Where have all the birds gone? - A multi-species approach to confirm distribution of threatened Mauritian birds in the Bambou Mountains (Mauritius) in the aftermath of Covid-19, through AudioMoth

Mauritian Wildlife Foundation report
for African Bird Club

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2021

AFRICAN BIRD CLUB

MAURITIAN WILDLIFE FOUNDATION

Table of Contents

Introduction and aims

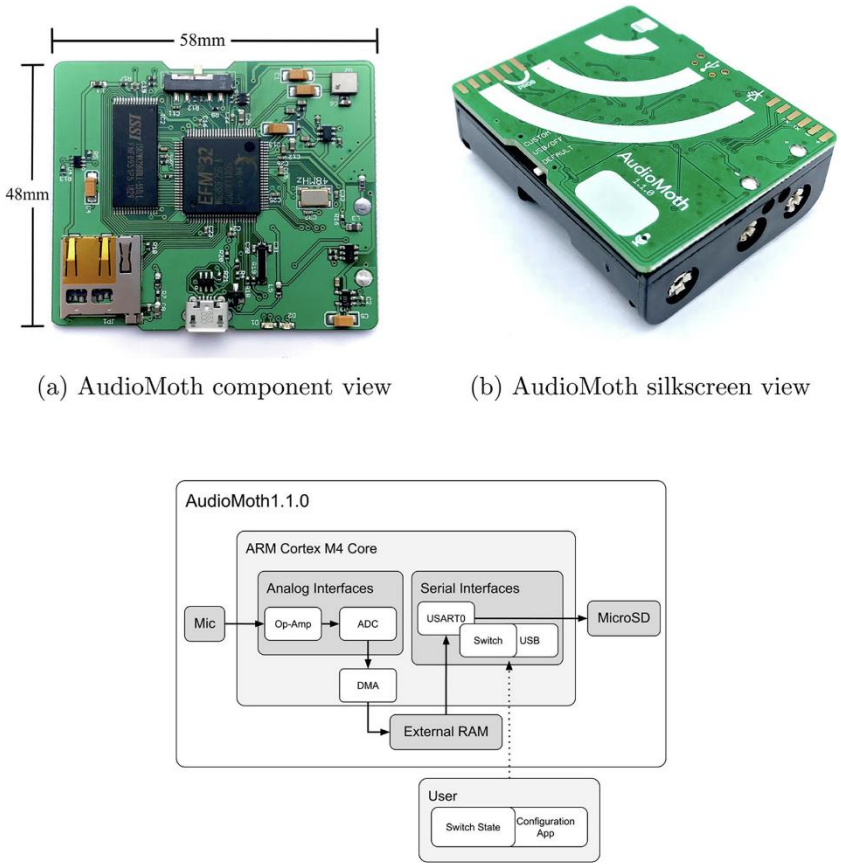
Eco acoustics (Sueur and Farina, 2015) is a recent branch of ecological research. It is the analysis of environmental sound that are collected from audio devices that are battery powered. There is a full list of recommended acoustic hardware and software in the WWF guidelines (Browning et al., 2017) for acoustic monitoring in conservation sciences. However, these devices are often expensive (e.g. the SongMeter series (www.wildlifeacoustics.com) and the BAR series (www.frontierlabs.com) that are well known but for a starting price at $499). Here at the Mauritian Wildlife Foundation we chose to use AudioMoth that are acoustic monitoring devices which are a lower cost alternative. These devices will be used to confirm the persistence and current distribution of previously released Echo Parakeets (*Alexandrinus (Psittacula) eques*, Vulnerable), Pink Pigeons (*Nesoenas mayeri*, Vulnerable), Mauritius Cuckoo-shrikes *(Lalage typica*, Vulnerable), Mauritius Paradise Flycatchers (*Terpsiphone bourbonnesis desolata*; Least Concern) and Mauritius Kestrels (*Falco punctatus*, Endangered) in the Bambou Mountains (c.4500 ha; Mauritius' second largest block of forest). These birds were reintroduced to the Bambou Mountains (southeast Mauritius) to restore the distribution of the species. They had become locally extinct due to predation, habitat destruction, hunting, and additionally the use of organochloride pesticides for kestrels and cuckoo-shrikes. Recently reintroduced Pink Pigeons and Echo Parakeets were locally extinct for over a century, and cuckoo-shrikes since the 1960s. Detection of some of the species has been difficult since they occur at low densities e.g., only one known breeding site for the Echo Parakeet (and a few sightings), few breeding records of Pink Pigeons, occasional sightings and no breeding records of cuckoo-shrikes and flycatchers. The distribution of Mauritius Bulbuls (*Hypsipetes olivaceus*, Vulnerable), which survived in the Bambou Mountains, is patchy. However, Mauritius Kestrels have been reintroduced there since 1988 and our knowledge is fairly complete.

