TOANUI/FLESH-FOOTED SHEARWATERS

Toanui/flesh-footed shearwater population monitoring and estimates: 2021/22 season

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Cover image: Toanui/flesh-footed shearwater in flight © Dan Burgin.

CONTENTS

EXECUTIVE SUMMARY

This report covers the findings from the first year of flesh-footed shearwater (*Ardenna carneipes*) research under Conservation Services Programme project POP2021-04. Here we report on the ongoing population monitoring of flesh-footed shearwaters on Ohinau and Lady Alice Islands. A separate report on an updated population estimate for Titi Island, Marlborough Sounds is presented in a separate report.

During the 2021/22 season we monitored 261 and 302 study burrows on Ohinau and Lady Alice Islands respectively. The breeding success (burrows with an egg that produce a chick that is likely to survive to fledging) on Ohinau Island was 59%, similar to the 58% measured in the 2020/21 season. Breeding success on Lady Alice Island was 51%, which was also similar to the 48% measured in 2020/21 season. There were no detectable differences in breeding success between study and burrowscope (control) burrows, indicating no impact of handler disturbance. We were able to identify 73% of the birds in breeding study burrows on Ohinau Island and 93% in burrows on Lady Alice Island. An additional 349 and 165 flesh-footed shearwaters were banded on Ohinau and Lady Alice Island respectively.

KEY OBJECTIVES & OUTPUTS

This research was carried out as part of the Conservation Services Programme (CSP), flesh-footed shearwater research project (POP2021-04). The key objectives we were funded by Department of Conservation to complete were:

1. **To collect key demographic parameters of flesh-footed shearwater at Lady Alice Island/Mauimua and Ohinau Islands, especially juvenile survival and recruitment**

2. **Estimate the current breeding population of flesh-footed shearwaters at Titi Island, Marlborough Sounds**

Objective 1 is ongoing, and Objective 2 was completed in the 2021/22 season and is reported in a separate report (Burgin 2022).

Toanui/flesh-footed shearwater population monitoring 2021/2022

1. INTRODUCTION

Toanui/flesh-footed shearwaters (*Ardenna carneipes*) are a medium sized seabird acting as apex predators in the Indian and Pacific Oceans (Priddel et al. 2006). Breeding colonies are found on islands off the coast of northern New Zealand (Taylor 2000), Australia (Lavers 2015) and on St Paul Island (Île Saint-Paul) in the Indian Ocean (Marchant & Higgins 1990). Populations are thought to be in decline globally (Waugh et al. 2013; Lavers 2015). Under the New Zealand threat classification system, the decline of flesh-footed shearwaters has been recognised, although this species has recently been reclassified as "At Risk- relict" (Robertson et al. 2021). The International Union for Conservation of Nature's Red List of Threatened Species lists the species as "Near Threatened" and in decline across its range (Birdlife International 2019). Redolent of many seabird species, the primary threats to flesh-footed shearwaters include accidental bycatch in both commercial and recreational fisheries (Baker & Wise 2005; Abraham et al. 2010), plastic ingestion (Hutton et al. 2008; Lavers et al. 2014; Lavers et al. 2021), invasive species (Taylor 2000; Croxall et al. 2012), and climate change (Bond & Lavers 2014). Flesh-footed shearwaters have been reported as one of the most commonly caught species in New Zealand long-line fishing and are also prone to being caught in trawl fisheries (Robertson et al. 2004; Abraham & Thompson 2011). It is estimated that between 496 and 1,020 flesh-footed shearwaters are killed annually in commercial fisheries (Richard et al. 2020). Flesh-footed shearwaters are known to have a wide-reaching distribution, utilizing Australian and New Zealand waters during the breeding season, and migrating to northern hemisphere portions of the Pacific Ocean post-breeding (Taylor 2000; Rayner et al. 2011). These threats will be prevalent across their range, meaning effective conservation management for this species must be supported by international cooperation to avoid continued declines.

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 have been based on small sample sizes (Barbraud et al. 2014). Long-term studies help with gaining a better understanding of demographic parameters such as adult survival, recruitment, age at first return and age at first breeding. This will consequently help provide more accurate population trends, and thus aid future management for the species, particularly in light of the myriad threats this species faces (Croxall et al. 2012).

Flesh-footed shearwaters represent a high trophic level in their ecosystem, and can be valuable indicators of marine environmental change (Waugh et al. 2013). Gathering multi-generational datasets are therefore paramount for documenting, understanding and mitigating changes to the marine environment (Waugh et al. 2013). The possible decline of flesh-footed shearwaters coupled with a general lack of demographic and population estimates particularly in New Zealand (Taylor 2000), has warranted the establishment of a long-term population 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 – Mauimua/Lady Alice Island (hereafter 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 five consecutive seasons from 2016/17 – 2020/21. This report presents results on the most recent 2021/22 season, and a recent population survey for Titi Island, in the Marlborough Sounds, is presented in a separate report (Burgin 2022).

2. METHODS

2.1 Study Sites and Dates

Ohinau Island

Ohinau Island (Mercury Islands Group, 36.73°S, 175.88°E) is a 43 ha 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 1). These study burrows have been monitored intensively since 2016 (Mischler 2016; Crowe *et al.* 2017; Crowe 2018; Crowe & Bell 2019; Crowe 2020). There are an estimated total of 4,007 (3,044 – 4,791) occupied burrows on the island (Crowe 2018). A team of two personnel was based on the island during the following dates:

- **Trip 1**: 2 December 2021 – 22 December 2021; 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:** 28 April 2022 – 6 May 2022; checking all study burrows to determine breeding success and banding all chicks in burrows and on the surface at night.

