Threatened Species Recovery Hub

National Environmental Science Programme

Ecology, genetics and conservation management of the Norfolk Island morepork and green parrot

Interim report

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1. Introduction and summary

Background and aims

Norfolk Island (29.042°S, 167.952°E) is an isolated sub-tropical island group positioned ~1700 kilometres from Sydney, Australia, ~1100 km from Auckland, New Zealand, and ~875 km from New Caledonia. Norfolk Island mostly consists of an elevated plateau bound by cliffs, except for a small area of coastal flats and the two mountain peaks, Mount Pitt and Mount Bates that are 318 and 319 metres above sea level respectively (Director of National Parks 2018). The island receives an average of 1312 mm of rain per year, with an average relative humidity of 77%. Norfolk Island National Park spans two distinct areas; a 460 ha area centred on the most mountainous area of the main island, and the 190 ha Phillip Island. On the main island, the National Park supports two predominant vegetation communities: palm forest and hardwood subtropical rainforest. Palm forest occurs in high gullies and on slopes, where the community is dominated by Norfolk Palm (*Rhopalostylis baueri*) with some hardwood species present within the canopy. Hardwood subtropical forests occur on the slopes and gullies at lower altitudes within the park. This community supports Bloodwood (*Baloghia inophylla*), Ironwood (*Nestegis apetala*) and Sharkwood (Dysoxylum bijugum) which form canopies alongside emergent Norfolk Island Pines (*Araucaria heterphylla*). The remainder of the island is primarily cleared. Although some drier forests persist outside of the National Park, these are typically dominated by invasive African Olive (*Olea europaea*) and Red Guava (*Psidium guajava*).

The island has numerous threatened endemic species. Two of those species – the Norfolk Island morepork (or boobook) Ninox *novaeseelandiae undulata* and the Norfolk Island green parrot *Cyanoramphus cookii* – are the focus of this study. Both are priority species under the Threatened Species Strategy and a priority for management by Norfolk Island National Park.

Both the morepork and the green parrot have a single small population. They have experienced severe genetic bottlenecks and are subject to several common extrinsic and intrinsic threats that limit their population recovery; for the morepork there are particular concerns over rates of breeding and population replacement. To identify and implement more effective population and habitat management actions, including potential translocations, further information is urgently required on the species' populations, range movements, breeding success, habitat preferences and genetic viability.

These topics are being investigated through a collaborative research project being undertaken by Parks Australia, Monash University, the Australian National University and University of Melbourne. The results will directly inform important conservation management decisions in relation to population management and threat abatement that Parks Australia needs to make for the two species.

Summary of progress and results

Norfolk Island morepork

- Field surveys, including population monitoring, call playback surveys, nest searches, passive audio recorders, molecular sampling, banding and GPS tracking have been undertaken to inform the ecology and conservation management of the Norfolk Island morepork.
- Fieldwork was undertaken in November-December 2019, October 2020 – January 2021 and May-June 2021.
- Based on combined data from field surveys and GPS tracking, the total population of owls is estimated to be 25-35 individuals. Eight pairs of owls (ie 16 birds) have been identified across the island, with several additional pairs and unpaired individuals also likely to be present.
- There were a total of two breeding attempts during the 2019 and 2020 breeding seasons, both from the same pair. The nest in 2019 successfully fledged two chicks. The nest in 2020 failed at the egg stage. One of the female chicks from the 2019 clutch was GPS tracked in May 2021 and found to occupy the same territory as a male within the National Park.
- Molecular samples have been collected from 12 free-flying adult moreporks and two fledglings. Molecular samples have also been obtained from 69 Southern Boobook, 10 Tasmanian morepork, 2 New Zealand morepork and 1 Lord Howe morepork from the Australian National Wildlife Collection. These samples are central to the molecular study that seeks to understand the processes that have shaped contemporary genetic variability necessary for informing future conservation management.

- A total of 10 individual owls have been tracked in the period Nov 2019 to May 2021. Seven of these owls occupy territories that overlap with the National Park. Six of the 10 individuals have been tracked over two seasons providing insight into seasonal variation and stability of territories.
- Owls holding territories outside of the National Park occupy larger territories than those within the National Park. Gullies and the associated vegetation appear to be important habitat attributes for owls across the island, while owls within the National Park tend to avoid areas of woody weeds.
- Collection and analysis of regurgitated pellets demonstrated that the diet primarily consists of invertebrates. Nine out of ten moreporks sampled consumed vertebrates and four were confirmed to have consumed rodents. Pellets of moreporks within the National Park contained significantly higher prey taxa richness than those from outside the park.
- Acoustic, citizen science and call playback monitoring surveys were conducted over eight weeks during Spring 2020 and over six weeks during Autumn 2021. The results from these programs are being analysed.

Norfolk Island green parrot

- Two fieldtrips (total = 10 weeks) were undertaken in February / March and April / May, 2021, to establish an understanding of the current status and population trajectory of the green parrot population.
- 65 feather samples were collected for DNA from the forest floor, nests, adult birds and nestlings. Three eggshells and one blood sample were also collected for DNA sequencing.
- In late April 2021, 10 green parrots were caught in mist-nets. Feather samples and standard morphometric data were taken from each bird when possible.
- 158 DNA samples, including 42 from blood samples and 54 from feathers collected by previous researchers between 2013 and 2015, have been sent to Diversity Arrays Technology (DArT) for sequencing. Single nucleotide polymorphism genotype data will be used to assess genetic diversity and population structure.
- A large proportion of the green parrot population was found to be unbanded. Two surveys were undertaken to sample the percentage of birds in the population with bands, finding that less than 25% of the population is currently banded.
- The large proportion of unbanded green parrots suggests that many are nesting in natural nests unknown to park staff. This is contrary to the understanding that only parrots nesting in fortified predator-proofed nests survive predation and breed successfully. Analyses are underway to determine the proportion of the population that attempts to nest in natural hollows, and the survival and reproductive rates of those birds.
- 11 active nests were monitored using motion activated cameras. This sample included six fortified nests and five natural nests. Camera footage revealed nest success for two natural nests and one cat predation event.
- Hollow measurements and site characteristics were recorded at all 71 actively managed fortified nest boxes and six natural nest sites. This data will be analysed to determine preferred characteristics for green parrot use.
- GPS tracking of green parrots was trialed in April with a package successfully deployed on one male bird.
- Mist-netting uncovered a problem with the current banding scheme used for the green parrots, whereby birds are tampering with bands, causing possible injuries. This will necessitate a new banding method in consultation with the Australian Bird and Bat Banding Scheme.

Impact of COVID-19

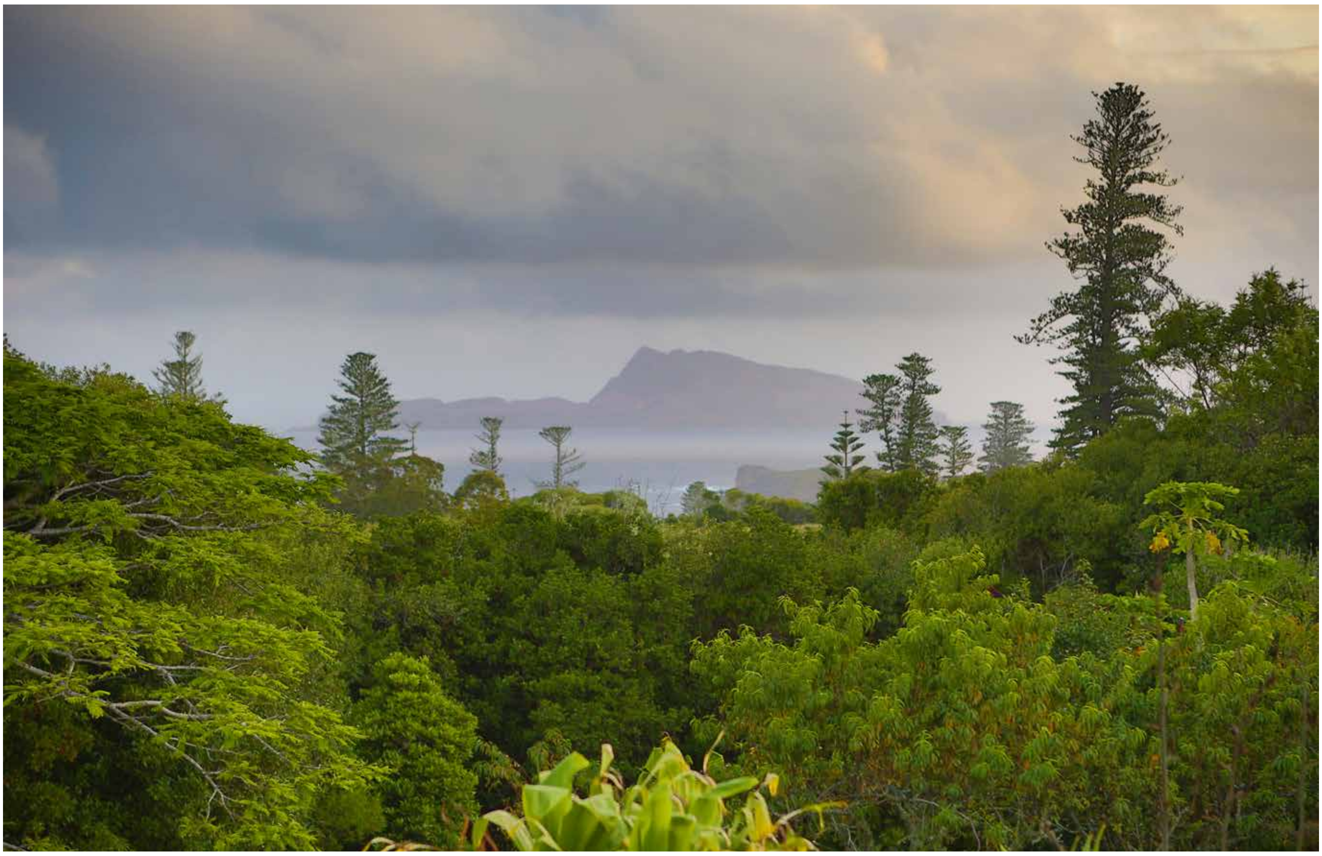
Delays caused by travel restrictions and other factors associated with COVID-19 had a significant impact on the project. As a result of travel restrictions, it was not possible to travel to Norfolk Island to collect data on the morepork in March 2020 despite considerable investment in planning for that field trip. The spring field trip for the morepork was planned for September to December 2020; however, the second COVID-19 wave centred on Victoria delayed this trip to an October arrival after two weeks of quarantine in Darwin. The planned field survey for the non-breeding season originally intended for Autumn 2020 was rescheduled; it commenced in May 2021 and is ongoing at the time of writing. Travel restrictions also prevented fieldwork on the green parrot starting until 2021. In addition, travel restrictions and closures have delayed obtaining museum specimens. The time required for processing of genetic samples by third-party laboratories was also longer than normal due to disruptions in 2020.

