Status of Northern Royal Albatross *Diomedea sanfordi* nesting on the Chatham Islands, December 2020

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Cover photograph: Northern Royal Albatross nesting among scattered *Leptinella featherstonii* on Rangitautahi, December 2020 (Canon EOS 1000D, F/L 300 mm, f/20, ISO 1600, 1/1024s, photo credit: Jemma Welch)

EXECUTIVE SUMMARY

1. An aerial photographic survey of Northern Royal Albatross (toroa) *Diomedea sanfordi* was carried out on 18 December 2020 over three outlying islands in the Chatham archipelago: Motuhara, Rangitautahi and Te Awanui. Together these three islands support 99% of the global breeding population of this species.

2. A total of 4174 toroa were counted overall. The breeding status of many birds could not be determined unambiguously and had to be assessed using 39 close-up images across all three islands (covering 3654 individuals). The number of birds clearly occupying a nest, partnering a sitting bird, loafing, or still unclassifiable were counted and the proportions of birds in each category (ignoring the unclassifiable individuals) were used to reallocate the 4174 individuals originally counted to the three behaviour classes.

3. These adjusted figures gave a total of 3994 birds (95% confidence limits: 3784–4214) occupying nests: 42.3% on Motuhara; 34.3% on Rangitautahi; and 23.3% on Te Awanui. The remaining 180 birds were either partners of sitting birds (29%) or not obviously associated with a nest (loafing, pre-breeders scouting for a future nest site, or birds in transit to or from a nest: 71%). The status of occupied nests could not be determined but up to 13% could have been empty.

4. The 3994 pairs occupying nests in the 2020 breeding season can be added to the 2043 pairs considered to have fledged a chick the previous year to give an estimated current adult breeding population of 6037 pairs. This is similar to the 5908 pairs estimated by Bell et al. (2017) using the same method. This is ~37% lower than the average recorded in the late-1980s and mid-1990s and 24% lower than that estimated for the mid-1970s. The reasons for this are briefly discussed.

5. Image quality was generally insufficient to allow straightforward and consistent discrimination between nesting and loafing Buller’s Mollymawk, let alone distinguishing these birds from their often dark and fissured backgrounds in their nesting areas. Likewise, only incomplete counts of Northern Giant Petrel adult and chicks were obtained, limited largely to those visible in close-up images. Consequently, data for these species are not reported here.

1. Introduction

Around 99% of the global population of Northern Royal Albatross or toroa *Diomedea sanfordi* breeds on three outlying islands in the Chatham archipelago: Motuhara (Forty-Fours) and, in the Rangitatahi (The Sisters) group, Rangitautahi (Big Sister) and Te Awanui (Middle Sister). Toroa breed biennially, with birds that successfully rear a chick in one year only returning to breed again two years later at the earliest. Pairs that fail during incubation or the early nestling stage in one year—weeks 1-6 of the ~35 week nestling period—may return to nest again the following year (Department of Conservation 2001). Annual counts of breeding birds therefore cover more than half the total breeding population, depending on nesting success the previous season and how many of the failed breeders then return to re-nest the following year. Taking the number of breeding pairs in a year plus the number of successful breeding pairs the previous year, Bell *et al*. (2018) estimated the total breeding population on these islands in 2017 to be 5908 pairs. An additional 40 pairs, on average, breed annually at Taiaroa Head, Otago Peninsula. Using the same formula as Bell *et al*. (2017) and annual breeding success in recent years (summarised in Cooper 2019), gives an average breeding population at Taiaroa Head of 62 pairs, ~1% of the world's population.

Because individuals breed for the first time only when about 9 years old on average, there is a substantial population of immature and sub-adult birds (Richard *et al*. 2013). Some of these visit the nesting colonies a year or more before starting to breed, to prospect for mates and nest sites. Any census of the birds present during the breeding season needs to take account of these birds by distinguishing them clearly from incubating and brooding birds. Overall, these features introduce much uncertainty into the population estimates for this species.

The breeding population of toroa on Motuhara and Rangitatahi has been assessed sporadically by 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 (Robertson 1998; Baker *et al*. 2017). Assessments of breeding success have usually involved aerial photographic surveys conducted in the following July–August, prior to the chicks fledging in September (Robertson 1998; Frost 2017a). These have also been conducted irregularly. This report covers the most recent aerial survey of toroa nesting on these islands, carried out on 18 December 2020 during the early stage of incubation.

These islands are also key breeding sites for Northern Buller's Mollymawk *Thalassarche bulleri platei* and Northern Giant Petrels *Macronectes halli*. Almost the whole global population of Northern Buller's Mollymawk breeds on Rangitautahi, Te Awanui and Motuhara (estimated population in December 2017 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. Unfortunately, neither species could be censused satisfactorily during the present survey.

2. Methods

2.1 Sites

Motuhara (called Motchuhar by Moriori, and previously known as The Forty-Fours) is positioned at 43.9622°S, 175.8347°W, 42 km east of Rēkohu (Chatham Main I.). It comprises an 11.5-ha, 60-m high main island and five small, steep-sided offshore rocky stacks. The island consists predominantly of hard, fine- to medium-grained, partly recrystallised quartzofeldspathic sandstones or feldsarenites, and is the most easterly outcrop of Mesozoic basement rocks in New Zealand (Andrews *et al*. 1978).

The patchy and generally thin soils support a mixture of open herb-fields and low-growing shrubland dominated by the Chatham Island button daisy *Leptinella featherstonii*. The button daisy evidently thrives on nutrient inputs from nesting seabirds. The shrublands are mostly concentrated in the middle and south-east sections of the central plateau.

Rangitatahi (The Sisters), centred at 43.5642°S, 176.8075°W, 20 km due north of Rēkohu, comprises three islands: Rangitautahi (Big Sister, 7.3 ha), Te Awanui (Middle Sister, 4.8 ha) and Little Sister, a low-lying c. 5-ha reef. In contrast to the predominant sandstones and feldsarenites of Motuhara, Rangitatahi rocks are of volcanic origin, comprising massive limburgitic basalt with associated deposits of breccia, scoria, and tuff (Campbell *et al*. 1988).

The soils on Rangitautahi and Te Awanui are generally thin and support only sparse vegetation except in some basins on the plateaus where the Chatham Island button daisy and the groundsel, *Senecio radiolatus,* are well established.

