# Final Evaluation Report

| Your Details | |
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| **Full Name** | Raphaël Reinegger |
| **Project Title** | A systematic survey of long-tailed macaques in Mauritius using drone-mounted thermal infrared cameras |
| **Application ID** | 39995-D |
| **Date of this Report** | 09-07-2025 |

**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 |
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| Measure detection errors associated with thermal drone surveys of *Macaca fascicularis* by comparing visual counts of habituated macaque groups with counts obtained from thermal drones | | | X | The study was successfully published in the International Journal of Remote Sensing and provided essential correction factors for the population estimate at the landscape scale and for comparisons with detection probabilities estimated by our statistical models. |
| Population survey of *M. fascicularis* at the landscape scale, using a systematic plot sampling design | | | X | We successfully surveyed *M. fascicularis* at the landscape scale (a total of 1550 ha surveyed) and estimated population size. We are currently in the final stages of write up and data analysis, as we only recently acquired macaque capture data from the three major macaque breeders (accounting for ~90% of all legal macaque capture).<br><br>Using two different statistical methods (N-mixture models and a modified Horvitz-Thompson estimator), we found that the population is around 60,000 macaques. Access to agricultural crops and deer food (a mix of molasses, maize and malt) were the most important predictors of macaque abundance, indicating that macaque abundance decreased with increasing |

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| | | | | distance from agricultural fields and hunting estates with a daily supply of deer food. Power analysis indicated that population declines of 50% can be reliably detected after one year of monitoring under the current sampling design, while reliable detection of smaller declines (10 and 20%) requires three to five years of monitoring. To make comparisons with previous estimates, we had to recalculate our estimates, as the study from 1986 assumed a much smaller habitat extent than our study (450 instead of 710 $km^2$ as indicated in older land cover maps). This resulted in an estimate of ~38,000 macaques, with confidence intervals that extensively overlapped with the estimate from 1986 (35,000 macaques), providing evidence for a relatively stable population.<br><br>We did not encounter any problems whilst counting or identifying macaques with the drone. The thermal signatures and movements of macaques were clearly distinguishable from other animals (e.g., birds and flying foxes). Even when a thermal signature was unclear, we could completely avoid misidentification by using our zoom camera. |
| Meeting with macaque breeders and local government | | X | | Even though we have had several meetings with both the government authority (National |

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| authorities to discuss options for developing clearer management plans using drone-based population monitoring. | | | | Park and Conservation Service) and macaque breeders separately, we have yet to sit down with all parties. We are participating in the Primate Management Conference Mauritius (PMCM, 29 – 31 July 2025) aimed at knowledge exchange between parties and discussing future macaque management. Nevertheless, priority areas for control based on our data have already been highlighted during previous meetings. |

**2. Describe the three most important outcomes of your project.**

**a)** We established an optimal flight plan for effectively counting *M. fascicularis* with thermal drones and estimated flight parameters associated with our method. The estimated errors can also be used to adjust thermal drone-acquired counts for other primates with similar behavioural ecology to *M. fascicularis* in secondary forests with simple canopies.

**b)** We established a thermal drone survey protocol for monitoring *M. fascicularis* at large spatial and temporal scales in Mauritius, measured the effectiveness of our method to detect changes in the population over time and provided a baseline population estimate.

**c)** The macaque breeders and NPCS have been made aware of areas with highly inflated macaque numbers. These require additional control effort, other than capture. This recommendation is taken quite seriously, as these areas are generally avoided by breeders due to high tuberculosis rates in the local macaque populations. Therefore, the high abundance here poses a risk to public health, because males commonly migrate between groups and macaque groups also eventually split and spread into other areas when abundance increases. Additionally, we now have the opportunity to provide recommendations about future control efforts to all macaque breeders at the PMCM. We are going to propose implementation of sterilization in areas with high densities. Such an operation would first require a trial.

**3. Explain any unforeseen difficulties that arose during the project and how these were tackled.**

Most forests in Mauritius that are not on steep slopes are hunting estates. Some of these estates are private, others are owned by the state. However, state-owned land is usually leased to private companies. Our main collaborator who greenlighted the study (NPCS) was not aware of the complex land ownership structure in some areas. Therefore, we were under the wrong impression that many study sites were accessible with the permit provided by the Forestry Service. As a result, we had to

spend more time identifying, contacting and meeting landowners. Flight in these sites then had to be reapproved by the Department of Civil Aviation (DCA). Luckily, most land owners were very cooperative. Land owners were identified with the help of macaque breeders, who have large networks.

Another challenge was getting flights approved by the DCA, because most staff at the department does not fully understand the current drone regulations. The DCA ended up charging 1000 MUR (16 GBP) per site in the end (n = 62 sites) and an additional 10,000 MUR (162 GBP) for the final permit. Considering the additional time required to complete the field work (~ 4 months) and these unforeseen costs, we ended up doing a budget revision. We were forced to lower the research assistant's salary to 23000 MUR = 374 GBP, which matches the salary of a research assistant employed at the University of Mauritius.

**4. Describe the involvement of local communities and how they have benefitted from the project.**

The NPCS benefitted from this project as they intend to now purchase and use thermal drones combined with our protocol for long-term monitoring of *M. fascicularis*. Additionally, one staff member was assigned to our project. We trained him in detecting macaques in thermal imagery and involved him in the data analyses and write up of the first manuscript. Moreover, I have been asked to provide additional statistics training and assist with testing thermal drones for counting flying foxes. However, this will depend on whether I can obtain the Rufford completion grant.