Audio recordings are collected by 15 AudioMoth devices (the first AudioMoth survey was completed in the Ferney fenced forest plot in August 2021). Analyses of the recordings will permit us to determine the presence and distribution of the focal species to guide conservation management within the region, and potentially identify nesting attempts and minimum number of birds. We may obtain additional data on the Mauritius Kestrel as well. Determining the distribution of released bird species using Passive Acoustic Monitoring (PAM) will improve monitoring efforts and will inform the success of release techniques by providing an indication of post release survival.

Hardware description

AudioMoth (Hill et al., 2019) was created by two computer science PhD students at the University of Southampton, Andrew Hill and Peter Prince, together with Alex Rogers, a computer science professor at the University of Oxford. The AudioMoth is the first product of their Open Acoustic Devices initiative.

AudioMoth can be configured to record at many sample rates (Hill et al., 2019). We can record and analyse sounds from different source types. For example, anthropogenic noise (such as gunshots or engine noise: 8 kHz sample rate); audible wildlife (such as bird, insect or frog vocalization: 48 kHz sample rate); and ultrasonic wildlife (bats or amphibian calls: 384 kHz sample rate). So, this device will not only be useful for this particular study (endemic birds), it will also be able to capture other species like endemic bats in future studies.



(a) AudioMoth component view (b) AudioMoth silkscreen view

(c) Hardware Overview

Figure 1: AudioMoth device, small size (non-invasive), low cost, low power consumption (good for long term scientific research). (Hill et al., 2019)

Project details

The project combines a species-based and site-based approach. The species concerned by the project are:

- Echo Parakeet (*Alexandrinus (Psittacula) eques*, Vulnerable),
- Pink Pigeon (*Nesoenas mayeri*, Vulnerable),
- Mauritius Cuckoo-shrike (*Lalage typica*, Vulnerable, but qualifies for Endangered or Critically Endangered when re-assessed),
- Mauritius Paradise Flycatcher (*Terpsiphone bourbonnesis desolata*; Least Concern, although the Mauritian subspecies is far rarer than the species from Réunion Island),
- Mauritius Bulbul (*Hypsipetes olivaceus*, Vulnerable) and
- Mauritius Kestrel (*Falco punctatus*, Endangered).

The project will be conducted in the Bambou Mountains, an Important Bird Area (IBA, designated by BirdLife International) and a Key Biodiversity Area (KBA, designated by Critical Ecosystems Partnership Fund). Bambou Mountains are included in the Protected Area Network Expansion Strategy (2017-2026), and has previously been suggested as a future national park. Much of the

upper reaches of the area are protected by law as 'Mountain Reserves', whether in private or government ownership and management. There are some successful private sector initiatives covering conservation and education, such as at Ferney Valley and Vallée de l'Est and others in development (e.g. Kestrel Valley with which we are associated at various levels).

It is expected that the AudioMoth will bring forth biological data of a higher quality about the native bird community than ever before. The microphones will record activity during the breeding and non-breeding season for endemic birds. It is to be noted that significantly more effort has been devoted to monitoring birds and areas during the breeding season rather than the non-breeding season. Therefore, these recorders will help fill the gap of bird activity in the non-breeding season.

Although not a focal species for this application, the AudioMoth should also provide a better understanding of the ubiquitous Mauritius Grey White-eye (*Zosterops mauritianus*, Least Concern), Mascarene Cave Swiftet (*Aerodrama francicus*, recently listed as Near Threatened), seabirds (e.g. White-tailed Tropicbirds, *Phaethon lepturus*, Least Concern), and may yield records of unsuspected endemic birds, such as the Mauritius Fody (*Foudia rubra*, Endangered).

