TOANUI/FLESH-FOOTED SHEARWATERS

Toanui/flesh-footed shearwater population monitoring and estimate Ohinau Island: 2022/23 season

WMIL Wildlife Management International

TOITŪ CARBON ZERO ISO 14064-1 ORGANISATION

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This report was prepared by Wildlife Management International Limited for the Department of Conservation as partial fulfilment of the contract (DOC- 7172757 - POP2021-04 Flesh-footed Shearwater Research) dated 17 October 2022.

Version History:

VERSION	DATE	AUTHOR	REASON FOR CHANGE
1	21/08/2023	WMIL: Ray, S., and Burgin, D.	First draft version.
2	8/09/2023	WMIL: Ray, S., and Burgin, D.	Second draft version.

21 August 2023

Citation:

This report should be cited as:

Ray, S. and Burgin, D. (2023). Flesh-footed shearwater population monitoring and estimate Ohinau Island: 2022/23 season. Report prepared by Wildlife Management International Limited for the New Zealand Department of Conservation, Wellington. 50p.

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

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EXECUTIVE SUMMARY

This report covers the findings from the year of flesh-footed shearwater (*Ardenna carneipes*) research under Conservation Services Programme (CSP) project POP2021-04 for the 2022/2023 season, funded by Department of Conservation (DOC). Here we report on the ongoing population monitoring of flesh-footed shearwaters on Ohinau Island.

During the 2022/23 season WMIL monitored 271 study burrows on Ohinau Island. The breeding success (burrows with an egg that produce a chick that is likely to survive to fledging) on Ohinau Island was 10%. This represents a large decrease compared to the 59% measured in the 2022/23 season. This is postulated to be because of the significant storm events that occurred in the region just after peak laying (December 2022 through to February 2023), and therefore as a result of climate change. There was a detectable difference in breeding success between study and burrowscope (control) burrows, indicating potential impact of handler disturbance. However, it is believed this is more likely due to the topography and location of the burrowscope colony compared to the other colony sites, which allowed these burrows to avoid the worst of the flooding. We were able to identify 51.5% of the birds in breeding study burrows on Ohinau Island. An additional 75 flesh-footed shearwaters were banded on Ohinau Island this season, with 47 adults and 28 chicks.

Due to weather constraints that led to 8 days being lost during the January 2023 expedition, an updated population estimate for Ohinau Island was unable to be completed. WMIL has recommended that the limited data that was able to be collected, not be used for the purposes of calculating a population estimate. Instead WMIL recommends postponing this work until the 2023/2024 season.

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.**
- **A repeat population estimate on Ohinau Island be undertaken in January 2024.**
- **Undertaking plastic collection from the surface of colonies, necropsy of dead individuals found at colony sites, as well as the lavage technique to understand more about plastic ingestion.**
- **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 shearwater at Ohinau Island, especially juvenile survival and recruitment**
2. **Estimate the current breeding population of flesh-footed shearwaters at Ohinau Island, to compare with past population estimates.**
3. **Attach satellite tracking tags to ten fledgling flesh-footed shearwaters in May 2023.**

Objective 1 is ongoing, and Objective 2 was unable to be completed this season due to bad weather and Objective 3 was completed on Ohinau Island in May of the 2022/23 season.

Ray, S., and Burgin, D. (WMIL)

Toanui/flesh-footed shearwater population monitoring 2021/2022

1. INTRODUCTION

Toanui/flesh-footed shearwaters (*Ardenna carneipes*) are a medium sized seabird acting as apex predators in the Indian and Pacific Oceans (Priddel et al. 2006). Breeding colonies are found on islands off the coast of northern New Zealand with the southernmost breeding colony on Titi Island, in the Marlborough Sounds on the 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 (Waugh et al. 2013; Lavers 2015). Under the New Zealand threat classification system, the decline of flesh-footed shearwaters has been recognised, although this species has recently been reclassified as "At Risk-relict" (Robertson et al. 2021). The International Union for Conservation of Nature's Red List of Threatened Species lists the species as "Near Threatened" and in decline across its range (Birdlife International 2019). Redolent of many seabird species, the primary threats to flesh-footed shearwaters include accidental bycatch in both commercial and recreational fisheries (Baker & Wise 2005; Abraham et al. 2010), competition for prey with commercial and recreational fisheries (Gaskin & Rayner 2013), habitat degradation from fishing practices such as bottom trawling (Gaskin & Rayner 2013), plastic ingestion (Hutton et al. 2008; Lavers et al. 2014; Bond *et al*. 2021; Lavers et al. 2021), invasive species (Taylor 2000; Croxall et al. 2012), and climate change (Bond & Lavers 2014). Flesh-footed shearwaters have been reported as one of the most commonly caught species in New Zealand long-line fishing and are also prone to being caught in trawl fisheries (Robertson et al. 2004; Abraham & Thompson 2011). It is estimated that between 496 and 1,020 flesh-footed shearwaters are killed annually in commercial fisheries (Richard et al. 2020). Flesh-footed shearwaters are known to have a wide-reaching distribution, utilising Australian and New Zealand waters during the breeding season, and migrating to the northern hemisphere portions of the Pacific Ocean post-breeding (Taylor 2000; Rayner et al. 2011). 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 (Reid 2010; Lavers et al. 2014; Lavers 2015), long-term studies measuring demographic parameters for New Zealand populations of this species have been based on small sample sizes (Barbraud et al. 2014). Long-term studies help with gaining a better understanding of demographic parameters such as adult survival, recruitment, age at first return and age at first breeding. This will consequently help provide more accurate population trends, and thus aid future management for the species, particularly in light of the myriad threats this species faces (Croxall et al. 2012).

Flesh-footed shearwaters represent a high trophic level in their ecosystem and can be valuable indicators of marine environmental change (Waugh et al. 2013). Gathering multi-generational datasets are therefore paramount for documenting, understanding and mitigating changes to the marine environment (Waugh et al. 2013). The possible decline of flesh-footed shearwaters coupled with a general lack of demographic and population estimates particularly in New Zealand (Taylor

2000), has warranted the establishment of a long-term population study. In addition to this, the need to update old population estimates, or survey islands for which robust estimates do not exist, is fundamental to the conservation management of the species. Two islands in northern New Zealand – Mauimua/Lady Alice Island (hereafter Lady Alice Island) and Ohinau Island - were both identified by Waugh *et al.* (2014) as suitable sites for such long-term studies due to being relatively easy to access and having large colony sizes.

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 seven consecutive seasons 2016/17 -2022/23. Lady Alice was not able to be monitored in the 2022/23 season due to Department of Conservation budget cuts and has been deferred for a year. WMIL have undertaken population estimates on both of these islands, Lady Alice in 2019, and Ohinau in 2018. GPS tracking of adults has been undertaken on both islands to determine incubation and chick rearing routes. Satellite tracking of chicks has also been carried out on Ohinau Island, to determine chick fledgling migration routes over this monitoring period.

This report presents results on the most recent work undertaken during the 2022/23 season on Ohinau Island.

2. METHODS

2.1 Study Sites and Dates

Ohinau Island

Ohinau Island (Mercury Islands Group, 36.73°S, 175.88°E) is a 43ha island located off the east coast of Coromandel Peninsula. The island is owned by local iwi, Ngati Hei, and co-managed with the Department of Conservation. There are 12 flesh-footed shearwater colonies on Ohinau Island, of which five contain study burrows (Camp, Camp South, South of Gully, Hilltop and Pohutukawa; Figure 1). These study burrows have been monitored intensively since 2016 (Mischler 2016; Crowe *et al.* 2017; Crowe 2018; Crowe & Bell 2019; Crowe 2020; Crowe & Burgin 2021; Burgin & Ray 2022). There is an estimated total of 4,007 (3,044 – 4,791) occupied burrows on the island (Crowe 2018). A team of two or three personnel was based on the island during the following dates:

- **Trip 1**: 8 January 2023 – 30 January 2023; checking all study burrows to determine breeding status, identify adult birds breeding in all burrows and band/recapture adult birds seen on the surface at night, as well as completing transects in all known breeding colonies.

- **Trip 2:** 2 May 2023 – 8 May 2023; checking all study burrows to determine breeding success and banding all chicks in burrows and on the surface at night. Additionally, the team were to attach 10 satellite tracking tags to chicks to track them as they fledge.

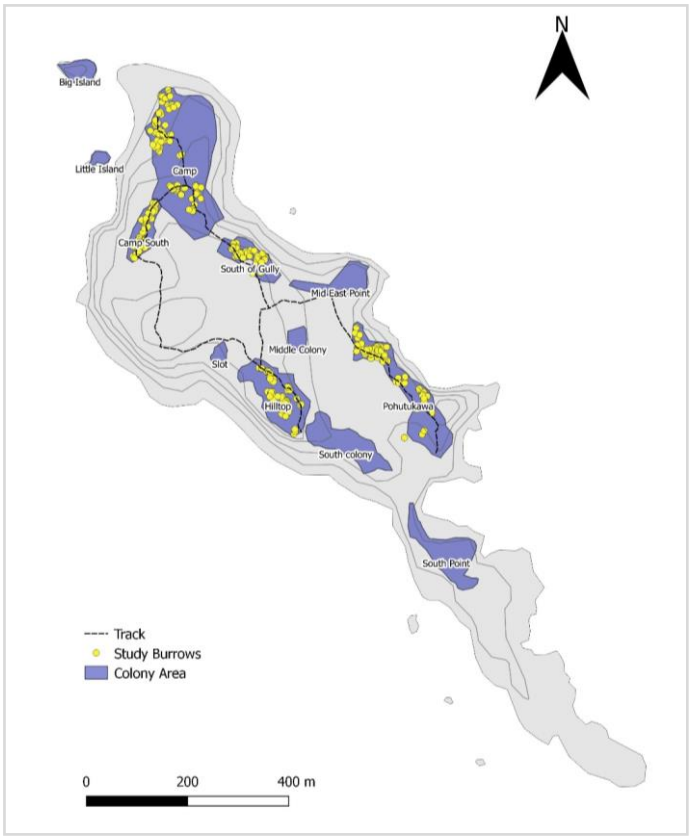

Figure 1. *Map of Ohinau Island showing the location of all flesh-footed shearwater colonies and all marked study burrows.*

2.2 Field Methods

Population monitoring

January Trip

Each study burrow was checked regularly during the January trip to determine the breeding status of the burrow and identify both partner birds. All birds found in these burrows were banded or had their band number checked and recorded. The sex of the bird was determined (or confirmed) from known partner birds with determined sex. Birds found in burrows were marked with correction fluid on the top of their head to prevent unnecessary handling during future burrow checks, and then placed back in their burrow. To reduce disturbance on incubating birds, smartphones were held down the burrow to use the flashlight and video tools to check on the occupants particularly for correction fluid on their head.

Once an egg was found in a burrow and both partners were banded and identified, the burrow was no longer checked for the duration of the trip. This helped minimise disturbance to the birds and the burrow. Empty and non-breeding burrows were checked all the way up until the day WMIL departed each island.

For any burrows that had failed (i.e., 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.

A subset of burrows are marked as to only be monitored using a burrowscope or smartphone, and the adult birds are never removed from the burrow. Importantly no hatches are dug in to these burrowscope burrows. Burrowscope burrows were checked only once during the January trips. The burrowscope, or smartphone, was fed down the entrance of the burrow until a bird was seen and then confirmed as to whether it was incubating an egg or not. If no bird was seen after a thorough search, the burrow was recorded as being empty.

Night work was carried out to increase the total number of banded birds and to recapture banded birds. Night work was primarily carried out between 21:00 and 23:00. Adults were caught by hand on the surface and were banded, marked with correction fluid and the general capture location was recorded relative to the known study colony. The bird was then released at the same location they were captured.

May Trip

At the start of May, Ohinau was revisited, to check study burrows again. All study burrows were checked, regardless of their breeding status in January. Chicks found in burrows were banded, weighed and had wing length measurements taken, before then being placed back in their burrows. All banded chicks were marked with correction fluid on their head to prevent unnecessary recapture when undertaking night banding. Breeding success is defined here as burrows with an egg that produce a chick that is likely to survive to fledging. Because chicks fledge in early May (Priddel et al. 2006), burrows with healthy chicks during this trip were assumed to have bred successfully. Where possible, the cause of failed breeding attempts was recorded. Empty burrows were checked thoroughly to make sure there was no sign of a chick or egg.

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

Night work on this trip was primarily aimed at catching any chicks coming out of burrows to exercise and preparing to fledge. Chicks caught were banded, weighed and had wing length measurements taken. They were also marked with correction fluid and the general capture location was recorded relative to the known study colony. Birds were then released at the same location they were captured.