Nevertheless, significant progress has been made, and all elements of the research are progressing well.

The project partners will continue collaborative research on the two species over the next few years.

Acknowledgements

We are grateful to colleagues at Parks Australia and members of the Norfolk Island community for assistance and providing invaluable insights into the geography of the park and island and behaviour of the birds. ANU researchers Ross Crates, Dejan Stojanovic and Linda Neaves contributed to the development of research directions for the green parrot. Nick Bradsworth, Jolene Oliver, Amy Tipton, Jacinda Goodwin, Mark Hallam and Ron Ward helped with the field components of the NI morepork program. Thanks to Norfolk Island Regional Council, in particular Lilli King for assistance with the morepork monitoring programs and to Margaret Christian and the Flora and Fauna society for assisting with community engagement. We are grateful to Leo Joseph for facilitating collection of samples from the Australian National Wildlife Collection and for suggesting possible research directions. All research on the green parrot was conducted under ANU Animal Ethics approval A2020_13. All research on the morepork was conducted under Monash University Animal Ethics approval SBS_21670.



Norfolk Island. Image: Peter James McNally, CC BY-SA 4.0, Wikimedia Commons

2. Ecology and conservation management of the Norfolk Island morepork

Introduction

The Norfolk Island morepork, *Ninox novaeseelandiae undulata* is a small hawk owl, endemic to Norfolk Island and is listed as Endangered under the EPBC Act. The species is also listed under the Threatened Species Strategy and as a priority for management by Norfolk Island National Park. The morepork has experienced severe genetic bottlenecks and is subject to extrinsic and intrinsic threats that limit its population recovery; this includes apparent limited successful breeding between 2011 and the commencement of this project (Garnett et al. 2011, Brown et al. 2020). In order to design and employ more effective population and habitat management actions, including potential translocations, further information was urgently required on the species' population, range movements, breeding success, habitat preferences and genetic viability. These were key recommendations of an expert workshop on the NI morepork convened by Parks Australia in June 2019 (Brown et al. 2020).

Norfolk Island morepork. Image: Parks Australia

This study used telemetry to evaluate range movement as well as monitoring of banded breeding pairs and nest sites to assess breeding success. These techniques provide understanding of landscape use, diurnal roost locations, territory size, potential area of occupancy and estimation of Norfolk Island carrying capacity. The work will also inform any potential re-introductions of the species to nearby Phillip Island (also part of Norfolk Island National Park) to increase total population size. All owls captured for banding and GPS tracking purposes were also subject to molecular sampling for later genetic analysis.

The key outcomes of the project will: confirm whether and where successful breeding is occurring and identify intrinsic and extrinsic threats to breeding success. An understanding of these factors will inform the prioritisation of management interventions; identify range movements and habitat preferences for foraging, roosting and nesting to inform optimal nest placement and design, and to inform habitat restoration and pest animal control; and, obtain information necessary to support any future attempts to introduce additional individual moreporks.

Here we summarise outcomes of three field surveys (one ongoing at the time of writing) and all recent analysis, the first undertaken in November and December 2019, the second from October 2020 to January 2021 and the third in May and June 2021.

Methods

All fieldwork was conducted on Norfolk Island in November and December 2019, October 2020 to January 2021, and May and June 2021. Most fieldwork was focused on Norfolk Island National Park, however all areas of the island were also monitored during researcher-led and citizen science monitoring programs, and when owls outside of the National Park were being targeted for capture and tracking.

Capture

During the first field trip (Nov to Dec 2019) four weeks of island-wide surveys were conducted after sunset to listen for morepork calls and to determine approximate territories. Mist-nets were set up in one area per night, in locations confirmed to be near roost sites of individual moreporks. Call broadcast of New Zealand morepork, Southern Boobook and Norfolk Island morepork was used to attract the target owl. After capture, owls were immediately removed from the mist-net and a cloth bag was placed over their head to minimise any stress response. Owls were weighed and measurements of tarsus, wing, bill, head-bill, and tail length were taken with either a butt ended ruler or vernier calipers. ABBBS bands were fitted to all unbanded birds. No more than 70 uL of blood was sampled from the right brachial vein by venepuncture and collected with the aid of gravity in a capillary tube. The blood sample was immediately stored in 95% ethanol and subsequent refrigerated. Three feathers were also collected from the breast area and stored in 95% ethanol. Each individual owl was photo-documented using a digital camera with flash.

GPS tracking

Captured birds that were considered suitable for tracking (ie no evidence of active tail moult etc) were fitted with a Lotek Pinpoint VHF-75 tracker. Trackers were attached to the central two tail feathers with tesa tape. After release, morepork roosts were located using beacon signals tracked with a Yagi directional antenna and receiver unit. GPS tracking units were left on the owl for a minimum of two weeks before recapture of each individual was attempted. In instances in which a tracker was shed by the bird recapture was not attempted nor required. Habitat features at each roost site were quantified in the field.

All data was downloaded using the remote download function available with this tag type. Once data was obtained, horizontal dilution of position (HDOP) values were filtered for each data point and values above five were excluded. HDOP values were selected for data filtering consistent with minimum recommended data quality as stated in the literature. Data obtained from two owls with territories that abutted marine environments at the edge of the island were sea-masked to remove a small number of outlier data points that place the bird over the sea surface (all within ~200 m of the coastline).

Population monitoring

Researcher-led monitoring

Researcher-led monitoring occurred over six nights over a six-week period during the 2020 breeding season and a 5-week period during Autumn and Winter 2021. Surveys were conducted by Monash University researchers and trained staff from Norfolk Island National Park and Norfolk Island Regional Council. Twenty-five sites were selected at random across Norfolk Island by overlaying a 1km grid over the National Park and a 1.5km grid over the remainder of the island. A larger spacing between survey points outside of the National Park was selected because calls travel further in open areas (F. Sperring unpubl. data). Map grid locations were then inspected in the field and the most suitable site within 200 m based on the following hierarchy of criteria was then selected: 1) ease of access; 2) preference for ridge or elevated position; 3) minimal slope and 4) clear line of sight/clearing or open area. Access was prioritised to ensure monitoring locations could be accessed safely and efficiently and ridges and flat surface were prioritised next to maximise the capacity of the observer to detect calls. Surveys were conducted between 30 minutes and 4 hours after sunset and each site was monitored for 10-minutes. Upon arrival at the site, a 10 minute standard pre-recorded sequence of morepork calls was broadcast. The recording commenced with two minutes of silence followed by two minutes male morepork calls, two minutes of silence, two minutes of female morepork calls at a lower volume to that of the male calls and two further minutes of silence. Female and male calls were used to attract both sexes and the second playback was played more quietly to increase the likelihood of a response from owls that may have approached during the first call sequence, but had not responded vocally. During the last two minutes of silence, surveyors used spotlights with white light to search for owls that may have approached but otherwise gone undetected. Playback volume was broadcast at between 65 and 70 decibels at each site. No playback was used for another two minutes to listen for a response. If any owls were detected (sight or sound), the time, distance, direction and duration of the call was documented. Call playback was continued regardless of call responses to ensure that a standardised survey technique was applied at all sites.

