Toanui/Flesh-footed Shearwaters

Toanui/flesh-footed shearwater (Ardenna carneipes) population estimate for Titi Island, Marlborough Sounds: January 2022

WMIL Wildlife Management International

TOITŪ CARBON ZERO ISO 14064-1 ORGANISATION

Toanui/flesh-footed shearwater *(Ardenna carneipes)* population estimate for Titi Island, Marlborough Sounds: January 2022

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Cover image: ***Toanui/flesh-footed shearwater*** *(Ardenna carneipes) within the Marlborough Sounds, New Zealand © Dan Burgin*

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EXECUTIVE SUMMARY

This report covers the findings from the first year of toanui/flesh-footed shearwater (*Ardenna carneipes*) (Threat Status - At Risk: Relict) research under the Department of Conservation's Conservation Services Programme, project '*DOC CSP POP2021-04*'. Here we report on the flesh-footed

shearwater population estimate undertaken on Titi Island, Marlborough, to update previous estimates made in 2010 and 2014.

Burrow transects were carried out on Titi Island to gather data for an updated population estimate for flesh-footed shearwaters known to breed on the island. It is estimated that there are a total of 528 (250 – 806, 95% CI) occupied flesh-footed shearwater burrows on Titi Island with an average 15% burrow occupancy calculated across all colony areas. Through this transect work, it was also possible to calculate a population estimate for the tītī/sooty shearwaters (*Puffinus griseus*) (Threat Status - At Risk: Declining) breeding on that island. It is estimated that there are a total of 1038 (544 - 1533, 95% CI) occupied sooty shearwater burrows on Titi Island with an average 25% burrow occupancy calculated as an average across all colony areas.

The flesh-footed shearwater population estimate presented here for Titi Island is slightly higher than the previous estimate carried out by Baker *et al.* (2010) and Waugh et al. (2014). We conclude that our estimates are not necessarily reflective of a population increase, but more likely a result of more in-depth and higher-quality sampling and analysis techniques giving a more accurate estimate of population sizes compared to the two previous estimates.

Toanui/flesh-footed shearwater (Ardenna carneipes) population estimate for Titi Island, Marlborough Sounds: January 2022

1. INTRODUCTION

Flesh-footed shearwaters (*Ardenna carneipes*) breed on offshore islands around the coast of northern New Zealand, southern Australia and on St Paul Island (Île Saint-Paul) in the Indian Ocean (Waugh et al. 2013, Lavers 2015, Barbraud et al. 2021). Populations are thought to be in decline both in New Zealand and globally (Waugh et al. 2013, Lavers 2015). Under the New Zealand threat classification system, flesh-footed shearwaters are ranked as "At Risk: Relict", an increase thought to be related to the eradication of rodents from many of their breeding islands, as well as changes in fisheries operations that have reduced accidental bycatch (Robertson et al. 2021). Recent declines were attributed primarily to accidental bycatch in commercial fisheries and recreational fisheries, with flesh-footed shearwaters reported to be one of the most commonly caught species in New Zealand long-line fishing and prone to being caught in trawl fisheries (Robertson et al. 2004, Abraham & Thompson 2011). Recent work estimates that between 496 and 1,020 flesh-footed shearwaters are killed annually in commercial fisheries operations (Richard et al. 2020).

While the population of flesh-footed shearwaters on Lord Howe Island in Australia has been relatively well studied (Priddell et al. 2006, Reid 2010), long-term studies measuring demographic parameters for both Australian and New Zealand populations of this species have been limited or based on small sample sizes (Barbraud et al. 2014, Lavers 2015). 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 in future management decisions for the species, particularly in light of the myriad threats this and many other seabird species face (Croxall et al. 2012).

The possible decline of flesh-footed shearwaters coupled with a general lack of demographic and population estimates particularly in New Zealand (Taylor 2000), has highlighted the need to update old population estimates, or survey islands for which robust estimates do not exist. This will be fundamental to the conservation management of the species. Population estimates have been undertaken by WMIL from 2016 to present, on Ohinau and Lady Alice Island, as well as additional islands; Middle, Motumahanga, Coppermine, Whatupuke, and Taranga/Hen (Bell & Boyle 2017, Crowe 2018, Crowe & Bell 2019, Crowe & Burgin 2021). During the 2021/22 season a population estimate was undertaken on Titi Island, to update previous estimates calculated (Baker et al. 2010, Waugh et al. 2014). This population estimate is reported on here.

KEY OBJECTIVES & OUTPUTS

This research was carried out as part of the Conservation Services Programme (CSP), flesh-footed shearwater research project (POP2021-04). The key objectives we were funded by the Department of Conservation (DOC) to complete were (bold text indicates objective covered in this report):

1. To estimate key demographic parameters of flesh-footed shearwater at Lady Alice and Ohinau Island.
2. **To estimate the current population size of flesh-footed shearwaters at Titi Island, Marlborough.**

Objective 1 is an ongoing objective, and will be reported in a separate report (due 15 June 2022). Objective 2 was completed in January 2022 and is reported on here.

