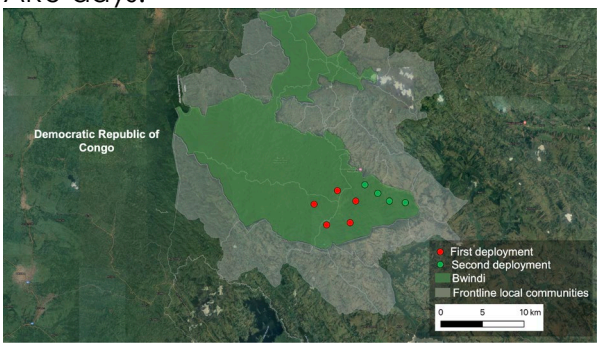
Final Evaluation Report

Your Details	
Full Name	Badru Mugerwa
Project Title	Improving local capacity for acoustic-based wildlife and law enforcement monitoring in Bwindi Impenetrable National Park, Uganda
Application ID	32411-1
Date of this Report	11.07.2022

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
Demonstrate the potential of passive acoustic monitoring as a law enforcement monitoring tool to local wildlife managers and ultimately to national wildlife authorities and NGOs, as it will be the first PAM project in the country with that objective, as far as we are aware.				We conducted three acoustic field surveys: a) deep inside Bwindi (hereafter "first deployment"), b) at a forest patch outside the Bwindi, and c) adjacent (2 km into the interior) from villages bordering Bwindi (hereafter "second deployment"). Our goal was to collect the training and test acoustic data for developing/testing the semi-automated detection algorithms needed to detect dog barks and human voices in the large datasets generated by acoustic grids. We spaced the autonomous recording units (ARUs) approximately 1-2 km apart to avoid overlap in the detection of calls (Figure 1). The acoustic sensors used were of two types: Cornell University's SWIFT and Open Acoustic Device's AudioMoth. For the first deployment, we deployed five SWIFT ARUs in a star-like pattern for 24 days each. In the forest patch outside, we deployed two AudioMoth ARUs for 24 days each. For the second deployment, we deployed SWIFT four sensors at locations 2 km from the PA boundary into the interior for 62 days each. These were areas known to be poaching hotspots based on Embaka's ongoing interactions with the Uganda Wildlife Authority and ex-poachers. We deployed four of five ARUs for the second deployment because our fifth ARU was broken beyond repair. The ARUs recorded continuously (around the clock) at an 8 KHz sampling rate ("frequency"), recording the data on on-board SD cards. The first deployment and deployment in the forest patch outside Bwindi didn't perform to our expectations. We encountered sensor failures. While the same sensors worked in the earlier surveys

				flawlessly, most recorded little to no data inside the forest. From the same deployments, we also learned that the existing dog barking algorithm we had, needed to be better adjusted to Bwindi's soundscape, in order to improve its recall rate – i.e., rate of true positive to false negative detections. The overall failure of the sensors could have been caused by the unusually high amounts of rainfall and humidity during the survey period. In preparation for the second deployment, we assessed whether the sensor failures were due to a scheduling mistake during the wet (rainfall) season or true technical failure of the sensors. We therefore subsequently deployed the sensors during the dry season. We also improved on the dog barking algorithm which improved its recall rate. The results we report here are from the second deployment for which the ARUs performed to our expectations. The acoustic and the overall soundscape data we collected demonstrated the potential of passive acoustic monitoring to detect, and report, where and when human activity is prevalent inside protected areas. We collected a total of 287 and 286 independent detections (detections > 60 minutes apart) of dogs and humans respectively over a sampling effort of 248 ARU days.  Figure 1. Locations of ARUs for the first and second deployments in Bwindi.
Advance PAM's value as a force multiplier for wildlife law enforcement in African rainforests,				Our results are based on an imperfect detection algorithm that was originally developed in Greece and adjusted for the Bwindi data. It needs to be improved but works well enough to show the potential

