Aerial survey of Northern Royal Albatross | Toroa (*Diomedea sanfordi)* populations on the Chatham Islands, December 2023

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Front cover
Aerial views of part of the Northern Royal Albatross colony on the eastern end of Motuhara taken on 20 December 2022 (top) and 9 December 2023 (bottom), illustrating the difference in vegetation cover, which afforded nesting birds and others greater protection in 2022. The presence of many more non-nesting birds during the 2022 survey than in 2023 is also notable, although the number of birds on nests in the two years was similar (photo credit: Gemma Greene, both images)

Summary

1. A total of 4322 occupied nests of Northern Royal Albatross | Toroa, *Diomedea sanfordi*, was counted on aerial photographs taken on 9 December 2023 during an aerial survey of three offshore islands in the Chatham Islands group: Motuhara (1853 occupied nests); Rangitautahi (1501); and Te Awanui (968). The birds were at the early incubation stage of their breeding cycle. These islands support almost the entire global breeding population of the species.

2. The number of birds assumed to be occupying nests on Motuhara (1853), derived from the analysis of the aerial photographs, was 300 more than those counted on the ground 6 weeks later on 20 January 2024 (a total of 1472 active or recently failed nests). Some birds could have been sitting on eggs at the time of the aerial survey but failed before the ground count was made 6 weeks later and were not identified then as such. The possibility of a small, systematic, positive bias in counting birds as occupying a nest when they were not, must also be considered.

3. The estimate of 4322 occupied toroa nests overall is slightly above the average reported for the corresponding stage during the 2017–2023 breeding seasons (4021 ± 117 nests), but still around 1224 fewer than that reported for 2007–2010 (5546 ± 159 nests). The slight apparent increase may be due to the higher breeding success reported in recent years (53.7 ± 8.9%) relative to that recorded in 2007–2010 (39.3 ± 6.3%). This may be associated with increases in vegetation cover, at least on Motuhara and Te Awanui.

4. Four recommendations are made.

    1.1 Regular monitoring of the Northern Royal Albatross population breeding on the Chatham Islands should continue, ideally involving twice yearly aerial surveys, once during the early incubation period, then again immediately prior to the chicks fledging, to enable calculation of breeding success.

    1.2 Close liaison between those conducting periodic ground-based studies on Motuhara and those planning the aerial surveys is needed to ensure, as close as possible, synchrony between the two, so that the population assessments are comparable, and any sources of potential bias identified.

    1.3 Under present circumstances, where it is nearly impossible for the aerial survey data alone to produce absolutely accurate counts of the number of breeding pairs of Northern Royal Albatrosses (*i.e.,* excluding birds sitting on empty nests), it may be more practical to continue reporting the number of occupied nests (which may include a proportion of birds sitting on empty nests) to maintain comparability with earlier aerial surveys, also essentially just of birds occupying nests. Nevertheless, work on trying to identify and reduce sources of bias, inherent in assessing aerial photographs, should continue.

    1.4 The permanent sample plots set up on Motuhara to monitor population trends of both Northern Royal Albatross and Northern Buller's Mollymawk populations on Motuhara should continue to be maintained and surveyed, along with finding ways to reduce errors in interpretation.

1. Introduction

Almost the entire breeding population of Northern Royal Albatross | Toroa, *Diomedea sanfordi*, currently estimated to be around 6300 pairs, nest on three outlying islands in the Chatham archipelago: Rangitautahi (Big Sister) and Te Awanui (Middle Sister) in the Rangitatahi/The Sisters group, and Motuhara (Forty-Fours) (Frost *et al*. 2023). An additional ~62 pairs breed at Pukekura/Taiaroa Head, Otago Peninsula (Frost 2023). The number nesting in any one year varies. Because the species is a biennial breeder, birds successfully rearing a chick in one year only return to breed again two years later at the earliest, whereas around 73 ± 18% of pairs that fail during incubation or early in nestling stage in one year return to nest again the next (unpublished data from Pukekura/Taiaroa Head, 2017–2022). Annual counts of nesting birds therefore encompass more than half the total breeding population, depending on nesting success the previous season and how many of the failed breeders return to re-nest the following year.

There is much uncertainty in the estimates of the number of pairs actively nesting in any one year. Counts of birds on the ground during the incubation and brood-guard stages of chick rearing can include various classes of non-breeding individuals: pre-breeders visiting a colony one or more years before attempting to nest for the first time; sub-adult birds or mature individuals looking for mates; and partners of birds at active nests. If not distinguished clearly from incubating and brooding birds, they risk being counted as part of the current nesting population, thereby overestimating it. Conversely, individuals that continue to occupy a nest for a while after its failure can be misinterpreted as non-breeders, thereby underestimating the breeding population.

The numbers of toroa nesting annually on Motuhara and Rangitatahi have been assessed intermittently through a combination of ground counts of nesting birds—normally done during the early incubation period (November–December)—and counts of birds visible on aerial photographs taken around the same time, sometimes later (Robertson 1998; Baker *et al*. 2017). This report covers the most recent aerial survey of Northern Royal Albatross nesting on these islands, conducted on 9 December 2023 during the early stage of incubation.

These islands are also key breeding sites for Northern Buller's Mollymawk (also called Toroa), *Thalassarche bulleri platei*, and Northern Giant Petrels | Pāngurunguru, *Macronectes halli*. Almost the whole global population of Northern Buller's Mollymawk breeds on Rangitautahi, Te Awanui and Motuhara (estimated population in December 2017 was 16,138–17,969 nesting pairs, depending on the extent of adjustment made for the presence of loafing birds). Ground counts of Northern Giant Petrel chicks made on Motuhara in December 2016 (Bell *et al*. 2017) and Rangitatahi in December 2017 (Bell *et al*. 2018), extrapolated to the number of breeding pairs, after accounting for the number of failed nests present, gave an estimated 2133 breeding pairs on the Chatham Is, around 18% of the global total. Attempts were made to census these species during the present survey, but were not successful.

2. Methods

2.1 Study area

Rangitatahi (The Sisters), centred at 43.5642°S, 176.8075°W, lie 20 km due north of Rēkohu (Chatham Main Island). They comprises three islands: Rangitautahi (Big Sister, 7.3 ha), Te Awanui (Middle Sister, 4.8 ha) and the Reef (Little Sister), a low-lying c. 5-ha rock platform. Northern Royal Albatross, Northern Buller's Mollymawk and Northern Giant Petrel nest only on Rangitautahi and Te Awanui. The islands are volcanic in origin, comprising massive limburgitic basalt with associated deposits of breccia, scoria, and tuff (Campbell *et al*. 1988). The soils are generally shallow and support only sparse vegetation except in some basins on the plateaus where the Chatham Island button daisy *Leptinella featherstonii* and the groundsel, *Senecio radiolatus,* are well established.

Motuhara, also known as The Forty-Fours, is located at 43.9622°S, 175.8347°W, 42 km east of Rēkohu. It consists of an 11.5-ha, 60-m high main island and five small rocky stacks. Unlike volcanic Rangitatahi, Motuhara is the easternmost outcrop of Mesozoic basement rocks in New Zealand, primarily composed of quartzofeldspathic sandstones and feldsarenites (Andrews et al. 1978). The island's shallow soils are found mainly in the central plateau's middle and southeast areas, supporting open, rock-studded herb-fields and low shrubland dominated by the Chatham Island button daisy.

2.2 Aerial survey

An aerial photographic survey of the islands was conducted from an Air Chathams Cessna 206 on 9 December 2023 between 11h07 and ~12h37. Two Department of Conservation officers photographed the islands. One used a Canon 7D camera (EF75-300mm f/4-5.6 lens) to take a mix of 1939 mid-scale and close-up images, 35% at 240<300 mm focal length and the balance at less than 240 mm focal length. The second photographer used a Canon 77D (EF-S18-135mm f/3.5-5.6 lens) to take 319 wide-angle images of islands, 80% of which were taken at 135 mm focal length, with the rest being taken at 18–78 mm focal length. With an average distance to the edges of the islands of 324 ± 160 m (± 1 SD; median 306 m, N = 318), even those images taken at 135 mm focal length were often too small to be wholly useful. Almost all of the images analysed were those taken with the Canon 7D.

Details of the survey portions of the flight are given in Table 1. The total time spent flying around Rangitatahi (Rangitautahi and Te Awanui combined) and Motuhara was ~17 minutes each. Whereas the survey flight around Motuhara was relatively straightforward, involving 10 circuits flown at a range of distances offshore, those around Rangitatahi were more complicated, mostly involving joint circuits around both Rangitautahi and Te Awanui, with short sequences of photographs of the islands being taken during each. Just three passes were made between the two islands, only one of which involved a few photographs being taken of the eastern side of Rangitautahi (Figure 1).

