Nesting of Northern Royal Albatross | Toroa *Diomedea sanfordi* on the Chatham Islands: 2022-23 Breeding Season

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Front cover

Adult Northern Royal Albatross | Toroa present in the centre of Motuhara, 20 December 2022, either incubating eggs or loitering (top), and near-fledging chicks in the same area, 16 August 2023 (bottom).

Photo credits: *Jemma Welch/Liam Aitchison (top), Gemma Green/Nathan Gregory (bottom)*

Executive Summary

1. This report covers two aerial surveys of Northern Royal Albatross | Toroa *Diomedea sanfordi* nesting on Rangitautahi, Te Awanui and Motuhara in the Chatham Is archipelago during the 2022–23 breeding season. The first survey was carried out on 20 December 2022, approximately mid-way during the birds' incubation period; the second survey was flown on 16 August 2023, about two weeks before the first chicks were expected to fledge. The number of Northern Giant Petrel | Pāngurunguru *Macronectes halli* seen in the aerial photographs were also counted on all three islands.

2. The aim of the surveys and subsequent analyses of the images was to determine the number of birds apparently sitting on nests, and therefore breeding, early in the breeding season, and the number of chicks present in the weeks prior to fledging. From these data, maximum apparent nesting success could be estimated for the 2022–23 breeding season.

3. Both aerial surveys coincided with the presence of a two-person research team on Motuhara immediately prior to the surveys. The teams counted the overall number of nesting albatrosses in December 2022 (*i.e.,* those birds incubating eggs and the number of recently failed nests), and the number of near-fledging chicks in August 2023. During the latter period the numbers of nesting Northern Giant Petrel were also counted. For both species, these ground counts provided a partial control on the numbers estimated from the aerial photographs.

4. In December 2022, there were 4149 apparently occupied Northern Royal Albatross nests across the three islands, 1744 (42% of the total) on Motuhara, 1508 (36%) on Rangitautahi and 897 (22%) on Te Awanui. The number calculated for Motuhara is higher than the number of active nests counted there on the ground a week earlier (1498 nests), most likely because the assumption that the classified birds in the close-up images are a random subset of the whole is flawed. Just under half of the birds seen in the close-up images of Motuhara could not be classified.

5. From ground surveys on all three islands since 2017, 7–8% of toroa nests are known to have failed up to mid-incubation. Applying this to the estimates derived from the aerial and ground surveys in December 2022, around 4,330–4370 pairs of toroa bred on the Chatham Is during the 2022–23 breeding season.

6. Combining the August 2023 ground count of chicks on Motuhara (1211, compared with 1204 from the aerial survey), and the aerial survey estimates for Rangitautahi (782) and Te Awanui (587), gives 2580 near-fledging chicks in 2023.

7. Overall nesting success for the 2022–23 breeding season is therefore around 59–60%, slightly lower than that calculated solely from the aerial photographic analyses (64%). Both estimates are substantially higher than those recorded in recent years (42–55%).

8. A total of 2128 Northern Giant Petrel were counted from the aerial photographs, of which 93% were on Motuhara. There is much uncertainty around numbers derived from aerial photographic analyses, but those obtained in August 2023 are broadly similar to those counted in earlier years.

Introduction

Around 99 % of the global population of Northern Royal Albatross or Toroa, *Diomedea sanfordi*, a biennial breeding species, nest on three outlying islands in the Chatham Islands archipelago: Rangitautahi (Big Sister) and Te Awanui (Middle Sister) in the Rangitatahi group (The Sisters), and Motuhara/Motchuhar (The Forty-Fours). The only other colony is the small one at Taiaroa Head Pukekura, Otago Peninsula, where up to 40 pairs nest each year.

The breeding population of Toroa on Motuhara and Rangitatahi has been assessed sporadically since the 1970s through a mix of ground counts of nesting birds, usually made during the early incubation period (November–December), and counts of birds from aerial photographs, also taken early in the breeding season (Robertson 1998; Baker *et al*. 2017). Assessments of breeding success have been equally sporadic, typically involving aerial surveys carried out in July–August, before the chicks start fledging in early September (Robertson 1998; Frost 2017, 2019, 2021).

This report details the counts of Northern Royal Albatross adults visible on aerial photographs of Rangitautahi, Te Awanui and Motuhara taken on 20 December 2022, mid-way through the incubation period, and of chicks and adults visible in images taken on 16 August 2023, about two weeks before the first chicks were expected to fledge. During the analysis of the aerial images taken in August 2023, all Northern Giant Petrel | Pāngurunguru *Macronectes halli* visible in the images were also counted. This species was starting to nest at that time, but birds occupying nests could not be consistently distinguished from those just sitting around, so the counts reported here are largely for record purposes.

Methods

Salient details of the climate, geology, topography and vegetation of the three islands on which Northern Royal Albatross | Toroa nest have been given in earlier reports (Frost 2017, 2019, 2021).