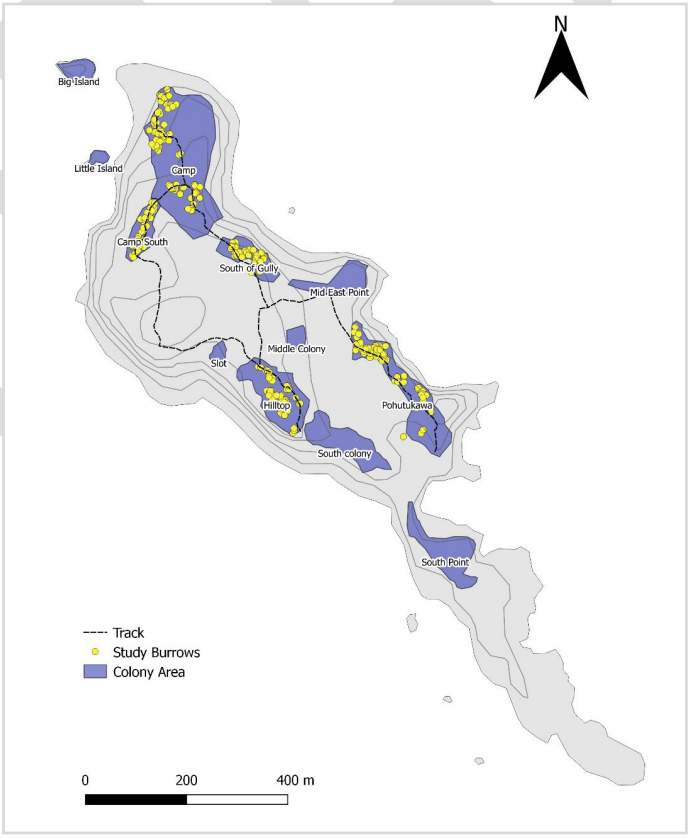

Figure 1. Map of Ohinau Island showing the location of all flesh-footed shearwater colonies and all marked study burrows.

Lady Alice Island

Lady Alice Island (Hen and Chickens Group, 35.89°S, 174.72°E) is a 155 ha Nature Reserve located 40km southeast of Whangarei (Figure 2). The most recent, accurate population survey estimates a total of 3,217 (2,180- 4,255, 95% CI) occupied flesh-footed shearwater burrows on the island (Crowe & Bell 2019). Seven main colonies on Lady Alice Island have been identified (Figure 3). The current study focuses on the LA1 colony, which has been monitored to varying degrees for 13 seasons between 1999 and 2012 by other researchers, and intensively since 2016 by WMIL (Barbraud *et al.* 2014; Crowe *et al.* 2017; Crowe 2018). A team of two to three personnel was based on the island during the following dates:

- **Trip 1:** 11 January 2022 – 30 January 2022; 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:** 21 April 2022 – 27 April 2022; checking all study burrows to determine breeding success and banding all chicks in burrows and on the surface at night.

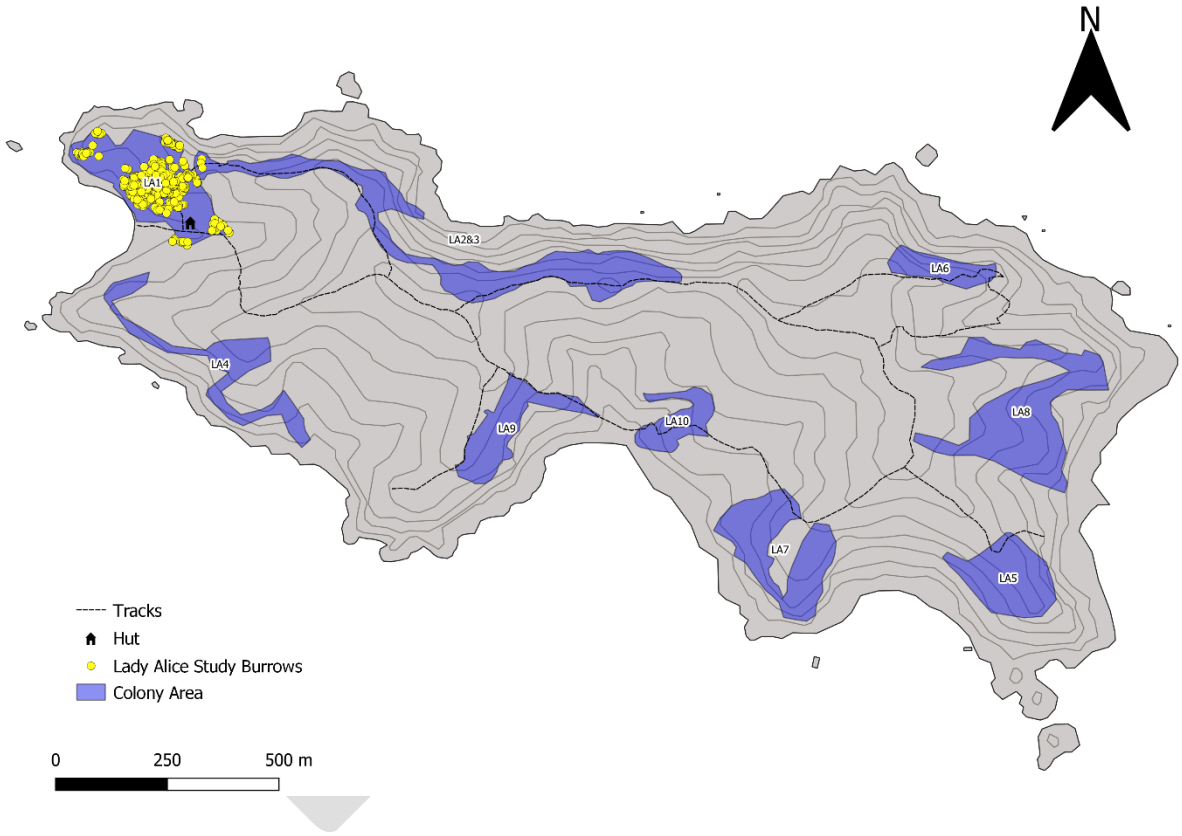

Figure 2. Map of Lady Alice Island showing the location of study burrows and all known flesh-footed shearwater colonies.