2. METHODS

2.1 Study Site and Survey Dates

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 the Department of Conservation and has been free of introduced predators since the 1970's (Gaze 2000). There were 9 known flesh-footed shearwater colonies on Titi Island (Figure 1) established through previous work by Baker et al. (2010), and it is well established that they reside alongside tītī/sooty shearwaters (*Puffinus griseus*) (Threat Status - At Risk: Declining) in lower numbers (Bell 1969, Gaze 2000). Baker et al. (2010) had estimated a total of 337 (0 – 950) occupied flesh-footed shearwater burrows on the island, whilst Waugh et al. (2014) estimated a total of 157 flesh-footed shearwater breeding pairs on the island. A team of two WMIL personnel was based on the island from 8 to 17 January 2022 to undertake transect work and provide an updated estimate for the flesh-footed shearwater population.

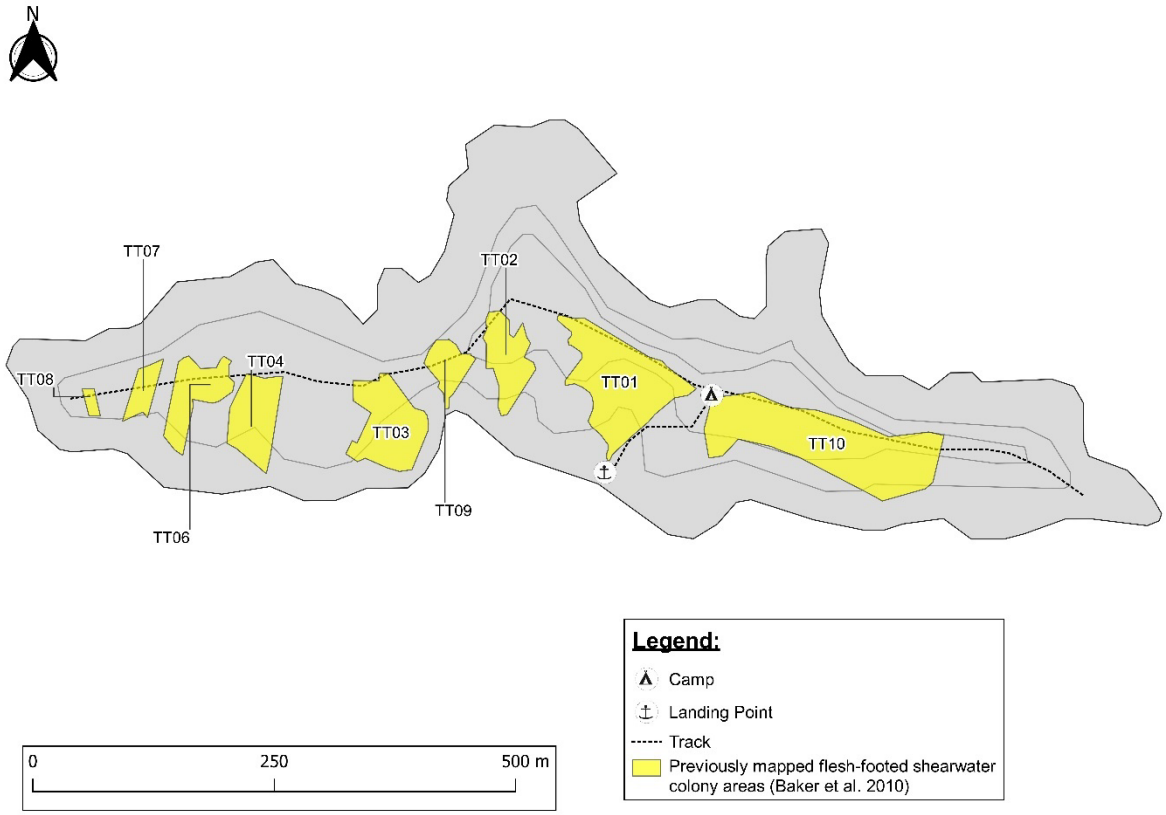

Figure 1. Map of Titi Island showing the size and location of all previously mapped flesh-footed shearwater colonies (Baker et al. 2010) prior to the population estimate presented here.

2.2 Field Methods

The same method was used as described in other flesh-footed shearwater population estimates undertaken by WMIL; Middle Island (Bell & Boyle 2017), Ohinau Island (Crowe 2018), Motumahanga and Lady Alice Island (Crowe & Bell 2019), and Coppermine and Whatupuke Islands (Crowe & Burgin 2021).

Transect start points and bearings (transect direction) were randomly generated using QGIS version 3.16 within the previously mapped flesh-footed shearwater colony boundaries on Titi Island provided by Baker et al. (2010). A tape was run out for 30 m from the start point on the randomly generated bearing. Burrows were searched for in a 2 m strip to the right-hand side of the tape, i.e., each 30 m transect covered 60 m^2. Following Waugh et al. (2013) and Baker et al. (2010), burrows were classified by the size of the entrance (small or large), with large burrows defined as burrows >20 cm long, with an entrance size >14 x 8 cm. On Titi Island, flesh-footed shearwaters are known to breed in burrows amongst larger colonies of sooty shearwaters, and therefore examining burrows is crucial to correctly identify which species is present. All burrows along each transect, within each colony area, were therefore assessed using a burrowscope to determine the contents of the burrow and generate an occupancy estimate for each colony area. Great care was taken when examining burrows to accurately determine the contents of each burrow particularly differentiating between flesh-footed and sooty shearwaters. The species, breeding status, presence/absence of tuatara and any other observations were recorded. 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. For the majority of the transects, a single person carried out the transect with each transect being walked two or three times to ensure counts were accurate and no burrows were missed. Occasionally the second person would assist in particular densely burrowed areas to ensure the transect was fully surveyed, and all burrows were assessed using a burrowscope. The team made a concerted effort to walk and ground truth as many of the colony area perimeters that had been shared with us by Barry Baker (Baker et al. 2010). This prior knowledge of the location and size of each colony area on Titi Island greatly supported the team's efforts.

