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Seabird Population Research, Chatham Islands 2016/17 aerial photographic survey

Final Report

Report prepared for

Department of Conservation
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Executive Summary

Northern royal albatrosses *Diomedia sanfordi* and northern Buller's albatrosses *Thalassarche bulleri platei* are endemic to New Zealand, with 99% of the population of both taxa breeding in the Chatham Islands (ACAP 2009a, 2009b). Within the Chatham Islands, both species breed principally on the Forty-Fours and The Sisters, two island groups that are privately owned and difficult to access. Because these islands are isolated, there have been few population counts undertaken for both Northern royal albatross and Northern Buller's albatross.

In November and December, 2016, we used aerial photography and satellite imagery to determine the population size of northern royal albatross breeding and northern Buller's albatross on the Forty-Fours and The Sisters, and to compare the estimates derived from these techniques with ground counts. In addition, we also used the opportunity to test the feasibility of using aerial photography to estimate population size of northern giant petrels (*Macronectes halli),* which also breed on the two island groups.

Aerial photography was undertaken on 23 November, using a a single-engine Cessna 207 fixed-wing aircraft, and timed to coincide with the end of egg laying/ early incubation period of both albatrosses. Ground counts were undertaken on The Forty-Fours on 8 December 2016, 15 days after the aerial survey was undertaken. No ground counts on The Sisters were undertaken. Very High Resolution (VHR) WorldView-3 optical satellite images of both the Forty-Fours and The Sisters were acquired on 20 December 2016, which was 27 days after the aerial survey was undertaken, and 13 days after the ground count. This timing of all surveys was not ideal for the giant petrel, which were in the late incubation/ early chick provisioning stage of breeding in November/December.

The flight to obtain aerial phots was conducted in calm conditions and fine weather. We were able to obtain clear photographs of all colonies at both The Sisters and the Forty-Fours.

The estimated annual count of **royal albatross** derived from aerial survey after adjustment to account for the presence of loafing birds in the colony was of **4,772** annual breeding pairs after correction using aerial close-up photos (correction factors 0.068 – The Sisters, 0.057 – The Forty-Fours), and **4,406** annual breeding pairs after correction using ground counts (correction factor 0.136). The count derived from satellite imagery for The Sisters and The Forty-Fours was 2,578 and 2,533 Apparently Occupied Sites, respectively, which was **21% lower** than the raw aerial count for The Sisters (3,269 birds) and **38% higher** than the raw aerial count for the Forty-Fours (1,830 birds). The ground count for the Forty-Fours was **1,404** annual breeding pairs.

The estimated annual count of **Buller's albatross** derived from aerial survey after adjustment to account for the presence of loafing birds in the colony was 17,969 annual breeding pairs after correction using aerial close-up photos (correction factors 0.017 – The Sisters, 0.022 – The Forty-Fours), and 16,138 annual breeding pairs after correction using ground counts (correction factor 0.121). Most birds (85.3%) were breeding on The Forty-Fours. The ground count for the Forty-Fours was 16,492 annual breeding pairs, which included an estimate of 3,445 nesting attempts that had failed. Adjusted aerial counts for The Forty-Fours were 7.1% and 16.5% lower than the ground count, although a direct comparison is difficult due to the 14-day difference between the ground and aerial counts, and the inclusion of failed nests in the ground counts, which would not have been detectable from the air. There were no counts derived from satellite imagery for Buller's albatross as the resolution of the imagery is unsuitable for counting this species.

Aerial counting of northern giant petrels was not effective at either The Sisters or The Forty-Fours. Birds were not clearly visible in most images and detecting birds was difficult. An aerial count of 370 chicks at The Forty-Fours, was 30% of the 1,235 giant petrel chicks counted on the ground.

The use of WorldView-3 satellite imagery to count albatross populations is a new phenomenon which has potential application to the other greater albatross species. The mixed results obtained in this study indicate there may be more to be learnt to refine the technique. At this stage use of either aerial photographic surveys or on-ground counts remain the preferred methods for estimating population size and monitoring in the Chatham Islands.

1. Introduction

The Chatham Islands form an archipelago 650 kilometres east of mainland New Zealand and comprise about ten islands within a 40-kilometre (25 mi) radius, the largest of which are Chatham Island and Pitt Island. The islands are the principal breeding sites for three species of albatrosses and two endemic petrels, as well as a number of other seabird species. A population assessment of the albatrosses and northern giant-petrels that breed on two of the outer island groups, The Forty Fours and The Sisters, forms the subject of this report.