Table 1. Flight details for the aerial photographic survey of Rangitatahi and Motuhara, 9 December 2023

	Survey time total (min)	Altitude Mean ± SD (m)	Airspeed Mean ± SD (kt)	Airspeed (kph)	Distance (km)
Rangitatahi	16.42	240 ± 41	80.9 ± 9.2	149.6	42.0
Motuhara	17.08	265 ± 48	81.3 ± 7.1	151.4	41.4

	No. circuits/ sequences	Photo time /island (min)	No. photos	Distance offshore Mean ± SD [N] (m)	Median distance offshore (m)
Rangitautahi	8	4.23	443	354 ± 186 [63]	308
Te Awanui	7	5.88	352	364 ± 143 [54]	347
Motuhara	10	15.00	1463	304 ± 153 [201]	293

The flight path was recorded on a Garmin 64s GPS, with position and altitude logged at 1-sec intervals (Figure 1). From this, airspeed and direction were calculated. Although the camera times were not synchronised with the GPS, the approximate position of the first image taken with the Canon 77D camera was determined by matching the image's viewpoint with its apparent position along the initial track around Rangitautahi. From difference between the image time and that GPS point, the offset between the two was calculated (+45.8 min). This offset was then applied to the times recorded on all images taken with that camera, which were then geo-tagged using Garmin BaseCamp (v.4.7.4) to establish approximately from where each Canon 77D image was taken. The accuracy of this was checked visually by comparing the viewpoints of several images and their locations. The distances from these images to their nearest point on the relevant island were then calculated using the vector analysis tool *Shortest line between features* in the QGIS Processing Toolbox to estimate the distance offshore from where the images were taken (Table 1).

2.3 Image selection and processing

Mid-scale images of each island (90% at 125 < 200 mm focal length: Tables A1–A3) were selected to fully cover the plateaus where Northern Royal Albatrosses nested. Each image overlapped enough with the others covering adjoining areas for a series of uniquely differentiated, contiguous zones to be delineated without overlaps or gaps. Prominent rocks, fissures, bare patches and vegetation clumps, identifiable on two or more adjacent images, were used as boundary markers. Each zone was labelled (Appendix Figure A1). Where possible, the boundaries between these zones followed those used in the December 2020 survey (Frost 2021). The main difficulty was in marking adjacent areas on the plateau crests, where each could only be seen fully from opposite viewpoints. Although extra care was taken when marking these boundary lines, some uncertainty still remained, estimated to be less than 1% of the total count. Where feasible, additional sets of images were marked for duplicate counts.

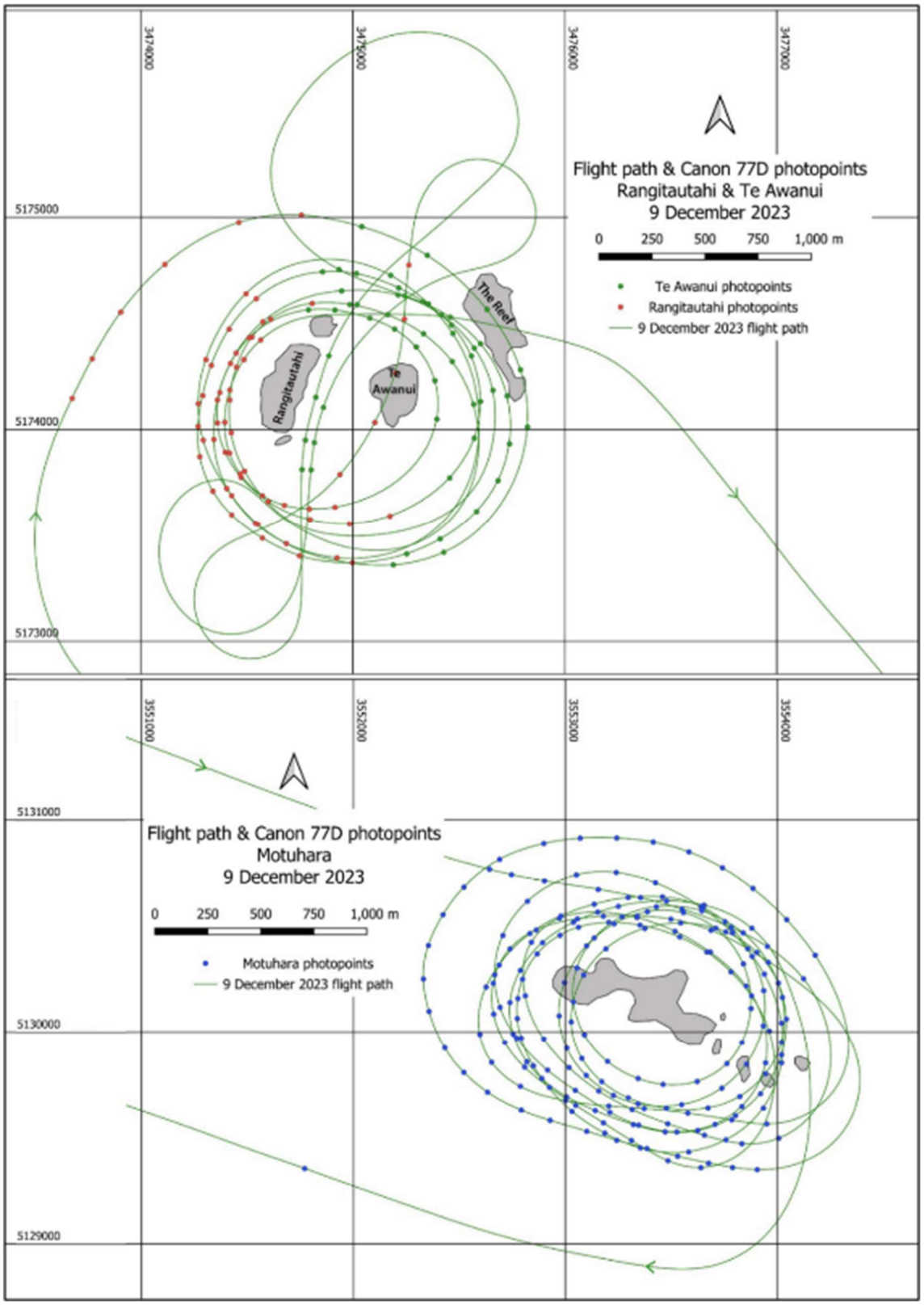

Figure 1. Flight paths and photopoints for the Canon 77D images during the 9 December 2023 aerial survey of Northern Royal Albatross | Toroa colonies on Rangitatahi (The Sisters) and Motuhara (The Forty-Fours)

Images were processed first in Photoshop Elements 2024™, to lighten shadows, darken highlights, enhance midtone contrasts, and adjust hue and saturation, as necessary, all aimed at heightening the visibility of the birds and other relevant features (*e.g.*, nests). Most images were further enhanced with either Photoshop Element's Sharpen tool or the Denoise and Sharpen modules in Topaz Photo AI™. When using these tools, the images were checked to ensure that no artifacts were introduced, or any important small features omitted or distorted.

In addition to marking out each of the survey zones on one or more images, 15 close-up images were chosen from each island (80% at 210 < 300 mm focal length: Appendix Tables A4–A6). As large a central section as possible was marked out on each for analysis. Most of these images did not overlap but, in a few cases where they did, the area in common was identified, marked out, and excluded from further consideration in one of the pair. Choice of these images was roughly stratified to encompass the range of densities of nesting birds on each island and, within that, selected solely on how well the birds in them could be seen clearly.

2.4 Counting

All Northern Royal Albatross visible on the ground in each zone and in the close-up images, even if only partially seen, were counted and their status recorded using DotDotGoose (v.1.7.0, Ersts 2024). Individuals were classed as follows:

1. *Adult sitting on nest*
2. *Partner accompanying adult on nest*
3. *Adult standing on an empty nest*
4. *Loafer or transient bird*
5. *Status unclear*
6. *Carcass*

The numbers of birds in each of these classes counted initially in each zone were treated as provisional. They were then corrected later using the more detailed classification of birds seen in the close-up images.

In addition, within the marked zones (but not the close-up areas), the numbers of Northern Giant Petrel and Northern Buller's Mollymawk were also counted, but no attempt was made to categorise their age or status (*e.g.*, nesting, resting) as these were impossible to determine with any confidence because of the birds' small size and poor resolution.

2.5 Population assessment

Because each count zone was unique and discrete, data analysis was relatively simple. The number of apparently occupied nests (AON) was simply the sum of all birds seen sitting on nests. This does not imply the presence of an egg, although that is probable in most cases. It is impossible to tell from an analysis of the aerial photographs alone how many actual breeding pairs (*i.e.,* incubating birds) there were. Where a bird was seen standing on or next to an obviously empty nest this is referred to as an adult on an empty nest (AEN) (Appendix Tables A1–A3). The occupant could be a non-breeder or a recently failed breeder. Given the timing of the survey, it is unlikely that this would have been a bird yet to lay.

In the analyses of close-up images, individuals were classified into one of four behavioural states—bird on nest (AON), partner to a bird on nest, bird on an empty nest (AEN), and loafers or transients—as well as those individuals that could still not be seen clearly enough to be classified (Appendix Tables A4–A6). The proportions of individuals in each group were then calculated for each island, these being based only on those birds that were seen clearly enough in these images to be classified (*i.e.,* they exclude unclassified individuals).