Additional areas on Titi Island were highlighted as "search areas" that we thought may potentially have flesh-footed shearwater colonies. Potential colony areas were identified by examining aerial photographs, and we then conducted ground searches in these areas looking for highly-burrowed areas.

Updates to colony area boundaries were mapped using Maps.Me and MapToaster applications on an iPhone XR, as well as a Garmin 64st hand-held GPS.

2.2.1 Bird Counts

To raise the value of the time spent on Titi Island, the team also completed bird counts extensively across the island during the entire trip. This was done in order to gather vital bird observations for this remote part of the Marlborough Sounds. All bird species detected were listed as part of complete checklists with varying durations and distances and uploaded via eBird to the New Zealand Bird Atlas portal. A list of all the bird species encountered on the island is given in Appendix 1 and is also **online**.

2.3 Data Analysis

To calculate the surface area of each colony, an eight metre resolution Digital Elevation Model (DEM) was downloaded from the LINZ Data Service website and a slope raster layer was created. A spatial join between each mapped colony polygon and the slope raster then calculates the average slope in radians within that colony. The 3D surface area for each colony is then calculated as:

[3D] Surface Area = [2D] Planimetric Area / cosine (Slope Angle in radians)

This is the same method used in Cuthbert (2019) to calculate colony areas for Hutton's shearwater. Burrow density was then calculated as;

Burrow Density = Total Large Burrows / Total area of Transect (m^2)

Mean burrow density and 95% confidence interval for each colony was calculated using the transect data and multiplied by the 3D surface area to give an estimate of the 'Total Number of Burrows' in each colony area. The measured 'Occupancy Rate' for each colony was then calculated as:

Occupancy = Total burrows with known flesh-footed shearwater breeding / (Total Burrows Checked –Total Burrows with Unknown Outcomes)

Measured 'Occupancy rate' was then multiplied by the mean burrow density to give an 'Occupancy Burrow Estimate':

Occupancy Burrow Estimate = Mean Burrow Estimate * Occupancy Rate

This then gave an estimate of the total number of occupied flesh-footed shearwater burrows within each of the colony areas. Occupancy rate was then averaged over all the colony areas, whilst estimated occupied burrows was summed from all colony areas to give an estimate, with 95% Confidence Interval values, as shown in Table 1.

3. RESULTS

A total of 105 transects were carried out across four colonies on Titi Island between 8 and 17 January 2022. All transects were 30m long, with the exception of three transects that had to be shortened due to steep and unsafe terrain, and four transects which were excluded from the analysis as they fell outside the updated colony area of TT10 (Figure 2). TT08 and TT07 colonies were merged as it was found that they joined together with burrows. Additionally, no flesh-footed shearwaters were found or estimated within TT10. As a result, there are seven flesh-footed shearwater colonies on Titi Island. Occupancy rates ranged from 0 to 0.29 across all of the colonies, and burrow density was generally low (Table 5). The flesh-footed shearwater population estimate for all colony areas on Titi Island is 528 occupied burrows (250 – 806, 95% CI). We calculated an average 15% burrow occupancy across all colony areas. A description of each colony is provided below and a summary of all transect data can be found in Table 1.

