# Flesh-footed shearwater population monitoring and estimates: 2018/19 season

WMIL Wildlife Management International

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# Executive Summary

This report covers the population monitoring of flesh-footed shearwaters (*Puffinus carneipes*) on Ohinau and Lady Alice Islands carried out under Conservation Services Programme project POP2018-04. It also covers two flesh-footed shearwater population estimates: Lady Alice Island and Motumahanga Island.

During the 2018/19 season we monitored 247 and 264 study burrows on Ohinau and Lady Alice Island respectively. The breeding success on Ohinau Island was 62%, down from 68% in the previous season. Breeding success on Lady Alice Island remained consistently low at 52%. There was no significant difference in breeding success between the two islands. Burrowscope (control) burrows, had a higher measured breeding success on both islands, however, the difference was again not statistically significant. We were able to identify both partners in 81% of burrows on Ohinau Island and 95% of burrows on Lady Alice Island. An additional 868 flesh-footed shearwaters were banded over both islands this season, including 453 chicks banded on Ohinau Island alone.

Burrow transects were carried out on Lady Alice Island to gather data for an updated population estimate for the island. 371 transects, each covering 40m², were completed within nine different colonies on the island. Occupancy rates varied greatly between colonies with the majority of flesh-footed shearwaters occupying burrows in colonies on the northern side of the island. Colonies to the east, west and south were either mixed-species colonies, or primarily grey-faced petrel colonies. We estimate that there are a total of 3217 occupied burrows (2180 – 4255, 95% CI) on Lady Alice Island.

A complete survey of burrows on Motumahanga Island revealed a total of 562 burrows occupied by flesh-footed shearwaters. This represents a significant increase from the 1989/90 estimate of just 100 burrows.

# 1. Introduction

Flesh-footed shearwater populations are thought to be in decline both in New Zealand and globally (Waugh *et al.* 2013; Lavers 2015). Under the New Zealand threat classification system, the decline of flesh-footed shearwaters has been recognised, and as such the species is now ranked as "Nationally Vulnerable" (Robertson *et al.* 2017). This decline has been attributed primarily to bycatch in commercial fisheries and recreational fisheries. Flesh-footed shearwaters are reported to be one of the most commonly caught species in New Zealand long-line fishing, and are prone to being caught in trawl fisheries (Abraham & Thompson 2011). It is estimated that between 1,079 and 1,769 flesh-footed shearwaters are killed annually in commercial fisheries (Richard *et al.* 2011). Looking at the causes of seabird mortality in the Bay of Plenty, Tennyson *et al.* (2012) found that all fifteen necropsied flesh-footed shearwaters had been killed in fishing-related activities. Most of these deaths were attributed to physical trauma such as broken wings, crushed skulls and stab wounds, while two of the birds contained hooks used in recreational fishing.

While the population of flesh-footed shearwaters on Lord Howe Island in Australia has been relatively well studied (Reid 2010), long-term studies measuring demographic parameters for New Zealand populations of this species are lacking. Long-term studies help to gain a better understanding of demographic parameters such as adult survival, age at first return, age at first breeding and recruitment. This will consequently help provide more accurate population trends, and thus aid in future management decisions for the species.

The possible decline of flesh-footed shearwaters coupled with a general lack of demographic parameter measurements, particularly in New Zealand, has warranted the establishment of a long-term population monitoring study. In addition to this, the need to update old population estimates, or survey islands for which robust estimates do not exist, is fundamental to the conservation management of the species. Two islands in northern New Zealand - Lady Alice Island and Ohinau Island - were both identified by Waugh *et al.* (2014) as suitable sites for such long-term studies due to being relatively easy to access and having large colony sizes. Both of these colonies have now been monitored intensively by Wildlife Management International (WMIL) staff for three consecutive seasons from 2016/17 – 2018/19, and this report focuses on the most recent 2018/19 season. Additionally, we have updated the population estimates for Lady Alice Island and Motumahanga Island, and also report on those here.

## 1.1 Key Objective and Outputs

This research was carried out as part of the Conservation Services Programme (CSP), flesh-footed shearwater research project (POP2018-04). The key objectives we were funded by Department of Conservation to complete were (bold text indicates objectives that have been completed or partially completed):

1. **To estimate the current population size of flesh-footed shearwaters at Motumahanga Island, Taranaki.**
2. **To obtain updated estimates of the population size of flesh-footed shearwaters nesting at the Chicken Islands (Lady Alice, Whatupuke and Coppermine Islands)**
3. **To estimate key demographic parameters of flesh-footed shearwater at Lady Alice Island/Mauimua and Ohinau Island.**
4. To carry out simultaneous tracking of flesh-footed shearwaters at Lady Alice (Hauraki Gulf) and Ohinau Islands (Bay of Plenty) in one breeding season during the incubation and early chick rearing period.
5. To describe the breeding phenology, particularly egg-laying dates at two breeding sites (Lady Alice and Ohinau Islands) to assess if inter-annual and site variation exists.

Objective 1 was completed in full. Objective 2 was partially completed with the Lady Alice Island population estimate completed this season. Objective 3 was completed but is an ongoing objective, so will be continually reported on each season. To achieve objective 3, the main outputs for the 2018/19 season were:

- Establish and identify the partners in up to 200 study burrows on each island.
- Determine the sex of birds in study burrows by cloacal examination where possible, and by DNA sexing of feathers where not possible.
- Determine the breeding success of pairs in all study burrows, and where possible record cause of burrow failure.
- Monitor ≥ 30 burrows using a non-invasive burrowscope on both islands to determine the effect, if any, of handler disturbance on breeding success.
- Band adults on the surface at night to increase the banded population of flesh-footed shearwaters.
- Band all chicks in study burrows prior to fledging.
- Band as many chicks as practical on the surface prior to fledging to increase the number of banded chicks each season.
- Record details of any recaptured banded birds.

# 2. Methods

## 2.1 Study Sites and Dates

During the 2018/19 season work was undertaken on three islands: Ohinau Island (demographic work); Lady Alice Island (demographic work and population estimate); and Motumahanga Island (population estimate).


**Figure 1.** Locations of Ohinau, Lady Alice and Motumahanga Islands.

### 2.1.1 Ohinau Island

Ohinau Island (Mercury Islands Group, 36.73°S, 175.88°E) is a 43ha island located off the east coast of Coromandel Peninsula. The island is owned by local iwi, Ngati Hei, and co-managed with the Department of Conservation. There are 12 flesh-footed shearwater colonies on Ohinau Island, of which five contain study burrows (Camp, Camp South, South of Gully, Hilltop and Pohutukawa; Figure 2). These study burrows have been monitored intensively since 2016 (Mischler 2016; Crowe *et al.* 2017; Crowe 2018a). There are an estimated total of 4,007 occupied burrows on the island (Crowe 2018a). A team of two personnel was based on the island during the following dates:

- **Trip 1:** 3 December 2018 – 21 December 2018; checking all study burrows to determine breeding status, identify adult birds breeding in all burrows and band/recapture adult birds seen on the surface at night.
- **Trip 2:** 1 May 2019 – 11 May 2019; checking all study burrows to determine breeding success, band all chicks in burrows, band chicks captured on surface at night time and deploy GPS tags on 10 chicks prior to fledging to determine migration routes. The results of this tracking are presented in a separate report.

