Numbers of Northern Royal Albatross chicks and Northern Giant Petrel adults on the Chatham Islands, September 2020

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Cover image

Northern Royal Albatross chicks and Northern Giant Petrel adults on Motuhara, September 2020 (Canon EOS 1000D, FL 280 mm, f/20, 1/1000s)
(photograph taken by Nicola Tuanui)

Summary

1. An aerial photographic survey of Northern Royal Albatross or toroa, *Diomedea sanfordi*, and Northern Giant Petrel *Macronectes halli* colonies on Rangitautahi and Te Awanui (both islands in the Rangitatahi/Sisters group) and Motuhara was carried out on 14 September 2020. These colonies hold, respectively, >99 % and ~17.5 % of the global populations of these two species.
2. A total of 250 photographs were taken during the flight, from which counts of both species were made in defined sections wholly covering each island. These counts and the survey procedures are compared with those from previous surveys, helping both to assess long-term trends and improve future surveys.
3. Of the 1814 toroa counted on the islands, 1798 (95% CL: 1716—1833) were classed as chicks, most on the point of fledging. Assuming that fledging started in early September, a few toroa chicks had probably already fledged. Data on the phenology of toroa fledging at Taiaroa Head, Otago Peninsula, was used to correct the number of fledglings present at the start of fledging to ~2043 (95% CL: 1950–2083). This is similar to the 2149 fledglings recorded in 2017/18 for the same reproductive cohort of this biennial breeding species.
4. Counts of Northern Giant Petrel were uncertain: 1799–2251. Comparisons with previous surveys are complicated by differences in the timing of the counts relative to the phenology of breeding but, overall, the counts suggest a broadly stable trend.
5. Compared with earlier surveys, this one was marked by fewer and wider circuits of the islands, higher average airspeeds, and fewer photographs, mostly taken at focal lengths <100 mm. This reduced image quality, adding to the uncertainty of the counts.
6. Uncertainty could be reduced if future surveys were more standardised, with optimal airspeeds around 75–80 knt (about 140–180 kph), more circuits (ideally 6-10 around each island) and more circular flight paths, preferably 250–400 m offshore at altitudes of 250–350 m (820–1150 feet), obviously contingent on air-safety considerations. This would provide more vertical views of the islands and clearer views of the nesting birds. More images (ideally >500), both medium-scale (focal length: 75–135 mm) and close-up (FL 200–300 mm), with greater overlap across successive views, would provide more choice among those images selected for analysis. Some discussion on this and how to improve image quality is given in an appendix.

Frontispiece. Landscape-level view of Areas D1-2 on Motuhara (top) and intended close-up view of the same area (bottom), illustrating the general nature of the images analysed in this study (photographs taken by Gemma Green and Nicola Tuanui, respectively).

Introduction

About 99 % of the world population of Northern Royal Albatross or toroa, *Diomedea sanfordi*, breeds on three outlying islands in the Chatham Islands: Rangitautahi (Big Sister) and Te Awanui (Middle Sister) in the Rangitatahi group (The Sisters), and Motuhara/Motchuhar (The Forty-Fours). The only other colony is a tiny one, less than 40 pairs, at Taiaroa Head, Otago Peninsula. The species breeds biennially, with a breeding cycle, from incubation to fledging, taking 10.5 months. Birds that successfully rear a chick in one year have no time to recover physiologically to breed again the following season.

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

These islands are also key breeding sites for the Northern Giant Petrel, *Macronectes halli*, in New Zealand. 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 by considering the number of apparently recently failed nests, yielded an estimate of 2,133 breeding pairs on these islands: Motuhara, 1977 pairs in December 2016 (Bell et al. 2017); Te Awanui, 110 pairs, and Rangitautahi, 46 pairs, both in December 2017 (Bell et al. 2018). A further c. 234 pairs bred on Campbell Island in 1996–97 (Wiltshire & Scofield, 2000); c. 233 pairs bred on Antipodes Island in 1999–2000 (Wiltshire & Hamilton, 2003); and c. 340 pairs on the Auckland Islands in 2014–2015 (Parker et al., 2016), all extrapolated from counts of chicks with allowances made for prior nest failures. The total New Zealand population is therefore c. 2940 pairs, just under 25 % of the estimated 12,170 breeding pairs of this species globally (ACAP 2010, adjusted for more recent population assessments). The Chatham Is populations constitute around 17.5 % of this global number.

This report details the counts of Northern Royal Albatross fledglings and adults, as well as Northern Giant Petrel adults, visible on aerial photographs of Rangitautahi, Te Awanui and Motuhara taken in mid-September 2020. After adjusting for differences in seasonal timing, these counts are then compared with those from previous surveys to assess if there are any noticeable trends. The report concludes with an assessment of some practical aspects of the survey procedures.

Study area

Rangitatahi (The Sisters), centred at 43.5642°S, 176.8075°W, 20 km due north of Rēkohu (Chatham Main I.), 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. The islands are of volcanic origin, comprising massive limburgitic basalt with associated deposits of breccia, scoria, and tuff (Campbell *et al*. 1988). The soils on the two higher-lying islands are generally thin and support only sparse vegetation other than in basins on the plateaus, where the Chatham Island button daisy, *Leptinella featherstonii*, and a groundsel *Senecio radiolatus*, are well established. The button daisy apparently thrives on nutrient inputs from nesting seabirds.

Motuhara (called Motchuhar by Moriori, and previously known as The Forty-Fours), centred at 43.9622°S, 175.8347°W, is an 11.5-ha, 60-m high island lying 42 km east of Rēkohu. In contrast to the volcanic origin of Rangitatahi, Motuhara consists predominantly of hard, fine- to medium-grained, partly recrystallised quartzofeldspathic sandstones or feldsarenites (Andrews *et al*. 1978). It is the most easterly outcrop of Mesozoic basement rocks in New Zealand. The soils are patchy and generally thin, supporting a mixture of open herb-fields and low-growing shrubland dominated by the Chatham Island button daisy, mostly concentrated in the middle and south-east sections of the central plateau.