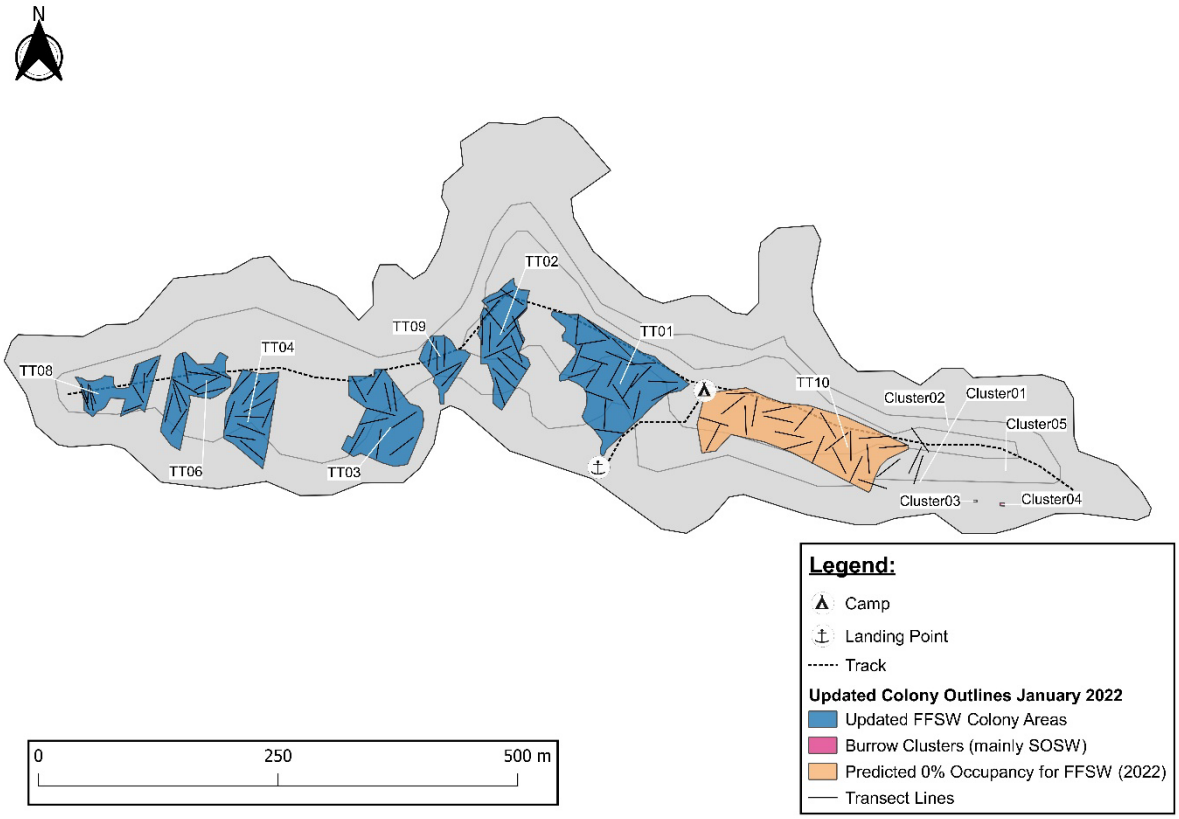

Figure 2. Map of Titi Island showing the current extent of flesh-footed shearwater colonies as mapped in 2022, transect lines, as well as additional small clusters of burrows found.

Table 1. Flesh-footed shearwater Population Estimate Statistics for all Titi Island Colony Areas (January 2022)

Colony	Dates Surveyed	Area sampled (m^2)	Large burrows counted	Burrow Density (burrows/m^2)	Number of burrows examined	Occupancy Rate	Colony Area (m^2)	Estimated Occupied Burrows	Lower 95% CI	Upper 95% CI
Titi-01	10, 11 January 2022	1200	84	0.07	84	0.09	10434	63	41	85
Titi-02	11, 16 January 2022	900	95	0.11	95	0.09	5349	50	30	69
Titi-03	12 January 2022	600	49	0.08	49	0.23	6251	119	55	184
Titi-04	13 January 2022	600	43	0.07	43	0.24	4823	84	32	137
Titi-06	13 January 2022	600	50	0.08	50	0.12	3898	39	10	68
Titi-08*	14 January 2022	570	98	0.17	98	0.29	2973	148	71	224
Titi-09	12 January 2022	267	17	0.06	17	0.18	2238	25	11	39
Titi-10	9 January 2022	1260	47	0.04	47	0.00	12892	0	0	0
	Titi 08 was merged with Titi 07 as it was found they were joined by burrows on the island									
Titi Island	**9 - 16 January 2022**	**5997**	**483**		**483**		**48858**	**528**	**250**	**806**

3.1.1 TT01

The second largest area in extent, TT01 was a densely burrowed colony on the south facing side of Titi Island. Mainly taupata (*Coprosma repens*) scrub with soft soil and steep terrain, especially towards the ridge making the colony very fragile in places. Burrows extended all the way down through open areas (Figure 3) until it reached taupata scrub as it funnelled towards the landing location. During nightwork, many flesh-footed shearwaters were seen towards this bottom section (Figure 4), with more sooty shearwaters seen further up the colony towards the ridge. The outline provided by Baker *et al.* (2010) was accurate and did not need updating. We calculated a low occupancy rate (9%) of flesh-footed shearwaters for this colony. Sooty shearwater occupancy was much higher (44%), as expected, in the colony and were the predominant species detected in the burrows. Kororā/little blue penguins were also detected during nightwork (maximum seen 5), as well as during transect surveys, in two burrows each undergoing moult, with two additional empty burrows having evidence of a kororā having completed moult (burrow coated heavily in kororā feathers).

Figure 3. TT01 Open areas above taupata section.

Figure 4. Flesh-footed shearwater seen at night on Titi Island in TT01.

3.1.2 TT02

Densely burrowed in areas, this colony area extended above the original Baker et al. (2010) boundary. Consequently, this top area was remapped whilst on the island, and added on to the initial boundary. 5 new random transect points and bearings were generated in QGIS to survey this extra area. This was the second highest burrow density (0.11m^2) across all colony areas, but a low occupancy rate (9%) of flesh-footed shearwaters. The lower boundary ended in thick ferns and taupata scrub and was densely burrowed throughout, even under ferns and the fallen tree limbs. The original lower boundary was shifted slightly up from the southern tip as it turned from open understory with many burrows to an exposed cliff below dominated by low plant communities. No burrows were in this area before the cliff dropped into the water below. The western boundary turned very scrubby in places with thick undergrowth, however there were still lots of burrows present.