Methods

We purchased 15 AudioMoths and waterproof casing from LabMaker and other accessories (SD cards, usb cables, batteries) locally. We selected sites for deployment that are known or suspected to host important biodiversity, in particular birds, in the Bambou Mountains. Devices are positioned in habitats considered most likely to support the species, based on previous surveys and historical records of occurrence. The trial will concern areas of good native habitat, previous bird release areas (e.g. Ferney Valley), sites where species of interest have previously been observed, at Echo Parakeet and Mauritius Kestrel artificial nest boxes or known natural cavities, and areas that are remote and unlikely to be well covered by a reduced staffing due to COVID-19 pandemic.

1. Device settings

Recorders should be setup to 48 kHz and 24-bit depth if we want to cover the entire audible range. This will produce detailed data on frequency and amplitude and we would be able to produce clear spectrograms and analysis information. However, if the study is focused on particular target species (with lower frequency calls), then a lower sample rate can be used to save on storage and battery life (Darras et al., 2018). The Nyquist–Shannon sampling theorem states that a sampling rate of more than twice the maximum frequency of the signal to be recorded is needed, so here to be safe, 32 kHz sampling rate should be sufficient (considering that our species max frequency should be around 10 000 Hz) to save battery life and storage on the SD cards. When we look at bird populations monitoring by point count, human ears should be separated by approximately 300m to limit the chance of overlapping detection, and to ensure independence between sites (Ralph et al., 1995). However, we don't really know the detection range of our devices yet (test should be conducted).

2. Pre-recordings tests

We chose to test the microphones and their detectability in places where we know our species will occur at high densities. This recording test phase is also an opportunity to capture a variety of good

recordings of the species and use them as references later to try to autodetect our birds using specific software. Here is the list of the different locations:

1. On Ile aux Aigrettes (IAA; 20.4205°S, 57.7325°E), with many places of interest: two Mauritius Fody aviaries and Mauritius Olive White-eye feeders. Placing devices at these points can help us to build calls databases for these passerines.
2. At Plaine Lievre (PLL; 20.3795°S, 57.4474°E) feeders where we can easily find Echo Parakeets, Pink Pigeons, and Mauritius Bulbuls.
3. At Brise Fer – inside the CMA[1] (BFCMA; 20.38°S, 57.44°E) where there are Mauritius Cuckoo-shrikes, Echo Parakeets, Pink Pigeons, Mauritius Bulbuls, Grey White-eyes and Mauritius Kestrels.
4. There are bird feeders at Bel Ombre (20.4747°S, 57.4211°E) where we can catch Echo Parakeets, Pink Pigeons, and Mauritius Bulbul calls.
5. At Combo forest (20.465894°S, 57.515041°E) where Olive White-eye, Paradise Flycatcher, Pink Pigeons, Mauritius Bulbul & Grey White-eye are present.

Figure 2 : AudioMoth deployment locations since the beginning of the project

3. Sampling method

For the first year we will start as a trial, by collecting occupancy information (presence/absence), and that is the main information we need. But we can also make it as the first year of a standardised protocol to reveal useful long-term indicators such as temporal abundance and species richness.

Birds will be recorded for 2 periods of 1 week (at the beginning and the end of the breeding season to not miss any early or late breeders) during September-March (breeding period) when detection

[1] Conservation Management Area

should be greater relative to other months of year. Bird detection probability normally varies with time of the day, weather etc. So, if our recording times are distributed throughout the day and during an entire week, we should sample the entire community most effectively (La and Nudds, 2016).

Scientific studies have found that a stratified 'on-off' time sampling programme (e.g. recording 1 minute in every 10), can capture comparable data to continuous recording, with consequent benefits in terms of battery life, data storage and processing time (Bayne et al., 2017; La and Nudds, 2016). Bayne et al. found that larger proportion of all the species in their dataset (193 species/ 872 stations) are detected with more, shorter duration point counts than with fewer, longer duration point counts. Furthermore, sampling for a period of approximately a week will result in detection of higher proportion of the entire species pool at a point, compared to a single day sampling. It was found that recording during a month didn't show higher estimates of occurrence (Bayne et al., 2017). Here in Ferney, we will test the efficacy of 10-minute recording periods at the beginning of every hour. Recording will begin 30 minutes before sunrise, and will continue until sunset.