Population Estimate

The same method was used as that in Crowe (2018) on Ohinau Island. Transect start points and a bearing (transect direction) were randomly generated within the colonies (Figure 4). A tape was run out for 20m from the start point on the generated bearing. Burrows were searched for in a 2m strip to the right-hand side of the tape i.e., each transect covered 40m^2. Transects were done 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.

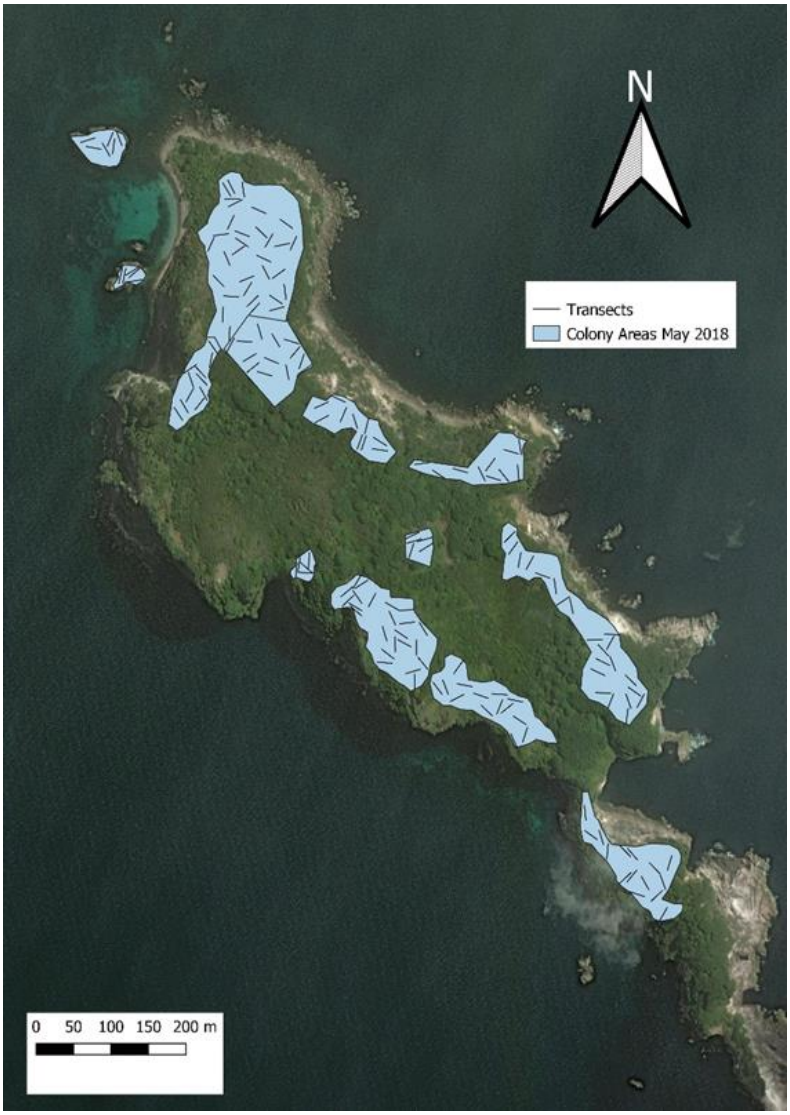

Figure 2. *Map of random transects for calculating an updated population estimate for flesh-footed shearwater, Ohinau Island.*

GLS Deployment

Twelve Intigeo-C330™ GLS devices (manufactured by Migrate Technology™) were deployed on adult flesh-footed shearwaters in January at Camp and Camp South Colony burrows. GLS devices were attached to each birds' metal leg band using two small, plastic cable ties. Each bird was weighed before being fitted with a GLS device. Attachments typically took less than 10 minutes. Once the device had been attached, the bird was placed back in its burrow.

These devices will be retrieved in December 2023 or January 2024 and will track the birds over the remainder of the incubation period, chick rearing and migration.

Figure 3: *GLS attached to metal band of adult flesh-footed shearwater January 2023.*

Chick Tracking

During May burrow checks a key objective was attaching 10 satellite devices to fledging flesh-footed shearwater chicks. One device unfortunately failed and as such 9 devices were deployed.

A day trip was undertaken to Titi Island, Marlborough Sounds, on 20 April 2023 to scout out possible flesh-footed shearwater breeding burrows with potential chicks for tracking (Figure 4). This was in light of being concerned about the breeding success on Ohinau Island and scouting out a different population to potentially undertake the tracking from. WMIL had previously been to Titi Island in 2022 to undertake a population estimate and so had an understanding of where flesh-footed shearwater breeding burrows were likely to be found (Burgin 2022).

Figure 4: *WMIL staff banding a flesh-footed shearwater chick Titi Island*.

Unfortunately, due to the lack of study infrastructure on Titi Island, it was very difficult to find enough flesh-footed shearwater burrows with chicks in to then potentially attach GPS devices on to track in May 2023. Only 6 potential flesh-footed shearwater chicks were found, with many more sooty shearwater chicks found. Two flesh-footed shearwater chicks were banded, alongside 15 sooty shearwater chicks. Additional landslips had removed a large quantity of previously known flesh-footed shearwater burrows too which reduced the number of potential flesh-footed shearwater burrows to access (Figure 5). Importantly without the infrastructure chicks were not easily reachable without having hatches installed, something that WMIL were not keen on installing without knowing that further monitoring work would be undertaken on this island. It was therefore decided that Ohinau Island would remain the focus of GPS attachment in May 2023.

Figure 5. *Landslip Titi Island April 2023.*

On Ohinau Island WMIL noted chicks in burrows that looked suitable for tracking, e.g., had a long wing length (290mm +), were a good size (620 – 800g), had a long tail length (110-115mm), with tail feathers no longer in pin and had lost most of their down feathers. WMIL also considered the burrow entrance size to make sure it was suitable for a bird with a tag attached to easily enter and exit its burrow. When a suitable bird was found that met our criteria, a Lotek Sunbird Argos PTT tag (satellite tag) was deployed as either a back mount (five deployments) or tail mount (four deployments). Details of each attachment method are described below.

Tail mount

PTT tags were attached to a secure yet lightweight plastic baseplate (Figure 5). The plastic baseplate measured 50mm x 25mm and was larger than the PTT tag itself. This was to prevent any feathers covering the solar panel, and thereby impede charging, and to create a surface area large enough to attach tape to.

The baseplate was first taped to two central tail feathers using three strips of Tesa tape (a piece at the top, bottom and middle of the baseplate). Baseplates were taped a finger width below the base of the tail feather. Two additional tail feathers were then taped to the baseplate using three bits of Tesa tape overtop of the original tape. A piece of fishing trace was threaded through the top baseplate hole and tail feathers and back up the second top hole. This was repeated for the bottom baseplate holes. Araldite epoxy glue was applied to the bottom of the PTT to secure it to the tape. Both pieces of fishing trace were threaded through the PTT tag and tied. A small amount of superglue was put over the fishing line knot and PTT tag holes to prevent it coming undone. An additional piece of Tesa tape was then put over the top and bottom of the PTT tape securing it to the baseplate, taking care to avoid tape covering the solar panel. Tail covets were trimmed to avoid feathers covering the solar panel and thereby impede charging.

Figure 3. *Pictures of tail mount a) with baseplate and PTT attached b) after PTT tag deployment was completed.*

Figure 4. *Pictures of back mount a) with baseplate at beginning of attachment b) after baseplate has been firmly attached with tape, and c) after PTT tag deployment was completed.*

Back mount

As with the tail mount deployments, PTT tags were attached to secure yet lightweight plastic baseplates of the same dimensions described above. Two pieces of fishing trace were threaded through the top and bottom holes of the baseplate before attachment (Figure 6).

The baseplate was taped to the bird using four strips of Tesa tape of varying width. Araldite epoxy glue was applied to the bottom of the PTT to secure it to the tape. Both pieces of fishing trace were threaded through the PTT tag and tied. A small amount of superglue was put over the fishing line knot and PTT tag holes to prevent it coming undone. An additional piece of Tesa tape was then put over the top and bottom of the PTT tape securing it to the baseplate, taking care to avoid tape covering the solar panel to avoid impeding the device from charging.

Māhoe die-off and subsequent understory growth

Previous trips to Ohinau Island in 2020 revealed that in some areas of the island, the dominant canopy species māhoe (*Melicytus ramiflorus*) had died off and this had caused nightshade (*Solanum* sp.) and inkweed (*Phytolacca octandra*) to grow in the understory (Crowe & Burgin 2021). Most areas with māhoe had experienced some die-off with nightshade and inkweed growth. Some areas, particularly the northwest facing slopes around Camp Colony, had extensive die-off and thick nightshade and inkweed growth. The māhoe die-off was likely caused by the drought conditions that were experienced in the 2019/20 summer in northern parts of the North Island (NIWA 2020). This caused issues with finding study burrows within these areas, and the regrowth of nightshade and inkweed was found to be even thicker in the 2021/22 season, particularly in the eastern parts of Camp Colony. Additionally, windfall of since dead trees made it very difficult to access areas and burrows, with some known burrows being entirely lost as a result. These issues continued in 2022/23 season (Figure 7).

Despite our best efforts, it was immensely difficult to locate burrows as tags were either covered up entirely, or the trees that they had been fixed too had fallen over and buried the marker. Additionally moving through this area was difficult and the risk of collapsing burrows was high without being able to see where WMIL staff were stepping. This led us to make the decision to retire 21 burrows in December 2020 in the camp colony area where the regrowth was thickest. WMIL then found new burrows within other areas of the study colonies, to replace these and ensure 200 breeding study burrows were reached, as well as 50 breeding burrowscope burrows. This deadfall continued into the April/May 2022 trip too, with continual deadfall and weed growth causing a further 3 burrows to be retired in Camp Colony. A further two burrows were retired in the 2022/23 season due to māhoe die off or being lost in deadfall.

Figure 7. *Example of windfall on Ohinau Island January 2023.*

3. RESULTS

3.1 Occupancy

Ohinau Island

A total of 271 study burrows were monitored throughout the entire 2022/23 season on Ohinau Island (Table 1). This consisted of 263 study burrows monitored in the previous season and 8 new study burrows put in over the January and May trips combined. Three study burrows were retired over the course of the season on the island, one of those being in Camp Colony due to the māhoe die off. Another in Pohutukawa which had collapsed. The other burrow in Camp South was retired due to being lost.

Of the 271 study burrows, 62% (*n* = 168) were breeding burrows and 4.8% (*n* = 13) were non-breeding burrows. The remaining 90 burrows were empty or held other species (Table 1). A total of 51.5% (173 of 336) of birds in breeding study burrows were identified. WMIL were able to successfully identify both partners for 21.4% (*n* = 36) of these 168 breeding burrows (Table 1). 60.1% (*n* = 101) of breeding burrows had only one partner identified while the remaining 18.5% of burrows (*n* = 31) had neither partner identified. Of those 31, 90.3% (n=28) were burrows in January where an egg was found but no incubating adults, 6.5% (n=2) were burrows with birds out of reach and the remaining 3.2% (n=1) had a chick discovered in May, which was thought to be empty in January.

Table 1. *Breakdown of burrow status for all study burrows on Ohinau Island 2022/23 season*.

Burrow Status	Ohinau Island
Breeding	
- 0 partners	31
- 1 partner	101
- 2 partners	36
Total breeding burrows	**168**
Non-breeding	
- 1 bird	7
- 2 birds	6
Total flesh-footed shearwater burrows	**181**
Other species	
- Kororā/little Penguin (Eudyptula minor)	1
- Ōi/grey-faced Petrel (Pterodroma gouldi) (chick in Jan)	1
Empty	88
Total Study Burrows	**271**
Newly Retired	**3**
Previously Retired	**50**
Total Retired Burrows	**53**

3.2 Breeding Success

Study Burrows

Breeding success for Ohinau Island this season was 10% (*n* = 17)**.** 25 chicks were found alive in study burrows during the May trip, but 8 of these were small and in poor condition (Appendix 1). These 8 chicks were not expected to fledge and breeding success output reflects this by removing them from the total. It appears more burrows failed during the incubation stage rather than the chick-rearing stage on both islands, however, there is a large degree of uncertainty, as the cause of burrow failure could not be determined in the majority of cases (Table 2).

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

	Ohinau	
	Study Burrows (*n*= 271)	**Burrowscope (*n* = 54)**
Breeding Burrows	168	32
Breeding success	17 (10%)	10 (31%)
Failed, pre-hatching	34 (20%)	4 (13%)
Failed, post-hatching	13 (8%)	0 (0%)
Failed, unknown reason	104 (62%)	18 (56%)

Breeding success was variable between study colonies and ranged from 0% to 25%, and burrowscope colony breeding success was 31% (Figure 8).

