


Population estimate of Flesh-footed Shearwaters on Middle Island

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EXECUTIVE SUMMARY

During a field trip to Middle Island, from 5-10 January 2017, a total of 25 transects recorded burrow density of Flesh-footed Shearwaters at 0.0745 burrows/m^2.

Burrow density varied for the three vegetation types found on Middle Island, with burrow density in the Karo-Taupata scrub estimated at 0.089 burrows/m^2; the Wharangi-Mahoe forest at 0.146 burrows/m^2; and in the Milk Tree Forest at 0.025 burrows/m^2.

Night work also indicated that Flesh-footed Shearwater numbers vary amongst vegetation type, with more birds recorded in Karo-Taupata scrub and Wharangi-Mahoe forest than the Milk Tree forest on the plateaus.

From burrows where their contents could be determined using a burrowscope, burrow occupancy was calculated as 71.8%.

Area calculations for the three vegetation types estimate that there is 63,360$m^2$of Karo-Taupata scrub, 13,486m^2 of Wharangi-Mahoe forest, and 19,954m^2 of Milk Tree forest on Middle Island. Stratifying for the three vegetation types, and correcting for burrow occupancy the population of Flesh-footed Shearwaters on Middle Island is estimated to be 5,822 breeding pairs (95% confidence interval 2,400-9,244).

This confirms that Middle Island has the largest Flesh-footed Shearwater population in New Zealand.

The only previous population estimate for Middle Island, 3,000 breeding pairs, was based on data collected in 2003; re-analysis of this data, stratifying for vegetation and using 2017 burrow occupancy rates, estimates the 2003 population was 4,441 breeding pairs; within the confidence interval of the 2017 results.

1. INTRODUCTION

The Flesh-footed Shearwater (*Puffinus carneipes*) is a large, all dark, shearwater of the Indian and Pacific Oceans. Away from New Zealand colonies occur on St Paul Island (Southern Indian Ocean) and on many islands off the west and south coasts of Australia, and Lord Howe Island.

In New Zealand, breeding has been reported from 20 islands, mainly off northern North Island, with a few small colonies in Cook Strait (Waugh *et al.* 2013). However most of the New Zealand population occurs on just seven islands: Karewa (2561 pairs), Middle, (3000 pairs), Ohinau (2071 pairs), Coppermine (1425 pairs), Whatupuke (1210 pairs), Lady Alice (921 pairs) and Titi (337 pairs) (Baker *et al.* 2010, Waugh *et al.* 2013).

Waugh *et al.* (2013) estimated the total New Zealand population at 10,000-15,000 breeding pairs and suggested that the population is currently in decline.

Birds forage close to breeding grounds in the summer but migrate to the northern hemisphere in winter. Birds occur in waters off Japan in June-August, and the central Pacific in August-September on their return to the Southern Hemisphere (Marchant and Higgins 1990, Onley and Scofield 2007, Checklist Committee 2010).

The only previous population estimate for Middle Island was 3,000 burrows in 2003 (Waugh *et al.* 2013).

This report details the results of a population census carried out on Middle Island in January 2017. This survey was carried out as part of the Flesh-footed shearwater: Various locations population project (POP2015-02) funded through the Conservation Services Programme. The key objective was:

Objective 1: To estimate the population size of flesh-footed shearwater at Middle Island (Mercury Islands).

2. METHODS

2.1 Middle Island

Middle Island (175ºº51'E, 36º38'S,) lies 8.5km off the north-east Coromandel Coast and is the second smallest island in the Mercury Island Group. It is a Nature Reserve with landing restrictions. The 13ha Island has steep cliffs, with two raised plateaus. Middle Island lacks recent human modification and has always been rat-free, enabling it to support significant seabird and reptile populations, including a number of critically endangered reptile species.