by contributing towards the development of dog and human detection algorithms, which can be used in Bwindi and beyond to detect hotspots of human activities other than hunting and logging (i.e., the gunshots and chainsaw detectors are currently available).				value of the PAM. The limitations of the algorithm are: a) low recall rate (i.e., it finds only about 5-10% of the actual dog barks, or about 30% of 1-minute intervals with at least one bark) - we need to improve it further so that it picks closer to 75% of the calls; and b) this algorithm currently requires licensed software. Ideally, we could develop an algorithm that is available to all at no cost. We tried the online Arbimon acoustic data storage platform, which has a pattern recognition tool. That worked even better than the recall rates reported above, but it is a time-consuming tool that requires data to be uploaded 1 minute at a time to the platform – this is not a great solution to protected area managers who just want to get SD cards, run an algorithm and review results (and especially in places where internet connection is weak or non-existent). Further, we don't currently have a human voice detection algorithm. The data we present here are observations made while reviewing putative dog barks. Hence, the resolution and recall rate of human voices could be improved massively.
Provide a valuable baseline record of Bwindi's soundscape and levels of anthropogenic activities, for future reference.				We have been able to record Bwindi's soundscape and provided a baseline on the levels and spatial and temporal patterns of activity of humans and dogs as their commensals.
Train local wildlife personnel in modern applied conservation skills, improving the impact of their conservation efforts as well as their chances for maintaining a career in wildlife conservation - and therefore to directly benefit from the national park (beyond the tourist				We trained a local team in the deployment and maintenance of acoustic sensors. The training was conducted at the Institute of Tropical Forest Conservation (ITFC) to two ITFC personnel, who later trained six UWA rangers. The workshop combined presentations, hands-on training (e.g., in programming acoustic sensors), and computer practical (e.g., in interpreting acoustic data using powerful yet user-friendly software). We report that this objective was partially achieved because we did not train all the 18 persons, we proposed in the grant application. This was because of the

sector).				nationwide covid regulations that: 1) restricted workshops and meetings to not more than five people, and 2) restricted travel of people from the different Bwindi ranger outposts.
Strengthen existing collaborations among wildlife managers, tourist companies and local conservation NGOs (e.g., Embaka) for more efficient and effective wildlife conservation.				We strengthened existing collaborations among the Bwindi Uganda Wildlife Authority (UWA), Embaka (a local community-based conservation organization https://www.savingafricangoldencat.com) , and the Institute of Tropical Forest Conservation (ITFC).

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

a) Passive Acoustic Monitoring (PAM) has potential to detect, and report, where and when human (and dogs as human commensals) activity is prevalent inside Bwindi. We detected 287 and 286 independent detections of dogs and humans respectively over a sampling effort of 248 sensor days.

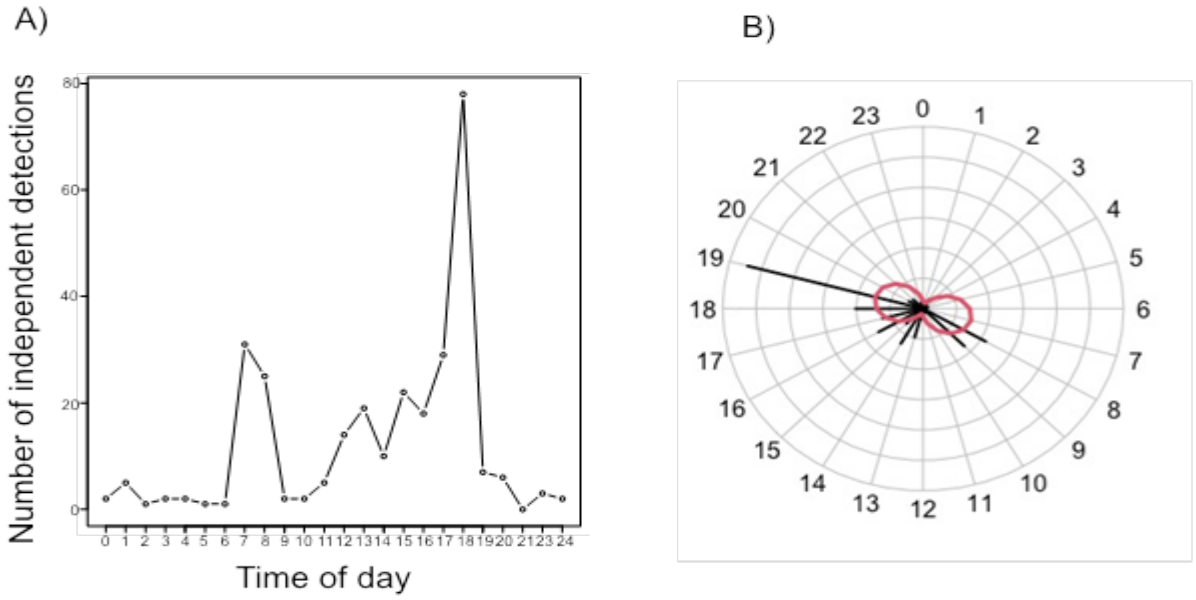


Figure 2. Number of independent dog detections (detections 60 minute apart) for each time of the day (A). Rose diagram displaying the observed (radial lines) and predicted (curved polygons) dogs' diel activity pattern (B). Predicted patterns were derived from regression models. The diel activity patterns are plotted hourly, where the percentage of detection events per hour is shown on the response scale (axis at 12 noon).

