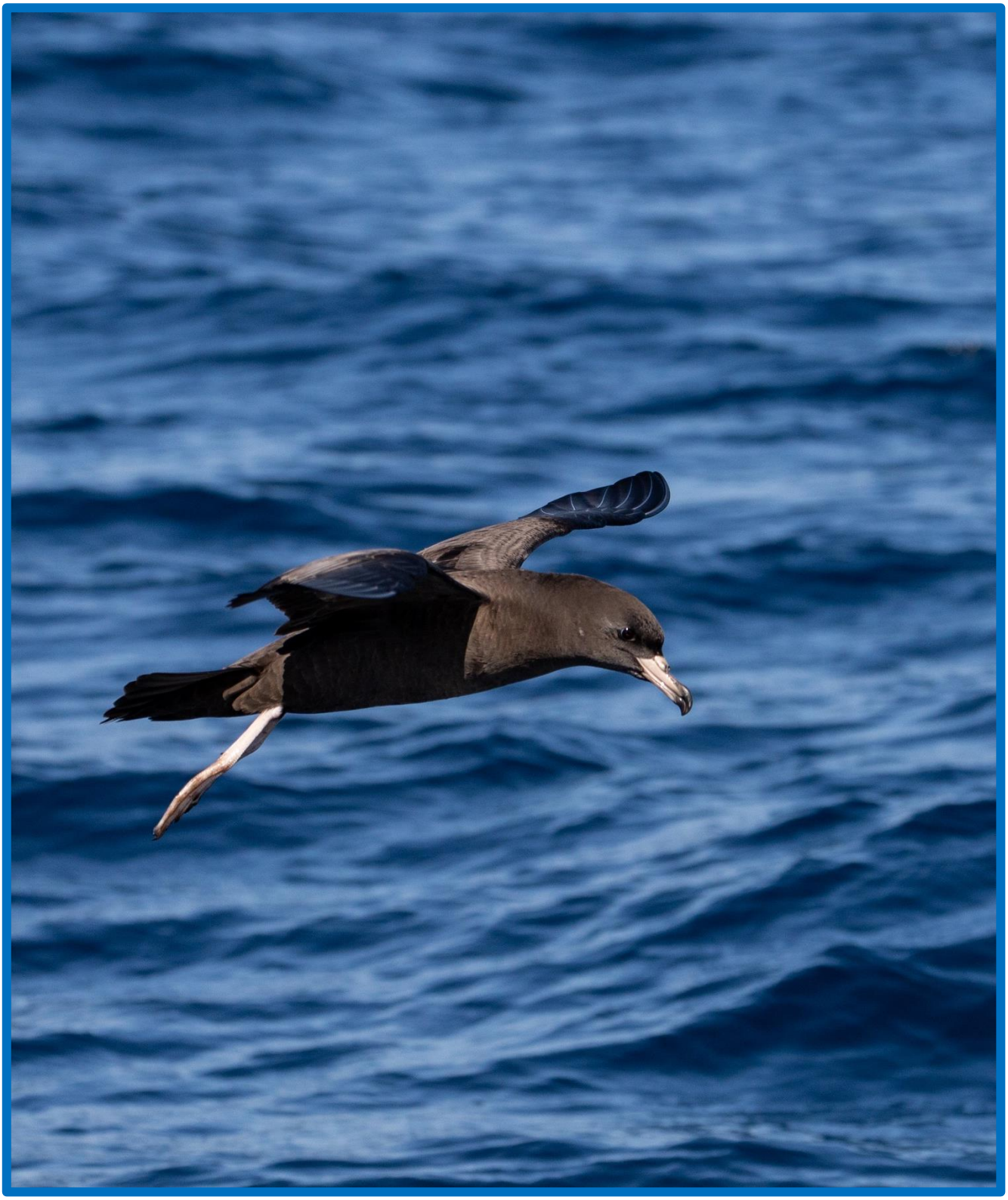
TOANUI/FLESH-FOOTED SHEARWATERS



Toanui/flesh-footed shearwater population monitoring and estimates: 2023/24 season – Draft report for CSP meeting 25 July 2024

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

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EXECUTIVE SUMMARY

This report covers the findings from the year of toanui/flesh-footed shearwater (*Ardenna carneipes*) research under Conservation Services Programme (CSP) project POP2021-04 for the 2023/2024 season, funded by Department of Conservation (DOC). Here we report on the ongoing population monitoring of flesh-footed shearwaters on Ohinau Island and Mauimua/Lady Alice Island. As well as updated population estimates and tracking of adults for both islands.

During the 2023/24 season WMIL monitored 263 and 291 study burrows on Ohinau Island and Lady Alice Island respectively. Of these 71.5% and 71.8% were breeding burrows for Ohinau and Lady Alice respectively. We were able to identify 61% of breeding birds in burrows on Ohinau Island and 86% of burrows on Lady Alice Island. Determining breeding success was not a deliverable for this season. On Ohinau 5.1% of chicks, which have been banded since monitoring began, have been recaptured at the colony and on Lady Alice 11.8% of banded chicks have been recaptured.

Burrow transects were carried out on both Ohinau Island and Lady Alice Island to gather data for an updated population estimate for these islands. On Ohinau 116 transects, each aiming to cover 40m², were completed within eight different colonies on the island. We estimate that there are a total of 3,722 occupied breeding burrows (1,881 – 5,566, 95% CI) on Ohinau Island which is a decrease of 4.17% since 2018. On Lady Alice Island 323 transects were completed within nine colonies. We estimate that there are a total of 2,367 occupied breeding burrows (1,431-3,303, 95% CI) which is decrease of 26.4% since 2019.

Tracked adults from Lady Alice foraged in similar areas to previous years during incubation. Travelling around the west coast of the North Island and out to the Louisville Seamount. Birds were undertaking reasonably long trips with an average of 13 days. No devices were retrieved from Ohinau Island, with adults being away for 12 days or more.

Fledging chicks from Titi Island travelled north through the pacific, taking two routes either east or west up the North Island.

WMIL recommendations include:

- Population monitoring on Ohinau and Lady Alice Islands be continued with 200 breeding study burrows monitored annually over two expeditions (Dec/Jan and Apr/May).
- The number of burrowscope burrows monitored annually continue to be 50 on each island.
- There is continued, focused effort to band and recapture as many flesh-footed shearwaters on the surface and in burrows on both islands.
- Titi Island, Marlborough Sounds, be considered as a potential future monitoring location.
- Repeat population estimates on Ohinau Island, Lady Alice Island and Titi Island be undertaken as soon as possible.
- Other breeding colony sites for flesh-footed shearwaters be considered for population estimates.
- Future tracking should use lighter devices with a maximum of 2.5% device body weight and be undertaken at Lady Alice, Ohinau and/or Titi Islands during chick fledging.
- Trial harnesses for chick tracking.
- A survival analysis be undertaken to estimate adult survival on each island.

KEY OBJECTIVES & OUTPUTS

This research was carried out as part of the Conservation Services Programme, flesh-footed shearwater research project (POP2021-04). Key objectives WMIL were funded by DOC to complete:

1. To collect key demographic parameters of flesh-footed shearwaters at Ohinau and Lady Alice Islands, especially adult survival, juvenile survival and recruitment rates.
2. To estimate the current breeding population of flesh-footed shearwaters on both Ohinau and Lady Alice Islands to compare with past surveys.
3. To carry out GPS tracking of flesh-footed shearwaters during the incubation period on both islands (DOC to supply GPS tags).

Objective 1 is ongoing, and Objective 2 and Objective 3 were completed on both Ohinau Island and Lady Alice Island in December and January of the 2023/24 season.

Toanui/flesh-footed shearwater population monitoring: 2023/2024

1. INTRODUCTION

Toanui/flesh-footed shearwaters (*Ardenna carneipes*) are a medium sized seabird resident to the Indian and Pacific Oceans (Priddel et al., 2006). Breeding colonies are found on islands off the coast of northern New Zealand with the southernmost breeding colony on Titi Island, in the Marlborough Sounds on Te Waipounamu/South Island (Taylor, 2000). Breeding colonies are also found off the coast of 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 (Lavers, 2015; Waugh et al., 2013). 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 (Abraham et al., 2010; G. B. Baker & Wise, 2005), competition for prey with commercial and recreational fisheries, habitat degradation from fishing practices such as bottom trawling (Gaskin & Rayner, 2013), plastic ingestion (Bond et al., 2021; Hutton et al., 2008; Lavers et al., 2014, 2021), invasive species (Croxall et al., 2012; G. Taylor, 2000), 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 (Abraham & Thompson, 2011; C. J. R. Robertson et al., 2004). 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, utilising Australian and New Zealand waters during the breeding season, and migrating to the northern hemisphere portions of the Pacific Ocean post-breeding (Rayner et al., 2011; G. Taylor, 2000). These threats are known to be prevalent across their range, meaning effective conservation management for this species must be supported by international co-operation to avoid continued declines.

While the population of flesh-footed shearwaters on Lord Howe Island in Australia has been relatively well studied (Lavers, 2015; Lavers et al., 2014; 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 (G. 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.

Lady Alice has been monitored intensively by Wildlife Management International (WMIL) staff for six consecutive seasons from 2016/17 – 2021/22 and Ohinau Island for eight consecutive seasons 2016/17 - 2023/24 (Mischler, 2016; Crowe et al., 2017; Crowe, 2018; Crowe & Bell, 2019; Crowe, 2020; Crowe & Burgin, 2021; Burgin & Ray, 2022; Ray & Burgin, 2023). Lady Alice was not able to be monitored in the 2022/23

season due to Department of Conservation (DOC) budget cuts and was deferred for a year. WMIL have undertaken population estimates on both of these islands, Lady Alice in 2019, and Ohinau in 2018 (Crowe, 2018a; Crowe & Bell, 2019). WMIL has also undertaken a population estimate for Titi Island in the Marlborough Sounds, in 2022 (Burgin & Lamb, 2022). GPS tracking of adults has been undertaken on both Ohinau and Lady Alice to determine incubation and chick rearing routes (Kirk et al., 2017; Crowe, 2018b). and tracking of fledging chicks in 2019 and 2023 (Ray & Burgin, 2023).

This report presents results on the most recent work undertaken during the 2023/24 season on Ohinau Island, Lady Alice Island and Titi Island.

2. METHODS

2.1 Study Sites and Dates

2.1.1 Ohinau Island

Ohinau Island (south of the 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 DOC. There are 12 flesh-footed shearwater colonies on Ohinau Island, five of which contain monitored study burrows (Camp, Camp South, South of Gully, Hilltop and Pōhutukawa; Figure 1). These study burrows have been monitored intensively since 2016 seasons 2016/17 -2023/24 (Mischler, 2016; Crowe et al., 2017; Crowe, 2018; Crowe & Bell, 2019; Crowe, 2020; Crowe & Burgin, 2021; Burgin & Ray, 2022; Ray & Burgin, 2023) There is an estimated total of 4,007 (3,044 – 4,791) occupied burrows on the island (Crowe, 2018a). A team of four WMIL staff were based on the island from 29 November to 21 December, 2023.

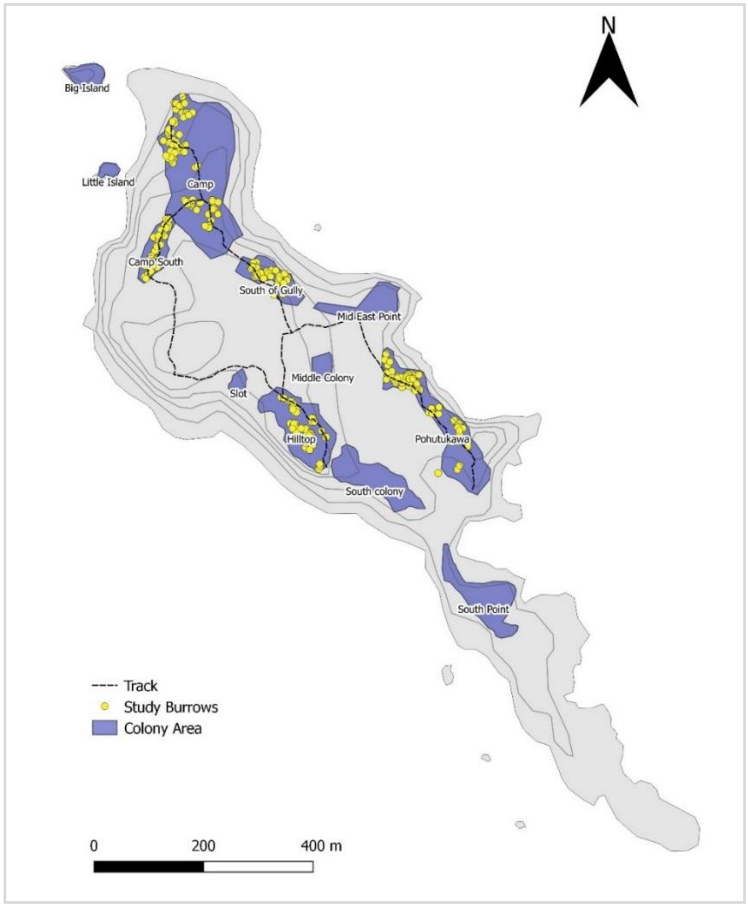

Figure 1. *Map of Ohinau Island showing the location of all flesh-footed shearwater colonies and all marked study burrows.*

2.1.2 Lady Alice Island

Lady Alice Island (Hen and Chickens Group, 35.89°S, 174.72°E) is a 155-ha Nature Reserve located 40km southeast of Whangarei. The island is co-managed by DOC and Ngāti Wai. Seven main colonies on Lady Alice Island have been identified (Figure 2). 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 (Booth, unpublished data; Waugh et al., 2014; Barbraud et al., 2014) and for six consecutive seasons by WMIL since 2016 (Crowe et al., 2017; Crowe, 2018; Crowe & Bell, 2019; Crowe, 2020; Crowe & Burgin, 2021; Burgin & Ray, 2022). 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). A team of seven WMIL and DOC staff were based on the island from 8 to 26 January 2024.

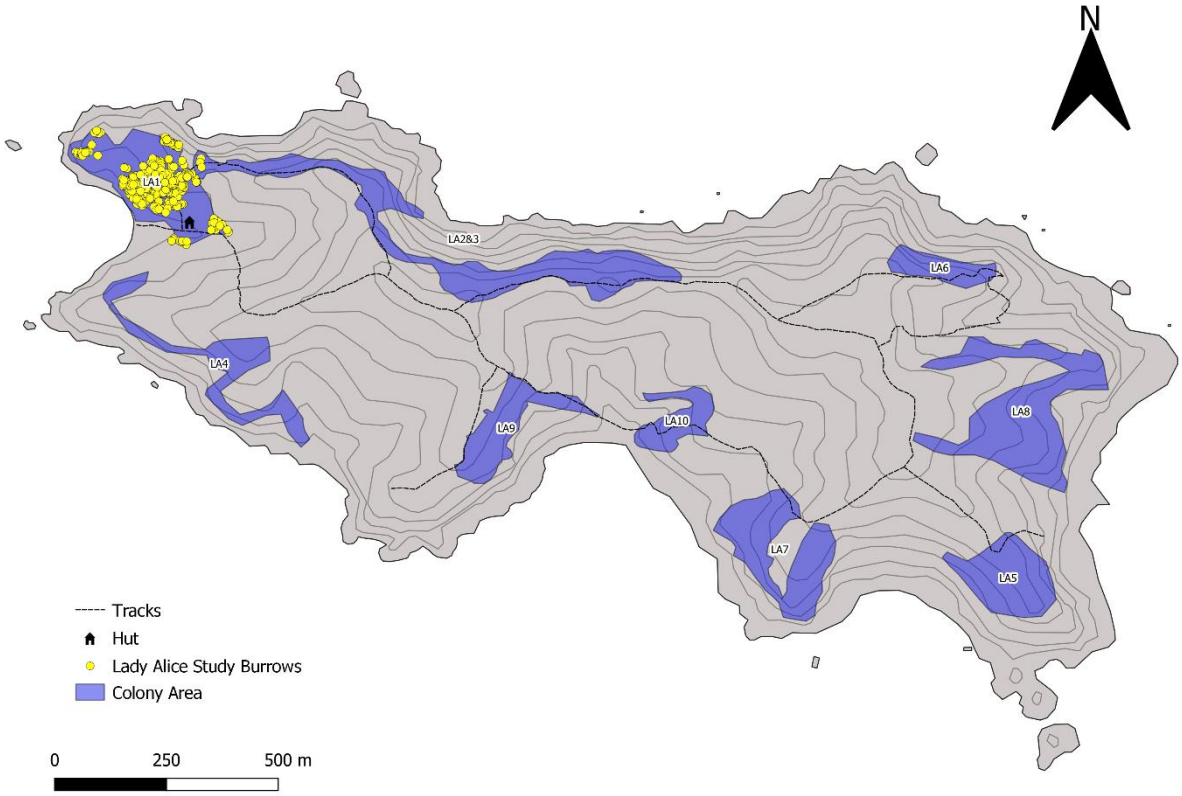

Figure 2. *Map of Lady Alice Island showing the location of study burrows and all known flesh-footed shearwater colonies.*

2.1.3 Titi Island

Titi Island (Marlborough Sounds, 40.57°S, 174.08°E) is a 32-ha Nature Reserve located in the outer Marlborough Sounds. The island is administered by DOC in consultation with Ngāti Kuia and has been free of introduced predators since the 1970's (Gaze, 2000). There are seven known flesh-footed shearwater colonies on Titi Island (Figure 3) established through recent work by WMIL (Burgin & Lamb, 2022). This built on previous work by Baker et al. (2010), and confirmed historical accounts that flesh-footed shearwaters reside here in lower numbers alongside tītī/sooty shearwaters (*Ardenna grisea*) (Threat Status - At Risk: Declining), (Gaze, 2000; Robertson et al., 2021). In January 2022, WMIL estimated 528 (250 – 806, 95% CI) occupied flesh-footed shearwater burrows on Titi Island (Burgin & Lamb, 2022).