Atkinson (1963) and Cameron (1990) described four vegetation types from the island (Figure 1) -

1. Cliff vegetation on shallow rocky soils - present on the steep cliffs around the island.
2. Karo-Taupata scrub on burrowed very friable clay loam – present on the steep to moderately steep slopes which fringe the island.
3. Wharangi-Mahoe forest on burrowed very friable clay loam – present on very steep to moderately steep slopes and forms the transition between the Karo-Taupata scrub and the plateau Milk Tree forest.
4. Milk Tree forest on burrowed very friable clay - confined to the gentle slopes of the two plateaus.

Flesh-footed Shearwaters were only found breeding in the Karo-Taupata scrub, Wharangi-Mahoe forest and Milk Tree forest where the soil depth allowed for burrowing.

Figure 1. Examples of vegetation types on Middle Island where Flesh-footed Shearwater breeding was recorded. A) Karo-Taupata scrub covered slope near coast; B) Highly burrowed ground under Karo-Taupata scrub; C) Highly burrowed open floor of Wharangi-Mahoe forest.

2.2 Survey design

Determining population estimates for burrow nesting seabirds inevitably involves sampling a proportion of a colony, and extrapolating density, area and occupancy estimates to determine the number of active or occupied burrows at breeding sites (Wolfaardt and Phllips 2013). A range of guidelines and recommendations have been developed for determining population estimates for burrow nesting seabirds (see Wolfaardt and Phillips 2013, Parker and Rexer-Huber 2015). These identify a number of sources of error, which need to be addressed when undertaking a population estimate of burrowing seabirds.

1. Timing of the census – to reduce errors, time the census so the fewest assumptions and corrections are needed. Ideally a survey to count breeding pairs should occur immediately following the completion of egg laying, but before many egg failures will have occurred.
2. Burrow detection probability – an assessment should be carried out to test the assumption that every burrow will be found on transects or quadrats. The habitat (vegetation, topography etc.) and breeding behaviour (cryptic burrow entrances etc.) can influence the number of burrows counted.
3. Occupant detection probability - detailed burrow occupancy assessment is needed to accurately determine burrow occupancy. Potential sources of error include multiple burrows with the same entrance or several entrances for the same burrow. The assumption that every occupant of a burrow present will be found also needs to be tested
4. Ensure representative areas are sampled - ensure transects are representative of the range of habitats over the whole extrapolated area
5. Observer bias – it is important to check burrow counts and content data for observer differences. Differences, even between experienced observers, have been recorded and bias needs to be accounted for.

In order to reduce possible errors, these recommendations were incorporated into the survey design for the Middle Island Flesh-footed Shearwater study.

The field work was carried out between Jan 5th and 10th 2017. Egg laying in Flesh-footed Shearwaters is highly synchronised and reported to occur over two weeks from the last week of November through to the first week of December (Marchant and Higgins 1990). However, field work on Lady Alice Island found that egg-laying started in the first week of December and continued until the fourth week of December (M. Bell pers. obs). The field trip to Middle Island was timed to occur immediately following the end of the egg laying period, in early incubation, to avoid underestimating burrow occupancy as all eggs should have been laid and few would have failed by then.

In order to determine the breeding population of Flesh-footed Shearwaters on Middle Island, 20 x 2m transects (10m either side of the track), were carried out every 30m along the existing track network. A 20m tape measure was laid out on the surface, and one observer counted the number of burrows within a 2m band to one side of the tape. Following Waugh *et al.* (2003) and Baker *et al.* (2010) burrows were classified by the size of the entrance (small or large), with large burrows defined as burrows >20cm long, with an entrance size >14 x 8cm. A second observer then checked the contents of each large burrow using a burrowscope to determine burrow contents. The vegetation and slope of each transect were recorded to enable burrow density estimates to be calculated for each habitat type.

As Middle Island is densely burrowed by seabirds the forest floor is relatively open, and burrow entrances are easy to locate. One observer counted burrows, and a second observer checked burrow contents. The second observer also checked for burrows missed by the first observer, in order to ensure no burrows were missed or double counted.