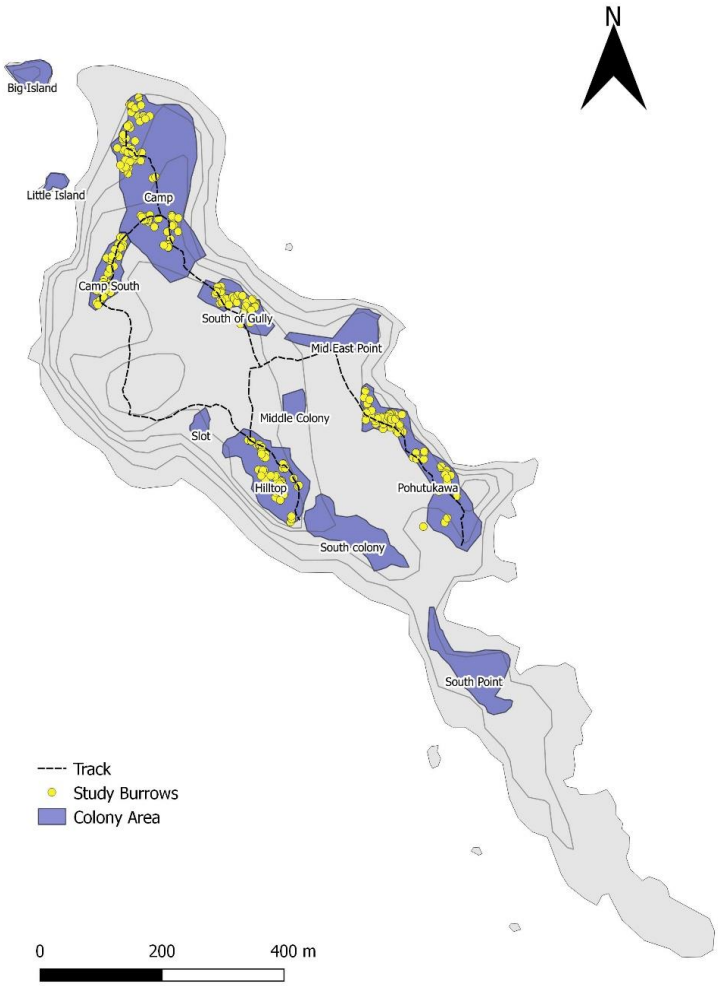


**Figure 2.** Map of Ohinau Island showing the location of all flesh-footed shearwater colonies and all marked study burrows.

### 2.1.2 Lady Alice Island

Lady Alice Island / Mauimua (Hen and Chickens Group, 35.89°S, 174.72°E) is a 155 ha Nature Reserve located 40km southeast of Whangarei (Figure 1). The most recent, accurate population survey estimates a total of 921 (237- 1,605, 95% CI) occupied flesh-footed shearwater burrows on the island (Baker *et al.* 2010). Seven main colonies on Lady Alice Island have been identified (Figure 3). The current study focussed on in the LA1 colony which has been monitored to varying degrees for 13 seasons between 1999 and 2012 and intensively since 2016 (Barbraud *et al.* 2014; Crowe *et al.* 2017; Crowe 2018a). A team of three personnel was based on the island during the following dates:

- **Trip 1:** 7 January 2019 – 25 January 2019; checking all study burrows to determine breeding status, identify adult birds breeding in all burrows and band/recapture adult birds seen on the surface at night. Also updating the population estimate for Lady Alice Island by carrying out burrow transects in known colonies, mapping colony boundaries and searching for other colonies.
- **Trip 2:** 26 April 2019 – 28 April 2019; checking all study burrows to determine breeding success and banding all chicks in burrows.

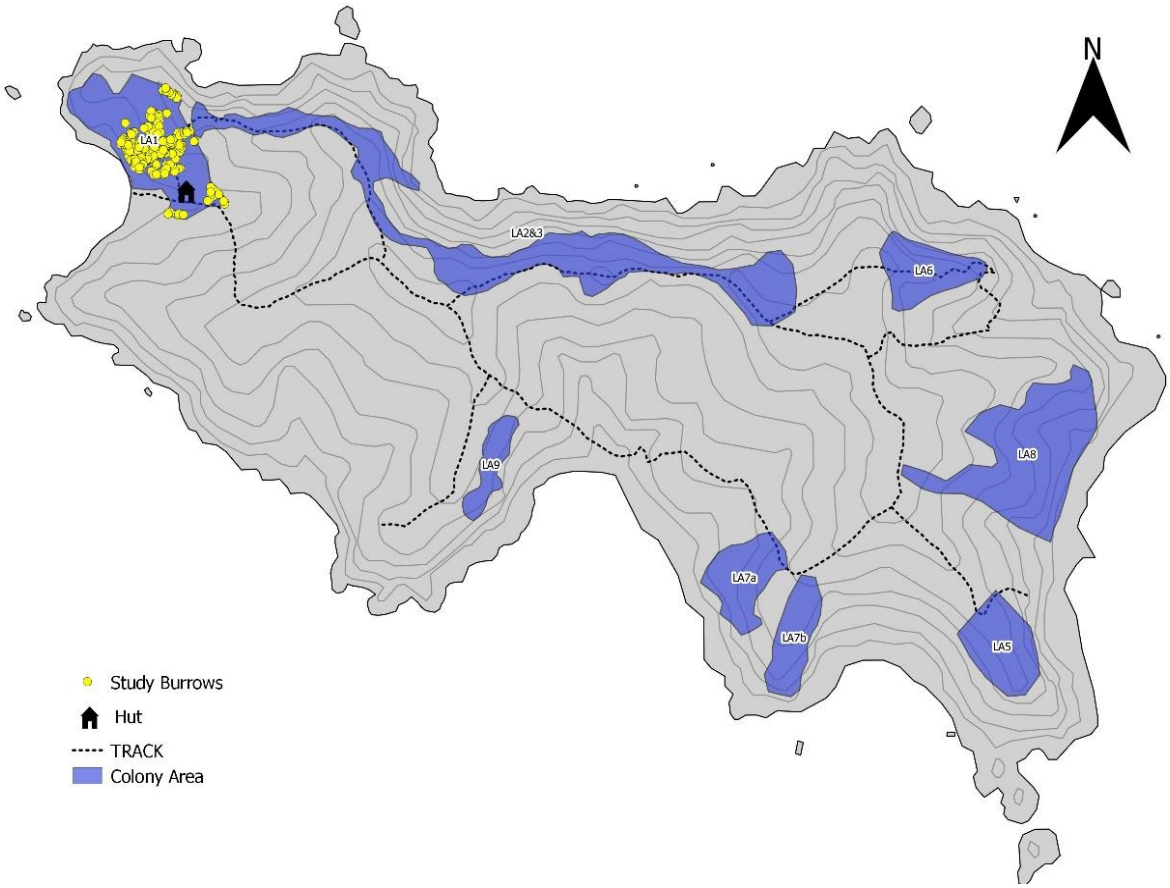


**Figure 3.** Map of Lady Alice Island showing the location of study burrows and all known flesh-footed shearwater colonies prior to the population estimate presented here.

### 2.1.3 Motumahanga Island

Motumahanga/Saddleback Island (Ngā Motu/Sugar Loaf Islands, 39.05°S 174.02°E) is a 2ha island located approximately 1.5km north-west of New Plymouth (Figure 4). There have been no surveys specifically for flesh-footed shearwaters on the island and only rough estimates have been recorded when working on other species on the island. The best estimate is probably around 100 breeding burrows (G. Taylor pers. obs.; Waugh *et al.* 2013). A team of three personnel was based on the Island between 17 January and 19 January 2019 to conduct a complete survey of burrows and develop a population estimate.