b) Dogs exhibited a predominantly bi-modal crepuscular activity (Figure 1.), with two distinct peaks:1) first peak during early morning hours between 0700 and

0900, with activity peaking between 0800 and 0900, and 2) second peak mostly at 1900.

c) Humans were predominantly diurnal, with detections recorded between 0700 and 1800, peaking between 1200 and 1400 (Figure 2).

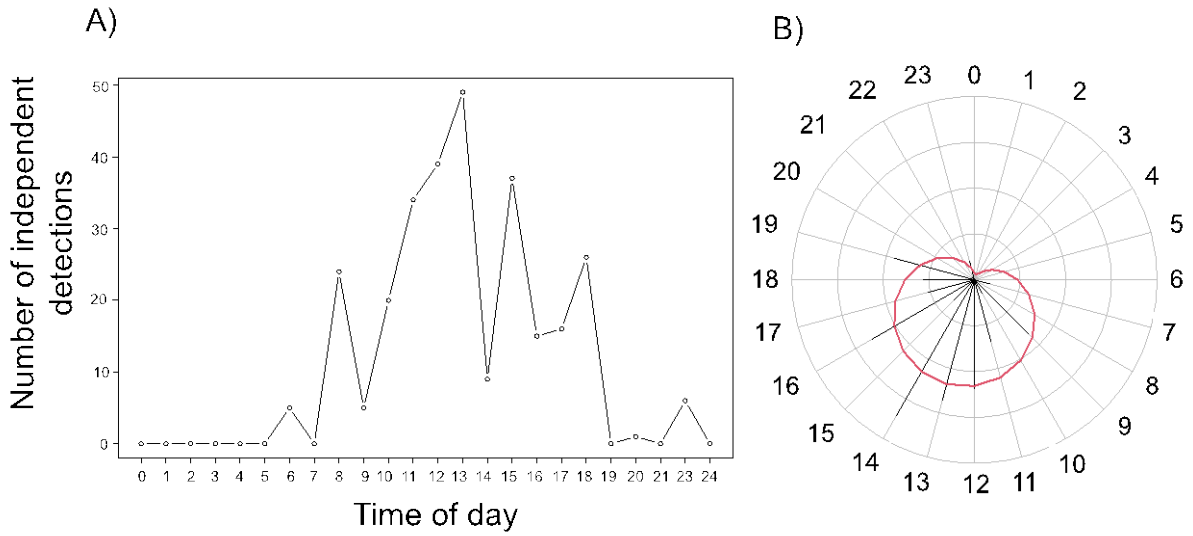


Figure 2 Number of independent human detections for each time of the day (A). Rose diagram displaying the observed (radial lines) and predicted (curved polygons) dogs' diel activity pattern (B). Predicted patterns were derived from regression models. The diel activity patterns are plotted hourly, where the percentage of detection events per hour is shown on the response scale (axis at 12 noon).

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

Rain! Our first deployment was severely impacted by unexpected amounts of rain. We, in fact, attribute sensor failures to heavy rain and cold humid conditions unexpected at that time of the year for Bwindi, even though our ARUs were enclosed in waterproof enclosures. After realising ARU failures in the first deployment, we re-deployed the sensors during the dry season which significantly improved ARU performance and data collection. Unfortunately, with climate change, favourable field seasons are becoming increasingly unpredictable.

Covid-19 restrictions to free movement and large group meetings hampered our plans for delivering training workshops. We navigated this limitation by training a few members in small groups.

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

For this project, we involved the local communities via different capacities. We involved the UWA Rangers, not only to strengthen UWA's law enforcement but also to strengthen community relations as UWA rangers are directly recruited from

frontline adjacent villages to Bwindi. The same is true for Embaka and ITFC staff, who further bring in their Bwindi research experience. We also engaged reformed poachers who are now registered members of the Embaka Community Based Conservation Organization. Reformed poachers were instrumental in identifying areas within the park rife with poaching. This knowledge was indeed a key factor for the successful ARU redeployment.