A team of six WMIL and DOC staff visited the island on 8 April, 2024 for a scoping trip. On 8 May, 2024, another team of six WMIL and DOC staff visited the island to attach satellite transmitters to fledging flesh-footed shearwaters.

shearwater *colonies.*

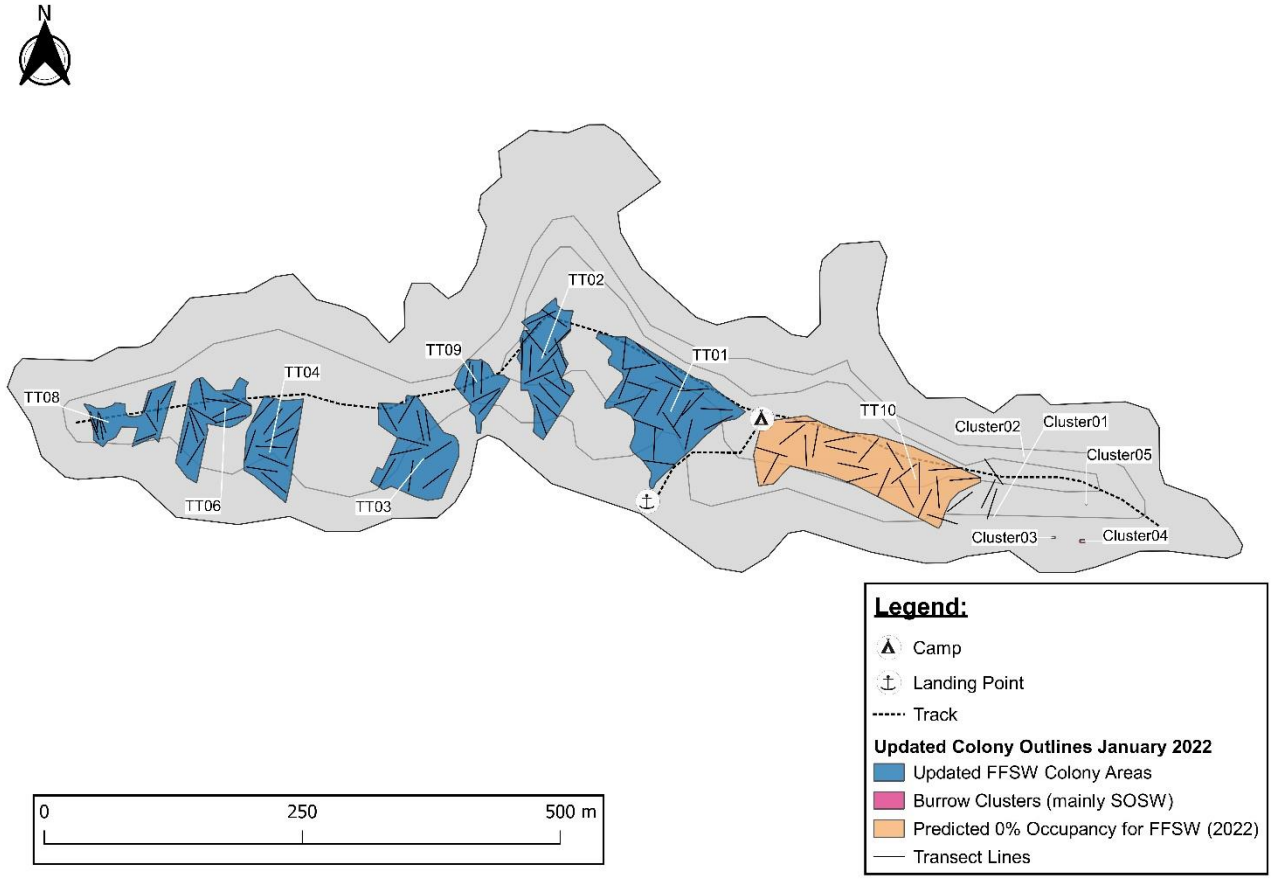

Figure 3: *Map of Titi Island showing the location of all known toanui/flesh-footed shearwater and tītī/sooty shearwater colonies*

2.2 Field Methods

2.2.1 Population monitoring

During the trips to Ohinau and Lady Alice, each study burrow was checked regularly 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 birds was determined (or confirmed) either from partner birds with known sex or, if just laid, from inspection of the cloaca. 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, using the flashlight and video tools to check on the occupants, particularly for correction fluid on their head. Hatches were dug if it the burrow was too long or complex to reach the nesting chamber.

To help minimize disturbance to the birds and the burrow, 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. Empty and non-breeding burrows were continually checked until the day WMIL departed each island.

For any burrows that had failed (e.g. due to a broken egg) before WMIL were able to identify both partners, WMIL 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 second partner bird was banded, or had its band number confirmed, the 'dummy' egg was removed.

Night work was carried out to increase the total number of banded birds and to recapture previously banded birds. Night work was carried out after sunset (21:00 and 23:00), or before dawn (04:00 – 06:00). Adults were

caught by hand on the surface and were banded, marked with correction fluid, and the general capture location recorded relative to known study colonies. The bird was released at the same location.

2.2.2 Population Estimates (Field Methods)

The field methods used to estimate the flesh-footed shearwater population on Ohinau Island and Lady Alice Island were the same as used previously by WMIL on both islands in previous breeding seasons (Crowe, 2018; Crowe & Bell, 2019) and at other flesh-footed shearwater colonies (Bell & Boyle, 2017; Crowe & Burgin, 2021; Burgin & Lamb, 2022). This is to ensure consistency between estimates and permit better comparisons over time and space.

Transects (consisting of a random location and a bearing (i.e., transect direction)) were randomly generated using QGIS within nine of the 11 previously mapped flesh-footed shearwater colonies. Colony outlines were mapped in previous seasons (Crowe, 2018a). A new transect was generated if the length of the generated transect intersected within 20 m of a previously generated transect, or the colony outline. For Ohinau Island, a minimum of five transects were generated for the smallest colonies (Middle and Slot colonies), with a greater number generated for larger colonies; 10 start points for Camp South, Mid East Point and South of Gully colonies, 15 start points for South and South Point colonies, 20 for Hilltop and Pōhutukawa colonies and 30 start points were generated for Camp Colony (Figure 4). Like the previous population estimate for Ohinau Island, no transects were done on Little and Big Island (Crowe, 2018a). For Lady Alice Island, the number of transect start points generated was approximately the same as the number generated for the previous population estimate (Crowe & Bell, 2019), number of transects conducted in parentheses were as follows; Colony LA1 (60), LA2/3 (40), LA4 (35), LA5 (30), LA6 (23), LA7 (59), LA8 (36), LA9 (30), LA10 (29) (Figure 5).

In the field, a tape was run out for 20 m from the start point along the generated bearing. Occasionally when GPS-location error caused start locations of a transect to intersect with a transect that had already been completed, the transect was abandoned and another transect (from a list of back-up transects) was chosen. Transects which were too steep and/or unsafe were not carried out or transects were truncated when they became too unsafe.

Burrows were searched within a two-metre strip to the right-hand side of the tape i.e., each transect covered 40m^2 if the whole transect could be surveyed. Transects were undertaken by a single individual or in pairs with one person searching for and counting burrows, while the other checked the contents of each burrow using a burrowscope or smart phone. The contents of each burrow were checked for its occupant and breeding status. On occasion, only a sub-sample of burrows were checked on a transect due to time constraints. Overall, a minimum of 30 burrows per colony were checked and efforts were made to spread the spatial distribution of checked burrows across the whole colony. Burrows that were on the edge of the search area were only checked if more than half of the burrow entrance was inside the search area. Following Waugh et al. (2014) 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. If the observer could not confidently determine the contents (or lack thereof) of the burrow, due to it being too deep or too complicated, then it was recorded as unknown and was excluded from the occupancy estimation.

Transects were carried out between 15-20 December on Ohinau and 12-21 January on Lady Alice.

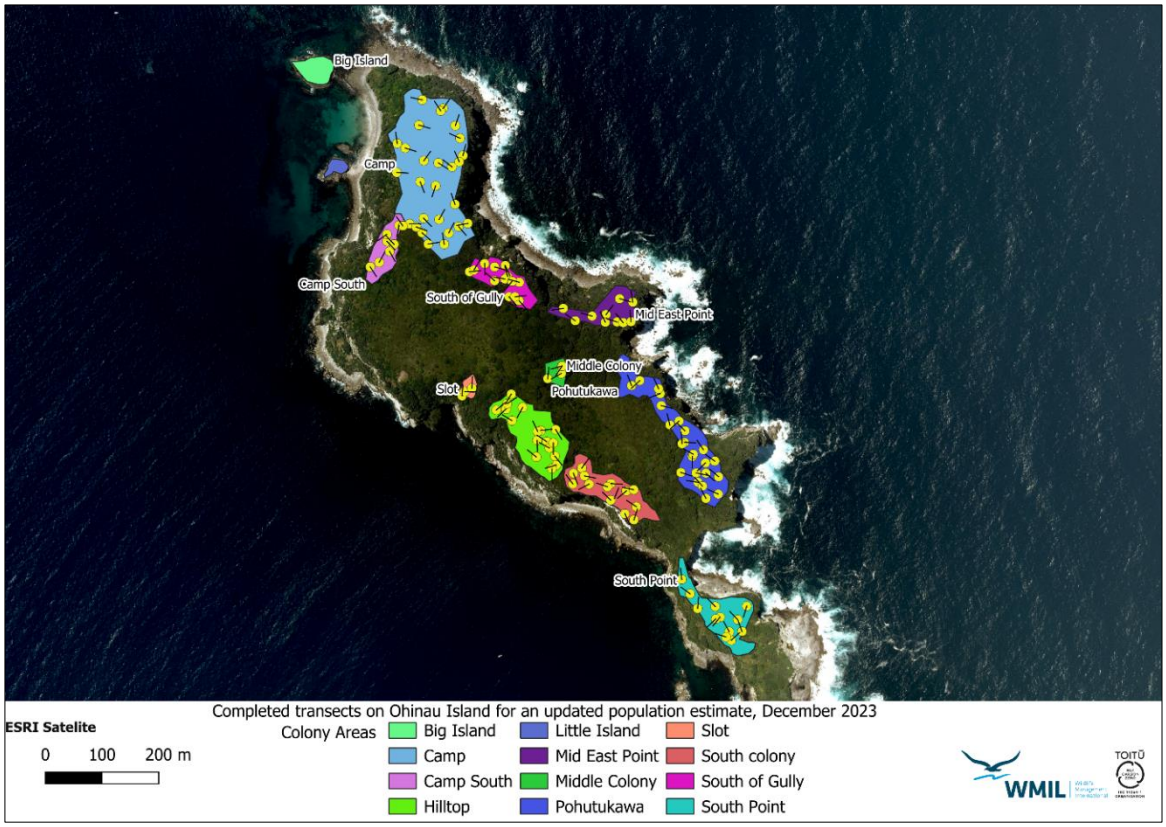

Figure 4: *Transects carried out on Ohinau Island for an updated flesh-footed shearwater population estimate, December 2023.*

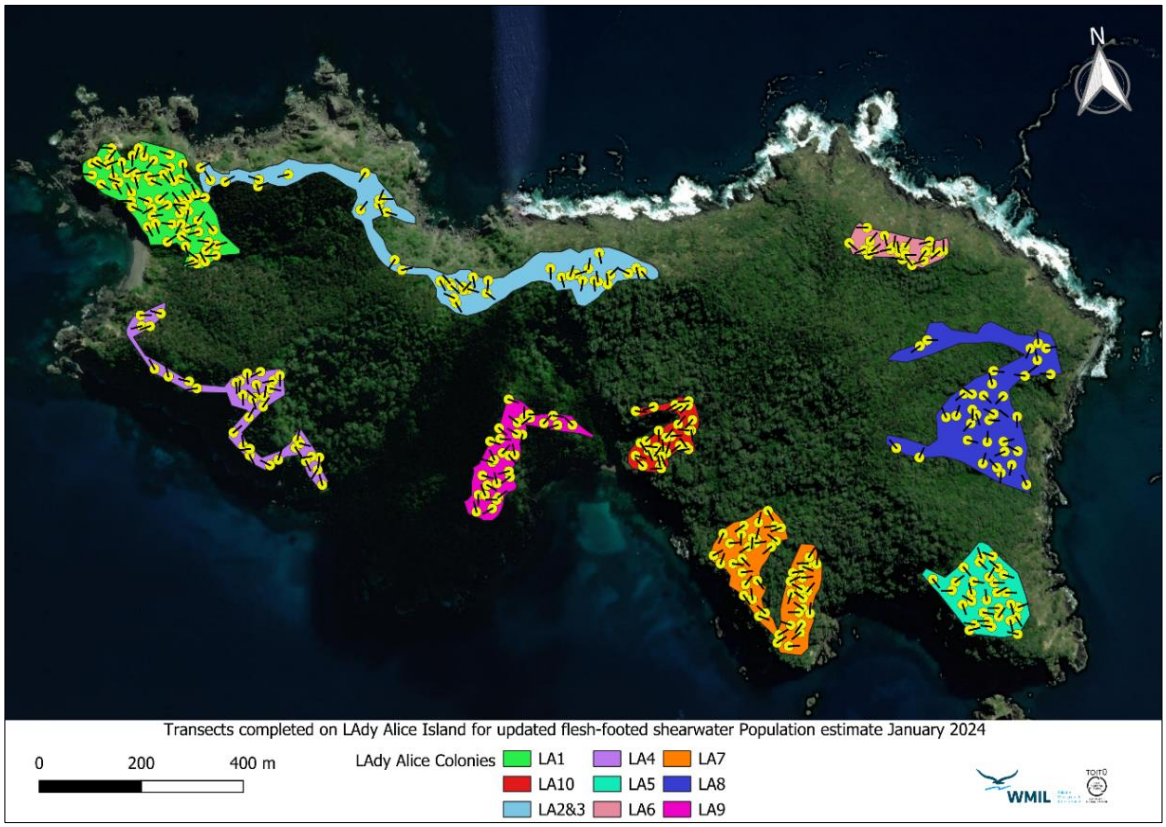

Figure 5: *Transects carried out on Lady Alice Island for an updated flesh-footed shearwater population estimate, January 2024.*

2.2.3 Population Estimate (Data analysis)

The island wide population estimate i.e., the estimated number of occupied breeding burrows e.g., was calculated using equation 1 (Burgin & Lamb, 2022):

Eq. (1):

$$\sum_{i=1}^{N} \hat{b}_i = \left(\left(\bar{d}_i \cdot s_i \right) \cdot o_i \right)$$

Where $\hat{b}_i$ is the estimated number of occupied breeding burrows for a colony (i), and is summed for number of colonies on the island (N). First the average burrow density of a colony is calculated, $(\bar{d}_i)$ given by equation 2:

Eq. (2):

$$\bar{d}_i = \frac{1}{n} \sum_{j=1}^{n} \left(\frac{l_j}{a_j} \right)$$

Where the burrow density $\left(\frac{l_j}{a_j}\right)$ of each transect (j) is averaged across the number of transects conducted within a colony (n_i), where (l_j) is the number of large burrows counted in transect and (a_j) is the transects' search area. WMIL find the estimated number of burrows across a colony by multiplying the colony's average density $(\bar{d}_i)$ by the 3D-surface area of the colony (s_i), where s_i is calculated by equation 3:

Eq. (3):

$$s_i = \frac{p_i}{\cos(\bar{x}_i)}$$

To calculate the 3D-surface area of each colony (s_i), WMIL downloaded an eight-metre resolution Digital Elevation Model (DEM) from Land Information New Zealand (LINZ) data service website (LINZ, 2024) and created a slope raster of the island. A spatial join between each mapped colony's polygon (the perimeter of the colony) and the slope raster then calculates the average slope of the colony (measured in radians). The final 3D-surface area is calculated by dividing the 2D-planimetric area of the colony (p_i) by the cosine of the average slope angle $(\bar{x}_i)$ of the colony. The occupancy rate (o_i) of a colony is calculated by equation 4.

Eq. (4):

$$o_i = \frac{m_i}{(k_i - u_i)}$$

Where m_i is the total number of burrows occupied by a breeding pair of flesh-footed shearwaters divided by the number of burrows where the status is known (k_i) minus the number of burrows where the status was indeterminate (u_i).

The estimated number of burrows of a colony $(\bar{d}_i \cdot s_i)$ is then multiplied by its occupancy rate (o_i) to find the estimated number of occupied burrows for a colony $(\hat{b}_i)$. To arrive at the population estimates for the entirety of each island, WMIL summed up the estimates calculated for each colony $(\hat{b}_i)$ and their associated 95% confidence intervals (Eq. 1.). Upper and lower 95% confidence intervals were calculated on colony's average burrow density $(\bar{d}_i)$ and its standard deviation. Sample size was the number of transects completed in each colony. For the colonies that were not surveyed (Big Island and Little Island) WMIL applied the island mean burrow density and mean occupancy rate (averaged across all surveyed colonies on the island) to obtain an estimated number of occupied burrows. To estimate the upper and lower 95% confidence intervals for the un-surveyed colonies, WMIL averaged the upper and lower estimated burrow

densities from all surveyed colonies. To investigate potential population changes in population size since the last estimate of Ohinau Island, WMIL re-calculated the 2017/2018 population estimate following the colony-by-colony approach (as the previous estimate was calculated on inputs that were averaged across the island). For colonies that were not surveyed in the 2017/2018 season, WMIL used the re-calculated island mean density and occupancy to derive estimates. The previous Lady Alice Island population estimate follows the same method as the current 2023/2024 estimate and so no re-calculation of the population estimate was applied.

2.2.4 Tracking

Adult tracking – Ohinau and Lady Alice Islands

Tracking was undertaken on Ohinau Island in December 2023, and on Lady Alice Island in January 2024, to obtain tracks of foraging adults during incubation. Each breeding bird found in a study burrow was weighed before GPS devices were deployed. On Ohinau females were selected for tracking as males undertake the first long incubation shift after egg laying. Whereas on Lady Alice, birds which were thought to have been incubating eggs in burrows for a long period and were likely to undertake a changeover with their partners shortly, were selected for tracking.

Birds were fitted with i-GotU GPS devices, pre-encased in resin for waterproofing. Devices weighed either ~25g (Ohinau) or ~22g (Lady Alice). These devices are heavier than devices used previously but much cheaper and were used as a trial for this species. The GPS devices were programmed to take one position fix every 10 minutes. All birds were slightly lighter than the 3% of body mass threshold suggested by Phillips et al. (2003) for device attachment to albatross and petrels.

Devices were attached by back mount by taping the feathers with five pieces of Tesa tape® and superglue (Figure 6). Once devices had been attached, the birds were placed back in their burrow. Burrows were checked daily to ensure they had left and then checked every few days to retrieve devices when they had returned from a foraging trip.

Seven devices were deployed on Ohinau Island and nine on Lady Alice Island.