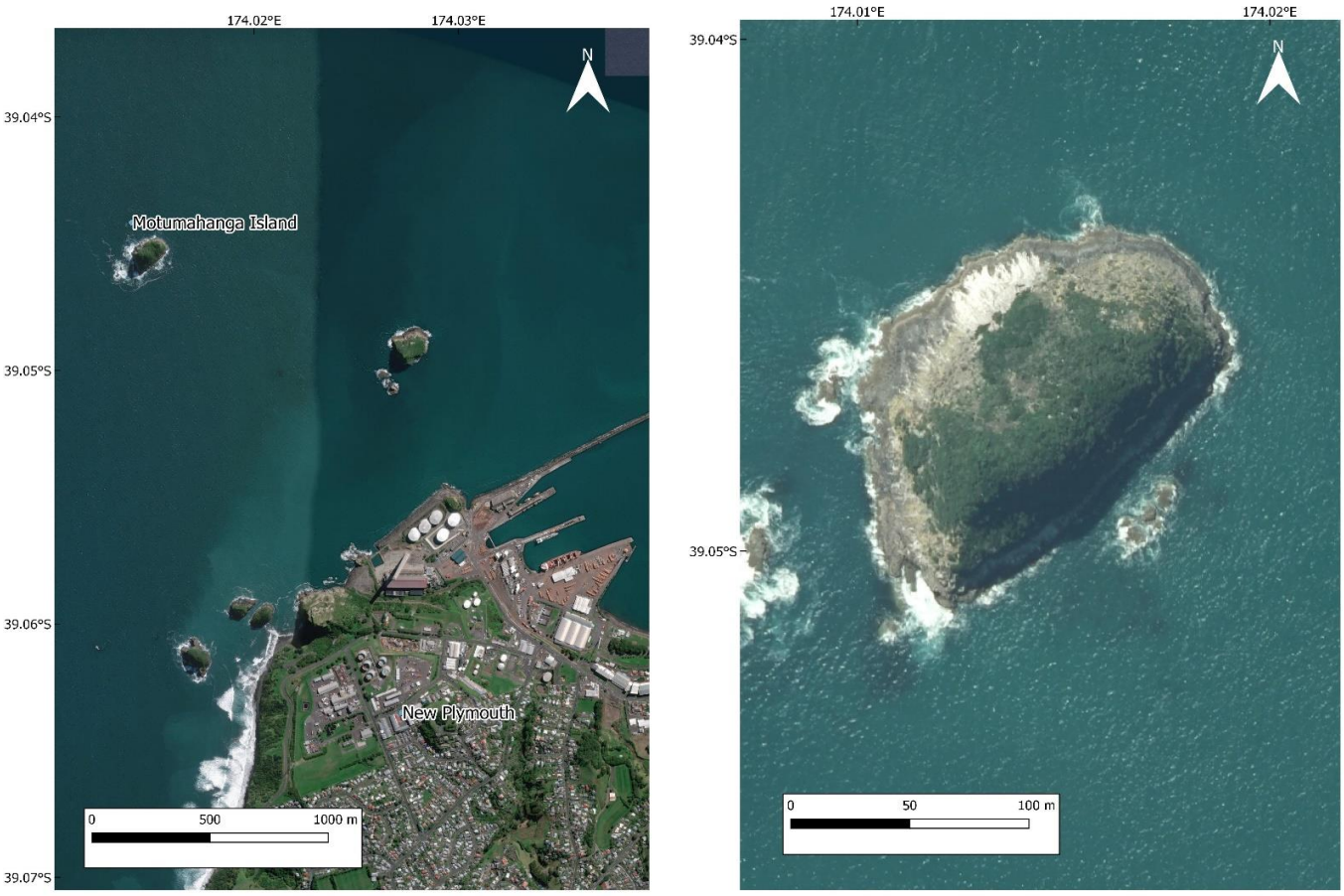


**Figure 4.** Maps of Motumahanga/Saddleback Island showing the island and its location relative to New Plymouth.

## 2.2 Burrow Monitoring

Each study burrow was checked every 2 – 5 days. On Ohinau Island in December, checks were mostly undertaken every two days, as we were trying to determine the laying date of breeding pairs. All birds found in these burrows were banded and had wing length, head and bill length, minimum bill depth and weight measurements taken. Where possible the sex of the bird was determined by cloacal examination. For birds that could not be sexed, a sample of two breast feathers was taken to allow for DNA sexing. Only one bird from each burrow was sexed and the partner bird was assumed to be the opposite sex. All birds found in burrows were marked with correction fluid to prevent unnecessary handling during future burrow checks, then placed back in their burrow. To reduce disturbance on incubating birds, mobile phones were held down the burrow through the entrance or

hatch and used to video, under flashlight, the occupants. If correction fluid could be seen on the head of the bird then it was not removed from the burrow, and if no correction fluid was visible, the bird was removed and checked.

If no bird was present in the burrow, it was searched thoroughly for a sign of a failed breeding attempt, such as egg shell fragments. On Lady Alice Island, empty burrows were all checked at least once more at a later date to confirm they were indeed empty. On Ohinau Island, empty burrows were checked all the way up until the day we departed the island. Once an egg was found in a burrow and both partners were banded and identified, the burrow was no longer checked for the duration of the trip. This helped minimise disturbance to the birds and the burrow.

For burrows that had failed (such as a broken egg) before we were able to identify both partners, we removed the failed egg and replaced it with a wooden 'dummy' egg. On many occasions this proved to be successful, with the partner bird often found incubating the 'dummy' egg. Once the bird was banded, or had its band number confirmed, the 'dummy' egg was removed.

Burrowscope burrows were checked only once during the trip. This was carried out on 20 December on Ohinau Island after all breeding birds should have laid (Bell *et al.* 2017), and within the first three days on Lady Alice Island, to minimise the number of burrows that fail in the early stages of incubation. The burrowscope was fed down the mouth of the burrow until a bird was seen and then confirmed to be incubating an egg. If no bird was seen after a thorough search, the burrow was recorded as being empty. No hatches were dug in to burrowscope burrows.

At the end of April, or start of May, both islands were revisited and all burrows were checked. All study burrows were checked, regardless of their status in December. Chicks found in burrows were banded, weighed and had wing length measurements taken, before then being placed back in their burrows. All chicks banded were marked with correction fluid on their head to prevent unnecessary recapture when undertaking night banding. Because chicks fledge in early May (Priddel *et al.* 2006), burrows with chicks during this time were assumed to have bred successfully. Where possible, the cause of failed breeding attempts was recorded. Empty burrows were checked thoroughly to make sure there was no sign of a chick or egg.

All burrowscope burrows were checked again in the April trip. Chicks were extracted where possible by hand or leg hook to be banded and have measurements taken (as above), before then being placed back in their burrow. Empty burrows and failed burrows were confirmed using a burrowscope and/or probing the burrow with a stick.

## 2.3 Night Work

### 2.3.1 December & January Trips

Night work was carried out to increase the total number of banded birds and to recapture banded birds. Night work was primarily carried out between 01:00 and dawn. Adults were caught using a hand-net and were banded, marked with correction fluid and the capture location was recorded. Take-off "runs" were targeted during the pre-dawn exodus as this is where we see a large number of birds funneling in to a relatively small area to take off.

Some night work was carried out on Motumahanga Island to band any adults seen and recapture banded adults.

### 2.3.2 April & May Trip

Night work on these trips was primarily aimed at catching any chicks coming out of burrows to exercise and preparing to fledge. Chicks were banded, weighed and had wing length measurements taken. They were also marked with correction fluid and the capture location was recorded. There was no apparent preferred time for chicks to be on the surface, so catching took place at any time after dark. More chicks were observed on the surface at night as they got closer to fledging. Windy nights also seemed to bring more chicks out of their burrows. Some adults were still present on the islands at this point and were also captured. Adults were banded and released at the same location they were captured.

## 2.4 Population Estimates

### 2.4.1 Lady Alice Island

Transect start points and bearing (transect direction) were randomly generated within the known colonies. A tape was run out for 20m from the start point on the generated bearing. The same method was used as that in Bell & Boyle (2017) for Middle Island and for Ohinau Island (Crowe 2018a). Burrows were searched for in a 2m strip to the right hand side of the tape i.e. each transect covered 40m$^2$. Following Waugh *et al.* (2003) and Baker *et al.* (2010) burrows were classified by the size of the entrance (small or large), with large burrows defined as burrows >20cm long, with an entrance size >14 x 8cm. All large burrows encountered on transects were burrowscoped to determine the contents of each burrow and generate an occupancy estimate for each colony. LA9 and LA10 colonies were the only exception to this where only a proportion of burrows were inspected. Transects were mostly done in pairs with one person searching for and counting burrows, while the other checked the contents of each burrow using a burrowscope (Figure 5).

**Figure 5.** Example of a burrow transect showing the tape run out for 20m and a burrow being examined using burrowscope.

A number of areas on Lady Alice Island were highlighted as "search areas" that we deemed to potentially have flesh-footed shearwater colonies. Potential colony areas were identified by examining aerial photographs, topographic maps and a vegetation map drawn by Percy (1956). We then conducted ground searches in these areas looking for highly-burrowed areas. Searches yielded two additional flesh-footed shearwater colonies. In these two colonies, random transects were generated and measured using the same method described above.

The boundaries of all colonies were mapped using a Garmin 64st hand-held GPS. To calculate the surface area of each colony, an eight metre resolution Digital Elevation Model (DEM) was downloaded from the LINZ Data Service website, then 'clipped' using a shapefile containing a polygon describing the boundary of each colony. The resulting clipped DEM was then used to create a Triangular Irregular Network (TIN) describing the 3D surface of the colony, and the 3D surface areas of the TIN were calculated using the Surface Volume tool in ArcMap 10™.