Burrow occupancy was checked using a burrowscope. Previous experience with Flesh-footed Shearwater burrows on Lady Alice and Ohinau Islands had found that burrows are often long, and have large chambers. As such extreme care was taken to ensure that burrows were thoroughly inspected to determine occupancy.

The densely burrowed nature of Middle Island makes it a very fragile Island; as a result restrictions on access were imposed by the Department of Conservation. This restricted the field team to working on the existing track network, with transects only allowed 10m metres either side of the track. Due to these restrictions a completely random covering of the whole island could not be undertaken. However transects did cover the range of vegetation types, slope and soil depths on the island and it is likely that although not random, the number and distribution of transects do reflect the habitat features of the island.

Observer bias was removed by having one observer undertaking burrow counts and one observer doing all burrow occupancy checks with a burrowscope.

To calculate the exact area of Middle Island we manually digitised the extent of each vegetation type from a georeferenced aerial photograph of Middle Island, then used the ‘Calculate geometry’ tool in Arcmap 10.4 to calculate the 2D (planar) area of mapped woody vegetation. A Digital Elevation Model (DEM) for Middle Island was sourced from the LINZ data service website (https://data.linz.govt.nz/) and we ‘clipped’ the Middle Island DEM using a polygon describing the mapped extent of vegetation types on the island. We used the clipped DEM to create a Triangulated Irregular Network surface (TIN) for each vegetation type and then used the ‘Surface volume’ tool in ArcToolbox to calculate the 3D surface area of the TIN, creating a 3D surface area of each vegetation type on the island, taking into account topography.

The population estimate was stratified for the three habitat types described by Atkinson (1964) and Cameron (1990). The density of burrows for each habitat area was calculated, and the number of burrows extrapolated from area calculations. This figure gave the number of burrows, and was corrected for occupied burrows to provide an estimate of the breeding population.

3. RESULTS

A field team of two camped on Middle Island from Jan 5th to Jan 10th 2017. A total of 25 transects were completed between January 6th and 9th 2017 (Figure 2, Table 1). Most transects were 20m, however two transects were shortened as these went over areas of steep cliff which made it unsafe to continue.

The mean density of large burrows was 0.0745 burrows/m² (range 0 - 0.3 burrows/m²). Burrow density varied for the three vegetation types, with burrow density in the Karo-Taupata scrub estimated at 0.089 burrows/m² (range 0 – 0.188 burrows/m², n=8). In the Wharangi-Mahoe forest 0.146 burrows/m² (range 0.05 – 0.3 burrows/m², n=6), and in the Milk Tree forest 0.025 burrows/m² (range 0-0.05 burrows/m², n=11).

Area calculations for the three vegetation types estimate that there is 63,360m²of Karo-Taupata scrub, 13,486m² of Wharangi-Mahoe forest, and 19,954m² of Milk Tree forest. Extrapolating from burrow densities recorded in transects a total of 8,109 large burrows are estimated to be on Middle Island (Table 2).

Burrow occupancy was calculated to be 71.8% from burrows where the contents could be determined using a burrowscope (Table 1).

Stratifying for the three vegetation types and burrow occupancy, the population of Flesh-footed Shearwaters on Middle Island is estimated to be 5,822 breeding pairs (95% confidence interval 2,400 – 9,244; Table 2).

During field work on Middle Island, we spent each night walking the existing track network and coastline to assess Flesh-footed Shearwater activity to compare with results from transects. The first night was an exceptionally good night, with high shearwater activity, but each following night had less and less activity. This night work confirmed the differences in burrow density in the different vegetation types; The Milk Tree forest on the plateaus held few birds, there were good numbers of birds in areas of Karo-Taupata scrub (especially in the Camp Gully, along the coastal fringe and on the southern-most “peninsula”) and the highest densities of birds occurred in areas of steep Wharangi-Mahoe forest fringing the plateaus and along the southern end of the island.