Northern royal albatrosses *Diomedia sanfordi* and northern Buller's albatrosses *Thalassarche bulleri platei* are endemic to New Zealand, with 99% of the population of both taxa breeding in the Chatham Islands (ACAP 2009a, 2009b). Within the Chatham Islands, both species breed principally on the Forty-Fours and The Sisters, two island groups that are privately owned and difficult to access. Because these islands are isolated, there have been few population counts undertaken for both Northern royal albatross and Northern Buller's albatross (hereinafter royal albatross and Buller's albatross, respectively) (survey effort summarised in ACAP 2009a, 2009b).

The total breeding population of royal albatross was estimated to be approximately 5,800 annual breeding pairs, with most breeding on the Forty-Fours (60%, census date 2003) and The Sisters (c.39 %, census date 2003), respectively (ACAP 2009a). A small population of c. 50 annual pairs breed at Taiaroa Head on the Otago Peninsula on New Zealand's South Island (ACAP 2009a). For Buller's albatross, the breeding population on the Forty-Fours and The Sisters was estimated to be 14,674 (87% global share, census date 2008) and 2,150 (13% global share, census data 1994-96), respectively (ACAP 2009b). Both aerial and ground counts have been used to develop population estimates for both species, but differences in methodology preclude complete understanding of population trend. High resolution satellite imagery has also been used recently (Fretwell et al 2017) to estimate the number of apparently occupied sites (AOSs) for royal albatrosses in the Chatham Islands, and provided estimates that were much lower than ground-based counts undertake on The Sisters in 2009/2010.

About 2,000 pairs of Northern giant-petrels (*Macronectes halli*) are thought to breed in the Chatham Islands but the size of New Zealand populations generally are poorly known (Taylor 2000). ACAP (2010) does not provide population estimates for the Forty-Fours and The Sisters, but Fraser et al (2010) reports annual nest counts from two sample areas along the north-eastern part of the Forty-Fours, that ranged from 270 to 430 over the period 2007-2009. There are no other recently published records.

We have now been contracted by the Department of Conservation to collect information on key aspects of the biology of selected at-risk seabird species in order to reduce uncertainty or bias in estimates of risk from commercial fishing. Specifically, the objectives of the project are to:

1. Determine through aerial photography the population size of northern Buller's albatross;
2. Determine the population size of northern giant petrel;
3. Determine through aerial photography and satellite imagery the population size of northern royal albatross; and

provide technical reports for each species detailing the methods used and results found, including, where appropriate, population estimates and analysis of population trend, and a comparison with ground census techniques.

In this report we describe the methods and results used in the aerial survey undertaken in the 2016/17 breeding season in the Chatham Islands, and compare the estimates obtained by this methodology with counts from ground and VHR satellite imagery.

2. Methods

The Site

The Sisters (43º 34'S, 176º 49'W) are located 20 km to the north of the main Chatham Island and comprises two islets known as Big Sister and Middle Sister, a few small rock stacks and an exposed reef. Big Sister (8 ha) is long and flat-topped at about 90m, with cliffs rising steeply from the sea. Middle Sister (6.5 ha, also known as Little Sister) is a steep-sided islet with cliffs rising to 40-80m (Tickell 2000).

The flat tops of Middle and Big Sister are sparsely vegetated and hold important populations of northern royal albatross; northern Buller's albatross and a few northern giant petrels. A few Buller's also utilise the cliff ledges for breeding (Amanda Baird, DOC, unpublished).

The Forty Fours (43º 58'S, 175º 50'W) lie 68 km east of the main Chatham Island and comprise one island, Motuhara (14 ha), and four large stacks (Tickell 2000, B. Baker unpublished). Steep cliffs rise 100 m from the sea to a fairly flat top which is rocky, with no water more permanent than small shallow rain pools and seeps (Tickell 2000).