#### 2.4.2 Motumahanga Island

Access to Motumahanga Island was by way of helicopter and landing at the north-east end of the island (Figure 8). A campsite was established towards the southern end of the island.

A complete count of large burrows was conducted over the three days spent on Motumahanga Island. This was done by keeping a running tally of burrows and spray marking each one after it had been counted. A random selection of burrows were burrowscoped to determine the occupancy rate.

As every large burrow on the island was counted, there was no need to measure the colony area for extrapolating data and the estimate was developed by simply multiplying the total number of burrows by the measured occupancy rate.

# 3. Results

## 3.1 Study Burrows

### 3.1.1 Ohinau Island

A total of 247 study burrows were monitored during this season on Ohinau Island (Table 1). This consisted of 226 burrows monitored in the previous season and 21 new burrows. Two burrows were retired because they had collapsed, and had not had any flesh-footed shearwater activity in the previous two seasons.

Of the 247 study burrows, 85% (*n* = 209) were breeding burrows and 5% (*n* = 12) were non-breeding burrows. The remaining burrows were empty or held other species. We were able to successfully identify both partners for 81% (*n* = 170) of these breeding burrows (Table 1). 17% (*n* = 36) of breeding burrows had only one partner identified while the remaining three burrows had neither partner identified. Two of these burrows had eggs laid in them but no bird was ever found to be incubating, while the other one had been extended by the occupants and the nest chamber had become inaccessible. This was confirmed with the burrowscope, but adult birds could not be extracted.

### 3.1.2 Lady Alice Island

A total of 264 study burrows were monitored on Lady Alice Island this season (Table 1). This consisted of 223 burrows monitored in the 2017/18 season and 41 new burrows. Nine burrows were retired because they had collapsed, the entrance was too small for flesh-footed shearwaters, or there had been no activity in the burrow for the previous two seasons.

Of the 264 burrows, 74% (*n* = 195) were breeding burrows and 5% (*n* = 14) were non-breeding burrows. The remaining burrows were empty or held other species. We were able to identify both partners in 95% (*n* = 186) of breeding burrows. Four percent (*n* = 8) of breeding burrows had only one partner identified and one burrow had no partners identified. This burrow had an egg present during the first check, but no subsequent checks revealed any flesh-footed shearwaters in that burrow.

| **Burrow Status** | **Ohinau Island** | **Lady Alice Island** |
|---|---|---|
| **Breeding** | | |
| *- 0 partners* | 3 | 1 |
| *- 1 partner* | 36 | 8 |
| *- 2 partners* | 170 | 186 |
| **Total breeding burrows** | 209 | 195 |
| **Non-breeding** | | |
| *- 1 bird* | 8 | 7 |
| *- 2 birds* | 4 | 7 |
| **Total flesh-footed shearwater burrows** | 221 | 209 |
| Other species | | |
| - *Little Penguin* | | 3 |
| - *Grey-faced Petrel* (chick in Dec/Jan) | 3 | 3 |
| - *Pycroft's Petrel* | | |
| - *Little Shearwater* | | |
| - *Sooty Shearwater* | | 3 |
| Empty | 23 | 46 |
| **Total Study Burrows** | 247 | 264 |
| Retired | 2 | 9 |

**Table 1.** Status of all study burrows monitored on Ohinau and Lady Alice Islands during the 2018/19 season.

## 3.2 Breeding Success

Breeding success is defined here as burrows that produced a chick that is likely to survive to fledging.

### 3.2.1 Study Burrows

Breeding success for Ohinau Island was 62% (*n* = 129) while on Lady Alice Island it was 52% (*n* = 102). There was no significant difference in breeding success between the two islands (Pearson Chi-Square, $\chi^2_1 = 3.65$, p = 0.06). It appears more burrows failed during the egg stage than chick stage on both islands, however, there is a large degree of uncertainty, as the cause of burrow failure could not be determined in many cases (Table 3).

| | **Ohinau** | | **Lady Alice** | |
|---|---|---|---|---|
| | **Study Burrows (*n*= 247)** | **Burrowscope (*n* = 44)** | **Study Burrows (*n* = 264)** | **Burrowscope (*n* = 38)** |
| Breeding Burrows | 209 | 40 | 195 | 30 |
| Breeding success | 129 (62%) | 29 (73%) | 102 (52%) | 21 (70%) |
| Failed, pre-hatching | 16 (8%) | 0 (0%) | 19 (10%) | 0 (0%) |
| Failed, post-hatching | 5 (2%) | 1 (3%) | 5 (3%) | 2 (7%) |
| Failed, unknown reason | 59 (28%) | 10 (25%) | 69 (35%) | 7 (23%) |

**Table 2.** Summary of breeding outcomes for study burrows and burrowscope burrows on Ohinau and Lady Alice Islands

Grey-faced petrels were present in a large number of burrows on both islands this season. On Ohinau Island they were present in 10% (*n* = 21) of breeding study burrows in May. All of these burrows failed and three still contained the remains of a dead chick in the burrow. The state of decomposition made it difficult to determine if the chicks had been killed by a grey-faced petrel or had died before the grey-faced petrel began to occupy the burrow. By comparison, 5% (*n* = 2) of breeding burrowscope burrows contained grey-faced petrels.

On Lady Alice Island, grey-faced petrels were present in 7% (*n* = 14) of breeding study burrows. None of these burrows contained dead chicks, but five other burrows contained dead chicks, of which two had notable injuries consistent with grey-faced petrel attacks (bald and bleeding head or any piercing to the body). A further two burrows had live chicks that had wounds from an apparent grey-faced petrel attack.

### 3.2.2 Burrowscope Burrows

For the first time in three seasons, breeding success measured in burrowscope (control) burrows was higher than that measured in the study burrows (Figure 6). Breeding success for Ohinau Island burrowscope burrows was 73% (*n* = 29), however, the difference was not statistically significant to the 62% measure in the study burrows (Pearson Chi-Square, $\chi^2_1 = 1.68$, p = 0.20).

Breeding success for Lady Alice burrowscope burrows was 70% (*n* = 21) for Lady Alice Island, but again this was not a statistically significant difference compared to the 52% measured for the study burrows (Pearson Chi-Square, $\chi^2_1 = 3.28$, p = 0.07).

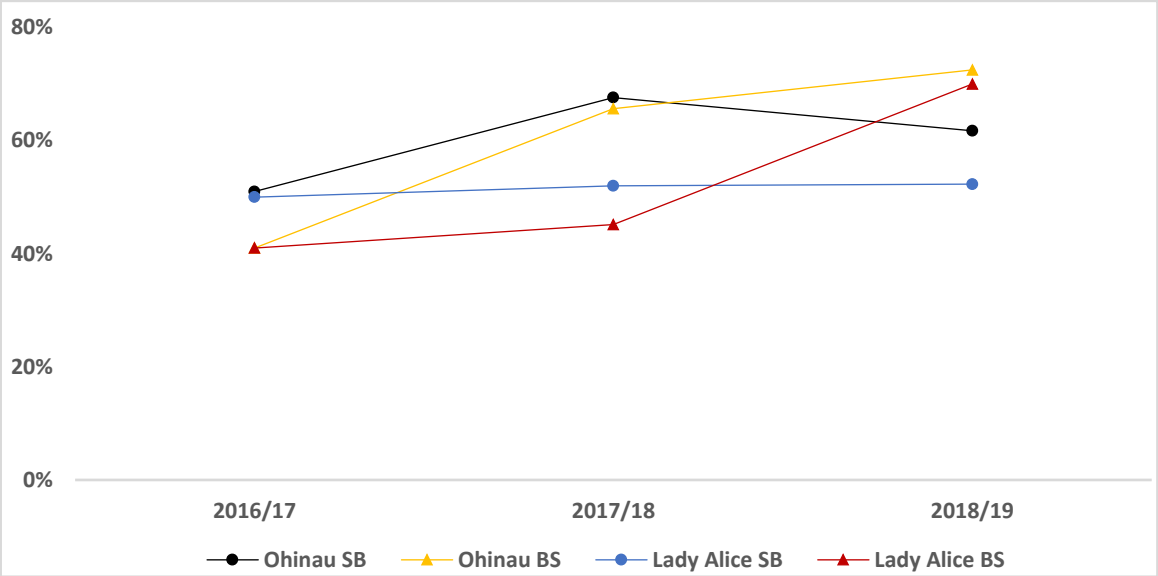


**Figure 6.** Breeding success in study and burrowscope burrows on Lady Alice and Ohinau Islands for the previous three seasons. SB = Study Burrows; BS = Burrowscope Burrow.