The two survey flights were undertaken in the Air Chathams Cessna 206 with two Department of Conservation staff from the Chatham Islands onboard as photographers. The flights followed the same routine as in earlier surveys, namely circling each island in turn (sometimes alternating the circuits around Rangitautahi and Te Awanui) and taking numerous photographs of the islands at various scales. During the 16 August 2023 flight, the position of the aircraft was tracked at 1 s intervals using a Garmin 64sx GPS, the data from which was downloaded and analysed. Figure 1 illustrates the flight path and patterns for the 16 August flight (no GPS data are available for the 20 December 2022 flight).

Further details of these flights (time taken, number and duration of circuits—available for both flights—and mean altitude, airspeed and distances from the islands, available only for 16 August flight) are given in Appendix 1 (Tables A1 and A2), along with a summary of the cameras and lenses used and number of images taken during the two surveys (Table A3). One notable feature is the sizable average distance offshore from the islands flown during the August survey, measured from the GPS-determined position of the aircraft every 10 sec to the closest point on the plateaux rims of each island using the programme NNJoin in QGIS. This ranged from 570 ± 270 m around Rangitautahi to 340 ± 148 m around Motuhara (Table A2). As a result, the birds seen in the images, even at 300 mm focal length, were quite small.

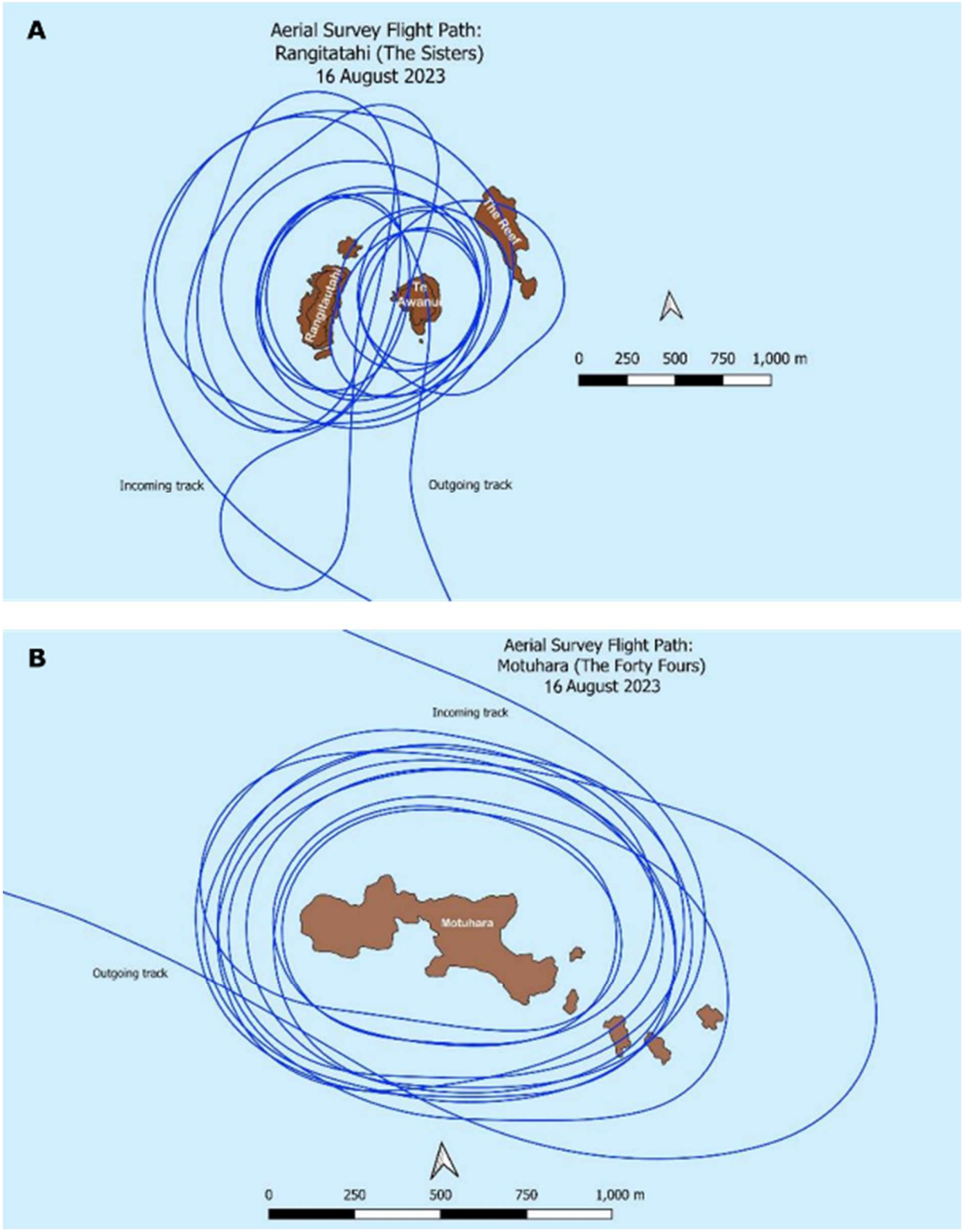

Figure 1. Flight path taken by the aircraft during the 16 August 2023 aerial survey: A. Rangitatahi (The Sisters); B. Motuhara (The Forty Fours). Note the differences in scale and also the relative wide circuits around the islands (see text for details).