Figure 8. *Breeding success (%) for each study colony and Burrowscope colony on Ohinau Island 2022/23.*

Historic breeding success for both islands, and across study and burrowscope burrows are shown below in Figure 9. Note no values are shown for Lady Alice Island colonies this season due to lack of funding to support a trip here this season. This season breeding success on Ohinau Island reveals a large decrease (>30-50%) compared to previous seasons.

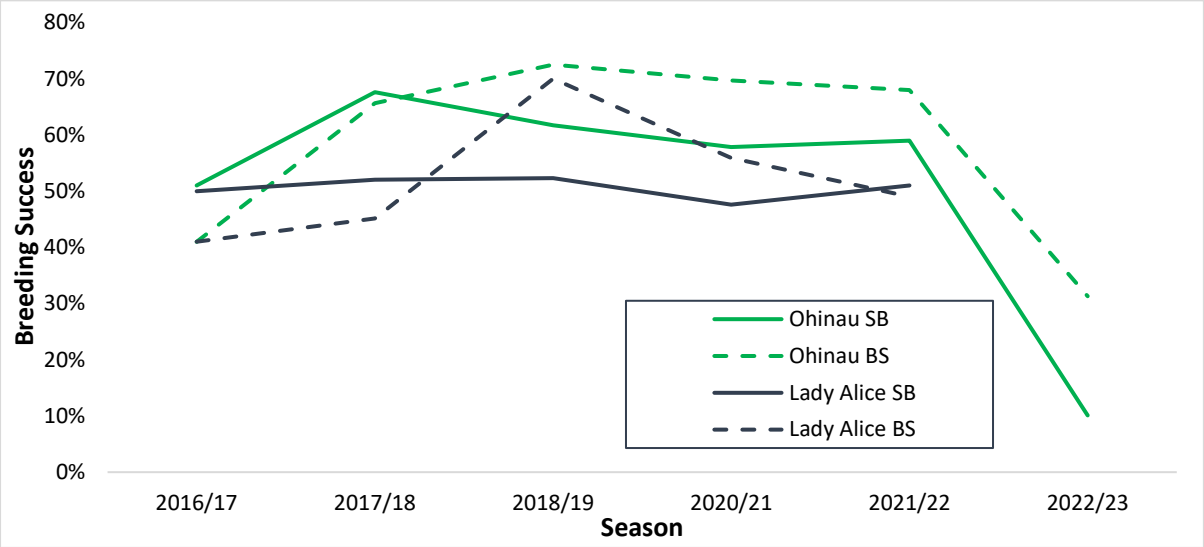

Figure 9. *Breeding success (%) for both study burrows (SB) and burrowscope burrows (BS) on Lady Alice and Ohinau Island from 2016/17 through to the 2022/23 season.*

The average breeding success for all burrows combined (study and burrowscope) since 2016 is 52% for Ohinau Island. Combined breeding success in the 2022/23 season was 14%. Breeding success has been higher on Ohinau Island compared to Lady Alice Island, in all seasons apart from the 2016/17 season when it was marginally lower (Figure 10). Lady Alice Island was not monitored during the 2022/23 season and WMIL are therefore not able to compare breeding success. Figure 10 highlights how combined breeding success from study and burrowscope burrows on Ohinau Island decreased by 47% between 2021/22 and 2022/23 seasons.

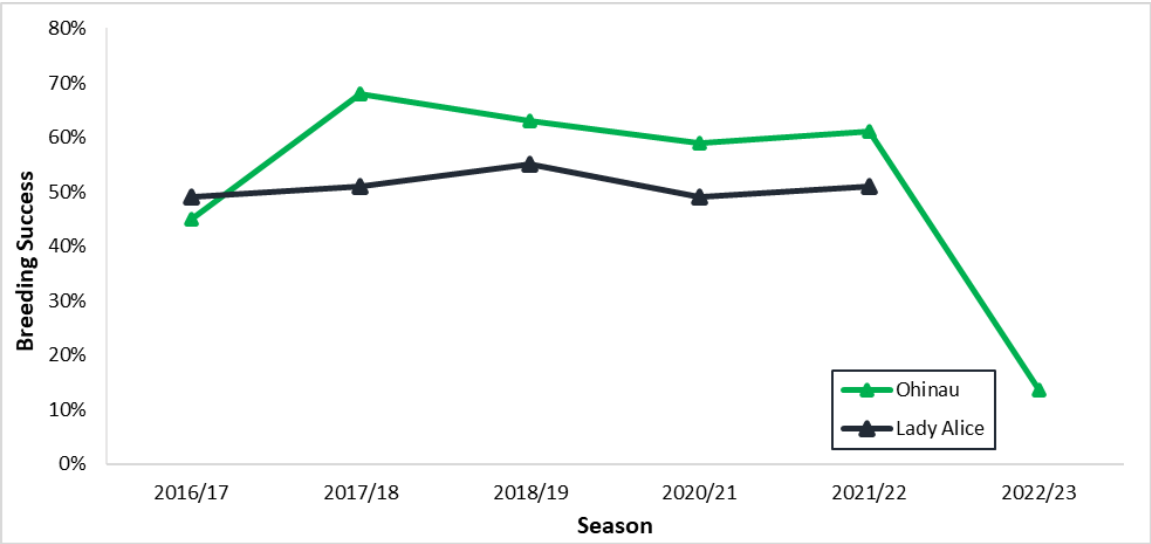

Figure 10. *Combined breeding success (%) from study and burrowscope burrows on both Lady Alice and Ohinau Island from 2016/17 to the 2022/23 season.*

Over three months (Dec-Jan 2022/23) Whitianga experienced an average of 362mm of rain, which is well above the average of 132mm since 2016 (Figure 11; NIWA 2023). There was also an increase in peak daily rainfall for December and February 2023 compared to previous seasons (Figure 12; NIWA. 2023). No peak daily rainfall data was available for January 2023.

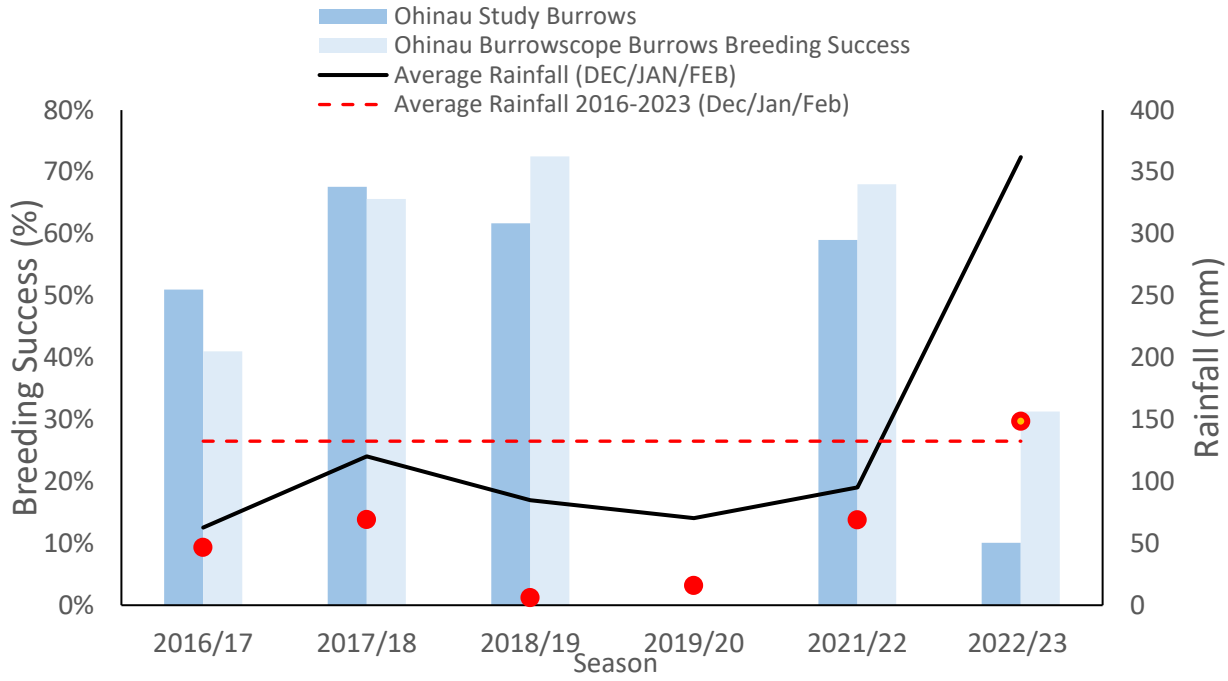

Figure 11. *Whitianga mean daily rainfall over three months (Dec-Jan) and Ohinau Island study burrow and burrowscope breeding success each season.*

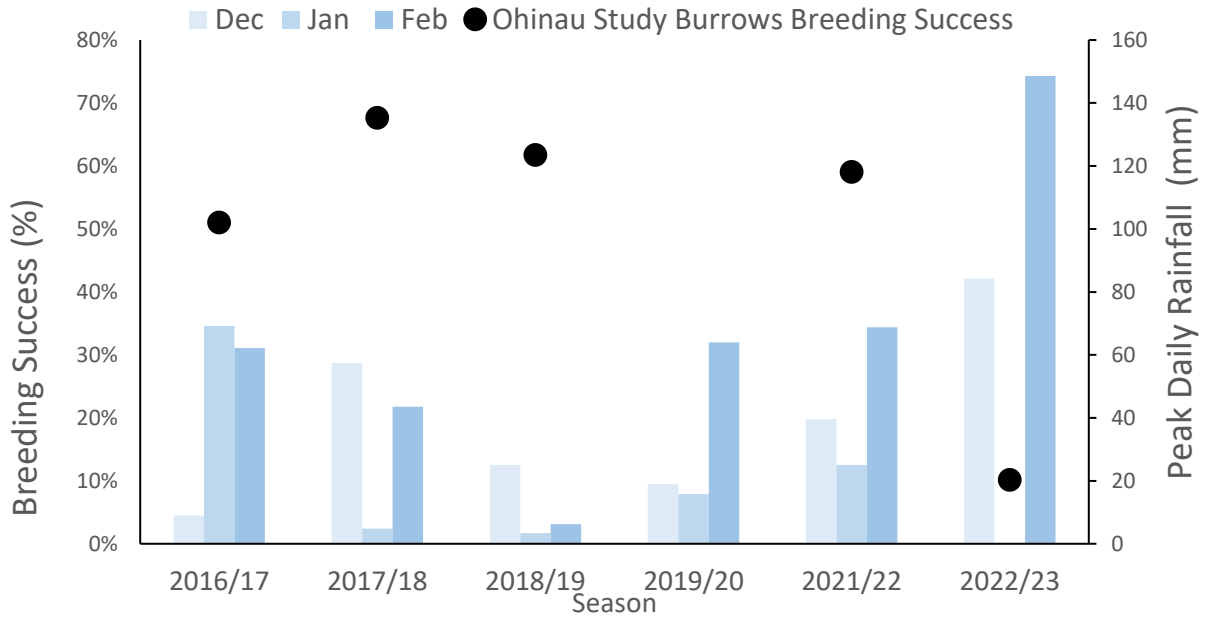

Figure 12. *Whitianga peak daily rainfall for Dec-Feb and Ohinau study burrow breeding success each season. Peak Daily rainfall data was not available for Jan 2023.*

Burrowscope Burrows

Breeding success in Ohinau Island burrowscope burrows was 31% compared to 10% in study burrows. This difference was significant indicating that there was an impact of handler disturbance or other factors impacting breeding success between burrowscope and study burrows this season (Pearson Chi-Square, $\chi^2_1 = 6.56$, $p = 0.01$).

3.3 Chick Condition

The average chick weight from 2015 to 2023 was 704.6g on Ohinau Island compared to 784g on Lady Alice Island. The 2022/23 season was the lowest average chick weight (634.3g) on Ohinau since 2015 although this was only slightly lower than the previous two seasons (2020/21 and 2021/22) (Figure 13). See Appendix 1 for weights of each banded chick during the 2022/23 season.