These proportions were then used to allocate the total number of individuals counted on each island to one of these four classes. This assumes that the classified birds are a more-or-less random sample of all birds present, so that the proportions for each group can be applied to the total count of birds made during the broadscale assessment.

In addition to these whole-colony counts, the numbers of Northern Royal Albatross sitting on nests in five 20 x 20 m permanently marked sample plots on Motuhara were also counted (NRA 1–5; Figure 2). Mike Bell established these PSPs in January 2021, marking them with by bright orange-painted rocks at each corner. Because these plots were contained within larger images, they were extracted digitally, and the boundaries determined by drawing straight lines on the images between the corner markers. When selecting which images to analyse, preference was given, where possible, to those taken from more vertical angles, relative to the image, to give as perpendicular view of the area as possible.

Ten 10 x 10 m permanent sample plots had previously been established on the western plateau of Motuhara in areas with high densities of nesting Northern Buller's Mollymawk (Figure 2). Five of these (NBM PS1–PS5) were set up in 2007–2008 by Paul Scofield and Mike Fraser (Fraser *et al*. 2010), and a further five (NBM MB6–MB10) were added in 2021 by Mike Bell (Bell 2022). Images in which these plots were visible were processed in the same way as for the NRA PSPs.

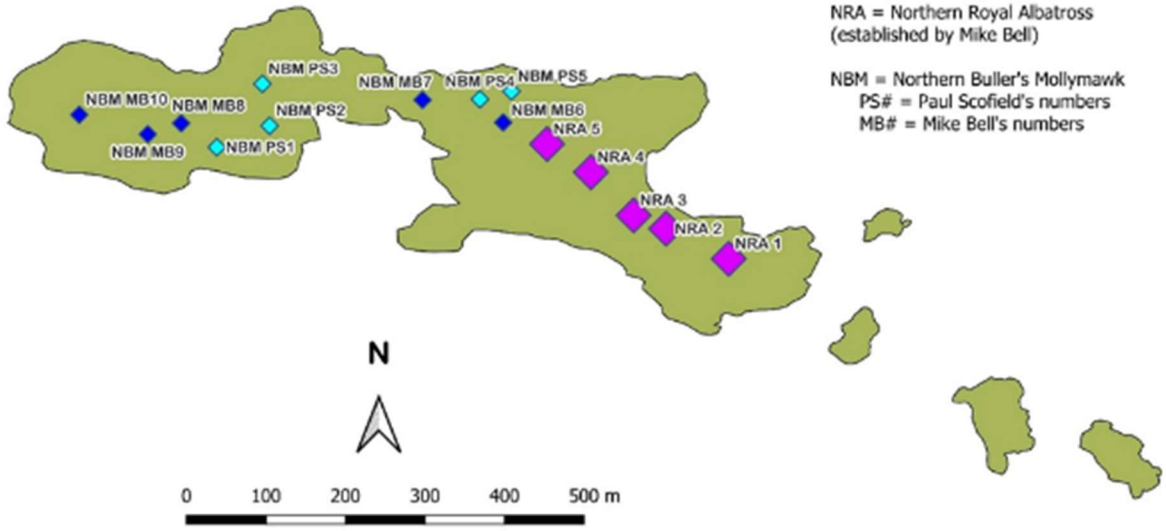

Figure 2. Locations of the five 20 x 20 m Northern Royal Albatross (NRA 1–5) and ten 10 x 10 m Northern Buller's Mollymawk (NBM 1–10) permanent sample plots on Motuhara.

To express the uncertainty in the counts for each island, 95 % confidence limits (CL) were calculated for the totals in each category using the *poisson.exact* function in the R package *exactci* (Fay 2017). These correspond to the exact central confidence interval of Garwood (1936), widely used for calculating this parameter in a one-sample case, here being the number of counts in each category. This assumes the counts conform to a Poisson distribution, in which the mean and variance of a sample are the same (Baker et al. 2013).

Results

Northern Royal Albatross

A total of 4973 birds were counted on the ground across all three islands (Motuhara, 2178; Rangitautahi, 1968; Te Awanui 1097: Table 2). Of these, 3875 were occupying nests (AON), most presumably incubating eggs (Motuhara, 1616; Rangitautahi, 1412; and Te Awanui, 847: Table 2). Of the remainder, 400 (8%) were either accompanying a sitting bird, standing on an apparently empty nest (AEN), loafing or in transit through the colonies, while 698 (14.0%) were not seen clearly enough to be reliably categorised (*i.e.,* 'status unclear'). At least 23 reasonably intact (*i.e.,* not dismembered) carcasses were counted, around 0.5% of the number of birds present on the ground overall. The counts of birds in the various marked areas in each analysed image on each island are given in Tables A1–A3.

The analyses of close-up images overall encompassed 2823 individuals on the ground: 1161 on Motuhara, 987 on Rangitautahi and 675 on Te Awanui. Of these, 93%, 96% and 90%, respectively, were classifiable. The overall proportion of birds apparently on nests averaged 0.870, ranging from 0.851 on Motuhara to 0.884 on Rangitautahi (Tables A4–A6). The rest were either partners accompanying birds on a nest, birds at an empty nest, or others not obviously associated with a nest. The status of 187 individuals (6.6% of the total) could still not be determined.

When the initially counted totals are adjusted, using the proportions of birds in each behaviour class, as seen in the close-up images, to account for those that could not be classified or were misclassified initially, 4322 birds overall (86.9%) were judged to be occupying nests (Motuhara, 1853; Rangitautahi, 1501; Te Awanui, 968: Table 2). The remaining 652 individuals across the three islands were either accompanying a bird sitting on a nest (98, 2.0% overall), standing or sitting on an apparently empty nest (131, 2.6%) or simply loafing or in transit through a colony (423, 8.5%).

The number of birds present in the five 20 x 20 m permanent sample plots (PSP) are given in Table 3. Several images of each PSP were examined, some clearer and taken from more suitable angles and distances than others. Overall, there was reasonable consistency in the counts of total numbers of birds obviously occupying nests within each PSP, ranging from an average (± 1 SD) of 33 ± 0.5 birds in NRA1 (N = 4 images), to 37 ± 0.5 birds in NRA2 (N = 3 images). To these can be added the number of birds obviously not occupying a nest (*i.e.,* partners to sitting birds; loafers or transients), which varied more widely, both among the PSPs and between successive images, averaging from 3 ± 0.5 birds (NRA1) to 12 ± 5.8 (NRA4).

Table 2. Summary of the aerial photographic survey results of Northern Royal Albatross | Toroa breeding on the Chatham Islands, 9 December 2023

	Motuhara			**Rangitautahi**			**Te Awanui**		
Status	**Initial count**	***Proportion estimated from close-up photos*[1]**	**Corrected number**	**Initial count**	***Proportion estimated from close-up photos*[1]**	**Corrected number**	**Initial count**	***Proportion estimated from close-up photos*[1]**	**Corrected number**
Bird on nest (AON)	1616 *1538–1697*	*0.851*	1853 *1770–1939*	1412 *1339–1488*	*0.884*	1501 1426–1579	847 *791–906*	*0.882*	968 *907–1030*
Partner of a bird on nest	25 *16–37*	*0.018*	39 *28–53*	32 *22–45*	*0.020*	34 23–47	36 *25–50*	*0.023*	25 *16–37*
Apparently on empty nest (AEN)	49 *36–65*	*0.055*	120 *99–143*	3 *1–9*	*0.000*	0 0–4	3 *1–9*	*0.010*	11 *5–19*
Loafing or transient	56 *42–73*	*0.077*	168 *143–195*	150 *127–176*	*0.096*	163 139–190	46 *34–61*	*0.084*	92 *74–113*
Status unclear	432 *392–475*			101 *82–123*			165 *141–192*		
Carcass	10 *5–18*			6 *2–13*			7 *3–14*		
Total on ground	2178 *2087–2271*		2180[2] *2089–2273*	1698 *1618–1781*		1698 1618–1781	1097 *1033–1164*		1096[2] *1032–1162*

[1] See text for details

[2] The difference between these corrected totals and the number of birds counted initially are due to rounding errors

Table 3. Counts from a selection of images of Northern Royal Albatross | Toroa present on five 20 x 20 m permanently marked sample plots on Motuhara, 9 December 2023. See text for further details.