2.2 Field Methods

December and January Trips

Each study burrow was checked regularly during the December and January trips to determine the breeding status of the burrow and identify both partner birds. All birds found in these burrows were banded or had their band number checked and recorded. The sex of the bird was determined (or confirmed) by cloacal examination, during the December trip, or from known partner birds with

determined sex. Birds found in burrows were marked with correction fluid on the top of their head to prevent unnecessary handling during future burrow checks, and then placed back in their burrow. To reduce disturbance on incubating birds, smartphones were held down the burrow to video the occupants and check for correction fluid on their head.

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. Empty and non-breeding burrows were checked all the way up until the day we departed each island.

For any burrows that had failed (i.e., due to 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 has proven 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.

A subset of burrows are marked as to only be monitored using a burrowscope or smartphone, and the adult birds are never removed from the burrow. No hatches are dug in to burrowscope burrows. After previous recommendations (Crowe & Burgin 2021) burrowscope burrow numbers were increased from 30 to 50 on both Ohinau and Lady Alice Island this season. Burrowscope burrows were checked only once during the December and January trips. This was carried out on 21 December (Ohinau) and 19 January (Lady Alice) after all breeding birds were expected to have laid (Bell et al. 2017). The burrowscope, or smartphone, was fed down the entrance of the burrow until a bird was seen and then confirmed as to whether it was incubating an egg or not. If no bird was seen after a thorough search, the burrow was recorded as being empty.

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 21:00 and 23:00, or 03:00 and 06:00. Adults were caught using a hand-net and were banded, marked with correction fluid and the general capture location was recorded relative to the known study colony. The bird was then released at the same location they were captured.

April-May Trips

At the end of April/start of May, both islands were revisited, to check study burrows again. All study burrows were checked, regardless of their breeding 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 banded chicks were marked with correction fluid on their head to prevent unnecessary recapture when undertaking night banding. Breeding success is defined here as burrows with an egg that produce a chick that is likely to survive to fledge. Because chicks fledge in early May (Priddel et al. 2006), burrows with chicks during this trip 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/May trip. Chicks were extracted where possible by hand or leg hook to be banded and have measurements taken (as above), before being placed back in their burrow. Empty burrows and failed burrows were confirmed using the burrowscope, smartphone and/or probing the burrow with a stick.

Night work on these trips was primarily aimed at catching any chicks coming out of burrows to exercise and preparing to fledge. Chicks caught were banded, weighed and had wing length measurements taken. They were also marked with correction fluid and the general capture location was recorded relative to the known study colony. There was no apparent preferred time for chicks to be on the

surface, so catching took place at any time after dark. Some adults were still present on the islands at this point and were also captured. Adults were either banded, or their band number taken, marked with correction fluid and the general capture location was recorded relative to the known study colony. Birds were then released at the same location they were captured.

Māhoe die-off and subsequent understory growth

Previous trips to Ohinau Island in 2020 revealed that in some areas of the island, the dominant canopy species māhoe (*Melicytus ramiflorus*) had died off and this had caused nightshade (*Solanum* sp.) and inkweed (*Phytolacca octandra*) to grow in the understory (Crowe & Burgin 2021). Most areas with māhoe had experienced some die-off with nightshade and inkweed growth. Some areas, particularly the northwest facing slopes around Camp Colony, had extensive die-off and thick nightshade and inkweed growth. The māhoe die-off was likely caused by the drought conditions that were experienced in the 2019/20 summer in northern parts of the North Island (NIWA 2020). This has caused issues with finding study burrows within these areas, and we found the regrowth of nightshade and inkweed to be even thicker this season (2021/22), particularly in the eastern parts of Camp Colony (Figure 3).

During the December trip, despite our best efforts, it was immensely difficult to locate burrows as tags were either covered up entirely, or the trees that they had been fixed too had fallen over and buried the marker. Additionally moving through this area was difficult and the risk of collapsing burrows was high without being able to see where we were stepping. This led us to make the decision to retire 21 burrows in December 2020 in the camp colony area where the regrowth was thickest. We then found new burrows within other areas of the study colonies, to replace these and ensure we reached 200 breeding study burrows, as well as 50 breeding burrowscope burrows. This deadfall continued into the April/May 2022 trip too, with continual deadfall and weed growth causing a further 3 burrows to be retired in Camp Colony.

Figure 3. Thick regrowth within drought hit areas of Camp Colony on Ohinau Island, December 2021

3. RESULTS

3.1 Occupancy

Ohinau Island

A total of 261 study burrows were monitored throughout the entire 2021/22 season on Ohinau Island (Table 2). This consisted of 232 study burrows monitored in the previous season and 29 new study burrows put in over the December and May trips combined. 35 study burrows were retired over the course of the season on the island, 24 of those being in Camp Colony due to the māhoe die off. Other burrows were retired either due to being lost because of treefall, understory regrowth, the burrow had collapsed, or was too deep to access birds inside the burrow.