Methods

Aerial survey

The survey was carried out from an Air Chathams Cessna 206 on 14 September 2020 between 12h17 and 13h26, during a narrow window of suitable weather within what was otherwise a prolonged preceding spell of unfavourable weather. Conditions at the time were clear and sunny with a moderate NW wind (Beaufort Force 2-3, 4–10 knots, judging from the sea state visible in some of the images).

The flight path was recorded by GPS (Garmin 64s), and the camera times synchronised at the start of the flight with that shown on the GPS. This allowed the approximate positions from which the images were taken to be calculated by geo-tagging them using the recorded location of the aircraft at the corresponding time shown on each image.

Time spent circling and photographing Rangitatahi and Motuhara was short: 7.5 min and 14.5 min, respectively. At Rangitatahi, both Rangitautahi and Te Awanui were circled in the same wide circuit, rather than each island being surveyed separately as had been done on previous occasions (Fig. 1). As a result, the east coast of Rangitautahi and the west coast of Te Awanui were only visible in the background of a few images, resulting in poorly resolved views of these coasts. These two coasts normally have no more than a few nesting toroa along their upper edges, so the final count for this species is unlikely to be greatly affected. In contrast, Northern Giant Petrel numbers are probably underestimated to a greater degree because, from past surveys, several pairs occur along the upper edges of these two coasts.

Apart from the relatively high airspeed, the aircraft's flight paths were some distance from the islands (Fig. 1). The QGIS plugin NNJoin was used to measure the distance from where individual photographs were taken to the nearest point on a vector tracing the edge of an island's plateau. This distance is only approximate, however, because of the time lag between the GPS registering the aircraft's position and the actual location from where the photographs were taken.

Assessed this way, the average image distances (± 1 sd; range) were: Rangitautahi, 642 (235; 210–1134) m; Te Awanui, 681 (92; 361–896) m; Motuhara, 728 (385; 172–1781) m. On 18% of occasions, the flight paths around Rangitautahi and Te Awanui were within 500 m of the islands, whereas around Motuhara, 32% of images were taken within 500 m. Airspeed, altitude and distance from the islands all influence the level of detail discernible on the resulting images.

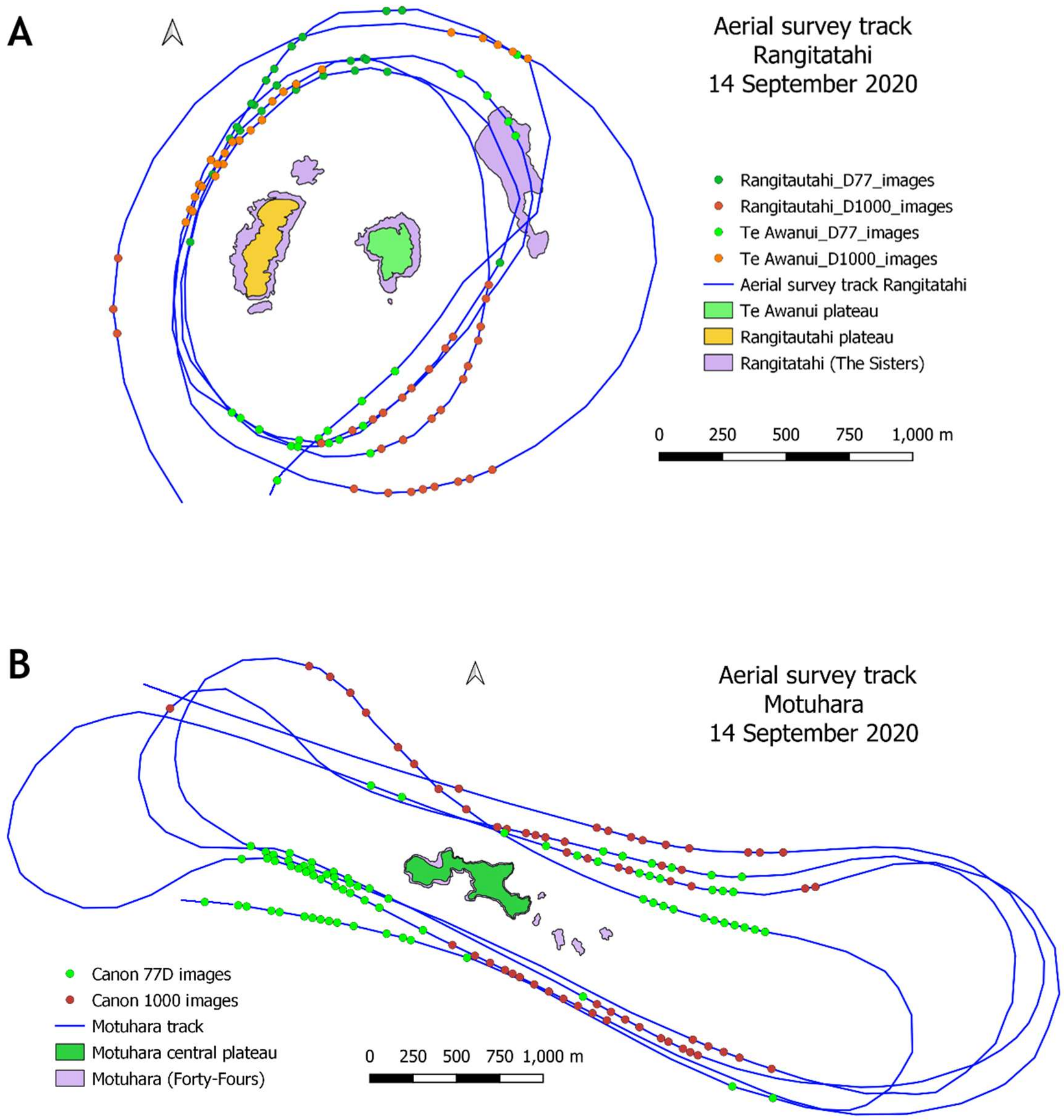

Figure 1. Flight paths flown during the September 2020 aerial survey of Northern Royal Albatross colonies: A. Rangitatahi (The Sisters), 5 circuits; B. Motuhara (The Forty-Fours), 4 circuits.