In both flights, one photographer concentrated on taking relatively wide-angle photographs of the colonies, while the other took close-up photographs of groups of nesting birds, to allow for more precise definition of activities of the birds on land. Across the islands, 74%–87% of the wide-angle photographs were taken at focal lengths 50–100 mm, with 53%–77% of close-up photographs taken at focal lengths of 250–300 mm. Whereas the wide-angle photographs overall covered the whole island, there were inevitable gaps in the coverage of the close-up photographs, meaning that counts of the total number of birds present came from images in which individual birds were visually fairly small and seldom sufficiently well-resolved to determine their status unequivocally. The close-up images were used for that purpose, as explained below.

From among the wide-angle images of each island, a series was chosen that completely covered the plateau areas on which the Northern Royal Albatrosses | Toroa nested. Each selected image overlapped sufficiently with others so that one or more central areas could be demarcated with the boundary lines of these areas in turn being definable on the adjacent images, eventually allowing the whole area to be delineated sequentially. Prominent rocks, bare areas, distinct clumps of vegetation, water puddles and even the birds themselves were used as markers if visible on complementary images (ensuring that any birds were included consistently on one or other side of these boundaries). In this way, each island was partitioned into a series of unique, precisely contiguous areas, without either overlap or gaps between them. In most cases, several sets of images covering the same area were marked up, enabling duplicate counts to be made.

The main difficulty experienced was in delineating adjacent areas on the crowns of the plateaux, where the partitioned areas on either side of a crest could only be wholly seen and marked when viewed from opposite sides of the island. Particular care was taken when drawing these crown boundary lines. Nevertheless, a few birds may have been misplaced, leading either to small local undercounts or overcounts, but the total error is assessed at much less than 1% based on the number of individuals along these crests as a proportion of the numbers present on either side.

Another potential source of error lay with birds nesting or sheltering among rocks, in shallow gullies, or shielded by tall vegetation. Often only a head or tail was visible, and sometimes not even these, at least not in the main photographs used for the overall census. This was a particular problem in the December 2022 survey on Motuhara, and to a lesser extent on Te Awanui, where prolific growth of the herb *Leptinella featherstonii* sheltered many birds. Not only was it difficult to find such 'hidden' individuals but also to determine their status (on a nest; partner to an incubating bird; or just loafing). To lessen these uncertainties, hopefully, additional images were searched, focusing on these areas of concern to resolve the number and nature of birds present. Overall, these variations are thought to add no more than 1–3% uncertainty to the counts.

In the end, to compare nesting success among different landscapes, various smaller contiguous survey areas were amalgamated into several larger zones, each with its own landscape physiognomy (exposure, relief, microtopography and vegetation cover). These zones are shown in Figure 2.