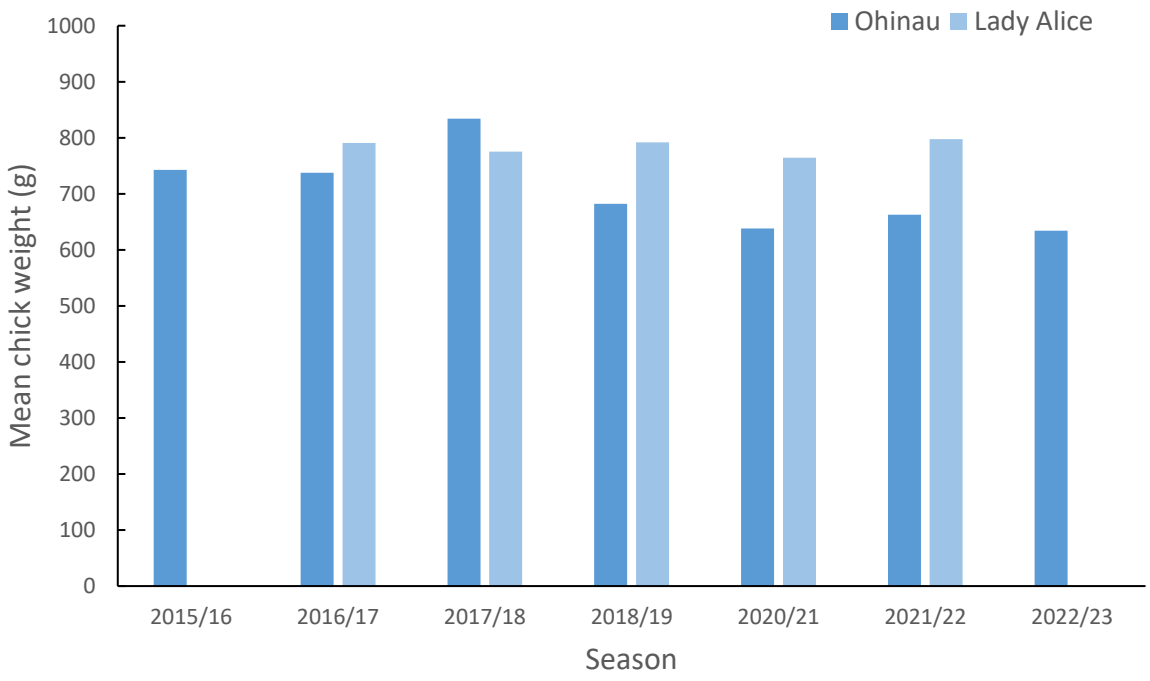

Figure 13. *Mean weights for flesh-footed shearwater chicks on Ohinau and Lady Alice Islands from 2015/16 to 2022/23.*

3.4 Banding Totals

During the 2022/23 season, 75 birds were banded on Ohinau Island (Table 3). Some of the chicks banded are not expected to fledge. In total, 4,465 flesh-footed shearwaters have been banded across Ohinau and Lady Alice Islands during this study.

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

Ohinau	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	**Total**
Adult	90	528	182	210	470	188	180	47	**1,897**
Chick	267	133	131	453	0*	127	169	28	**1,307**
Total	357	661	313	663	470	315	349	75	**3,204**

Lady Alice	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	**Total**
Adult	0	285	163	102	118	38	59	-	**765**
Chick	0	94	83	103	0*	110	106	-	**496**
Total	0	379	246	205	118	148	165	-	**1,261**

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

Total birds banded during study	**4,465**

3.5 Recaptures

Of the 1,848 adults that had been banded on Ohinau Island as part of this study from 2015-22, 42% (*n* = 773) have been recaptured again.

One bird that was banded as a chick as part of the 2015/16 Ohinau Island cohort was recaptured this season as an adult. This is in addition to the seven that were caught in the 2021/22 season, three in the previous season (2020/21) and the four caught in the 2019/20 season. The age at first return of this bird is six years old and was recaptured breeding in a burrow in the same colony it fledged from and close to their natal burrow (27m). An additional chick banded in April 2017 season was found this season at 5 years old, as well as a chick from April 2018 at four years old. Both birds were found on the surface in the same colonies they fledged from. In total therefore, 5.6% (*n* = 15) of the 267 chicks banded on Ohinau Island in 2015/16 have been recaptured so far (Appendix 1).

There were no trips to Lady Alice Island in the 2022/23 season and therefore no further recaptures are available for this site.

3.6 Population Estimate

Unfortunately, not all of the transects could be undertaken during the January trip due to weather delays both before landing, and whilst on Ohinau Island. All Pōhutukawa and Middle colony transects were completed. Only a third of Camp Colony transects were completed and these were all at the southern end of the colony. A quarter of the South of Gully colony transects were completed, all of which were at northern point of colony (Figure 14).

Transects were only able to be carried out in just four of the twelve known flesh-footed shearwater colonies on Ohinau Island, with only 35% of the total planned transects completed (Table 4). The colonies in which transects were carried out were predominately on the Eastern side of the ridge on the Island (Figure 14).

Table 4. *Transects completed and not completed for each colony on Ohinau January 2023 for an updated population estimate.*

Pōhutukawa	22	0
Middle Colony	5	0
Camp Colony	9	21
South of Gully	2	8
Camp South	0	10
Mid-East Point	0	10
Slot	0	5
South Point	0	15
Hilltop	0	20
South Colony	0	10
Big Island	0	5
Little Island	0	5
Total	**38**	**109**

Figure 14. *Colonies in which transects were completed January 2023. Blue indicates colonies where transects were carried out and red where no transects were carried out. Dashed lines in Camp Colony and South of Gully Colony represent the approximate areas transects were carried out. Pōhutukawa and Middle colony transects were*

3.7 Chick Tracking

Nine PTT tags were deployed on chicks, five as back mounts and four as tail mounts. The devices were active on average 50 days; for tail mounts the average was 31 days whereas back mounts lasted over twice that at 64 days (Table 5).

Table 5. *PTT tag deployment details for chicks May 2023*.

Burrow	Band #	Tag #	Weight (g)	Wing length (mm)	Date on (NZDT)	Mount method	Fledging Date	Date device stopped (GMT)	Days Active
CC104	Z59007	242225	620	317	5/05/23	Tail	12/05/23	16/06/23	35
SG41	Z59004	242227	720	294	7/05/23	Back	20/05/23	1/08/23	73
SG36	Z59000	242230	750	300	7/05/23	Back	20/05/23	9/08/23	81
SG47	Z59006	242228	730	309	7/05/23	Tail	12/05/23	23/06/23	42
SG26	Z59019	242233	680	321	7/05/23	Tail	12/05/23	21/05/23	9
HT52	Z58998	242229	680	321	7/05/23	Tail	15/05/23	21/06/23	37
BS44	Z59016	242226	630	302	7/05/23	Back	11/05/23	15/07/23	65
CC69	Z59008	242234	625	303	8/05/23	Back	18/05/23	20/08/23	94
SG44	Z59002	242231	620	295	8/05/23	Back	12/05/23	20/05/23	8

All nine chicks travelled north through the Pacific Ocean. Chicks followed a similar path, however one initially travelled more north-east. The furthest north a chick travelled was between Taiwan and Hawaii in the Pacific (Figure 15). See Appendix 3 for individual chick tracks.

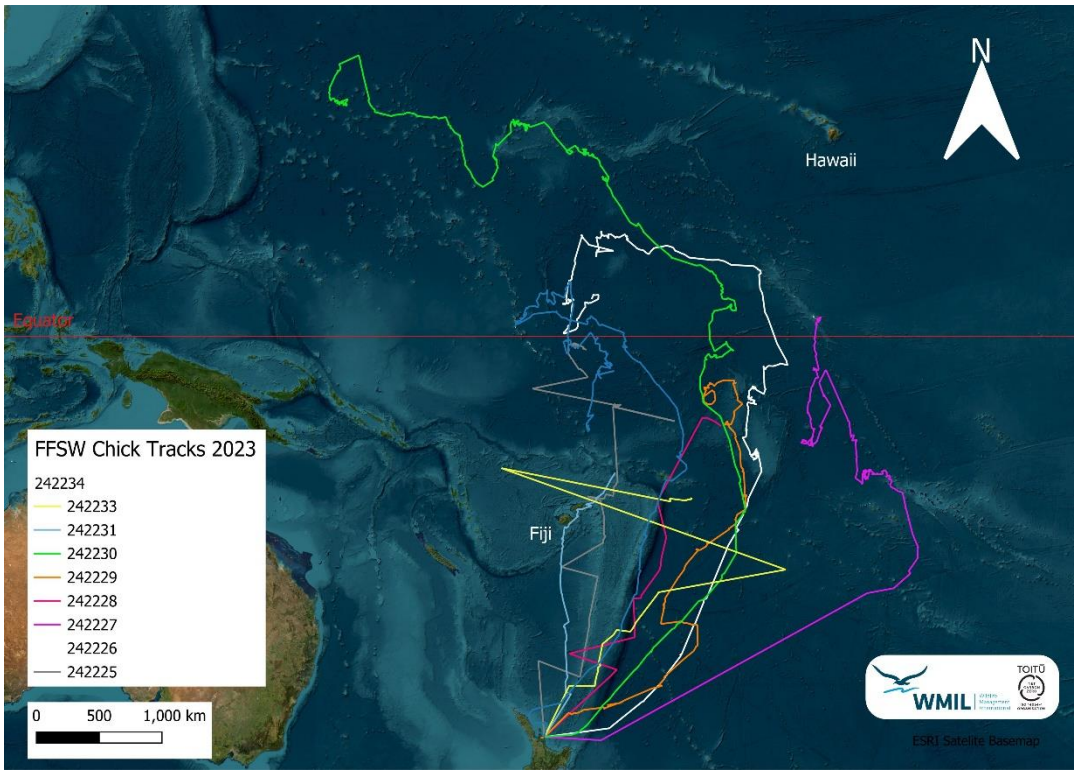

Figure 15. *All flesh-footed shearwater chick PTT tag tracks 2023.*

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. Large amounts of rainfall during the January trip reduced the number of workdays available to the team and as a consequence the team were only able to survey 168 breeding burrows instead of the usual 200. Burrows that have collapsed, are continually occupied by a different species, or remain inactive for multiple seasons, were retired. A small number of burrows were retired on Ohinau this season (*n* = 3).

The occupancy rate on Ohinau Island has remained relatively similar to previous seasons, although this season (62%) was much lower than last year (85%). The team weren't able to identify a higher number of breeding partners on Ohinau Island due to eight days of heavy rain during the January trip, which prevented burrow checks being undertaken as well as carrying out population estimate work (see Section 4.5 below).

4.2 Breeding Success

On Ohinau Island, breeding success was calculated at 10% for this season. This is significantly reduced from the 59% measured in the 2021/22 season and 68% measured in the 2017/18 season. In two study colonies all breeding burrows monitored failed. This was a substantial drop in breeding success and is

outside the range that would be expected for this species in a predator-free environment. On Woody Island, Western Australia, breeding success for flesh-footed shearwaters was measured as 40% and 53% for two consecutive seasons (Powell *et al.* 2007). Priddel *et al.* (2006) observed a 50% breeding success rate during the 2002/03 breeding season on Lord Howe Island in the Tasman Sea. Reid *et al.* (2013) incorporated data from the literature with their own field studies on Lord Howe Island, and estimated breeding success for the 2008/09 season to be 60%. Both Lord Howe and Woody Islands had ship rats (*Rattus rattus*) present, which are known to predate the eggs and young of several species of burrowing *Procellariiformes* (Moors & Atkinson 1984).

During the 2022/23 season Ohinau experienced more notable climate-related events than previous seasons. In particular during January and early February Whitianga and surrounding regions were impacted by flooding on more than one occasion, as well as ex-tropical cyclone Hale and Cyclone Gabrielle reaching that area. All these events brought large amounts of rainfall to the region and over Dec-Jan, Whitianga experienced an average of 362mm of rain (Figures 11 & 12), which was significantly more than previous seasons (NIWA 2023). Additionally, peak rainfall in Whitianga was much higher in December and February compared to previous seasons (NIWA 2023). No peak rainfall data was available for January 2023 unfortunately. While undertaking fieldwork on Ohinau Island the team discovered some burrows filled with water and others damp, a notable difference from previous season's monitoring work. A large number of breeding failures are therefore thought to be due to these extreme weather events. It is unfortunate the funds weren't available to monitor the Lady Alice population during the 2022/23 season to analyse how the breeding success fared for this population with such extreme weather events in the upper North Island. Climate change will continue to be a threat to this population and could have large impacts on this species. Sea-surface temperatures are projected to increase in New Zealand (Chiswell & Grant 2018), in tandem with projected global warming and increased frequency and magnitude of large storm events (IPCC 2014). This will likely increase the risk of flooding and associated impacts (Tait 2019) for locations like Ohinau Island as we saw this season. WMIL believe this season's low breeding success outcome may be an indication of what future seasons hold for this, and possibly other seabird species in the face of climate change impacts.