Other details of the flight around the islands are given in Table 1. Average airspeed and altitude were calculated only for relatively straight sectors of the flights around the islands (deviation in heading <5° in either direction), to avoid the distortions introduced when calculating airspeed from successive GPS readings of a turning aircraft. With the more circular paths flown around Rangitatahi, there were many fewer relatively straight sectors (21) than around Motuhara (102).

Table 1. Times, average airspeeds and altitudes flown during the 14 September 2020 aerial survey of Northern Royal Albatross colonies

Island group	Start	End	Survey time (min:s)	Mean airspeed (±1 SD), kph	Mean altitude (±1 SD), m a.s.l.
Rangitatahi	12:29:20	12:37:00	7:30	182.7 (23.5)	217.9 (9.5)
Motuhara	12:56:30	13:11:00	14:30	197.0 (30.6)	224.6 (38.7)

Image processing

A total of 250 photographs were taken using two cameras: 59 of Rangitautahi; 46 of Te Awanui; and 145 of Motuhara. Particulars of the cameras and settings used are summarised in Table 2. Both cameras were set on automatic focusing with a comparatively high ISO number, high pre-selected shutter speeds and shutter priority, to counter the aircraft's relatively high airspeed. Changes in lighting were compensated for by automatic adjustments to the aperture setting, but given the high ISO number, these all produced reasonable depths of field (see Frontispiece for an example).

Table 2. Cameras and settings used during the September 2020 aerial survey of Northern Royal Albatross colonies. Shutter speed and ISO number were fixed, and aperture allowed to vary depending on lighting conditions

Camera	Lens	Shutter speed	ISO	Aperture	Focal length
Canon EOS 77D	EF-S18-135mm f/3.5-5.6 IS USM	1/1579 s	1600	F3.5-F20	18–135 mm
Canon EOS 1000D	EF75-300 f/4–5.6	1/1024 s	1600	F9–F29	75–280 mm

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). The time stamp on a photograph taken of the time showing on the GPS at the start was checked against the image's Exif details to confirm that the times were synchronous.

Images were received in Canon RAW format and, after some initial processing using Digital Photo Professional 4 (v.4.12.60), mainly to correct colour balance, they were converted to JPEG format. 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 bring out as much detail as possible without introducing confusing artefacts. This level of processing was necessary to correct for the relatively low resolution of most birds when enlarged.

Almost 95% of the images were taken at focal lengths of 135 mm or less. Those taken at longer focal lengths were sporadically distributed. Given the distance offshore from where most photographs were taken, this proved to be a constraint, as the birds visible in most images were not well resolved when examined closely (e.g., in trying to distinguish adult albatrosses from late-stage fledglings). The smaller and darker Northern Giant Petrels were also often difficult to pick out especially among similar-coloured rocks.

Image analysis

Images from each island were collated and subsets chosen that, together, covered all of the island concerned. Within these subsets a series of discrete, contiguous (non-overlapping) areas were identified and outlined, using prominent common features visible in adjacent images—rocks, fissures, distinctly shaped bare areas, or conspicuous clumps of vegetation—as boundary markers. Where a boundary line passed close to a bird, care was taken to ensure that it was properly included or excluded in the demarcated zone on both images, to avoid it being double-counted or left out. It was not possible to demarcate exactly the same zones as used in earlier surveys. Those delineated in this survey are shown in Fig. 2.

All birds seen in each zone were counted and catalogued using DotDotGoose v.1.5.1 (Ersts 2020). Individuals were classed as follows: toroa chick; toroa adult; toroa carcass; toroa uncertain; Northern Giant Petrel (NGP) adult; NGP uncertain. It was usually not possible to distinguish adult toroa from late-stage fledglings. Features used in earlier surveys, such as differences in bill colour (pink in adults, pale grey in chicks), could not be discerned consistently because of the distance from which the images were taken. Consequently, the only birds classed as adult toroa were those seen approaching a chick that was begging (stretched out head and neck), feeding a chick or standing tall immediately next to one.

For Northern Giant Petrel, many determinations were uncertain, especially for birds among similar-coloured rocks and concealing vegetation. For identified individuals, the distinguishing features used, other than body shape and colour, were obviously pale bills and, sometimes, faces.