Acoustic monitoring

AudioMoth recorders in waterproof cases and AviaNZ software were tested in a pilot study near Starlings Gap Campground, Yarra Ranges, Victoria using the Southern Boobook as a proxy. Once appropriate settings were established, AudioMoths were deployed on Norfolk Island at 15 locations in Spring and Summer 2020 and at 14 locations in Autumn and Winter 2021. Sites were established randomly by overlaying a 1.5 km grid over the island with a 1 km buffer from the coastline. Map grid locations were then inspected in the field and the most suitable site within 200 m based on the following hierarchy of criteria was then selected: 1) preference for slope position; 2) clearing or open area 3) ease of access. Four, one-hour recordings were taken each night between sunset and sunrise for the duration of the recording period. These automated recorders were maintained in the field for a period of 4-6 weeks with data being periodically downloaded and archived.

Citizen science monitoring

Citizen science monitoring occurred on eight nights over an eight-week period during the 2020 breeding season and on six nights over a six-week period during Autumn and Winter 2021. Twenty sites were established randomly by overlaying a 1.5 km grid over the island. The most suitable site within 200 m based on the following hierarchy of criteria was then selected: 1) proximity to a community volunteer's household 2) ease of access 3) clearing or open area 4) preference for ridge or elevated position. Citizen science volunteers monitored the same site for 1 hr, commencing ~30 min after sunset on a predetermined night each week. Presence or absence of owls was recorded for each 15-minute period, alongside the total number of calls, and their distance and direction.

Nest Monitoring

Two active Norfolk Island morepork nests were identified within nestboxes during the study period. For the first nest one Moultrie and one Reconyx camera were deployed facing the nest at nestbox-height from a distance of approximately 5 m. Both cameras were established for a period of 50 days between 31 October and 20 December 2019. Two Moultrie cameras were deployed at the nest that was identified in Spring 2020 for a period of 45 days between 11 November and 23 December 2020. All cameras were programmed to take three photos when heat and/or movement signatures were detected. Cameras were checked and batteries and SD cards were replaced every two or four weeks.

Diet studies

Roost sites were located using beacon signals from the GPS trackers. Pellets were difficult to obtain from the ground because they were extremely brittle (mostly exoskeletal remains of invertebrates). To overcome this, 1 m x 1 m cotton sheets were suspended ~1 m off the ground below known roost sites. The positioning of the sheet was informed by the location of existing whitewash of the roosting owl in many instances. Sheets were checked and pellets collected every 1-5 days. Collected pellets were stored individually in vials containing 70% ethanol. Faecal samples were also collected where possible.

All vials containing pellets and a small reference collection of insects were subsequently examined under laboratory conditions. Each pellet was emptied into a single-use petri dish and visual analysis of the whole sample was conducted with the aid of a dissecting microscope. Identification of prey remains relied on the reference collection and the assistance of experts from relevant taxonomic fields. The abundance of each prey was assessed by counting the minimum possible number of individuals represented by identifiable remains.

Analysis

Unless otherwise stated all data was analysed and visualised using the coding language 'R' (R Core Team 2019). Data were checked to ensure that it met the assumptions of parametric statistical tests.

Home range estimates

To calculate 50% (core area), 90% and 95% autocorrelated kernel density estimates (AKDE) of home range size for owls tracked in 2019, the CTMM package in RStudio (Version 1.2.5001) was used. Variogram fitting and maximum likelihood fitting determined that the Ornstein-Uhlenbeck (OU) movement model was the most appropriate for all owls as opposed to Individual Identity Distribution (IID) and Ornstein-Uhlenbeck F (OUF). The IID model was not appropriate as this assumes no autocorrelation. Robust satellite fixes were less likely within densely vegetated areas of an owl's home range, causing a temporal bias towards sections of the home range with a more exposed canopy. To account for this sampling bias, a weighted OU model was employed in all analyses. AKDE polygons were imported into ARCGIS (10.6.1) and seamasked to further refine home range estimates. Minimum Convex Polygons were also calculated in ArcGIS (10.6.1) for comparison with other species as this method has been commonly used in literature.

LiDAR calculations

A canopy height model for all of Norfolk Island was generated by subtracting a digital elevation model from a digital surface model (1m) sourced from CSIRO (https://doi.org/10.25919/5e4a0e4e93d4c). Values for canopy height for all GPS points obtained from tracking were generated using the "Extract Multi values to points" tool in ArcGIS.

Results and discussion

Range movement

A total of twelve adults and two morepork chicks have been captured between October 2019 and June 2021. Ten of these owls had GPS trackers attached to their central two tail feathers and six owls had trackers attached during two different seasons (two owls caught during Spring 2019 and Spring 2020 and four owls caught during one Spring and one Autumn season). All owls had their trackers attached for between 12 to 30 days. To date, seven owls were recaptured and their trackers were recovered for subsequent use. Where owls avoid recapture the trackers are lost when the tail feathers are shed. At the time of writing there were five owls fitted with active trackers. Five of the tracked owls were paired, with two of these being from the same pair. From a total of nine territories tracked (combining one pair using the same territory), all territories combined have occupied a total area of ~10km^2 on Norfolk Island, ~1/3 of the total area of available land on the island Norfolk Island (Figure 2.1).

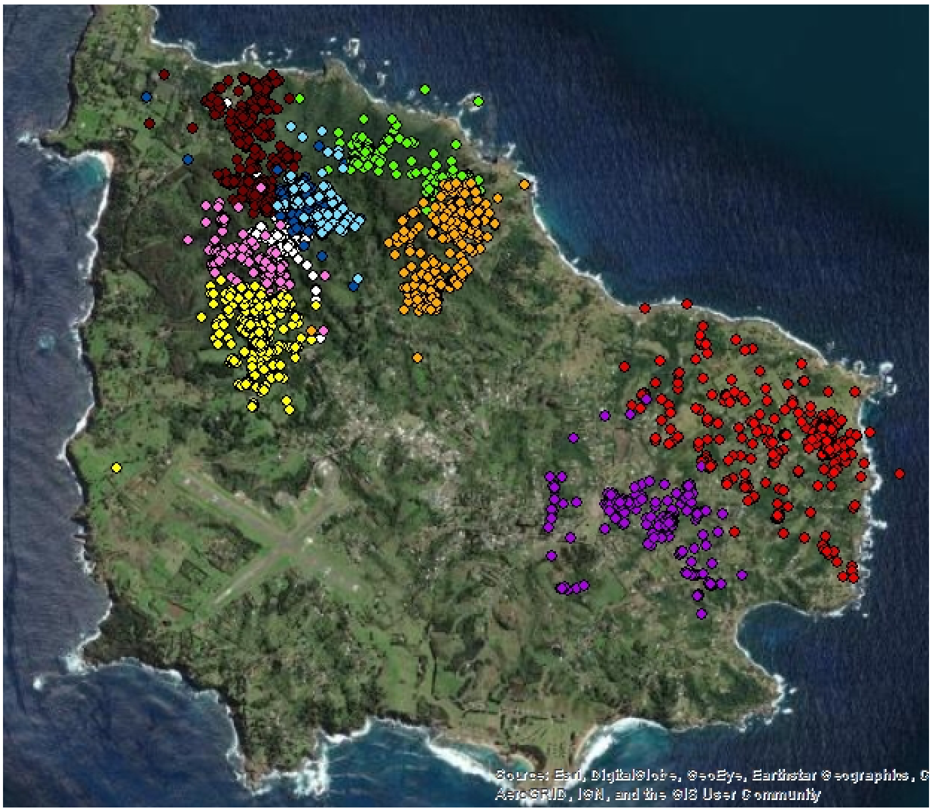


Figure 2.1. *GPS points of all owls tracked between 2019 and 2021. The most recent tracking data is shown for all repeat captures except two (red and maroon GPS points) because at the time of writing trackers have been attached for less than 1 week.*

Owls have been tracked both within the National Park and across the broader human-modified landscape. Results show that home ranges are relatively well defined, with little overlap between known territories within the National Park and no overlap between known territories outside of the National Park. The data demonstrates some variation in territory size of owls within the National Park, and that territory sizes are larger outside of the National Park. Owls also display routine activities where individuals repeatedly visit the same locations over time. Two owls that were captured in both 2019 and 2020 occupied simillar home ranges in both Spring seasons, and home ranges appear to be simillar for the owls tracked within the Spring and Autumn seasons (Figure 2.2).