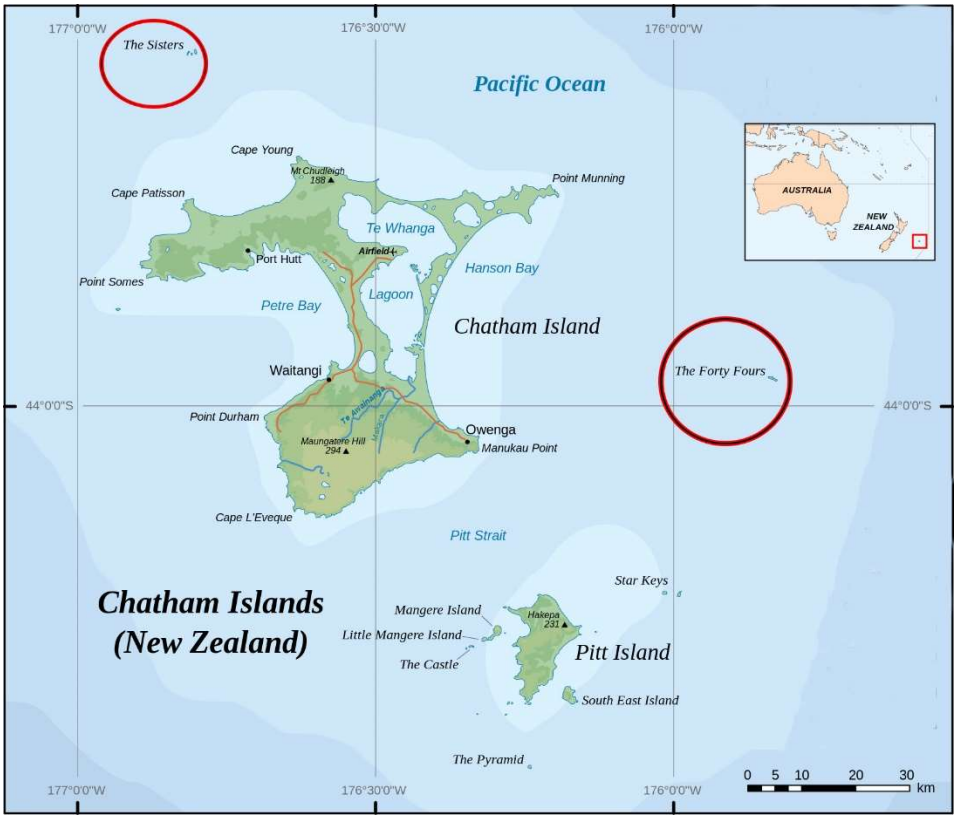


Figure 1. Topo map of the Chatham Islands showing the location of The Sisters and The Forty fours. **Map credit: https://commons.wikimedia.org/w/index.php?curid=3349240**

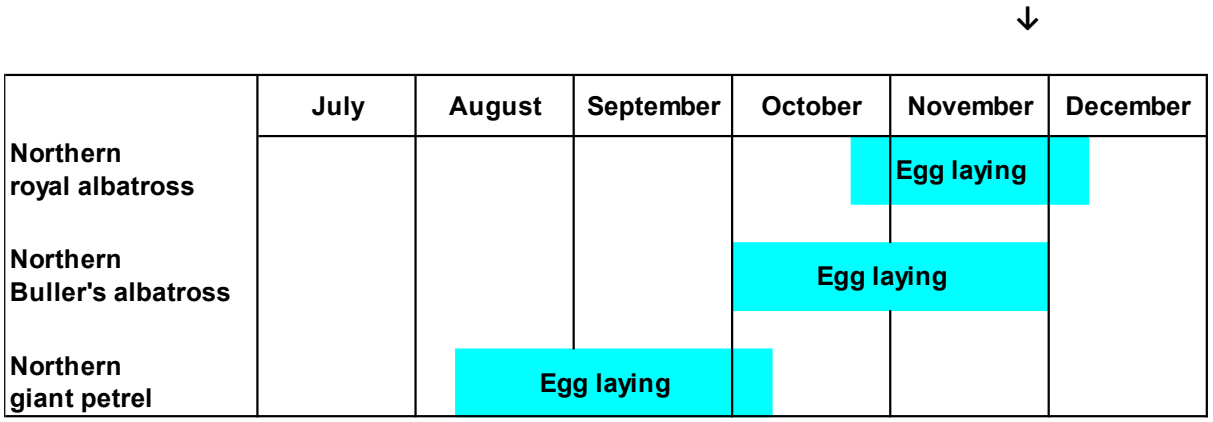
Field Work –

On 23 November 2016 we chartered a fixed wing aircraft from Air Chathams to conduct a return flight to The Sisters and the Forty-Fours Island groups. The aircraft, a single-engine Cessna 207, was piloted by Charlotte Fuller. On board was Barry Baker (photographer and project coordinator), and Department of Conservation representative Tansie Bliss.

The flight was conducted in late November to coincide with the end of egg laying/ early incubation period of the breeding cycle of royal and Buller's albatrosses. At this time it was anticipated that most birds would have just completed egg laying (ACAP 2009a, 2009b), and hence most birds that attempted to breed would still be attending active nests (Figure 2). This timing was not ideal for the giant petrel, which lays eggs between early August and early October – in late November giant petrels were in the late incubation/ early chick provisioning stage of breeding.

For the flight we selected a weather window for the operation that predicted clear flying conditions with minimal low-level cloud. At the time of the 23 November 2016 flight the weather around the Chatham Islands was calm and fine. We were able to obtain clear photographs of all colonies at both The Sisters and the Forty-Fours.