Figure 6: *i-GotU GPS device taped to the back of adult toanui/flesh-footed shearwater for tracking during incubation, Lady Alice January 2024.*

Chick tracking – Titi Island

Satellite tracking of flesh-footed shearwater chicks was carried out on Titi Island, to determine chick fledgling migration routes over this monitoring period. From previous experience working on Titi Island in 2022 WMIL targeted colonies where flesh-footed shearwaters were likely to be found at higher occupancy rates (Burgin & Lamb, 2022). An initial trip to Titi Island was undertaken on 8 April day to scout out flesh-footed shearwater breeding burrows with chicks in a suitable condition for tracking in May. Burrows were checked for flesh-footed shearwater chicks and, if found, the birds were banded, weighed with a Pesola® scale, and their wing lengths measured. Hatches were installed on the burrow if the chick was difficult to reach, as well as a temporary marker at burrow entrances to assist with finding the burrow again come May.

In the interim period between trips, WMIL calculated an estimated wing chord growth rate of between 3-4 mm day^{-1} for each chick, to gather a rough extrapolation on chick size for the next visit in May. This helped to understand whether the chicks WMIL had found would be old enough for device attachment.

On 8 May burrows which were located and marked in April were revisited. Any chicks in burrows were weighed, wing length measured, and the length of their primaries assessed to find those close to fledging. Seven chicks were selected with minimal down (especially across the back), weighing over 600g and with wing lengths greater than 310 mm. A Sunbird satellite transmitter was first attached to a lightweight plastic baseplate with glue and Teflon® ribbon threaded through the device and tied. Baseplates were larger than the tag itself to prevent feathers covering the solar panel, and thereby impede charging, and to create a surface area large enough to attach tape to. Five pieces of Tesa tape were used to tape the baseplate and device to feathers on the backs of the chicks. Care was taken to avoid tape covering the solar panel. Additional tape was used on the back in a ‘V’ above the device and along the sides of the device to prevent feathers covering the solar panel (Figure 7)

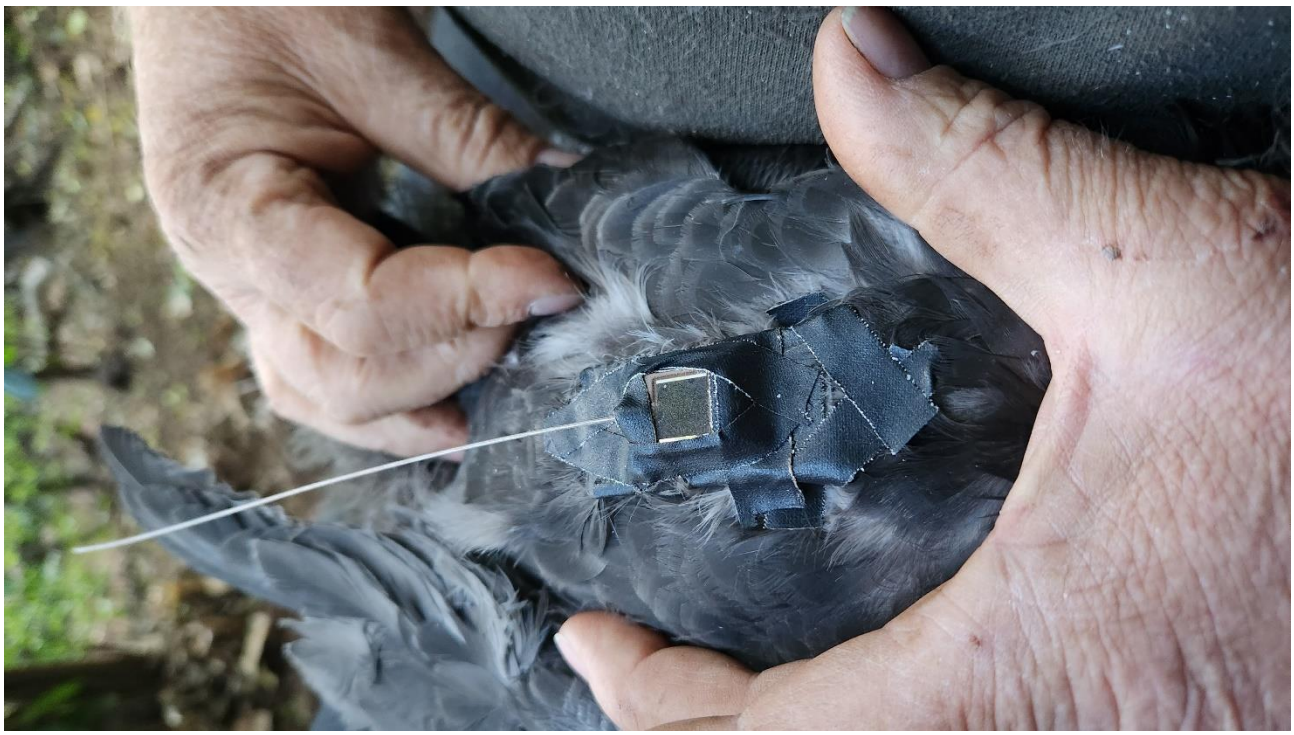

Figure 7: *Sunbird satellite transmitter taped to the back of toanui/flesh-footed shearwater chick for tracking during and after fledging, Titi Island, January 2024.*

GLS tracking – Ohinau Island

Twelve Intigeo-C330™ GLS devices (manufactured by Migrate Technology™) were deployed on adult flesh-footed shearwaters in January 2023 (Ray & Burgin, 2023). During the December 2024 trip any adults which had returned to burrows had their devices removed. WMIL were successful in retrieving five devices during the trip. Further analysis of data and tracks will be undertaken in the future and is not reported on here.

3. RESULTS

3.1 Occupancy

Ohinau Island

A total of 263 study burrows were monitored throughout the entire 2023/24 season on Ohinau Island (Table 1). This consisted of 261 study burrows monitored in the previous season and two new study burrows put in over the December trip. A total of 11 study burrows were retired over the course of the season, nine of those being in Camp Colony due to the māhoe die off, another in Hilltop which had collapsed, and the remaining burrow was retired in Camp South due to being lost in the undergrowth.

Of the 263 study burrows, 71.5% (n=188) were breeding burrows and 7.6% (n=20) were non-breeding burrows. The remaining 55 burrows were empty or held other species (Table 1). A total of 61.4% (231 of 376) of birds in breeding study burrows were identified. WMIL were able to successfully identify both partners for 29.8% (n=56) of these 188 breeding burrows (Table 1). 63.3% (n=119) of breeding burrows had only one partner identified while the remaining 6.9% of burrows (n=13) had neither partner identified. Of those burrows where neither adult was identified 15.4% (n=2) were burrows in January where an egg was found but no incubating adults, 84.6% (n=11) were burrows with birds out of reach.

Lady Alice Island

A total of 291 study burrows were monitored throughout the entire 2023/24 season on Lady Alice Island (Table 1). All of these study burrows were last monitored during the 2021/22 season and no new burrows were added during the January trip. Six study burrows were retired over the course of the season on the island due to either collapsing (n=4), being lost (n=1) or being too long and complicated (n=1).

Of the 291 study burrows, 71.8% (n=209) were breeding burrows and 3.8% (n=11) were non-breeding burrows. The remaining 78 burrows were empty or held other species (Table 1). A total of 85.6% (358 of 418) of birds in breeding study burrows were identified. WMIL were able to successfully identify both partners for 75.1% (n=157) of these 209 breeding burrows (Table 1). 21.1% (n=44) of breeding burrows had only one partner identified while the remaining 3.8% of burrows (n=8) had neither partner identified. Of those burrows where neither adult was identified 62.5% (n=5) were burrows in January where an egg was found but no incubating adults, 37.5% (n=3) were burrows with birds out of reach.

Table 1 also discloses additional species that were detected in burrows on both islands, including kororā/little penguin (*Eudyptula minor*), ōi/grey-faced petrel (*Pterodroma gouldi*), tītī/sooty shearwater (*Ardenna grisea*) and Pycroft's petrel (*Pterodroma pycrofti*). Interestingly the latter three species were only found within study burrows on Lady Alice Island and not on Ohinau Island.

Table 1: *Breakdown of burrow status for all study burrows on Ohinau Island and Lady Alice Island 2023/24 season.*

Burrow Status	Ohinau Island	Lady Alice Island
Breeding		
- 0 Partners	13	8
- 1 Partner	119	44
- 2 Partners	56	157
Total Breeding burrows	**188**	**209**
Non-breeding		
- 1 bird	16	7
- 2 birds	4	4
Total flesh-footed shearwater burrows	**208**	**220**
Other species		
- Kororā/little penguin (*Eudyptula minor*)	0	2
- Ōi/grey-faced petrel (*Pterodroma gouldi*)	5	3
- Tītī/sooty shearwater (*Ardenna grisea*)	0	1
- Pycroft's Petrel (*Pterodroma pycrofti*)	0	4
Empty	50	68
Total Study Burrows	**263**	**291**
Newly Retired	11	6
Previously Retired	54	13
Total Retired Burrows	**65**	**19**

3.2 Breeding Success

Determining breeding success was not an objective for the 2023/24 season therefore no chick banding trips were undertaken to either island and breeding success was not analysed for this season.

3.3 Banding Totals

During the 2023/24 season, 105 adult flesh-footed shearwaters were banded on Ohinau Island and 176 on Lady Alice Island (Table 2). No chicks were banded on either island this season as no chick trips were planned due to changes in the monitoring deliverables from DOC. In total, 4,745 flesh-footed shearwaters have been banded across Ohinau and Lady Alice Islands during this study (Table 1).

Table 1: *Number of flesh-footed shearwaters banded on both islands over the past nine seasons 2015-2024.*

	Season									
Ohinau	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**TOTAL**
Adult	90	528	182	210	470	188	180	47	105	2,000
Chick	267	133	131	453	0*	127	169	28	-	1,308
Total	**357**	**661**	**313**	**663**	**470**	**315**	**349**	**75**	**105**	**3,308**
Lady Alice	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**TOTAL**
Adult	0	285	163	102	118	38	59	-	176	941
Chick	0	94	83	103	0*	110	106	-	-	496
Total	**0**	**379**	**246**	**205**	**118**	**148**	**165**	**-**	**176**	**1,437**
**** COVID-19 prevented WMIL from undertaking a chick trip***										
TOTAL BIRDS BANDED DURING STUDY									**4,745**	

3.4 Recaptures

3.4.1 Ohinau Island

As of the end of the 2023/24 season, 8.2% of the 267 (n=22) chicks banded in 2015/16, 2.3% of the 133 (n=3) chicks banded in 2016/17, and 1.5% of the 131 (n=2) chicks banded in 2017/18 on Ohinau have been recaptured. Therefore, a total of 27 returnees (5.1%) from 531 chicks banded over those three years, have been detected at the colony.

This season on Ohinau Island, 12 flesh-footed shearwaters banded as chicks were recaptured as adults, ten from the 2015/16 cohort (seven first records of returnees), one from the 2016/17 cohort (one new returnee), and one from the 2017/18 cohort (one new returnee). It was the first confirmed breeding record for six of these birds (five from the 2015/16 cohort and one from 2016/17), and for five of these first breeders, it was also their first recapture. All breeding first-recaptures were breeding within their natal colony, close to the burrows they fledged from.

All returnees are shown in Appendix 1.

3.4.2 Lady Alice Island

This season on Lady Alice Island, 33 flesh-footed shearwaters banded as chicks between 2016 and 2019 were recaptured at the colony. 10.6% of the 94 (n=10) chicks banded in 2016/17, 8.4% of the 83 (n=7) chicks banded in 2017/18, and 15.5% of the 103 (n=16) chicks banded in 2018/19 on Lady Alice have been recaptured. These 33 returnees represent just 11.8% of the 280 chicks banded over those three years.

Two of the flesh-footed shearwater chicks from the banding previously undertaken by Andrea Booth and Barbraud et al. (2014) were confirmed breeding at 24 years of age, the oldest known-age birds breeding in

the colony on Lady Alice Island. A total of 789 flesh-footed shearwaters (193 chicks, 596 adults) were banded between 2000 and 2009 (Booth, unpublished data; Barbraud et al., 2014) on Lady Alice.

Some of the recent recaptures provided the first breeding record of individuals. Nine of the recaptures were first confirmed breeding records (six from the 2016/17 cohort, one from 2017/18, and two from 2018/19). The two birds from the 2018/19 cohort are confirmed breeding for the first time at five years old.

All returnees are shown in Appendix 2.

3.5 Population Estimates

3.5.1 Ohinau Island

A total of 116 transects were carried out across nine of the 11 colonies on Ohinau Island. No transects were carried out on Big and Little Island. All transects were 20 m long except for seven transects that were truncated due to steep and unsafe terrain.

WMIL estimate the flesh-footed shearwater population on Ohinau Island to be 3722 (1881 – 5566, 95% CI) occupied breeding burrows in the 2023/2024 breeding season (Table 3).

Burrow density, occupancy and thus estimated number of breeding pairs ranged considerably across the nine colonies. Burrow density between the colonies ranged between 0.03 burrows m^{2-1} in Pōhutukawa Colony to 0.13 burrows m^{2-1} in Hilltop and South Colony (Table 3). The lowest occupancy rate on Ohinau Island was recorded in South Point Colony at 0.33 and the highest was recorded in Pōhutukawa Colony at 0.64. The estimated number of flesh-footed breeding burrows ranged between 22 occupied burrows in Slot Colony and 1,217 occupied burrows in Camp Colony (Table 3). Using the island wide mean burrow density and occupancy, WMIL were able to estimate the number of occupied burrows on Big and Little Island to be 109 (36 – 182, 95% CI) and 37 (12 – 61, 95% CI), respectively.

Table 3: *Toanui/flesh-footed shearwater Population Estimate Statistics for all Ohinau Island Colony Areas (December 2023).*

Colony	Dates Surveyed	Number of transects	Area sampled (m^2)	Large burrows counted	Average burrow density /m2	Number of burrows with known status	Occupancy Rate	Colony Area (m^2)	**Estimated Occupied Burrows**	**Lower 95% CI**	**Upper 95% CI**
Camp + Camp South	17-18 Dec 2023	33	1,290	82	0.06	70	0.54	36,092.14	**1,217**	847	1,587
Hilltop	19-20 Dec 2023	14	560	71	0.13	57	0.53	1,1474.10	**766**	329	1,203
South	19 Dec 2023	10	388.8	51	0.13	46	0.52	9,386.82	**624**	378	871
South Gully	17 Dec 2023	10	400	37	0.09	35	0.63	5,718.34	**332**	101	564
Mid-East	15 Dec 2023	10	400	18	0.05	18	0.39	5,826.29	**102**	20	184
Pōhutakawa	15 Dec 2023	20	800	25	0.03	25	0.64	14,100.00	**282**	139	425
South Point	16 Dec 2023	12	456	18	0.05	15	0.33	8,932.20	**140**	20	260
Middle Colony	16 Dec 2023	4	126	16	0.12	15	0.47	1617.93	**91**	0*	183
Slot	20 Dec 2023	3	120	5	0.04	3	0.67	800.00	**22**	0*	45
Big Island	Not surveyed	-	-	-	0.08**	-	0.52**	2,741.53	**109****	36**	182**
Little Island								919.60	**37****	12**	61**

Total/ average		**116**	**4,540.8**	**323**	**0.08**	**282**	**0.52**	**97,608.94**	**3,722**	**1,881**	**5,566**

Lower 95% CI estimates were truncated to zero
****Big and Little Island were not surveyed, but the average burrow density and occupancy rates were used to estimate the number of occupied burrows***

3.5.2 Lady Alice Island

A total of 323 transects were carried out across all nine colonies on Lady Alice Island. All transects were 20 m long except for 12 transects that were truncated due to steep and unsafe terrain.

WMIL estimate the flesh-footed shearwater population on Lady Alice Island to be 2,367 (1,431 – 3,303, 95% CI) occupied breeding burrows (Table 4).

Flesh-footed shearwaters were predominantly concentrated in colonies located along the northern and western slopes of the island and were either absent or occurred at low numbers in colonies located along the southern and eastern slopes. Burrow density between all colonies ranged between 0.02 to 0.08 burrows m^{2-1} with the highest burrow density generally occurring within the southern/eastern colonies. Colonies along the northern/western side were generally similar to one another (0.03 to 0.05 burrows m^{2-1}). Occupancy ranged between 0 to 0.62, with the northern/western colonies having the highest occupancy (0.16 to 0.62) and the southern/eastern having the lowest (0 to 0.1) (Table 4).

Table 4: *Toanui/flesh-footed shearwater Population Estimate Statistics for all Lady Alice Island Colony Areas (January 2024)*

Colony	Dates Surveyed	Number of transects	Area sampled (m^2)	Large burrows counted	Average burrow density /m2	Number of burrows with known status	Occupancy Rate	Colony Area (m^2)	**Estimated Occupied Burrows**	**Lower 95% CI**	**Upper 95% CI**
LA1	17-21 Jan 2024	60	2,400	78	0.03	71	0.39	39,173	502	315	689
LA2 & 3	13-14 Jan 2024	39	1,504	75	0.05	64	0.34	61,873	1,023	624	1,421
LA4	17 Jan 2024	36	1,440	44	0.03	43	0.16	24,535	122	53	191
LA5	15 Jan 2024	30	1,184	31	0.03	28	0.00	28,332	0	0	0
LA6	13 Jan 2024	20	742	49	0.06	34	0.62	12,616	491	304	677
LA7	15-18 Jan 2024	44	1,734	66	0.04	59	0.10	34,652	132	78	186
LA8	12 Jan 2024	36	1,400	33	0.02	32	0.06	51,997	74	44	104
LA9	20 Jan 2024	30	1,196	100	0.08	83	0.00	21,546	0	0	0
LA10	18-20 Jan 2024	28	1,074	52	0.05	50	0.04	12,389	23	12	34
Total/av		**323**	**12,674**	**528**	**0.04**	**464**	**0.18**	**287,113**	**2,367**	**1,431**	**3,303**

3.5.3 Comparison with past population estimates

Ohinau Island

Since the last population estimate on Ohinau Island during the 2017/18 breeding season, the estimated number of occupied breeding burrows has decreased by 4.17%, equating to an overall loss of *c.* 23 breeding burrows per year over the last seven years (Table 5). The average burrow density on the island decreased from 0.09 to 0.08 whereas average occupancy rate increased from 0.36 to 0.52 between 2017/18 and 2023/24 seasons. Reductions and increases in active breeding burrows were mixed throughout the colonies. Of the colonies that were surveyed across both estimates, the largest reduction in occupied burrows was observed in Pōhutukawa and Camp (including Camp South) colonies from 380 (134-625, 95% CI) to 282 (139-425, 95% CI) and 1,495 (975-2,015) to 1,217 (847-1,587), respectively. This equates to a loss of 98 occupied burrows, or a 25.79% decrease, in Pōhutukawa Colony, and a loss of 278 occupied burrows, or 18.60% decrease, in Camp Colony.