To our knowledge, no prior studies have examined the detection range of AudioMoth devices concerning birds. In a recent article comparing the detectability range of two birds (*P. flaviventris and A. clamosus)* between two Wildlife Acoustic ARUs[2], authors found that many factors such as wind direction, humidity, relative elevation, where the calling individuals are positioned in space and the ARU themselves, affected the detectability (Thomas et al., 2020). For our first deployment we chose to test a 100x100m grid (assuming a detectability range of 50 meters in covered area). With 100 meters of space between recorders it would provide 0.08 km² (8 ha) of sampling area in the Ferney fenced plot. We deployed 15 AudioMoths (version 1.1.0) from 12/08/2021 to 20/08/2021. We used the AudioMoth Configuration App to set the sample rate to 32 kHz, gain at medium level, sleep duration at 3000 seconds, and recording duration at 600 seconds (10 minutes of recording every hour, starting 30 minutes before sunrise until sunset). These settings allowed daily recordings, resulting in 13 daily files sized up to 38 MB each, totalling approximately 499 MB/day. Under these conditions, battery usage each day was predicted to be 28 mAh, indicating that the three Alkaline batteries in each AudioMoth could last 53 days. We tried to not place them near a river (for background noise) and place them at an acceptable height to minimize risk of deer antler rubbing.

AudioMoths will be formatted and switched on before being deployed. They will be protected by IPX7 Waterproof Cases supplied by the manufacturer, and tied to secure trees. Since this is a pilot project, there is likely to be a learning phase during early use, and methodologies may change in response to factors such as habitat type, species of interest, recording results etc.

[2] Autonomous recording unit

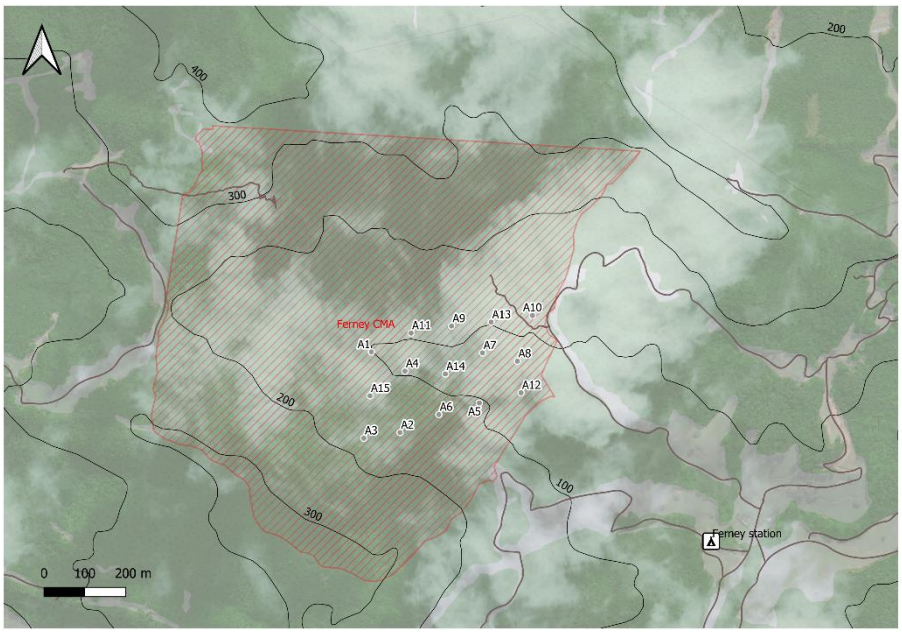


Figure 3: AudioMoth deployment grid (100x100m) at Ferney CMA, Mauritius

Storage & Analysis

1. Analysis software

On the 4th October 2021 We were recently successful in an application to Wildlife Acoustics, receiving a year's subscription to the specialist audio analysing software Kaleidoscope Pro®. Wildlife Acoustics is an American company that provides grants to support the advancement of animal biology research, habitat monitoring and environmental conservation.