Figure 2. Breeding phenology (timing of egg laying) of albatrosses and giant petrels breeding at the Forty-Fours and The Sisters, Chatham Islands. The timing of aerial photography is indicated by the arrow.



Photography was timed to occur between 1100 to 1600 NZDT. Although there is little information on the behaviour of breeding royal and Buller's albatrosses in the Chatham Islands, information from other albatross species indicates that during the early incubation period the ratio of incubating to loafing birds is high as most loafers are at sea during the middle of the day (Baker et al 2015).

In November 2016 photography for each site was conducted as follows:

— The Sisters c.1054 to 1119 Chatham Island DT; and
— The Forty-Fours 1143 to 1223 Chatham Island DT;

At each site we conducted at least 10 circuits to provide images suitable for counting the breeding birds on the island, which were taken using a photo-extension of between 70 to 135 mm. Additional photographs using maximum photo-extension (200mm) were also taken to assist in determining the proportion of empty nests and non-breeding birds in the colonies.

For the photography, the photographer was positioned on the rear seat of the port side of the aircraft, with the rear window open during photographic work. All photographs were taken using Nikon D800 digital cameras and an image-stabilised Nikkor 70— 200 mm F2.8 zoom lens. Shutter speeds were set at 1/1000 s or faster to minimise camera shake, and every effort made to ensure that the photographs were taken as close to perpendicular to the land surface as the flight approach permitted. The focal length of the zoom lens was not adjusted within each pass sequence over each site. The photos taken are a complete series of overlapping images that cover the entire area of the sites where albatrosses and giant petrels were nesting; approximately 550 and 270 digital photographs were taken during the survey flight at the Forty-Fours and The Sisters, respectively. All photographs were taken as NEF raw files. The survey photographs of were taken at an altitude of about 300-350 metres. The entire set of photographs were subsequently replicated to ensure that four complete back-up sets existed both on portable hard drives and in at least three different locations. A full set of photographs will be provided to Department of Conservation officer Mr Kris Ramm on completion of the project.

Ground counts on The Forty-Fours

Wildlife Management International were commissioned to undertake ground truthing of aerial survey by transect counts. This work was undertaken on The Forty-Fours on 8 December 2016, which was 15 days after the aerial survey was undertaken. The results of this work have been reported separately (Bell et al. 2017), but are also summarised in this report). Ground-truthing was carried out by a member of the field team walking slowly along a transect which contoured across the slope and assessing the breeding status of all birds encountered. Birds were categorised as follows: 1. sitting on a nest with an egg (incubating), 2. sitting on a nest without an egg (apparently incubating), 3. standing or sitting upright on a nest without an egg, 4. 'loafing' and not on a nest. The status of all birds encountered within approximately 2 m either side of the transect line were recorded, with all birds on empty nests categorised as either sitting or standing when first observed (Bell et al. 2017).

Satellite imagery

One of the main limitations in the use of satellite data for counting individual animals has been their resolution. In March 2015, the U.S. Congress relaxed restrictions on the spatial resolution of commercial satellite imagery from 50 to 30 cm. This has meant that the threshold size of objects that can be seen from space is now much smaller, and the definition and the reliability with which they can be discriminated are much improved. WorldView-3 is currently the only satellite providing commercial imagery at sub-40-cm resolution, offering optical imagery at a spatial resolution of 31 cm in the panchromatic band, and of 1 m in the visible and near-infrared bands (http:// www.satimagingcorp.com/satellite-sensors/worldvie w-3/). This more than doubles the potential density of pixels from 4 pixels/m2 (for a 50-cm resolution image) to 10.4 pixels/m2 (31-cm resolution), thus increasing the number of species for which individual animals are potentially visible, or can be visualized at considerably higher definition by satellite (Fretwell et al. 2017).

A complete description of the methodology used to obtain and count albatrosses from Very High Resolution (VHR) optical satellite imagery is described in Fretnell et al (2017). Briefly, we obtained single WorldView-3 VHR satellite images, with the visible bands (2/3/5) pan-sharpened to provide a 31 cm resolution colour image using the Gram Schmidt algorithm in ENVI image processing software, to assess population size of Northern royal albatross on both the Forty-Fours and The Sisters. Images of the Forty Fours and of the Sisters (Big Sister and Little Sister) were acquired on 20 December 2016, and counts of northern royal albatross made from a single image. The timing of satellite imagery acquisition was planned to correspond as best as possible with programmed aerial survey using a fixed wing aircraft, and on-ground surveys (see above). To account for topographic distortion, it is desirable to orthorectify satellite images to match as closely as possible GPS ground-truthed nest locations with the pixels in satellite images, using a high resolution (5-m cell size), photogrammetrically compiled digital elevation model (DEM) (Fretwell et al. 2017). As no appropriate ground-truthing data for the Forty-Fours and The Sisters were available at the time our counts from satellite imagery were obtained, orthorectification was not possible.