Figure 2. Vegetation types, track network and location of transects on Middle Island, January 2017.

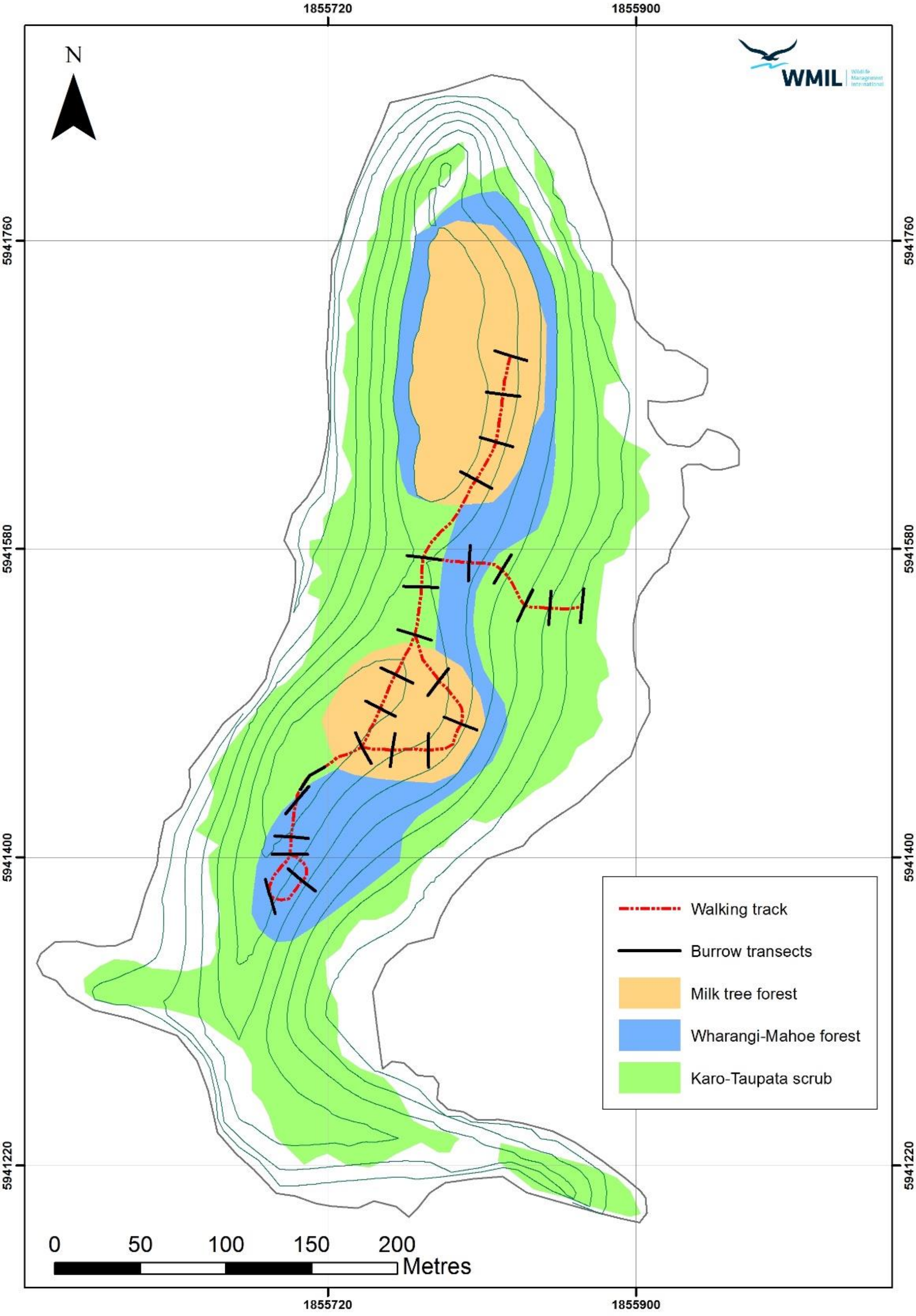

Table 1. Results of 25 transects carried out on Middle Island Jan 6-9th 2016.