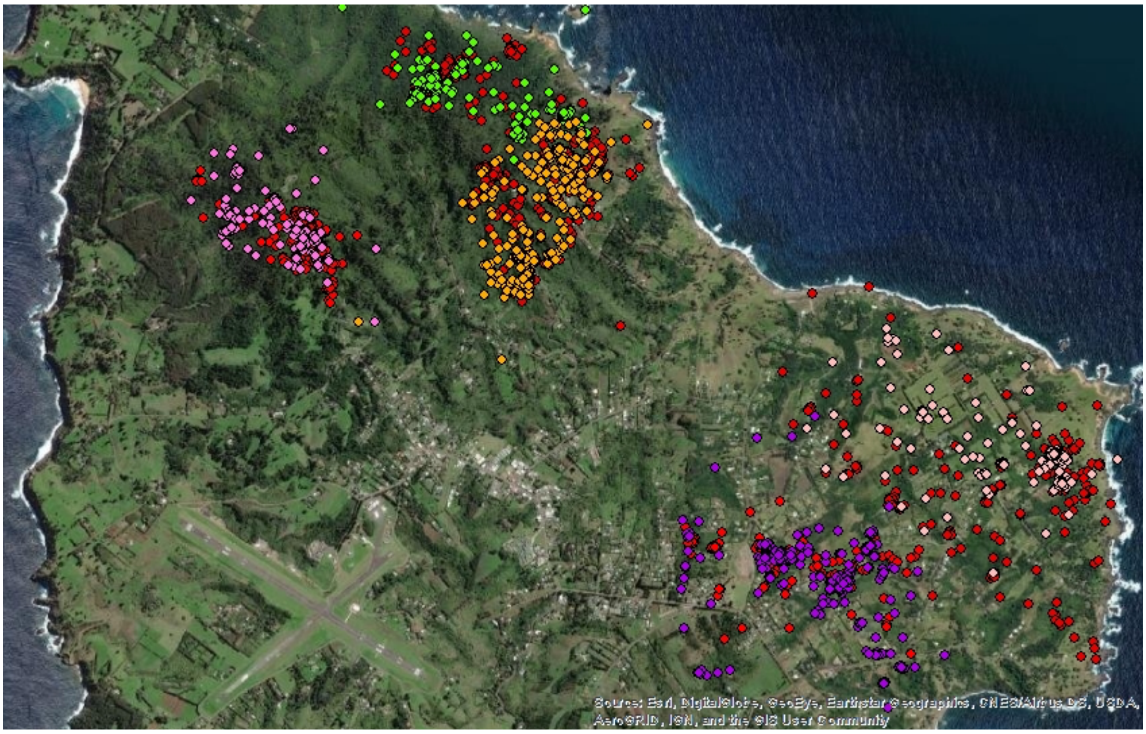


Figure 2.2. *GPS points of owls caught more than once. One recaptured owl is not included because at the time of writing it had been tracked for less than one week. Coloured GPS points represent the most recent trapping season and red GPS points represent an earlier trapping season.*

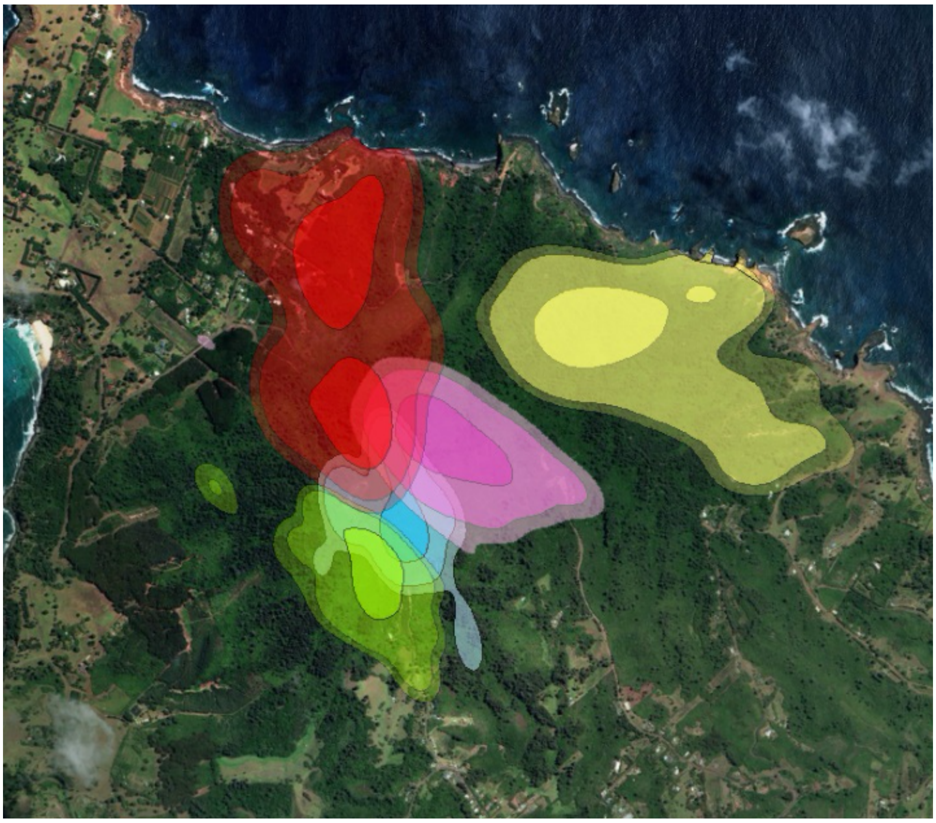


Figure 2.3. *AKDEs for the five owls tracked during 2019. The bold inner rings represent 50% AKDEs followed by the 90% ring and 95% ring.*

AKDE estimates for owls caught during Spring 2019 show a greater degree of overlap between territories than actual GPS points but no overlap between core areas (Figure 2.3). The method of calculating AKDEs and the AKDEs for all other owls will be further refiened and finalised in the coming months.

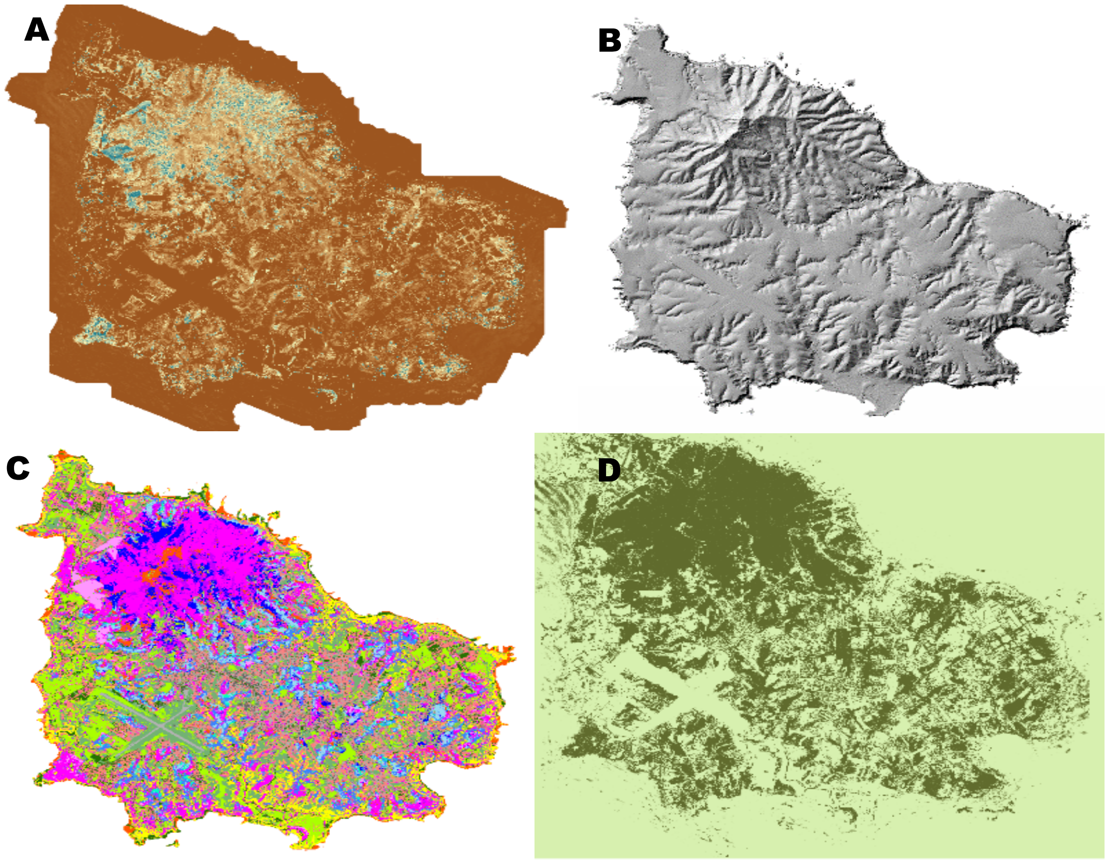


Figure 2.4. *Canopy height (A), elevation (B), vegetation class (C) and canopy cover (D) models for Norfolk Island*

Collaboration with CSIRO and the Drone Discovery Platform through Monash University has assisted in efficient analysis of vegetation and geographic data. Using aerially derived LiDAR data collected by CSIRO in September 2019, we extracted digital elevation, canopy height and canopy density models across Norfolk Island (Figure 2.4). By overlaying GPS data points and AKDEs with elevation data, it is clear that gullies play an important role for territory determination (Figure 2.5). Gully ridges appear to form a clear barrier between territories in the National Park and owls frequently roost within gullies. Vegetation class data has also revealed that owls appear to actively avoid spending time in woody-weeded vegetation, and core areas are typically associated with high quality habitat such as moist palm valleys (Figure 2.6).