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

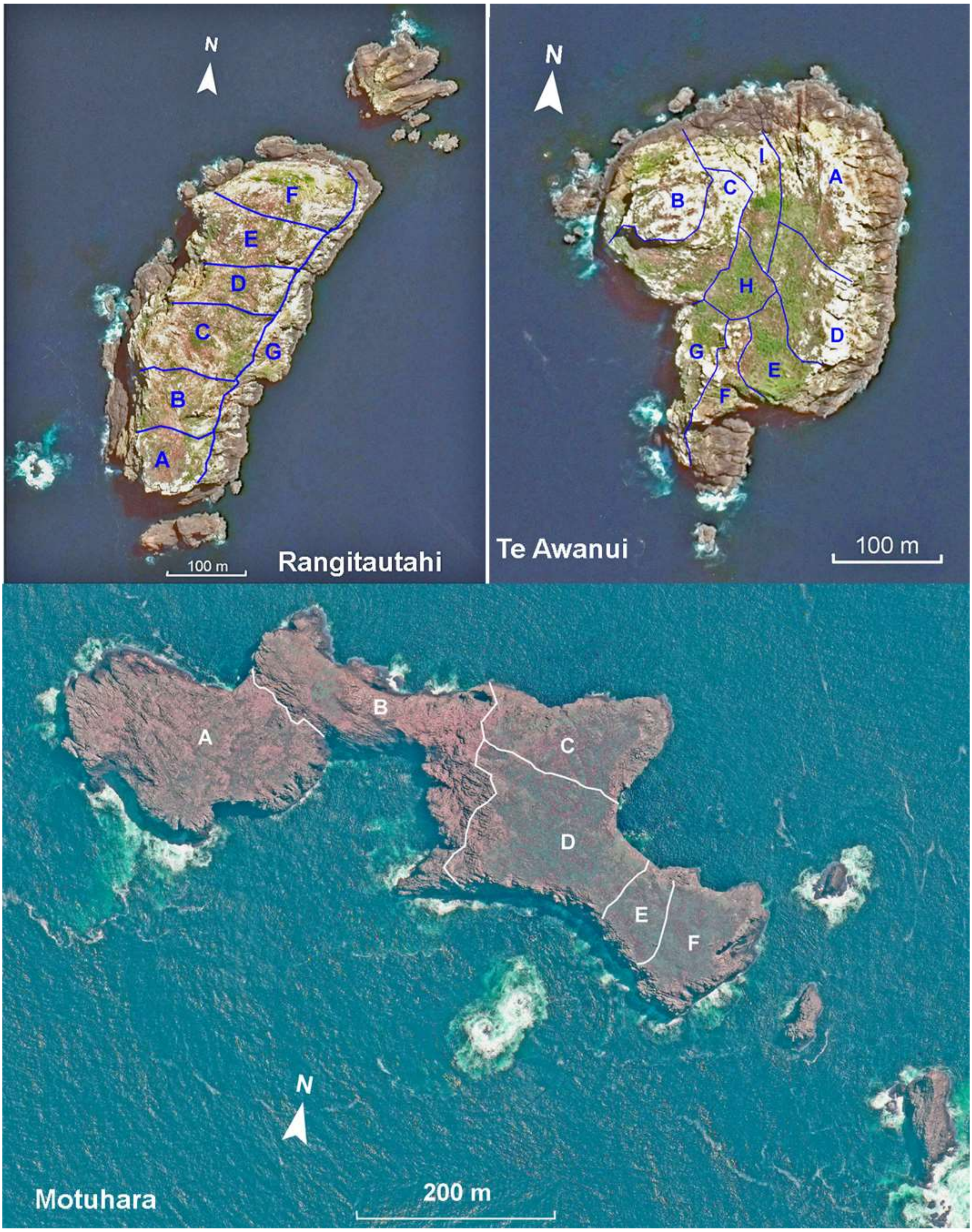

Figure 2. Location of the count zones demarcated on each island on the September 2020 images, within which the numbers of Northern Royal Albatross and Northern Giant Petrels were tallied separately.

Results

Northern Royal Albatross

A total of 1798 Northern Royal Albatross (toroa) fledglings (95% CL: 1716–1883) were counted across all three islands (Table 3). A further 16 birds were identified as adults along with 25 reasonably recent carcasses (whole birds, not dismembered). Another 29 white objects, obscured by vegetation or among pale rocks, were identified as possible toroa, but they could also have been pale, guano-daubed rocks. They constituted only 1.6 % of the identified toroa (all classes) and are not considered further.

Table 3. Numbers of Northern Royal Albatross (toroa) adults, fledglings and carcasses, and undifferentiated adult/sub-adult Northern Giant Petrel (NGP) counted in the various demarcated zones on Rangitautahi, Te Awanui and Motuhara on images taken on 14 September 2020. The locations of these zones are shown in Figure 2.

Island	Area	toroa adults	toroa fledglings	toroa carcass	toroa uncertain	NGP	NGP uncertain
Rangitautahi	A	0	46	0	1	24	2
	B	0	21	0	0	47	8
	C	1	69	1	1	32	12
	D	0	70	1	0	4	10
	E	0	93	2	1	4	9
	F	2	127	2	0	6	8
	G	0	0	0	6	0	0
	Total	4	425	6	9	125	41
	95% CL	*1–10*	*386–467*	*2–13*	*4–17*	*104–149*	*29–56*
Te Awanui	A	1	45	0	1	5	0
	B	1	16	0	0	2	0
	C	0	39	0	1	5	4
	D	0	57	1	0	6	0
	E	0	46	0	0	7	0
	F	0	11	0	0	43	16
	G	0	19	1	0	2	0
	H	0	55	1	0	10	0
	I	0	27	0	0	7	0
	Total	2	314	3	2	88	20
	95% CL	*0–7*	*280–351*	*1–9*	*0–7*	*71–108*	*12–31*
Motuhara	A	1	51	0	4	44	0
	B	0	5	0	0	52	0
	C	6	247	2	14	413	127
	D	3	567	7	1	229	9
	E	0	52	1	1	274	47
	F	2	130	5	5	426	107
	Total	10	1059	16	18	1586	391
	95% CL	*5–18*	*996–1125*	*9–26*	*11–28*	*1509–1666*	*353–432*
Overall total		16	1798	25	29	1799	452
95% CL		*9–26*	*1716–1883*	*16–37*	*19–42*	*1717–1884*	*411–496*

All but a few toroa seen clearly on Rangitautahi and Te Awanui were close to fledging. Disregarding posture (sitting on their tarsi or exercising their wings) and accepting that bill colour could not be confidently determined as a feature distinguishing grey-billed fledglings from pink-billed adults, most of the fledglings resembled adults. A few birds still had some down feathers protruding from their scapulars and were therefore clearly fledglings. These were not listed separately because this feature could not be recorded consistently.

In contrast, some fledglings seen on Motuhara were still at a late-downy or residual down stage of feather development (see Frost 2019, Annex 1, for images and brief descriptions of these classes). These birds were also not listed separately because the stages of plumage development could not be determined reliably across all the birds viewed. Most fledglings, however, were similar to those seen on the other two islands.

The numbers of toroa fledglings present were 15–16 % lower than the counts of fledglings in the same colonies in late-July 2017, about 6 weeks before the start of fledging, and in late-August 2018, around 2 weeks before fledging (Table 4). This suggests that some birds had already fledged, but we do not know how many. The phenology of fledging on the Chatham Islands is unknown but chicks at the tiny colony at Taiaroa Head, Otago Peninsula, start fledging in early September (Sugishita 2013), the same time as has been assumed for the Chatham Is birds. The departure dates of the fledglings at Taiaroa Head have been recorded for many years and so may provide some insight into the broader time course of fledging.

The cumulative number of birds fledging through a season at Taiaroa Head, based on data for the last four seasons, 2016/17 – 2019/20, is shown in Fig. 3. The overall pattern is sigmoid, as might be expected, with a few individuals fledging early (the earliest was 6 September) and a few fledging late (the latest on 23 October). According to these data, by 14 September, just over a week after fledging started at Taiaroa Head, around 12 % of chicks had fledged. If the same proportion had fledged by then from the Chatham Is colonies—assuming that fledging had started on the same date—then the remaining 1798 fledglings represented ~88% of the initial number present at the start of fledging: 2043 chicks.