Transect	Vegetation type	Length	Small burrows	Large burrows	Large burrow contents					Burrows/m2
					Bird on egg	Egg only	Empty, chamber with nest	Empty*	Undetermined	
MIT01	Wharangi-Mahoe forest	20	43	2	1			1		0.050
MIT02	Wharangi-Mahoe forest	20	51	4	1			2	1	0.100
MIT03	Wharangi-Mahoe forest	20	65	5	4		1			0.125
MIT04	Wharangi-Mahoe forest	20	69	4	2		1	1		0.100
MIT05	Wharangi-Mahoe forest	20	54	8	8					0.200
MIT06	Karo-Taupata scrub	20	46	2	2					0.050
MIT07	Karo-Taupata scrub	20	85	2	2					0.050
MIT08	Milk Tree forest	20	68	0						0.000
MIT09	Milk Tree forest	20	90	0						0.000
MIT10	Milk Tree forest	20	85	1	1					0.025
MIT11	Milk Tree forest	20	63	2		1		1		0.050
MIT12	Milk Tree forest	20	56	2	1		1			0.050
MIT13	Milk Tree forest	20	50	1			1			0.025
MIT14	Milk Tree forest	20	60	1	1					0.025
MIT15	Karo-Taupata scrub	16	51	6	4		2		1	0.188
MIT16	Milk Tree forest	20	49	2	1			1		0.050
MIT17	Milk Tree forest	20	49	1	1					0.025
MIT18	Milk Tree forest	20	57	0						0.000
MIT19	Milk Tree forest	20	68	1	1					0.025
MIT20	Karo-Taupata scrub	20	47	3	3					0.075
MIT21	Karo-Taupata scrub	20	57	3	2			1		0.075
MIT22	Wharangi-Mahoe forest	20	29	12	8		2	2		0.300
MIT23	Karo-Taupata scrub	10	41	0						0.000
MIT24	Karo-Taupata scrub	20	52	5	3			2		0.125
MIT25	Karo-Taupata scrub	20	66	6	4		1	1		0.150
	Total	486	1451	73	50	1	9	12	2	0.075

Table 2. Population estimate for Flesh-footed Shearwater on Middle Island by vegetation type.

Vegetation type	Burrow density (burrow/m²)	Area (m²)	Burrows	Population estimate (breeding pairs)	95% confidence interval
Karo-Taupata scrub	0.089	63,360	5,643	4,052	1,730 - 6,373
Wharangi-Mahoe forest	0.146	13,486	1,967	1,412	497 – 2,326
Milk tree forest	0.025	19,954	499	358	171-545
Total			8,109	5,822	2,400-9,244

3.1 Population trend

The only previous census of Flesh-footed Shearwaters on Middle Island was conducted by Graeme Taylor from 4-8 November 2003, when 13 transects (20x2m transects) were carried out. Data from G.Taylor has been provided and allows a direct comparison with the 2017 census.

Mean burrow density in 2003 was identical to 2017 (T-test P=0.98), with 0.75 burrows/m² (range 0-0.355 burrows/m², n=13) compared with 0.745 burrows/m² (range 0-0.3 burrows/m², n=25).

Furthermore, there was no difference in burrow density for different vegetation types between 2003 and 2017 (Table 3).

Table 3. Burrow density of Flesh-footed Shearwater burrows on Middle Island 2003 and 2017.