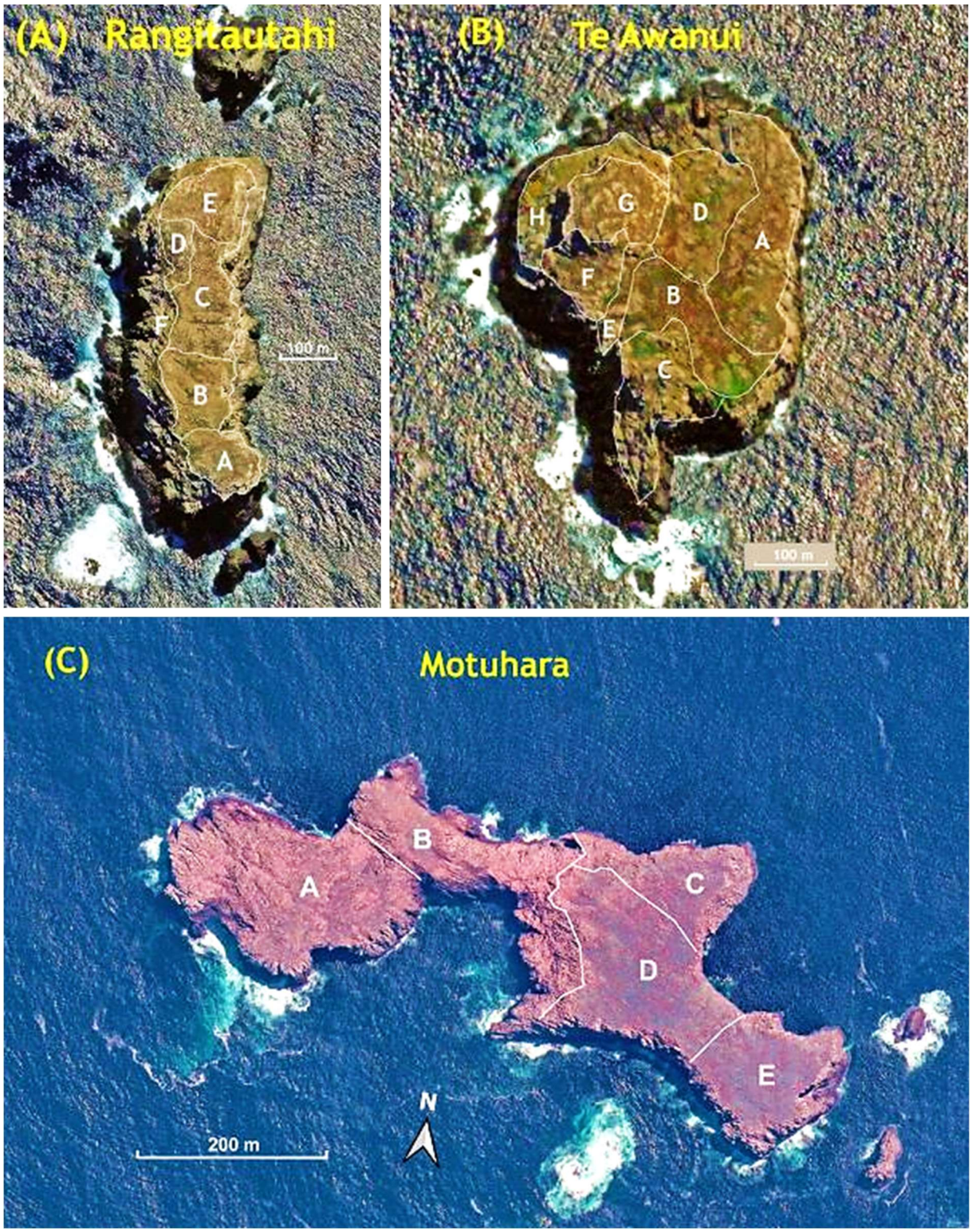

Figure 2. Satellite images of the three islands on which Northern Royal Albatrosses nest (not to the same scale), showing the zones on each into which counts were amalgamated for summary. The actual counts were done on several subsections in each of these zones.

The marked-up images were assessed using the counting software DotDotGoose (Ersts 2022). Each area was gridded (grid size could be adjusted and the grids were used solely for guiding the counting). All visible individual birds were categorised into one of several categories and counted, attempting to distinguish between those birds apparently on nests (AON), those clearly not on a nest (although they may be accompanying a sitting bird), and any others whose precise status could not be determined (including many 'heads only' birds sitting or standing in the *Leptinella* or behind rocks or other individuals).

Around one-third of the birds present on the ground in December 2022 were unclassified as to whether they were occupying a nest or just sitting/standing around. To address this, I analysed a series of close-up images taken more or less simultaneously with the wide-angle photographs from which the initial area-counts had been made. Fifteen images of each island, taken at 280-300 mm focal length, were processed to enhance clarity, colour and contrast. All the main sub-colonies were represented in these images. On each image, I chose as large a central area as possible, ensuring that this was not covered by any other image in the set or, if it was partially, excluding the area of overlap in one or other of the overlapping images. All individuals in this central area were then classified as follows:

(1) **AON**—birds actually sitting with visible nest material beneath them, presumably incubating an egg (very occasionally standing with an egg visible)

(2) **partner**—accompanying a bird on a nest, either sitting alongside or standing next to it

(3) **transient**—non-breeding birds, including duos (two birds not associated with a nest, but standing next to each other in an apparently relational way); groups of 3-7 displaying birds; and loafers, either stationary (sitting or standing around), or walking through the nest areas; and

(4) **unclassified**—any birds that could still not be assigned to one of the above groups (usually because only part of it, most often just its head, was visible).

The analyses of close-up images overall covered 4496 individuals on the ground—2090 on Motuhara, 1481 (Rangitautahi) and 925 (Te Awanui)—of which 51.5%, 78.7% and 71.2%, respectively, were classifiable. The overall proportions of individuals in each of the three behavioural states were then calculated for each island. These proportions are based only on the number of the positively classified birds (*i.e.,* it excludes the unclassified class), and these were used to allocate the total number of individuals counted in wider views of these islands to one of the three classes. The assumption is that the classified birds are a more-or-less random sample of all the birds present, so that the proportion of individuals in each group can be applied to the total count of birds taken from the wide-angle images.

I calculated the 95% Confidence Limits for these counts using the *poisson.exact* function in the R package *exactci* (Fay 2017). This corresponds to the exact central confidence interval of Garwood (1936), widely used for calculating this parameter in a one-sample case, assuming that the counts follow a Poisson distribution, in which the mean and variance of a sample are the same (Baker et al. 2013).

The analysis of the 16 August 2023 images was simpler. Less than 1% of birds on the ground were classed initially as 'uncertain'. These individuals were examined in the close-up images, and all were determined to be chicks, so there was no need to analyse the close-up images in detail beyond this. All individual birds were assigned to one of two categories:

(1) **chick** (identified on a combination of characters, primarily the presence of patches of down on the bird's head, neck, scapulars and breast, but including begging from an adult, exercising its wings and, for developmentally well-advanced chicks, soiled bellies—from sitting on muddy nests—and squatting on their tarsi: Figure 3)

(2) **adult** (identified primarily if they were feeding a chick or standing upright alongside one; by their upright posture and 'clean' plumage, walking upright through a colony or, if they met the plumage characteristics, at or close to a take-off point on the edge of a colony).