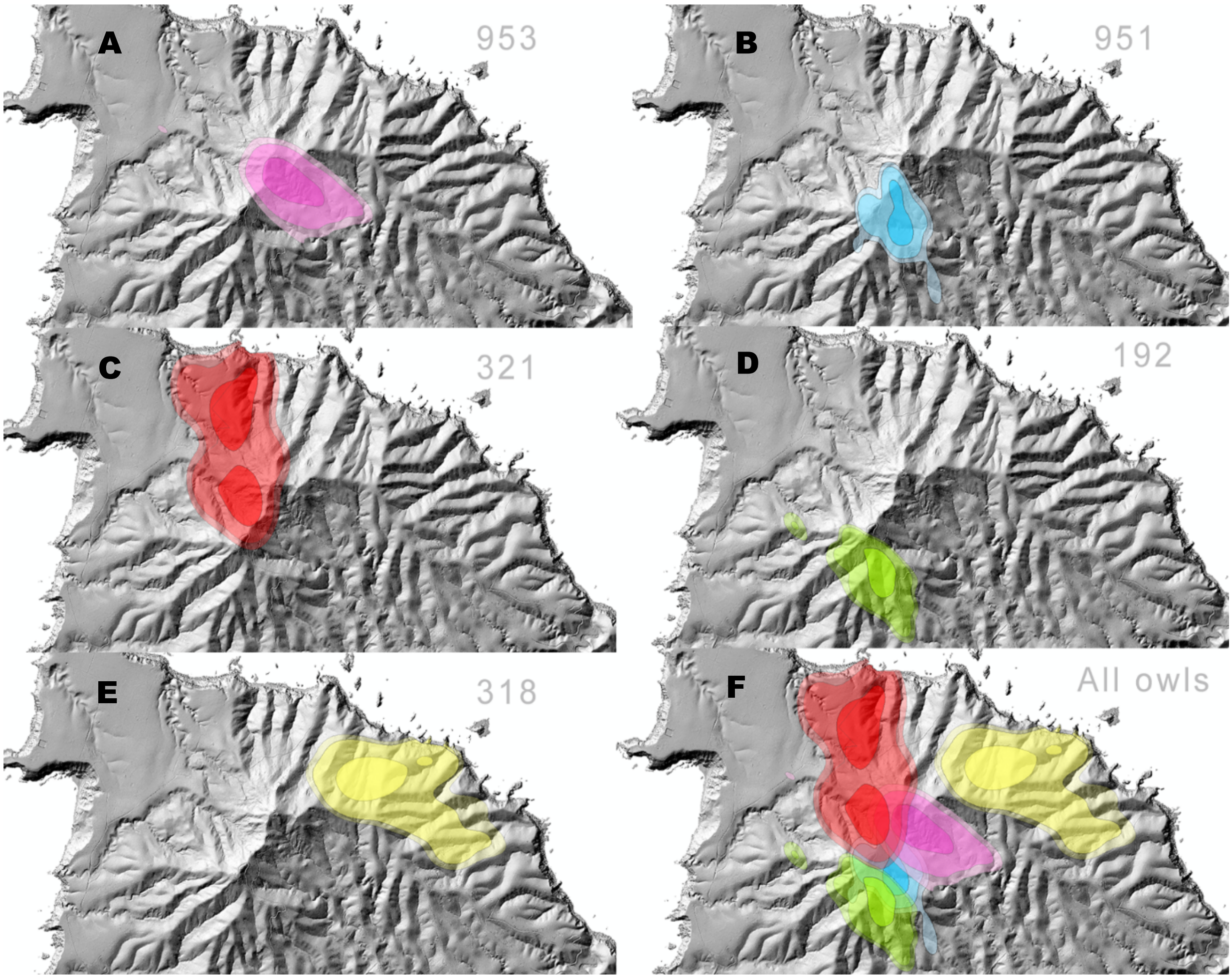


Figure 2.5. *Estimated territories for five GPS tracked Norfolk Island moreporks within and adjacent to Norfolk Island National Park in Spring 2019. 50%, 90% and 95% AKDE estimates of territory size are shown using stronger transparency for the core areas for each owl.*

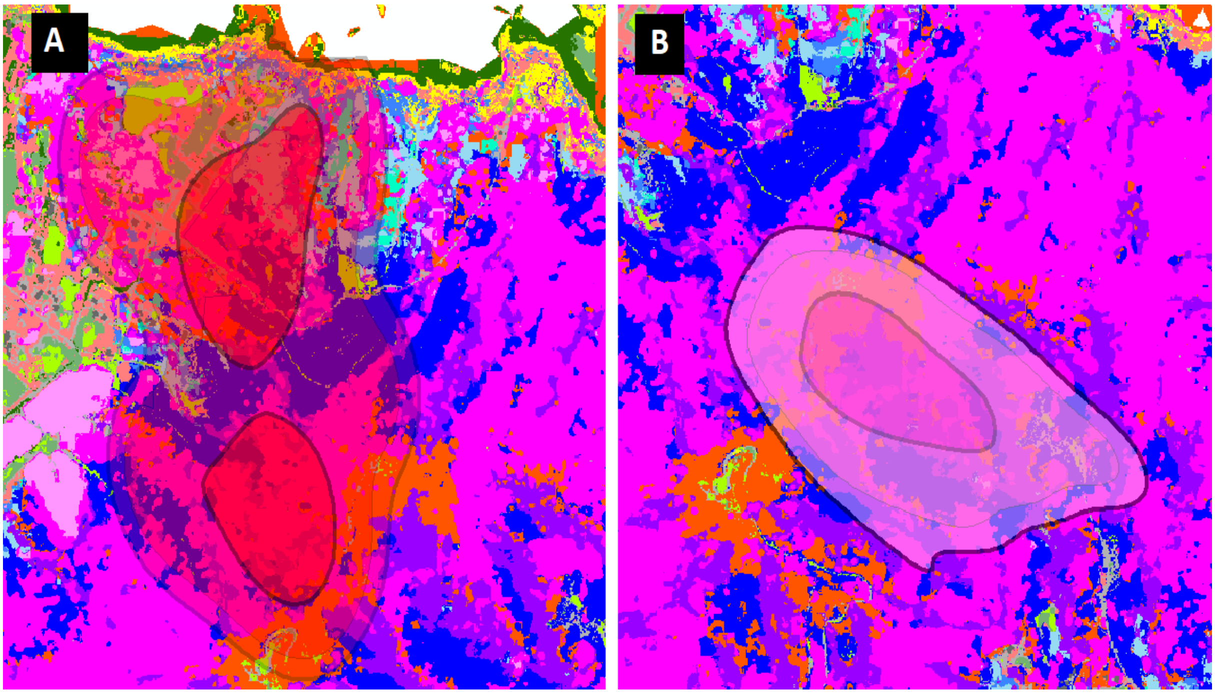


Figure 2.6. *Vegetation class data overlaid with two Norfolk Island morepork AKDEs. The owl in figure A has a core area distinctly split in two by a band representing a woody weed (either guava or olive). The owl in figure B has a core area that lies neatly over a moist palm valley.*

Breeding success

In 2019, one pair successfully fledged two chicks. Remote camera footage and thermal camera nest watches demonstrated frequent visits from the parents (one visit per 3.6 minutes $\pm$ 0.7 during one hour of monitoring). One of these chicks was suspected to have paired with an older male along Bridle Track within the National Park, as an owl was found in 2020 to be paired with a previously unpaired adult and the left leg band matches the colour of the left leg band of one of the 2019 chicks (i.e. a likely but not confirmed identification). The other chick (identified as a female from her call) was captured in May 2021 and found to be roosting with, and occupying the same territory as, a male previously tracked in 2019.

On 11 November 2020, two eggs were found in a nest box ~25m away from the nest that had been successful in 2019. Remote camera footage and thermal camera nest watches demonstrated there were infrequent nest visits each night by adult owls (just three visits during one 90-minute survey). On 18 December, the nest was checked the nest with a camera pole. The female flushed from the nest and two unhatched eggs were visible. By this date the eggs should have already hatched. On 23 December, the nest was checked again; no adult owls were present, and it was clear the nest had failed. The eggs were removed from the nest, measured and sampled for genetic analysis (Fig. 2.7). One egg had not been fertilised and the other appeared to have been fertilised but with no substantial embryo development.

Figure 2.7. *Two failed eggs from the 2020 Norfolk Island morepork breeding attempt*

An additional seven pairs of owls, excluding the successful breeding pair, have been located across the island with two of these occupying territories outside of the National Park. Behaviour associated with breeding has been detected (e.g. parent-parent provisioning, nest box occupation, preening and calling associated with breeding). However, despite intensive monitoring no breeding has been confirmed in the period November 2019 to June 2021 for any of these pairs.

Genetic structure

Based on island-wide surveys and tracking data, the current population is estimated to be between 25 and 35 individuals. Blood and feather samples have been collected from 12 adult moreporks and two chicks. Molecular samples have also been obtained from 69 southern boobooks, ten Tasmanian moreporks, two New Zealand moreporks and one Lord Howe boobook from the Australian National Wildlife Collection. Samples from the founding pair and 51 Norfolk Island morepork chicks from 1989 – 2007 previously collected by Penny Olsen have also been included. DNA has been extracted for analysis.

Other museum collections have been reviewed and target specimens and museums have been determined. These include additional New Zealand morepork, Lord Howe Island morepork, and historic Norfolk Island morepork samples from Victoria Museum, Australian Museum, Auckland Museum and the American Museum of Natural History. We intend to contact the museums at the conclusion of current fieldwork taking place on Norfolk Island.