2.2 Aerial survey

The aerial survey was carried out on 18 December 2020 between 10h35 and 12h13 from an Air Chathams Cessna 206 carrying two Department of Conservation staff as photographers, and the pilot. Weather conditions were fine with high cloud and little wind (Beaufort Scale 2-3, 4-10 knots, based on observation of sea conditions visible in some images). Motuhara was surveyed first, followed by Rangitatahi.

The flight paths around the islands were notably elongate (Fig. 1), similar to those flown around Motuhara during the September 2020 aerial photographic survey of toroa chicks (Frost 2021). The turning points were 1.9–3.0 km from the islands, presumably to avoid any perceived chance of sudden bird strike while the aircraft was turning. In contrast, more circular paths were flown during most of the earlier surveys (e.g., July 2017: Frost 2017). Tighter turning circles allow for a greater diversity of viewpoint angles.

Details of the flight during the surveys (altitude, airspeed and the duration of flypasts) are given in Appendix 1. The time spent photographing the colonies was relatively short, around 5.0 min at Motuhara, 2.4 min at Rangitautahi and 1.8 min at Te Awanui. The average airspeed during the flypasts was higher (110 ± 5.0 knt) than in previous surveys (average values previously ranged from 75 to 105 knts: see Frost 2021 for further discussion).

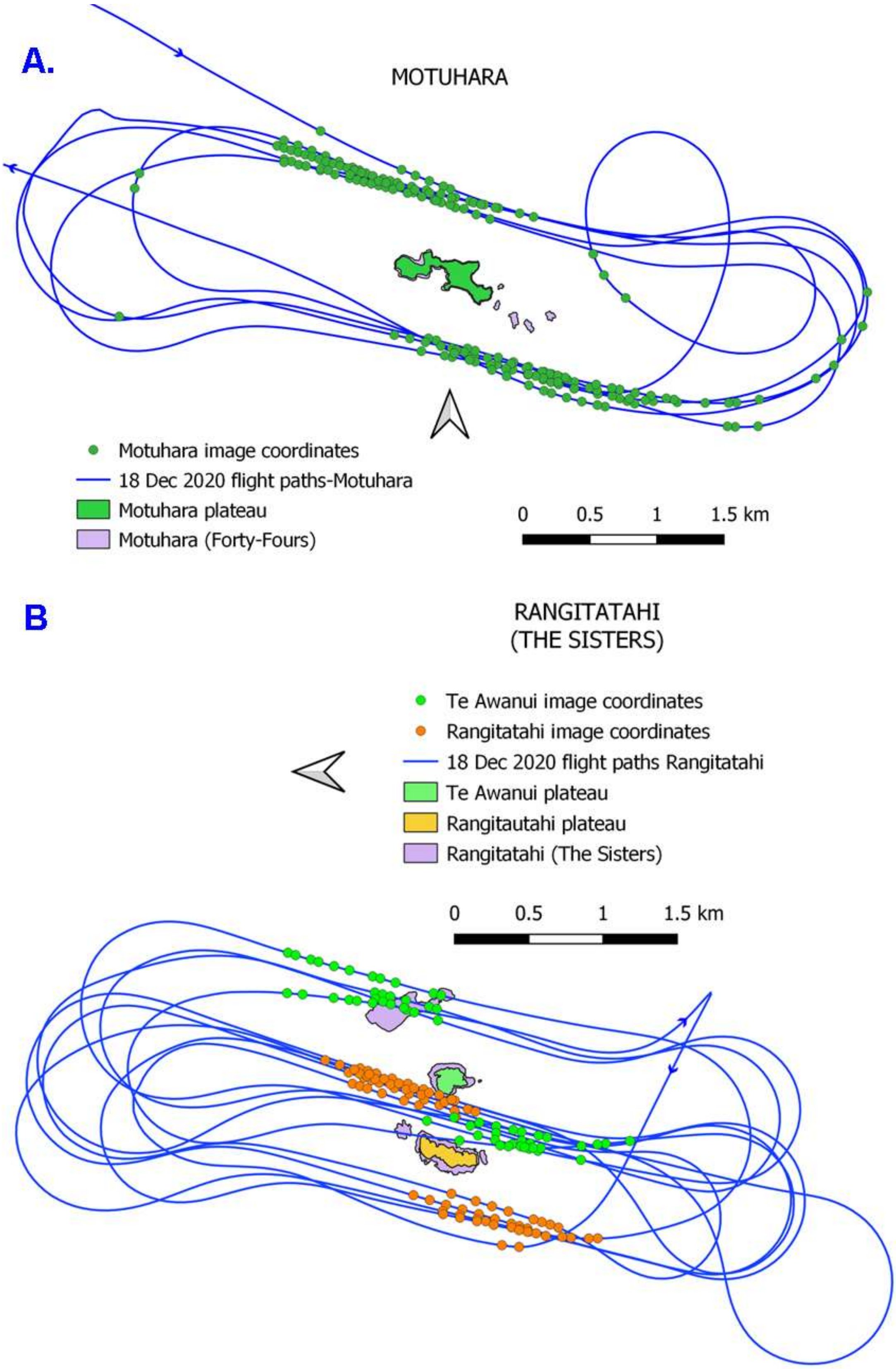

Figure 1. Flight paths flown during the 18 December 2020 aerial photographic survey of Northern Royal Albatross nesting on (**A**) Motuhara (Forty-Fours) and (**B**) Rangitatahi (The Sisters). Note the elongate tracks and that the photographs, shown here as dots, were taken largely looking forward from the aircraft rather than at right angles towards the focal points on the islands. The image for Rangitatahi (**B**) has been rotated 90° to the left for convenience.

Details of the cameras used, their settings and the numbers of images taken during the survey are also given in the Appendix 1. Two cameras were used to photograph Motuhara, one taking landscape-scale views of the colonies (18<135 mm focal length), the other mostly taking close-up photographs of the nesting birds (>275 mm focal length). Unfortunately, the capacity of the SD card in the first camera (Canon EOS 77D) was limited, filling up at Motuhara. That camera could thus not be used to photograph the colonies at Rangitautahi and Te Awanui. The second camera (Canon EOS 1000D) was therefore used to photograph both close-up (195<300 mm focal length, 39 % of images taken) and wide-angle views (<175 mm focal length, 61 % of images) of these two islands. Overall, 19% of the 329 images taken were photographed from more than 1 km away and lacked sufficient detail to be useful for delineating the colonies or counting the birds in them (Fig. A1). Only 20% were taken at the optimal distance of 400 m or less.