As with the December 2022 images, 95% confidence intervals were calculated for these counts. For both assessments, any apparently recent carcasses, as well as adults flying over the survey areas, were also noted, the latter just for completeness.

Figure 3. (A) Adult feeding a chick on Rangitatahi, 16 August 2023, with another chick squatting nearby, illustrating the distinct plumage features of most chicks at the time (down still present on the neck and scapular regions). (B) A group of chicks on Motuhara showing various features used to identify them as chicks (wing-flapping; soiled bellies; squatting posture; all marked on foreheads during the ground-count a few days earlier)

The numbers of Northern Giant Petrel | Pāngurunguru seen in the analysed August 2023 aerial images were also counted, where possible. No attempt was made to classify these birds as it was difficult enough just seeing some of them.

Results

Northern Royal Albatross | Toroa

The total number of birds on the ground on Motuhara, Rangitautahi and Te Awanui counted from aerial photographs taken on 20 December 2022 were, respectively, 2366 [95% CL 1982–2769], 1657 [1367–2003] and 1076 [813–1400] (Table 1). After adjusting for the proportions of birds in the three behavioural classes, based on the analysis of close-up images, the number of apparently occupied nests on the three islands were [95% CL in brackets]: Motuhara, 1744 [1461–2041]; Rangitautahi 1508 [1244–1823]; and Te Awanui 897 [678–1168]. Assuming that each apparently occupied nest involves a breeding pair, there were therefore an estimated 4149 [3383–5031] actively breeding pairs of Northern Royal Albatross | Toroa on the Chatham Is in mid-December 2022, about halfway through the incubation period for the 2023 breeding season (Table 1).

Table 1. Summary of counts of Northern Royal Albatross in various behavioural states derived from an analysis of aerial photographs taken on 20 December 2022, mid-way through the incubation period. The proportions estimated from the close-up photographs are assumed to come from a random subset of the total count, N.

Island (*i*)		Motuhara			Rangitautahi			Te Awanui		**Total**
Total count N_i (*95% CL*)		2366	*(1982–2769)*		1657	*(1367–2003)*		1076	*(813–1400*)	**5099**
Behaviour class (*k*)	Close –up counts	*Proportion estimated from close –up photos (p_i)*	Adjusted number ($N_i * p_{ik}$)	Close –up counts	*Proportion estimated from close –up photos (p_i)*	*Adjusted number ($N_i * p_{ik}$)*	Close –up counts	*Proportion estimated from close –up photos (p_i)*	Adjusted number ($N_i * p_{ik}$)	**Total adjusted numbers**
AON (most likely incubating)	794	*0.737*	1744	1061	*0.910*	1508	550	*0.834*	897	**4149**
			1461 –2041			*1244 –1823*			*678 –1168*	*3383–5031*
Partner of bird AON	15	*0.014*	33	18	*0.015*	25	7	*0.011*	12	**70**
			28 –39			*21 –20*			*9 –15*	*57–84*
Transient (loafing, gamming, walking)	268	*0.249*	589	87	*0.075*	124	102	*0.155*	167	**880**
			494 –689			*103 –150*			*126–217*	*722–1057*
Unclassified	1013			315			266			1594
Total surveyed close –up	2090			1481			925			4496
Total on ground (adjusted)			**2366**			**1657**			**1076**	**5099**
95% CL			*1992 –2769*			*1367 –2003*			*813–1400*	*4162–6172*
In flight			26			5			4	35
Carcass			0			0			1	1

A total of 2573 chicks were counted across the three islands, 1204 (46.8% of the total) on Motuhara, 782 (30.4%) on Rangitautahi, and 587 (22.8%) on Te Awanui (Table 2). Only 47 adults were identified, more than two-thirds of them on Motuhara. In contrast to the December 2022 survey, when only one recent carcass was seen, at least 37 carcasses were counted across all three islands in August 2023, almost 60% of them on Motuhara. Most of these appeared to be dead chicks.

Table 2. The number of Northern Royal Albatross | Toroa chicks counted from aerial photographs taken of Motuhara, Rangitautahi and Te Awanui on 16 August 2023

	Motuhara N (± *95% CL*)	**Rangitautahi** N (± *95% CL*)	**Te Awanui** N (± *95% CL*)	**Total** N (± *95% CL*)
Chick	1204 (*1137–1274*)	782 (*728–839*)	587 (*541–637*)	2573 (*2406–2750*)
Adult	37 (*26–51*)	7 (*3–14*)	3 (*1–9*)	47 (*30–74*)
In flight	4	1	0	5
Carcass	22	11	4	37

Northern Giant Petrel | Pāngurunguru

The numbers of Northern Giant Petrel were only counted in the August 2023 aerial survey images. A total of 2128 individuals, presumably all adults given the time of year, were positively identified across the three islands, almost 90% of which were on Motuhara (Table 3). Around 3% of these birds were in flight at the time; some double-counting is possible but likely to be minimal. No allowance has been made for this. In addition, a further 417 'possible' Northern Giant Petrels were counted, these being similar-size and similar-coloured objects to giant petrels, usually hidden between rocks or under overhangs or too far away or too blurry for distinguishing features to be seen, but which looked as if they could have been giant petrels. Obviously, there is no way of knowing how many birds were completely hidden from view or which blended invisibly into their background.