Increases in occupied burrows were observed in South Colony from 546 (304-788 95% CI) to 624 (378-871%), in South Gully Colony from 287 (160-413 95% CI) to 332 (101-564, 95% CI), and in Slot Colony from 10 (0-26, 95% CI) to 22 (0-45 95% CI). This represents increases of 78 occupied burrows or 14.3%, 46 occupied burrows or 15.96%, and 12 occupied burrows or 122.2%, respectively. Owing to the randomised nature of the survey design and lower sampling effort, surveys in the South Point Colony during the 2017/18 season did not contain any burrows within the search area, thus the number of occupied flesh-footed shearwater burrows within the colony was estimated at zero. The current 2023/24 estimate for South Point Colony puts the number at 140 (20-260, 95% CI) occupied burrows. Mid-East Colony and Middle Colony were not surveyed in 2017/18 and thus the number of occupied burrows were estimated using the island wide average. Based on Ohinau Island's average burrows density and occupancy rate estimates, Mid-East Colony has decreased in number from 179 (76-282, 95% CI) to 102 (20-184, 95% CI) occupied burrows/ This represents a decrease of 77 burrows or 43.02%. Conversely, Middle Colony increased from 50 (21-78, 95% CI) to 91 (0-183, 95% CI) occupied burrows, representing a gain of 41 occupied burrows, or 82%.

Lady Alice

Between 2018/19 and 2023/24 the estimated population size of flesh-footed shearwater on Lady Alice Island has dramatically reduced by 26.44%, an estimated loss of *c.* 142 burrows per year over the last six years (Table 5). The island wide average burrow density decreased from 0.5 to 0.4 and the average occupancy rate decreased from 0.24 to 0.18. Declines in occupied burrows were observed across all the colonies except two, with declines ranging from 17.86% to 100%.

The number of occupied burrows in LA1 Colony decreased from 809 (565-1,054, 95% CI) to 502 (315-689, 95% CI) occupied burrows, representing a drop of 37.95%. Further examination of the study burrows has found that breeding occupancy of the LA1 study colony burrows that have been monitored continuously over that period (i.e., not including burrows added after 2018/19 season) has simultaneously decreased by 7.86% (70.83% in 2018/19 to 65.26% occupancy in 2023/24). The drop follows a wider pattern of decreasing occupancy from when monitoring began with occupancy in those same burrows dropping by 20.28% from 2016/17 to the 2023/24 season (81.87% in 2016/17 to 65.26% occupancy in 2023/24).

LA2/3 Colony decreased from 1,398 (975-1822, 95% CI) to 1,023 (624-1421, 95% CI) occupied burrows, representing a drop of 26.82%. LA4 Colony decreased from 193 (104-282, 95% CI) to 122 (53-191, 95% CI) occupied burrows, representing a drop of 36.79%. The LA8 Colony decreased from 157 (104-211, 95% CI) to 74 (44-104, 95% CI) occupied burrows, representing a drop of 52.87%. Finally, LA10 Colony decreased from 28 (19-38, 95% CI) to 23 (12-34, 95% CI) occupied burrows, representing a drop of 17.86%.

No flesh-footed shearwaters were recorded in LA5 Colony and LA9 Colony in 2023/24. These colonies were previously estimated at 73 (44-101, 95% CI) and 125 (96-155, 95% CI) occupied burrows in 2018/19. LA6 and LA7 colonies saw increases in estimated number of occupied burrows from 340 (211-468, 95% CI) to 491 (304-677, 95% CI) and from 94 (63-125, 95% CI) to 132 (78-186, 95% CI). This represents an increase of 151 (44.41%) and 38 (40.43%) occupied burrows, respectively.

Table 5: *The estimated number of occupied toanui/flesh-footed shearwater breeding burrows on Ohinau Island and Lady Alice Island between the surveyed breeding seasons and the difference between estimates.*

Island	2017/18	2018/19	2023/24	Difference
Ohinau Island	3,884 (2,060-5,715)	-	3,722 (1,881-5,566)	-162 (-4.18%)
Lady Alice Island	-	3,217 (2,180-4,255)	2,367 (1,431-3,303)	-850 (-26.42%)

3.6 Adult Tracking

3.6.1 Ohinau Island

Unfortunately, none of the seven I-GotU GPS devices deployed on Ohinau were retrieved from incubating adults in December 2023. All birds had not returned to the colony for 12 days or more. At the end of the trip, four of the GPS burrows had cold eggs alone. The tracked adults weighed between 600g to 670g when devices were deployed. On average devices were 3.9% of the tracked birds body weight (ranged from 3.7 to 4.2%). A summary of all deployments can be found in Appendix 4.

3.6.2 Lady Alice Island

Of the nine I-GotU GPS devices deployed on incubating flesh-footed shearwaters in January 2024, only four devices were retrieved. Three birds were documented traveling up the east coast of Te Ika-a-Māui/North Island round to the west coast of the North Island, with one traveling to The Three Kings Ridge north of New Zealand. The final bird was documented travelling out to the Louisville Seamount Chain (Figure 4; Appendix 5). Trip durations ranged from 11 to 15 days (average 13.3 days) however, two birds undertook more than one trip before the devices were retrieved. A summary of all deployments can be seen in Appendix 4.

At the end of the trip, five of the burrows where a flesh-footed shearwater had had a GPS device attached, were found to have either a cold egg left alone, or the egg had disappeared. The tracked adults were between 525g and 590g when devices were deployed with devices being on average 3.9% of birds body weight (ranged from 3.7% to 4.2%). Body weight increase after leaving and returning to the colony ranged from 11.5% to 32.2% (Appendix 4).

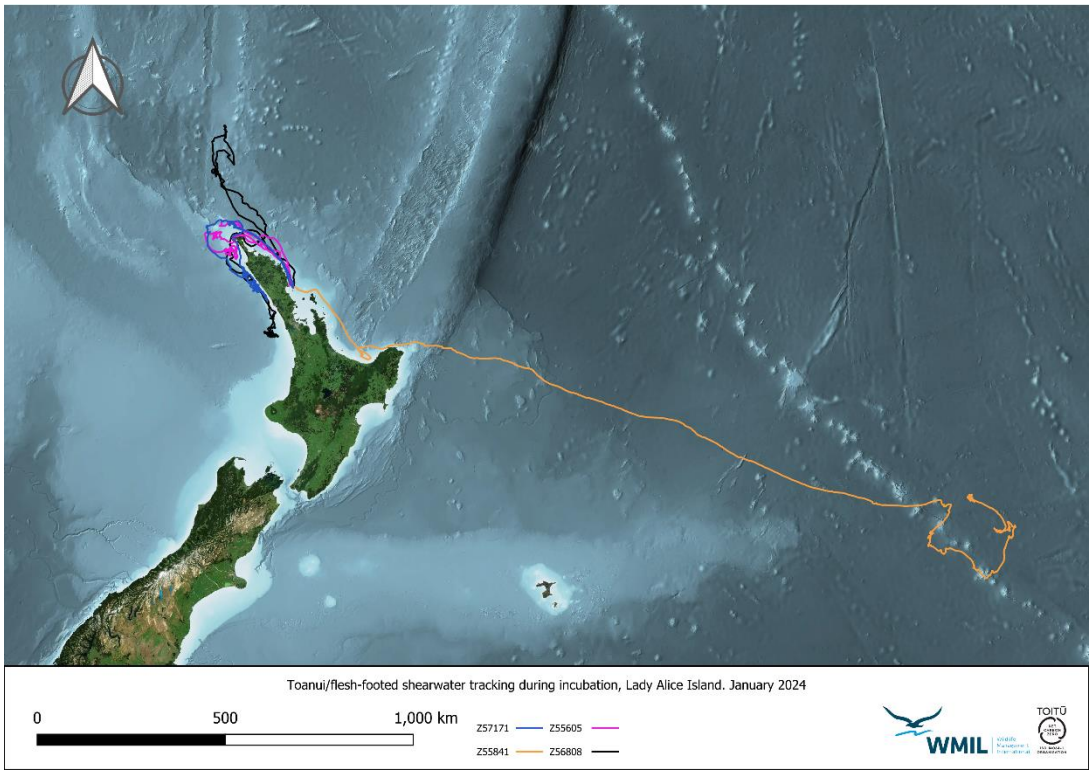

Figure 3: *Map of GPS tracks for incubating toanui/flesh-footed shearwaters Lady Alice Island, January 2024.*

3.7 Chick Tracking

Six of the seven devices deployed on flesh-footed shearwater chicks had connected to satellites upon them fledging. Of the six devices working, four individuals were tracked travelling north up the west coast of the North Island after fledging from Titi Island, one chick was tracked travelling up the east coast of the North Island and the remaining chick didn't connect to the satellite until it was well north of New Zealand, so the route taken is unfortunately unknown. All chicks travelled north through the Pacific near Vanuatu (Figure 5; Appendix 7). As of 15 June 2024, three devices were still transmitting and three had stopped, one on 30 May, another on 2 June and the remaining device on 9 June. The devices which stopped had transmitted for 16, 19 and 26 days respectively (Appendix 6).

After devices were deployed the chicks stayed on the island for a short period of time, resulting in all devices losing their battery charge. It wasn't until the chicks fledged and the solar panels were able to recharge the batteries that the satellites received signals from the devices again. Therefore, fledging date of each chick is unfortunately unknown. However, all devices had connected to satellites on either 14 or 16 May and fledging is believed to have been at least a day before these dates. A summary of deployment details can be seen in Appendix 6.

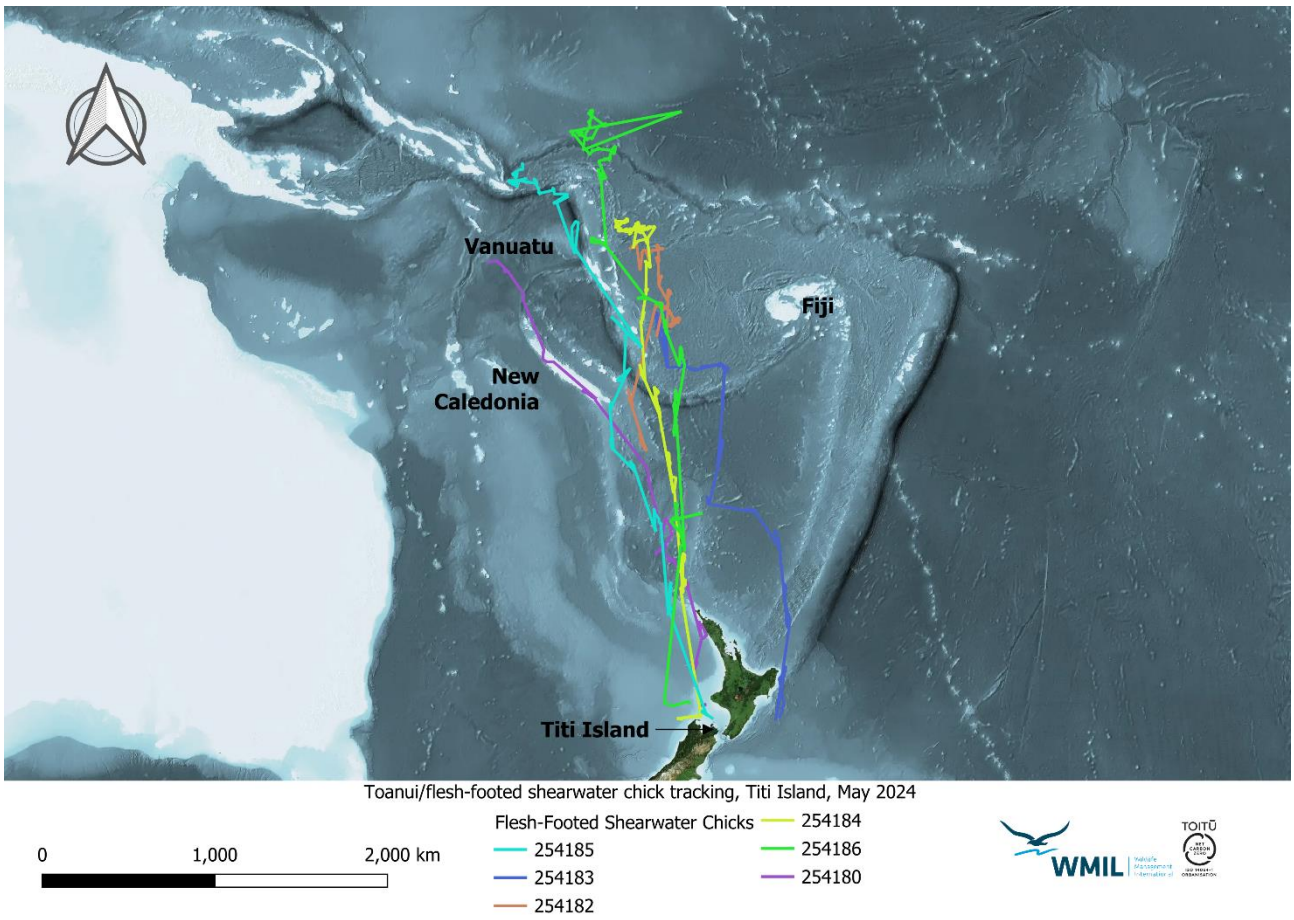

Figure 5. Toanui/flesh-footed shearwater chick tracks after fledging from Titi Island, 8 May to 15 June 2024

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. All previous study burrows were checked and Ohinau was found to have 188 burrows and Lady Alice 209 breeding burrows. As breeding success was not being analysed for either Ohinau or Lady Alice Islands this season additional burrows did not need to be added at Ohinau to reach 200 breeding burrows. Burrows that have collapsed, are lost, are continually occupied by a different species, or remain inactive for multiple seasons, are retired, and as stated previously a small number of burrows were retired on Ohinau (n=11) and Lady Alice (n=6) this season.

The occupancy rate on Ohinau Island has remained relatively similar to previous seasons, although this season (71%) was an increase from than last year (62%). Occupancy on Lady Alice Island has also remained relatively similar to previous seasons, however this season (72%) there was a slight increase from the 2021/22 season (67%).

4.2 Breeding success

Determining breeding success was not an objective for this season therefore no chick banding trips were undertaken to either island and breeding success was not analysed for the 2023/24 season.

4.3 Banded birds

4.3.1 Ohinau Island

With the exception of the 2022/23 season (n=47), the number of adults banded has remained consistently high across all seasons with most birds encountered on the surface at night being un-banded. This season however, was the 3rd lowest tally of adults banded for the project (n=105). It is important to disclose that this lower tally is a reflection of a myriad of factors. Notably, the large amount of work undertaking burrow checks, a population estimate and tracking reduced the team's ability to spend much time banding at night. Additionally, most of the birds encountered in existing study burrows were banded already, although a small number of newly banded birds were in study burrows too, with non-breeders and new breeders encountered.

No chick trip was undertaken this season due to changes in the study design, so no chicks were banded. This should be taken into account when using this season's data for any modelling or further analysis.

4.3.2 Lady Alice Island

The number of adults banded was the second highest recorded (n=176), with the lowest being in the 2020/21 season (n=38). Having DOC staff to assist with the work helped increase capacity for more banding to be undertaken, particularly at night. The large amount of work undertaking burrow checks, a population estimate and tracking work reduced the WMIL team's ability to spend much time banding at night. Despite most of the birds encountered in existing study burrows being banded already, a small number of newly banded birds were in study burrows too, with non-breeders and new breeders encountered.

No chick trip was undertaken this season due to changes in the study design, so no chicks were banded. This should be taken into account when using this season's data for any modelling or further analysis.

4.4 Recaptures

4.4.1 Ohinau Island

So far, 8.2% (n=22) of the 267 chicks banded on Ohinau Island in 2015/16 have been recaptured. Five of these individuals had their first recorded breeding record this season, confirming breeding at eight years old. Other individuals are most likely non-breeders as they have either been caught on the surface at night or found within non-breeding burrows. A single returnee chick from this cohort was found alone in a random burrow during transect work, which is a valuable record. Monitoring burrows over the coming seasons might provide further information on additional first breeding attempts.

A total of three chicks from the 2016/17 cohort have been recaptured, with the third chick found this season at seven years old, within a burrow in its natal colony incubating an egg. A total of two chicks from the 2017/2018 cohort have been captured, the first last season on the surface and at just over four years old, and the second this season in December 2023 in a non-breeding pair in a burrow at just over five years old. These captures help provide more detail that may provide further information regarding age at first return and recruitment for this species. Future monitoring will be vital to elucidate return and first breeding dates for more recent cohorts that have not yet been captured on the islands (Barbraud et al., 2014). WMIL anticipate that more birds from the 2015/16 cohort and a smaller number from later cohorts will be recaptured in forthcoming seasons, but the low numbers may suggest a low recruitment due to the numerous threats this species face out at sea.

4.4.2 Lady Alice Island

10.6% (n=10) of the 94 chicks banded on Lady Alice Island in 2016/17 were recaptured this season, with six of these birds having confirmed breeding records at seven years of age. One of the seven individuals captured from the 2017/2018 cohort had a confirmed breeding record at six years of age, and the sixteen records from the 2018/2019 cohort confirms this species returning to the breeding colony from four years of age (Taylor,

2022). Interestingly, two of those individuals had confirmed breeding records, being the earliest confirmed breeders at this colony at just four years old.

With no fieldwork on the island last year WMIL have potentially missed detecting some of the returnees from certain cohorts. The seven chicks from the 2017/2018 cohort and 16 from the 2018/2019 cohort, is encouraging and confirms the successful return of this species at five to six years old. WMIL anticipate that more birds will be detected in forthcoming seasons, but again, the low numbers may suggest a low recruitment due to the numerous threats this species face out at sea.

4.5 Population Estimates

Based on our current estimates, the Lady Alice flesh-footed shearwater population has undergone a dramatic decline of 26.42% over the last six years since the last population estimate was carried out in 2018/19. This drop equates to a loss of *c.*142 occupied breeding burrows per year over the last six years. The decline on Ohinau Island was estimated at 4.18% between population surveys, equating to a drop of *c.*23 occupied burrows per year over the last seven years. The reasons contributing to the large decline on Lady Alice Island are unknown but likely numerous.