									Ground survey 20 Jan 2024	
Image No	**PSP No.**	**Total birds on ground**	**Bird on nest (AON)**	**Bird not on nest[1]**	**Status unclear**	**Empty unoccupied nests**	**Possible total active nests[2]**	**Potential total nests[3]**	**Total active nests[4]**	**Total nests for season[5]**
IMG0883	NRA 1	39	34	3	2	2	36	38	35	36
0I0A0950		38	33	3	2	1	35	36		
0I0A1122		38	33	2	3	2	36	38		
0I0A1859		38	33	3	2	2	35	37		
0I0A0975	NRA 2	41	37	2	2	1	39	40	40	41
0I0A1214		42	38	2	2	1	40	41		
0I0A1862		42	37	3	2	1	39	40		
0I0A0864	NRA 3	40	35	4	1	0	36	36	34	35
0I0A0975		41	35	6	0	0	35	35		
0I0A1151		41	35	6	0	0	35	35		
0I0A0943	NRA 4	54	30	12	12	1	39	40	31	33
0I0A1513		53	35	3	15	1	49	50		
0I0A1632		56	34	16	6	2	38	40		
0I0A1701		54	35	18	1	2	36	38		
0I0A1712		54	37	12	5	1	41	42		
0I0A0821	NRA 5	42	34	5	3	1	37	38	35	38
0I0A1090		46	36	6	4	1	39	40		
0I0A1895		44	37	5	2	0	39	39		

Notes

1. Includes partners of sitting birds and others loitering or transiting through the colony. It excludes those whose status is unclear.
2. The sum of birds on nests and the proportional allocation of birds on nests to all clearly classified birds, applied to those whose status is unclear.
3. This includes unoccupied empty nests assumed to have been used earlier in the breeding season.
4. Those nests containing an egg or a chick on 20 January 2024 (Bell 2024).
5. All nests counted during the ground survey, including those recorded as having failed earlier in the season.

In all cases, there were also several birds whose status could not be determined directly. If these are factored in by allocating them proportionally to the behaviour classes seen among those birds that could be classified clearly (*i.e.,* excluding those whose status is unclear), then the estimated number of occupied nests ranged from 35 ± 0.6 nests (NRA3) to 41 ± 5.0 nests (NRA4).

For NRA4, the high variation among the five examined images reflects the difficulties of getting clear views of this sample plot. Being positioned in the centre of the plateau, furthest from the circling aerial survey aircraft, most views of it were at a low oblique angle, resulting in horizontal compression of the field of view. This was further compounded by the relatively dense vegetation, and presence of many non-nesting birds.

Except for NRA4 and, to a lesser extent, NRA5, the number of birds occupying nests were almost the same as those counted 6 weeks later on the ground either still incubating an egg or brooding a recently hatched chick. The closeness of the aerial and ground survey results is still apparent when the number of presumed empty, recently-used nests are added to the aerial survey results and compared with the total nests counted in the January 2024 ground survey (including failed nests). Only the NRA4 aerial survey results are anomalous, with 11 more birds recorded as occupying nests in early December compared to the overall number of nests recorded 6 weeks later in mid-late January.

Northern Buller's Mollymawk

No attempt was made to count all the Northern Buller's Mollymawk present on the three islands. The birds' nesting areas were often among fractured or fissured rocks, or in shadowed recesses on the cliffs, where their colours blended in well with their backgrounds. The images also did not cover all of each island, despite the photographers' best efforts, while the limited resolution of the images in many cases, did not allow sufficient detail to be seen to be able to distinguish among the different classes of birds present. Nevertheless, a total of 8732 birds, intermingled with or immediately adjacent to the Northern Royal Albatross colonies on these islands, were noted when seen (Rangitautahi – 893; Te Awanui – 460; Motuhara – 7379), although not all of these were nesting.

To offset the difficulty of being able to survey the whole Northern Buller's Mollymawk population on these islands, attention focused on counting the number of birds present in the ten 10 x 10 m permanently marked sample plots, noting how many birds seemed to be occupying nests. The results are shown in Table 4. It was difficult to find suitable images showing the PSPs clearly, so replication was possible only with four of the PSPs (PS1–3 and MB6).

The most notable feature is the difference between duplicate counts made from separate images of the same site (PS1–3 and MB6; only one suitable image was found for each of the other sites). The number of birds judged to be sitting on nests sometimes differed substantially: +41% (PS2), +26% (PS1) and +20% (MB6). In each case the difference is expressed as a percentage of the lower count.

Table 4. Counts from a selection of images of Northern Buller's Mollymawk present on ten 10 x 10 m permanently marked sample plots on Motuhara, 9 December 2023. See text for further details and Table 3 footnotes for explanations of the footnotes here.

Image No	PSP No.	Total birds on ground	Bird on nest (AON)	Bird not on nest[1]	Status unclear	Empty unoccupied nests	Possible total active nests[2]	Potential total nests[3]	Ground survey 18 Jan 2023	
									Total active nests[4]	Total nests for season[5]
0I0A1029	PS1	47	35	6	6	1	40	41	31	54
0I0A1172		51	44	6	1	5	45	50		
0I0A0917	PS2	78	37	14	27	2	57	59	32	60
0I0A1566		68	52	7	9	6	60	66		
0I0A0805	PS3	48	32	2	14	6	45	51	22	50
0I0A0918		51	33	2	16	5	48	53		
0I0A2009	PS4	75	54	6	15	5	68	73	44	73
0I0A2009	PS5	51	36	3	12	16	47	63	34	77
0I0A2009	MB6	60	35	16	9	6	41	47	32	71
0I0A1787		58	42	11	5	7	46	53		
0I0A1578	MB7	46	22	18	6	3	25	28	24	57
0I0A1029	MB8	59	35	8	16	7	48	55	34	62
0I0A1029	MB9	54	36	3	15	6	50	56	31	56
0I0A0904	MB10	50	29	15	6	5	33	38	32	51

These differences reflect the difficulty sometimes of deciding whether a bird was occupying a nest or simply sitting around. Although many Northern Buller's Mollymawks build elevated nests, not all do and this can be a source of error if birds sitting close to the ground are judged not to be on a nest when seen from one angle, but the opposite when seen from another. Difficulties were also experienced with deciding consistently if a bird was in or outside the perimeter of a plot when viewed from different angles. In effect, these are all errors in the image analyst's decision-making.

Smaller differences were recorded in the total number of birds present at each of four replicated sites (+3% to +15% across the sites, with the lower count being the denominator), again perhaps reflecting the difficulty of deciding consistently whether a bird was inside or outside the plot boundary. The average interval of 128 ± 40 sec between the successive images could also have allowed time for some non-breeding birds to come and go.

Comparing the '*possible total active nests*' (Table 4, which includes the proportional allocations of birds whose status was unclear) in December 2023, with the number incubating an egg or brooding a chick in the same plots 6 weeks later in January 2024 (Bell 2024), unsurprisingly showed the December counts to be 28 ± 15% higher, on average (for the replicated counts, the mean difference was used). This no doubt reflects nest failures occurring between the two dates.

A better comparison, perhaps, would be to compare '*potential total nests*' (Table 4) in December 2023, which include the count of then-empty, unoccupied nests, with the '*total nests for season'* (Table 4), which incorporates the number of failed nests counted in January (Bell 2024). These results are less consistent, however, with most aerial survey counts producing lower numbers in December than those counted on the ground 6 weeks later in January 2024 (up to 29% fewer nests in MB7: Table 4). This may be due to failed nests being more accurately identified on the ground, some of which were probably undetected in assessment of the December images. Overall, the aerial assessment of the numbers of Northern Buller's Mollymawk occupying nests in the permanent sample plots in this survey are considered unreliable.

Northern Giant Petrel

Northern Giant Petrel were noted whenever they were seen in images being analysed for Northern Royal Albatross. A total of 1152 birds were counted across all three islands (Rangitautahi – 140; Te Awanui – 109; Motuhara – 903). These numbers are almost certainly substantial undercounts. With egg laying occurring in August-September, any nests would have had more-or-less half-grown chicks in them (a few such chicks were seen). But both the colour of the chicks and adults (grey and deep brown, respectively), together with the birds' choice of nest site, often in relatively dense vegetation or between rocks, meant that individuals blended well with their backgrounds, making them difficult to see clearly, if at all.

Discussion

A total of 4322 occupied Northern Royal Albatross nests were recorded in 2024 (95% confidence limits 4103–4548).[1] What proportion of these overall involved a bird incubating an egg as opposed to sitting on an empty nest, for whatever reason, is not known. The only near comparison is with a ground count of nesting toroa on Motuhara, conducted on 20 January 2024, 6 weeks later, when 1472 active nests, containing an egg or chick, and 81 failed nests were recorded (Bell 2024). This is 300 nests less than the 1853 apparently occupied nests recorded from the analysis of aerial photographs reported here. This might suggest that as many as 16% of the nests counted in early December involved birds sitting on empty nests, but the biases and errors in both the aerial survey analysis and the ground counts are unknown.

This overestimate is similar to that recorded in the December 2022 survey of Motuhara, also ~16% (Frost 2023). The similarity may just be coincidental. Some birds occupy empty nests for several reasons and durations: *e.g.*, still to lay; recent failure; waiting unwittingly for a deceased or departed partner; pre-breeder (a so-caller 'tryer') occupying a site early. We know little about such individuals and their associated behaviours. The overestimate could also represent a systematic bias in analysing the aerial photographs (*e.g.*, when there is some slight uncertainty, recording the bird as sitting on a nest would produce a positive bias). Given differences in image quality and perspective is difficult to be consistent. Errors could also arise if adjustments to account for uncertainties in the initial count are based on detailed examination of birds visible in a subset of close-up but non-representative images. There is also the assumption that the ground counts are made without error, which may not be true. Given all these uncertainties, it is debatable if the figure of 16% empty-nest occupancy should be used to deflate the aerial counts. If they are used, how wide spatially and in time should this be? Because a correction factor for birds sitting on empty nests was not obviously applied to the counts in earlier surveys, and for the several reasons discussed by Baker *et al*. (2023), it is not applied here: nevertheless, *caveat usor*.