A preliminary family tree has been constructed using banding data from 1989 – 2007 (Figure 2.8). Approximately 33% of known owls prior to 2007 (19 out of 57) were offspring from a single pair, and were 2nd generation offspring since the hybridisation. Surveys in 2019, 2020 and 2021 detected just two previously banded birds of the 12 captured (one banded in 2003, the other in 2006), suggesting undetected breeding at some point in time. Genetic analysis of molecular data from the current and historic population will help to refine the family tree and add further detail about where the unbanded owls fit within the population.

Analysis of diet

Regurgitated pellets (2019: n = 22, 2020: n=89, 2021: n = 7) and scats were collected from 13 moreporks (including pair members of captured owls) by establishing a sheet below roosting locations. Pellets from the 2020 field season (ten moreporks sampled) were examined under a microscope and it was demonstrated that the Norfolk Island morepork is a generalist invertebrate and small vertebrate predator. NI moreporks primarily consumed invertebrates (most commonly orthopterans in 84.27% of pellets and coleopterans in 61.8% of pellets). Cerambycidae (longhorn beetles) and Scarabaeidae (scarab beetles) were the most common Coleopterans identified. More vertebrates were consumed than expected, with evidence that nine out of ten moreporks had consumed vertebrates during the monitoring period. Four of these owls were confirmed to have consumed rodents, while the vertebrate bones obtained from the pellets orginating from two additional owls have not been identified.

Individual pellets of moreporks within the National Park contained significantly higher unique prey taxa than moreporks outside of the National Park (National Park: $\bar{x}$=3.23 ± 0.17 SE, non-National Park $\bar{x}$=2.43 ± 0.21 SE) (t(46.9)=-2.9, p=0.005). These results suggest a greater diversity of diet per night for owls inside the National Park. Orthoptera were present in more pellets of owls inside the National Park (75% of pellets) than pellets of owls outside of the National Park (33%) (t(53.52)=-4, p<0.01) and passerine remains were found in owl pellets only within the National Park. These results are likely to reflect the availability of these prey types outside of the National Park. Nestbox contents from the successful breeding pair in 2019 confirmed consumption of orthopterans, coleopterans, rodent, white tern, Norfolk Island robin (*Petroica multicolour*) and slender-billed white-eye (*Zosterops tenuirostris*).

The application of eDNA analysis for detecting rodents in the pellets and scats is being investigated. Further analysis will attempt to confirm unknown vertebrate remains and compare the use of eDNA to microscopic analysis of pellets.

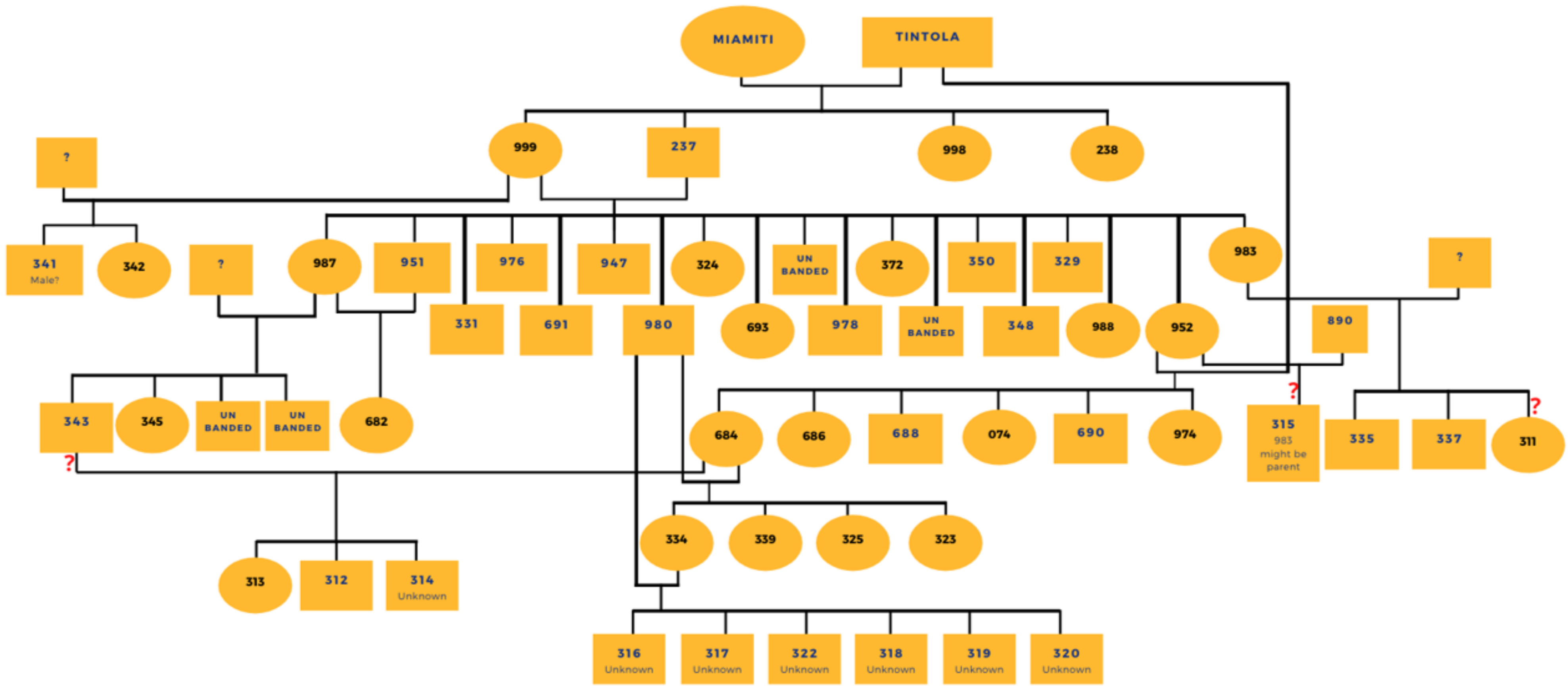


Figure 2.8. *Family tree using banded Norfolk Island morepork (and NZ morepork) information from 1989 to 2007. Females are represented by round tiles and males are represented by square tiles. Individuals of unknown sex are labelled as such. Unconfirmed relations and individuals are identified with "?".*

Population monitoring

During the 2020 Spring and 2021 Autumn field seasons, three population monitoring programs were trialled. hese include citizen science, acoustic and call-playback surveys. Data from these surveys will be used to inform the development of a long-term monitoring program that seeks to provide robust and achievable measures of population trends into the future. The monitoring program will consist of either one or a combination of these techniques.

Citizen science

An eight-week citizen science program ran from 29 October to 17 December 2020 and a six-week program will run from 13 May to 17 June 2021. Over the course of the survey period a total of 50 volunteers listened for owls at their designated site for one hour. Volunteers were actively engaged and reliably monitored their sites each week. The program was successful in engaging the community and required minimal coordination effort. The program was more difficult to run during the autumn season due to cancellations or reduced detectability of owls from weather conditions.

Acoustic monitoring

Acoustic recording devices (Audiomoths) were established at 15 locations across the island between 24 October 2020 and 14 January 2021 and 14 locations will be monitored between 9 May and 13 June. Analysis of this data using AviaNZ software to detect the presence of morepork calls is underway.

Researcher-led monitoring

Twenty-five sites were monitored once per week for six weeks by Monash University, Norfolk Island National Park and Norfolk Island Regional Council staff from October to December 2020. The same sites were monitored over five weeks from 11 May to 8 June 2021. Comparison of the survey effort required to achieve the same level of confidence for each monitoring technique is underway.

Additional results

On 12 May 2021, an injured owl was reported on a community member's property. Upon inspection the owl was found to be largely immobile and unable to stand upright. It was subsequently taken to the vet where vitamin K and antibiotics were administered. The owl was taken into care where it was kept warm and fed with diced beef. After four days the owl was taken to the Norfolk Island National Park aviary and was able to perch and fly well. Morphometric measurements and feather samples were collected, and the owl was banded with an ABBBS band on the right leg. The owl was then released into the forestry area at the end of Greg Quintal Drive on 16 May 2021. The owl was suspected to be poisoned by a second-generation rat bait or alpha-chloralose used to sedate feral chickens on the island. Scat samples were taken for analysis to investigate the type of poisoning.

Measures of body mass were obtained and are reported here for eleven owls across the three field seasons (excluding the rehabilitated owl) (Tables 2.1 and 2.2). Head and bill, bill, wing, and tail measurements were obtained for twelve owls including the rehabilitated owl (Table 2.3). A summary of morphometrics by sex will be possible once the sex of each individual is determined using molecular techniques.