Timing of the population surveys and effort (i.e., number of transects conducted) on Lady Alice were relatively similar between 2018/19 and the current survey (Crowe & Bell, 2019), suggesting that in the absence of methodological disparities between surveys that the scale of the decline could potentially point to either a proportionate increase in breeding failure occurring earlier in the season (and thus leading to an underestimate in occupancy), or a large drop in adult survivorship occurring at this colony. Indeed, within the monitored study burrows, breeding failure by the end of the trip on Lady Alice Island (25 January) was at 15.79% of study burrows that recorded a breeding attempt, whereas at the same date during the previous population estimate in 2019, breeding failure of study burrows was at 5.13%. Therefore, there is a possibility that breeding occupancy could have been slightly underestimated if breeding failure had also proportionally increased in the other colonies. Additionally, occupancy of monitored burrows have also decreased slightly over the same time period (from 70.83% in 2018/19 to 65.26% in 2023/24) and thus may be an additional source of variation contributing to the large drop in the overall population estimate.

In long lived species such as flesh-footed shearwater, population growth and stability are more strongly tied to adult survivorship than to variation in breeding success (Sæther & Bakke, 2000; Wooller et al., 1992). Mark-recapture modelling estimates for adult flesh-footed shearwater survival in New Zealand are relatively high at 0.93-0.94 (including at Lady Alice Island) and comparable to other shearwater species (Barbraud et al., 2014). However, at other sites, such as at Woody Island off South Australia, annual apparent adult survival of flesh-footed shearwater is substantially lower ranging from 0.68-0.84 (Lavers et al., 2019). It would be worth re-examining apparent annual adult survivorship since the last estimates were calculated up to 2014 (Barbraud et al., 2014), to detect whether in the proceeding years survivorship had declined. In light of ongoing climate change and the anticipated increases in the frequency and severity of extreme weather events, there could be major negative implications for biological systems such as those that flesh-footed shearwaters rely on during the non-breeding and breeding seasons (Easterling et al., 2000; Ummenhofer & Meehl, 2017; Van de Pol et al., 2017). As the Lady Alice Island population was not monitored in 2022/23 (Ray & Burgin, 2023), it is unknown how the extreme weather events (i.e., Cyclone Gabrielle and ex-tropical Cyclone Hale) experienced in January/February 2023 impacted the Lady Alice population, nor on the populations residing on many of the islands e.g., Middle and Karewa Island, that lay in the pathway of cyclones. As a result of these extreme weather events WMIL were able to monitor the breeding success on Ohinau Island being unprecedently low (Ray & Burgin, 2023), but how adult survivorship was impacted as a result of the extreme weather events has not yet been investigated.

A decline at Lady Alice Island was already previously identified by Barbraud et al. (2014), with the authors suggesting that in the face of apparent high adult survivorship, the decline may be more attributable to low recruitment rates of juveniles coming back to the colony as adults to breed, rather than changes in adult annual survivorship. Knowledge of recruitment rates and juvenile survival remain a large gap in the understanding of flesh-footed shearwater biology and should be the target of future monitoring effort. Many seabirds including flesh-footed shearwater are 'naïve' when they fledge from their nest, and do not rely on

parental guidance (as parental care ceases in the last weeks prior to fledging) and thus fledglings must rely on innate cues until experience accumulates (Delord et al., 2024; Riotte-Lambert & Weimerskirch, 2013; Wynn et al., 2022; Yoda et al., 2017). Additionally, as seabirds have long delayed maturity compared to many other vertebrates, the mortality risk for fledging seabirds until they reach maturity is predicted to be incredibly high (Afán et al., 2019; Sæther & Bakke, 2000).

In this report WMIL re-calculated the 2017/18 population estimate using the same methods applied by the 2018/19 population estimate onwards (Crowe, 2018a). Previously, the Ohinau Island estimate was calculated using summarised totals and averages for the entire island, whereas WMIL have now calculated each colony's estimated number of occupied breeding burrows separately that when summed, provides an estimate for the island as a whole. Additionally, WMIL surveyed two colonies that were not previously surveyed. As colonies tend to differ in their density and occupancy, WMIL believe this allows this recent population estimate to capture more heterogeneity across the island, thus building a more accurate picture. Because of the large overlap in the estimated confidence intervals between surveys of Ohinau Island, this population estimate could simply reflect natural fluctuations in the breeding population size, that over a longer time series would show as an expected variation. Continued population monitoring and surveys are therefore warranted to determine whether this decrease represents a natural oscillation or whether it represents the start of a sustained decline.

There are likely myriad interacting factors causing the documented drop in breeding occupancy across the islands. Flesh-footed shearwaters face numerous ongoing threats that could contribute cumulatively to the decline (Abraham & Thompson, 2011; G. B. Baker & Wise, 2005; Bond et al., 2021; Bond & Lavers, 2014; Croxall et al., 2012; Gaskin & Rayner, 2013; Hutton et al., 2008; Lavers et al., 2014, 2021; G. Taylor, 2000). Additionally, there is also the potential that each island's population is under different pressures that have not yet been documented. For instance, plastic pollution (transported to the island via foraging adults) is common on Ohinau Island (Buxton et al., 2013), and suspected to be more severe than on Lady Alice with many dead chicks found in burrows and on the forest floor on Ohinau Island with high consumption of plastics (Burgin & Ray, 2022). However, because trips to Lady Alice Island during chick fledging have not occurred for two years, this aspect has not been investigated on Lady Alice Island.

Tracking undertaken by WMIL may also pertain to some of the other reasons that may be causing a decline. For the Lady Alice Island population, previous tracking of incubating adults shows that birds from Lady Alice take on average longer foraging trips (16.6 days) compared to those from Ohinau Island (11.8 days) (Crowe, 2020a). The foraging trips of the two individuals equipped this breeding season with GPS trackers that were still incubating eggs at the time of retrieval, took 11 and 13 days. Longer foraging trips could be suggestive of lower body condition as individuals are taking longer to meet a healthy weight before they return to the colony to switch incubation duties, or could indicate increased difficulty in finding enough food. These longer incubation shifts are likely to lead to increased breeding failure as the incubating birds may be unable to sustain their weight and leave before their partner arrives to take over incubation duties. Continual monitoring is warranted to investigate this potential cause further.

The threat status of flesh-footed shearwater was recently improved in the latest New Zealand threat rankings, moving from 'Near Threatened' to 'At Risk – Relict' (Robertson et al., 2021). This was postulated to be due to the removal of invasive mammals from many of their breeding islands and from changes in fisheries practices that have reduced bycatch mortality (Graeme Taylor, DOC, pers. obs.). However, in light of these dramatic losses, WMIL strongly recommend the threat classification status being reviewed, especially if other nearby islands where flesh-footed shearwaters breed reveal similar declines in population size. Additionally, there are still many gaps in our understanding of flesh-footed shearwater biology such as recruitment rates and juvenile survival that need to be investigated. Continued monitoring at study colonies and frequent population surveys are vital to understand the trajectories and potential changes of the populations and the species as a whole.

4.6 Adult Tracking

There was a low retrieval rate of devices on both Ohinau (0%) and Lady Alice (44%). Burrow failure was thought to be the cause for some of these devices not being retrieved, with birds not returning to the colony

and/or not staying in burrows. Over both islands nine of the 16 tracked burrows failed. However, one device from a failed burrow was recovered during night work. A number of factors may have contributed to these burrow failures including time of year, tracking newly banded birds and the weight of the devices used.

Tracking on Ohinau was undertaken during egg laying and at least one tracked burrow failed due to another pair taking over the burrow shortly after device attachment. WMIL recommends that future tracking should be avoided during this period of the breeding cycle due to the risks of tracked birds being subject to breeding burrows still being established and potentially switched during this time.

Three newly banded birds were tracked this season and two of these burrows failed. The extra time handling these birds, possibly breeding for the first time, may have contributed to these failures and WMIL recommend tracking birds which have bred in burrows previously.

Finally, the I-GotchU devices used were on average 3.9% of the tracked birds body weight. This was slightly above the 3% of body weight threshold suggested by Phillips et al. (2003) for albatrosses and petrels. Furthermore, Crowe (2020) found lowering the maximum device-body weight threshold to 2.5% appeared to alleviate the negative impacts on breeding success that were encountered during flesh-footed shearwater tracking in 2018. The devices used for tracking this season were a trial to determine if the slightly heavier but cheaper devices could be used for tracking flesh-footed shearwaters, however they appear to be above the threshold tolerated by this species and WMIL recommends that future tracking should use lighter devices with a maximum of 2.5% device body weight.

Foraging may have been impacted for one of the tracked birds with a weight gain of only 12% between departing and returning to the colony. The egg from this burrow did also fail. This is the same average weight gain seen during the 2018 tracking (Crowe, 2018b) and is well below the 25% weight gain between observed at Bethels Beach (G. Taylor pers. comm.). However, the other three tracked birds from this season returned to the colony with a weight increase of 19%-32%, just below or well above those observed at Bethels Beach and similar to averages seen during WMIL tracking previously in 2019/2020 at Lady Alice (17%) and Ohinau (20%) (Crowe, 2020)

Incubation foraging trips were reasonably long on Ohinau Island. GPS tracked birds from active breeding burrows had been away for 12 days or more without returning. Unfortunately, no devices were retrieved by the end of the December 2023 trip. Similar trip lengths were recorded in 2020 where GPS birds were away on average 11.8 days but trips varied from 6-16 days (Crowe, 2020a). The average Lady Alice foraging trip during incubation was 13.3 days, with another bird still to return to an active burrow after 16 days. This average is shorter than previous seasons which found average foraging trips of 14.7 and 16.6 day, but still within the range of trip lengths for previous seasons (10-23 days) (Crowe, 2018b; Crowe 2020). Long foraging trips could be due to poor body condition or lack of food resources, which may then cause birds to abandon eggs (see section 4.5).

4.6.1 Spatial distribution

Tracked adult flesh-footed shearwaters tracked travelled either to the west coast of the North Island, or out to the Louisville Seamount Chain. Both the west coast of the North Island and the area around Louisville Ridge are highly important to flesh-footed shearwaters from both Lady Alice and Ohinau Islands during incubation and chick rearing (Crowe, 2018b, 2020c). A number of seabird species use the Louisville Seamount Chain during breeding and non-breeding seasons including toroa/Antipodean albatross (*Diomedea antipodensis*; Walker & Elliott, 2006) pararā/broad-billed prions (*Pachyptila vittata*; Grecian et al., 2016), and ranguru/Chatham Island petrel (*Pterodroma axillaris*; (Rayner et al., 2012) and tāiko/Chatham Island taiko (*Pt. magentae*; G. Taylor pers. comm.). This area is also targeted by commercial fisheries (Global Fishing Watch, 2024) and as such has implications for conservation management.

4.7 Chick Tracking

To better understand the movements of flesh-footed shearwater chicks from New Zealand breeding colonies, tracking of chicks was undertaken this season from Titi Island. The tracked chicks travelled up both the east and west coast of New Zealand to the Pacific around Vanuatu. The average time back mounts were active in

2023 was 64 days (Ray & Burgin, 2023), however this season three devices had stopped transmitting after 16-26 days, which is a shorter timeframe than was hoped. The reason for this are unknown but could be due to devices being pulled off, device failure, feathers covering solar panels or the chicks suffering mortality as accidental bycatch in recreational or commercial fisheries. The area where the devices have stopped transmitting is known to have high fishing activity (Global Fishing Watch, 2024). The first few months are also challenging for juvenile seabirds as they navigate the open ocean for the first time, and lack of experience in foraging may also result in mortality, as suspected by other work (Afán et al., 2019).

Tracking of this seasons Titi chicks and those from Ohinau in 2019 and 2023 have shown all birds travelling north through the pacific, with Titi chicks travelling slightly west of Ohinau birds (Ray & Burgin, 2023). Chicks fledged from Titi were spending their time moving around the pacific islands and were yet to travel past the equator after 29 days. Three devices were still transmitting as of the 12 June and may reveal more about the Titi chick fledging movements over time.

WMIL believes the data collected on the chicks' movements this season has provided valuable insights into this species fledging movements and prompts further research questions for future monitoring and conservation for this species. Harnesses were to be trialled this season with the hopes to get data from a longer period but logistically couldn't be undertaken. However, is recommended to be trialled for future work. Tracking from Titi has also shown chicks travelling past the Taranaki coast near where an offshore wind farm has been proposed which may have impacts on this species in the future. To conclude, further tracking work to understand these movements more remains valuable.

5. CONCLUSIONS & RECOMMENDATIONS

WMIL conclude that this season's work has continued to provide valuable insights into flesh-footed shearwater biology, as well as provided key lessons learned that should be taken forward for future work on this species. There are numerous areas of future research, however the high concerns regarding the population declines and the potential impacts of climate change and other factors present a priority research task for the future of this species.

5.1 Demographic monitoring

The number of established study burrows on Ohinau and Lady Alice Islands creates a valuable infrastructure for continual long-term demographic monitoring. Significant effort has been put in to setting this up, and banding flesh-footed shearwaters on both islands since 2016, and it is recommended that it continues to be utilised. Recapture efforts of breeding adults, non-breeders and returnee chicks need to be consistently large scale to provide a robust mark-recapture dataset and the large banding effort will help to achieve this, however continued banding is still of great value.

WMIL recommends that:

- **Population monitoring on Ohinau and Lady Alice Islands be continued with 200 breeding study burrows and 50 burrowscope burrows monitored annually over two expeditions (Dec/Jan and Apr/May).**
- **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.**
- **Titi Island, Marlborough Sounds, be considered as a potential future monitoring location.**

A significant mark/recapture dataset has been collected and an attempt should be made to analyse this data and obtain updated estimates 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.

Undertaking monitoring at the most southern breeding location for this species, Titi Island, is recommended in light of climate change and to therefore better understand how breeding success varies across the national breeding locations.

5.2 Population Estimates

In light of the apparent declines found at these two breeding colonies, there is a pressing need to continue to repeat these population estimates, and undertake them at other breeding colonies to understand if these declines are happening across the breeding range.

WMIL recommends that:

- **A repeat population estimate on Ohinau Island be undertaken as soon as possible.**
- **A repeat population estimate on Lady Alice Island be undertaken as soon as possible.**
- **A repeat population estimate on Titi Island be undertaken as soon as possible.**
- **Other breeding colony sites for flesh-footed shearwaters be considered for population estimates.**

Continued and more frequent population estimates for this species will better inform conservation management by providing higher resolution data to understand how the populations at these two sites fares over the coming seasons, as well as understand possible natural fluctuations. Understanding population size dynamics at sites such as Titi Island will be crucial for comparison and to better understand the national population dynamics.

5.3 Tracking

The difficulties and lessons learned from this season's tracking should be collated and inform future tracking of this species.

WMIL recommends that:

- **WMIL recommends that future tracking should use lighter devices with a maximum of 2.5% device body weight.**
- **Tracking be undertaken at Lady Alice, Ohinau and/or Titi Islands during chick fledging.**
- **Trial harnesses for chick tracking.**

Continued tracking of chicks would provide more information on chick movements after fledging and trialling the use of harnesses movements could provide data over a longer period of time post-fledging.

6. MANAGEMENT OF RECORDS

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

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

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9. APPENDICES

9.1 Appendix 1 Ohinau Island Chick Re-sighting

Key: "X" = Banded, "0" = not re-sighted, "1" = re-sighted, "-" = not alive.

Island	Band #	Date Banded	Natal burrow / Surface	First Return Date	Age at First Return	Age Now	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Ohinau	Z67117	22-Apr-16	CC08	06-Dec-21	5	8	X	0	0	0	0	0	1	0	0
Ohinau	Z67149	23-Apr-16	PK35	07-Dec-21	5	8	X	0	0	0	0	0	1	0	1
Ohinau	Z67167	24-Apr-16	PK54	24-Jan-20	3	8	X	0	0	0	1	0	0	0	0
Ohinau	Z67180	25-Apr-16	SG10	24-Feb-20	3	8	X	0	0	0	1	0	0	0	0
Ohinau	Z67187	25-Apr-16	SG17	09-Dec-21	5	8	X	0	0	0	0	0	1	0	0
Ohinau	Z67220	26-Apr-16	HT23	21-Jan-23	6	8	X	0	0	0	0	0	0	1	0
Ohinau	Z67263	27-Apr-16	CS27	06-Dec-21	5	8	X	0	0	0	0	0	1	0	0
Ohinau	Z67308	29-Apr-16	Surface	20-Jan-20	6	8	X	0	0	0	1	1	0	0	1
Ohinau	Z67339	30-Apr-16	Surface	02-Dec-21	5	8	X	0	0	0	0	0	1	0	0
Ohinau	Z67361	01-May-16	CC24	08-Dec-21	5	8	X	0	0	0	0	0	1	0	0
Ohinau	Z67392	02-May-16	BS13	22-Jan-20	3	8	X	0	0	0	1	0	0	0	0

Island	Band #	Date Banded	Natal burrow / Surface	First Return Date	Age at First Return	Age Now	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Ohinau	Z67398	03-May-16	CC29	14-Dec-20	4	8	X	0	0	0	0	1	0	0	0
Ohinau	Z67405	02-May-16	Surface	15-Dec-20	4	8	X	0	0	0	0	1	0	0	0
Ohinau	Z67438	04-May-16	Surface	02-Dec-21	5	8	X	0	0	0	0	0	1	0	0
Ohinau	Z67450	04-May-16	Surface	20-Jan-20	3	8	X	0	0	0	1	0	0	0	1
Ohinau	Z67267	27-Apr-16	CS(Retired)	14-Dec-23	7	8	X	0	0	0	0	0	0	0	1
Ohinau	Z67390	02-May-16	BS10	4-Dec-23	7	8	X	0	0	0	0	0	0	0	1
Ohinau	Z67403	02-May-16	Surface	10-Dec-23	7	8	X	0	0	0	0	0	0	0	1
Ohinau	Z67127	23-Apr-16	PK08	13-Dec-23	7	8	X	0	0	0	0	0	0	0	1
Ohinau	Z67160	24-Apr-16	PK46	13-Dec-23	7	8	X	0	0	0	0	0	0	0	1
Ohinau	Z67166	24-Apr-16	PK53	1-Dec-23	7	8	X	0	0	0	0	0	0	0	1
Ohinau	Z67194	25-Apr-16	Next to SG22	17-Dec-23	7	8	X	0	0	0	0	0	0	0	1
Ohinau	Z66478	30-Apr-17	PK29	15-Jan-23	5	7	-	X	0	0	0	0	0	1	0
Ohinau	Z66485	30-Apr-17	PK45	16-Dec-21	4	7	-	X	0	0	0	0	1	0	0

Island	Band #	Date Banded	Natal burrow / Surface	First Return Date	Age at First Return	Age Now	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Ohinau	Z66376	27-Apr-17	HT10	7-Dec-23	5	6	-	X	0	0	0	0	0	0	1
Ohinau	Z66688	27-Apr-18	SG08	13-Jan-23	4	6	-	-	X	0	0	0	0	1	0
Ohinau	Z66679	27-Apr-18	SG03	1-Dec-23	4	6	-	-	X	0	0	0	0	0	1

9.2 Appendix 2 – Lady Alice Island Chick Re-sighting

Key: "X" = Banded, "0" = not re-sighted, "1" = re-sighted, "-" = not alive, "*" = No trip undertaken.