Vegetation type	2003	2017	T-test	Significant
Karo-Taupata scrub	0.045	0.089	P=0.17	No
Wharangi-Mahoe forest	0.225	0.146	P=0.25	No
Milk tree forest	0.015	0.025	P=0.45	No
Total	0.75	0.745	P=0.98	No

Burrow density estimates from 2003 are similar to that recorded from 2017 (Table 3), but the 2003 trip was before egg laying started, and as such there is no data on burrow occupancy and an estimate of occupancy was used to determine the population estimate. Using occupancy data from 2017 trip (71.8%) revises the population estimate for 2003 to 4,441 (95% confidence interval 165 – 9,046) breeding pairs, and is comparable to 2017 (Table 4)

Table 4. Middle Island Flesh-footed Shearwater population estimate 2003 and 2017.

	Population estimate (breeding pairs and confidence intervals)	
Vegetation type	2003	2017
Karo-Taupata scrub	2,047 (206 – 3,888)	4,052 (1,730 - 6,373)
Wharangi-Mahoe forest	2,179 (11-4,349	1,412 (497 – 2,326)
Milk tree forest	215 (0-812)	358 (171-545)
Total	4,778 (237 – 9,556)	5,822 92,400-9,244)

4. DISCUSSION

The Flesh-footed Shearwater population on Middle Island is estimated at 5,822 breeding pairs. This makes Middle Island the largest population of Flesh-footed Shearwater in New Zealand (Baker *et al.* 2010, Waugh *et al.* 2013).

The only previous estimate from Middle Island (3,000 breeding pairs in Waugh *et al.* 2013) was based on data collected in 2003 by G Taylor (G. Taylor *pers. comm*.); re-analysis of this data estimates the 2003 population at 4,441 breeding pairs.

The results from this survey are higher than expected, but during night work on the island, very high numbers of birds were recorded ashore, and this population estimate seems reasonable.

Furthermore, the current survey methodology was designed to reduce potential errors following Wolfaardt and Phillips (2013) and Parker and Rexer-Huber (2015). The survey was carried out in Early January, immediately after egg laying was complete (late Dec, M Bell *Pers. Obs*.). As such occupancy would have been close to its peak, as only burrows failing during early incubation would have been empty, reducing occupancy estimates.

The open nature of the forest floor on Middle Island and using two experienced observers, working together on each transect, removed errors around burrow and occupant detection probability and observer bias.

Due to the very fragile nature of Middle Island (highly burrowed forest floor) we were restricted to working from tracks, with transects only extending 10m either side of the track. As such the survey design was not random. Although this may have impacted on burrow density estimates, the track network covered all vegetation types, and the number of transects in each vegetation type were evenly distributed. As such the effects of a non-random sampling design are unlikely to have significantly affected the population estimate. This assumes the burrows are spread throughout each of the habitat types across the island and not patchy in distribution.

In addition to transects, night work was carried out along the tracks, and shore line to determine the distribution of shearwaters. We found flesh-footed shearwaters to be very common on the island, although they were not evenly distributed. The difference in burrow density for vegetation types appear to be consistent with were we saw, and heard shearwater activity. There were fewer birds in the Milk Tree forest of the plateaus, and higher numbers in the Karo-Taupata scrub and Wharangi-Mahoe forest. Night work indicated that although transects only covered relatively small areas of these habitat types, shearwater numbers were consistent through all areas of this habitat. Population estimates from other islands in New Zealand (Baker *et al.* 2010) may have considerably underestimated the numbers on these islands. Baker *et al.* (2010) recorded relatively low burrow occupancy (Mean 44.2%; range 5.8 – 65.4%) but a number of field trips were undertaken from 10 – 16 December, when egg laying would still have been underway and many birds would have still been away on exodus (pers. obs.), and would therefore have underestimated occupancy rates. Field work by WMIL on both Ohinau Island and Lady Alice Island suggest that the population estimates for both of these islands are vastly underestimating the number of Flesh-footed Shearwaters there, casting doubt on other island population estimates and therefore the national population estimate for New Zealand. Further work to re-census other populations of flesh-footed shearwater and update the national population estimates are warranted.

5. ACKNOWLEDGMENTS

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