The estimate of 4322 occupied toroa nests overall is slightly above the average reported for the corresponding stage during the 2017–2023 breeding seasons (4021 ± 117 nests), but still around 1224 fewer than that reported for 2007–2010 (5546 ± 159 nests, Table 5). Some year-to-year variation in numbers is expected, depending on breeding success the previous season, given that around three-quarters of pairs that fail early in one season re-nest the next, along with nearly all those pairs that bred successfully two years previously.[2] There is no evidence that the previous breeding season (chicks fledged in 2023) was any less successful than normal, so the small increase could be real.

[1] Following the convention used in the Agreement on the Conservation of Albatrosses and Petrels (ACAP), for species that breed across two calendar years ('split-year'), population counts are assigned to the calendar year in which the chicks fledge (ACAP 2005).

[2] Data for the years 2017–2022 from the small managed population of Northern Royal Albatross nesting on the mainland at Pukekura Taiaroa Head, Otago Peninsula, show 98% of pairs breeding successfully in one year return to breed two years later, while 73 ± 18 % of failed breeders try again the next year (Department of Conservation, unpublished data).

Table 5. Summary of Northern Royal Albatross | Toroa populations on the Chatham Is, 2006–2023, derived primarily from aerial survey (data sources listed on the next page). The December 2015 and mid-February 2016 survey results come from visual analysis of very high resolution satellite imagery.

	Apparently occupied nests				Chicks/Fledglings				Apparent breeding success (%)			
Date of survey	Rangitautahi	Te Awanui	Motuhara	Total	Rangitautahi	Te Awanui	Motuhara	Total	Rangitautahi	Te Awanui	Motuhara	Overall
10/12/2006[a]	2128	1381	1879	5388								
6/08/2007[a]					871	670	1018	2559	40.9	48.5	54.2	47.5
29/11/2007[a]	2018	1371	2212	5601								
1/09/2008[a]					288	435	1093	1816	14.3	31.7	49.4	32.4
28/11/2008[a]	2081	1316	2055	5452								
5/09/2009[a]					496	483	1036	2015	23.8	36.7	50.4	37.0
28/11/2009[a]	1893	1159	2692	5744								
5/09/2010[a]					655	569	1083	2307	34.6	49.1	40.2	40.2
29/12/2015[b]	1096	709	no data	–								
12&19/02/2016[b]	553	429	2632	3614								
23/11/2016[c]	1724	1327	1726	4777								
20/12/2016[d]	1442	1136	2553	5111								
27/07/2017[e]					574	539	1003	2116	33.3	40.6	58.1	44.3
4/12/2017[f]	1317	813	1789	3919								
23/08/2018[f]					550	405	1194	2149	41.8	49.8	66.7	54.8
14/09/2020 (raw / *adj.)* [g, h]					425 */483*	314 */357*	1059 */1203*	1798 */2043*				
18/12/2020 [i]	1368	930	1696	3994								
1/02/2022 [j]	993	675	1601	3269								
20/12/2022 [k]	1508	897	1744	4149								
16/08/2023 [k]					782	587	1204	2573	51.9	65.4	69.0	62.0
9/12/2023 [l]	1501	968	1853	4322								

Data sources

[a] Scofield P. 2011. Aerial photography of Northern Royal Albatrosses at the Chatham Islands, 2006-2010. NIWA Report to the Ministry of Fisheries, Project PRO2006-01A-E, Wellington, New Zealand.

[b] Fretwell PT; Scofield P; Phillips RA. 2017. Using super-high resolution satellite imagery to census threatened albatrosses. *Ibis* 159: 481–490.

[c] Baker GB.; Jensz K; Bell M; Fretwell PT; Phillips RA. 2017. Seabird population research, Chatham Islands 2016/17 aerial photographic survey. Report prepared for Department of Conservation, Contract 4686-2, Latitude 42 Environmental Consultants Pty Ltd, Kettering, Tasmania.

[d] These data come from an analysis of WV3 satellite imagery taken on 20/12/2016 (Baker *et al*. 2017).

[e] Frost, PGH. 2017. Aerial census of Northern Royal Albatross (*Diomedea sanfordi*) fledglings on Rangitatahi (The Sisters) and Motuhara (Forty-Fours), July 2017. Report prepared for the Marine Species and Threats Team, Department of Conservation, Wellington. 23 pp.

[f] Frost PGH. 2019. Aerial surveys of Northern Royal Albatross (*Diomedea sanfordi*) on the Chatham Islands: 2017-2018 breeding season. Report prepared for the Marine Species and Threats Team, Department of Conservation, Wellington. 29 pp.

[g] Frost PGH. 2021. Numbers of Northern Royal Albatross chicks and Northern Giant Petrel adults on the Chatham Islands, September 2020. Report to Marine Species Team, Department of Conservation, Wellington, New Zealand. 17 pp

[h] Note: The second set of numbers, *in italics*, are adjusted counts, allowing for those chicks that likely fledged in the two weeks preceding the aerial survey.

[i] Frost PGH. 2021. Status of Northern Royal Albatross *Diomedea sanfordi* nesting on the Chatham Islands, December 2020. Report to Marine Species Team, Department of Conservation, Wellington, New Zealand. 20 pp.

[j] Frost PGH. 2022. A census of Northern Royal Albatross nesting on the Chatham Islands, February 2022. POP2021-03 final report for the Department of Conservation. 24 pp.

[k] Frost PGH. 2023. Nesting success of Northern Royal Albatross | Toroa *Diomedea sanfordi* on the Chatham Islands: 2023 Breeding Season. Report to the Conservation Services Programme, Department of Conservation. Science Support Service, Whanganui, 16 p.

[l] This study.

Breeding success appears to have increased since the mid-2000s when it averaged 39.3 ± 6.3% through 2007–2010. More recently, 2017–2023, overall apparent breeding success averaged 53.7 ± 8.9%, a notable increase (Table 5). (Breeding success should be referred to here as *apparent breeding success* to account for the uncertainty around whether all of the occupied nests initially had birds sitting on an egg.) The reasons for the increase, if real, are not known. One hypothesis is that it is related to a gradual increase in vegetation cover on the islands, especially Motuhara and Te Awanui, providing nesting birds and chicks not only with more cover during periods of inclement weather but also with additional nesting material, allowing the birds to build more substantial and better insulated nests compared to those where eggs are in direct contact with the ground. Figure 3 shows the eastern end of Motuhara in December 2017, 2020, 2022 and 2023, illustrating an apparent increase in vegetation cover. The same pattern is seen more broadly, not only elsewhere on Motuhara but also on Te Awanui, at least under comparable edaphic conditions. Apparent breeding success on Motuhara, the most vegetated island, was regularly higher. In contrast, breeding success is consistently lower on Rangitautahi, the island where vegetation cover is least, and where nesting birds are generally more exposed (Table 5).

Figure 3. Images of the same area on the eastern end of Motuhara taken in December in different years, 2017–2023, showing differences in vegetation cover, particularly the apparent increase in 2022 and 2023 over that present in 2017 and 2020 (photo credits: Sara Forder [2017], Jemma Welch [2020], Liam Acheson [2022], Cassidy Solomon [2023]).

Extreme weather events—high temperatures and cyclonic winds—are known to cause high mortality among nesting toroa eggs and chicks, both directly and through overcrowding in subsequent breeding seasons when failed breeders attempt to renest alongside normal biennially-breeding successful pairs (Robertson 1998). During 1983/84–1993/94, there were seven severe storms, some in close succession, all characterised by mean maximum wind speeds of >140 km^{-1} and gusts up to 280 km^{-1}, some lasting more than a day (Robertson 1998).

Could the weather in recent decades have been relatively more benign than that which occurred during the mid-1980s to mid-1990s? The limited climate data available for the Chatham Islands over the past two decades, monitored at the automatic weather station at Inia William Tuuta Memorial Airport on Rēkohu (Chatham Main Island), 38 km SE of the Rangitatahi group and 54 km ~WNW of Motuhara, suggests this is possible. The longest more-or-less complete data series available for this period are daily wind run, maximum and minimum temperatures, and rainfall amounts. Data on extreme wind gusts, reported only as the maximum gust recorded each month (with the date), are more sporadic and available only up to mid-2021. Of these weather variables, wind run is arguably the most relevant to nesting albatrosses as it integrates wind speed into the total amount of wind passing a point, and thus broadly reflects overall daily wind strength (Figure 4).