Island	Band #	Date Banded	Natal burrow/ Surface	First Return Date	Age at First Return	Age Now	Andrea Booth (2000-2009)	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Lady Alice	Z55745	21-Apr-17	A5	23-Jan-24	6.8	7	-	X	0	0	0	0	0	*	1
Lady Alice	Z55747	21-Apr-17	B5	17-Jan-24	6.8	7	-	X	0	0	0	0	0	*	1
Lady Alice	Z55792	22-Apr-17	D1	13-Jan-24	6.8	7	-	X	0	0	0	0	0	*	1
Lady Alice	Z55795	22-Apr-17	J11	9-Jan-24	6.8	7	-	X	0	0	0	0	0	*	1
Lady Alice	Z56001	22-Apr-17	J27	17-Jan-24	6.8	7	-	X	0	0	0	0	0	*	1
Lady Alice	Z56002	22-Apr-17	J29	15-Jan-24	6.8	7	-	X	0	0	0	0	0	*	1

Island	Band #	Date Banded	Natal burrow/ Surface	First Return Date	Age at First Return	Age Now	Andrea Booth (2000-2009)	2016/ 17	2017/ 18	2018/ 19	2019/ 20	2020/ 21	2021/ 22	2022/ 23	2023/ 24
Lady Alice	Z56013	22-Apr-17	H16	11-Jan-24	6.8	7	-	X	0	0	0	0	0	*	1
Lady Alice	Z56016	22-Apr-17	H3	25-Jan-24	6.8	7	-	X	0	0	0	0	0	*	1
Lady Alice	Z56026	22-Apr-17	F8	9-Jan-24	6.8	7	-	X	0	0	0	0	0	*	1
Lady Alice	Z56048	23-Apr-17	L5	11-Jan-24	6.8	7	-	X	0	0	0	0	0	*	1
Lady Alice	Z55942	21-Apr-18	D2	19-Jan-24	5.8	6	-	-	X	0	0	0	0	*	1
Lady Alice	Z55959	21-Apr-18	M7	19-Jan-24	5.8	6	-	-	X	0	0	0	0	*	1
Lady Alice	Z55964	21-Apr-18	I3	22-Jan-24	5.8	6	-	-	X	0	0	0	0	*	1
Lady Alice	Z55968	22-Apr-18	G8	18-Jan-24	5.8	6	-	-	X	0	0	0	0	*	1
Lady Alice	Z55973	22-Apr-18	H13	19-Jan-24	5.8	6	-	-	X	0	0	0	0	*	1
Lady Alice	Z55977	22-Apr-18	H10	18-Jan-24	5.8	6	-	-	X	0	0	0	0	*	1
Lady Alice	Z55989	22-Apr-18	J12	19-Jan-24	5.8	6	-	-	X	0	0	0	0	*	1
Lady Alice	Z57231	26-Apr-19	D8	25-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57233	26-Apr-19	D12	17-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57234	26-Apr-19	D5	25-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1

Island	Band #	Date Banded	Natal burrow/ Surface	First Return Date	Age at First Return	Age Now	Andrea Booth (2000-2009)	2016/ 17	2017/ 18	2018/ 19	2019/ 20	2020/ 21	2021/ 22	2022/ 23	2023/ 24
Lady Alice	Z57236	26-Apr-19	F9	18-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57241	26-Apr-19	I7	25-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57246	27-Apr-19	J54	9-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57249	27-Apr-19	J13	19-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57306	27-Apr-19	J44	19-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57318	27-Apr-19	J57	17-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57352	27-Apr-19	H5	21-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57357	27-Apr-19	H12	18-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57360	27-Apr-19	H28	23-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57364	27-Apr-19	E5	25-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57365	27-Apr-19	E4	18-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z57366	27-Apr-19	E6	19-Jan-24	4.8	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z66962	01-May-19	CC48	24-Jan-24	4.7	5	-	-	-	X	0	0	0	*	1
Lady Alice	Z59517	05-May-09	Unknown	N/A	N/A	15	X	1	0	1	1	1	1	*	1

Island	Band #	Date Banded	Natal burrow/ Surface	First Return Date	Age at First Return	Age Now	Andrea Booth (2000-2009)	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Lady Alice	Z50137	18-Mar-00	Unknown	5-Jan-06	6	24	X	0	1	1	1	1	1	*	1
Lady Alice	Z22291	03-May-06	Unknown	N/A	N/A	18	X	1	1	1	1	0	1	*	1
Lady Alice	Z50196	06-May-00	Unknown	N/A	N/A	24	X	1	1	1	1	1	1	*	1
Lady Alice	Z22269	09-May-05	Unknown	N/A	N/A	19	X	1	0	0	0	0	0	*	1
Lady Alice	Z53987	03-May-04	Unknown	N/A	N/A	20	X	1	1	1	1	1	1	*	1
Lady Alice	Z53829	03-May-02	Unknown	15-Jan-07	5	22	X	1	1	1	1	1	1	*	1
Lady Alice	Z53958	03-May-03	Unknown	N/A	N/A	21	X	1	1	1	1	1	1	*	1
Lady Alice	Z22271	09-May-05	Unknown	N/A	N/A	19	X	1	1	1	1	1	1	*	1
Lady Alice	Z53814	03-May-01	Unknown	N/A	N/A	23	X	1	1	1	1	0	0	*	0
Lady Alice	Z53954	03-May-03	Unknown	N/A	N/A	21	X	1	1	0	0	0	0	*	0
Lady Alice	Z53955	03-May-03	Unknown	N/A	N/A	21	X	1	1	0	0	0	0	*	0
Lady Alice	Z53963	04-May-03	Unknown	16-Dec-07	4	21	X	1	1	1	0	0	0	*	0
Lady Alice	Z53979	02-May-04	Unknown	N/A	N/A	20	X	0	1	0	0	1	1	*	0
Lady Alice	Z53997	04-May-04	Unknown	N/A	N/A	20	X	0	1	1	1	0	0	*	0

Island	Band #	Date Banded	Natal burrow/ Surface	First Return Date	Age at First Return	Age Now	Andrea Booth (2000-2009)	2016/ 17	2017/ 18	2018/ 19	2019/ 20	2020/ 21	2021/ 22	2022/ 23	2023/ 24
Lady Alice	Z22264	08-May-05	Unknown	N/A	N/A	19	X	0	1	1	1	1	1	*	0
Lady Alice	Z46052	23-Apr-07	Unknown	N/A	N/A	17	X	0	1	1	1	0	0	*	0
Lady Alice	Z46053	23-Apr-07	Unknown	N/A	N/A	17	X	1	0	0	0	0	0	*	0
Lady Alice	Z59519	05-May-09	Unknown	N/A	N/A	16	X	0	0	0	1	0	0	*	0

9.3 Appendix 3

Summary of burrow transect data and population estimate for Ohinau Island carried out in the 2017/18 breeding season.

Colony	Dates Surveyed	Number of transects	Area sampled (m^2)	Large burrow counted	Burrows/m^2	Number of burrows with known status	Occupancy Rate	3D surface colony area (m^2)	Estimated Occupied Burrows	Lower 95% CI	Upper 95% CI
Camp + Camp South	29 Dec 2017-1 Jan 2018	25	975	79	0.08	74	0.51	36,092.14	1,495	975	2,015
Hilltop		5	200	31	0.16	28	0.46	11,474.10	826	342	1,310
South		9	360	45	0.13	43	0.47	9,386.82	546	304	788
South Gully		9	360	44	0.12	39	0.41	5,718.34	287	160	413
Pōhutukawa		13	520	36	0.07	36	0.39	14,100.00	380	134	625
South Point		3	120	0	0.00	0	0.00	8,932.20	0	0	0
Slot		4	160	7	0.04	7	0.29	800.00	10	0	26

Mid-East	Not surveyed	-	-	-	0.09*	-	0.36*	5,826.29	179	76	282
Middle	-	-	-	-	0.09*	-	0.36*	1,617.93	50	21	78
Big Island	-	-	-	-	0.09*	-	0.36*	2,741.53	84	36	133
Little Island	-	-	-	-	0.09*	-	0.36*	919.60	28	12	45
Total/Average		**68**	**2695**	**242**	**0.09**		**0.36**	**97,608.94**	**3,884**	**2,060**	**5,715**
Mid-East, Middle, Big and Little Island were not surveyed, but the average burrow density and occupancy rates were used to estimate the number of occupied burrows											

Summary of burrow transect data and population estimate for Lady Alice Island carried out in the 2018/19 breeding season. Data reproduced from Table 4. of Crowe & Bell (2019)

Colony	Dates Surveyed	Number of transects	Area sampled (m^2)	Large burrow counted	Burrows/m^2	Number of burrows with known status	Occupancy Rate	3D surface colony area (m^2)	Estimated Occupied Burrows	Lower 95% CI	Upper 95% CI
LA1	16, 17 January 2019	60	2400	87	0.04	87	0.57	39173	809	565	1054
LA2 & LA3	16, 17 January 2019	39	1498	71	0.05	71	0.49	61873	1398	975	1822
LA4	24 January 2019	35	1400	41	0.03	41	0.27	24535	193	104	282
LA5	15 January 2019	30	1200	38	0.03	38	0.08	28332	73	44	101
LA6	12, 20 January 2019	22	856	48	0.06	48	0.48	12616	340	211	468
LA7	21 January 2019	59	2360	108	0.05	108	0.06	34652	94	63	125

LA8	12, 20 January 2019	34	1346	39	0.03	39	0.10	51997	157	104	211
LA9	15, 19 January 2019	30	1200	124	0.10	79	0.06	21546	125	96	155
LA10	19, 20 January 2019	30	1200	79	0.07	59	0.03	12389	28	19	38
Total		**339**	**13460**	**635**	**0.05**	**570**	**0.24**	**287113**	**3217**	**2180**	**4255**

Comparison of previous and current population estimates for Ohinau and Lady Alice Island carried out by WMIL (Crowe, 2018; Crowe & Bell, 2019). Estimates are the number of occupied breeding burrows (± 95% confidence intervals. Change in number depicts that absolute difference between population surveys with the percentage change following in parentheses).

Ohinau Island				Lady Alice Island			
Colony	**2017/18 estimate (± 95% CI)**	**2023/24 estimate (± 95% CI)**	**Change in number (%)**	**Colony**	**2018/19 estimate (± 95% CI)**	**2023/24 estimate (± 95% CI)**	**Change in number (%)**
Camp + Camp South	1,495 (975-2,015)	1,217 (847-1,587)	-278 (-18.61)	**LA1**	809 (565-1,054)	502 (315-689)	-307 (-37.95)
Hilltop	826 (342-1,310)	766 (329-1,203)	-60 (-7.27)	**LA2 & LA3**	1,398 (975-1,822)	1,023 (624-1,421)	-375 (-26.82)
South	546 (304-788)	624 (378-871)	+78 (+14.34)	**LA4**	193 (104-282)	122 (53-191)	-71 (-36.79)
South Gully	287 (160-413)	332 (101-564)	+46 (+15.96)	**LA5**	73 (44-101)	0	-73 (-100)
Pōhutakawa	380 (134-625)	282 (139-425)	-98 (-25.79)	**LA6**	340 (211-468)	491 (304-677)	+151 (+44.41)
South Point	0	140 (20- 260)	+140 (n/a)	**LA7**	94 (63-125)	132 (78-186)	+38 (+40.43)
Slot	10 (0-26)	22 (0- 45)	+12 (+122.22)	**LA8**	157 (104-211)	74 (44-104)	-83 (-52.87)
Mid-East	179 (76-282) *	102 (20-184)	-77 (-43.02)	**LA9**	125 (96-155)	0	-125 (-100)
Middle	50 (21-78) *	91 (0-183)	+41 (+82)	**LA10**	28 (19-38)	23 (12-34)	-5 (-17.86)

Big Island	84 (36-133) *	109 (36-182) *	+25 (+29.76)				
Little Island	28 (12-45) *	37 (12-61) *	+8 (+32.14)				
Overall	**3884 (2060-5715)**	**3722 (1881- 5566)**	**-162 (-4.17)**		**3217 (2180-4255)**	**2367 (1430-3302)**	**-850 (-26.42%)**

Mid-East, Middle, Big and Little Island colonies were not surveyed in 2017/18. Estimates for the number of occupied burrows for these colonies were estimated using the Ohinau Island wide average burrow density and average occupancy rates for the 2017/18 season. Big Island and Little Island colonies were not surveyed in the 2023/24 season, population size for these colonies was estimated using the 2023/24 Ohinau Island wide average burrow density and average occupancy rates.
All instances of negative lower estimates were truncated to zero.

9.4 Appendix 4

Adult tracking deployment and retrieval data for Ohinau and Lady Alice Islands.

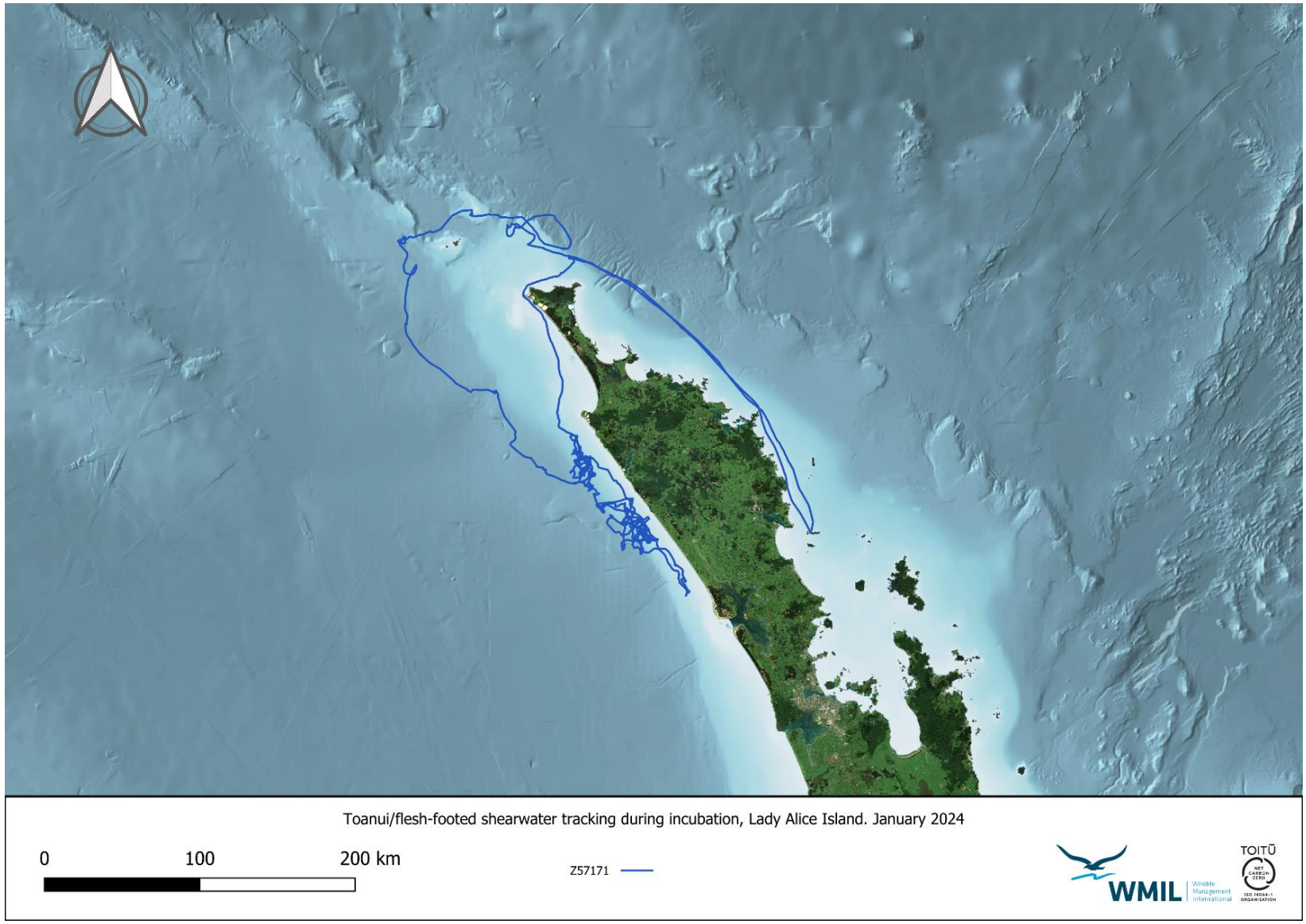
Island	Band #	Sex	Tag #	Date On (NZDT)	Time to Deploy (mins)	Date Retrieved (NZDT)	Weight on (g)	Device-body weight %	Weight Off (g)	Trip Length	Burrow Outcome (Dec/Jan)
Ohinau	64002	Female	22	6/12/2023	22	N/A	640	3.91	N/A	N/A	Egg alone
Ohinau	66752	Female	7	8/12/2023	41	N/A	640	3.91	N/A	13+	Bird on egg
Ohinau	58149	Female	18	8/12/2023	32	N/A	620	4.03	N/A	13+	Bird on egg
Ohinau	59081	Female	24	9/12/2023	32	N/A	660	3.79	N/A	N/A	Egg alone
Ohinau	15079	Female	5	9/12/2023	30	N/A	600	4.17	N/A	12+	Bird on egg
Ohinau	67014	Female	9	10/12/2023	34	N/A	670	3.73	N/A	N/A	Egg alone
Ohinau	59051	Female	4	10/12/2023	30	N/A	650	3.85	N/A	N/A	Egg alone
Lady Alice	56808	Unknown	18	9/01/2024	11	25/01/2024	565	3.89	630	*15	Egg broken
Lady Alice	55605	Male	9	9/01/2024	12	23/01/2024	560	3.93	685	**14	Bird on egg