2.3 Image analysis

Images were received in Canon RAW format and converted to JPEG. Selected images were then processed further using a combination of Adobe Photoshop Elements 2020 (v.18.0 x64) and Topaz Sharpen AI (v.2.2.4 2021), to highlight as much detail as possible without distortion. This level of processing was needed to compensate for the small size and relatively low resolution of most of the birds when enlarged.

Images from each island were collated and subsets chosen that, together, covered each of the islands concerned (Fig. 2). Within these selected images, adjacent, discrete (i.e., non-overlapping) areas were identified and outlined, using prominent common features visible in adjoining images as boundary markers: rocks, fissures, distinctive bare areas, or conspicuous clumps of vegetation. Where a boundary line passed close to a bird, care was taken to ensure that it was either included or excluded in the delineated zones to avoid double-counting or omission.

All birds seen in each zone were counted and catalogued using DotDotGoose v.1.5.1 (Ersts 2020). Individual toroa were classed as follows: adult incubating (Fig. 3 A-D); adult sitting or standing next to an incubating bird (assumed to be a partner: Fig. 3A); adult apparently standing on a nest (Fig. 3B); adult apparently standing or sitting away from a nest (Fig 3 C–D); recent carcass (i.e., not dismembered); and unclassified (i.e., birds whose status was unclear).

For clearer discrimination among the different behavioural classes, a series of closeup photographs (250 mm focal length or more) were analysed and counted with DotDotGoose, using the same behaviour categories as above. These images were much clearer but, unfortunately, did not cover all the colonies. Because there were gaps in coverage, they could not be amalgamated into an overall contiguous series covering all the toroa nesting areas.

For Motuhara, 11 close-up images were analysed. Of the 1453 individuals assessed, 92 were classed as indeterminate, and so were excluded when calculating the proportions of birds in the various behavioural classes. For Rangitautahi and Te Awanui, 17 and 11 close-up images were analysed, covering 1272 and 929 individuals, respectively. Of these, 31 and 21 birds on the Rangitautahi and Te Awanui images, respectively, were judged to be indeterminate and excluded from further consideration.

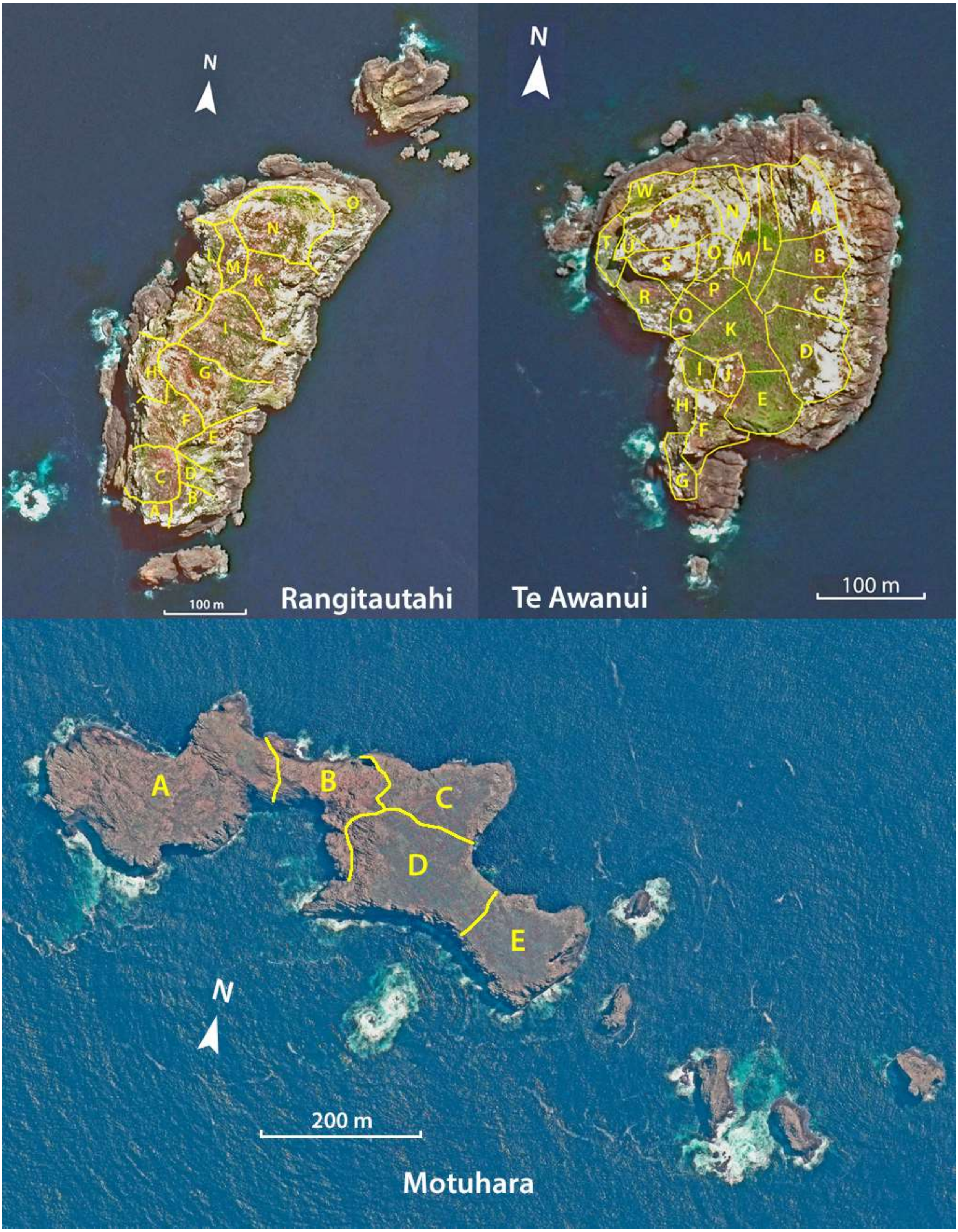

Figure 2. Approximate locations of the partitions on each island in which toroa were counted. In most cases, these marked areas were themselves subdivided and further delineated to cover discrete groups of nesting birds visible in a single aerial photograph. They are not shown here for reasons of clarity. The islands are not shown at the same scale.