Table 3. The numbers of Northern Giant Petrel | Pāngurunguru counted from aerial photographs taken of Motuhara, Rangitautahi and Te Awanui on 16 August 2023

	Motuhara N (± *95% CL*)	**Rangitautahi** N (± *95% CL*)	**Te Awanui** N (± *95% CL*)	**Total** N (± *95% CL*)
Sitting	1440 (*1367–1516*)	68 (*53–86*)	140 (*118–165*)	1648 (*1538–1767*)
Standing	414 (*375–456*)	7 (*3–14*)	5 (*2–12*)	426 (*380–482*)
Flying	42 (*30–57*)	7 (*3–14*)	5 (*2–12*)	54 (*35–83*)
Total known	1896 (*1772–2029*)	82 (*59–115*)	150 (*121–189*)	2128 (*1953–2332*)
Uncertain	*303 (270–339)*	*61 (47–78)*	*53 (40–69)*	*417 (357–486)*

Discussion

Northern Royal Albatross | Toroa

The estimated 1744 apparently occupied nests (AON) on Motuhara derived from an analysis of the aerial photos taken on 20 December 2022 is 246 'nests' higher than the 1498 active nests counted on the ground there a week earlier (Bell 2023). There were also 116 nests that had already failed that season, giving a total of 1614 nesting attempts on Motuhara for 2023. This is still 130 nests less than the 22

December estimate, even if the failed nests still had one or both nesting birds present at the time of the aerial survey. There are several possible reasons for this discrepancy. Misidentifying some sitting individuals as incubating when they were just sitting on the ground is one possibility (despite the effort to count only those birds apparently sitting on a nest mound). Not all the birds sitting on a nest need necessarily be incubating an egg. Some could be pre-breeders occupying an empty nest. Moreover, the individuals seen and classified in the close-up images may not be a random subset of the whole population, contrary to the assumption that it was. Because the prolific growth of *Leptinella featherstonii* sheltered many birds, 48.5% of the individuals examined in the close-up images could not be classified. The subset of classified individuals may therefore not be random.

There were no comparable ground counts on Rangitautahi or Te Awanui for December 2022 so the difference between the estimates derived from the aerial photographs and the actual number of active nests on the ground is not known. The subset of closely examined, classified individuals may be more representative of the overall numbers of birds counted, however, given that the percentage of unclassified individuals in these close-up images was much less than on Motuhara: Rangitautahi (21.3%) and Te Awanui (28.7%). Some indication of the likely disparity between aerial survey estimates and ground counts for these two islands can be gauged from near-simultaneous surveys carried out on Rangitautahi and Te Awanui in early December 2017 (Bell *et al*. 2018; Frost 2019). For Rangitautahi, the aerial survey estimate was just 2.4% higher than the ground count: aerial survey, 1317 apparently occupied nests (Frost 2019); ground count, 1286 nests with eggs (a further 105 failed nests were also recorded: Bell *et al*. 2018). The difference on Te Awanui was less, just 0.9% higher: aerial survey, 813 apparently occupied nests (Frost 2019); ground count, 806 nests with eggs (a further 58 failed nests were also noted: Bell *et al*. 2018). Although from a different year with lower plant cover, these comparisons suggest that the difference between the aerial survey estimates of the number of apparently active nests in December 2022 may not be too different from the actual number at that time, were a ground count to be done. Given that 7–8% of nests fail up to mid-incubation, a more realistic estimated of the total number of nesting pairs of toroa for the 2022–23 breeding season would be 4330–4370 pairs, compared with 4149 pairs estimated from the aerial survey counts alone.

For the August 2023 aerial survey of the number of chicks on the three islands, a comparable ground count of the number of chicks is also available for Motuhara (Mike Bell, Toroa Consulting, pers. comm.). The difference between the two sets of numbers is small, +7 chicks (aerial survey estimate, 1204; ground survey, 1211), which suggests that some birds identified as adults in the aerial photographs may really have been chicks close to fledging. These misidentified birds could not be found on a review of the images.

Maximum nesting success for the 2022–23 breeding season can be estimated from these aerial survey results (Table 4). Because there are also ground counts of the number of active and recently failed nests on Motuhara in December 2022 (Bell 2023) and of chicks there in mid-August 2023 (Mike Bell, Toroa Consulting, pers. comm), nesting success from these ground surveys can also be calculated and compared with the less accurate aerial survey results.