Lady Alice	55841	Unknown	17	9/02/2024	10	25/01/2024	575	3.83	760	11	Bird on egg
Lady Alice	57171	Female	19	10/01/2024	9	24/01/2024	570	3.86	680	13	Bird on egg
Lady Alice	57254	Female	12	10/01/2024	10	N/A	525	4.19	N/A	16+	Bird on egg
Lady Alice	56838	Unknown	4	10/01/2024	9	N/A	550	4.00	N/A	N/A	Egg disappeared
Lady Alice	55666	Female	13	10/01/2024	10	N/A	580	3.79	N/A	N/A	Egg alone
Lady Alice	56869	Unknown	3	10/01/2024	11	N/A	550	4.00	N/A	N/A	Egg alone
Lady Alice	57529	Unknown	1	10/01/2024	10	N/A	590	3.73	N/A	N/A	Egg alone

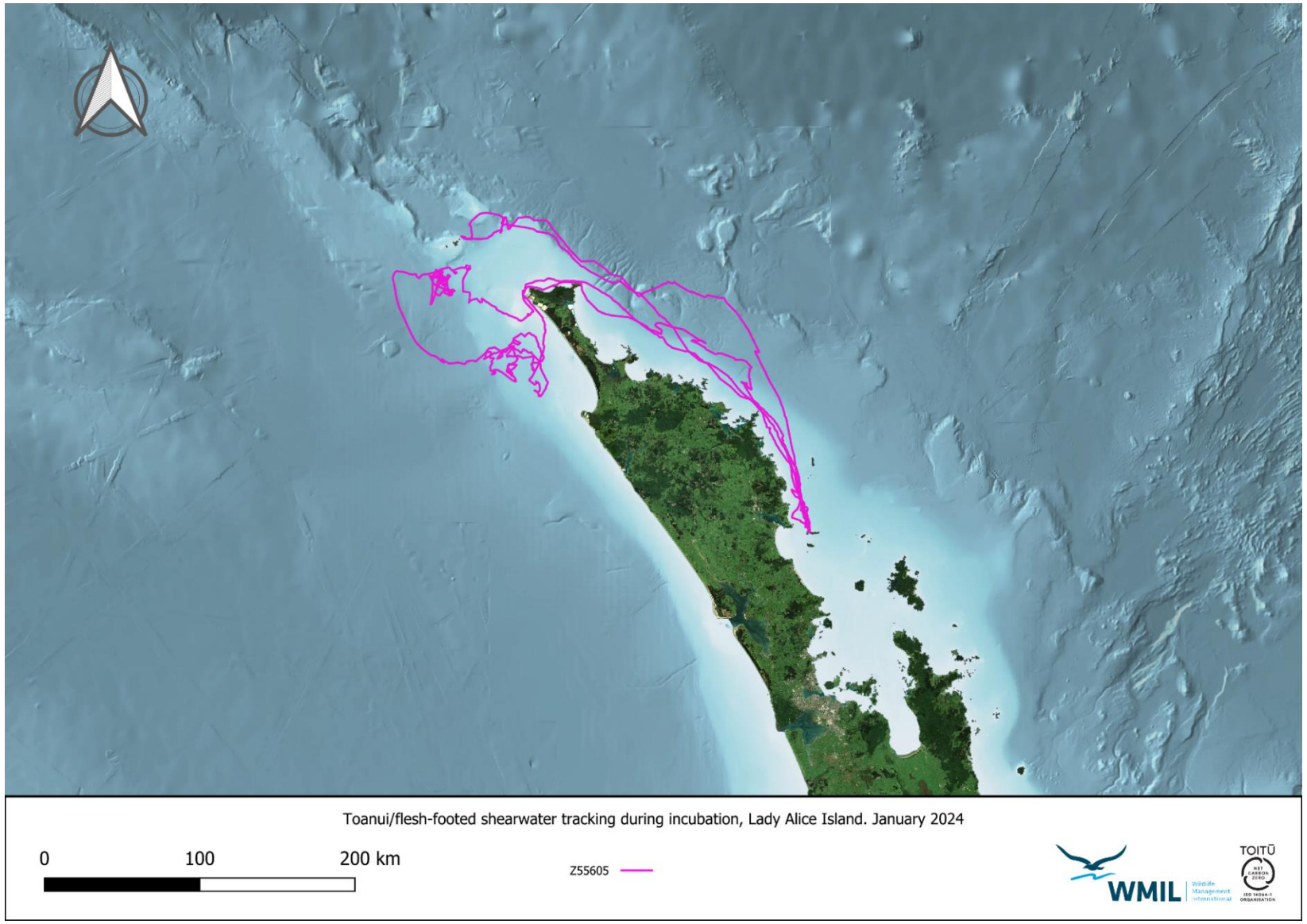
Note: No devices were retrieved from Ohinau, *1 day trip and then a longer 14 day trip, **Multiple short trips, possibly four trips

9.5 Appendix 5

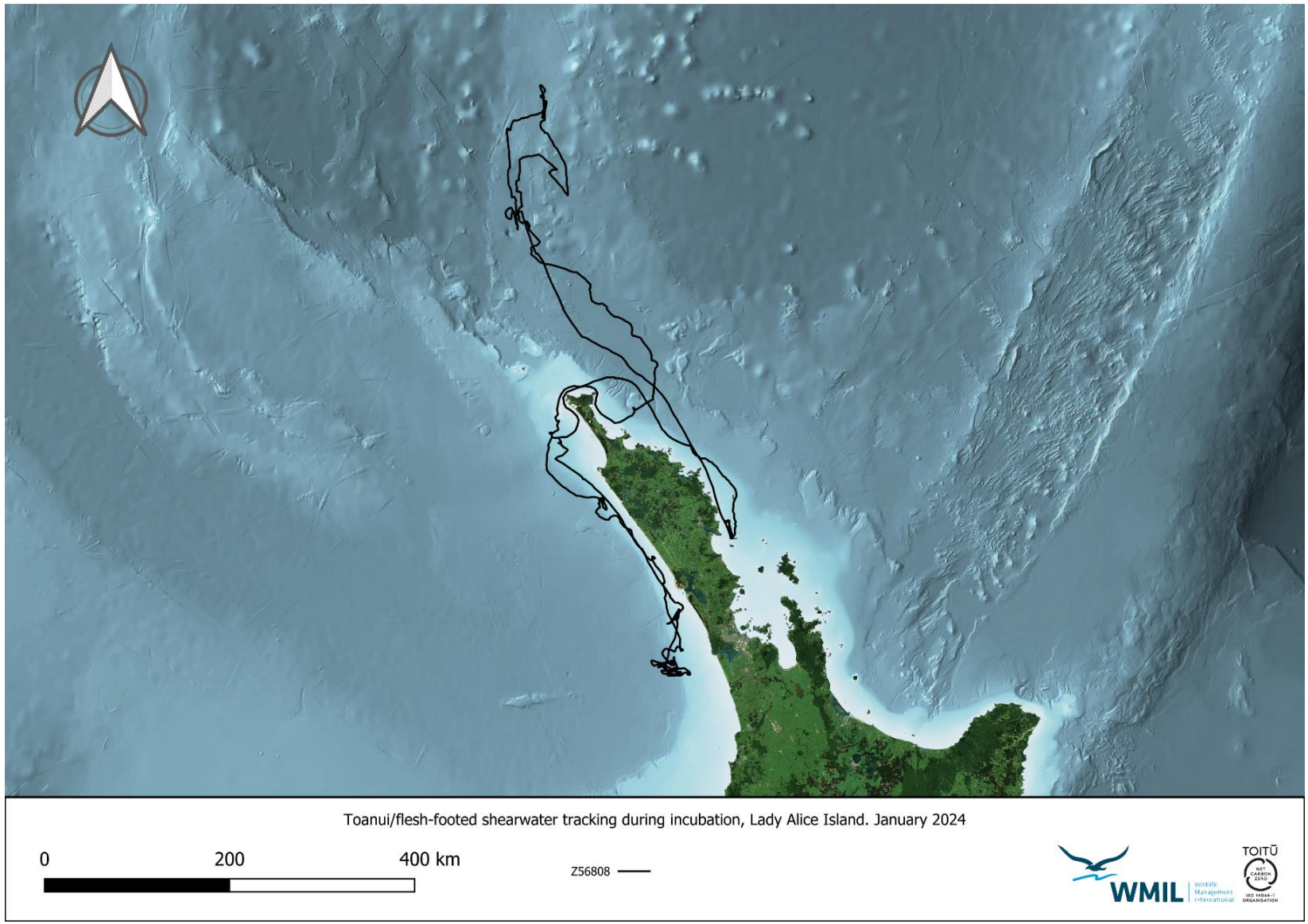
Individual adult tracking maps during incubation, Lady Alice Island.



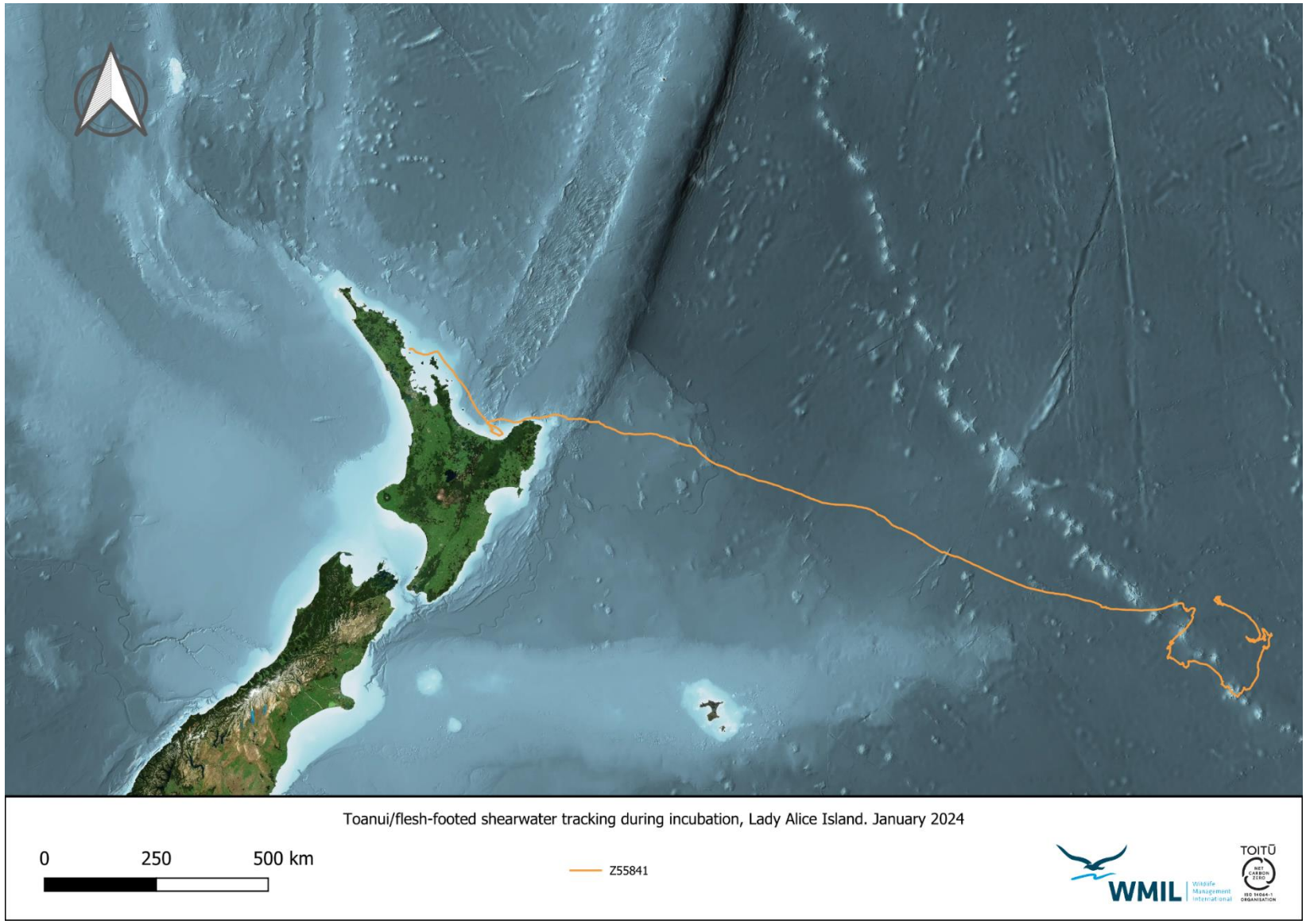
Ray, Lamb, Burgin & Olsthoorn (WMIL), 2024



Ray, Lamb, Burgin & Olsthoorn (WMIL), 2024



Ray, Lamb, Burgin & Olsthoorn (WMIL), 2024



Ray, Lamb, Burgin & Olsthoorn (WMIL), 2024

9.6 Appendix 6

Device deployment details for tracking chicks fledging from Titi Island

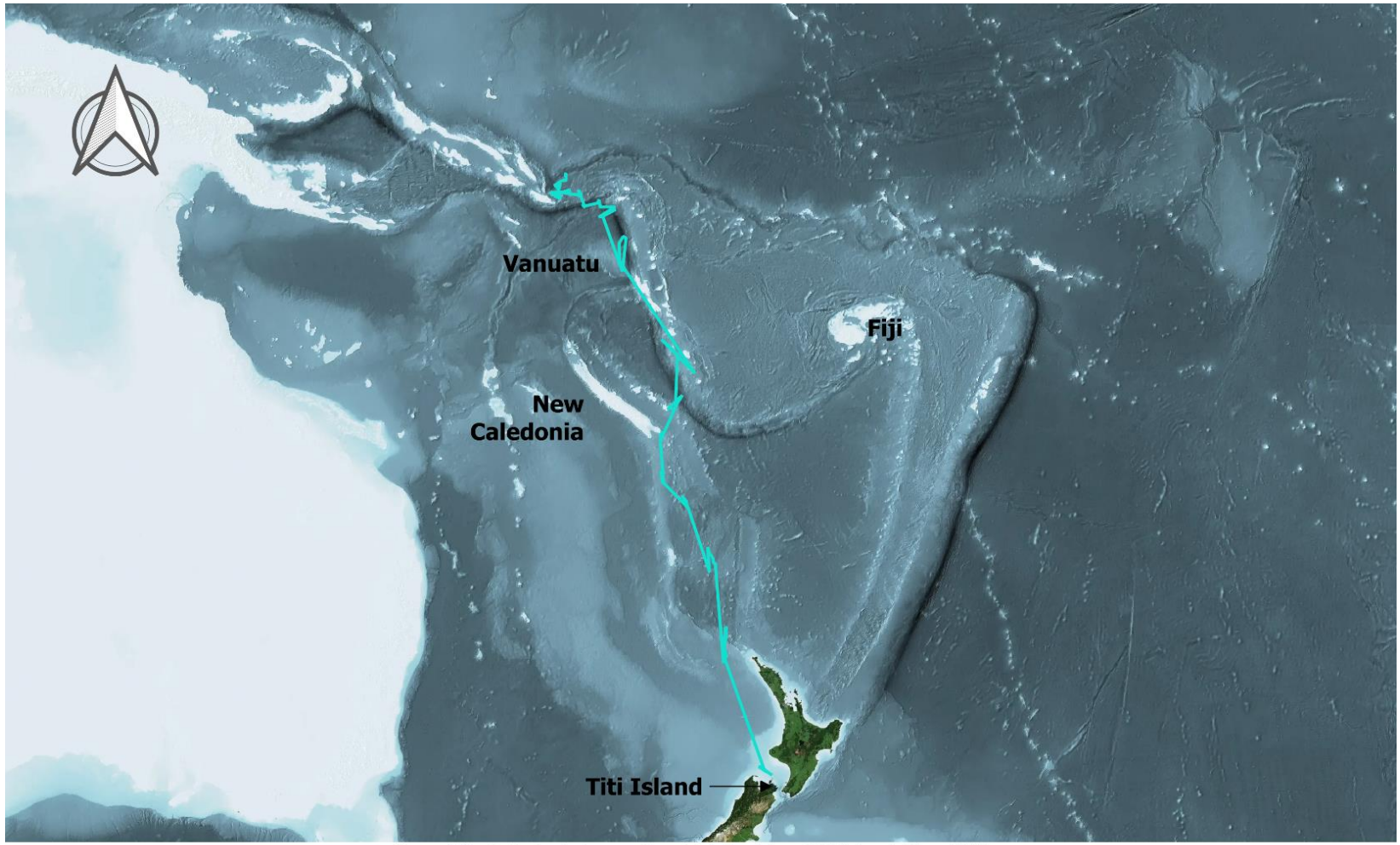
Band	Device #	Weight (g)	Wing Length (mm)	Time to deploy	Date Device Active	Date Device stopped*	Days Active
68356	254186	660	319	**13	14/05/2024	9/06/2024	26
68279	254185	700	309	13	14/05/2024	N/A	29
68299	254182	655	317	14	14/05/2024	2/06/2024	19
68295	254180	710	313	14	14/05/2024	30/05/2024	16
68353	254184	660	310	14	14/05/2024	N/A	29
68253	254183	680	322	15	16/05/2024	N/A	27
68255	254187	760	322	15	N/A	N/A	N/A