3. Results

Northern royal albatross

In November 2016, we estimated the total count of nesting royal albatrosses (Apparently Occupied Sites) to be 3,269 (95%CI 3,155 — 3,383) for The Sisters (Annex 1); and 1,830 (1,744— 1,916) for The Forty-Fours (Annex 2), based on raw counts. These counts have been adjusted downwards to account for the presence of 38 and 32 birds assessed as being the partners of incubating birds at The Sisters and The Forty-Fours, respectively. The total raw count for both sites was 5,099 (4,956— 5,242) nesting royal albatross pairs (Potential Occupied Sites) (Table 1).

Analysis of 10 close-up photographs randomly selected from both sites showed that in November 2016 most of the birds visible in the photographs were sitting on nests (The Sisters: 604 of 648, or 93.2%, Annex 3; The Forty-Fours: 492 of 522, or 94.3%, Annex 4). Forty-four (6.8%) and 30 (5.7%) of the birds at The Sisters and The Forty-Fours, respectively, were clearly not associated with a nest, and we were unclear of the status of a further 259 and 218 birds, respectively (Annexes 3 and 4).

Ground counts of nests inspected on the ground on The Forty-Fours on 8 December 2016 showed that 577 of 603 occupied nests (95.7%) contained eggs and 26 (4.3%) were empty (Annex 5). The 577 nesting birds comprised 86.4% of the total of 668 birds observed in the transect counts, with 91 (13.6%) being loafers. The estimated breeding population size of royal albatross on The Forty-Fours on 8 December derived from ground counts was 1,404 annual breeding pairs (Bell et al. 2017) (Table 1).

The count of royal albatross on December 20th derived from satellite imagery was 1,442 (AOSs) on Big Sister and 1,136 (AOSs) on Middle Sister, giving a total of 2,578 AOSs for The Sisters. On The Forty-Fours there were 2,533 AOSs. The total number of sites apparently occupied by royal albatross in the Chatham Islands was 5,111. (Table 1).

The estimated annual count derived from aerial survey for both breeding sites in the Chatham Islands was adjusted to account for the presence of loafing birds as determined by aerial close-up photos (correction factors 0.068 – The Sisters, 0.057 – The Forty-Fours) and ground counts (correction factor 0.136 from The Forty-Fours), giving an adjusted estimate of annual breeding pairs in the Chatham Islands of 4,772 and 4,406, respectively, for each method of adjustment (Table 1)

Table 1. Population estimates of nesting northern royal albatrosses, breeding on the Chatham Islands in November/December 2016, derived from aerial photography, ground counts and satellite imagery. Aerial counts also include 95% Confidence Intervals, and counts adjusted to take into account the proportion of loafers in colonies, as determined by aerial 'close-up' counts, and ground counts. Ground and satellite counts are based on data collected 14 and 27 days, respectively, after the date of aerial photography. Ground counts were only conducted on The Forty-Fours. Aerial and ground counts are annual breeding pairs; Satellite-based counts are Apparently Occupied Sites.

Island	survey type and time from aerial survey (days)				
	Aerial raw count	Aerial adjusted count	Aerial adjusted count	Ground count	Satellite imagery
				+14 days	+ 27 days
The Sisters	**3,269**	**3,047**	**2,824**		**2,578**
LCI	3,155	2,936	2,718		
UCI	3,383	3,157	2,931		
The Forty-Fours	**1,830**	**1,726**	**1,581**	**1,404**	**2,533**
LCI	1,744	1,643	1,502		
UCI	1,916	1,809	1,661		
Total Chatham Islands	**5,099**	**4,772**	**4,406**		**5,111**
LCI	4,956	4,634	4,273		
UCI	5,242	4,911	4,538		
Correction factor		**0.068, 0.057** [1]	**0.136** [2]		

[1.] Less proportion of loafing birds from aerial 'close-ups'
[2.] Proportion of loafing birds from ground count at The Forty-Fours

Northern Buller's albatross

In November 2016 we estimated the total count of nesting Buller's albatrosses (Apparently Occupied Sites) to be 2,703 (95%CI 2,599 — 2,807) for The Sisters (Annex 6); and 15,702 (15,451— 15,953) for The Forty-Fours (Annex 7), based on raw counts. These counts have been adjusted downwards to account for the presence of 11 and 35 birds assessed as being the partners of incubating birds at The Sisters and The Forty-Fours, respectively. The total raw count for both sites was 18,359 (18,088— 18,630) nesting Buller's albatross pairs (Potential Occupied Sites) (Table 2).