Ōi/grey-faced petrels are still likely to cause at least some breeding failures on Ohinau Island. Grey-faced petrels are known to evict the unguarded chicks of flesh-footed shearwaters when they arrive to clean out burrows in April (Barbraud *et al*. 2014, Waugh *et al*. 2014). On Ohinau Island none of our study burrows with grey-faced petrels present in May contained a flesh-footed shearwater chick. Grey-faced petrels were observed on the surface at night and in previous seasons there has been evidence of chicks having been killed by them.

On both islands there are usually a small percentage of burrows (typically <2%) that have a chick present in April/May that had no egg in December/January. Only one of these was found in May 2023. It is also possible that some or all of the chicks present in these burrows had actually been displaced from their natal burrow by a grey-faced petrel or other seabird (Taylor 2000). As all birds are expected to have laid by the end of December, for field trips to the islands in January any chick found in a burrow in May, that did not have an egg in January, can be assumed to have been displaced from a different burrow or the egg was missed in January.

The breeding success observed in burrowscope burrows was significantly higher compared to that observed in study burrows on Ohinau island when a Pearson Chi Square analysis was undertaken. Burrowscope breeding success was 21% higher this season than study burrows. This may be due to the hatches on study burrows allowing more water to enter study burrows during the heavy rain

events. However, the majority of burrowscope burrows are in their own colony with a flatter typography. It could be this colony was less impacted by weather events due to its location on the island. Any use of breeding success estimates in population modelling should use the burrowscope measurements as these are likely to be more representative measurements of breeding success for the population as a whole. The primary purpose of the study nests is for monitoring a marked population of adults.

4.3 Banded Birds

A total of 75 flesh-footed shearwaters, consisting of 47 adults and 28 chicks were banded on Ohinau Island this season. With the exception of the 2022/23 season, the number of adults banded has remained consistently high across all seasons with most birds encountered on the surface at night being un-banded. The majority of birds caught at night on Ohinau Island are caught on, or just off, the main track, which goes up through Camp Colony. Most birds encountered in existing study burrows are already banded.

This lower number of flesh-footed shearwaters banded for the season is a reflection of myriad factors. Notably, the large amount of rainfall during the January 2023 trip reduced the team's ability to spend much time banding at night. Additionally, it also limited their ability to visit burrows and band any un-banded birds as the team do not extract birds during rainfall to avoid wetting their feathers whilst in the burrow. The cohort of chicks for the 2022/23 season was very small as a result of the low breeding success, which attributed to the low number of banded chicks both in study burrows and on the surface at night. This should be taken into account when using this season's data for any modelling or further analysis.

4.4 Recaptured Birds

So far, 5.6% (n = 15) of the 267 chicks banded on Ohinau Island in 2015/16 have been recaptured. The first of these return chicks was found breeding in a burrow in January 2023 and was breeding about 27m from its natal burrow. The remaining individuals are most likely non-breeders as they have either been caught on the surface at night or found within non-breeding burrows. Monitoring these burrows over the next two years might provide further information on additional first breeding attempts.

A total of two chicks from the 2016/17 cohort have been recaptured, with the second chick found this season at 5 years old, on the surface at its natal colony. The first chick from April 2018 was also captured at four years old on the surface at the colony it fledged from in January 2023. As birds do not generally start to return to their natal colonies until an average of 6 years old it is expected that recent cohorts will not have been captured on the islands (Barbraud et al. 2014). WMIL anticipate that a larger number of birds from the 2015/16 cohort and a smaller number from later cohorts will be recaptured in the forthcoming seasons. An even smaller number of these may be detected breeding within the study burrows.

4.5 Population Estimate

Baker et al. (2010) first estimated there to be 2,071 occupied flesh-footed shearwater burrows on Ohinau Island. The population survey by Jamieson & Waugh (2015) also yielded a relatively low occupancy of burrows and they suggested this represented a decline in the number of birds nesting on the island. However, this survey was conducted between 18 January and 18 February 2014 which is 1-2 months after egg laying has finished (Bell et al. 2017). Many burrows are likely to have failed over this period and thus occupancy is more likely to be underestimated. A population estimate carried out by WMIL in 2018 produced a population estimate considerably larger at 4,007 occupied

burrows (Crowe 2018). As this survey was carried out in the two weeks following the conclusion of egg-laying, the 2018 measurement of occupancy is a better representation of actual occupancy.

As a number of years had passed since the latest population estimate was completed, an updated population estimate was planned to be carried out in 2023. The weather during the January trip was very volatile as noted above, with 8 days of fieldwork lost to large amounts of rainfall or high winds. Transects which were able to be completed in January were predominantly on one side of the island. Occupancy was variable between study colonies from each side of the Island and highlights the large amount of variability over such short distances. Therefore, occupancy extrapolated out from the 2023 transects would not be representative of the island and would yield an estimate that was not scientifically robust. The transects carried out in Camp Colony and South of Gully were also at one end of these large colonies and WMIL feels these are not representative of each respective colony. WMIL strongly feels the transect data collected is not comparable to the 2017 population estimate as transects were not able to be carried out in all colonies surveyed in 2017 (Crowe 2018). In wishing to ensure the updated population estimate is comparable to the 2017 estimate, WMIL have recommended the population estimate be deferred to the next breeding season.

4.6 Chick Tracking

To better understand the movements of flesh-footed shearwater chicks from New Zealand breeding colonies, tracking of chicks was undertaken in 2019 by WMIL. These devices were all attached using the back mount method. All chicks travelled north through the central Pacific to seas offshore from various Pacific Islands, however all devices stopped in a similar area around the Pacific Islands just South of the Equator and were no longer transmitting by 30 June. This meant an average transmission period of 21 days, which was much shorter than expected. Battery failure was thought not to be the cause of failure as the final readings given revealed good battery levels. Possible explanations for the devices stopping transmitting could be that the birds pulled the devices off, that the devices all had failures relating to other components other than the battery, or that the chicks suffered mortality events in this area. Whilst plastic ingestion and mortality of chicks on Ohinau Island has recently been documented (Burgin & Ray 2022), the possibility that these individuals also suffered mortality as a result of accidental bycatch in commercial or recreational fisheries in the area could also be likely. The first few months are challenging for juvenile seabirds as they navigate the open ocean for the first time, and lack of experience in foraging may be a key reason, as suspected by other work (Afán et al. 2019). However, elucidating the exact reason for the devices in 2019 failing remains difficult.

The 2023 season tracking of flesh-footed shearwater chicks provided an opportunity to re-attempt tracking this species on their first movements after fledging. Different mounts were trialled for the devices to see if that made a difference on transmission range, and despite the challenges with the weather and low breeding success, the team were able to attach 9 devices successfully. The data collected from the trackers reveals that the chicks also travelled north through the central Pacific with the exception of one bird travelling more north easterly initially. Interestingly, back mounts lasted about twice as long on average as those attached using the tail mount method, at 64 days, with the longest lasting 94 days. The reasons for the tail mounts not lasting as long could be because of feather moulting, or feather growth over the solar panel. Additionally, it may have been easier for the chicks to chew through the attachment on their tail feathers compared to back feathers. Of course, interactions with fishing vessels, both commercial and recreational, and possible accidental bycatch could also be the reason for the devices stopping transmitting. 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. To conclude, further tracking work to understand these movements more remains valuable.

4.7 Plastic Pollution

Plastics have been documented on Ohinau Island before (Buxton *et al*. 2013), and through the monitoring of this species by WMIL since 2016, plastics have been noted on the surface and within burrows (M. Bell and P. Crowe *pers. comm*). Last season on Ohinau Island, in May 2022, 11 chicks were found dead either on the surface or within their burrow, and when dissected were found to contain plastic fragments (Burgin & Ray 2022). WMIL collected all plastic fragments found during over the 2021/22 season and have continued to during the 2022/23 season. WMIL staff are currently processing them for a separate publication. Additionally, these plastic samples have been shared with Auckland University researchers for further research. Due to time constraints during both trips in the 2022/23 season, no dissections were able to be carried out on dead adults and chicks found this season.

More work will be undertaken during future surveys to search burrows and carcasses of flesh-footed shearwaters for plastic, on both Ohinau and Lady Alice Islands to understand this further.

5. Conclusions and Recommendations

5.1 Demographic monitoring

The number of study burrows on Ohinau and Lady Alice Islands are a suitable number for long-term demographic monitoring. Significant effort has been put in to banding flesh-footed shearwaters on both islands since 2016 with over 1,800 chicks and over 2,600 adults having been banded across both islands taking the total number of birds over 4,400. Recapture efforts of breeding adults and non-breeders need to be consistently large scale to provide a robust mark-recapture dataset and the large banding effort will help to achieve this.

Climate change may be a big threat to flesh-footed shearwaters. The Ohinau population suffered very low breeding success this season after numerous climate events hit the Island. With no monitoring of the Lady Alice population this season, WMIL are unable to determine if this population was adversely impacted by weather events during the 2022/23 season.

WMIL recommends that:

- **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.**
- **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 an estimate of adult survival. A concerted effort to continue to band and recapture birds on both islands will allow more robust estimates of age at first return (i.e., recruitment) and adult survival to be made, estimate juvenile survival and age at first return, and measure changes in these demographic parameters over time.

WMIL anticipate that the māhoe and inkweed growth around study burrows on Ohinau Island will be an ongoing issue for at least the next two seasons until the māhoe regrows to form a new canopy and

shade out the weedy areas. This needs to be taken into account for logistics as at least two days will be required at the start of each trip to clear the tracks and access points to study burrows (with great care not to damage burrows) to allow easier observer access for burrow checks.

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 Estimate

As the team were not able to undertake all of the randomised transects across all of the known flesh-footed shearwater colonies on Ohinau Island this season, WMIL feels the limited data gathered are not representative of each respective colony. WMIL strongly feels the transect data collected is therefore not comparable to the 2017 population estimate as transects were not able to be carried out in all colonies surveyed in 2017 (Crowe 2018). In wishing to ensure the updated population estimate is comparable to the 2017 estimate, and as scientifically rigorous as possible, WMIL recommends the population estimate be deferred to the next breeding season in 2023/24.

- **WMIL recommends that a repeat population estimate on Ohinau Island be undertaken in the 2023/2024 season.**

5.3 Plastics

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

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

Plastic pollution could pose a significant risk to the future of this species, and it is important that urgent action be taken to gather more data to better understand this risk more, and better inform conservation management and policy. Comparing plastic levels found in other birds through necropsy and beach patrol schemes would also be valuable.

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

Copies of the field records of all newly banded birds during our trips and any previously banded birds 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.

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.

7. Acknowledgements

This project was funded by the Conservation Services Programme, Department of Conservation project POP2021-04, partially through a levy on the quota owners of the relevant commercial fish stocks. We appreciate Ariel-Micaiah Heswall (Auckland University), Tiffany Plencner (DOC) and Simon Lamb (WMIL), for assisting with fieldwork and Cam Maclean (WMIL) for assistance with data analysis. A huge thanks to Marie Everth and James Blackmore from the Department of Conservation (DOC) for providing us with gear and for helping us get on and off Ohinau Island safely. Thanks also to Graeme Taylor and Kris Ramm from DOC for supervision and providing guidance throughout the duration of the project. Samhita Bose, Graeme Taylor and Johannes Fisher from DOC and Mike Bell (Toroa Consulting) were pivotal in providing valuable guidance on PTT tag deployment methods. A huge thanks also to Craig Rasmussen and Ann Ward at Dive Zone Whitianga for helping our volunteers get on and off Ohinau Island. We continue to be grateful to Ngātiwai and Ngāti Hei for their support of this research.