Several caveats must be applied to this extrapolation, however. The chicks at Taiaroa Head are managed through fostering, supplementary feeding, fly control and alleviation of heat stress, all aimed at maximising the birds’ chances of survival (Robertson 1998). These measures could affect growth rates and fledging times. Moreover, the birds nesting at Taiaroa Head may not be on exactly the same schedule as those on the Chatham Is. In the absence of any other data to indicate approximately what proportion of the birds on the Chatham Is had already fledged by mid-September, however, this extrapolation seems reasonable and allows the counts to be compared broadly with those made in earlier years.

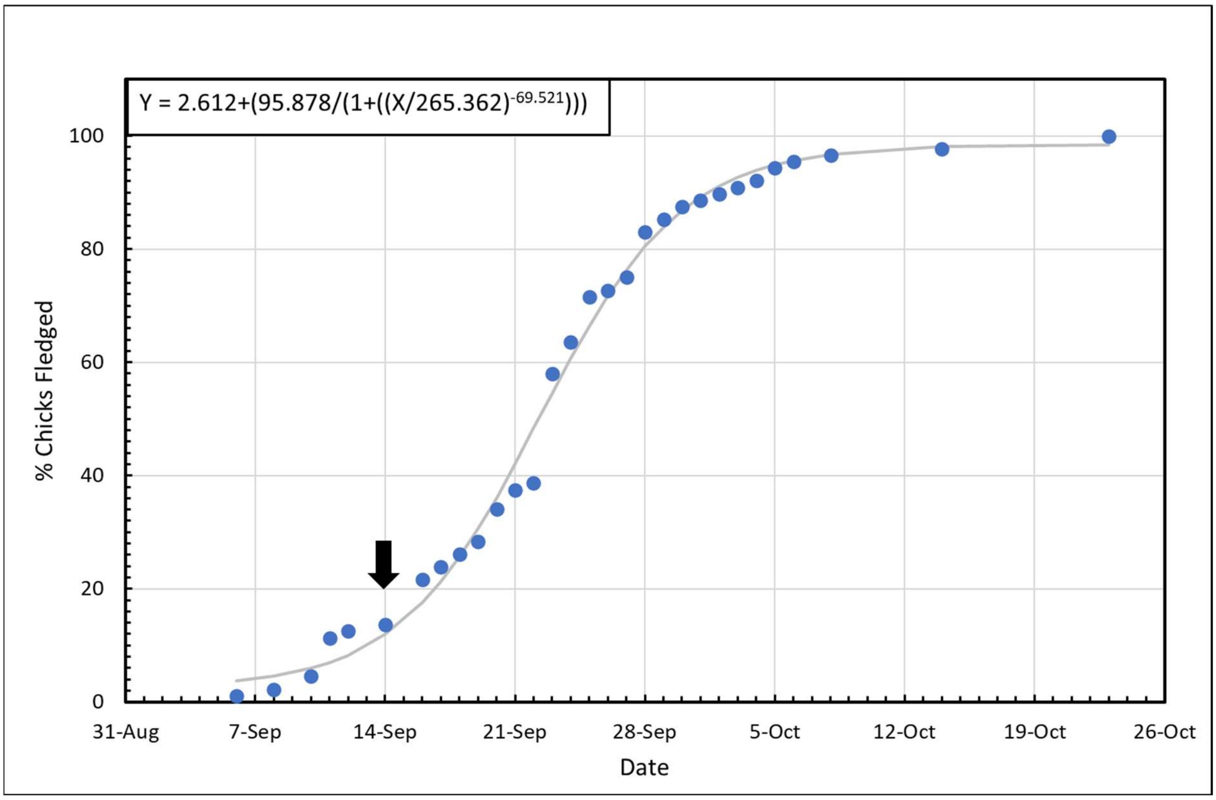

Figure 3. Time course of fledging of toroa chicks at Taiaroa Head, Otago Peninsula, over four seasons, 2016/17 – 2019/20 (data kindly provided by the Department of Conservation, Dunedin). The fitted curve (—) is a Four Parameter Logistic (4PL) curve (AAT Bioquest, Inc. 2021), calculated using Day of Year (Jan 1 = 1) on the X axis. The arrow points to 14 September (Day 257), the date when the aerial survey was carried out on the Chatham Is.

Northern Giant Petrel

The number of Northern Giant Petrels and dark objects that could be giant petrels ('NGP uncertain') are given in Table 3. A total of 1799 Northern Giant Petrels (NGP, 95% CL: 1717–1884) were reasonably confidently identified across all three islands. These birds were not uniformly distributed on these islands but were concentrated in areas covered by broken boulders, often in well-vegetated places (e.g., A–C on Rangitautahi, F and the northern corner of H on Te Awanui, and C–F on Motuhara: Table 3, Fig. 2). This habitat preference, along with the birds' tendency to shelter under vegetation, between boulders, or below overhangs, made it difficult to identify and count them unambiguously.

Objects that could be giant petrels (similar size and shape but lacking any obvious defining features: 'NGP uncertain' in Table 3) comprised 20 % of both NGP categories combined, an indication of the uncertainty involved in identifying and counting this species. Another measure is to consider the difference in paired counts made of NGPs in the same area from different images. On average, almost twice as many giant petrels across all islands were counted in the most populous view than in the alternative (average multiplier, 1.97; 95 % confidence limits 1.68–2.25; N = 16). This variation resulted from a combination of distance, photographic angle and lighting conditions. More distant images, taken from a low angle relative to the horizontal, especially those looking into the light, produced lower counts.

