comparative Biology in January 2020. I also shared my results, condensed for a general audience, with Fanamby. I plan on publishing the lemur hormonal validation and captive lemur study (using captive samples from the Duke Lemur Centre and wild samples from Daraina) in *General and Comparative Endocrinology* (manuscript in-prep) and the results of the field-based study in *Conservation Physiology* (manuscript in-prep). By the end of 2020/beginning of 2021 I

plan to submit my first dissertation chapter, concerning space use and resource needs of golden-crowned sifaka, to *Biological Conservation*. I will also continue sharing my results on *Wild Labs* and *Conservation X Labs*, specifically to help other conservationists apply tracking technology and hormonal quantification to their studies of threatened and endangered wildlife.

I will continue working with the two primary schools and a secondary school in Daraina to share the results of my field seasons. By helping expose Malagasy children to the wildlife surrounding them, we hope to connect them with nature in a way that compels them to be stewards of the environment and advocates of sustainability practices in their homes and local communities. Overall, being able to effectively connect my science to local individuals will also aid in stronger communication pathways between grassroots communities all the way up to local authorities.

7. Timescale: Over what period was the grant used? How does this compare to the anticipated or actual length of the project?

I used the grant from January-October 2020, which was the anticipated length of this portion of the project.

8. Budget: Provide a breakdown of budgeted versus actual expenditure and the reasons for any differences. All figures should be in £ sterling, indicating the local exchange rate used. It is important that you retain the management accounts and all paid invoices relating to the project for at least 2 years as these may be required for inspection at our discretion.

Item	Budgeted Amount	Actual Amount	Difference	Comments
Malagasy guide stipends	2260	3800	+1540	Over the course of the field season, I hired 28 local guides. At each new forest fragment, I hired 1 Daraina guide and 4 guides from the local village. Thus, I hired more local guides than initially planned, but this enabled the opportunity to spread out employment over the region and work with a variety of individuals. Guides were also compensated for all training programs they took part in.
Malagasy PhD student stipend	1700	1770	+70	The Malagasy student stipend was slightly more than anticipated.
Food for myself, guides, and Malagasy student	1810	1770	-40	Due to being able to purchase rice in bulk, we were able to save funds.

Building supplies (cement, tools, etc.)	3750	5210	+1460	Due to difficulty of obtaining supplies and opting to build an outdoor covered space.
Transport between forests (porters, zebu carts)	450	450		The funding requested was the exact amount needed to hire porters.
TOTAL	**9970**	**13000**	**+3030**	Exchange rate: 1 pound = 4800 Ariary (at the time of the field season)

9. Looking ahead, what do you feel are the important next steps?

The immediate next steps for my project include further in-depth analyses of the collected behavioural, hormonal, and spatial data, as well as finishing the hormonal analysis of the faecal samples. By understanding the impact of habitat type on sifaka spatial behaviour and physiological responses, we can understand the impacts of land management practices. Once we have quantified glucocorticoid metabolites from the faecal samples, we can understand how measures of chronic physiological stress differs across various habitats and degrees of fragmentation.

Second, we have recently upgraded our tracking collars which are now more efficient based on battery life and functionality of the radio sensors (allowing us to collect more precise group-based behaviour). Now that these collars are in their final, improved form, we want to be able to deploy them on various golden-crowned sifaka groups.

Third, a vital step of this project is expanding the curriculum of the Daraina Outreach Centre educational programme. Over the past 6 months we have predominantly focused our programme on the topics of biodiversity in the region, water security, and reforestation and maintaining existing forests. Due to the current status and confusion caused by COVID-19, we want to collaborate with a public health worker from northern Madagascar, the local Daraina doctor, and our outreach coordinator to provide Daraina community members with factual information about the pandemic. We also hope to host a mask constructing workshop for students, guides, and any other members of the community so they can remain safe when indoors or in close proximity to others.

Additionally, community members have expressed an interest in becoming involved in other entrepreneurial objectives. Thus, we are hoping to start an apiary to sustainably produce honey (because the current process of obtaining honey in the region involves cutting down trees in which hives are found) and sustainably harvesting sap from the largest tree species in the region. These haramy trees (local vernacular) produce a sap with a very pleasant fragrance that local guides have found can be used in various ways. We hope these maintainable programmes will help provide local individuals with jobs that are alternatives to gold mining, charcoal production, or logging.