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9. Appendix 1 – Chicks Banded 2023

Band #	Date	Burrow	Weight (g)	Wing Length (mm)	Chick condition	Notes
Z58991	03-May-23	HT11	640	253	Full down	Small
Z58992	04-May-23	HT18	630	285	3/4 down	
Z58993	04-May-23	HT22	255	224	Full down	Small and skinny
Z58994	04-May-23	HT56	595	263	3/4 down	Small
Z58995	04-May-23	HT30	510	245	3/4 down	Skinny
Z58996	04-May-23	HT50	540	305	3/4 down	Small
Z58997	04-May-23	HT46	650	289		
Z58998	04-May-23	HT52	810	302	1/4 down	
Z58999	04-May-23	SG27	660	295	1/4 down	
Z59000	04-May-23	SG36	740	286	1/2 down	
Z59001	04-May-23	SG25	500	278	1/2 down	Small
Z59002	04-May-23	SG44	710	276	3/4 down	
Z59003	04-May-23	SG11	750	296	Fully feathered	
Z59004	04-May-23	SG41	760	291	1/2 down	
Z59005	04-May-23	SG50	725	270	3/4 down	
Z59006	04-May-23	SG47	680	297	Fully feathered	
Z59017	04-May-23	SG40	450	233		Small
Z59019	04-May-23	SG26	680	321		
Z59007	05-May-23	CC104	620	317	1/4 down	
Z59013	05-May-23	CC101	600	253	3/4 down	
Z59008	06-May-23	CC69	720	290	1/2 down	
Z59009	06-May-23	CC57	460	246	Full down	Skinny
Z59010	06-May-23	CC28	850	281		
Z59011	06-May-23	CC50	520	295	1/2 to 3/4 down	Skinny
Z59012	06-May-23	CC43	670	288	3/4 down	
Z59014	06-May-23	BS15	650	268	3/4 down	
Z59016	06-May-23	BS44	665	300	Fully feathered	
Z59020	08-May-23	CC102	720	311		

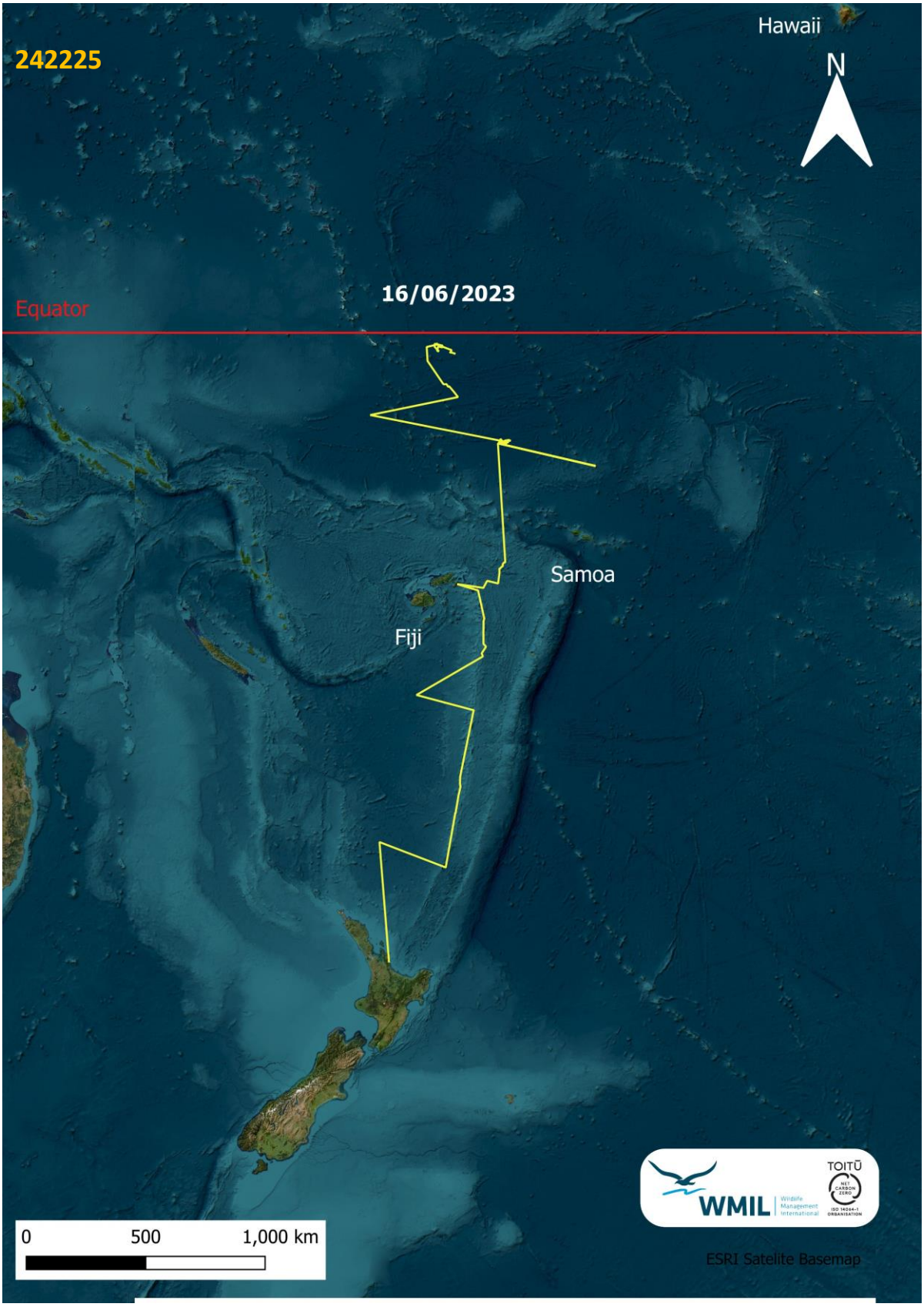
Appendix 2 – Chick Return Table for Ohinau Island

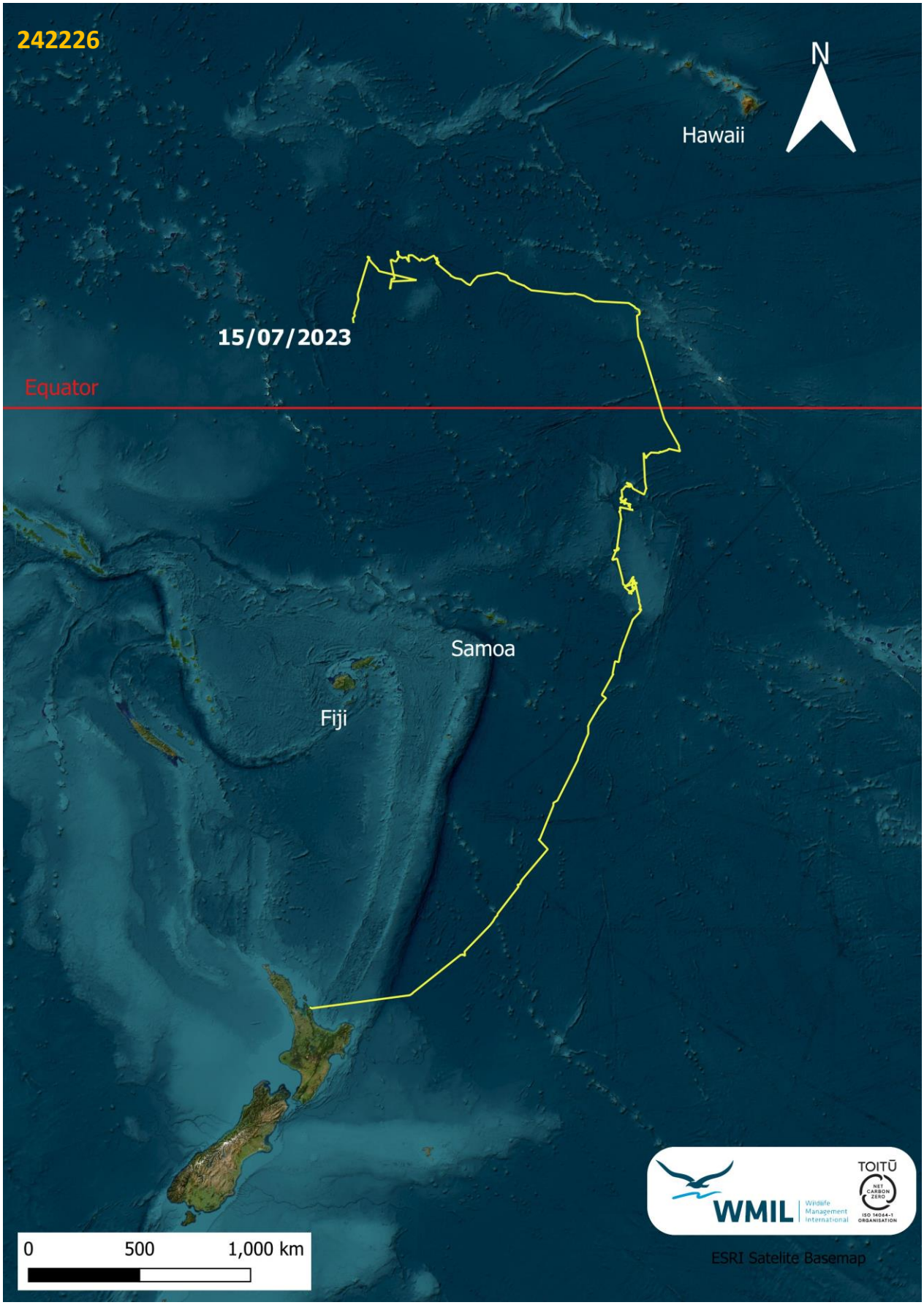
Band number	Natal burrow/Surface	Date Banded	First Return Date	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022
Z66485	PK45	30-Apr-17	16-Dec-21	-	X	0	0	0	0	1
Z67117	CC08	22-Apr-16	06-Dec-21	X	0	0	0	0	0	1
Z67149	PK35	23-Apr-16	07-Dec-21	X	0	0	0	0	0	1
Z67167	PK54	24-Apr-16	24-Jan-20	X	0	0	0	1	0	0
Z67180	SG10	25-Apr-16	24-Feb-20	X	0	0	0	1	0	0
Z67187	SG17	25-Apr-16	09-Dec-21	X	0	0	0	0	0	1
Z67263	CS27	27-Apr-16	06-Dec-21	X	0	0	0	0	0	1
Z67308	Surface	29-Apr-16	20-Jan-20	X	0	0	0	1	1	0
Z67339	Surface	30-Apr-16	02-Dec-21	X	0	0	0	0	0	1
Z67361	CC24	01-May-16	08-Dec-21	X	0	0	0	0	0	1
Z67392	BS13	02-May-16	22-Jan-20	X	0	0	0	1	0	0
Z67398	CC29	03-May-16	14-Dec-20	X	0	0	0	0	1	0
Z67405	Surface	02-May-16	15-Dec-20	X	0	0	0	0	1	0
Z67438	Surface	04-May-16	02-Dec-21	X	0	0	0	0	0	1
Z67450	Surface	04-May-16	20-Jan-20	X	0	0	0	1	0	0

Z67220	HT23	26-Apr-16	21-Jan-23	X	0	0	0	0	0	1
Z66478	PK29	30-Apr-17	15-Jan-23	-	X	0	0	0	0	1
Z66688	SG08	27-Apr-18	13-Jan-23	-	-	X	0	0	0	1

X = Banded, 0 = not re-sighted, 1 = re-sighted.