Analysis of 10 and 11 close-up photographs randomly selected from The Sisters and The Forty-Fours, respectively, showed that in November 2016 most of the birds visible in the photographs were appeared to be sitting on nests (The Sisters: 466 of 474, or 98.3%, Annex 8; The Forty-Fours: 749 of 766, or 97.8%, Annex 9). Eight (1.7%) and 17 (2.2%) of the birds at The Sisters and The Forty-Fours, respectively, were clearly not associated with a nest, and we were unclear of the status of a further 36 and 118 birds, respectively (Annexes 8 and 9).

Ground counts of nests inspected on the ground on The Forty-Fours on 6 December 2016 showed that 850 of 865 occupied nests (98.3%) contained eggs and 15 (1.7%) were empty (Annex 10). The 850 nesting birds comprised 87.9% of the total of 967 birds observed in the transect counts, with 117 (12.1%) being loafers. The estimated breeding population size of Buller's albatross on The Forty-Fours on 6 December derived from ground counts was 16,492 annual breeding pairs (Table 2) and included an estimate of 3,445 nesting attempts that had failed (Bell et al. 2017).

The estimated annual count derived from aerial survey after adjustment to account for the presence of loafing birds in the colony was 17,969 annual breeding pairs after correction using aerial close-up photos (correction factors 0.017 – The Sisters, 0.022 – The Forty-Fours), and 16,138 annual breeding pairs after correction using ground counts (correction factor 0.121) (Table 2). Adjusted aerial counts for The Forty-Fours were 7.1% and 16.5% lower than the ground count, although a direct comparison is difficult due to the 14-day difference between the ground and aerial counts, and the inclusion of failed nests in the ground counts, which would not have been detectable from the air.

There were no counts derived from satellite imagery for Buller's albatross as the resolution of the imagery is unsuitable for counting this species.

Table 2. Population estimates of nesting northern Buller's albatrosses, breeding on the Chatham Islands in November/December 2016, derived from aerial photography and ground counts. Aerial counts also include 95% Confidence Intervals, and counts adjusted to take into account the proportion of loafers in colonies, as determined by either aerial 'close-up' counts or ground counts. Ground counts are based on data collected 14 days after the date of aerial photography. Ground counts were only conducted on The Forty-Fours. Raw aerial counts are Apparently Occupied Sites, corrected aerial and ground counts are annual breeding pairs.

Island		survey type and time from aerial survey (days)			
		Aerial raw count	Aerial adjusted count	Aerial adjusted count	Ground count
					+14 days
The Sisters		**2,692**	**2,646**	**2,366**	
	LCI	2,588	2,543	2,269	
	UCI	2,796	2,749	2,464	
The Forty-Fours		**15,667**	**15,322**	**13,771**	**16,492**
	LCI	15,417	15,075	13,537	
	UCI	15,917	15,570	14,006	
Total Chatham Islands		**18,359**	**17,969**	**16,138**	
	LCI	18,088	17,700	15,883	
	UCI	18,630	18,237	16,392	
Correction factor			**0.017, 0.022** [1]	**0.121** [2]	

[1.] Less proportion of loafing birds from aerial 'close-ups'
[2.] Proportion of loafing birds from ground count at The Forty-Fours

Northern giant petrel

Aerial counting of northern giant petrels was not effective at either The Sisters or The Forty-Fours. Birds were not clearly visible in most images and detecting birds was difficult, no doubt due in large part to the habit of giant petrel chicks to seek cover under available vegetation. We counted a total of 44 chicks at The Sisters, and 370 chicks at The Forty-Fours, giving a total of 414 chicks in the Chatham Islands. In comparison, Bell et al. (2017) counted 1,235 Giant Petrel chicks on The Forty-Fours.

4. Discussion

A meaningful comparison between aerial, ground and satellite-based counts for royal albatross (Table 1) was confounded by the differences in the dates of data capture (aerial v ground

counts 14 days; aerial v satellite-based counts 27 days; ground v satellite-based counts 13 days). However, a direct comparison of the data for royal albatross indicates:

- The aerial counts for the Forty-Fours adjusted using both aerial 'close-ups' and ground counts to account for non-breeding birds (loafers) were 22.9% and 12.6%, higher, respectively, than a ground count undertaken 14 days later;
- The raw aerial count for The Sisters was 26.8 % higher than the satellite-based count;
- The raw aerial count for The Forty-Fours was 27.8 % lower than the satellite-based count;
- The satellite-based count for The Forty-Fours was 80.4% higher than the ground count conducted 13 days earlier;

For Buller's albatross, the concordance between aerial and ground counts (Table 2) was high, particularly when the difference in timing between the two counts is taken into account, and the knowledge that the ground-based estimate included a total of 3,345 failed nesting attempts. These were defined by Bell et al (2017) to include all '*nests with a broken or abandoned egg, or dead chick'* – such nesting attempts would not have been evident from the air.