Figure 3. The variety of behaviour categories used to classify and count toroa on Motuhara and Rangitatahi. Most birds in these close-up images would be classed as incubating. **A**. A bird on a nest with a partner alongside (circled). **B**. A bird standing on a nest with an egg clearly visible (circled), and so counted as incubating, plus two birds that are largely obscured by vegetation, counted as indeterminate. **C** and **D** show loafing birds (circled), either standing away from a nest (**C**) or sitting on bare rock (**D**). Photographs taken by Jemma Welch.

Analysing the close-up images allowed the activity of the birds present to be assessed more accurately, especially those judged initially to be loafing. In many cases, a bird could be seen standing over an egg (Fig. 3B). These were counted as incubating. In cases where the occupied nest appeared empty, suggesting either that the nesting attempt had failed or had not yet started, the birds were counted as loafers. In some cases, it was difficult to tell unequivocally whether a bird was standing or sitting, especially if partly obscured by intervening vegetation (Fig. 3B) or if a standing bird was facing away from the photographer. In such cases, the birds were classed either as incubating or indeterminate depending on the situation. The total number of birds counted initially in the wide-angle images were then multiplied by the proportions of birds in the various behavioural classes counted in the close-up images (excluding unclassifiable individuals) to provide adjusted figures.

To express the uncertainty in the counts, 95% confidence limits were calculated using the *poisson.exact* function in the R package *exactci* (Fay 2017). These limits correspond to the exact central confidence interval of Garwood (1936), a widely used method for calculating this parameter in a one-sample case. This assumes that the counts follow a Poisson distribution, as Baker et al. (2013) have shown for the White-capped Mollymawk, *Thalassarche steadi*, and applied later to other colonial nesting seabirds (e.g., Baker et al. 2017).

3. Results and Discussion

The analysis of aerial photographs taken of the three islands on 18 December 2020 produced a total of 4174 toroa on land across all behaviour categories (95% CL: 3869–4567, Table 1). Of these, 1782 (42.7%) were counted on Motuhara, 1431 (34.3%) on Rangitautahi and 961 (23.0%) on Te Awanui. The proportion of birds on nests was initially assessed at 88% (Motuhara) to 94–95% (Rangitautahi and Te Awanui). But 116 of the birds counted on Motuhara could not be accurately classified, in contrast to much smaller numbers (3-4) on the other two islands, primarily because the taller and denser vegetation in which the birds on Motuhara were nesting made it difficult to discern their activity. In contrast, the other two islands have much less vegetation to obscure nesting birds, so the number of unclassified individuals was much smaller. Moreover, on all three islands, 4–5% of birds were classed as loafing, but a check of close-up photographs showed at least some of these were standing on nests containing eggs. Consequently, it seemed appropriate to adjust the numbers in each behaviour category based on the proportions of birds in these categories as assessed in the close-up photographs.

The adjusted figures showed that 3994 birds occupied nests (95% CL: 3784–4214)—1696 (42.3%) on Motuhara; 1368 (34.3%) on Rangitautahi; and 930 (23.3%) on Te Awanui (Table 1). Of the remaining 180 birds, 52 (28.9%) were alongside a sitting bird and so were presumably partners, and 128 (71.1%) were either loafing, or pre-breeders exploring future nesting opportunities, or birds in transit to or from an occupied nest.

It was not possible to tell how many of these occupied nests were empty. Fraser et al. (2010) sampled 100 occupied nests on Motuhara during the early incubation period in December 2009 and found that 13% of them were empty. In early December 2016, also on Motuhara, Bell et al (2017) found 121 (8.0%) of 1521 toroa nests had failed (a further 129 nests were empty). Similarly, on Rangitautahi and Te Awanui combined, 6.8% of nests had failed by early December 2017. A further 5.6% were empty (Bell et al. 2018), but it is unclear what proportion of these nests had birds present at the time. If present, these would have been counted as occupied when viewed from the air. Comparing near simultaneous ground and aerial counts made on Rangitatahi in December 2017, the aerial counts of all occupied nests (2130: Frost 2019) were 1.8% higher than the ground counts of birds sitting on eggs (2092: Bell et al. 2018). If these rounded figures of 2% and 13% represent lower and upper bounds on the proportion of occupied nests that do not contain an egg, then the corresponding lower and upper bounds on the estimated number of breeding pairs in December 2020 would be 3475 and 3914 pairs, respectively.

Table 1. Summary of both initial (actual) counts and adjusted numbers, based on the proportions of birds in the various behaviour categories as assessed from analyses of close-up aerial photographs, of Northern Royal Albatross (toroa) on Motuhara, Rangitautahi and Te Awanui surveyed on 18 December 2020. Italicised values in parentheses represent 95% confidence limits of the counts. See text for details.

	Motuhara			Rangitautahi			Te Awanui		
Behaviour	Actual count	*Proportion estimated from close-up photos*	Adjusted number	Actual count	*Proportion estimated from close-up photos*	Adjusted number	Actual count	*Proportion estimated from close-up photo*	Adjusted number
Incubating	1575 *(1482–1655)*	*0.952*	1696 *(1616–1779)*	1351 *(1280–1425)*	*0.956*	1368 *(1297–1443)*	911 *(853–972)*	*0.968*	930 *(871–992)*
Partner of nesting bird	15 *(8–25)*	*0.018*	32 *(22–45)*	11 *(6–20)*	*0.009*	13 *(7–22)*	7 *(2–14)*	*0.007*	7 *(3–14)*
Loafing	76 *(60–95)*	*0.031*	55 *(41–72)*	66 *(51–84)*	*0.035*	50 *(37–66)*	39 *(28–53)*	*0.025*	24 *(15–36)*
Unclassified	116 *(96–139)*		–	3 *(1–9)*		–	4 *(1–10)*		–
Total on ground	1782 *(1646–1914)*		1783[1] *(1679–1896)*	1431 *(1338–1538)*		1431 *(1341–1531)*	961 *(885–1050)*		961 *(889–1042)*
Flying	3		–	0		–	0		–
Carcass	0		–	6		–	0		–

[1] The difference between the original number counted and the sum of the three adjusted categories on Motuhara is due to rounding.