Kaleidoscope (Wildlife Acoustics Inc, Maynard, USA) is capable of **classification/identification,** it can predict the identity of sounds captured in recordings. The software detects and classifies groups of syllables based upon their spatio-temporal properties, and how they combine to form phrases or song. It then compares acoustic patterns of detected signals and groups the similar detections into clusters (that can be manually labelled as species) based upon their similarity. Kaleidoscope assigns a score to detections, based upon their distance from the centre of the cluster (Brooker et al., 2020). These functions will allow us to detect our species. We started to build recognizers using the cluster analysis function (to be able to auto-detect our birds of interest after each deployment), following tutorial videos available from the software developer and instructions within the Kaleidoscope documentation. The other advantage is that we don't need to clean any audio files, Kaleidoscope will still be able to see through the audio white noise.

2. Storage

The AudioMoths are recovered after deployment, data downloaded, batteries changed (if needed) and data analysed to prevent a large backlog of data analysis at the end of the project. Audio recordings files will be stored as site name/date of recording. File will be named as the following format: « Device_yyymmdd_hhmmss » (e.g. A1_20210812_110000). GPS coordinates of each recorder will be kept and the audio files will be stored in a local folder on a computer (for analysis) and on online drive to prevent any loss of data

3. Staff training

The scientific data officer (Adrien Gellé) attended to five online training courses (10 hours) from Wildlife Acoustics, Inc. (May-June 2021 sessions) and a webinar on Acoustics for endangered birds held in February 2021. The courses covered a wide range of sound analysis using Kaleidoscope Pro® with birds, bats and other land animals.

Courses	Date	Staff	Wildlife Acoustics Trainer
Kaleidoscope for Bat Analysis (Beginner)	12/05/2021	Adrien Gellé	Paul Howden-Leach
Kaleidoscope Pro Cluster Analysis for Birds and Land Animals	25/05/2021	Adrien Gellé	Dave Roberts
Kaleidoscope Pro Cluster Analysis for Birds and Land Animals (Intermediate)	16/06/2021	Adrien Gellé	Paul Howden-Leach
How do you find your sound: Clustering vs Classifiers	22/06/2021	Adrien Gellé	Dave Roberts
Kaleidoscope Pro Cluster Analysis for Birds and Land Animals (Intermediate)	29/06/2021	Adrien Gellé	Dave Roberts

Results

1. Test phase

→ On 03/05/2021 we tested our first AudioMoth in urban area (Vacoas) from 11:30 to 14:00 (configuration: Sample rate 32 kHz /Gain: Medium/sleep duration: 3000s/recording duration: 600s/ Filter: Low-pass: 16.0kHz). It was very hard for our ears (and Kaleidoscope) to recognise birds in this environment (trucks, motorcycles, cars, road works…)

→ On 04/05/2021 we tested one AudioMoth in the Brise Fer forest (Black River Gorges National Park) near an Echo Parakeet nest from 6:00 to 18:15 (configuration: Sample rate 32 kHz /Gain: Medium/sleep duration: 3000s/recording duration: 600s/ Filter: Low-pass: 16.0kHz. 13 audio files were analysed using Kaleidoscope Pro®. Two endemic birds were detected (Echo Parakeet and Mauritius Cuckooshrike), two exotic birds (Zebra Dove & Red-Whiskered Bulbul) and some insects. 62% of the detected calls were Red-Whiskered Bulbul.

→ On 07/05/2021 we tested one AudioMoth on Ile aux Aigrettes (south-east coast of Mauritius) from 8:00 to 16:00 (configuration: Sample rate 32 kHz /Gain: Medium/sleep duration: 3000s/recording duration:600s/ Filter: Filter: Low-pass: 16.0kHz) to update our calls database. 10 audio files were analyse using Kaleidoscope Pro®. One endemic birds was detected (Mauritius Fody), three exotic birds (Zebra Dove, Red-Whiskered Bulbul, House Crow) & some insects.