Table 4. Estimated nesting success of Northern Royal Albatross | Toroa on Rangitautahi, Te Awanui and Motuhara (Chatham Is archipelago) for the 2022–23 breeding season. These estimates were derived from counts of the number of adults apparently on nests (AON) counted on aerial photographs taken on 20 December 2022 (mid–way during the incubation period) and the number of chicks counted in the same way from photographs taken during an aerial survey done on 16 August 2023, about two weeks before the first chicks were due to fledge. See text for further explanation

Island	Areas[1]	AON (20 Dec 2022)	Chicks (16 Aug 2023)	Max. nesting success (%)
Rangitautahi	**Total**	**1511**	**782**	**51.8**
	A	*216*	*87*	*40.3*
	B	*266*	*153*	*57.5*
	C	*581*	*278*	*47.8*
	D	*129*	*70*	*54.3*
	E	*311*	*192*	*61.7*
	F	*8*	*2*	*25.0*
Te Awanui	**Total**	**898**	**587**	**65.4**
	A	*223*	*153*	*68.6*
	B	*295*	*204*	*69.2*
	C	*105*	*67*	*63.8*
	D	*114*	*76*	*66.7*
	E	*76*	*50*	*65.8*
	F	*28*	*15*	*53.6*
	G	*55*	*21*	*38.2*
	H	*2*	*1*	*50.0*
Motuhara	**Total[2]**	**1614**	**1211**	**75.0**
	Total[3]	**1739**	**1204**	**69.2**
	A	*79*	*40*	*50.6*
	B	*29*	*15*	*51.7*
	C	*349*	*252*	*72.2*
	D	*867*	*654*	*75.4*
	E	*415*	*243*	*58.6*

Notes:
1. These areas are amalgamations of the generally many smaller sections used when counting because they were spread across several aerial images (see Figure 2)
2. Ground counts of birds on eggs and failed nests in December 2022 (1498 active nests, 116 failed: Bell 2023) and chicks in August 2023 (Mike Bell, Toroa Consulting, pers. comm.)
3. Based on apparently occupied nests (AON) as determined from aerial photographs, adjusted for known proportions of birds on nests derived from analyses of close–up images. The zone totals for AON are also based on adjusted counts.

Because 7–8% of nests are known to have failed during the early part of the incubation period, before either the ground counts or the aerial survey were done (Bell *et al*. 2018, Bell 2023), and some chicks, alive in mid–August, might yet have died before fledging (this is considered to be low), overall nesting success for the

2023 breeding season is more likely 59–60% (based on 2580 chicks and an initial 4330–4370 nests). Nesting success based solely on the analyses of the aerial photographs was 64% (Table 5). This is an upper limit given all the uncertainties involved.

Table 5. Numbers of Northern Royal Albatross | Toroa chicks estimated to have fledged from the three Chatham Island colonies and overall, in four recent breeding seasons along with estimated nesting success on each island and overall, for the 2017, 2018 and 2023 breeding seasons. There was no survey of the number of nesting pairs at the start of the 2020 breeding season and therefore no estimate of breeding success

	Number of chicks counted near fledging (*Nesting success %)*			
Season	**Motuhara**	**Rangitautahi**	**Te Awanui**	**Total**
2017	1003 (*58.1*)	574 (*30.5*)	539 (*38.9*)	2116 (*42.4*)
2018	1194 (*66.7*)	550 (*41.8*)	405 (*49.8*)	2149 (*54.8*)
– – –				
2020[1]	1203	483	357	2043
– – –				
2023	1204 (*69.2*)	782 (*51.8*)	587 (*65.4*)	2573 (*64.0*)[2]

Note: [1] The figures for 2020 have been adjusted to account for the estimated 12% of chicks that had probably fledged by mid –September, when the aerial survey took place

[2] To be consistent with previous years, these estimates are based solely on the estimates from the aerial survey (*i.e.,* 4149 apparent nesting pairs in 2022–23, excluding Bell's counts of active and recently failed nests for Motuhara up to December 2022)

Northern Giant Petrel | Pāngurunguru

Numbers of Northern Giant Petrel | Pāngurunguru counted on the ground from aerial photographs of Motuhara taken during the 16 August 2023 survey are remarkably similar to ground counts of birds on nests carried out two days earlier, on 14 August 2023 (Table 6). That ground count itself is less than the 1912 active nests counted on 11 August. During the intervening period, 11–14 August, 136 nest failed (7% of the initial total), while 85 nests contained newly laid eggs (Mike Bell, Turoa Consulting, pers. comm.). Despite the closeness of these counts, therefore, they are considered to be coincidental.

The large number of 'uncertain' birds recorded during the aerial survey assessment shows the difficulty of clearly distinguishing the Northern Giant Petrels from their backgrounds and similarly coloured and sized rocks. This is further complicated by the preference shown by the petrels for nesting and roosting in rocky areas, such as the north-eastern promontory and extreme western end of Motuhara (area C and western end of area A in Figure 2c) and areas C and E on Te Awanui (Figure 2b).