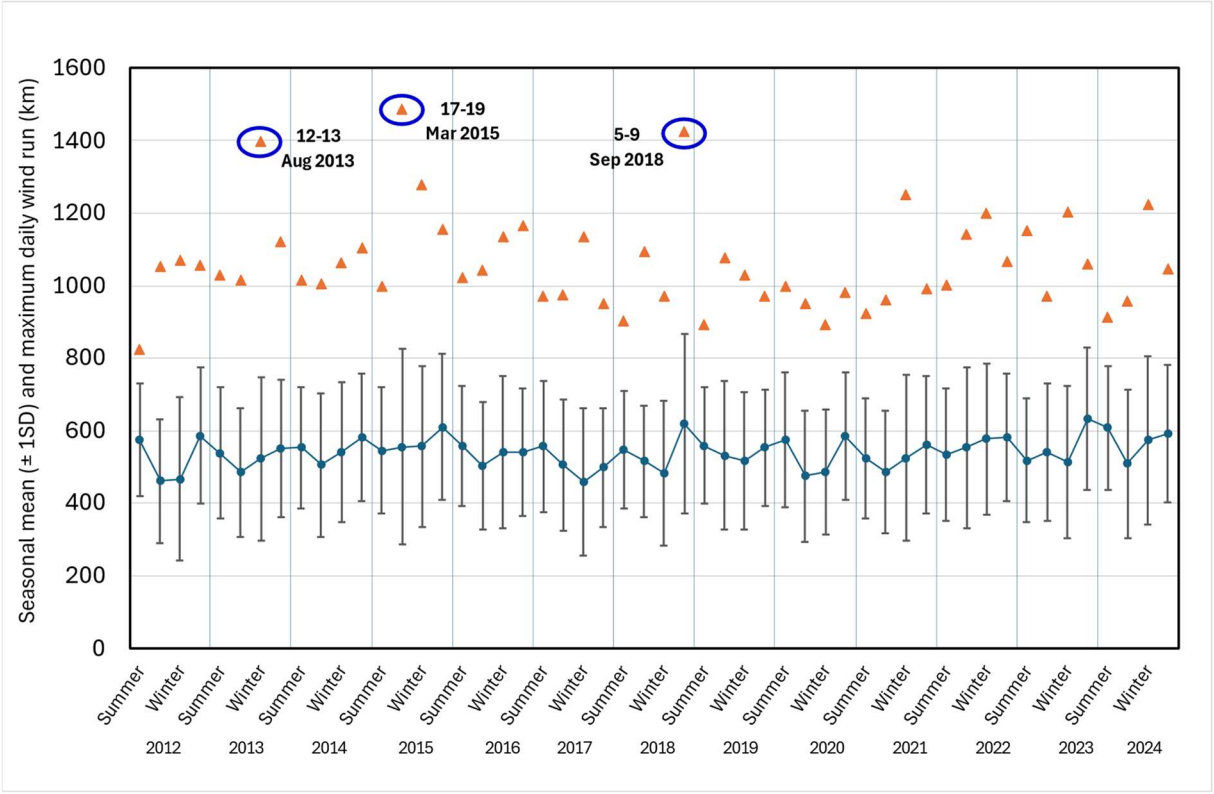

Figure 4. Seasonal average daily wind runs (± 1 SD, km day^{-1}) and highest recorded daily wind run in each season, Sep–Nov 2012 to Sep–Oct 2024, at Chatham Island Aero AWS (Station K98617, -43.8168, -176.4750). Data from the National Climate Database via CliFlo (http://cliflo.niwa.co.nz/), downloaded 28 October 2024. The database is now housed at the National Institute of Water and Atmospheric Research's DataHub (https://data.niwa.co.nz/).

Although the weather at the airport on Rēkohu is probably milder than that experienced on the smaller, more exposed offshore islands where the albatrosses nest, an analysis of daily wind-run data since 2012 shows no weather events as extreme as those reported in the early 1980s–1990s. The most extreme event, in terms of average and maximum daily wind run, occurred on 17–19 March 2015, averaging 1342 km day^{-1} for the three days (equivalent to a near-continuous windspeed of 56 kph). The peak run—1487 km (≡ 62 kph)—occurred on 18 March 2015 (Figure 4). Other notable gales occurred over 5–9 September 2018, when the daily wind run averaged 1180 km (≡ 49 kph) for five consecutive days, peaking on 6 September at 1426 km (≡ 59 kph), and on 12–13 August 2013, when the average daily wind run was similar (1188 km), but lasted only two days, with a peak run of 1398 km (≡ 58 kph) on the first day. Data on wind gusts is patchy, but the maximum gusts recorded during these events were 109 kph (March 2015), 97 kph (September 2018) and 91 kph (August 2013). The highest recorded gust overall during 2012–2021, was 111 kph on 12 October 2013 when the daily wind run was 1107 km. This occurred outside the vulnerable period for eggs and chicks.

These conditions may partly explain the seeming stabilisation of the Northern Royal Albatross population in recent years. Although there are uncertainties around the actual number of nesting pairs, a limitation that also applies to earlier counts, it seems that the population may even be increasing slightly, if the apparent increase in breeding success, at least compared with that recorded 14–17 years ago, is translating into a rise in recruitment.

In contrast to the notable difference between ground counts and estimates of the number of breeding toroa obtained from the aerial photographs, the variance between these two sets derived from counts of birds nesting within the five 20 x 20 m permanently marked sample plots was generally much less. Only one of the five PSPs produced an anomalous count, with the aerial estimate being almost one-third higher than the ground count. Results from an initial trial, conducted in February 2022 and also involving counts made from drone images, showed more similar numbers across all data platforms (Frost 2022). Likewise, comparisons between ground counts and estimates of nesting Northern Buller's Mollymawk derived from analyses of aerial images taken from an aircraft and a drone were similar in February 2022 but generally quite different in December 2023. Considerably more work is obviously needed to identify the reasons for these differences and how the analyses can be improved.

Except for Motuhara, where there is currently an active on-ground research programme (Bell 2023), these islands are seldom visited and difficult to access. Aerial photography remains the only practical means of monitoring the numbers and status of birds present at various stages during their breeding season. There are clearly many unknowns, not least of which is whether a bird seen on a nest is actually incubating or brooding a small chick, as opposed to sitting on an empty nest for whatever reason. Applying a correction factor not only requires near-simultaneous ground survey, to establish what proportion of nesting birds are sitting on empty nests, but one that is representative of the whole breeding population. In this respect, Motuhara presents opportunities to understand better the behaviour of breeding birds and others, as well as the extent of bias (systematic error) arising during in the analysis of aerial photographs.

Recommendations

1. Regular monitoring of the Northern Royal Albatross population breeding on the Chatham Islands should continue, ideally involving twice yearly aerial surveys, once in December during the early incubation period, then again in mid–late August, immediately prior to the chicks fledging from September onwards. This would allow breeding success to be calculated, a complementary parameter to juvenile, sub-adult and adult survival estimates, derived from the current mark-recapture programme on the island. These are all necessary inputs to any integrated population model for Northern Royal Albatross

2. Liaison between those visiting Motuhara periodically for ground-based studies and those planning the aerial surveys is essential for ensuring as close synchroneity as possible between the two, to serve as a check on the accuracy of the aerial surveys and their assessment. This may allow the sources of bias in the aerial survey assessments and the conditions under which these occur to be identified. Synchrony is not easy to achieve, however, given that landing on the island and conducting an aerial survey are both weather and personnel dependent.

3. Given the near-impossibility under present circumstances of accurate accounting of the number of toroa sitting on eggs (or brooding small chicks), and those individuals sitting on empty nests, and the uncertainties involved in estimating and applying correction factors, it may be more practical to continue reporting the number of occupied nests (recognising that some may be empty). This way, new data sets will continue to be comparable with those reported historically, and can serve as a basis for ongoing broad assessments of population trends. If changes are to be made in how these data are reported, then a sufficient period of overlap between the different reporting protocols will be needed, to assess previous extents of bias.

4. The maintenance and surveying of the permanent sample plots set up on Motuhara to monitor population trends of both the Northern Royal Albatross and Northern Buller's Mollymawk populations there should be continued. Although the present aerial survey has revealed difficulties in producing similar counts to those made on the ground, the feasibility of using these plots to track population trends when whole-island counts are impractical should continue to be explored.