→ On 19/05/2021 we used one AudioMoth on the island reserve of Ile aux Aigrettes from 8:00 to 16:00 (configuration: Sample rate 32 kHz /Gain: Medium/sleep duration: 3000s/recording duration:600s/ Filter: Band-pass: 1.0kHz - 16.0kHz) to update our calls database. 10 audio files were analyse using Kaleidoscope Pro®. Two endemic birds were detected (Mauritius Fody & Olive White-eye), three exotic birds (Zebra Dove, Red-Whiskered Bulbul, House Crow) & some insects.

→ From 21/05/2021 to 24/05/2021: one AudioMoth was deployed in the Bel Ombre forest (near the Echo Parakeet supplementary feeding stations) from 6:00 to 18:00 (configuration: Sample rate

32 kHz /Gain: Medium/sleep duration: 3000s/recording duration: 600s/ Filter: Band-pass: 0.2kHz - 10.0kHz). **After training Kaleidoscope Pro® with Brise Fer Echo Parakeet records, we successfully auto-detected these endemic birds at Bel Ombre Echo feeder.**

→ From 25/05/2021 to 28/05/2021: one AudioMoth has been deployed at Brise Fer (Echo Parakeet nest box) to add Echo Parakeet calls to our database. We noticed that one device's acoustic membrane got damaged, likely by insects. Another AudioMoth has been deployed at Pigeon Wood (National Park) feeders to capture Pink Pigeon calls. Another device was deployed at Combo (National Park) to try to capture Mascarene Paradise Flycatcher calls. A forth device was deployed at the Plaine Lievre feeders (National Park) to add Echo Parakeet calls to our database. A fifth device was deployed at the Combo tea fields (near Bois Cheri village) to try to capture multiple species calls. All 5 devices were recording from 6:00 to 18:00 (configuration: Sample rate 32 kHz /Gain: Medium/sleep duration: 3000s/recording duration: 600s/ Filter: Band-pass: 0.2kHz - 10.0kHz).

2. Ferney deployment

1st deployment

We noticed that three devices had damaged membranes too (like on 25/05/2021 deployment). Four endemic birds were detected using Kaleidoscope Pro® (Wildlife Acoustics, Inc.). Mauritius bulbuls were detected on A3, A5, A7, A8, A9, A11 & A13 recorders. Mauritius Grey White-eyes were detected on A6, A9, A11, A13 & A15 recorders. Mauritius Kestrels were detected on A9 & A13 recorders. Pink Pigeons were detected on device A9.

Figure 4: AudioMoth deployment grid at Ferney CMA and the associated endemic birds' detections from the 12th to 20th August 2021

2nd deployment

For the second deployment (04/03/2022) we decided to move the grid outside the CMA where the team saw a pair of Mascarene paradise flycatcher earlier during the season. The aim of this deployment is to test the ability of the ARUs to detect these birds using our sampling method.

We didn't find any Mascarene paradise flycatcher using Kaleidoscope Pro®. Mauritius Kestrel calls were detected on AudioMoth A12 during 6 different days (early morning and late afternoon).

Mauritius kestrel's detection is not very surprising considering that A12 was placed 5m from an artificial nest.

3rd deployment

For the third deployment (19/03/2022) we decided to move the grid inside Ferney CMA again but further West starting from the fence. The aim of this deployment is to search for Mauritius Cuckooshrike in another area of the CMA because the first deployment wasn't successful in detecting them. In recent years, most observations in Ferney have been of a single male Cuckooshrike within the fenced plot; he was seen on multiple occasions between October and December 2019, and in September 2020. In November 2021 a Cuckooshrike was heard in the forest below Ferney Cliff (in the forest at the top of the fenced plot). Cuckooshrike playbacks were played, and the male responded by territorial calling, and coming closer to the source of the playback. It was identified as the same individual seen in 2019 and 2020 and was aggressively responding to the playback, flying back and forth calling, and eventually coming within a few meters of the playback. This is why we decided to move the grid, assuming that the bird moved West of the initial release site.

Unfortunately, we didn't detect our species of interest during this deployment. One device stopped recording during the survey due to humidity/oxidation issues. The device (A7) is currently out of order and we have 14 devices left for future surveys.

Conclusion

The project will provide a greater insight into the native avian community composition and distribution in the Bambou Mountains, Mauritius' second largest block of forest. It will help us map presence and activity of recently reintroduced birds, and birds that occur at low densities in the tall canopy forest so have escaped detection.