There was no significant difference between chick weight or wing length measurements in study burrows and burrowscope burrows on either island.

## 3.3 Banded Birds

This season a total of 205 birds were banded on Lady Alice Island, and a total of 663 birds were banded on Ohinau Island. This is the highest recorded number of birds banded during a single season on Ohinau Island, consisting of 453 chicks and 210 adults (Table 3). In total 2,824 flesh-footed shearwaters have been banded during this study.

| **Ohinau** | 2015/16 | 2016/17 | 2017/18 | 2018/19 | Total |
|---|---|---|---|---|---|
| Adult | 90 | 528 | 182 | 210 | 1010 |
| Chick | 267 | 133 | 131 | 453 | 984 |
| Total | 357 | 661 | 313 | 663 | **1994** |

| **Lady Alice** | 2015/16 | 2016/17 | 2017/18 | 2018/19 | Total |
|---|---|---|---|---|---|
| Adult | 0 | 285 | 163 | 102 | 550 |
| Chick | 0 | 94 | 83 | 103 | 280 |
| Total | 0 | 379 | 246 | 205 | **830** |

| | |
|---|---|
| **Total banded during this study** | **2824** |

**Table 3.** Number of flesh-footed shearwaters banded on both islands in the past four seasons.

An additional forty-nine adult flesh-footed shearwaters were caught and banded around the campsite of Motumahanga Island at night time.

### 3.3.1 Management of Records of Banded Birds and Study Burrows

Copies of the field records of all newly banded birds during our trips and any previously banded birds have been deposited with the Marine Species and Threats team, Department of Conservation, Wellington. Banding schedule records have also been sent to the National Bird Banding Scheme managed by Department of Conservation, Wellington.

A list of all study burrows tagged on both islands and the GPS locations of each site, plus maps and relevant photos, have been deposited with the Marine Species and Threats team, Department of Conservation.

## 3.4 Recaptured Birds

The results for recaptured breeding adults were nearly identical to what was observed on both islands in the 2017/18 season.

On Ohinau Island, 78% (*n* = 259) of birds that were identified as breeding last season were found to be breeding again this season. Of these birds, 98% (*n* = 253) were found breeding in the same burrow, while the remaining 2% of birds (*n* = 6) were breeding in a different burrow. In all cases of birds shifting burrows, they only moved to a nearby burrow, usually within 10m of their previous burrow.

On Lady Alice Island, 83% (*n* = 277) of breeding birds found in the 2017/18 season were found breeding again this season. The exact same result as last season was found with 90% of these being in the same burrow, and the remaining 10% found in a different study burrow.

A total of 789 (193 chicks, 596 adults) flesh-footed shearwaters were banded between 2000 – 2009 on Lady Alice Island (Andrea Booth unpublished dataset, Barbraud *et al.* 2014). Of these, 9% (*n* = 18) of chicks and 15% (*n* = 89) of adults have been recaptured in the previous three seasons on Lady Alice Island. Thirty-seven of the 107 recaptures were birds that were banded as adults in 2000. Twenty-six of these birds were recaptured this season, making these birds at least 24 years old now.

Two banded flesh-footed shearwaters were recaptured on Motumahanga Island. These birds were banded as adults in 1997, making them at least 27 years old.

## 3.5 Population Estimates

### 3.5.1 Lady Alice Island

We carried out a total of 371 twenty-meter transects in colonies over the entire island between 12 and 24 January 2019. All transects were 20m long with the exception of six transects that had to be shortened due to steep and unsafe terrain. Four transects were abandoned completely for the same reason.

Occupancy varied greatly between colonies from 57% in the LA1 colony to only 3% in the LA10 colony. Burrow density also varied between colonies (Table 4). For this reason we stratified data into colonies and extrapolated the burrow density and occupancy data to get a population estimate for each colony. The population estimate for all colonies on Lady Alice Island is 3217 occupied burrows (2180 – 4255, 95% CI).

Flesh-footed shearwaters appear to dominate the northern side of the island while grey-faced petrels are the dominant burrowing procellariform on the southern side of the island. Nearly 80% (2547 of 3217) of occupied flesh-footed shearwater burrows were in the three colonies to the north of the island (LA1, LA2&3 and LA6). A description of each colony is provided below and a summary of all transect data can be found in Table 4.

**LA1**

This colony is the focus of the ongoing, long-term study into the demographics of flesh-footed shearwaters, and commenced in 2016. The colony was also studied to varying degrees between 2000 and 2012 (Barbraud *et al.* 2014). There are currently 312 marked burrows being monitored. The densest part of the colony is on the slopes facing south-west. The colony stretches to areas in behind the hut, on the southern side of the gully and over the ridge to north-facing slopes.

**LA2+3**

A narrow band of burrows along the northern slopes of the island, defined by suitable vegetation and soil type, above the sea cliffs. This area is relatively dense with burrows, which are primarily

occupied by flesh-footed shearwaters and occasional grey-faced petrel. The colony previously stretched further east towards LA6, but transects and further searches within this area yielded very few burrows, so the mapped colony area was reduced.

**LA4**

This colony was searched but deemed to not be a flesh-footed shearwater colony by Baker *et al*. (2010), we conducted ground searches and found patches of burrows linked by a narrow band of a smaller number of burrows. Occupancy was 27% indicating a reasonable number of flesh-footed shearwaters. This is likely a mixed species colony with grey-faced petrels.

**LA5**

This colony straddles the spur at the southeast end of the island. It has a relatively low density of burrows, and primarily a grey-faced petrel colony with only occasional flesh-footed shearwater burrows.

**LA6**

A small, but relatively dense flesh-footed shearwater colony that occurs at similar elevation, as well as slope and vegetation type, as the LA2+3 colony. Two transects ended short here, and two transects could not be started due to the terrain becoming too steep to safely survey. Some burrows were observed below this on very steep terrain.