Of the 261 study burrows, 85% (*n* = 221) were breeding burrows and 4% (*n* = 11) were non-breeding burrows. The remaining 29 burrows were empty or held other species (Table 2). A total of 73% (324 of 442) of birds in breeding study burrows were identified. We were able to successfully identify both partners for 54% (*n* = 120) of these 221 breeding burrows (Table 2). 38% (*n* = 84) of breeding burrows had only one partner identified while the remaining 8% of burrows (*n* = 17) had neither partner identified. Four of these 17 burrows had birds seen in them during December, but no eggs discovered. Seven were empty in December with no egg, but ultimately had a chick during the April/May burrow checks, indicating a bird that laid after we had departed the island. One of these was a re-discovered burrow in May, and the remaining five were all new burrows in May where a chick was found but no parents.

Table 2. Breakdown of burrow status for all study burrows on Ohinau and Lady Alice Islands 2021/22 season.

Burrow Status	Ohinau Island	Lady Alice Island
Breeding		
- 0 partners	17	5
- 1 partner	84	18
- 2 partners	120	179
Total breeding burrows	**221**	**202**
Non-breeding		
- 1 bird	9	9
- 2 birds	2	9
Total flesh-footed shearwater burrows	**232**	**220**
Other species		
- Little Penguin		11
- Grey-faced Petrel (chick in Jan)	8	2
- Little Shearwater	2	
-Pycroft Petrel		3
- Sooty Shearwater	1	3
Empty	17	82
Total Study Burrows	**261**	**302**
Total Retired Burrows	**35**	**12**

Lady Alice Island

A total of 302 study burrows were monitored on Lady Alice Island this season (Table 2). This consisted of 288 burrows monitored in the 2020/21 season and 14 new burrows. Two additional burrows were retired because they had collapsed or were lost.

Occupancy on Lady Alice Island was 67% (*n* = 202) this season of the 302 study burrows being breeding burrows and 6% (*n* = 18) being non-breeding burrows. The number of true empty burrows (no flesh-footed shearwaters or any other seabird species observed in the burrow) was higher this season (27%) compared to the 2020/21 season (24%), whereas the number of other species in study burrows was lower. Nineteen study burrows (6%) contained either a grey-faced petrel chick, little penguin, or sooty shearwater.

A total of 93% (376 of 404) of birds in breeding study burrows were identified. We were able to identify both partners in 89% (*n* = 179) of breeding burrows. 9% (*n* =18) of breeding burrows had only one partner identified and the remaining 3% (*n* = 5) had no partners identified. These burrows either had a cold egg present with no adults during checks, adults out of reach or were missed during the January trip.

3.2 Breeding Success

Study Burrows

Breeding success for Ohinau Island was 59% (*n* = 131) while on Lady Alice Island it was 51% (*n* = 104). The difference in breeding success between the two islands was not significant (Pearson Chi-Square, $\chi^2_1 = 2.77$, p = 0.10). It appears more burrows failed during the incubation stage rather than the chick-rearing stage on both islands, however, there is a large degree of uncertainty, as the cause of burrow failure could not be determined in the majority of cases (Table 3).

Table 3. Summary of breeding outcomes for study burrows and burrowscope burrows on Ohinau and Lady Alice Islands

	Ohinau		Lady Alice	
	Study Burrows (*n*= 261)	**Burrowscope (*n* = 58)**	**Study Burrows (*n* =302)**	**Burrowscope (*n* = 64)**
Breeding Burrows	221	53	202	49
Breeding success	131 (59%)	36 (68%)	104 (51%)	24 (49%)
Failed, pre-hatching	17 (8%)	3 (6%)	16 (8%)	0 (0%)
Failed, post-hatching	9 (3%)	0 (0%)	12 (6%)	3 (6%)
Failed, unknown reason	64 (29%)	14 (26%)	71 (35%)	22 (45%)

Historic breeding success for both islands, and across study and burrowscope burrows are shown below in Figure 4.

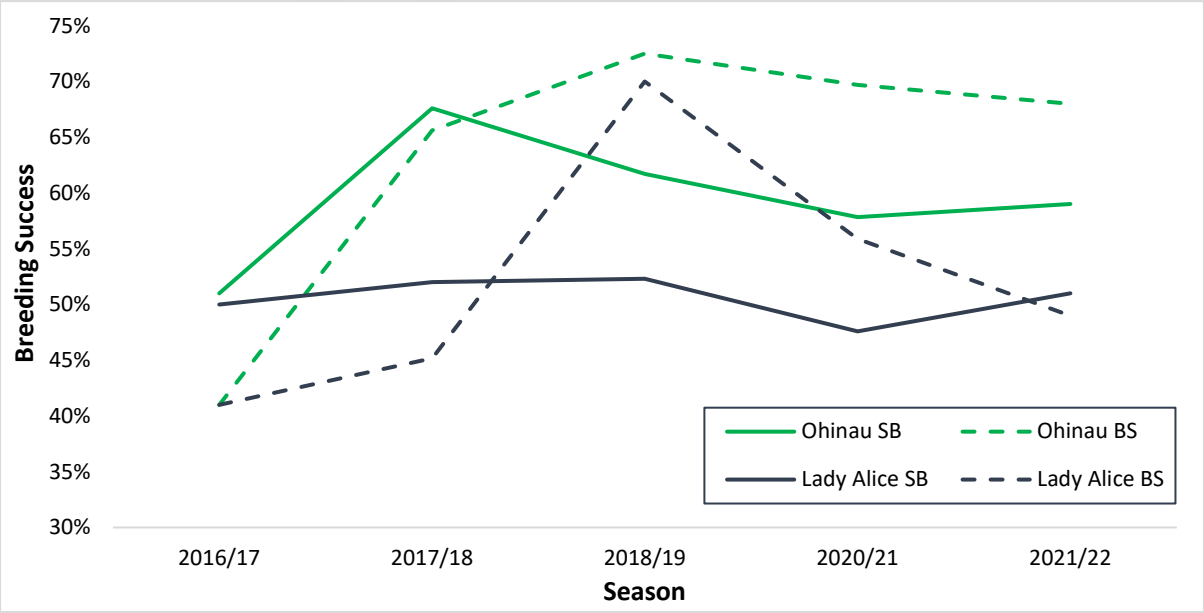

Figure 4. Breeding success (%) for both study and burrowscope burrows on Lady Alice and Ohinau Island from 2016/17 through to the 2021/22 season.