Determining the distribution of released bird species will improve monitoring efforts, improve the accuracy of population estimates and will inform the success of release techniques by providing an indication of post release survival. The project will facilitate the application of more effective conservation measures, as management efforts could be targeted more effectively to benefit species of interest such as forest restoration work, predator control measures, the provision of artificial breeding sites and the provision of supplementary food. Breeding sites will be more easily located and monitored and managed. Essential 'habitat corridors' may be identified that could become important points for conservation measures in the future e.g. provision of supplementary food and reinforcement releases to increase gene flow between fragmented populations.

The results from the project will lend support to further endemic bird releases in the Bambou Mountains, and raise the conservation profile and protection of this IBA[3] and KBA[4]. The low-cost,

[3] Important Bird and Biodiversity Areas
[4] Key Biodiversity Areas

remote, and technological approach could be applied in a variety of other locations, especially those that have received less focus e.g. the Moka Range (north Mauritius), or for recording returning translocated seabirds on Ile aux Aigrettes (south-east Mauritius). We recognised that this method needs lower labour requirements with approximately 3 hours to deploy 15 devices (with our sampling grid), 2 more hours to retrieve them and approximately 2 hours to analyse the recordings. That makes a total of 7 hours of work (with 3 staff involved) to obtain results from 253 hours of recording. Moreover, by using ARUs we achieved to remove one of the biggest bias in bird survey protocols which is the "listener effect."

The main aim of the project was to detect presence/absence of endemic birds in remote areas, and within a week we successfully confirm the detection of four endemic brids in the Bambou Mountains. Overall, we recognise the far-reaching biological conservation benefits of these ARUs. In the case of this project, these translate to better assessment of the multi-species bird community of Bambou Mountains, and lending greater support for the conservation and legal protection of this mountain range.

AudioMoth were chosen on the recommendation of various partners who have been using them, such as the Zoological Society of London (UK) and Chester Zoo (UK), and their growing reputation. They also appear to be an immediate, low-cost, efficient and reliable response to the reduced financial and human resources brought about by Covid-19.

Acknowledgements

We are grateful to MCB group, Gold Species Champions of the Pink Pigeon and Echo Parakeet, Standard Bank, Gold Species Champion of the Mauritius Kestrel, Ciel group for the support, releases and conservation work done in Ferney and to the African Bird Club and Wildlife Acoustics for supporting this research project.

About the organisation

The Mauritian Wildlife Foundation is the largest non-governmental organisation (NGO) in Mauritius to be exclusively concerned with the conservation of the endangered endemic plants and animals of Mauritius. The work carried out in Mauritius is one of the world's most successful conservation stories. This is due to MWF's restoration work started in the 1970s, which has succeeded in rescuing the Mauritius Kestrel, Echo Parakeet and Pink Pigeon, from the brink of extinction.

The organisation's head office is in Vacoas, Mauritius and its website is https://www.mauritian-wildlife.org/. This project is managed by the Fauna Manager (Mr. Sion Henshaw) and the Conservation Director (Dr. Vikash Tatayah).

Appendix

1. Expenses table

Item	Code	Quantity	Unit price	VAT	Total price
AudiMoth v1.1.0	Pack of 10 (US$69/pc) - SKU: H021	1	$ 690.00	19%	$ 690.00
Audiomoth IPX7 Case	SKU: H050	15	$ 39.99		$ 599.85
AudioMoth v1.1.0	Single - SKU: H020	5	$ 74.00		$ 370.00
Standard shipping	NA	1	$ 19.00		$ 19.00
AA batteries	Duracell Plus Power AA/LR6 4x	12	MUR 149.00	15%	MUR 1788.00
MSD cards	SanDisk Ultra MicroSDHC UHS-1 32GB	15	MUR 380.00	15%	MUR 6555.00

2. Fieldwork photos

Figure 5: Stephan Mellier & Adrien Gellé deploying an AudioMoth next to a Cuckooshrike release site (Ferney CMA), photo by Sion Henshaw

Figure 6: Deployed AudioMoth with its waterproof case in Ferney CMA, photo by Sion Henshaw

Figure 7: Adrien Gellé & Stephan Mellier heading to a deployment point in Ferney CMA, photo by Sion Henshaw