The use of WorldView-3 satellite imagery to count albatross populations is a new phenomenon which has potential application to the other greater albatross species (Fretwell et al. 2017), particularly for sites in remote areas that are difficult to access. The mixed results obtained in this study indicate there may be more to be learnt to refine the technique. At this stage use of conventional ground or aerial counting techniques are likely to be more cost effective, and remain the preferred methods for estimating population size and monitoring in the Chatham Islands.

Acknowledgements

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Annex 1: Raw counts of northern royal albatross (Apparently Occupied Sites) breeding on The Sisters, based on aerial photography taken on 23 November 2016.

Image	Count		
	Birds	**Pairs**	**Total occupied nests**
Middle Sister			
Run 1a	507	4	503
Run 2a	591	15	576
Side circuit 2a	15	0	15
Side circuit 2b	53	0	53
Side circuit 2c	239	1	238
Side circuit 2d	2	0	2
Big Sister			
Run 2a	229	5	224
Run 2b	431	5	426
Run 3a	484	6	478
Run 3b	232	2	230
Side circuit 1a	7	0	7
Side circuit 1b	81	0	81
Side circuit 2a	8	0	8
Side circuit 2b	179	0	179
Side circuit 2c	249	0	249
TOTAL	**3,307**	**38**	**3,269**
SE	57.51	6.16	57.18
LCI	3,192	26	3,155
UCI	3,422	50	3,383

Annex 2: Raw counts of northern royal albatross (Apparently Occupied Sites) breeding on The Forty-Fours, based on aerial photography taken on 23 November 2016.

Image	Count		
	Birds	Pairs	Total occupied nests
Run 6a	1,642	27	1,615
Run 6b	129	2	127
Run 6c	73	3	70
Side circuit 1a	4	0	4
Side circuit1b	0	0	0
Side circuit 1c	0	0	0
Side circuit 1d	8	0	8
Side circuit 1e	1	0	1
Side circuit 1f	5	0	5
Stack 1 (south)	0	0	0
Stack 1 (north)	0	0	0
Stack 2 (south)	0	0	0
Stack 2 (north)	0	0	0
Stack 3 (south)	0	0	0
Stack 3 (north)	0	0	0
Stack 4 (south)	0	0	0
Stack 4 (north)	0	0	0
TOTAL	**1,862**	**32**	**1,830**
SE	43.15	5.66	42.78
LCI	1,776	21	1,744
UCI	1,948	43	1,916

Annex 3: Counts of 10 randomly selected close-up photographs of nesting northern royal albatross taken at The Sisters colony in November 2016.

Image	Island	Apparently Incubating	Loafer	Unknown	Pairs
1	Big Sister	39	3	3	0
2	Big Sister	52	3	10	0
3	Big Sister	55	3	19	0
4	Big Sister	45	2	36	0
5	Big Sister	64	9	37	1
6	Big Sister	105	13	37	1
7	Middle Sister	109	3	33	0
8	Middle Sister	53	2	19	0
9	Middle Sister	51	3	15	1
10	Middle Sister	31	3	50	0
Total		**604**	**44**	**259**	**3**

Annex 4. Counts of 10 randomly selected close-up photographs of nesting northern royal albatross taken at The Forty-Fours colony in November 2016

Image	Apparently Incubating	Loafer	Unknown	Pairs
1	38	0	25	0
2	48	2	16	0
3	56	0	34	3
4	55	4	48	0
5	41	3	15	0
6	50	3	21	0
7	50	4	8	0
8	51	3	15	2
9	71	8	26	5
10	32	3	10	2
Total	**492**	**30**	**218**	**12**

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Annex 5. Ground counts of northern royal albatross taken in 23 randomly selected transects taken at The Forty-Fours colony on 8 December 2016

Transect	Time start	Time end	Incubating	Loafer - on empty nest	Loafer - not associated with nest	Total loafers
1	10:10	10:12	**14**		**1**	**1**
2	10:10	10:12	**22**		**5**	**5**
3	10:16	10:20	**32**	**1**		**1**
4	10:16	10:20	**40**	**2**	**5**	**7**
5	10:24	10:28	**34**			**0**
6	10:24	10:28	**52**	**2**	**6**	**8**
7	10:52	10:55	**22**	**2**	**2**	**4**
8	10:52	10:55	**18**	**1**	**1**	**2**
9	11:00	11:02	**12**	**2**	**3**	**5**
10	11:00	11:02	**14**	**2**	**3**	**5**
11	11:04	11:06	**10**		**3**	**3**
12	11:04	11:06	**12**	**1**	**6**	**7**
13	11:09	11:11	**11**			**0**
14	11:09	11:11	**8**	**1**	**1**	**2**
15	11:14	11:15	**10**		**3**	**3**
16	11:14	11:15	**10**			**0**
17	11:18	11:20	**15**			**0**
18	11:18	11:20	**7**		**2**	**2**
19	11:23	11:24	**6**			**0**
20	11:37	11:45	**73**	**2**	**7**	**9**
21	11:37	11:45	**64**		**14**	**14**
22	11:51	11:59	**43**	**6**	**2**	**8**
23	11:51	11:59	**48**	**4**	**1**	**5**
Total			**577**	**26**	**65**	**91**