***As of 15/06/2024 three devices still active**

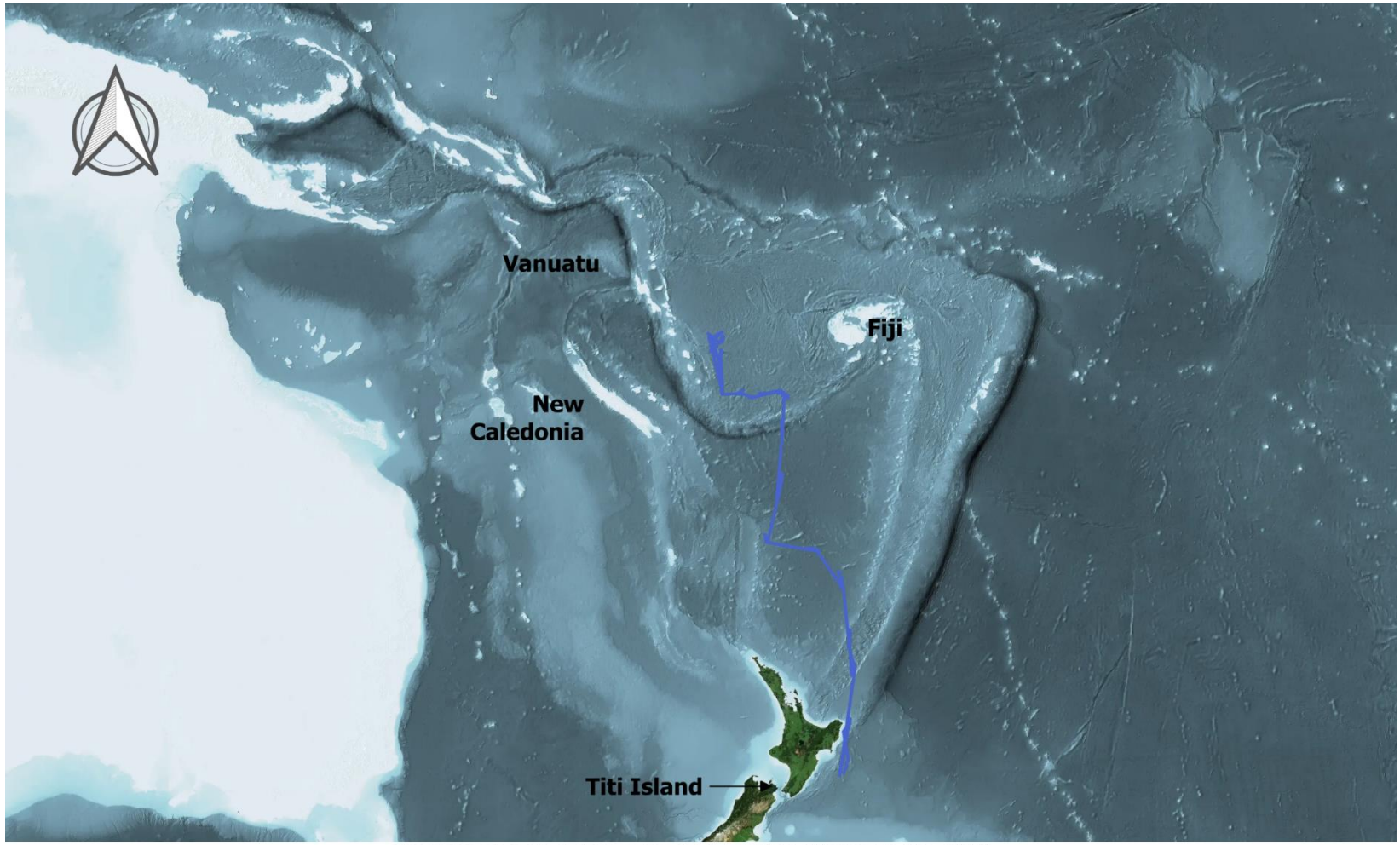
****Bird was in the hand much longer**

9.7 Appendix 7

Individual chick Tracks from Titi Island, as of 15 June 2024



Ray, Lamb, Burgin & Olsthoorn (WMIL), 2024

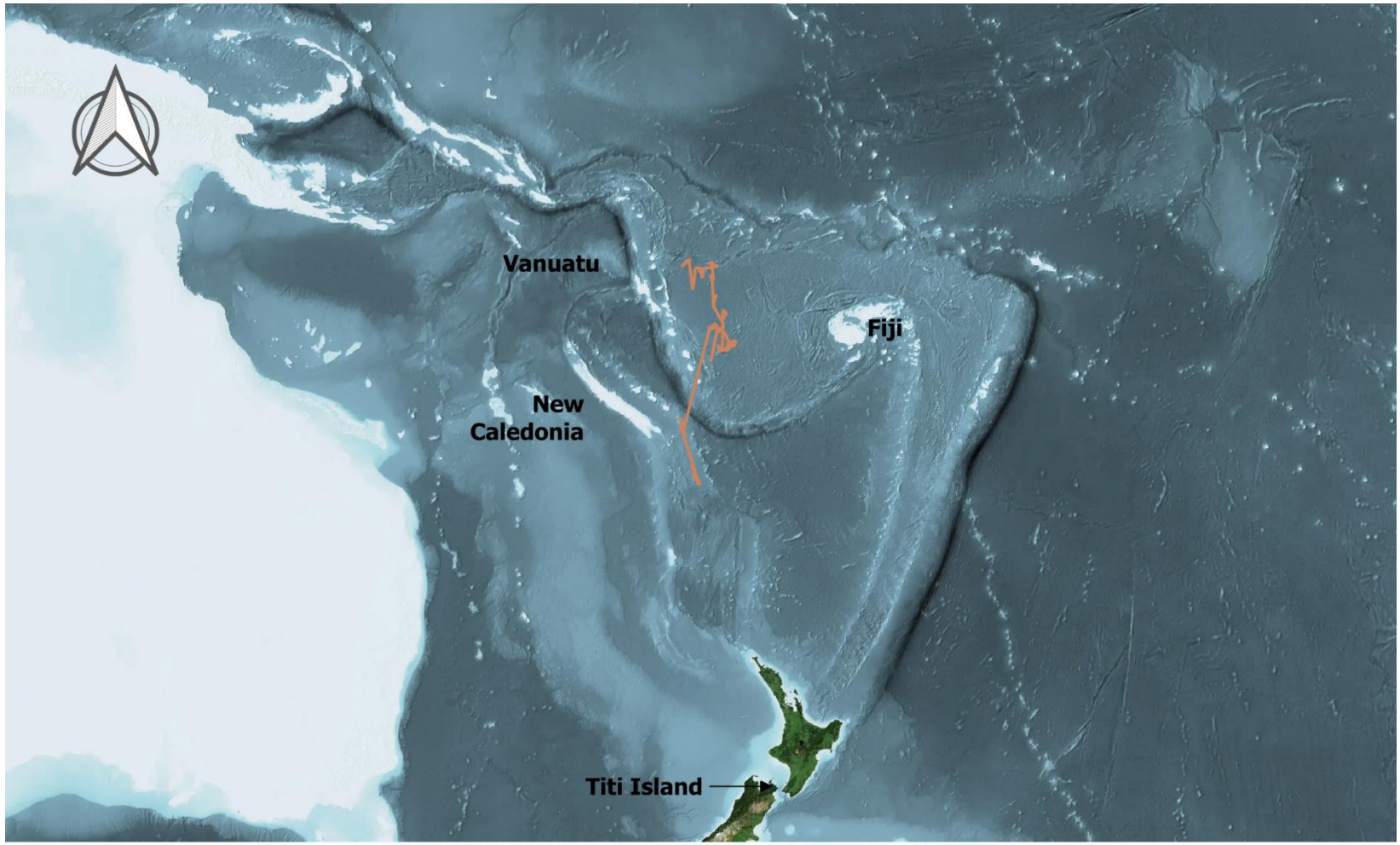


Toanui/flesh-footed shearwater chick tracking, Titi Island, May 2024

Flesh-Footed Shearwater Chick
254183

0 1,000 2,000 km

Ray, Lamb, Burgin & Olsthoorn (WMIL), 2024

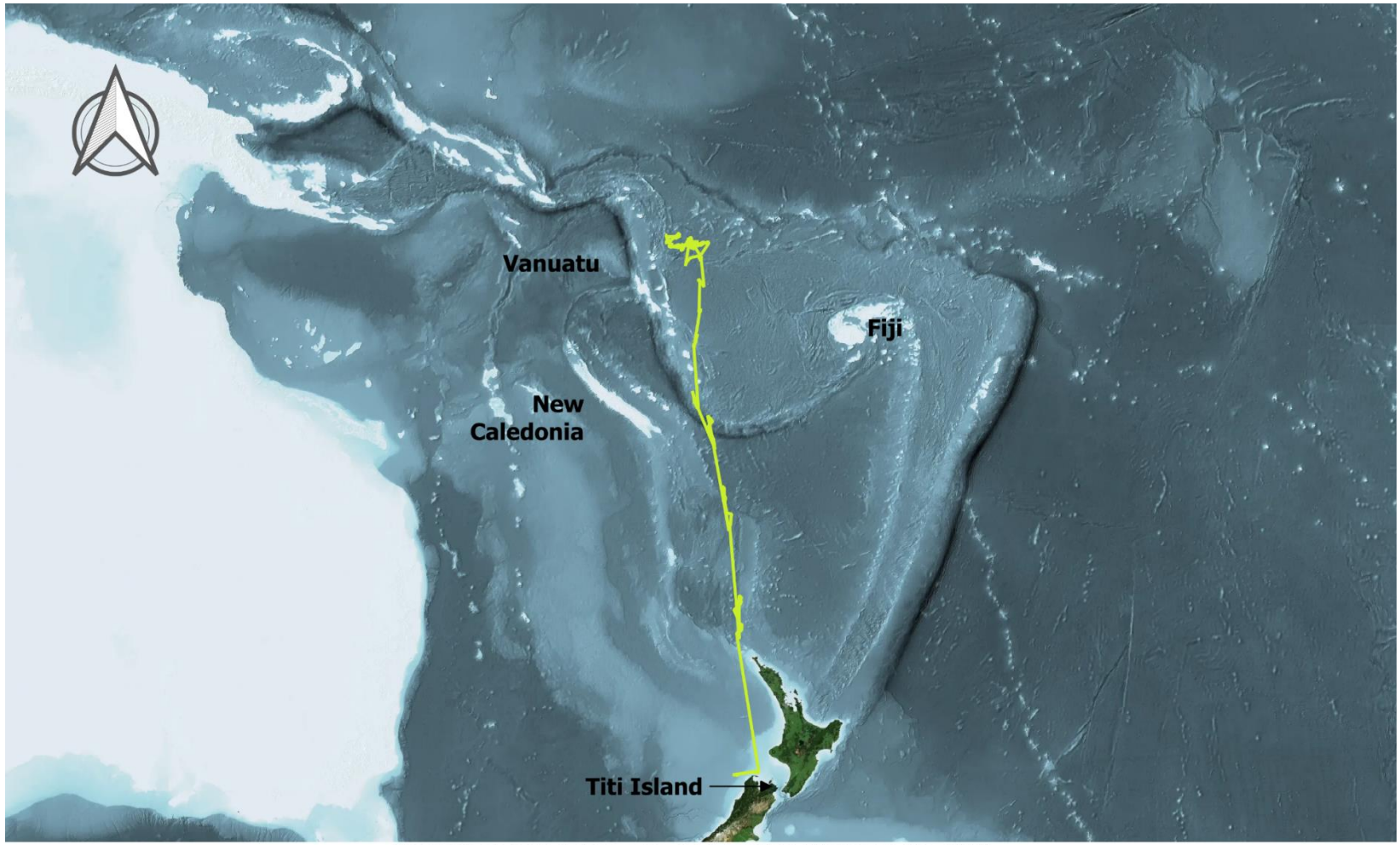


Toanui/flesh-footed shearwater chick tracking, Titi Island, May 2024

Flesh-Footed Shearwater Chick
254182

0 1,000 2,000 km

Ray, Lamb, Burgin & Olsthoorn (WMIL), 2024

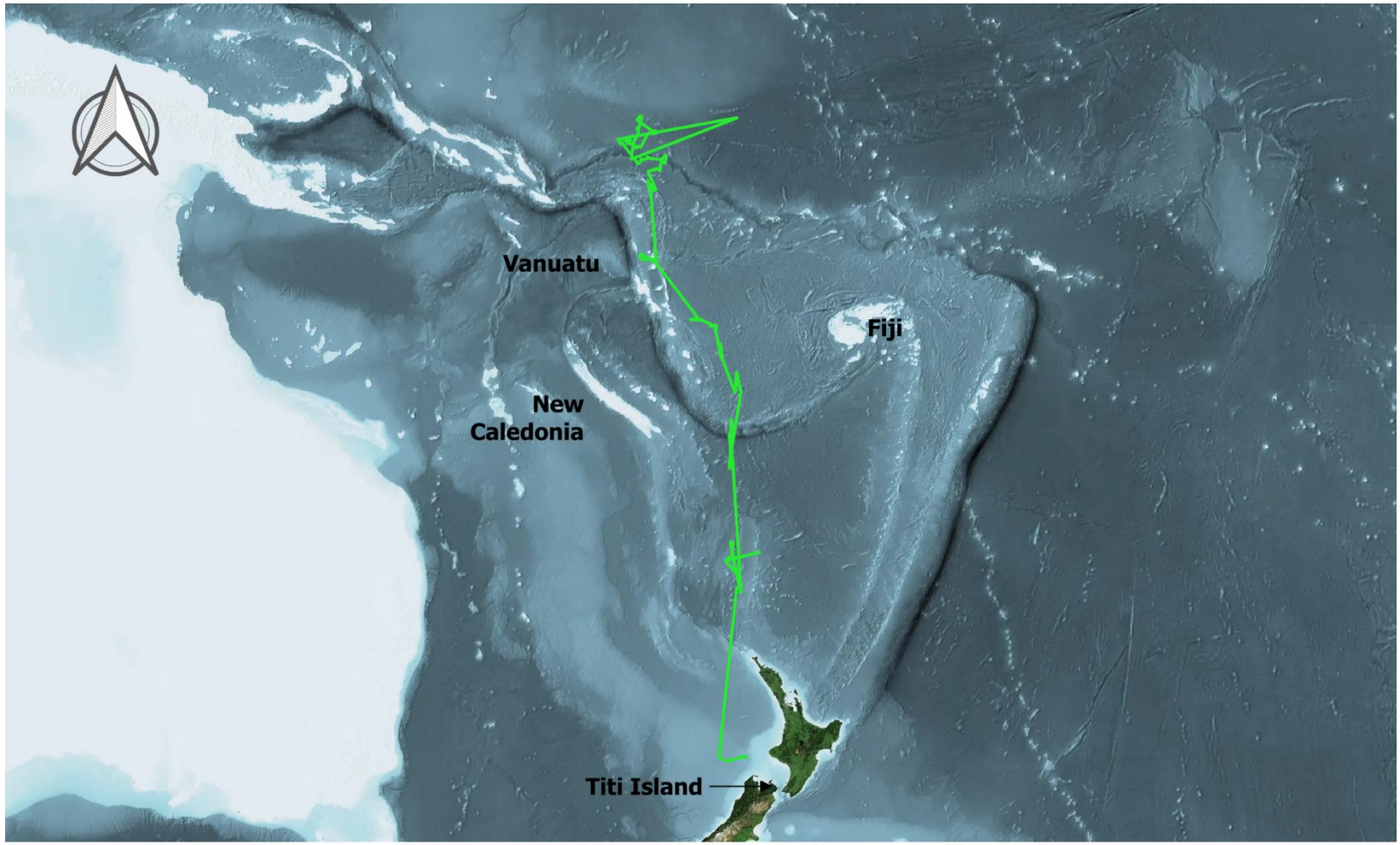


Toanui/flesh-footed shearwater chick tracking, Titi Island, May 2024

Flesh-Footed Shearwater Chick
254184

0 1,000 2,000 km

Ray, Lamb, Burgin & Olsthoorn (WMIL), 2024

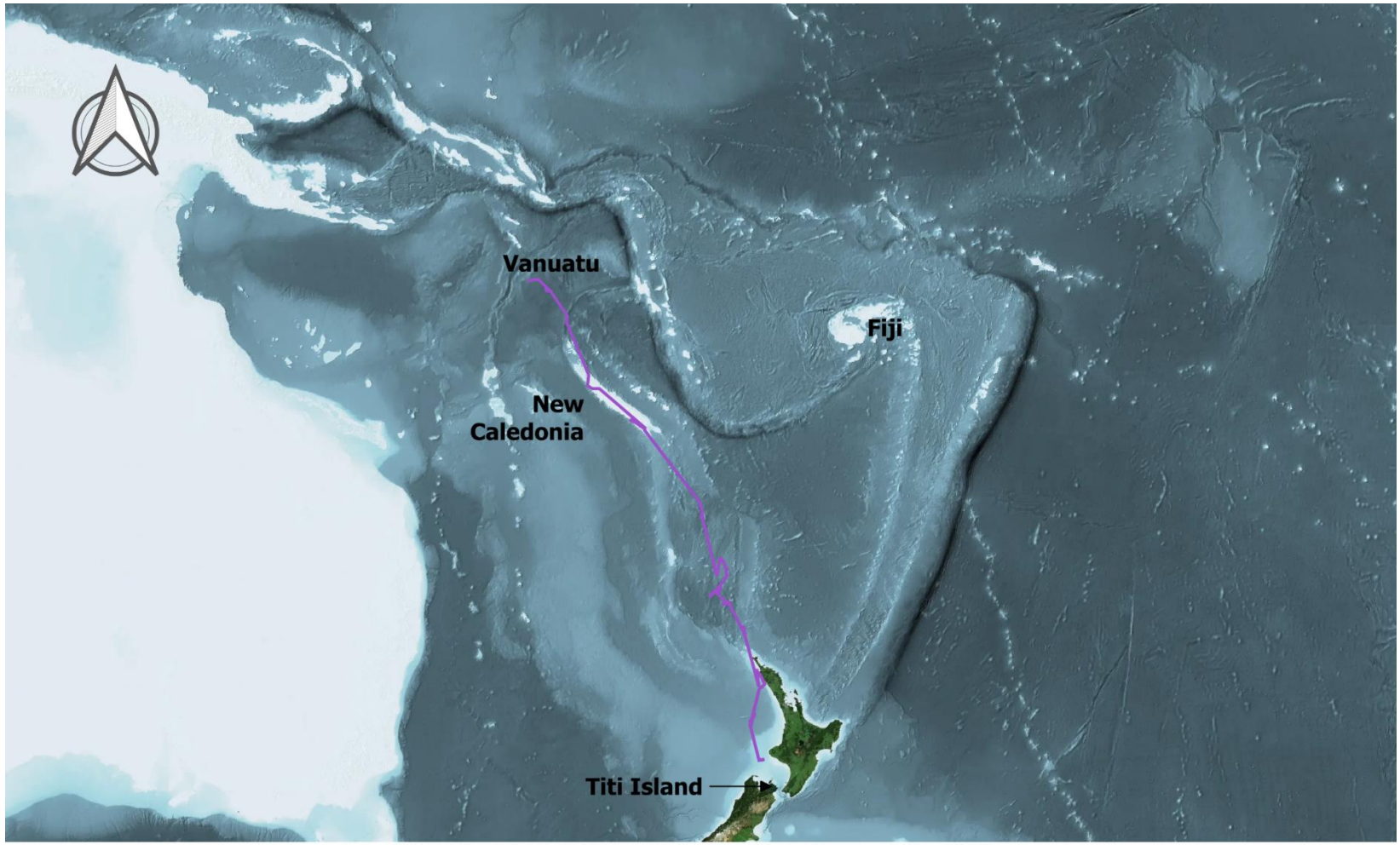


Toanui/flesh-footed shearwater chick tracking, Titi Island, May 2024

Flesh-Footed Shearwater Chick
254186

0 1,000 2,000 km

Ray, Lamb, Burgin & Olsthoorn (WMIL), 2024



Toanui/flesh-footed shearwater chick tracking, Titi Island, May 2024

Flesh-Footed Shearwater Chick
254180

0 1,000 2,000 km

Ray, Lamb, Burgin & Olsthoorn (WMIL), 2024