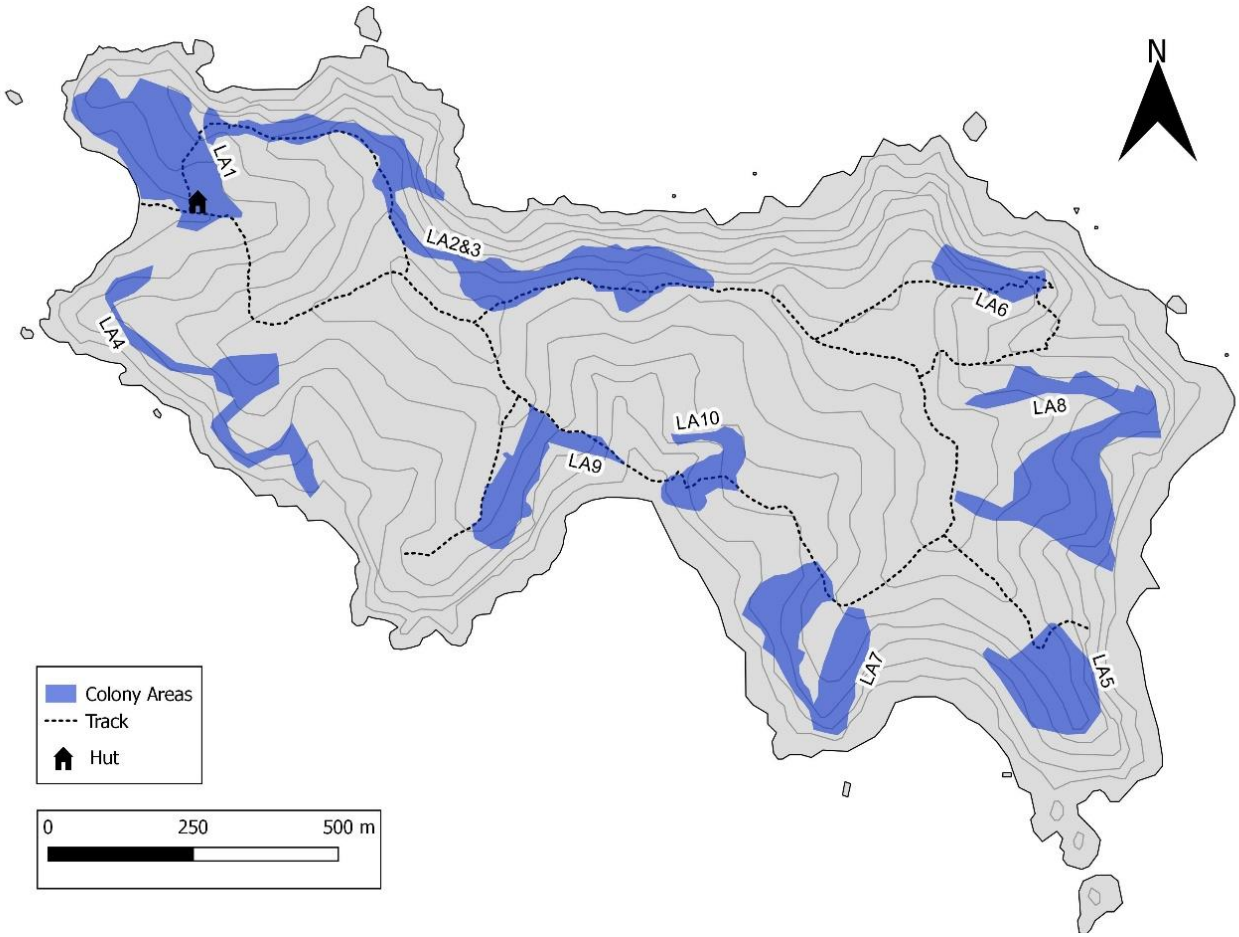


**Figure 7.** Map of Lady Alice Island showing the current extent of all flesh-footed colonies.

**LA7**

This colony was previously broken into two sub-colonies (7A and 7B). Searching the area in between the two sub-colonies we found a band of continuous burrows at the southern end of the colony. Transect data for the two sub-colonies was very similar, so the data was combined and analysed as a single colony. It is dense in some patches closer to the coast, yet this colony is primarily a grey-faced petrel colony, with only occasional flesh-footed shearwater burrows.

**LA8**

This covers a large area on the eastern side of the islands. Burrows run down both spurs and are joined by a swath of burrows lower down. Burrows are overall very sparse, with only some denser patches. Burrowscoping showed this colony is primarily a grey-faced petrel colony, with only occasional flesh-footed shearwater burrows.

**LA9**

This colony contains a band of burrows on the western side above South Bay. The vegetation is quite open. Burrows stretch from the track all the way along the southeast facing slope in areas where the soil is suitable for burrowing. Parts of this colony are some of the most densely burrowed areas on the island. Burrowscoping showed that this is almost entirely a grey-faced petrel colony.

**LA10**

This is a relatively open area to on the east of South Bay. Like LA9, it is quite a densely burrowed area, but it is almost entirely a grey-faced petrel colony, with only the very occasional flesh-footed shearwater burrow.

| Colony | Dates Surveyed | Area sampled ($m^2$) | Large burrows counted | Burrow Density (burrows/ $m^2$) | No. burrows burrowscoped | Occupancy Rate | Colony Area ($m^2$) | Estimated Occupied Burrows | Lower 95% CI | Upper 95% CI |
|---|---|---|---|---|---|---|---|---|---|---|
| **LA1** | 16, 17 January 2019 | 2400 | 87 | 0.04 | 87 | 0.57 | 39173 | **809** | 565 | 1054 |
| **LA2 & 3** | 16, 17 January 2019 | 1498 | 71 | 0.05 | 71 | 0.49 | 61873 | **1398** | 975 | 1822 |
| **LA4** | 24 January 2019 | 1400 | 41 | 0.03 | 41 | 0.27 | 24535 | **193** | 104 | 282 |
| **LA5** | 15 January 2019 | 1200 | 38 | 0.03 | 38 | 0.08 | 28332 | **73** | 44 | 101 |
| **LA6** | 12, 20 January 2019 | 856 | 48 | 0.06 | 48 | 0.48 | 12616 | **340** | 211 | 468 |
| **LA7** | 21 January 2019 | 2360 | 108 | 0.05 | 108 | 0.06 | 34652 | **94** | 63 | 125 |
| **LA8** | 12, 20 January 2019 | 1346 | 39 | 0.03 | 39 | 0.10 | 51997 | **157** | 104 | 211 |
| **LA9** | 15, 19 January 2019 | 1200 | 124 | 0.10 | 79 | 0.06 | 21546 | **125** | 96 | 155 |
| **LA10** | 19, 20 January 2019 | 1200 | 79 | 0.07 | 59 | 0.03 | 12389 | **28** | 19 | 38 |
| **Total** | | 13460 | 635 | | 570 | | 287113 | **3217** | 2180 | 4255 |

**Table 4.** Summary of burrow transect data and population estimate for Lady Alice Island.

### 3.5.2 Motumahanga Island

Flesh-footed shearwater burrows were encountered over the majority of the island and were the dominant seabird species on the island (Figure 8). A total of 784 burrows were counted. A representative sample of 99 burrows were burrowscoped with a measured occupancy rate of 0.717. Applying this occupancy rate to the total number of burrows, there are an estimated 562 occupied burrows on Motumahanga Island. A summary of the burrow count data is provided in Table 5.

| Total Burrows | Colony Area ($m^2$) | Burrows/ $m^2$ | Burrow-scoped burrows | Occupied burrow-scoped burrows | Occupancy rate | **Motumahanga Occupied Burrows** |
|---|---|---|---|---|---|---|
| 784 | 6983 | 0.112 | 99 | 71 | 0.717 | **562** |

**Table 5.** Summary of burrow count data on Motumahanga Island.

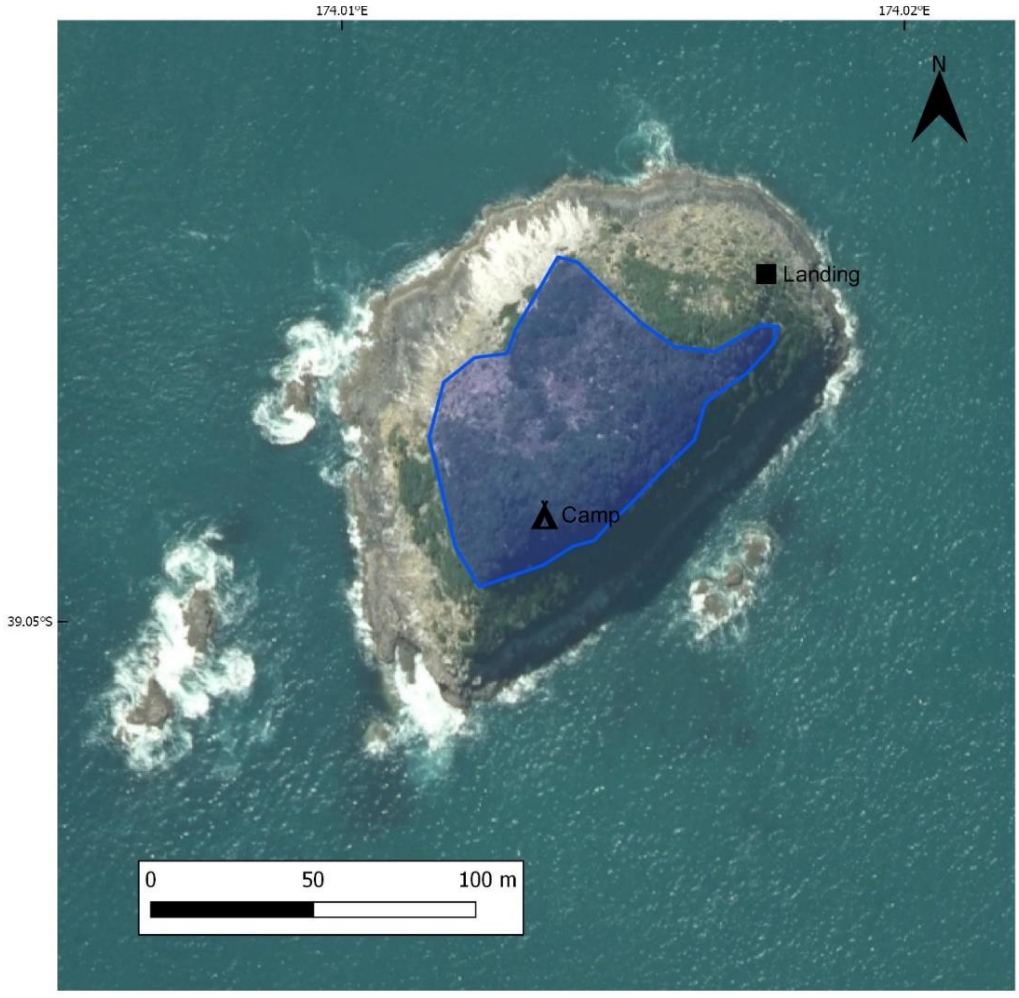


**Figure 8.** Aerial photo of Motumahanga Island showing the helicopter landing, campsite and approximate area of occupied flesh-footed shearwater burrows in blue.