The current count of the number of occupied nests on the three islands is broadly in line with those reported since 2016 (Fig. 4). All recent surveys have produced figures substantially lower than in the period 1989–1995, especially for Motuhara, although the high number of occupied nests there during that period probably partly reflect the high incidence of re-nesting each year, presumably caused by storm-induced nesting failures the previous season (Robertson 1998). Average nesting success in those years was just over 8% (range 2–18%), compared with 54% (range 45–60%) in the mid-1970s and 61% (range 55–67%) more recently in the 2017 and 2018 breeding seasons (Robertson 1998; Frost 2017, 2019). Seven major storms with wind speeds exceeding 140 kph hit these islands between 1985 and 1996, with the hurricane in 1985, in particular, destroying much of the toroa nesting habitat on the islands, especially on Motuhara. Breeding success was also reduced on the other two islands, although not to the same extent as on Motuhara: Rangitautahi—20% compared with 41% in the mid-1970s and 36% more recently; Te Awanui—28% compared with 38% in the mid-1970s and 44% more recently.

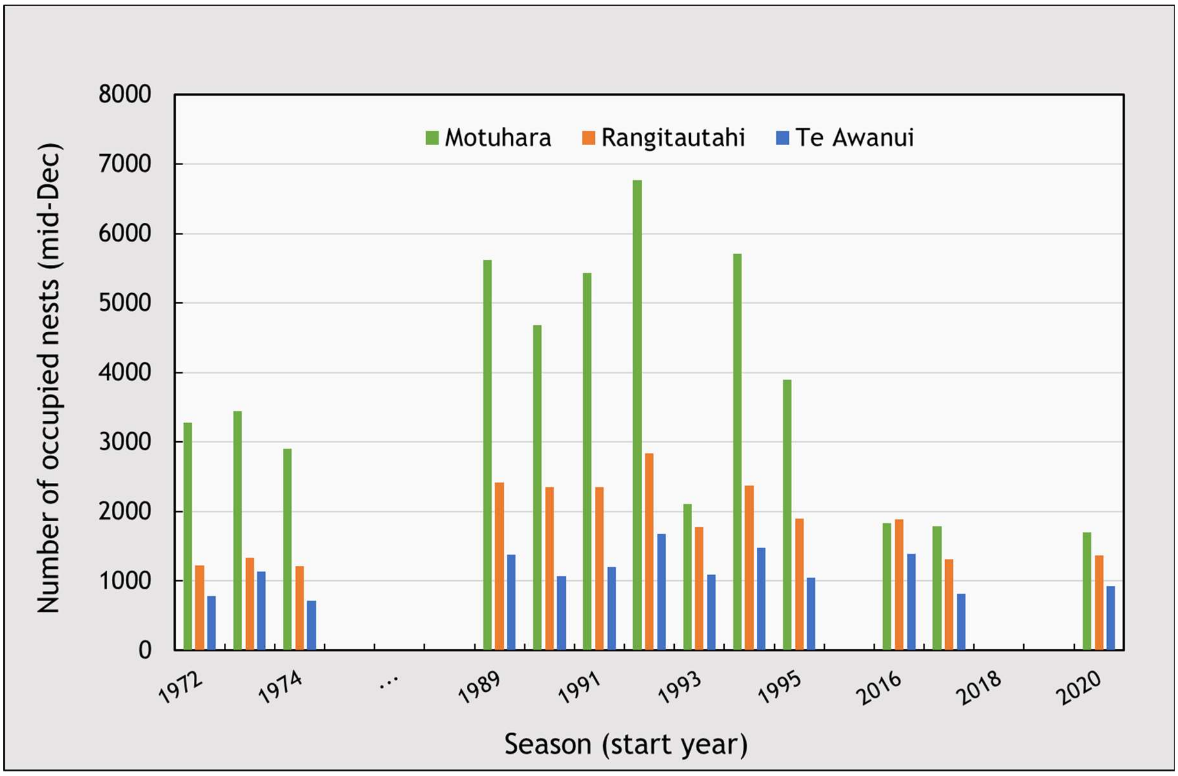

Figure 4. Numbers of Northern Royal Albatross occupying nests on Motuhara, Rangitautahi and Te Awanui over the period 1972–2020. The numbers recorded in earlier years come from Robertson (1998), Baker et al. (2017), Bell et al. (2018) and Frost (2019).

Bell et al. (2018) estimated the total breeding population of toroa on the Chatham Is in 2017 to be 5908 pairs, based on the number of breeding pairs present in December 2017 plus the number of successful breeding pairs from the previous 2016–17 breeding season. Using this approach and allowing for the unknown proportion of birds occupying nests without eggs, the current total breeding population of toroa on the Chatham Is is estimated to be around 6037 pairs (3994 occupied nests plus 2043 pairs successfully fledging a chick in the 2019-20 breeding season: Frost, 2021). This suggests little or no change since 2017.

The current total population of breeding adults is around 37% lower than the average population recorded in the late-1980s and mid-1990s and 24% lower than that estimated for the mid-1970s (Fig. 5). The reduction has been greatest on Motuhara (41% lower than in the mid-1970s; 46% lower than in 1989–1995), but little different from the numbers estimated for Rangitautahi and Te Awanui for the mid-1970s. The current low overall adult breeding population is probably due, at least partly, to the reduced number of chicks fledging in the mid-1980s to mid-1990s, which would have resulted in fewer recruits to the breeding population a decade or more later (Fig. 5).