Appendix 3 – Chick Tracks Ohinau Island, 2023

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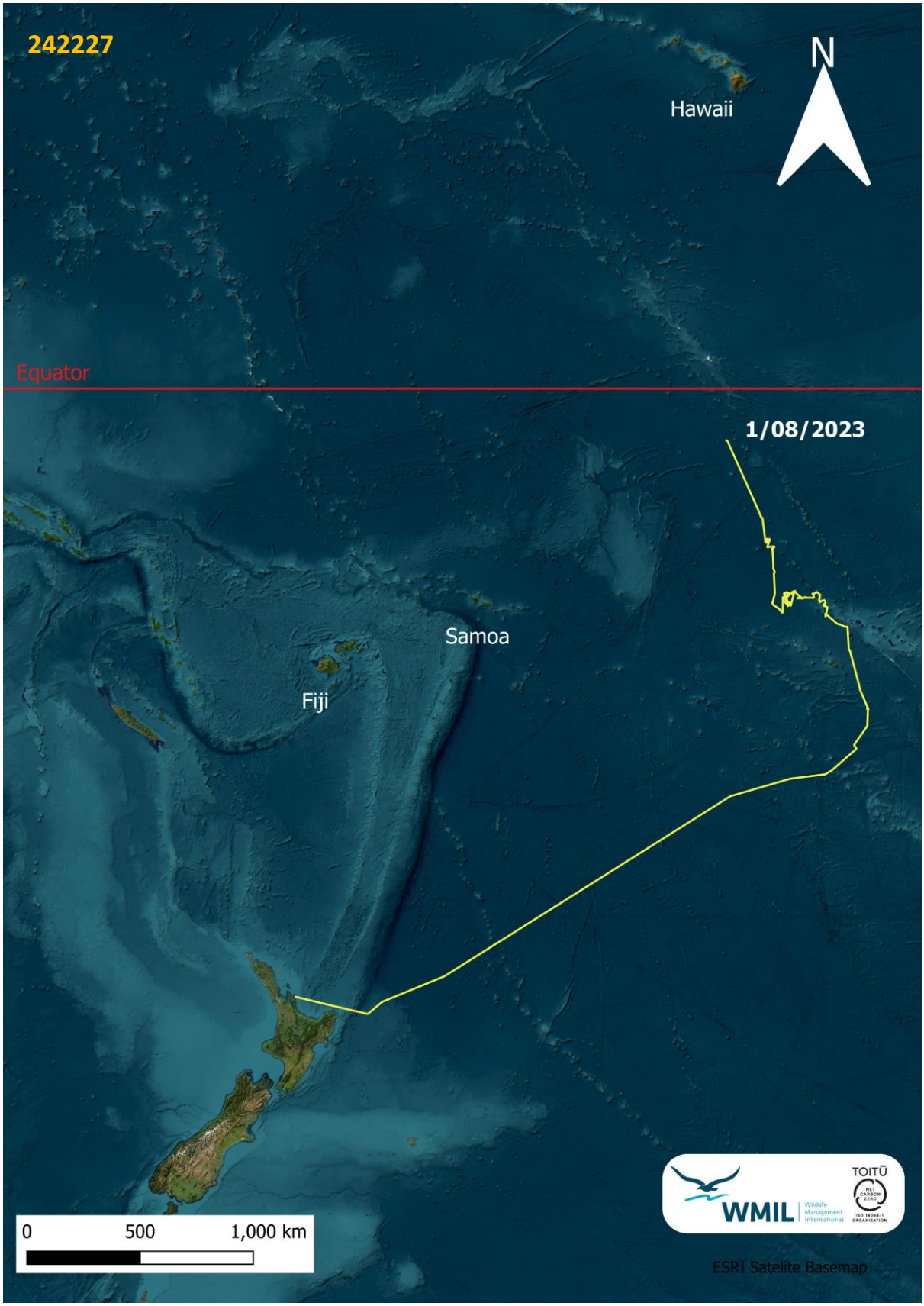
Hawaii
15/07/2023
Equator
Samoa
Fiji
0
500
1,000 km
WMIL
Wildlife Management International
TOITŪ
NET CARBON ZERO
ISO 14064-1 ORGANISATION
ESRI Satelite Basemap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1,000 km
WMIL
TOITŪ
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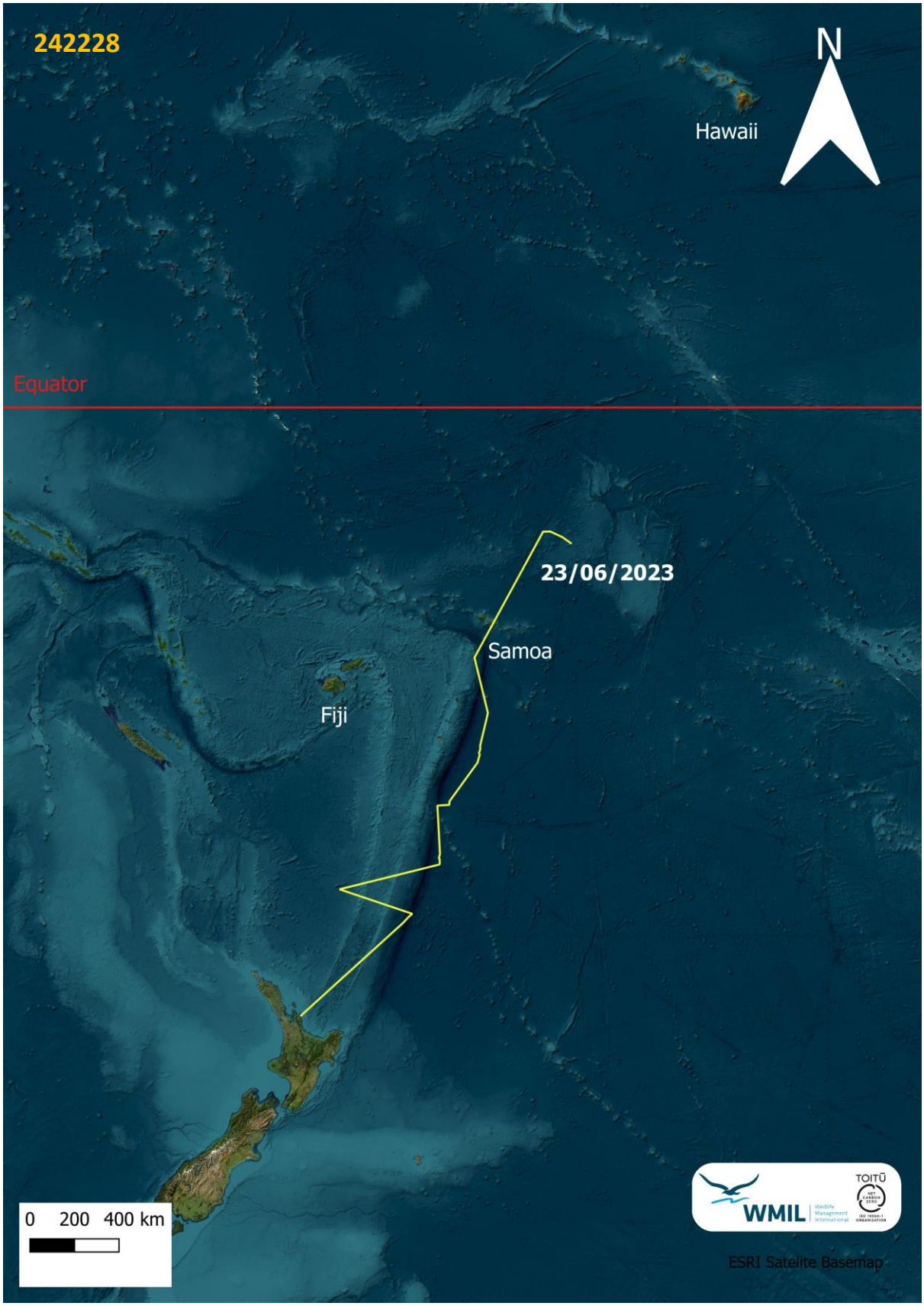
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WMIL
TOITŪ
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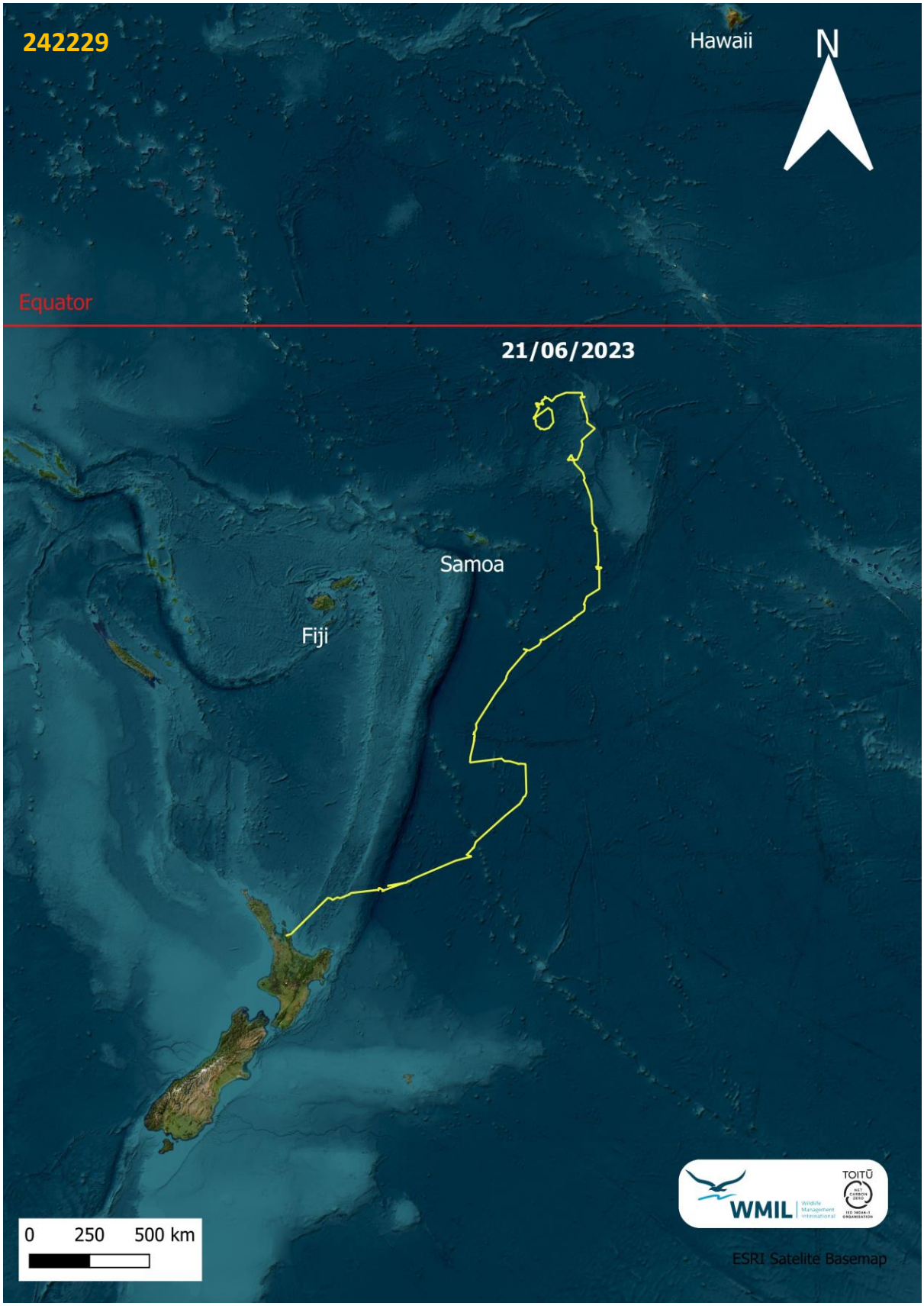
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Equator
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Samoa
Fiji
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WMIL
TOITŪ
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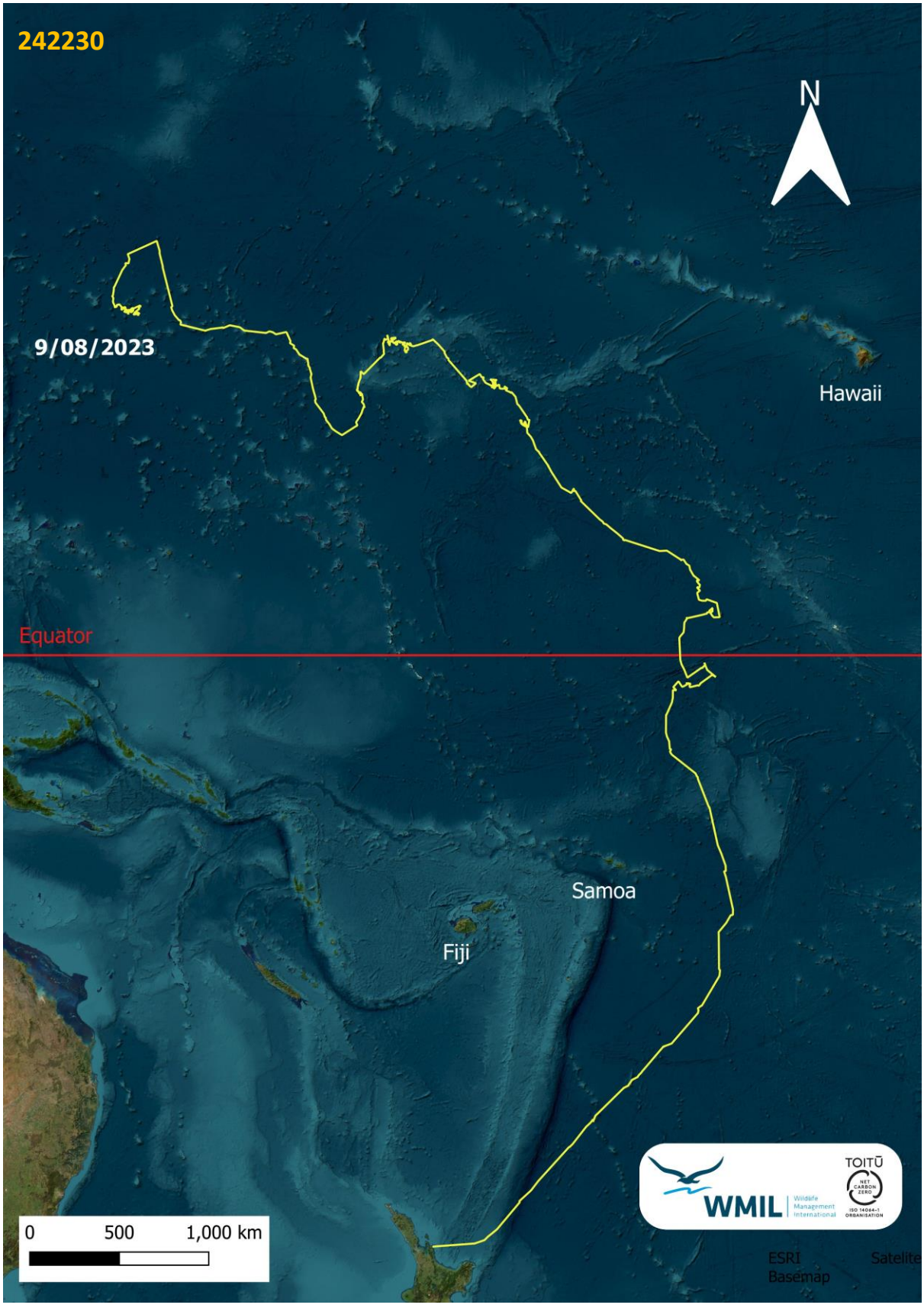