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Appendix

Table A1. List of images and marked areas examined on Motuhara and the corresponding initial categorisation of the birds seen in each

Image No	Focal length (mm)	Area	AON	Partner to AON	AEN	Loafer/ transient	Status unclear	Carcass	Bird in flight	Total adults on ground
0I0A1011	125	A1a	30	0	0	2	3	0	0	35
0I0A1029	125	A1a	27	0	0	3	5	0	0	35
0I0A1029	125	A1b	0	0	0	0	0	0	0	0
0I0A0909	125	A2a	58	0	4	2	4	0	0	68
IMG0817	137	A2b	0	0	0	0	0	0	0	0
0I0A0806	130	A3a	16	0	1	1	3	0	0	21
0I0A0810	130	A3b	16	1	0	2	5	0	0	24
0I0A0818	130	B2a	0	0	0	0	0	0	0	0
0I0A0815	130	B2b	0	0	0	0	0	0	0	0
0I0A0810	130	B3(bis)	0	0	0	0	0	0	0	0
0I0A0813	130	B3	0	0	0	0	0	0	0	0
0I0A0821-23_stitch	130	C1a	42	0	5	1	6	2	0	54
0I0A0823	130	C1a	41	0	8	2	3	1	0	54
0I0A0823	130	C1b	20	0	1	0	2	0	0	23
0I0A1468	190	C2a	13	1	0	0	4	0	0	18
0I0A1465	190	C2b	97	2	2	6	24	1	0	131
0I0A1464	190	C3a	79	2	2	3	27	2	0	113
0I0A0829	130	C3b	123	0	5	1	16	0	0	145
0I0A0821	130	D1a	86	1	6	3	9	0	0	105
0I0A0822	130	D1b	62	3	9	2	8	0	0	84
0I0A0873	125	D1b	55	3	0	0	27	0	0	85
0I0A0822	130	D2	100	3	5	4	29	0	0	141
0I0A0873	125	D2	97	4	1	2	37	0	0	141
0I0A0873	125	D3a	125	2	0	8	66	0	0	201
0I0A0868	125	D3b	265	1	6	5	89	3	0	366
0I0A0975	125	D4	187	1	5	12	42	2	0	247
0I0A0836	130	E1a	138	2	0	4	67	0	0	211
0I0A0848	125	E1a	163	4	1	1	43	0	0	212
0I0A0836	130	E1b	7	0	0	1	2	0	0	10
0I0A0848	125	E2a	36	1	1	1	3	0	0	42
0I0A0851	125	E2a	35	1	1	0	5	0	0	42
0I0A0851	125	E2b	17	0	0	0	5	0	0	22
0I0A0859	125	E3	82	3	2	2	26	1	0	115
0I0A1926	150	E3	85	5	2	8	17	2	0	117
Totals			**1616**	**25**	**49**	**56**	**432**	**10**	**0**	**2178**

Table A2. List of images and marked areas examined on Rangitautahi and the corresponding initial categorisation of the birds seen in each. The counts used in the final analysis are shaded.

Image No	Focal length (mm)	Area	AON	Partner to AON	AEN	Loafer	Status unclear	Carcass	Bird in flight	Total adults on ground
0I0A0124	140	A	34	1	0	6	1	1	0	42
0I0A0420	140	B	13	0	0	0	0	1	0	13
0I0A0432	140	B	13	0	0	0	0	1	0	13
0I0A0125	140	C1	80	5	1	13	9	0	0	108
0I0A0128	140	C2(lower)	10	1	0	0	0	1	0	11
0I0A0127	140	C2(upper)	69	2	1	2	2	0	0	76
0I0A0126-132 stitch	140	F1+F2(low)	1	0	0	0	0	0	0	1
0I0A0419	140	D	8	0	0	0	0	0	0	8
0I0A0415	140	E	1	0	0	0	0	0	0	1
IMG0675	135	F2a	13	0	0	0	1	0	0	14
IMG0675	135	F2b(i)	27	1	0	0	0	0	0	28
0I0A0133	140	F2b(ii)	4	0	0	0	5	0	0	9
0I0A0133	140	F3	55	0	1	1	8	1	0	65
0I0A0409	140	G1	141	2	0	15	8	1	0	166
0I0A0133	140	G2	10	2	0	0	0	0	0	12
0I0A0112	140	H	10	0	0	0	0	0	0	10
0I0A0135	140	H	12	0	0	0	0	0	0	12
0I0A0404	140	I1	84	1	0	8	9	0	0	102
0I0A0405	140	I1	83	2	0	9	8	0	0	102
0I0A0405	140	I2a	101	4	0	16	11	0	0	132
0I0A0407	140	I2a	105	5	0	17	3	0	0	130
0I0A0409	140	I2b (inner)	43	1	0	4	9	0	0	57
0I0A0409	140	I2b(inner)	42	1	0	5	10	0	0	58
0I0A0409	140	I2b (outer)	31	1	0	3	1	0	0	36
0I0A0192	140	I2b (inner)	50	2	0	0	3	0	0	55
0I0A0256	270	I2b (inner)	47	0	0	2	6	0	0	55
0I0A0257	270	I2b (inner)	52	1	0	0	3	0	0	56
0I0A0405	140	I2b(outer)	31	1	0	2	3	0	0	37
0I0A0397	140	K1	89	2	0	9	12	0	0	112
0I0A0399	140	K1	95	2	0	10	4	0	0	111
0I0A0400	140	K1	96	2	0	9	6	0	0	113
0I0A0400	140	K2	114	2	0	18	5	1	0	139
0I0A0404	140	K2	113	3	0	20	3	1	0	139
0I0A0404	140	K2a	79	2	0	11	4	1	0	96
0I0A0404	140	K2b	37	0	0	6	0	0	0	43
0I0A0405	140	K2b	35	1	0	5	2	0	0	43
0I0A9138	140	L1	3	0	0	0	0	0	0	3
0I0A0563	210	L2	9	0	0	0	1	0	0	10
0I0A0141	140	M1	110	2	0	5	8	0	0	125

Table A2 (continued) List of images and marked areas examined on Rangitautahi and the corresponding initial categorisation of the birds seen in each. The counts used in the final analysis are shaded.

Image No	Focal length (mm)	Area	AON	Partner to AON	AEN	Loafer	Status unclear	Carcass	Bird in flight	Total adults on ground
0I0A0142	140	M1	112	2	0	6	5	0	0	125
0I0A0143	140	M2	25	1	0	2	3	0	0	31
0I0A0114	140	M3	0	0	0	0	0	0	0	0
0I0A0396	140	N1	157	1	0	18	15	0	0	191
0I0A0397	140	N2	156	2	0	27	9	0	0	194
0I0A0397	140	N2b	106	2	0	13	8	0	0	129
0I0A0399	140	N2b	107	3	0	14	5	0	0	129
Total			**1412**	**32**	**3**	**150**	**101**	**6**	**0**	**1698**

Table A3. List of images and marked areas examined on Te Awanui and the corresponding initial categorisation of the birds seen in each. The counts used in the final analysis are shaded.

Image No	Focal length (mm)	Area	AON	Partner to AON	AEN	Loafer	Status unclear	Carcass	Bird in flight	Total adults on ground
0I0A0152	140	A	34	3	0	2	2	1	1	41
0I0A0152	140	B	40	2	0	7	7	1	0	56
0I0A0152	140	C	47	4	0	0	8	0	0	59
0I0A0232	150	C	51	3	1	4	3	0	0	62
0I0A0232	150	D1	92	2	0	2	13	0	0	109
IMG0668	135	D1	64	5	0	1	43	0	0	113
IMG0668	135	D2	3	1	0	0	1	0	0	5
0I0A0513	190	E1	67	3	0	6	19	0	0	95
0I0A0617	205	E2	27	0	0	3	4	0	0	34
0I0A0168	140	F	0	0	0	0	0	0	0	0
0I0A0436	150	G1	0	0	0	0	0	0	0	0
0I0A0439	150	G1	0	0	0	0	0	0	0	0
0I0A0642	205	G1	0	0	0	0	0	0	0	0
0I0A0436	150	G2	0	0	0	0	0	0	0	0
0I0A0168	140	G3	0	0	0	0	0	0	0	0
0I0A0642	205	G3	0	0	0	0	0	0	0	0
0I0A0437	150	H1	20	0	0	0	1	0	0	21
0I0A0439	150	H2	7	1	0	0	1	0	0	9
0I0A0455-56 stitch	200	I	53	0	0	4	1	1	0	58
0I0A0513	190	I	44	0	0	3	5	1	0	52
0I0A0612	205	I	48	0	0	2	3	1	0	53
0I0A0225	150	I	52	0	0	2	4	1	0	58
0I0A0513	190	J	25	0	0	0	0	0	0	25
0I0A0443	150	K1	108	4	0	16	44	0	0	172
0I0A0164	140	K1	131	5	0	6	33	0	0	175
0I0A0229	150	K2	50	2	0	1	14	0	0	67
0I0A0513	190	K2	53	3	0	0	9	0	0	65
0I0A0229	150	L1	8	0	0	1	3	0	0	12
0I0A0152	140	L2	24	0	0	1	14	0	0	39
0I0A0159	140	M1	30	1	0	0	2	0	0	33
0I0A0149	140	M2	30	0	0	0	3	1	1	33
0I0A0516	190	N1	1	0	0	0	0	0	0	1
0I0A0607	205	N2	0	0	0	0	0	0	0	0
0I0A0516	190	O	10	0	0	0	0	1	0	10
0I0A0515	190	P	43	2	0	1	4	0	0	50
0I0A0164	140	Q	26	2	1	1	6	0	0	36
0I0A0236	150	Q	25	2	1	1	7	0	0	36
0I0A0515	190	Q	27	2	0	1	6	0	0	36

Table A3 (continued). List of images and marked areas examined on Te Awanui and the corresponding initial categorisation of the birds seen in each. The counts used in the final analysis are shaded.