The average breeding success for all burrows combined (study and burrowscope) since 2016 is 59% for Ohinau Island and 51% for Lady Alice Island. Breeding success has been higher on Ohinau Island in all seasons apart from the 2016/17 season when it was marginally lower (Figure 5).

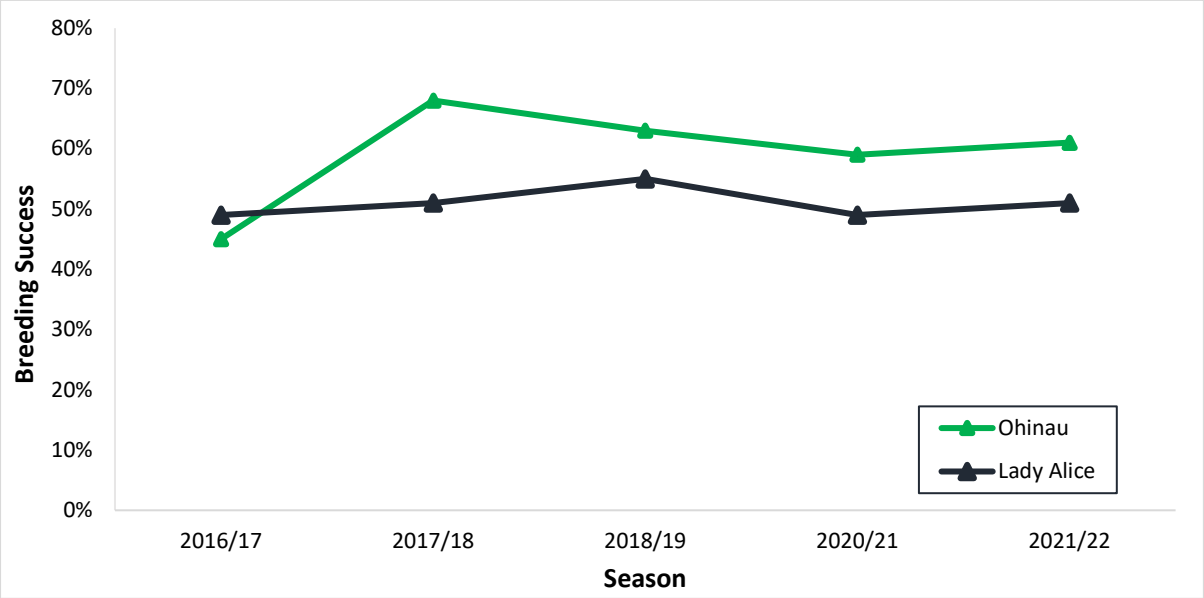

Figure 5. Combined breeding success (%) from study and burrowscope burrows on both Lady Alice and Ohinau Island from 2016/17 to the 2021/22 season

Burrowscope Burrows

Breeding success in Ohinau Island burrowscope burrows was 68% compared to 59% in study burrows, however, this difference was not significant indicating that there is little or no impact of handler disturbance (Pearson Chi-Square, $\chi^2_1 = 2.52$, $p = 0.11$). On Lady Alice Island, breeding success in burrowscope burrows was 49% compared with 51% in study burrows, and similarly this difference was not significant indicating that there is little or no impact of handler disturbance (Pearson Chi-Square, $\chi^2_1 = 0.16$, $p = 0.69$).

3.3 Banding Totals

During the 2021/22 season, 165 birds were banded on Lady Alice Island and 349 birds were banded on Ohinau Island (Table 4). In total, 3875 flesh-footed shearwaters have been banded across both islands during this study.

Table 4. Number of flesh-footed shearwaters banded on both islands in the past seven seasons.

Ohinau	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	**Total**
Adult	90	528	182	210	470	188	180	**1848**
Chick	267	133	131	453	0*	127	169	**1280**
Total	357	661	313	663	470	315	349	**3128**

Lady Alice	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	Total
Adult	0	285	163	102	118	38	59	**765**
Chick	0	94	83	103	0*	110	106	**496**
Total	0	379	246	205	118	148	165	**1261**

**** COVID-19 prevented WMIL from undertaking a chick trip***

Total birds banded during study	**4389**

3.4 Recaptures

A total of 789 (193 chicks, 596 adults) flesh-footed shearwaters were banded between 2000 and 2009 on Lady Alice Island (Andrea Booth unpublished dataset; Barbraud *et al*. 2014). Of these, 10% (*n* = 19) of chicks and 15% (*n* = 92) of adults have been recaptured in the previous six seasons on Lady Alice Island. There were no new recaptures of any of the 789 birds this season. Thirty-eight of the 111 recaptures were birds that were banded as adults in 2000. Twenty of these birds were recaptured during the 2021/22 season, making these birds at least 27 years old now. The oldest known-age birds breeding in the colony on Lady Alice Island are two birds banded as chicks in 2000 making these birds 22 years old.