3.1.3 TT03

This area had a low ground cover of ferns and a mixed canopy overhead. The colony runs right down to the short steep cliffs (~15m high) down to water. Burrows right to edge here under shrubby tree species including taupata, fern *spp.* and five finger (*Pseudopanax arboreus*). It was very densely burrowed at the base of the colony area before the cliffs. The outline provided by Baker *et al.* (2010) was accurate and did not need updating. We calculated the third highest occupancy (23%) for flesh-footed shearwaters in this area. While this is still a relatively low flesh-footed shearwater occupancy compared to other breeding islands, it was higher than the sooty shearwater occupancy rate of 19%.

3.1.4 TT04

The outline provided by Baker *et al.* (2010) was accurate and did not need updating. This area had a rocky central spur with no burrows present. There was a typical funnel of burrows at the base of the colony where the gully met the cliffs and coast with taupata scrub present again. There were some exposed areas with flax (*Phormium tenax*), grasses, and kōkihi (*Tetragonia tetragonoides*) which still had burrows present, one having a flesh-footed shearwater present. We calculated the second highest occupancy (24%) for flesh-footed shearwaters in this area. While this is still a relatively low flesh-

footed shearwater occupancy compared to other breeding islands, it was higher than the sooty shearwater occupancy rate of 5%.

3.1.5 TT06

The outline provided by Baker *et al.* (2010) was accurate and did not need updating. It had a large open area underneath a wharangi (*Melicope ternata*) canopy (Figure 5). No real burrowing around the western southern edge of this colony area where it turns steep, scrubby, and rocky, with heavy fern ground cover in places along the western edge. Incredibly fragile area at the southern tip, especially towards the cliff. We calculated a low occupancy (12%) of flesh-footed shearwaters for this area.

Figure 5. Transect in TT06 on Titi Island

3.1.6 TT08 (merged with TT07)

The outline provided by Baker *et al.* (2010) was not entirely accurate and was updated. The TT08 colony area was combined with TT07 due to the burrows on the ground merging the two areas together. There was a central rocky spur present with no apparent burrows present, only around the edges to connect the two areas. Ferns make up the undergrowth in areas. Very densely burrowed in the more open areas. The southern section was steep and incredibly fragile. Kohekohe (*Didymocheton spectabilis*) was present alongside taupata scrub. Burrows extended right up to the ridge. We calculated the highest occupancy (29%) of flesh-footed shearwaters in this area.

3.1.7 TT09

The outline provided by Baker *et al.* (2010) was accurate and did not need updating. Ongaonga (*Urtica ferox*) was thick at the top of the colony near the ridgeline before clearing below to where the burrows were. The canopy opened up at the lower funnel where the colony was densely burrowed. We calculated a low occupancy (18%) of flesh-footed shearwaters in this area.

3.1.8 TT10

The colony outline provided by Baker *et al.* (2010) needed remapping as there were no burrows present along and around the easternmost transects of the original colony area. Consequently, the eastern border was taken in quite a distance as seen in Figure 2. Burrows were present right up to the ridge at the northern boundary. There was very loose friable soil in this area, and it became rocky

along the ridge, so the burrow density decreased slightly. Ferns dominated patches, with kawakawa (*Piper excelsum*), five finger, lancewood (*Pseudopanax crassifolius*), poroporo (*Solanum laciniatum*), and native broom (*Carmichaelia australis*) present throughout. There were areas where very large boulders and rocky substrate dominated, and several large Nikau palms (*Rhopalostylis sapida*) were also found towards this eastern border. This area had the lowest occupancy rate (0%) for flesh-footed shearwaters with no birds found in any of the 46 burrows examined. Conversely, this area had the highest occupancy rate for sooty shearwaters (48%).

3.1.9 Other Searched Areas

Searches in other areas of the island yielded no additional flesh-footed shearwater colony areas. There were a few scattered burrows in very small and tightly packed clusters (maximum number counted 20) on the eastern side of the island (Clusters 1-5 in Figure 2). When some of these burrows were checked, they were either empty or contained breeding sooty shearwaters. Due to their incredibly small size these areas were not classed as colonies. Consequently, we deemed that none of these clusters were significant enough to warrant being a colony and were excluded from the analyses.

The northern slopes of the island are, as noted by previous authors (Gaze 2000, Baker et al. 2010), steep, rocky and unforested (Figure 6), thereby rendering them unsuitable for shearwater burrowing.