Table 6. Counts from aerial photographs of Northern Giant Petrel on the ground on Motuhara on 16 August 2023, compared with counts of the number of active nests two days earlier, both overall and in the three colonies on the island (in italics)

Source	Count	*Camp colony*	*Bowling green colony*	*Main colony*	Motuhara Total
This study	On ground	*76*	*32*	*1767*	1875
Bell (pers. comm.)[1]	Nests	*71*	*25*	*1765*	1861

Note: [1] These exclude the numbers of nests that failed between 11 and 14 August—136 overall—but include 85 nests with newly laid eggs in the same period (Mike Bell, Turoa Consulting, pers. comm.)

The August 2023 ground and aerial surveys were carried out right at the start of the 2023–24 breeding season. A few eggs were still being laid at the time. Table 7 shows the numbers of presumed adults and subadults at broadly comparable times in previous years just prior to the start of the breeding season or just after.

Table 7. Counts of Northern Giant Petrel | Pāngurunguru from aerial photographs in recent years around the start of the breeding season on Rangitautahi, Te Awanui and Motuhara (Frost 2017, 2019, and unpublished). A few pairs nest on other offshore islands in the Chathams archipelago, but these have not been surveyed from the air

Breeding season	**Survey date**	**Rangitautahi**	**Te Awanui**	**Motuhara**	**Total**
2018	27/07/2017	59	92	1738	1889
2018	21/10/2017	56	206	No count	No estimate
2019	23/08/2018	84	241	2506	2831
2021	14/09/2020	125	88	1586	1799
2024	16/08/2023	82	150	1896	2128

Despite its limitations, aerial surveys remain the most cost-effective means of monitoring toroa and other large albatrosses nesting on hard-to-reach offshore islands. Even so, the difficulties of arranging surveys so that they coincide with the start of incubation (although egg-laying can be spread out over 3–4 weeks), and in determining which sitting birds are actually on an egg, and which are simply loafing, add considerable uncertainty to any estimates. Estimating failure rates prior to ground or aerial counts delivers further uncertainty as to the true numbers of pairs breeding in any season.

Other sources of uncertainty come from the survey methods themselves. Some birds may be effectively invisible (as on Motuhara in December 2022 where many birds were barely visible among the prolific growth of *Leptinella featherstonii*), and so may be missed entirely when counting. If the birds sampled in the close-up images are not a random subset of the whole, then extrapolating the calculated proportions of birds apparently on nests—derived from close-up images—to the total number of birds counted will be flawed. Contemporaneous ground and aerial surveys, as in this study, can point to some errors, but their magnitude and how variable they are from one season (or island) to the next is currently not known. We also do not know the uncertainties around ground counts themselves. Continued monitoring using both approaches, where possible, is needed to gradually narrow down and compare the sources and magnitudes of the errors in each.

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Appendix 1

Table A1: Details of the 20 December 2022 aerial survey flight over the three islands on which Northern Royal Albatross | Toroa nest. No GPS data was available to provide details of airspeed, altitude or the distance offshore of the aircraft, but the resulting images did not appear exceptional and the mean time to fly the circuits around the three islands suggest that airspeed was similar. The number of circuits were estimated by deducing the aircraft's flight path from the image sequences

		Number of circuits	Total time (min)	Circuit time Mean ± SD (min)
Motuhara		10	19.8	1.71 ± 0.30
Rangitautahi	complete	6	8.1	1.35 ± 0.12
	partial	2	1.1	–
Te Awanui	complete	3	3.6	1.21 ± 0.01
	partial	2	1.1	–

Table A2: Details of the 16 August 2023 aerial survey flight over the three islands on which Northern Royal Albatross | Toroa nest

	Number of circuits	Survey time (min)	Circuit time Mean ± SD (min)	Mean airspeed (kph)	GPS altitude Mean ± SD (m)	Distance offshore Mean ± SD (m)
Motuhara	10	16.8	1.51 ± 0.30	139 ± 10.8	192 ± 15	340 ± 148
Rangitautahi	6	10.6	1.75 ± 0.23	149 ± 8.9	199 ± 35	570 ± 214
Te Awanui	7	8.1	1.13 ± 0.23	139 ± 10.8	180 ± 31	379 ± 186

Table A3. Details of the cameras, lenses and numbers of images taken of the Northern Royal Albatross | Toroa colonies on the Chatham Is at different focal lengths. Those under 200 mm were used to demarcate large contiguous areas in which all adults and chicks were counted. Images taken at focal lengths above 200 mm were used to classify and tally individual behaviours

		Camera, lens and focal length (mm)					
		Canon EOS 77D EF-S18-135mm f/3.5-5.6 (24 MP)			Canon EOS 7D EF 75-300mm f/4-5.6 (18 MP)		
Survey date	Island	< 50	50 < 100	100 < 135	75 < 150	150 < 200	200 < 300
20-Dec-22	Motuhara		470	109	73	214	477
	Rangitautahi	18	153	4	104	38	238
	Te Awanui	21	68	3	25	2	92
16-Aug-23	Motuhara	2	14	634	607	69	442
	Rangitautahi	1		290	175	21	152
	Te Awanui		19	300	112		181