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9/08/2023
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Equator
Samoa
Fiji
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Wildlife Management International
TOITŪ
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ESRI
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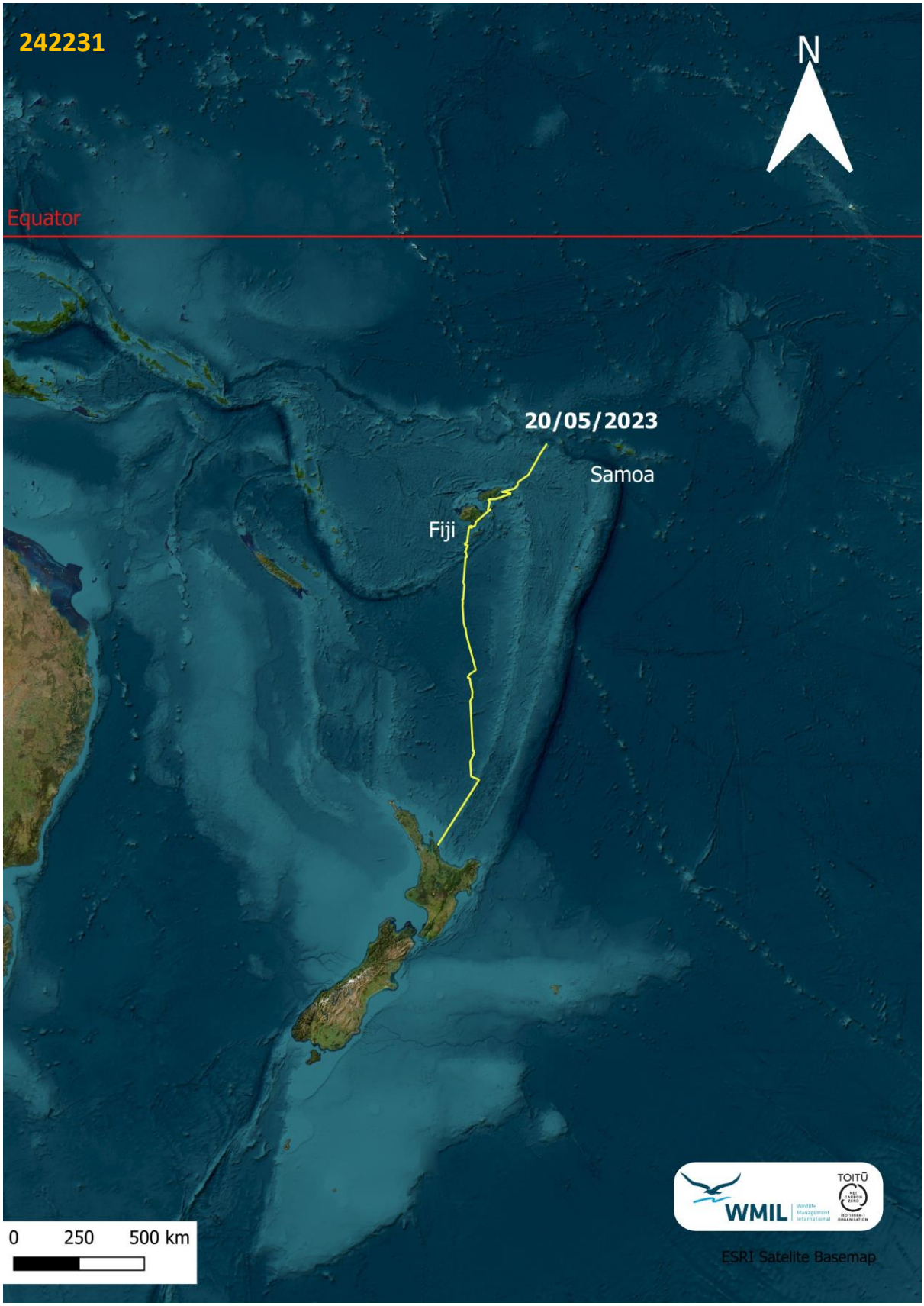
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500 km
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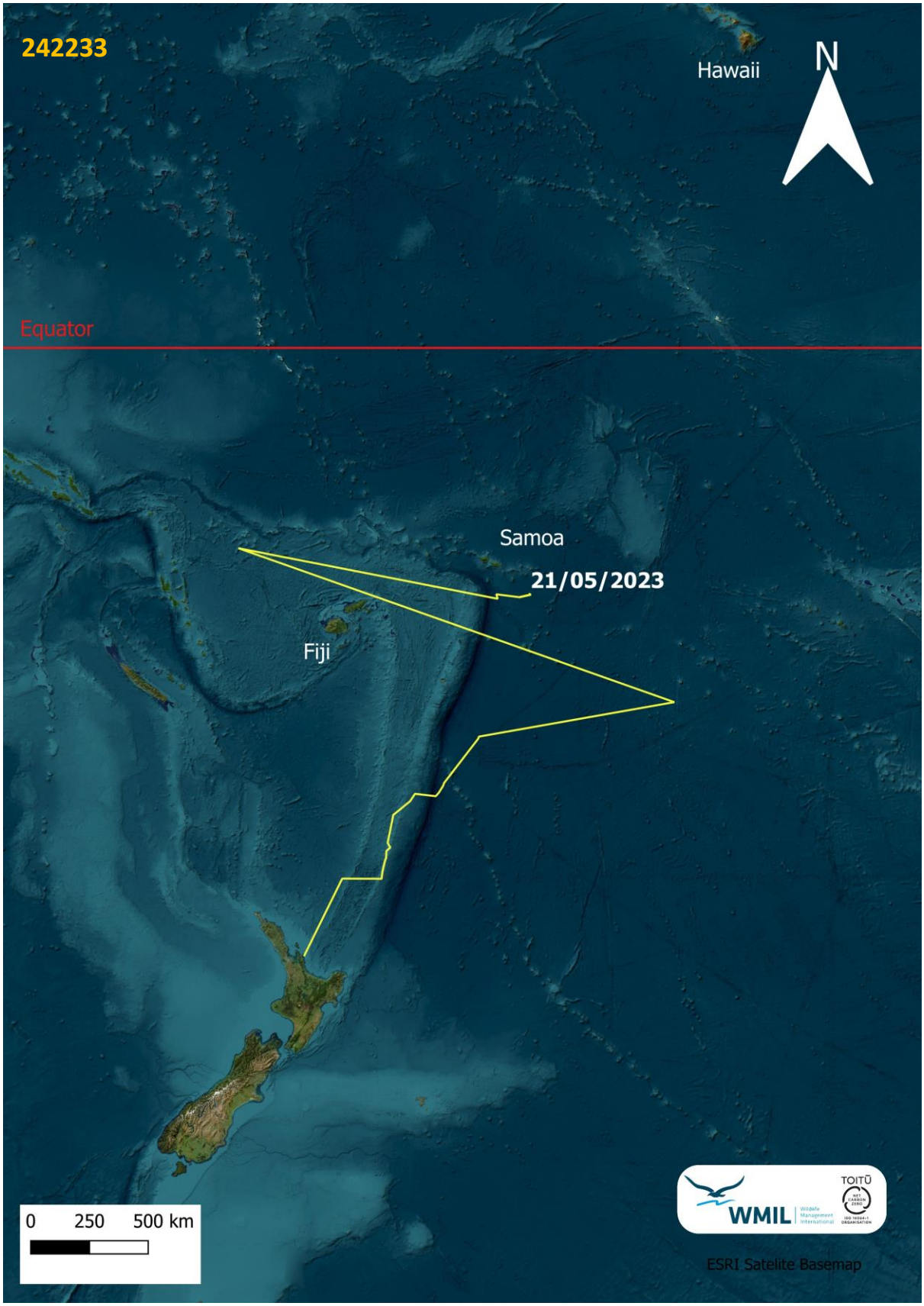
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Equator
Samoa
21/05/2023
Fiji
0 250 500 km
WMIL
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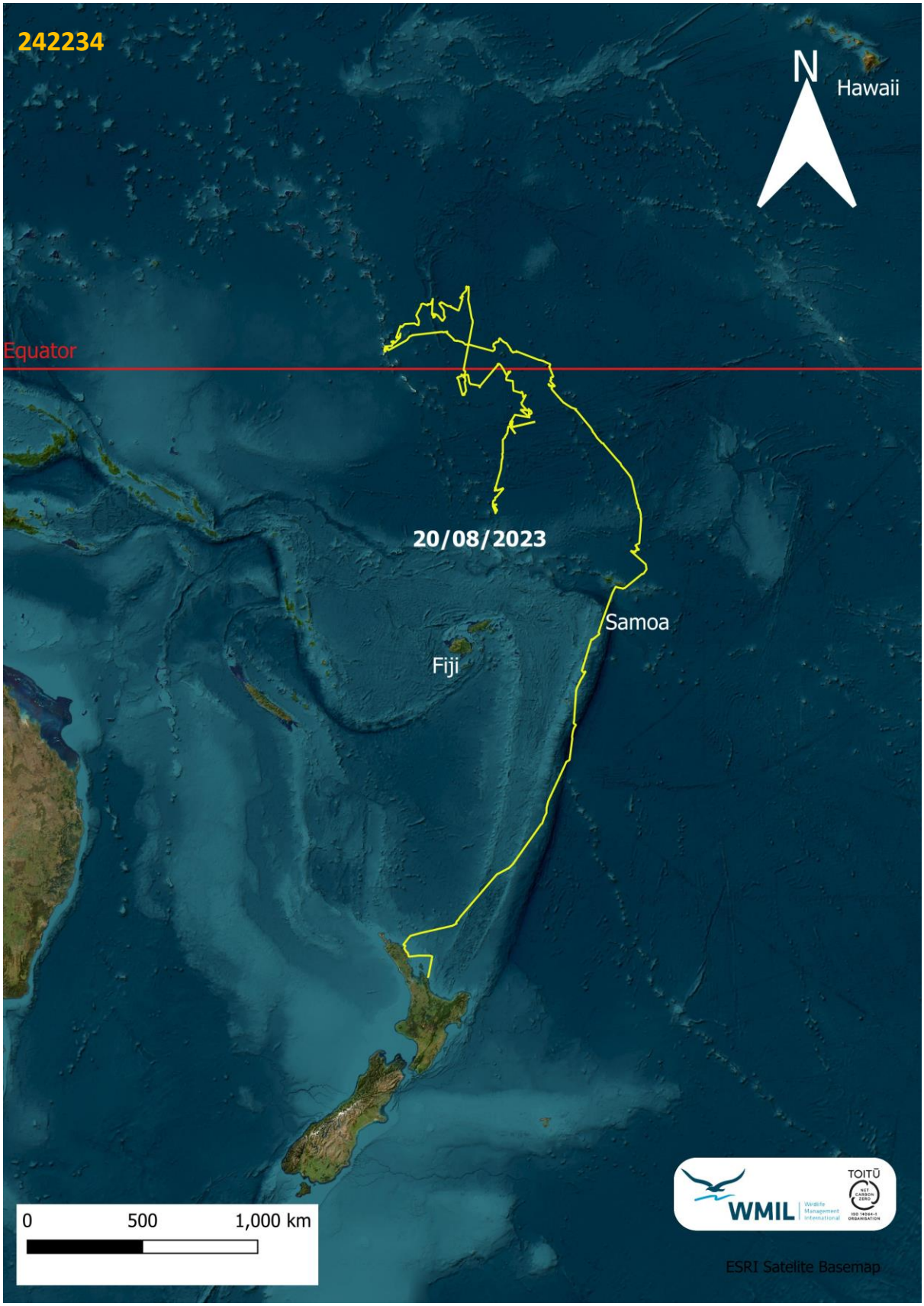
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Samoa
Fiji
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WMIL
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ESRI Satelite Basemap