# 4. Discussion

## 4.1 Study Burrows

The number of study burrows currently being monitored is at a suitable number and few (if any) burrows will need to be added in the forthcoming seasons. The majority of burrows are occupied by the same pair from season to season, and so occupancy of these marked study burrows remains equally high. While there are a greater number of study burrows on Lady Alice Island, the birds that breed in these burrows show a tendency to shift around more than the birds on Ohinau Island. We will continue to target burrows closely, as birds that move burrows between seasons do not appear to move a great distance.

Burrows that have collapsed, are continually occupied by a different species, or remain inactive for multiple seasons, will be retired and new burrows will be added if required, to reach 200 study burrows per island.

## 4.2 Breeding Success

Breeding success on Ohinau Island this season was 62%, down from the 68% measured in the 2017/18 season. While it is slightly lower, breeding success is still within a range that would be expected for this species in a predator-free environment. On Woody Island, Western Australia, breeding success for flesh-footed shearwaters was measured as 40% and 53% for two consecutive seasons (Powell *et al.* 2007). Priddel *et al.* (2006) observed a 50% breeding success rate during the 2002/03 breeding season on Lord Howe Island, Eastern Australia. Reid *et al.* (2013) incorporated data from the literature with their own field studies on Lord Howe Island, and estimated breeding success for the 2008/09 season to be 60%. Both Lord Howe and Woody Islands have Ship Rats (*Rattus rattus*) present which are known to predate the eggs and young of several species of burrowing Procellariiformes (Moors and Atkinson 1984).

The breeding success on Lady Alice was 52% and has been consistent over the past three seasons, varying by only 2%. Breeding success has been considerably lower than Ohinau Island for the previous two seasons, and lower than would be expected for this species in a predator-free environment. In the previous two seasons, there were notable climate-related factors that likely contributed to poor breeding success. In 2016/17 there was significant rainfall during chick-rearing that caused the flooding of many burrows, and in the 2017/18 season we suggested that the La Niña weather pattern led to increased sea-surface temperatures, resulting in poorer foraging in the Tasman Sea (Crowe *et al.* 2017; Crowe 2018a; Crowe 2018b). For the current season there were no significant weather events, nor was it a La Niña season. Only 10% of breeding burrows were determined to have failed prior to hatching versus 30% in the previous season, indicating that birds were not starving and being forced to abandon their burrow during incubation.

Grey-faced petrels are likely to be the cause of some breeding failures on Lady Alice, but this factor is equally, or more pronounced, on Ohinau Island. None of our study burrows with grey-faced petrels present in April contained flesh-footed shearwater chicks. Many grey-faced petrels were observed on the surface at night time on both islands, and there was evidence of chicks having been killed by them. Grey-faced petrels are known to evict the unguarded chicks of flesh-footed shearwaters when they arrive to clean out burrows in April (Barbraud *et al*. 2014, Waugh *et al*. 2014).

## 4.3 Banded Birds

A total of 453 chicks from Ohinau Island were banded this season, easily the largest number banded from a single cohort. The main reason for the greater banding success was that the trip to Ohinau Island was later in the season, and was longer in duration. We found that more chicks were present on the surface at night time, and for a longer period as they got closer to fledging. Windy nights also appeared to bring more chicks out of their burrows for a longer period.

In at least one of the two remaining seasons we will try to visit Lady Alice Island later in the season during the April/May trip to check the burrows, and band the chicks i.e. go to Ohinau Island first and Lady Alice second. In all of the previous three seasons, Lady Alice Island has been visited first and few chicks have been banded on the surface at night time. The result is that fewer than 25% of all chicks banded have been on Lady Alice. We will plan the trip to be late in the season to maximise the number of chicks on the surface at night, but not so late that our study burrow checks are compromised and some chicks have already fledged.

Having a large number of chicks banded each season is an important factor in this long-term study, as it will ensure we are able to determine age at first return, and age at first breeding, two factors not well understood, or with inferences made from small sample sizes. Based on the current literature, we should begin to recapture some chicks banded in the 2015/16 on Ohinau Island during the final year of this contract 2020/21 (Barbraud *et al.* 2014).

## 4.4 Recaptured Birds

Around 80% of flesh-footed shearwaters that bred in the 2017/18 season also bred this season. Last year, 81% of birds on both islands bred in successive years. This shows that flesh-footed shearwaters are mostly annual breeders, and the true percentage of annual breeders is probably higher, as breeding birds have been shown to move burrows between seasons.

The proportion of chicks banded between 2000–2009 that have returned to Lady Alice Island (9%) is very similar to the 8% return rate reported by Bell *et al*. (2016) in the black petrel population on Great Barrier Island / Aotea over a 20 year period. While this estimate of recruitment is extremely low and suggests a low juvenile survival rate, it is probably more a reflection on the detectability of returned chicks, more so than survival. Future work on both these islands will focus on night work to recapture surface birds. As mentioned above, recaptured chicks will help to determine age of first return. Other demographic parameters such as adult and juvenile survival rates can then be calculated by modelling mark/recapture data.

## 4.5 Population Estimates

### 4.5.1 Lady Alice Island

The population estimate presented here for Lady Alice Island is considerably larger than the most recent estimate by Jamieson & Waugh (2015) of 710 breeding pairs. It is also more than three times larger than the more commonly cited estimate by Baker *et al.* (2010) of 921 occupied burrows. The timing of the Jamieson & Waugh (2015) survey was an issue, with the survey beginning before peak laying for flesh-footed shearwaters and finishing just as laying had ended (Bell *et al.* 2017). This would have resulted in an underestimation of occupancy, and so population estimate. The primary reason for the large discrepancy between the current estimate and the Baker *et al.* (2010) estimate is simply the total area mapped and calculated for the colony. Our estimates for burrow occupancy and burrow density were relatively similar for many of the colonies, but measured and calculated areas for the colonies were sometimes up to eight times larger. Part of this comes down to spending

a large amount of time on the island, and thus gaining an understanding of the extent of the colonies through seeing and hearing birds at night, and searching for burrows during the day.

The Baker *et al.* (2010) estimate for the LA1 colony of 105 occupied burrows was known immediately to be incorrect, as we had over 200 marked burrows within the LA1 colony that were occupied this season. The LA1 colony was sampled during the 2017-18 season using the same methodology as described above. The 2017-18 estimate for LA1 was 867 (628 – 1107 95% CI) occupied burrows (Crowe 2018a), which is highly comparable to the estimate of 809 (565 – 1054 95% CI). This provides evidence that the method used here is a repeatable and reliable method for estimating the number of burrows within a defined colony. We have designed the survey methodology to reduce potential errors following recommendations from Wolfaardt & Phillips (2013), and Parker & Rexer-Huber (2015). A random sampling design was used to remove any sample bias. The open nature of the forest floor on both islands, and using two experienced observers, working together on each transect, removed errors around burrow and occupant detection probability, as well as observer bias. The surveys were carried out as early as possible in January, immediately after egg laying was complete (Bell *et al.* 2017). As such, error around estimating burrow occupancy would have been low, with only burrows failing during early incubation and retaining no sign of a failed breeding attempt being misidentified as a non-occupied burrow.