The University of Mauritius was also heavily involved in the project. During the field work, I was always accompanied by a research assistant and one or two volunteers from the University of Mauritius. They have all considerably improved their understanding of *M. fascicularis* morphology and behaviour. For example, towards the end of the first study, they were able to accurately assign individual macaques to specific age-sex classes and recognize agonistic and affiliative behaviours (both to people and to other macaques). These field skills are essential for conducting primate studies. One volunteer was particularly interested in feeding behaviour, so we often extended the field work in the mornings with additional feeding observations. This greatly helped shape the discussion for her recently published paper (https://doi.org/10.7717/peerj.19269).

I also assisted two students from the University of Mauritius with the statistical analyses for their thesis projects and two students with the design of a small research project about seed dispersal of *M. fascicularis*. Finally, I formally supervised one MSc student from the University of Liège. The MSc student assessed crop damage by *M. fascicularis* and investigated famers' perceptions towards *M. fascicularis* and capture activities. Besides assisting her with study design, I also provided field assistance once a week as her field sites overlapped with mine. She scored 16/20 under the French grading system. I have submitted her thesis together with this evaluation report.

**5. Are there any plans to continue this work?**

During data collection we noticed that flying foxes (*Pteropus niger*) were also easy to detect with the thermal drone. With assistance from the red-green-blue zoom camera we were then able to accurately distinguish between macaques and flying foxes. Therefore, I want to develop a thermal drone survey protocol for flying foxes and compare this method with ground-based survey methods that the NPCS currently employs. I believe that the drone-based method is more cost-effective, faster and accurate than the ground-based methods. Additionally, there is a growing gap between conservation science and practice. Therefore, I want to put more emphasis on providing NPCS staff with the necessary knowledge and skills to understand, analyse, and interpret ecological data (not just population data).

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

I have shared and will continue to share results through professional (LinkedIn and ResearchGate) and regular social media platforms (Facebook). I have also held oral presentations at the NPCS head office and three macaque breeding companies (Bioculture Ltd, Noveprim Ltd and LCL Cynologics). Additionally, I presented part of my results (online) at the annual meeting of the Belgian Group for Primatology (BGP) on 22-10-2024. Finally, I plan to present the final results at the PMCM. This presentation will be attended by the press. The presentation will be followed by a meeting with NPCS and macaque breeders to discuss the next management steps. I will also be part of a panel to deal with press inquiries.

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

It is necessary to emphasize the need for additional macaque control methods, such as sterilization. Breeders have to catch roughly 10% of their captive population every year in order to prevent inbreeding and maintain reproductive capacity. Around 15 years ago, this meant that the largest macaque breeders (Noveprim Ltd and Bioculture Ltd) caught around 1500 – 2000 macaques per year, whereas the three smaller companies caught around 750 per year. Previous population viability analyses showed that a population at carrying capacity would eventually go extinct in this capture intensity scenario, and that at least ~4100 females have to be captured each year to prevent the macaque population from growing. However, these capture targets are rarely met, because macaques become increasingly 'trap-shy' in some regions. In fact, trapping probably becomes increasingly ineffective as the local abundance decreases. Some regions are even largely avoided by companies due to high tuberculosis rates in the local macaque population.

Another important next step is to address the gap between conservation science and practice. Current monitoring methods largely rely on simple counts and do not account for imperfect detection. Application of methods that do account for imperfect detection largely remain restricted to academia, because conservation practitioners often lack training in advanced statistics and spatial modelling. Therefore, I plan to put more emphasis on providing adequate training to NPCS staff to ensure successful establishment and maintenance of monitoring programmes.

**8. 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?**

The Rufford Foundation logo was included on the opening slide of all powerpoint presentations and the Rufford Foundation was also acknowledged on the last slide. Additionally, the Rufford Foundation was included in the acknowledgements of the first published article related to this project. The article has been submitted together with this evaluation report.

**9. Provide a full list of all the members of your team and their role in the project.**
Dr Prishnee Bissessur, University of Mauritius – Prishnee has a PhD in applied ecology and was the research assistant for the first part of the project. She assisted with most project activities (e.g., field work and reporting).

Ms Geetika Bhanda, University of Mauritius – Geetika is doing a PhD in applied ecology at the University of Mauritius. She volunteered for the first component of the project (testing effectiveness of thermal drones for counting macaques) and then assisted with field work and reporting for the second part of the project (systematic survey).

Mr. Ishwaardev Meereechpersad, National Parks and Conservation Service (NPCS) – Ishwaardev is a scientific officer at the NPCS and assisted with data handling, analysis and write-up for the first project component.

Professor Gareth Jones, University of Bristol – Gareth was the main supervisor of the study. Gareth leads a research lab that conducts research on ecology, conservation biology, and animal behaviour and has years of experience in the design of ecological studies.

Dr Eva Gazagne, University of Liège – Eva specializes in drone surveys of primates. Eva provided remote assistance with manuscript writing.

Mr. Laurent Levallois, Noveprim Ltd. – Laurent was the operations manager at Noveprim Ltd during our study period. Laurent assisted with setting up meetings with macaque breeders.

Mr. Nada Padayatchy, Bioculture Ltd. – Nada is operation manager at Bioculture Ltd. and assisted with setting up meetings with macaque breeders.

Kevin Ruhomaun, National Parks and Conservation Service (NPCS) – Kevin is the director of NPCS and assisted with providing permits to carry out the study in Mauritius.

**10. Any other comments?**
None.

**ANNEX – Financial Report**

**[Intentionally deleted]**