Table 2.1. *Mass (g) of Norfolk Island moreporks captured during two different field seasons. NI morepork ID refers to the last 3 digits of the ABBBS band.*

Morepork ID	Year	Mass (g)
321	2019	150
321	2021	160
318	2019	165
318	2020	160
952	2019	165
952	2020	190
954	2020	155
954	2021	165
961	2020	155
961	2021	165

Table 2.2. Average mass ± SE of Norfolk Island moreporks captured during field seasons from 2019 to 2021

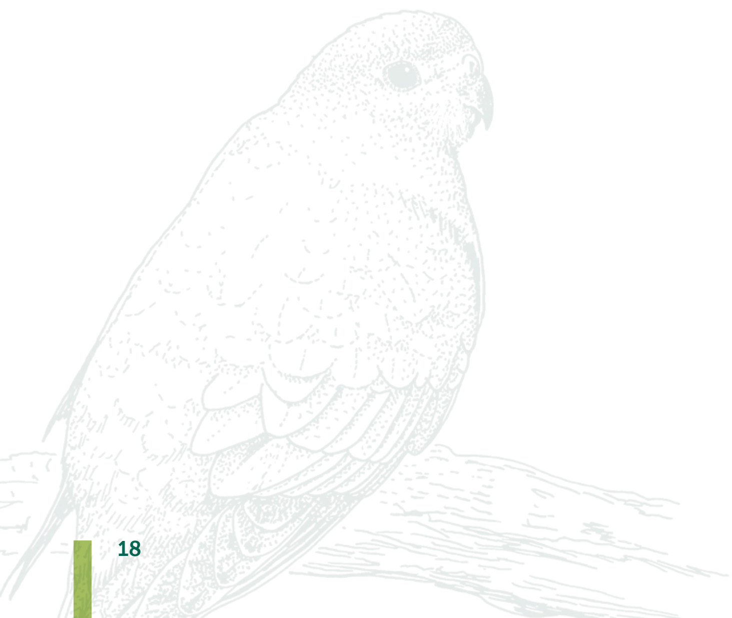
Year	Average Mass (g) ± SE
Spring 2019	153 ± 9
Spring 2020	167 ± 5
Autumn 2021	163 ± 1

Table 2.3. Head-bill, bill, wing and tail length measurements for all Norfolk Island moreporks captured between 2019 and 2021. NI morepork ID refers to the last 3 digits of the ABBBS band.

Morepork ID	Head-Bill length (mm)	Bill Length (mm)	Wing Length (mm)	Tail Length (mm)
321	53.0	14.9	186.3	123.0
318	47.6	15.1	189.3	129.7
953	48.7	14.9	189.7	121.7
952	52.3	16.2	190.0	122.7
951	51.4	16.8	195.0	129.3
311	49.1	16.6	195.0	130.7
954	48.7	14.8	199.0	122.3
961	50.3	15.7	193.0	129.3
960	52.1	15.6	205.0	142.0
962	52.0	16.5	200.7	130.3
959	49.9	14.4	186.0	140.0
955	49.6	16.3	183.5	129.5

Community consultation and outreach

Discussions were held with 70 households about the frequency and location of owl calls heard from individual properties. During these discussions, the current state of the morepork population and the work being undertaken to conserve the population was also routinely addressed. Four presentations have been delivered to the community with assistance from the Norfolk Island Flora and Fauna Society: one during each field season and two during the 2020 field season. The regular monthly Flora and Fauna Society meetings were also attended to enhance engagement opportunities with the community throughout the field season. Two presentations were also given to students from years 3 to 6 on the Norfolk Island morepork and the research being undertaken. One radio interview each season was also presented.



3. Breeding biology & population dynamics of the Norfolk Island green parrot

Introduction

The Tasman Parakeet or Norfolk Island green parrot (*Cyanoramphus cookii*) was once widespread across the Norfolk Island group but is currently confined mainly to the 460 hectare rainforest remnants of the Mt Pitt section of Norfolk Island National Park. *C. cookii* is listed as Endangered under the Environment Protection and Biodiversity Conservation Act 1999. Surveys conducted in 2013 indicated a dramatic decline in the population over the previous three years, with an estimated population of between 46 and 92 individuals remaining. The population increased again after 2013, after intensive management actions, to an estimated 350 individuals in 2017. The critical actions undertaken included improved control of exotic predators (rodents, cats) and competitors (mainly Crimson Rosellas, *Platycercus elegans*), and the provision and maintenance of predator-safe nesting sites. Management actions covering the short, medium and long-term were outlined in the *Norfolk Island Green Parrot Action Plan* developed in 2013. These aim to 1. increase the size and distribution of *C. cookii* on Norfolk Island and 2. enable establishment of a self-sustaining second population on nearby Phillip Island.

The above aims require further information on the drivers of population growth and decline, especially rates of mortality, breeding success, population genetic processes and habitat preferences. This field and lab based study of green parrots investigates breeding success and mortality rates at natural nests and artificial nests provided by managers, population genetics via DNA samples taken from captured birds and from shed feathers, and methods for population censusing and GPS tracking of individuals. The results of the project will provide the basis for optimal management of the green parrot population on Norfolk Island, and tools for planning translocations to other islands.

Research Directions and Progress

Overview of timeline

This part of the project was delayed approximately one year due to travel restrictions during the lockdown periods of COVID-19. Progress during 2020 included obtaining research permits and an ethics permit from ANU, recruiting a PhD student (D. Gautschi), obtaining and extracting DNA from 96 historical blood and feather samples, planning sessions with Parks Australia staff and other researchers from ANU, Monash and Massey Universities, and purchasing equipment. ANU travel restrictions were lifted in January 2021 and the field study was commenced in February 2021.

DNA collection and analysis

A major aim of this study is to use population genetics to determine the structure, viability, and population processes of the green parrot population. To this end DNA samples are being collected to answer several genetic-based research questions. In 2021, 65 feather samples, three egg membranes and one blood sample were collected and added to an existing sample of 54 feathers and 42 blood samples collected by previous researchers and Parks Australia staff. DNA is being sourced directly from adult birds and nestlings and indirectly from used nest sites and the forest floor. 158 DNA samples in total have been extracted and sent to Diversity Arrays Technology (DArT) for sequencing. We have also sourced 14 samples from Australian museum collections to allow comparisons of genetic diversity across approximately 30 years.

Using single nucleotide polymorphism genotype data, we are conducting a comprehensive genetic assessment of the only population of green parrots. We will 1) assess genetic diversity within the population, 2) quantify the effective population size ($\hat{N}_e$), 3) establish whether breeding is random and equal across the population or dominated by particular matrilines, 4) determine patterns of movement and dispersal within the population, and 5) identify individual level behavioural patterns including the mating system, nest site fidelity and whether families cluster together spatially. Individuals will be sexed molecularly allowing measures of the population sex ratio, and pairwise genetic distances will be calculated. We hope to gain genetic samples from most of the population so that we can track individuals and genotypes over time to build a thorough population picture. This information will help to determine population health and identify whether there are issues such as inbreeding requiring management. It will also inform the feasibility of translocation of individuals to other islands including providing information about the optimal representation of genotypes for founding new populations. We expect the results to reveal a small effective population size and vulnerability to genetic stochasticity, and to highlight the need to increase the population size to its highest possible levels to maximise retention of all genotypes.

Surveys for banded and unbanded green parrots

During the February / March 2021 field trip a prevalence of unbanded green parrots was detected. As almost all chicks from fortified nests are banded prior to fledging, high numbers of unbanded birds suggest the birds are successfully nesting in natural nest sites. This is contrary to the prevailing belief that eggs, chicks and nesting adult green parrots can survive only in the fortified predator proof nests provided and maintained by Parks Australia, and if confirmed has major implications for managing the population. A park-wide survey was conducted to establish the proportion of banded birds in the current population. Individuals were only included in the analysis if their tarsi were visible through binoculars. The first survey found that only 10.3% of birds were banded in a sample of 29 birds. The survey was repeated in May, finding that 23.1% of birds were banded from a sample of 39 birds (Table 3.1). These findings have highlighted the probable importance of natural nest sites to the population. The survey results combined with historical banding data will be used to establish, via population modelling, the likely number of natural nests being used each year and the survival of the green parrots that use them.

These surveys were also used to identify any bands applied in previous years that may be problematic for the birds (see below).

Table 3.1. *Results from surveys of banded birds in the National Park*

Survey	Time	Distance Covered	Birds Seen	Tarsus Visible	Banded	Unbanded	% of sample banded
March 2021	12.25 hrs	34km	46	29	3	26	10.3%
May 2021	11.5 hrs	30km	63	39	9	30	23.1%

Search for natural nests and nest monitoring

The results from our banding surveys suggest that there may be substantial numbers of breeding attempts in natural nests where females and nestlings survive predation. It was previously believed that predation from rats is too high for this to happen. Through ongoing passive and active searching, six natural nest sites have been discovered. Eleven active nest sites have been monitored with motion activated cameras since late February 2021. This includes six fortified nest sites and five natural nest sites. Regular nest monitoring is ongoing and will be used to determine breeding success rates, the sex-ratio of chicks, order of hatching, parental provisioning behaviour and causes of nest failure.

To date, fledging has been observed at two natural nests. Multiple visitations by rats have also been observed without a predatory event and one cat predation event was captured on camera (see Figures 3.1, 3.2 and 3.3). Nest monitoring will continue throughout the project duration to achieve a sufficient sample size for analysis. This information will prove crucial for understanding population structure and processes both from an ecological and management point of view.