Annex 6. Raw counts of northern Buller's albatross (Apparently Occupied Sites) breeding on The Sisters, based on aerial photography taken on 23 November 2016.

Image	Count		
	Birds	Pairs	Total occupied nests
Middle Sister			
Run 1a	10	0	10
Run 2a	5	0	5
Side circuit 2a	124	0	124
Side circuit 2b	129	0	129
Side circuit 2c	247	0	247
Side circuit 2d	30	0	30
Big Sister			
Run 2a	40	0	40
Run 2b	27	0	27
Run 3a	78	0	78
Run 3b	0	0	0
Side circuit 1a	482	2	480
Side circuit 1b	557	5	552
Side circuit 2a	274	1	273
Side circuit 2b	363	3	360
Side circuit 2c	337	0	337
TOTAL	**2,703**	**11**	**2,692**
SE	51.99	3.32	51.88
LCI	2,599	4	2,588
UCI	2,807	18	2,796

Annex 7. Raw counts of northern Buller's albatross (Apparently Occupied Sites) breeding on The Forty-Fours, based on aerial photography taken on 23 November 2016.

Image	Count		
	Birds	Pairs	Total occupied nests
Run 6a	1,186		1,186
Run 6b	7,216		7,216
Run 6c	2,809		2,809
Side circuit 1a	664	9	655
Side circuit1b	922	6	916
Side circuit 1c	470	5	465
Side circuit 1d	281	2	279
Side circuit 1e	860	6	854
Side circuit 1f	779	7	772
Stack 1 (south)	34		34
Stack 1 (north)	16		16
Stack 2 (south)	146		146
Stack 2 (north)	45		45
Stack 3 (south)	79		79
Stack 3 (north)	28		28
Stack 4 (south)	58		58
Stack 4 (north)	109		109
TOTAL	**15,702**	**35**	**15,667**
SE	125.31	5.92	125.17
LCI	15,451	23	15,417
UCI	15,953	47	15,917

Annex 8. Counts of 10 randomly selected close-up photographs taken at The Sisters northern Buller's albatross colony on 23 November 2016

Image	Island	Apparently Incubating	Loafer	Unknown	Pairs
1	Big Sister	56	0	9	1
2	Big Sister	27	1	3	0
3	Big Sister	28	1	0	0
4	Big Sister	98	1	2	1
5	Big Sister	73	2	12	0
6	Big Sister	31	1	0	0
7	Middle Sister	30	0	3	0
8	Middle Sister	35	2	1	0
9	Middle Sister	34	0	5	0
10	Middle Sister	54	0	1	0
Total		466	8	36	2

Annex 9. Counts of 11 randomly selected close-up photographs taken at The Forty-Fours northern Buller's albatross colony on 23 November 2016

Image	Apparently Incubating	Loafer	Unknown	Pairs
1	11	1	2	0
2	31	0	14	0
3	117	2	8	2
4	77	2	16	0
5	108	1	7	0
6	68	2	19	2
7	106	4	21	1
8	126	2	15	1
9	31	2	1	2
10	25	1	6	1
11	49	0	9	0
Total	749	17	118	9

Annex 10. Ground counts of 10 randomly selected transects taken at The Forty-Fours colony on 6 December 2016

Transect	Time start	Time end	Incubating	Loafer - on empty nest	Loafer - not associated with nest	Total loafers
1	11:30	11:40	**88**	**5**	**8**	**13**
2	11:45	11:50	**66**		**6**	**6**
3	11:53	12:00	**102**	**2**	**17**	**19**
4	12:03	12:07	**42**	**5**	**6**	**11**
5	12:12	12:25	**175**	**1**	**27**	**28**
6	12:28	12:31	**43**		**5**	**5**
7	12:34	12:38	**58**	**1**	**7**	**8**
8	12:40	12:44	**48**		**11**	**11**
9	12:51	12:54	**57**		**1**	**1**
10	12:56	13:05	**171**	**1**	**14**	**15**
Total			**850**	**15**	**102**	**117**