Of the 1480 adults that had been banded on Ohinau Island as part of this study from 2015-20, 50% (*n* = 737) have been recaptured again. For Lady Alice Island the result is higher with 65% (*n* = 499) of the 765 banded adults having been recaptured. This is understandable considering the larger number of birds banded before WMIL started it's monitoring on Lady Alice in 2016.

Seven birds that were banded as chicks as part of the 2015/16 Ohinau Island cohort were recaptured this season as adults. This is in addition to the five that were caught in the 2019/20 season, and two in the previous season (2020/21). The age at first return of these seven birds is five years old. Four birds were recaptured on the surface at night-time and were in the same colonies that they fledged from and mostly within the same immediate area as their natal burrow. The other three were found within non-breeding burrows that were very close to their natal burrow (range 0.1-19m). An additional chick banded in April 2017 season was found this season at 4 years old in a burrow 15m from its natal burrow. In total, 5.2% (*n* = 14) of the 267 chicks banded on Ohinau Island in 2015/16 have been recaptured so far.

No chicks from the 2016/17 cohort were recaptured this season on Lady Alice Island.

4. DISCUSSION

4.1 Occupancy

The number of study burrows currently being monitored is at a suitable number and, provided occupancy rates remain approximately the same, few burrows will need to be added in future seasons to maintain a sample of 200 breeding burrows per island. Occupancy rates were higher on Ohinau Island (85%) than Lady Alice Island (67%) and we suggest that the reason for higher occupancy was due to fewer number of study burrows being occupied by other seabird species, or being entirely empty. 14 new study burrows were added on Lady Alice Island to reach 202 breeding study burrows, whilst 29 new study burrows were added on Ohinau to ensure we reached over 200 breeding study burrows. Burrows that have collapsed, are continually occupied by a different species, or remain

inactive for multiple seasons, were retired, but there was a large proportion of burrows on Ohinau that were retired (*n* = 35) compared to Lady Alice (*n* = 2) predominantly due to the māhoe die off.

The occupancy rate on Ohinau Island has remained relatively similar to previous seasons, although this season being higher than last year (76%). The occupancy rate on Lady Alice Island was also higher this season than last season (54%). We weren't able to identify a higher number of breeding partners on Ohinau Island due to four days of heavy rain during the December trip, which prevented burrow checks being undertaken.

4.2 Breeding Success

On Ohinau Island, breeding success this season was 59%, down from the 62% measured in the 2018/19 season and 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 & Atkinson 1984).

The breeding success on Lady Alice was 51% which is an increase from the previous season. This is the second highest measurement for study burrows since the study began in 2016/17. It is only 1% lower than the highest measurement of breeding success on Lady Alice Island (52% in 2017/18 and 2018/19) and 3% higher than the lowest measurement (48% in 2020/21) and as such is a typical measurement of breeding success. Breeding success has been considerably lower than Ohinau Island for the majority of seasons, and lower than would be expected for this species in a predator-free environment. Previous seasons have had notable climate-related explanations such as floods or La Niña seasons which may have impacted birds breeding on Lady Alice Island to greater degree than those breeding on Ohinau Island. Grey-faced petrels are likely to cause at least some breeding failures on Lady Alice, but this factor is equally, or more pronounced, on Ohinau Island. On Ohinau Island none of our study burrows with grey-faced petrels present in April contained a flesh-footed shearwater chick, whereas two study burrows on Lady Alice contained both a flesh-footed shearwater and adult grey-faced petrel. 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).

On both islands there are usually a small percentage of burrows (typically <2%) that have a chick present in April/May that had no egg in December. It is assumed that birds breeding in these burrows laid after we departed the island prior to Christmas, however, it is also possible that some or all of the chicks present in these burrows had actually been displaced from their natal burrow by a grey-faced petrel or other seabird (Taylor 2000). Going by the assumption that these birds laid after our departure, there are also an unknown number of birds that lay after we depart the islands in December but fail (and leave no evidence of a breeding attempt) prior to our visit in April/May. This is a limitation of only having two visits to the island per breeding season but is pertinent only to when the summer visits are in December. As all birds are expected to have laid by the end of December, field trips to the islands in January should not be subject to this limitation and any chick found in a

burrow that did not have an egg in January can be assumed to have been displaced from a different burrow or the egg was missed in January.

Breeding success observed in burrowscope burrows was not significantly higher to that observed in study burrows on both islands when a Pearson Chi Square analysis was undertaken. Burrowscope breeding success on Lady Alice was 2% lower this season than study burrows though. This may be due to the increased sampling size this season, and further analysis will be needed as we know increasing the sample size of burrowscope burrows will continue to give greater statistical power to detect true differences in the breeding success of study and burrowscope burrows. This shows the value of returning to the Lady Alice to ascertain the breeding outcomes of the breeding burrows. It is important to note that this April trip was not funded by DOC, but solely funded by WMIL to gather that data. Any use of breeding success estimates in population modelling should use the burrowscope measurements as these are likely to be more representative measurements of breeding success for the population as a whole.

4.3 Banded Birds

A total of 349 birds consisting of 180 adults and 169 chicks were banded on Ohinau Island this season. The number of adults banded has remained consistently high across all seasons with most birds encountered on the surface at night-time being unbanded. The majority of birds caught at night-time on Ohinau Island are caught on or just off the main track which goes up through Camp Colony. Most birds encountered in existing study burrows are already banded.

The number of newly banded adults on Lady Alice Island has diminished slightly over the last two seasons and this is because the majority of the birds encountered in study burrows, or on the surface at night time, are now banded. A total of 165 flesh-footed shearwaters were banded on Lady Alice, consisting of 59 adults and 106 chicks. Most of these birds came from study burrows or random burrows within the colony and very few chicks were encountered on the surface at night time.