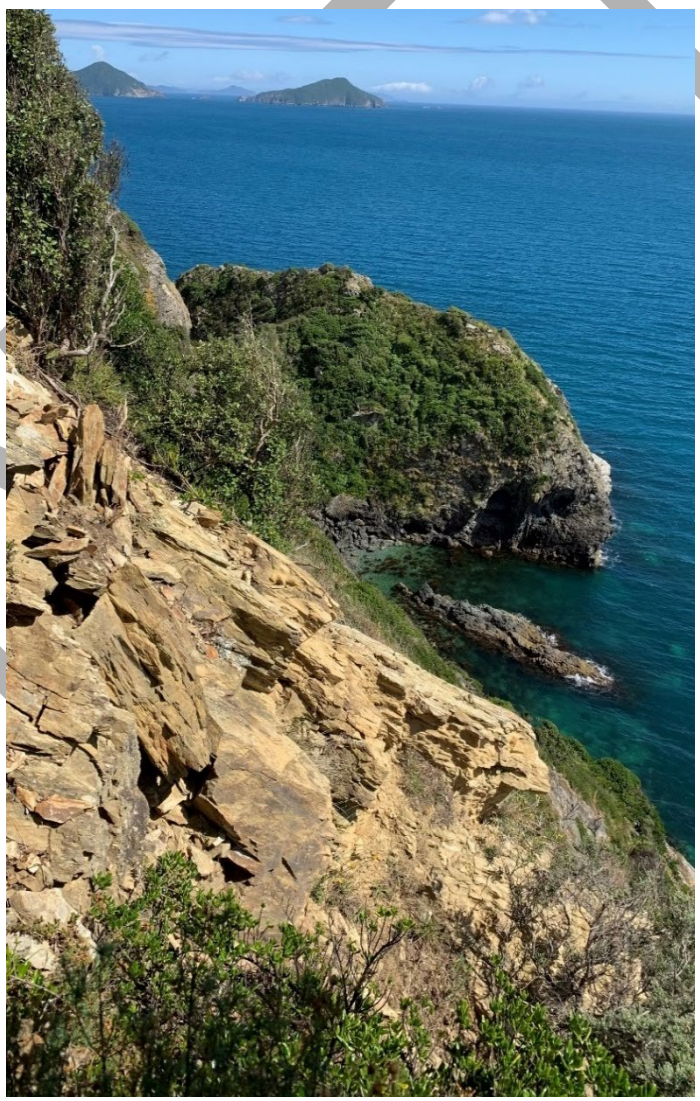

Figure 6. Steep northern slopes of Titi Island

3.2 Population Estimate Comparisons

The population estimate presented here for Titi Island is slightly higher than the previous estimate carried out by Baker *et al.* (2010) and Waugh et al. (2014) as shown in Table 2.

Table 2. Current and previous flesh-footed shearwater population estimate comparisons.

Island	Current Estimate			Previous Estimates			Difference between estimates
	Year	Estimated Occupied Burrows	95% Confidence Interval	Paper/Report	Estimated Occupied Burrows	95% Confidence Interval	
Titi Island	2022	528	250 – 806	*Baker et al. (2010)*	*337*	*0 – 950*	**+191**
				Waugh et al. (2014)	*157*	*N/A*	**+371**

For those three colony areas where Baker et al. (2010) did run transects, we found the occupancy measurements to be slightly different to what was calculated in our study. Table 3 shows the estimates from both studies for the three colony areas.

Table 3. Differences in Occupancy Calculations for TT01, TT02 and TT03 between the current study and Baker et al. (2010).

Colony Area	Occupancy Rate (Current Study 2022)	Occupancy Rate (Baker et al. 2010)	Difference
TT01	0.086	0.146	**-0.06**
TT02	0.088	0.058	**+0.030**
TT03	0.234	0.129	**+0.105**

TT01 has a very small reduction in occupancy rate between the two studies. The colony area boundary of TT02 was expanded, which may explain the increase, and TT03 had a higher occupancy rate in our study too.

3.3 Sooty Shearwaters

Sooty shearwaters were known to be more abundant than flesh-footed shearwaters from previous work (Gaze 2000, Waugh et al. 2014) and discussions (G. Taylor, P. Gaze, M. Bell, pers. comm.). Through our transect work and determining whether a sooty or flesh-footed shearwater was present in each of the burrows (Figure 7), we were also able to calculate a population estimate for the sooty shearwaters breeding on Titi Island without any additional work. Consequently, we estimate that there are a total of 1038 (544 - 1533, 95% CI) occupied sooty shearwater burrows on Titi Island, and calculated an average occupancy rate of 25% across all colony areas. This data is summarised in Table 4 below.

Figure 7. Sooty shearwater incubating an egg in a burrow on Titi Island

Table 4. Sooty Shearwater Population Estimate Statistics for all Titi Island Colony Areas (January 2022)

Colony	Dates Surveyed	Area sampled (m^2)	Large burrows counted	Burrow Density (burrows/m^2)	Number of burrows examined	Occupancy Rate	Colony Area (m^2)	Estimated Occupied Burrows	Lower 95% CI	Upper 95% CI
Titi-01	10, 11 January 2022	1200	84	0.07	84	0.44	10434	325	211	438
Titi-02	11, 16 January 2022	900	95	0.11	95	0.36	5349	205	125	284
Titi-03	12 January 2022	600	49	0.08	49	0.19	6251	98	45	150
Titi-04	13 January 2022	600	43	0.07	43	0.05	4823	17	6	27
Titi-06	13 January 2022	600	50	0.08	50	0.28	3898	91	23	159
Titi-08	14 January 2022	570	98	0.17	98	0.11	2973	57	27	86
Titi-09	12 January 2022	267	17	0.06	17	0.12	2238	17	8	26
Titi-10	9 January 2022	1260	47	0.04	47	0.48	12892	230	99	361
Titi Island	**9 - 16 January 2022**	**5997**	**483**		**483**	**0.25**	**48858**	**1038**	**544**	**1533**

3.4 Kororā/Little Blue Penguin

A total of 11 kororā/little penguins (*Eudyptula minor*) were found in 9 burrows moulting (one burrow had two individuals) (Figure 8), across all colonies, with an additional 18 empty burrows having evidence of kororā having completed their moult (mass of shed feathers on the burrow floor – see figure 9).