Table 4. Overall counts of Northern Royal Albatross adults, fledglings and carcasses, and undifferentiated Northern Giant Petrels adults and sub-adults counted on Rangitautahi, Te Awanui and Motuhara on images taken in September 2020, compared with counts made using similar methods in earlier seasons (Frost 2017, 2019, and unpublished). Two estimates are given for Northern Royal albatross in 2019/20: actual counts of birds present (regular font); and the number likely to have been present at the start of fledging, adjusted for birds that had probably fledged before the survey date (italics: see text for explanation). For Northern Giant Petrel, note that the breeding season extends from July to February, hence the differences between Northern Giant Petrel and Northern Royal Albatross (breeding season extending from November to September) in the specified breeding seasons for surveys conducted on the same dates

Northern Royal Albatross	**Breeding season**	**Survey date**	**Rangitautahi**	**Te Awanui**	**Motuhara**	**Total**
Fledglings	2016/17	27/07/2017	574	539	1003	2116
	2017/18	23/08/2018	550	405	1194	2149
	2019/20	14/09/2020	425 *483*	314 *357*	1059 *1203*	1798 *2043*
Adults	2016/17	27/07/2017	35	14	78	127
	2017/18	23/08/2018	21	3	41	65
	2019/20	14/09/2020	4	2	10	16
Carcasses	2016/17	27/07/2017	17	1	17	35
	2017/18	23/08/2018	13	6	24	43
	2019/20	14/09/2020	6	3	16	25
Northern Giant Petrel						
Presumed adults/sub-adults	2017/18	27/07/2017	59	92	1738	1889
	2017/18	21/10/2017	56	206	No count	No estimate
	2018/19	23/08/2018	84	241	2506	2831
	2020/21	14/09/2020	125	88	1586	1799

Discussion

As royal albatrosses are biennial breeders, the adults breeding in 2019/20 would have been predominantly the same birds as those nesting in 2017/18. The 2149 fledglings counted then, about 10-14 days before the first were expected to fledge (Frost 2019), therefore provides the most direct comparison. This is marginally more than the 2043 chicks estimated for 2019/20 (allowing for those that might have already fledged). Given all the caveats and uncertainties involved in the latter estimate, the number of chicks fledging in 2019/20 appears broadly similar to that recorded in recent years (Table 4).

The difficulty of censusing giant petrels from the aerial photographs has been commented on previously (Baker et al. 2017). The results of this survey confirm this. High uncertainty and large variations between counts of the same area from different photographic viewpoints compromised efforts to arrive at a reliable figure of the number of birds present. Nevertheless, the counts are not too dissimilar to those recorded in earlier surveys once differences in seasonal timing are considered (Table 4). How past surveys were carried out, and how future ones might be adjusted to improve image quality, and hence the precision and accuracy of the resulting estimates, are discussed in the Appendix.

Counts made in different years vary not only with the species concerned but also with the year (for example, toroa is a biennial breeding species), the stage in the nesting cycle when the surveys are undertaken, and the inferred status of the birds seen. Although egg laying is concentrated in a narrow period of the year, it is not completely synchronous. For toroa at Taiaroa Head it is spread over about four weeks, from late-October to late-November (Sugishita 2013). Fledging is equally spread out (Fig. 3). A similar pattern is likely on the Chatham Is.

The numbers of breeding adults can also be over- or under-estimated depending, respectively, on how many birds present during the survey and counted as nesting, do not in fact lay that season, and on how many fail early during incubation and leave before the survey. Ground-based surveys carried out on Motuhara in early December 2016, around 4–6 weeks after the start of nesting (Bell et al. 2017), and on Rangitautahi and Te Awanui in late-November/early-December 2017, 2–4 weeks into the nesting season (Bell et al. 2018), found 2.7–9.9 % of toroa nests were empty and 6.0–7.3 % had failed. Recent estimates of toroa nesting success, based mostly on analysing aerial images of incubating birds and, later in the same season, of late-stage fledglings, suggest 45–52 % of nests fail overall (Frost 2017, 2019). These numbers almost certainly vary from year to year, as likely does the timing of any losses. Estimating the numbers of breeding toroa is rather like trying to hit a moving target.

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References

Andrews, P.B.; Campbell, H.J.; Watters, W.A. 1978. The Forty Fours: The most easterly outcrop of Mesozoic basement in the New Zealand region (Note), *New Zealand Journal of Geology and Geophysics*, **21**, 649-652, DOI: 10.1080/00288306.1978.10424092

AAT Bioquest, Inc. (2021). Quest Graph™ Four Parameter Logistic (4PL) Curve Calculator. Online at https://www.aatbio.com/tools/four-parameter-logistic-4pl-curve-regression-online-calculator (accessed 16 March 2021).

Baker, G.B.; Jensz, K.; Bell, M.; Fretwell, P.T.; Phillips, R.A. 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.

Baker, G.B.; Jensz, K.; Cunningham, R. 2013. White-capped Albatross population estimate—2011/12 and 2012/13. Final research report by Latitude 42 for the Department of Conservation, Wellington. Online at URL https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-conservation-services/pop-2012-05-white-capped-Albatross-final-report.pdf.

Bell, M.D.; Bell, D.J.; Boyle, D.P.; Tuanui-Chisholm, H. 2017. Motuhara seabird research: December 2016. Technical report to the Department of Conservation, Wildlife Management International Ltd, Blenheim.

Bell, M.D.; Bell, D.J.; Boyle, D.P.; Tuanui-Chisholm, H. 2018. Rangitatahi seabird research: December 2017. Technical report to the Department of Conservation, Wildlife Management International Ltd, Blenheim.

Campbell, H J.; Andrews, P.B.; Beu, A.G.; Edwards, A.R.; Hornibrook, N. deB.; Laird, M.G.; Maxwell, P.A.; Watters, W.A. 1988. Cretaceous-Cenozoic lithostratigraphy of the Chatham Islands, *Journal of the Royal Society of New Zealand*, **18**, 285-308, DOI: 10.1080/03036758.1988.10426471.

Ersts, P.J. 2020. DotDotGoose (version 1.5.1). American Museum of Natural History, Center for Biodiversity and Conservation. Available from https://biodiversityinformatics.amnh.org/open_source/dotdotgoose. Accessed on 23-06-2020.

Fay, M. 2017. *exactci v1.3-3* Exact P-values and matching confidence intervals for simple discrete parametric cases. Online at URL: https://www.rdocumentation.org/packages/exactci.