Image No	Focal length (mm)	Area	AON	Partner to AON	AEN	Loafer	Status unclear	Carcass	Bird in flight	Total adults on ground
0I0A0446	150	R	9	0	0	1	1	2	0	11
0I0A0637	205	S	26	2	0	0	1	0	0	29
0I0A0361	300	T	0	0	0	0	0	0	0	0
0I0A0219	140	U	8	0	0	0	1	0	0	9
0I0A0449	150	U	9	0	0	0	0	0	0	9
0I0A0156	140	V1	7	2	0	1	0	0	0	10
0I0A0219	140	V1	7	2	0	1	0	0	0	10
0I0A0156	140	V2	37	2	0	3	1	0	0	43
0I0A0219	140	V2	35	1	1	4	2	0	0	43
0I0A0156	140	V3	14	1	0	2	0	0	0	17
0I0A0361	300	W (lower)	0	0	0	0	0	0	0	0
0I0A0449	150	W(upper)	0	0	0	0	0	0	0	0
0I0A0482	210	X(lower)	3	0	0	0	0	0	0	3
0I0A0219	140	X(upper)	0	0	0	0	0	0	0	0
0I0A0579	205	X(all)	3	0	0	0	0	0	0	3
Totals			**847**	**36**	**3**	**46**	**165**	**7**	**2**	**1097**

Table A4. List of close-up images examined on Motuhara to determine more precisely the status of the birds present. The areas from which these images come are also shown

Image No	Focal length (mm)	Area	AON	Partner to AON	AEN	Loafer	Status unclear	Total birds counted	Total adults clearly seen	Total occupied nests
0I0A0891	125	A	27	0	0	7	2	36	34	27
0I0A1758	300	E	35	0	0	7	3	45	42	35
0I0A1760	300	E	23	2	1	0	1	27	26	23
0I0A1761	300	D	85	2	2	5	3	97	94	85
0I0A1764	300	D	103	0	2	10	5	120	115	103
0I0A1765	300	C	60	1	3	5	8	77	69	60
0I0A1785	300	D	59	2	4	1	2	68	66	59
0I0A1789	300	C	35	1	7	4	1	48	47	35
0I0A1799	300	C	34	0	4	2	0	40	40	34
0I0A1801	300	C	28	2	2	5	7	44	37	28
0I0A1806	300	C	56	2	3	7	1	69	68	56
0I0A1810	300	C/D	119	3	19	6	10	157	147	119
0I0A1816	300	D	88	0	6	5	22	121	99	88
0I0A1819	300	D	105	2	5	13	9	134	125	105
010A1821	300	C	63	2	1	6	6	78	72	63
Totals			920	19	59	83	80	1161	1081	920

Table A5. List of close-up images examined on Rangitautahi to determine more precisely the status of the birds present. The areas from which these images come are also shown

Image No	Focal length (mm)	Area	AON	Partner to AON	AEN	Loafer	Status unclear	Total birds counted	Total adults clearly seen	Total occupied nests
0I0A0259	255	A	33	1	0	7	0	41	41	33
0I0A0263	255	C	26	1	0	8	1	36	35	26
0I0A0675	205	F2	29	1	0	2	0	32	32	29
0I0A0272	255	F3	40	0	0	3	2	45	43	40
0I0A0278	255	G-I2	60	2	0	11	3	76	73	60
0I0A0284	255	I1-I2a	55	1	0	2	0	58	58	55
0I0A0763	300	I1-K2b	52	3	0	4	2	61	59	52
0I0A0764	300	I1-K2b	33	0	0	3	2	38	36	33
0I0A0294	255	M1-M2	20	1	0	0	0	21	21	20
0I0A0563	210	M1	54	1	0	3	0	58	58	54
0I0A0209	140	N1-M2	68	3	0	15	2	88	86	68
0I0A0212	140	N1	176	2	0	17	4	199	195	176
0I0A0428	140	G1	101	0	0	12	11	124	113	101
0I0A0239	290	B-C1	28	0	0	0	4	32	28	28
0I0A0218	140	N2	66	3	0	4	5	78	73	66
Total			841	19	0	91	36	987	951	841

Table A6. List of close-up images examined on Te Awanui to determine more precisely the status of the birds present. The areas from which these images come are also shown.

Image No	Focal length (mm)	Area	AON	Partner	AEN	Loafer	Status unclear	Total birds counted	Total adults clearly seen	Total occupied nests
0I0A0322	255	B-C	38	0	1	7	9	55	46	38
0I0A0323	255	C	39	2	0	6	1	48	47	39
0I0A0332	255	E-K	77	3	0	4	11	95	84	77
0I0A0366	300	L-M	43	3	0	7	13	66	53	43
0I0A0373	300	E	74	1	1	10	12	98	86	74
0I0A0582	205	V	18	1	0	4	0	23	23	18
0I0A0617	205	E(2)	50	1	0	2	10	63	53	50
0I0A0723	300	V(2)	23	2	1	1	0	27	27	23
0I0A0724	300	M	23	0	0	0	0	23	23	23
010A0725	300	M	19	0	0	0	0	19	19	19
0I0A0727	300	D	26	0	0	3	5	34	29	26
0I0A0728	300	K	30	0	0	2	4	36	32	30
0I0A0729	300	K	15	1	0	1	3	20	17	15
0I0A0732	300	J	18	0	3	2	1	24	23	18
010A0735	300	I	40	0	0	2	2	44	42	40
			533	14	6	51	71	675	604	533

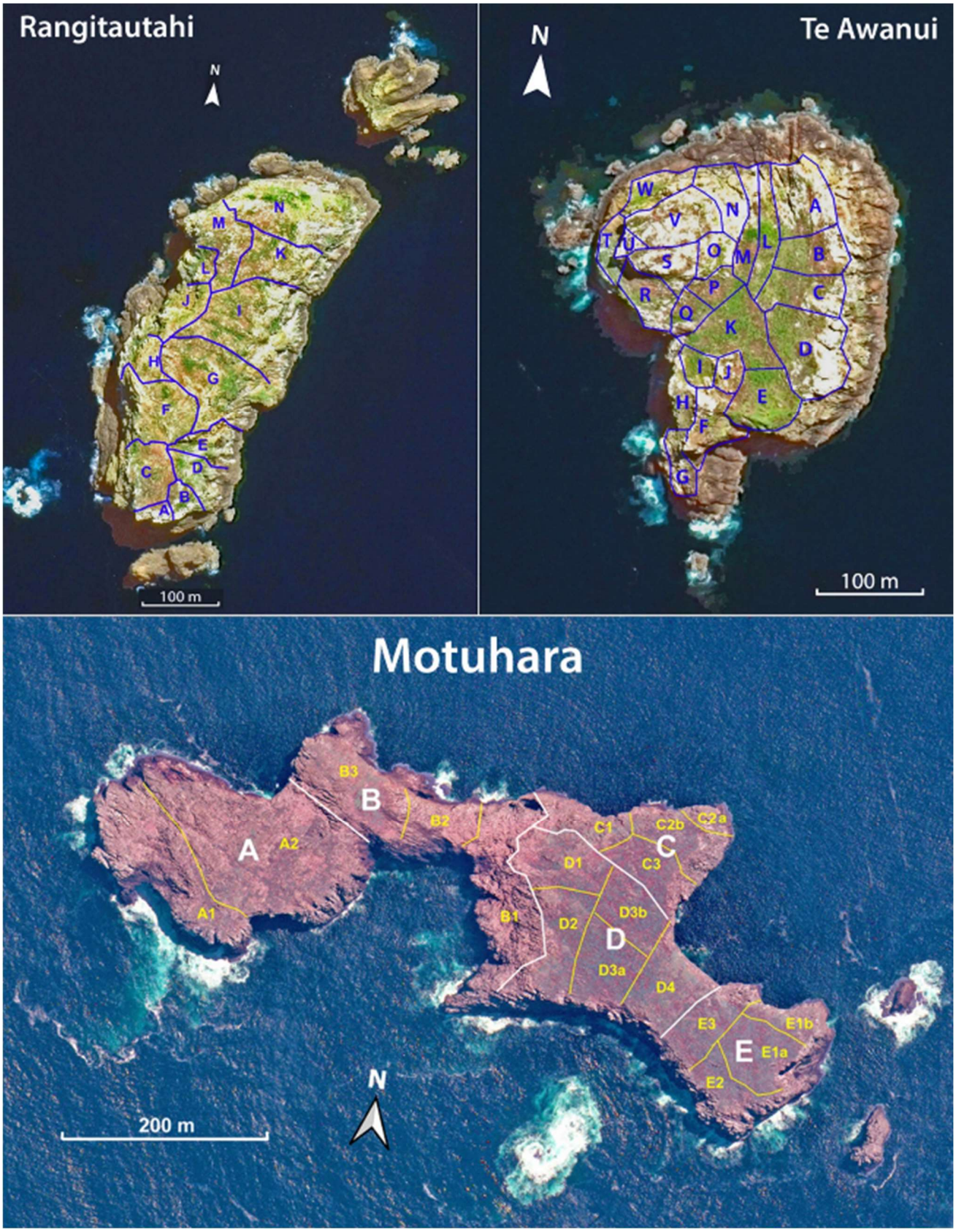

Figure A1. Locations and identity of the areas surveyed in December 2023.