Figure 8. Kororā in burrow moulting on Titi Island

Figure 9. Feather evidence of kororā moult in an empty burrow on Titi Island.

4. DISCUSSION

WMIL designed the survey methodology to reduce potential errors following recommendations from Wolfaardt & Phillips (2013) and Parker & Rexer-Huber (2015). A random sampling design within known colonies was used to remove any sample bias. The open nature of the forest floor in colonies on Titi Island and using two experienced observers walking and counting burrows on transects multiple times, removed errors around burrow and occupant detection probability, as well as observer bias. The surveys were carried out as early as logistically possible in January, after flesh-footed shearwater egg laying was complete (Bell et al. 2017). As such, errors around estimating burrow occupancy would have been low, with only burrows failing during early incubation and retaining no sign of a failed breeding attempt being misidentified as a non-occupied burrow.

We believe the primary reason for the apparent increase and discrepancies between the current estimate and the estimates of both Baker *et al.* (2010) and Waugh et al. (2014) is likely due to both the methodology used, and the increased time spent on the island. However, there are anecdotal reports of more flesh-footed shearwaters being detected within and further in the Marlborough Sounds (M. Bell, pers. comm.), which may link in with the apparent increase we have calculated here but we would strongly caution that this would need further analysis to increase confidence in these anecdotal statements.

When comparing our estimate with that of Baker et al. (2010), the discrepancy in the final estimate value is likely simply due to the way the total area has been calculated for each of the colonies. The three-dimensional surface area was calculated for all colonies to extrapolate transect data as opposed to using the two-dimensional calculations that Baker et al. (2010) utilised. For example, the area we calculated for TT03 colony was 6,251m² compared to Baker *et al.* (2010) who calculated it as 5,128m². TT02 was extended as discussed above, to capture burrows above the original outline mapped by Baker et al. (2010). The only colony that was found to be smaller, was TT10, which was due to its eastern border being taken in after we found no burrows within the colony area when undertaking transects. As most of the flesh-footed shearwater colonies are on steep terrain, we feel the three-dimensional approach is more applicable and gives a more accurate estimate. Additionally, in the absence of other occupancy data, Baker et al. (2010) applied the mean occupancy rate for just three of the colony areas to all other Titi Island colonies. With our more intensive survey method we were able to gather finer resolution estimates, which have resulted in a slightly higher, yet more accurate estimate. Our estimates are therefore not necessarily reflective of a population increase, but more likely a result of more in-depth and higher-quality sampling and analysis techniques giving a more accurate estimate of population sizes compared to the two previous estimates.

Unlike estimates on Ohinau, Lady Alice and Whatupuke Islands where we found major discrepancies in the mapped colony areas (Crowe 2018, Crowe & Bell 2019, Crowe & Burgin 2021), we found the colony areas mapped by Baker *et al.* (2010) for Titi Island to be very similar to what we mapped this season with a few discrepancies as discussed above. There were three changes to the colony area boundaries:

1. The eastern boundary of TT10 was brought in towards where the burrows finished as we found that the colony did not stretch as far making the area smaller than that originally mapped by Baker et al. (2010). This aligns with the fact that Baker et al. (2010) did not run transects in this area and this was the largest change in colony boundary extent.
2. TT02 was extended northwards to include burrows found above the northern boundary mapped by Baker et al. (2010).
3. TT08 and TT07 were merged into a single colony area, as it was found there was a continuous run of burrows connecting the two areas, rather than them being split as recorded by Baker et al. (2010).

The differences between the three colony areas surveyed during this study and by Baker et al. (2010) presented in Table 3 are likely due to the differences in methodology as discussed above. With only three of the colony areas surveyed fully by Baker et al. (2010), we again conclude that there has not necessarily been a true increase in population but instead a sampling/analysis-related increase.

All colony areas were inhabited more densely by sooty shearwaters, with the average occupancy rate of 25% across all colonies. The highest occupancy rates were found in TT10 (48%) and TT01 (44%), the two areas with the lowest occupancy rates for flesh-footed shearwaters (TT10 = 0%, TT01 = 9%). The estimates presented in Table 2 and 4 align with what was seen anecdotally by the team on the island, not just during transect work where more sooty shearwaters were encountered in burrows, but also during night work where more sooty shearwaters were also encountered and heard. This also aligns with conclusions from previous shearwater survey work on the island (Bell 1969, Gaze 2000). Additionally, there appears to be an apparent 'divide' where flesh-footed shearwaters were not detected during transect surveys within TT10 and further east.

Whilst no other colony areas were found in the additional areas we searched on the island, the low-density clusters (Figure 2) should be explored in future work as there is potential for them to expand as evidenced by a number of freshly dug, or 'in progress' burrows being seen. There were no flesh-footed shearwaters present in any of the burrows we checked, all being occupied by sooty shearwaters. However, this could well change and should be surveyed again during future work.