Figure 3.1. *Green Parrot chick fledging from a natural nest site*

Figure 3.2. *Rat visiting a natural nest site*

Figure 3.3. *Cat predation of a well-developed fledgling taken from inside a natural nest*

Fortified nest study

Seventy-one fortified nests are currently maintained by Parks Australia. Despite all nests being maintained for at least five years, roughly half have never been used by green parrots. Approximately half of the nesting hollows have also been used by crimson rosellas, a competitor species considered to be a threat to green parrots. Interestingly, birds have been observed nesting in apparently less suitable hollows, such as the nest pictured in Figures 3.1 and 3.2, despite fortified nest hollows being available within 200m. Measurements and site level characteristics were recorded for all 71 nest sites in May 2021. This data will be combined with nesting data compiled by Parks Australia staff since 2013 to model the preferred hollow dimensions and site characteristics for green parrot and crimson rosella nesting. Initial analysis of this data has shed light on the breeding seasonality of both green parrots and crimson rosellas over the last 7 years (Figure 3.4) and the distribution of green parrot nesting attempts between fortified nests (Figure 3.5). Analysis is expected to be complete by June 30, 2021. The aim of this analysis is to establish a better understanding of hollow choice among both species and inform the management of current nest sites and ideal attributes of nests constructed or fortified in the future.

Table 3.2 shows all site characteristics and hollow measurements that will be used in the analysis. For continuous variables mean, minimum and maximum values are provided. Categorical variables collected are denoted by a '✓'. Additional variables will be included in the model for each nesting attempt, such as the year, month and concurrent activity in nearby nests.

Table 3.2. Covariates collected for fortified nest study.

Measurement / Characteristic	Mean	Minimum	Maximum
Building Material / Tree Species	✓	✓	✓
Height of Stump / Tree	5.25m	1.25m	16m
Slope Gradient	✓	✓	✓
Slope Aspect (N, S, E, W)	✓	✓	✓
Hollow Aspect (N, S, E, W)	✓	✓	✓
Canopy Height	27.7m	10m	40m
Canopy Cover (%)	Still to be calculated from photos		
DBH (Diameter at Breast Height)	36.77cm	20.37cm	95.49cm
Number of Pine Stems (>10cm Diameter)	6	0	20
Number of Palms (Single stem at breast)	6	0	34
Number of Olive Stems (>10cm Diameter)	1	0	14
Number of Guava Stems (>5cm Diameter)	9	0	73
Number of Hardwood Stems (>10cm Diameter)	8	0	23
Number of Ferns (Single stem at breast)	1	0	10
Number of Cordyline Stems (>5cm Diameter)	1	0	4
Entrance Height	132cm	74cm	320cm
Chamber Depth	97cm	47cm	182cm
Floor Diameter	34cm	18cm	71cm
Entrance Minimum	7cm	5cm	12cm
Entrance Maximum	18cm	12cm	46cm
Height Above Entrance	44cm	0cm	150cm
Inner entrance to back wall	26cm	10cm	60cm
Width of wall at entrance	5cm	1cm	14cm
Width of wall at trapdoor	5cm	3cm	24cm
Metal sheeting around entrance (yes / no)	✓	✓	✓
Vertically connected to other trees / shrubs (yes / no)	✓	✓	✓
Horizontally connected to other trees / shrubs (yes / no)	✓	✓	✓
Distance to other nests (m)	✓	✓	✓
Distance to edge (m)	✓	✓	✓
GPS Coordinates	✓	✓	✓

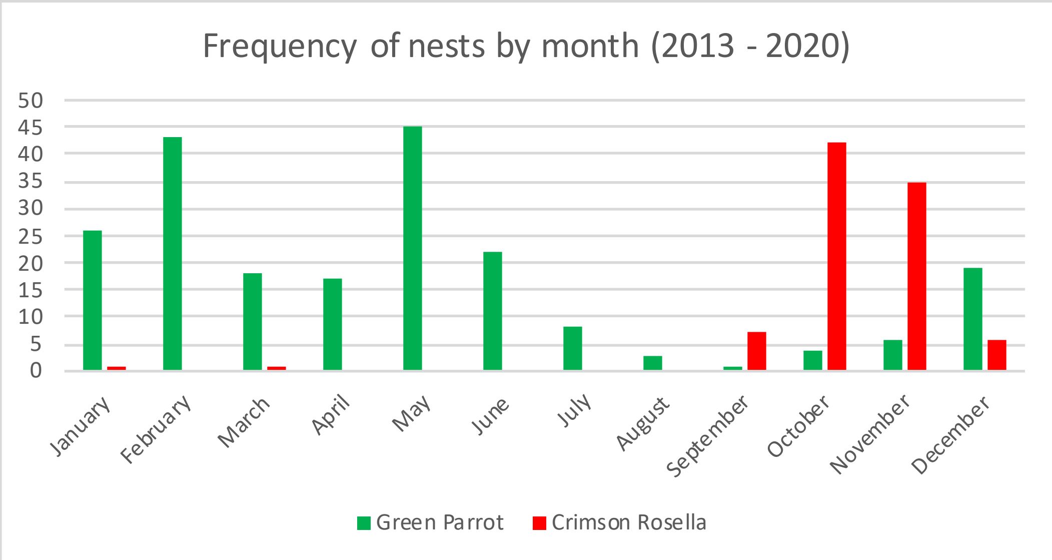


Figure 3.4. *Seasonality of green parrot and crimson rosella nesting. Includes all nesting attempts in fortified nests between 2013 and 2020.*

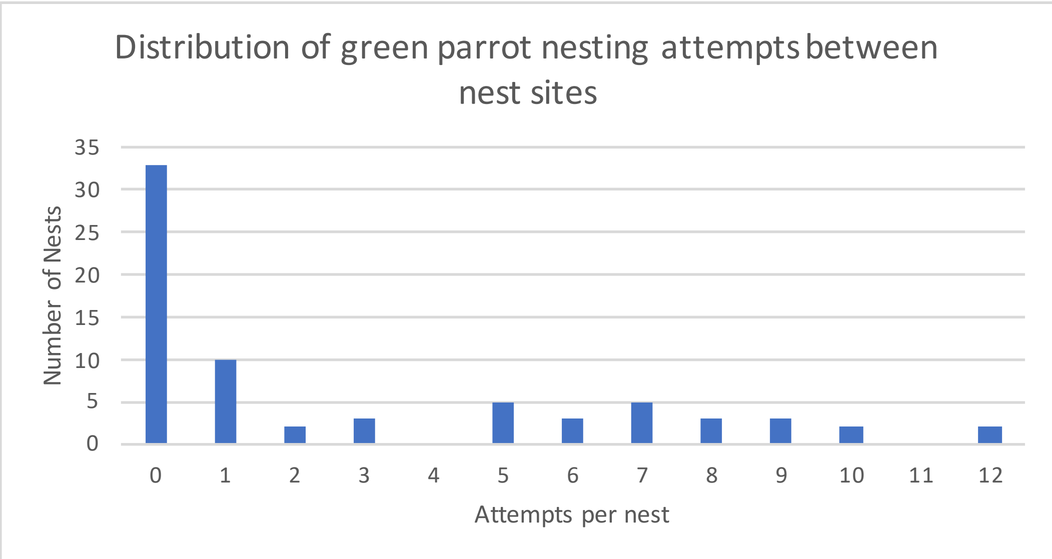


Figure 3.5: *Distribution of green parrot nesting attempts (n = 195) between fortified nesting sites (n = 71)*

Population census

The most appropriate method of censusing the green parrot population is being re-evaluated due to inadequacies of current methods. Traditional methods for counting animals such as distance sampling are difficult for green parrots due to their small range, flock sizes that are variable and difficult to count, and high mobility. Current estimates using these techniques have statistical errors that are too large to be useful in establishing long term population trends. Methods for improving distance sampling are being trialled.

Capture rates from mist-netting appear to be high enough to attempt Capture-Mark-Recapture methods for censusing the population using each individual's unique leg bands or genetic profile. The efficacy of using genetic profiles to develop a method for estimating population size will be explored when genetic data become available.

GPS tracking

A trial was successfully conducted for use of a VHF tracker / GPS logger system to track the movements of individual green parrots. The GPS logger was a Gipsy-5 by TechnoSmArt Europe and the VHF tracker was an A2445 by Advanced Telemetry Systems. The logger was attached to feathers on the upper back using marine-grade tape. The estimated tag mass was 4.7% of the animal's body mass (within the nominal 5% limit often cited for birds) and the parrot flew away successfully. As part of the planned procedure the bird was tracked the following morning using VHF telemetry. The bird was found to have issues with its Australian Bird and Bat Banding Scheme (ABBBS) band fitted less than 24 hours prior so was recaptured and its GPS logger was removed to avoid any welfare issues. Despite this, the GPS tracking trial can be seen as a success as the retrieval of the logger and data obtained confirmed the efficacy of both the GPS and VHF components. The bird also flew away strongly with the logger attached and there was no evidence of attempted removal. Attachment of further tracking units is planned for later in 2021 once the welfare concerns surrounding banding have been addressed.

Mist-netting and bird banding

In April 2021, 10 green parrots were captured in mist-nets with the purpose of taking DNA samples, standard morphometric measurements, and banding birds with both coloured and ABBBS bands. Several birds had bands from previous years that showed signs of wear to the extent they may be dangerous for the birds. We have detected, using binoculars, several other birds with problematic bands. Of the 23 banded birds seen in surveys, and observed opportunistically, approximately 52% had problematic or potentially problematic bands. We removed bands from four birds and suspended further banding operations until new methods can be determined in consultation with the ABBBS. Morphometric measurements were taken from all captured birds.

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Further information:

http://www.nespthreatenedspecies.edu.au

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Threatened Species Recovery Hub

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