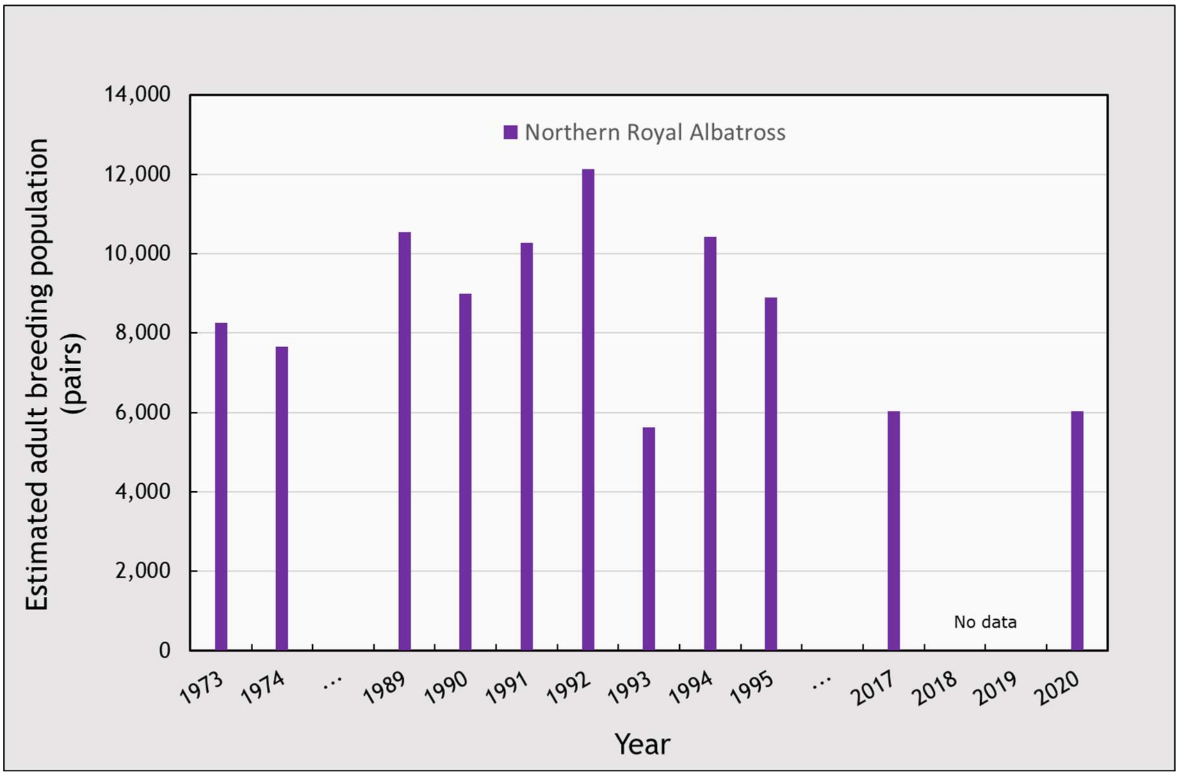

Figure 5. Total adult Northern Royal Albatross (toroa) breeding population over the past 47 years, estimated from counts of the number of pairs occupying nests in one year plus the number of pairs successfully fledging chicks the previous season (see Bell et al. 2018 for a discussion of this measure). Data compiled from Robertson (1998), Baker et al. (2017), Bell et al. (2018), Frost (2019, 2021), and the present report.

These results and conclusions serve to emphasise again the importance of long-term monitoring of long-lived, late-maturing, slow-reproducing species such as toroa if their longer-term dynamics are to be understood and predicted.

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Appendix 1

A1.1 Flight details

Overall, 19 and 29 minutes, respectively, were spent flying around Motuhara and Rangitatahi (surveying both Rangitautahi and Te Awanui). The time devoted to photographing the colonies was relatively short, however, around 5.0 min at Motuhara, 2.4 min at Rangitautahi and 1.8 min at Te Awanui, based on the sum of the time intervals between the first and last image taken on each flypast. The average duration of these flypast times is given in Table A1.

Table A1. Mean aircraft altitude, airspeed and the number and duration of flypasts of each island as determined from the GPS track of the 18 December 2020 aerial survey of the islands. These measurements are limited to those sections of the flight path that parallel the islands when the aircraft was in relatively level and straight flight.

Island	N	Altitude (m)		Airspeed (knt)		Flypast duration (s)		
	(from GPS)	Mean	*S.D.*	Mean	*S.D.*	Mean	*SD*	N
Motuhara	251	260	*39.1*	111	*5.2*	30	*10.2*	10
Rangitautahi	183	207	*23.9*	109	*4.5*	14	*2.0*	10
Te Awanui	143	209	*29.2*	109	*5.1*	14	*0.6*	8

A1.2 Photographic procedures

Photographs were taken using two cameras, one intended to take landscape-scale views of the colonies, the second to take close-up photographs of the colonies or sections of them. Unfortunately, the first camera (Canon EOS 77D) was fitted with an SD card with limited capacity and so, after Motuhara, could not be used to photograph the colonies at Rangitautahi and Te Awanui because the card was full. The second camera (Canon EOS 1000D) therefore had to be used for both purposes, with additional circuits being flown around the two islands to take the wider landscape photographs. A total of 329 images of the islands and colonies were available for analysis (Table A2), although at least 38 of the landscape-scale images of Motuhara were taken too far away, showing the whole island (including in some cases its stacks), but lacking sufficient detail to be useful for delineating the colonies or counting the birds in them.

The Exif data for each image—date and time when it was taken; camera make and model; shutter speed, aperture setting, ISO number and lens focal length—were extracted using Picture Information Extractor 6.99.10.61 (Picmeta Systems, http://www.picmeta.com). All images were taken with shutter speed priority, allowing the photographer to select the shutter speed with the aperture being adjusted automatically (i.e., automatic exposure lock on). Shutter speeds were set at just 1/1024s (70%) and 1/1328s (30%), resulting in more than 90% of images being taken at aperture values of F14-F20, producing more than sufficient depth of field.

Table 2. Cameras and shutter speed settings used, and number of images taken during the aerial survey of Northern Royal Albatross nesting on Motuhara and Rangitatahi islands, 18 December 2020.

Camera	Lens	Island	Shutter speed	Images
Canon EOS 77D	EF-S18-135mm f/3.5-5.6 IS USM	Motuhara	1/1328s (100%)	75
Canon EOS 1000D	EF75-300mm f/4-5.6	Motuhara	1/1328s (22%) 1/1024s (78%)	113
		Rangitautahi	1/1024s (100%)	81
		Te Awanui	1/1024s (100%)	60

Across all islands, 34% of images were relatively wide angle, taken at 115 mm focal length or less (including those taken of Motuhara as a whole), 29% were taken at 115–215 mm focal length, and the balance (37%) at 275–300 mm. In general, these would be ideal but, in this case, the suitability of many of these images for counting nesting birds was compromised because of the long distance between the point from which the images were taken and their focal points on the islands (Fig. A1).