3. Maps

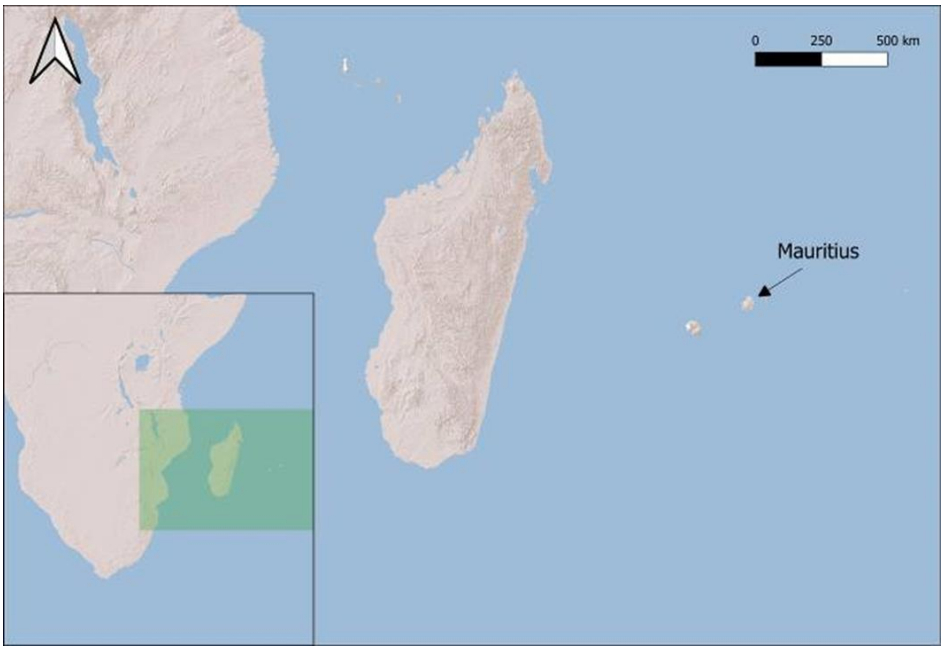


Figure 8 : The position of the island of Mauritius in the Indian Ocean, off the East Coast of Africa.

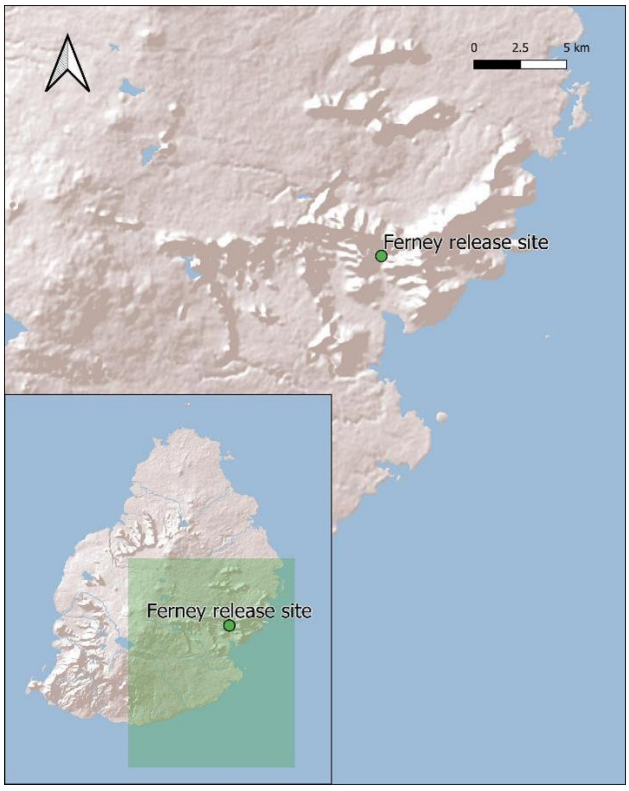


Figure 9 : The location of the Bambou Mountains in the South East of Mauritius; the main point of release for the Echo Parakeet, Pink Pigeon, Mauritius Cuckoo-shrike and Mauritius Paradise Flycatcher within the Ferney valley is marked on the map.

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