Frost, P.G.H. 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 URL: https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/reports/aerial-census-northern-royal-albatross-chicks-july-2017.pdf.

Frost, P.G.H. 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 URL: https://dcon01mstr0c21wprod.azurewebsites.net/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/reports/draft-reports/frost-aerial-surveys-northern-royal-albatross-2017-18.pdf.

Garwood, F. 1936. Fiducial limits for the Poisson distribution. *Biometrika,* **28**, 437–442.

Parker, G.C.; Muller, C.G.; Rexer-Huber, K. 2016. Northern giant petrel *Macronectes halli* breeding population survey, Auckland Islands, December 2015 – February 2016. Parker Conservation Report to the Conservation Services Programme, Department of Conservation. Typescript 16 p.

Robertson, C.J.R. 1998. Factors influencing the breeding performance of the northern royal albatross. *In*: G. Robertson; R Gales (eds), *Albatross Biology and Conservation*, pp. 99-104. Surrey Beatty & Sons, Chipping Norton, Australia

Sugishita, J. 2013 [updated 2017]. Northern royal albatross. *In* C.M. Miskelly (ed.) New Zealand Birds Online. www.nzbirdsonline.org.nz

Wiltshire, A.; Hamilton, S. 2003. Population estimate for northern giant petrels (*Macronectes halli*) on Antipodes Island, New Zealand. *Notornis 50*: 128–132.

Wiltshire, A.J.; Scofield, R.P. 2000. Population estimate of breeding northern giant petrels *Macronectes halli* on Campbell Island, New Zealand. *Emu 100*: 186–191.

Appendix

Improving image quality

The numbers derived from the aerial surveys are subject to various sources of 'error': failing to see and count all birds present (and, conversely, misidentifying and counting inanimate objects or individuals of another species); misclassifying adults as late-stage fledglings, and vice versa; categorising some individuals as nesting when they are not, and the other way around. Whereas the extent of these detection and classification errors depends partly on the skill and experience of the analyst—which is seldom tested—some depend also on the coverage and quality of the images taken of the colonies and, potentially, of any changes in equipment (cameras, lenses). All the cameras and lenses used during these surveys have been either the same or similar high-end models with wide dynamic range, so the minor changes in equipment that have occurred are not considered to have had any major impact on image quality.

There have been differences in the conditions and manner of use of the equipment, however. The most noticeable variations have been in the air speed, altitude and distance offshore flown by the survey aircraft (Table ST1, Fig. SF1), and in the focal length of the lenses used and the number of images taken (Fig. SF2).

Table ST1. Comparative flight parameters of three aerial photographic surveys of Northern Royal Albatross nesting on the Chatham Is, as derived from GPS data collected during the flights. There were no GPS data for the 21 October 2017 or 23 August 2018 surveys

Airspeed (kph)	**Rangitatahi**			**Motuhara**		
Date	Mean	SD	N	Mean	SD	N
27/07/2017	156	29.0	50	150	20.5	140
04/12/2017	139	26.8	319	139	31.7	396
14/09/2020	183	23.5	21	197	30.6	102
Altitude (m a.s.l.)						
27/07/2017	239	90.0	50	232	81.2	140
04/12/2017	159	29.9	319	174	38.4	396
14/09/2020	225	8.6	21	224	19.1	102
Distance offshore (m)						
27/07/2017	217	92.1	140	235	142.5	70
04/12/2017	185	79.5	65	211	106.6	82
14/09/2020	464	236.2	120	298	88.2	60

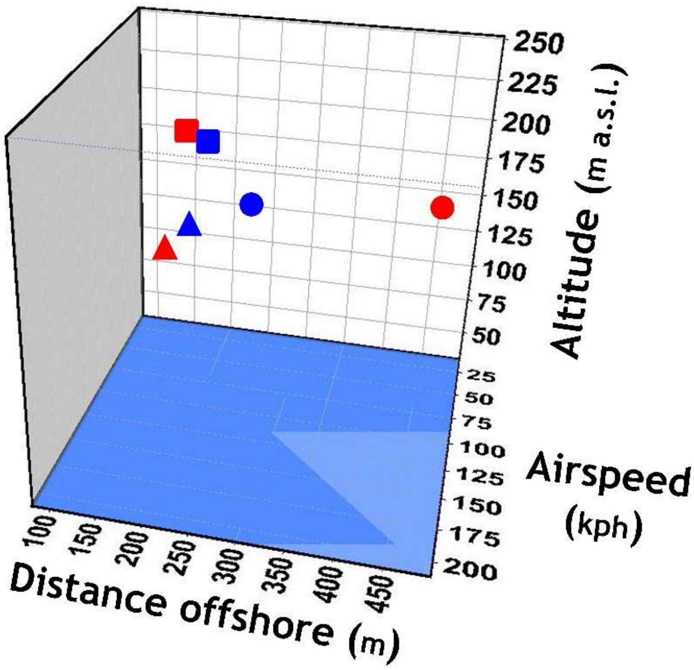

Figure SF1. 3-D plot of average estimated distance (m) flown offshore, average airspeed (kph) and average altitude (m a.s.l.) flown during aerial photographic surveys of Rangitatahi (red) and Motuhara (blue) in July 2017 (squares), December 2017 (triangles) and September 2020 (circles) as determined from GPS readings of the flight paths. See Table ST1 for details and the text for further explanation.