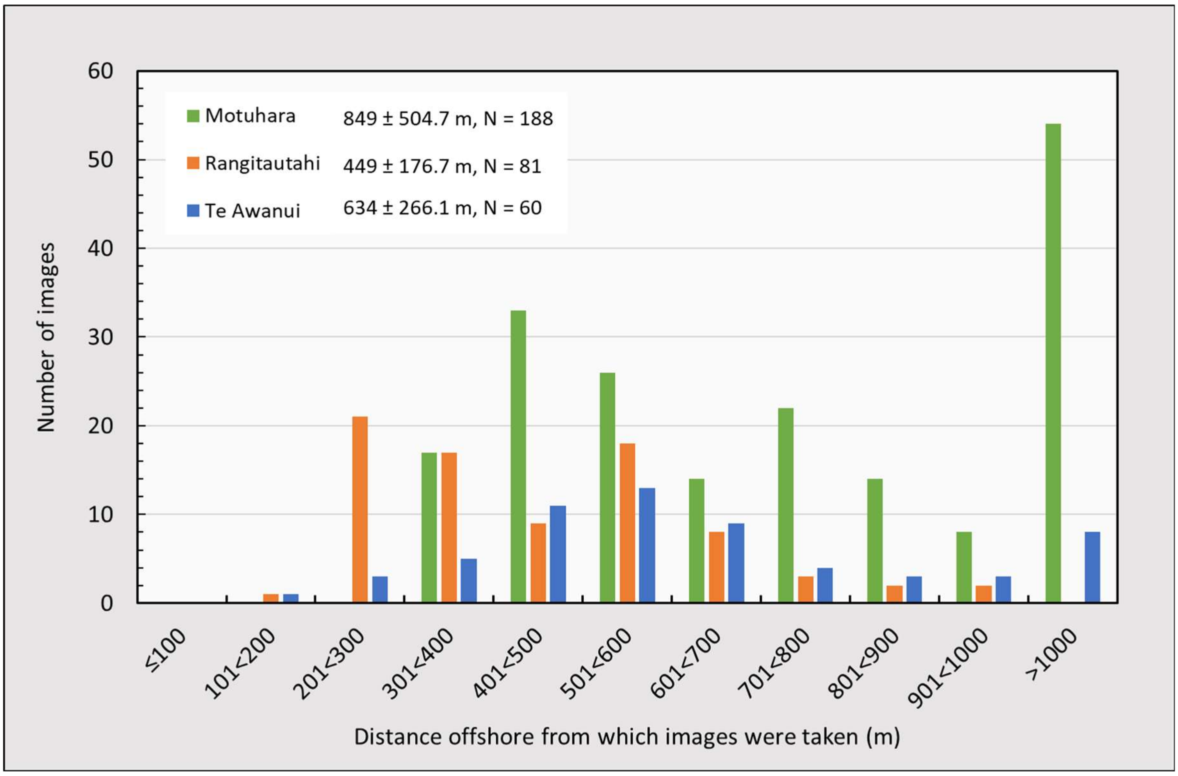

Figure A1. Frequency distribution of the distances offshore from which photographs were taken. Mean distances (± 1 S.D.) are shown, emphasising just how far from the islands some of these were taken. See text for further details.

The distance offshore from which each photograph was taken was calculated using the QGIS plugin NNJoin. For each island, this calculates the distance between individual image positions, based on their NZTM2000 grid coordinates, and the nearest point on a vector tracing the edge of an island's plateau. The locations from where the images were taken were estimated, first by determining the offset in time between GPS track times and the images, using the time stamps on photographs, then using these corrected times to geotag the images with the coordinates from the GPS track at the corresponding times.

Two features of this analysis make these distance measurements conservative. First, the edges of the plateaux were seldom the focal points of each image; those usually lay further away. Second, as can be seen from the positions from which the images are estimated to have been taken relative to the locations of the islands (Fig. 1, main text), most images were taken looking forward rather than at right angles to the aircraft's direction of flight, which lengthened the distance relative to points of closest approach to the colonies.

A1.3 Improving image quality

Frost (2021) made various recommendations for improving image quality, based on an assessment of the flight and photographic parameters of the aerial survey of toroa chicks on Motuhara and Rangitatahi in September 2020. The same recommendations apply here, perhaps even more so, although the limitation of having only one camera to photograph the colonies on Rangitautahi and Te Awanui must be acknowledged. The outcomes and assessments may have been different had two cameras been available.

The following comments and suggestions are made without any implied criticism, recognising the difficulties of carrying out such surveys when time is short and flight parameters (airspeed, elevation, distance offshore from the islands) are determined by the pilot, for whom air safety concerns are paramount.

1. Landscape-level photographs need to show sufficient detail on the ground to allow the islands to be partitioned entirely into discrete, contiguous areas. Whereas this was just possible with the images taken, there was often minimal overlap between adjacent areas (two areas on Rangitautahi only just abutted on two separate photographs, and a small section on the same island was missed in the landscape-scale photographs but, fortunately, it was found in one of the close-up photographs).

2. Landscape-level photographs need to be taken closer to the islands, and from a more perpendicular angle than the mostly distant and oblique-angled images that dominated the present set. Many of the images taken of Motuhara were too far away to be useful.

3. Close-up photographs of the colonies need to show individual birds sufficiently clearly to allow them to be identified, classified and counted, and yet together still cover the whole area. The quality of the close-up photographs taken in December 2020 was generally high, making it easy to identify, classify and count individual birds, but the images did not cover all of each colony.

4. Compared with earlier surveys (other than September 2020), the number of photographs taken was relatively small (291 usable images). In part, this was because one of the cameras did not have sufficient capacity on its SD card to photograph more than just Motuhara. This undoubtedly added to the pressures on the second camera and photographer, who had to take both close-up and wide-angle (landscape) photographs of Rangitatahi. In earlier surveys, the number of images taken overall—two cameras—have ranged from 583 to 1179 (average 886 ± 244, N = 4). Whereas these numbers resulted in considerable duplication of views, they had the merit of providing a choice of views from which the best combinations could be selected for analysis. Taking more photographs, regardless of duplication (but aiming for a range of viewpoints and overlaps) would help reduce uncertainty in the analysis and counts.

5. Taking more images means having memory cards with sufficient capacity to store the images. This can easily be achieved with a 64Gb SD, SDHC or SDXC card (300 images taken with the Canon 77D requires only around 10 Gb of memory; the same number of images taken with the Canon 1000D, which has a lower sensor resolution, need just 3.3 Gb of memory). Perhaps two dedicated 32 or 64 Gb cards should be supplied solely for use on these aerial surveys, so that the photographers, who may be using their personal cameras, are not constrained by limited card capacity.

6. If possible, subject to discussion beforehand with the pilot, airspeed should be reduced, and tighter turns taken around the islands. The time spend actually photographing the islands, as a percentage of the total time spent flying around the islands, was only about 26% on Motuhara and 14% at Rangitatahi. Decisions of this nature are clearly the responsibility of the pilot, who must put air-safety concerns foremost, but could be informed by pre-flight discussions about the objectives and ideal requirements of the survey.