4.1.1 Possible kārearea/New Zealand falcon predation of sooty shearwater

Whilst on Titi Island we detected a resident pair of kārearea/New Zealand falcon (*Falco novaeseelandiae*) each day, with a likely nest spot up on one of the central ridges. Whilst undertaking surveys we found two sooty shearwater carcasses on the surface within colony areas that showed potential evidence of kārearea predation, or at least consumption. Sooty shearwater carcasses were found with evidence of being plucked and the breast area eaten. Kārearea were also seen at dusk, including hunting passerine species at the same time that sooty shearwaters and flesh-footed shearwaters were being detected returning to the colony. This potentially aligns with observations recently made by Miskelly et al. (2022) and may indicate kārearea predation of sooty shearwater.

5. Conclusions and Recommendations

It is incredibly important to note again, that any difference between our population estimate and previous estimates are likely to be a result of more in-depth and higher-quality sampling and analysis techniques giving a more accurate estimate of population sizes compared to previous estimates. With that in mind, we recommend that follow up population estimates in the near future are undertaken to determine population changes.

Most of the population estimates conducted over the past five years by WMIL for flesh-footed shearwaters (Bell & Boyle 2017, Crowe 2018, Crowe & Bell 2019, Crowe & Burgin 2021) have shown substantial changes to previous estimates. With this in mind, surveys of other flesh-footed shearwater breeding colonies to update population estimates are warranted and utilising consistent research methodologies, as recommended by Waugh et al. (2013).

- **We recommend that the following islands be considered for surveys to update population estimates:**
    - **Green Island, Mercury Islands**
    - **Mauitaha, Hen and Chicken Islands**
    - **Wareware and Muriwhenua Islands, Hen and Chicken Islands**

There are challenges associated with surveying some of these islands, most notably Green Island being particularly fragile and so would require a modified sampling technique similar to that carried out on Middle Island (Bell & Boyle 2017). Green Island has a large number of diving petrels and so it would

be interesting to see if there has been similar displacement of diving petrels by flesh-footed shearwaters, as seen on Motumahanga Island (Crowe & Bell 2019).

Access to Mauitaha would require explicit permission from Ngātiwai. Wareware and Muriwhenua Islands have historically only had fluttering shearwaters noted as breeding on them (Waugh *et al.* 2014). However, given their locality to nearby flesh-footed shearwater colonies, plus comments about flesh-footed shearwaters being present received from experienced local DOC staff (N. Forrester, pers. comm.), consideration for a survey is warranted. Karewa Island (Bay of Plenty) holds a significant population of flesh-footed shearwaters and has not been surveyed since 2010 but is extremely fragile and currently under treaty negotiations so should not be considered.

We strongly recommend ongoing monitoring of the Titi Island population of flesh-footed shearwaters to help provide a longer multi-generational dataset for this species' southernmost breeding location in New Zealand. We feel this will help provide a more detailed picture of flesh-footed shearwater population changes moving forward. Tracking of individuals from this island could also assist with understanding their use of the Marlborough Sounds. As noted by Gaze (2000) and Waugh et al. (2014), the Titi Island population marks the southern limit range of flesh-footed shearwater in New Zealand and will therefore best reflect any expansion or contraction of the species' range more markedly than sites more central to its range.

Additionally, we recommend monitoring of the kororā present on the island and undertaking a more detailed population estimate. Recently classified as "At Risk: Recovering" under the Threat Classification (Robertson et al. 2021), we feel monitoring this population would be of great benefit to increase the general lack of knowledge on this species population size and population trends, particularly within the Marlborough region, as summarised in Mattern & Wilson (2018).

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8. APPENDICES

Appendix 1: All bird species detected on Titi Island 8-17th January 2022 from the online eBird Report.

- New Zealand Pigeon (*Hemiphaga novaeseelandiae*)
- Variable Oystercatcher (*Haematopus unicolor*)
- Silver Gull (*Chroicocephalus novaehollandiae*)
- South Black Backed Gull (*Larus dominicanus*)
- White-fronted Tern (*Sterna striata*)
- Little Penguin (*Eudyptula minor*)
- Northern Giant Petrel (*Macronectes halli*)
- Fairy Prion (*Pachyptila turtur*)
- Flesh-footed Shearwater (*Ardenna carneipes*)
- Sooty Shearwater (*Ardenna grisea*)

- Fluttering Shearwater (*Puffinus gavia*)
- Australasian Gannet (*Morus serrator*)
- Little Pied Shag (*Microcarbo melanoleucos*)
- Spotted Shag (*Phalacrocorax punctatus*)
- Pied Shag (*Phalacrocorax varius*)
- Reef Heron (*Egretta sacra*)
- New Zealand Falcon (*Falco novaeseelandiae*)
- Yellow-crowned Parakeet (*Cyanoramphus auriceps*)
- Tui (*Prosthemadera novaeseelandiae*)
- Bellbird (*Anthornis melanura*)
- Grey Warbler (*Gerygone igata*)
- New Zealand Fantail (*Rhipidura fuliginosa*)
- Welcome Swallow (*Hirundo neoxena*)
- Silvereye (*Zosterops lateralis*)
- Eurasian Blackbird (*Turdus merula*)
- Dunnock (*Prunella modularis*)
- Chaffinch (*Fringilla coelebs*)