### 4.5.2 Motumahanga Island

The population of flesh-footed shearwaters on Motumahanga Island has substantially increased from the rough estimate of 100 breeding burrows made in 1989 (G. Taylor pers. obs.; Waugh *et al.* 2013). This most likely represents a true increase, and not a result of estimation error. Previously, flesh-footed shearwater burrows were restricted primarily to the southern end, and patchily distributed on the western side of the island. The remainder of the island was dominated by a dense common diving petrel colony. This has now changed and flesh-footed shearwaters are the dominant seabird species, spread across the entire plateau.

The island seems to have undergone substantial changes in vegetation cover since the 1990s, which may have aided the change in the seabird composition on the island. The central plateau was previously covered in taller mature taupata (*Coprosma repens*) forest, with a relatively open understory. Karo (*Pittosporum crassifolium*) and houpara (*Pseudopanax lessonii*) were confined to the rocky areas at the northern and southern summits. Today the mature forest has collapsed, opening up into areas of bare soil and grasses, and regenerating houpara and karo are common on the plateau along with young taupata. The change in vegetation and resulting change in soil structure has probably meant that flesh-footed shearwaters have been able to burrow in more places and have displaced the diving petrels. Motumahanga Island now has one of the most densely burrowed colonies of flesh-footed shearwaters, with a burrow density of 0.11 burrows/$m^2$. For comparison, Middle Island, which has the largest population of flesh-footed shearwaters in New Zealand, had a burrow density of 0.09 burrows/$m^2$ in the karo-taupata scrub, which hosts the majority of the flesh-footed shearwater population on the island (Bell & Boyle 2017).

# 5. Conclusions and Recommendations

The continuing increase in population estimates is a surprising result as other literature indicates that flesh-footed shearwaters are in decline in New Zealand, and globally. The four islands that we have surveyed; Middle, Ohinau, Lady Alice and Motumahanga Islands, have all shown substantial increases from previous estimates. In total we have accounted for an additional 7500 breeding pairs, which represents at least a 50% increase on the 10,000 – 15,000 estimate given by Waugh *et al.* (2013). Population estimates for Coppermine and Whatupuke Islands are planned for the 2020/21 season, and with these we will provide a greater insights into the trends of flesh-footed shearwaters breeding in New Zealand.

For the 2019/20 season, the same breeding group of study burrows will be monitored. We will also continue to monitor burrowscope burrows to determine if our handling of birds is negatively impacting the burrows we monitor. Multiple seasons of breeding success data will be important for working out what "normal" success levels are and thus help for population modelling. Night work will continue to be carried out to maximise the banded populations on both islands. With there already being a large portion of birds on both islands banded, more focus can be put on to recapturing banded birds, and developing robust estimates for adult and juvenile survival rates.

In addition to the burrow monitoring, at least 25 breeding flesh-footed shearwaters will be tracked from Ohinau and Lady Alice Island simultaneously during incubation and chick-rearing. Tracking both populations simultaneously will eliminate possible seasonal or inter-annual variations observed in previous tracking.

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# 8. Appendices

## 8.1 Other bird species observed on Ohinau and Lady Alice Islands

Regular bird counts were completed on both islands and the results uploaded to eBird (www.ebird.org/content/newzealand/). Below is a summary of these observations.

| Species | Ohinau Island | Lady Alice Island |
|---|---|---|
| **Flesh-footed Shearwater** | Hundreds of birds on surface in December. Few adults seen per night in May | Hundreds of birds on surface in December. |
| **Sooty Shearwater** | One adult banded in burrow (non-breeding). One more seen | A few birds found in burrows around island a few birds seen or heard most nights. |
| **Fluttering Shearwater** | Occasionally heard calling at night | Heard calling most nights in January. Occasionally seen on surface |
| **Buller's Shearwater** | None observed | One breeding burrow found in the LA1 colony. Commonly seen flying off the coast |
| **Little Shearwater** | Up to 6 individuals seen most nights in December and May. 36 individuals banded | Occasional bird seen at night time |
| **Diving Petrel** | Heard calling just below camp on some nights | None observed |
| **Pycroft's Petrel** | Not common. Three adults banded and one breeding burrow | Lots seen on surface and occasional bird in burrows over whole island. 10 individuals banded |
| **Grey-faced Petrel** | Occasional chick still present in burrow in December. Adults very common in May. 58 individuals banded | A few chicks in burrows in January, very common in April on the surface and in burrows. 24 individuals banded |
| **Little Penguin** | Occasional bird in burrow | Some birds in burrows and on surface at night |
| **White-faced storm petrel** | None observed | Seen offshore usually around fishing vessels |

| | | |
|---|---|---|
| **Fairy Prion** | None observed | Seen on boat ride to island and occasionally offshore |
| **Pied Shag** | Up to 30 individuals roosting in bay near camp each day | Up to 10 birds roosting in bay near camp each day |
| **Little Shag** | One bird seen one day | None Observed |
| **White-faced Heron** | Occasional bird in bay near camp | None observed |
| **Reef Heron** | One seen on rocks with shags in December | None observed |
| **Variable Oystercatcher** | Two near landing beach one day | A pair most days at West Bay |
| **Black-backed Gull** | Nesting on flat island. Up to 30 offshore and a few around beach | Seen offshore and on beach near camp |
| **Red-billed Gull** | A few seen offshore | Large numbers seen offshore, a few birds on beach each day |
| **Australasian Gannet** | Small numbers feeding close to shore. More offshore | Common offshore |
| **Caspian Tern** | One on beach by camp | 1-2 birds seen offshore |
| **White-fronted tern** | Up to 15 offshore most days | Some birds seen offshore |
| **Kereru** | Up to two seen around Pohutukawa colony | Common. Usually at least one around camp |
| **Bellbird** | Very common throughout whole island | Abundant |
| **Tui** | Up to 2 regularly heard at Pohutukawa colony | Abundant |
| **Saddleback** | None observed | Common |
| **Tomtit** | None observed | One bird heard down the eastern side of island |
| **Fantail** | Common, seen most days | Common |
| **Kaka** | None observed | 2-5 birds seen each day |
| **Morepork** | Heard sometimes at night | Common |
| **Kingfisher** | Common throughout island | Common |

| | | |
|---|---|---|
| **Silvereye** | Very common throughout whole island | Common |
| **Welcome Swallow** | Common, seen most days | Common |
| **Grey Warbler** | Common throughout island | Common |
| **Long-tailed Cuckoo** | One bird heard one day | None observed |
| **Shining Cuckoo** | Heard calling about 3 times in December | Common |
| **Australasian Harrier** | Up to two individuals seen most days | 2-3 birds seen each day |
| **Dunnock** | Abundant | Common |
| **House Sparrow** | Small flocks heard around camp | None observed |
| **Blackbird** | Common throughout island | 1-2 birds seen each day |
| **Starling** | Heard most days throughout island | Common |
| **Chaffinch** | Singing daily, mainly at camp | Common |
| **Common Myna** | None | None observed |

## 8.2 Other bird species observed on Motumahanga Island

| **Species** | **Description** |
|---|---|
| **Flesh-footed Shearwater** | Many adults on surface in January |
| **Buller's Shearwater** | One bird caught and banded on the surface at night |
| **White-fronted tern** | 200 birds breeding in a colony on the western cliffs |
| **Red-billed gull** | 80 -100 birds breeding on the western cliffs |
| **Black-backed gull** | 12 individuals seen. Likely to be breeding |
| **Fluttering shearwater** | 20 + birds seen feeding in a tidal rip |
| **Gannet** | One bird seen offshore |
| **Variable Oystercatcher** | One pair seen |
| **Harrier** | At least one bird seen flying over island |

| | |
|---|---|
| **Rock (feral) pigeon** | Many birds observed |
| **Starling** | Three seen |
| **Dunnock** | One seen |
| **Blackbird** | Breeding on the island |

## 8.3 Additional Photos

### 8.3.1 Photo of South of Gully Colony on Ohinau Island. This is typical of flesh-footed shearwater colonies on Ohinau Island and Lady Alice Island. Pink study burrow marker tags can be seen in the foreground and to the right.

### 8.3.2 Motumahanga Island burrowed area with campsite in background.