4.4 Recaptured Birds

One of the main aims of the December trip to Ohinau Island was to focus effort at the start of the trips on recapturing birds on the surface at night time. Previous trips to these islands just prior to the commencement of egg laying have proved highly successful with large numbers of breeders and non-breeders encountered on the surface at night-time. Discrepancies between total recapture rates of banded adults (surface- and burrow-caught) on both islands most likely has two contributing factors. Firstly, a larger percentage of birds are banded on the surface on Ohinau Island. Surface banded birds have a lower recapture probability as they have a higher proportion of young and non-breeding birds who are more transient than burrow-caught birds (Barbraud *et al*. 2014). Secondly, all banding and recapturing effort on Lady Alice Island is concentrated within one relatively small area (the LA1 colony) whereas, on Ohinau Island, effort is spread over the island through multiple colonies.

The proportion of chicks banded between 2000 and 2009 that have returned to Lady Alice Island (10%) is very similar to the 8% return rate reported by Bell *et al.* (2016) in the black petrel population on Aotea/Great Barrier Island over a 20-year period. While this estimate of recruitment is extremely low and suggests a low juvenile survival rate, it is based on a small sample size and is probably a reflection of the detectability of returned chicks, more so than survival. 5.2% (n = 14) of the 267 chicks banded on Ohinau Island in 2015/16 have been recaptured so far. All of these individuals are most likely non-breeders as they have either been caught on the surface at night-time, or found within non-breeding burrows.

The first bird recaptured from a later cohort on Ohinau Island was a chick banded in April 2017 and found this season at 4 years old in a burrow 15m from its natal burrow. No birds from any later cohorts

have been recaptured on Lady Alice Island, but this was partly expected as birds do not generally start to return to their natal colonies until an average of 6 years old (Barbraud *et al.* 2014). We anticipate that a larger number of birds from the 2015/16 cohort and a smaller number from later cohorts will be recaptured in the forthcoming seasons. An even smaller number of these may be detected breeding within the study burrows.

4.5 Plastic Pollution

Plastics have been documented on Ohinau Island before (Buxton *et al*. 2013), and through the monitoring of this species by WMIL since 2016, plastics have been noted on the surface and within burrows (M. Bell and P. Crowe *pers. comm*). During the May 2022 trip to Ohinau Island, 11 chicks were found dead either on the surface or within their burrow, and when dissected were found to contain plastic fragments (Figures 6-9). A single adult was also found dead on the surface with plastic fragments inside the digestive tract. Fragments were of a variety of sizes and colours, but predominantly white, as found on Lord Howe Island (Lavers *et al*. 2014). The weight varied considerably between individuals. We collected all plastic fragments found and are currently processing them for a separate publication.

Plastic pollution is a threat of similar magnitude to climate change due to its negative impacts on global biological systems (Whitehead *et al*. 2019), including the world's oceans (Eriksen *et al*. 2014). Plastic ingestion by seabirds was first reported internationally in the 1960s for Laysan Albatross (*Phoebastria immutabilis*) (Kenyon & Kridler 1969) and has become a pervasive and increasing threat to all seabird species (Wilcox *et al*. 2015). Plastics have been documented along New Zealand's coastlines and within its marine environments (Gregory 1977; 1978; 1996; 1999; Young & Adams 2010; Yeo *et al*. 2015; Clunies-Ross *et al*. 2016). Plastics in New Zealand seabirds was first noted in the 1970s (Gregory 1978; Harper & Fowler 1987). The ingestion of plastics is a known threat for flesh-footed shearwaters, but predominantly from overseas literature (Hutton *et al*. 2008; Lavers *et al*. 2014; Bond *et al*. 2021), with little having been documented of its presence and effect for this species in New Zealand, as is still the case for many species of seabird in New Zealand (Taylor 2000; Buxton *et al*. 2013). Whilst we cannot be fully confident that the plastic fragments we found in the 11 chicks were the cause of death, the quantity within some of the deceased chicks was large relative to their assumed fledging body weight of 600-700g. One individual was found to have 35g of plastic in its gastrointestinal tract (Figure 6). This equates to roughly 5-6% of the average fledging weight of 600-700g. With it being thought that flesh-footed shearwater chicks are potentially unable to regurgitate indigestible material, as adults do through boluses, this plastic loading is concerning and could be the cause of death (Lavers & Bond 2016). Additional potential negative impacts for these chicks include internal and external perforations, blockage of the digestive tract, impairment of feeding capacity, and secondary poisoning from the leaching of toxic compounds and their interactive effects with the endocrine system (Gregory 2009; Buxton *et al*. 2013; Tanaka *et al*. 2013; Lavers *et al*. 2014). Furthermore, chicks could be experiencing reduced fat deposition and reduced body mass as a result of this ingestion (Auman *et al*. 1997; Lavers *et al*. 2014). Adult flesh-footed shearwaters will have picked up these plastic fragments whilst foraging at sea and passed them on when regurgitating food to their young. It is postulated that much of this plastic is likely floating on, or just below, the ocean's surface where adults are known to forage (Rayner *et al*. 2011). They are possibly mistaking floating pieces for prey items such as squid (Lavers *et al*. 2014; Lavers & Bond 2016), but it could also be that plastics are being ingested by prey items and bioaccumulating in this apex predator, as reported in Australian gannets (Morrus serrator; Jawad et al. 2021). Seabirds are ocean sentinels and act as indicator species for marine plastic pollution in New Zealand, as has been found in eastern Australia (Bond *et al*. 2021).