Appendix 2

A2.1 Initial counts, mainly from wide-angle images

Numbers of Northern Royal Albatross (toroa) counted on aerial photographs taken on 18 December 2020, reported for the various count zones delineated on the islands (see Fig. 2 in the main text for the approximate boundaries of these areas). The 95% confidence limits of the area counts, as well as the images used in this analysis are also listed. 'Loafing' is a general category encompassing individual or pairs of pre-breeders scouting for nest, birds in transit to or from a distant nest, and genuine loafers.

A. Motuhara

Area	On nest	Partner	Loafing	Uncertain	Total on ground	LCL	UCL	Images
A	105	3	7	3	118	84	162	IMG-7752/3/4/5
B	0	0	0	0	0	0	0	IMG-7540/63
C	518	7	35	30	590	493	702	IMG-7589/91
D	654	3	24	60	741	592	879	IMG-7580/9, 6047/9, 7580
E	298	2	10	23	333	257	430	IMG-7578
Totals	1575	15	76	116	1782	1426	2173	

B. Rangitautahi

Area	On nest	Partner	Loafing	Uncertain	Total on ground	LCL	UCL	Image
A	35	0	4	0	39	28	53	IMG_6120
B	10	0	2	2	14	8	24	IMG_6120
C	149	1	6	1	157	133	184	IMG_6123
D	5	0	0	0	5	2	12	IMG_6119
E	6	0	0	0	6	2	13	IMG-6118/69, 6235
F	81	0	6	0	87	70	107	IMG-6112/3/8
G	164	1	2	0	167	143	194	IMG_6118
H	6	0	0	0	6	2	13	IMG_6113
I	272	1	10	0	283	251	318	IMG-6117/8, 6233
J	3	0	0	0	3	1	9	IMG_6159
K	201	3	10	0	214	186	245	IMG-6116/7, 6232
L	7	0	0	0	7	3	14	IMG_6224
M	141	2	7	0	150	127	176	IMG-6126/7, 6225
N	271	3	19	0	293	260	329	IMG-6115/6
O	0	0	0	0	0	0	0	IMG_6115/6
Total	1351	11	66	3	1431	1216	1691	

C. Te Awanui

Area	On nest	Partner	Loafing	Uncertain	Total on ground	LCL	UCL	Image
A	35	0	1	0	36	25	50	IMG-6191/2
B	47	0	5	2	54	41	71	IMG_6192
C	36	1	3	0	40	29	55	IMG_6193
D	99	0	4	0	103	84	125	IMG_6185
E	114	0	3	2	119	99	142	IMG_6185
F	1	0	0	0	1	0	6	IMG-6185/96
G	1	0	0	0	1	0	6	IMG-6173/96
H	27	1	0	0	28	19	41	IMG_6173
I	40	2	4	0	46	34	61	IMG_6174
J	20	0	0	0	20	12	31	IMG_6174
K	203	0	9	0	212	184	243	IMG-6174/5
L	52	0	2	0	54	41	71	IMG_6178
M	51	1	2	0	54	41	71	IMG-6204/7
N	1	0	0	0	1	0	6	IMG_6206
O	12	0	0	0	12	6	21	IMG_6185
P	48	1	0	0	49	36	65	IMG_6185
Q	34	0	1	0	35	24	49	IMG_6175
R	17	0	0	0	17	10	27	IMG_6244
S	21	0	1	0	22	14	33	IMG_6175
T	0	0	0	0	0	0	0	IMG_6244
U	9	0	1	0	10	5	18	IMG-6175, 6245
V	43	1	3	0	47	35	63	IMG-6175/6
W	0	0	0	0	0	0	0	IMG-6245
Total	911	7	39	4	961	739	1255	

A2.2 Classified counts made from close-up images

Numbers of Northern Royal Albatross (toroa) counted and classified on close-up images taken on 18 December 2020 from which the proportions of birds in each category were calculated. These were used to adjust the original numbers of birds counted in these categories overall.

A. Motuhara

Area	Incubating	Partner	Loafing	Uncertain	Image
A1b(part)	38	0	3	0	IMG_6059
A3	25	0	1	0	IMG_6038
C2ab-3(part)	54	1	2	2	IMG_6018
C2b (part)	34	0	0	2	IMG_6016
C3-D3 (part)	149	1	4	16	IMG_6019
D2-3	219	3	6	25	IMG_6003
D3	142	6	4	11	IMG_6002
D3cb-C1,3 (parts)	291	5	8	29	IMG_6054
E1-2	179	2	4	4	IMG_6000
E1a, b (ii)	77	1	5	0	IMG_6022
E3-1ai	87	5	5	3	IMG_6023
Total	1295	24	42	92	
Proportion	0.952	0.018	0.031	-	

B. Rangitautahi

Area	Incubating	Partner	Loafing	Uncertain	Image
A	41	1	2	0	IMG_6154
B (part)	27	0	1	0	IMG_6138
C1 (part)	86	0	3	3	IMG_6137
C1 (part)	38	0	2	0	IMG_6139
F2	15	0	1	0	IMG_6140
F3	66	0	2	0	IMG_6136
G1 (upper end)	65	0	1	2	IMG_6141
G1/H/I1 upper	125	2	3	6	IMG_6142
I1 (upper)	60	1	3	2	IMG_6135
I1/G	97	1	10	0	IMG_6152
I2 (lower)	67	1	1	0	IMG_6151
I2/K1/M1 junction	66	0	2	2	IMG_6134
K2	63	1	0	0	IMG_6133
K2/M1 (part)	119	2	6	6	IMG_6150
mostly N2 (west)	165	2	6	10	IMG_6145
N1/K2 (east end)	46	0	0	0	IMG_6132
N1/N2 (east end)	40	0	1	0	IMG_6131
Total	1186	11	44	31	
Proportion	0.956	0.009	0.035	-	

C. Te Awanui

Area	Incubating	Partner	Loafing	Uncertain	Image
A/B	60	0	4	2	IMG_6192
B/C	161	0	7	5	IMG_6193
D/K (part)	116	1	3	1	IMG_6194
E	55	0	2	3	IMG_6197
E/K/J	90	0	1	2	IMG_6214
F (part)/H	19	1	1	0	IMG_6200
I/K(part)	58	2	1	0	IMG_6201
K/P/Q	179	1	1	5	IMG_6213
M1/N1/P/O	69	0	0	1	IMG_6189
S/P/Q (parts)	48	0	2	2	IMG_6202
V2	24	1	1	0	IMG_6203
Total	879	6	23	21	
Proportion	0.968	0.007	0.025	-	