Lastly, we received news in early October 2020 that a population of golden-crowned sifaka outside the Loky-Manambato region has been reported by a local village (and confirmed by the director of Fanamby and our head guide Amidou). The area circled

in white is the known global range of golden-crowned sifaka and I have sampled all known forests within this area. The yellow circled area marks the newly found population of sifaka. This is the first report of this species being able to cross the Loky or Manambato rivers (which were thought to be barriers to the dispersal of the species). If we receive additional funding, we are keen to travel to this new location during the 2021 field season to obtain a census of the population, collect faecal samples, study the composition of the forest, and build relationships with individuals in the local village. By studying sifaka within this forest, we can gain insights into how long the population has been there, whether the lemurs differ behaviourally from the other populations within the Loky-Manambato region, and work towards ensuring that a viable population of golden-crowned sifaka remain there.

10. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did the Foundation receive any publicity during the course of your work?

Yes, the Rufford Foundation logo was featured on a poster presentation at the Society for Integrative and Comparative Biology (USA, January 2020), at Virginia Tech for the 2020 Biological Sciences Research Day Conference (February 2020), and at the Interfaces of Global Change conference (USA, April 2020).

The Rufford Foundation was also given credit in a university wide magazine article about my research. This magazine was sent to over 100,000 alumni, students, and faculty of Virginia Tech.
https://www.vtmag.vt.edu/spring20/feature-lemurs.php

11. Please provide a full list of all the members of your team and briefly what was their role in the project.

Julie Ratovoson: Malagasy field technician
This field season, along with my previous field season, would not have been possible without Julie! She assisted in every stage of data collection from lemur habituation to vegetation sampling, faecal sample collection, and full day behavioural follows. She also provided important intellectual contributions and was a great asset to the project. She was also the driving force in combating issues regarding the construction if the outreach centre and in planning many of the lesson plans and activities that were used in the community.

Local guides from Daraina:
Over the course of the field season, I was able to hire over fifteen local guides from the Daraina guide association. The local guides have impressive knowledge of the terrain and hiking trails in the region, have superior tree species identification skills, and familiarity with the lemurs and other wildlife species. Julie and myself trained all guides on our protocols for collecting lemur behavioural data, faecal samples, and vegetation sampling. I was again able to hire the head of the Daraina guide association, **Amidou Souleimany**, for the entire field season. In addition to coordinating the guide hiring and training process, Amidou is also the president of Daraina's private primary school and was able to help organize outreach plans, assist with the construction of the outreach centre, and assist with the purchase of the parcel of land.

Mamy Rakotoarijaona
Dr. Rakotoarijaona is the Director of Operations for Madagascar National Parks (MNP). He provided invaluable assistance with organizing and planning outreach programs that we are in the process of implementing in Daraina.

Ignacio Moore
Dr. Moore is my academic advisor at Virginia Tech and Professor of Biological Sciences, who provides constant feedback on the development of the questions, field techniques, and faecal sample analysis for this project. As a behavioural endocrinologist, he has been particularly beneficial in helping run the hormonal analysis and streamlining the behavioural data collection.

Nicole Abaid
Dr. Abaid, an Assistant Professor in Biomedical Engineering and Mechanics at Virginia Tech, provided extensive knowledge in studying animal movements through the employment of technology and robotics. She helped with the design and manufacture of our FitPET devices and remote data retrieval technology. She is currently assisting with making all of our data, schematics, code, and documentation for the FitPET devices open source and displayed on Github.

FitPET Engineering team
Undergraduate engineering students and research **Scott Ziv, Lucas Munn, Amar Mohanty, Haoshen Lee, Rohan Walia, and Alex Moran** were the driving force in

helping manufacture and test the FitPET devices. Lucas Munn and Amar Mohanty were the two students who invested the most time into the collar portion of the project and both continue to assist with building additional collars and refining of the devices.

MICET, NGO in Antananarivo
Although MICET did not directly assist with logistics once I was in Daraina, they provided assistance with applying for a long-term research visa, government export permits for biological samples, transportation to Daraina, and connecting me with Julie, my Malagasy graduate research assistant.

Fanamby, local NGO
Although Fanamby staff were not directly involved in data collection, their assistance with vehicle rentals, hiring of local guides, and overall logistics was invaluable. **Dr. Serge Rajaobelina** (Founder of Fanamby) and **Tiana Andriamanana** (Executive Director of Fanamby) were essential resources and provided knowledge about the golden-crowned sifakas, their habitats, and conservation management plans in Daraina. As the director of Fanamby, Tiana was able to help my field team orchestrate various field season logistics and will also assist with the success implementation and running of the Eco-Schools program. Tiana also helped with confirming the new population of golden-crowned sifaka outside the Loky-Manambato region.

12. Any other comments?

I am incredibly appreciative for the Rufford Foundation's substantial contribution to my project for the past 3 years. This funding has enabled me to equip a strong field team of local Malagasy researchers and guides and this project would not have advanced nearly as far without the Rufford Foundation. This third round of funding enabled the construction of the outreach centre which myself and the Daraina community are forever grateful for.