We are concerned by the level of plastic being consumed by flesh-footed shearwaters at this breeding colony and believe it is a significant threat to this population, as has been found on Lord Howe Island (Lavers *et al*. 2014). If plastic ingestion in chicks is high, repeated years of low breeding success and

juvenile survival may result in declines. We assume chicks found alive in burrows fledge successfully, however they may have ingested plastic too and die after we leave the island due to the sublethal effects of ingestion (Tanaka *et al*. 2013; Lavers *et al*. 2014). For instance, one individual chick threw up a ~1.5cm piece of white plastic during handling when banding, indicating plastic ingestion. The interaction of this threat with other key threats; commercial and recreational bycatch, climate change and other forms of human disturbance and pollution could be having population level impacts on this and other breeding colonies. However, throughout the literature there is a noticeable lack of reported data for plastic ingestion in seabird species within New Zealand. Despite the high number of species and high relative risk for plastic ingestion within New Zealand (Wilcox et al. 2015), plastic pollution remains an overlooked aspect of seabird conservation. The flesh-footed shearwater colonies located on Ohinau and Lady Alice Islands present an opportunity to understand the long-term impacts of plastics pollution in New Zealand.

Figure 6. 35g worth of plastic removed from a dead flesh-footed shearwater chick's digestive tract on Ohinau Island, May 2022.

Figure 7. White and green plastic fragments (circled in red) visible within the digestive tract of a decomposing flesh-footed shearwater chick on the surface of Ohinau Island, May 2022

Figure 9. Decomposing flesh-footed shearwater chick on Ohinau Island, with white and red plastic fragments visible in digestive tract, May 2022.

Figure 8. Decomposing remains of a flesh-footed shearwater chick with green, blue and white plastic fragments visible in digestive tract on Ohinau Island, May 2022

5. Conclusions and Recommendations

5.1 Demographic monitoring

The number of study burrows on Ohinau and Lady Alice Islands are a suitable number for long-term demographic monitoring. Significant effort has been put in to banding flesh-footed shearwaters on both islands since 2016 with over 1,700 chicks and over 2,600 adults having been banded across both islands taking the total number of birds over 4,300. Recapture efforts of breeding adults and non-breeders need to be consistently large scale to provide a robust mark-recapture dataset and the large banding effort will help to achieve this.

We recommend that:

- **Population monitoring on Ohinau and Lady Alice Islands be continued with 200 breeding study burrows monitored annually over two surveys (Dec/Jan and Apr/May).**
- **The number of burrowscope burrows monitored annually continue to be 50 on each island.**
- **A survival analysis be undertaken to estimate adult survival on each island.**
- **There is continued, focussed effort to band and recapture as many flesh-footed shearwaters on the surface and in burrows on both islands.**

A significant mark/recapture dataset has been collected and an attempt should be made to analyse this data and obtain an estimate of adult survival. A concerted effort to continue to band and recapture birds on both islands will allow more robust estimates of age at first return (i.e., recruitment) and adult survival to be made, estimate juvenile survival and age at first return, and measure changes in these demographic parameters over time.

We anticipate that the māhoe and inkweed growth around study burrows on Ohinau Island will be an ongoing issue for at least the next two seasons until the māhoe regrows to form a new canopy and shade out the weedy areas. This needs to be taken into account for logistics as at least two days will be required at the start of each trip to clear the tracks and access points to study burrows (with great care not to damage burrows) to allow easier observer access for burrow checks.

5.2 Tracking

As the biggest current quantifiable threat to the population viability of flesh-footed shearwaters is adult mortality associated with commercial longline and trawl fisheries, the tracking data collected during the 2019/20 season can be used to improve estimates of the at-sea distribution and habitat use of adult flesh-footed shearwaters during the breeding season. These improved estimates can then be used to improve spatially-explicit models of bycatch risk and be used to help determine mitigation measures to help reduce the incidence of bycatch of flesh-footed shearwaters. Further tracking of juvenile birds post-fledging may help to determine juvenile mortality in the first month after fledging and better understand the low recruitment rates that have been recorded on Lady Alice Island so far.

- **We recommend that a simultaneous sample of 10 juvenile and 10 adult flesh-footed shearwaters be tracked using PTTs in April/May to determine migration routes, and any differences between adult and juvenile mortality during this period.**

By sampling both adults and juveniles simultaneously we will be able to determine differences in foraging distribution and behaviour, but also whether juveniles are particularly vulnerable to mortality events during their first few months at sea as suspected by other work (Afán et al. 2019).

5.3 Plastics

We recommend that focused monitoring be undertaken on plastics at both colonies. Only through continued population monitoring, undertaking regular population estimates over time, as well as monitoring for plastic pollution and ingestion at breeding colonies will we be able to determine how this species is faring under a plethora of interacting threats. We urgently need more research on plastic ingestion for flesh-footed shearwaters and other species in New Zealand, as it may hinder the recoveries hoped from relatively recent eradications of introduced predator at breeding sites (Buxton et al. 2014) and information is therefore crucial to linking increasing plastic pollution and population trends (Lavers & Bond 2016).

- **We recommend this involves undertaking plastic collection from the surface of colonies, necropsy of dead individuals found at colony sites, as well as the lavage technique, as used by Lavers *et al*. (2021).**

Plastic pollution at the colonies could pose a significant risk to the future of this species, and it is important that urgent action be taken to gather more data to better understand this risk more, and better inform conservation management and policy.

6. Management of Records of Banded Birds, Study Burrows and Transect Data

Copies of the field records of all newly banded birds during our trips and any previously banded birds will be deposited with the Marine Species and Threats team, Department of Conservation, Wellington. Banding schedule records will also be 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, will be deposited with the Marine Species and Threats team, Department of Conservation.

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