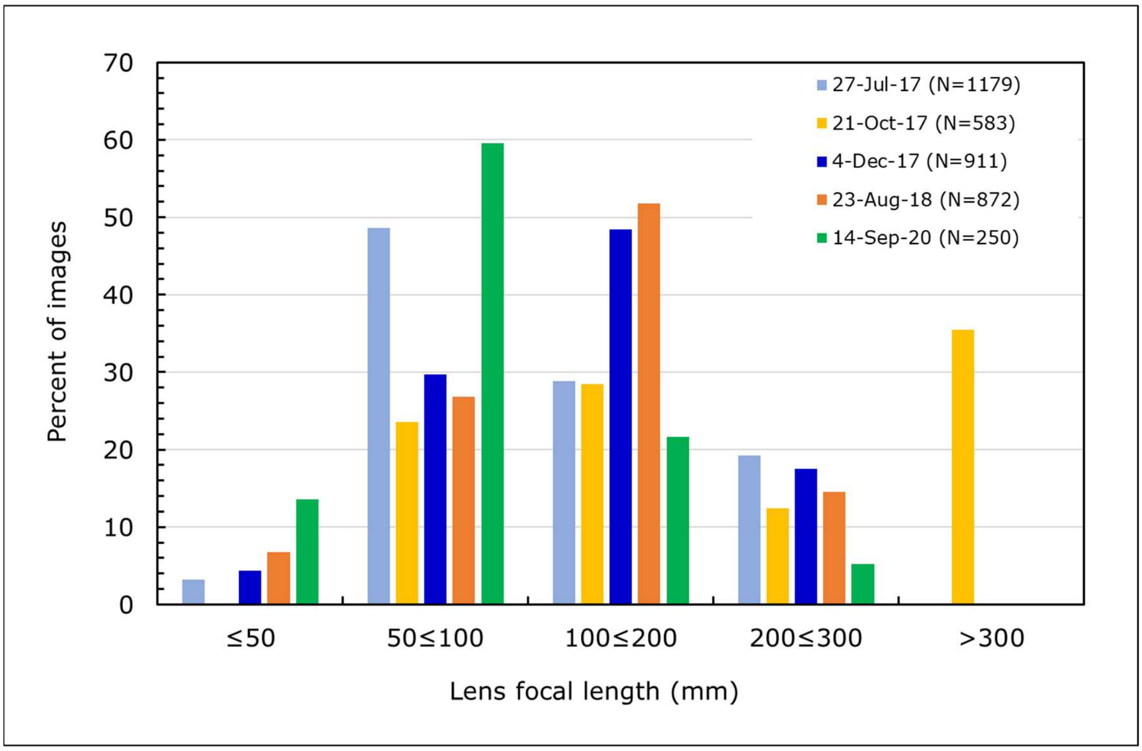

Figure SF2. Comparison of the focal lengths of lenses used to photograph the Northern Royal Albatross colonies on the Chatham Is during recent aerial censuses of the birds nesting there.

Airspeed, altitude and distance flown offshore from the islands are all controlled by the pilot, although the photographers can request changes in these to get more suitable views. Whether the pilot responds as requested depends ultimately on their assessment of the risks involved, primarily of bird strikes, wind updraughts and downdraughts, and low-level windshear close to an island. Safety is paramount.

The variations in airspeed, altitude and distance flown offshore in recent surveys partly reflects the pilot's assessment of the risks at the time, informed by past experience. The pilot who flew the September 2020 survey apparently had less relevant experience of this and was nervous of bird strikes close to the islands (Gemma Green, Department of Conservation, pers. comm.). This probably explains the resultant wide and high circuits flown around the islands during that survey (Fig. SF1, Table ST1).

The flight paths taken all influence the field of view and the level of detail seen on the resulting images (see Frontispiece for typical examples). Ideally, high and wide circuits require using longer focal lengths to compensate. Landscape-level photographs need to show sufficient detail on the ground to enable each island to be partitioned completely into discrete, contiguous areas. Close-up photographs of the colonies should show individual birds sufficiently clearly to be identified, classified and counted, and yet together still cover the whole area. This may require more photographs, and therefore more circuits to be flown, than was done in this survey, although in this case there may have been mitigating circumstances.

The optimal focal length depends on how far the aircraft is flying from the islands. An image taken at 135-mm focal length when the aircraft is, say, 200 m offshore, obviously covers a smaller area than one taken at the same focal length from further away. Any objects of interest (in this case toroa adults and chicks, and Northern Giant Petrels), will obviously be correspondingly smaller in those images taken from further away at the same focal length. In September 2020, the flight paths around the islands were, on average, further offshore but most photographs (73 %) were taken at focal lengths <100 mm (Frontispiece and Figure 5). This affected image quality, with individual birds generally being too small and unclear for fine details to be seen in magnified images. Although 48 % of images taken in July 2017 were also taken at short focal lengths, this had a smaller general effect on the quality of the images overall because the aircraft flew on average closer to the islands and at a lower average airspeed (Table ST1). Moreover, more than twice as many photographs were taken at longer focal lengths in July 2017 (576 images) than were taken overall in September 2020 (250: Fig. SF2).

On most of the recent surveys of toroa and Northern Giant Petrels on the Chatham Is, the photographers pre-selected the ISO number and shutter speed (1/1024s or above), giving the shutter priority to counter the speed of the aircraft. This resulted in widely varying automatic aperture settings as focal length was being varied to encompass different fields of view. Aperture priority was given preference in October 2017, an aerial survey of the Rangitatahi group focusing on Northern Giant Petrels, and in one of the cameras used in December 2017 to photograph toroa on Motuhara (although apertures were adjusted manually several times during that survey). Apertures were pre-set at F5.6-6.3, giving an adequate depth of field at the distances over which the photographs were taken. Both Shutter Priority and Aperture Priority produced reasonable images when the ISO number was set at 800 or above and shutter speeds were >1/1328s. Automatic mode, used with one of the survey cameras in August 2018, resulted in images being taken at generally low shutter speeds and low ISO numbers. Most were poorly resolved because of motion blur. Automatic mode should be avoided.

Finally, apparently because of the impending arrival of an unfavourable weather front during the September 2020 survey (Gemma Greene, Department of Conservation, pers. comm.), the combined time spent circling and photographing the islands was 33 % less than the average of earlier surveys, with correspondingly 75 % fewer photographs being taken. This had the unfortunate consequence of reducing the number and variety of views of the colonies, limiting the choice of which ones to mark and analyse, or to crosscheck in cases where there was uncertainty in the image being analysed. It would be useful in future surveys to increase both the number of circuits flown around the islands (ideally 6-10 around each island) and the number of photographs taken. For Rangitatahi, Te Awanui and Motuhara, the average number of images taken of each in earlier surveys were, respectively, 222, 235 and 572. These numbers are only guides, however, not targets. In these image sets, redundancy provided choice and potentially lessened uncertainty by allowing alternative views to be examined to check on ambiguities or even to replace one perspective with another.