5. Are there any plans to continue this work?

Yes, as one of the ongoing Embaka's community-based anti-poaching initiatives, we plan to build on this project to create the first ever community based anti-poaching PAM called the Sauti Guardian. Sauti Guardians, which stands for "Sound Guardians" in Swahili, will be a new anti- poaching community-based team that will utilise the near-real time warning of unauthorised human activity inside Bwindi. Specifically, a grid of five Rainforest Connection (RFCx, https://rfcx.org) PAM Guardian sensors will be placed inside Bwindi in each of the five Bwindi management zones; Nkuringo, Southern, Ruhija, Buhoma and Northern. The sensors, powered by solar panels and linked to Global System for Mobile communications (GSM) network, will send around the clock data on acoustic activity inside Bwindi. Automatic algorithms will scan those sounds for evidence of human voices and dog barks (tell-tale signs of poachers using dogs to drive wildlife towards snare lines) and forward warning (which can be acoustically reviewed for confirmation) to Sauti Guardians in a matter of minutes both on smartphones (via a RFCx app named Ranger App) and a desktop PC software (named RFCx Dashboard). The Sauti Guardians will then collaborate with UWA's community conservation and law enforcement departments to interject poaching events. The aim of Sauti Guardians program is not to apprehend those involved in poaching, but rather have them integrated in Embaka's community-based livelihood conservation initiatives.

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

We plan to present the findings of this work with UWA and other stakeholders via the annual research and conservation symposium of the UWA. We are also preparing a manuscript as a short communication to be submitted to the journal Remote Sensing for Ecology and Conservation. We will share these results also at conferences.

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

For this project, we have shown the potential of PAM as a law enforcement tool, able to detect unauthorised activity of dogs (feral or otherwise) and humans. The next important step should be to introduce PAM to local communities as a community-based conservation tool. As Embaka, we already have plans to create Sauti Guardians, a group of local community members using PAM as a community based anti-poaching watch tool. The Sauti Guardians programme will provide a unique opportunity for local communities to directly collaborate with UWA law enforcement teams in anti-poaching initiatives.

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?

Yes, we used the Rufford Foundation logo during our meeting with the UWA, and our application for the research permit to work during the covid pandemic. No, we have not received any publicity during the project.

9. Provide a full list of all the members of your team and their role in the project.

B.M, the applicant, lead this project, bringing to the team his considerable leadership experience and skills in designing, implementing and reporting on the findings of wildlife conservation projects in the Bwindi region.

Dr. Christos Astaras (https://www.fri.gr/index.php/en/staff/researchers/dr-astaras-christos) is an experienced wildlife researcher at the Forest Research Institute (Greece), assisted in the design of the introductory workshop, and the deployment of the acoustic grid. He also guided the acoustic data analysis. Having worked on the development of detection algorithms of anthropogenic and wildlife sounds, he was also involved in the efforts to develop the human speech and dog barking algorithms.

The field team consisted of the applicant as a team leader, two ITFC field assistants (**Avetino Nkwasibwe and Lawrence Tumugabirwe**), one Embaka staff (**Julius Mutale**) and six UWA rangers. The UWA rangers brought to the team-specific knowledge on strategies used by poachers, which helped identify the areas where we placed our acoustic grid. The ITFC field assistants are trained and experienced in ecological research in tropical forest landscapes and provided technical backstopping to UWA rangers when needed. Both the UWA rangers and ITFC field assistants also have a vast knowledge of the forest and have a good understanding of the Bwindi Impenetrable Forest conservation landscape as they are directly recruited from the frontline villages neighboring the park. The close working partnership between the UWA rangers, Embaka staff and ITFC field assistants will ensure that the application and use of the PAM for law enforcement will extend beyond the duration of this project.

10. Any other comments?

We are grateful to The Rufford Foundation for the funding support without which this work would have been impossible. This work has provided the sole foundation for Embaka's Sauti Guardians programme. I wish to thank Jane Raymond, and the whole RSG team for checking on us during the project implementation, and for supporting our decision to conduct a redeployment of the ARUs which allowed us to collect useful data. Many thanks to the scientific reviewers who gave their time to review and provide useful feedback to our project.