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White-capped albatross aerial survey 2015

Draft Final Report

Report prepared for

Department of Conservation

Contract 4625

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April 2015

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Executive Summary

White-capped albatrosses *Thalassarche steadi* are endemic to New Zealand, breeding on Disappointment Island, Adams Island and Auckland Island in the Auckland Island group, and Bollons Island (50-100 pairs) in the Antipodes Island Group (Gales, 1998). Previous population estimates that we have developed (Baker et al. 2014) show that most (95%) of the global population breeds on Disappointment Island, an area where access is restricted to maintain environmental values at the site.

Between 2006/07 and 2014/15 (hereinafter 2006 and 2014, respectively) we undertook repeated population censuses of the white-capped albatrosses breeding in the Auckland Islands using aerial photography. These population censuses were carried out in either December or January each year to estimate population size and track population trends. Our measure of population size was **'**Annual breeding pairs'**,** defined as *any pair of albatrosses that lays an egg in the breeding season of interest*. All other birds in colonies were assessed as 'Loafers', defined as *birds present in a colony but which do not appear to be associated with an active nest at the time of observation*.

In 2014 we estimated that there were 96,864 (95%CI 96,242 — 97,486), 4,741 (4,603 — 4,879) and 193 (165—221) annual breeding pairs at Disappointment Island, South West Cape and Adams Island, respectively, in 2014, based on the raw counts, giving a total for these sites of 101,798 (101,160 — 102,436) breeding pairs. Based on an assessment of 15 aerial close-up photos, 5.8% of birds in the colonies were loafers. After adjusting the raw counts to account for loafing birds, we estimate that there were 95,894 annual breeding pairs in the Auckland Islands in 2014. Previous annual counts have ranged from 73,838 to 116,025 annual breeding pairs (mean 90,781 annual breeding pairs).

Ground counts undertaken by Thompson et al. (2015) in January 2015, a few days before the 2014 aerial counts were undertaken, showed that of 1,127 birds sitting on nests, 909 (81%) were incubating eggs and 218 birds (19%) were sitting on empty nests. These data can be compared with ground counts of nests taken earlier in the breeding season (December) in 2008 that showed that 93.5% contained eggs and only 6.5% were empty. Aerial counts undertaken earlier in the breeding season are likely to provide a more accurate estimate of annual breeding pairs as nest failures occur progressively throughout the breeding season once egg laying has been completed. Ground-truthing data assessing the proportion of birds sitting on empty nests will not reliably provide a correction factor relevant to determining annual breeding pairs, as a bird sitting on an empty nest may have laid and subsequently lost its egg, may be yet to lay, or simply be a non-breeding loafer.

Count data over nine years show strong inter-annual fluctuations, a characteristic we have observed for many other seabird species. This variability would encompass counting error, the presence of non-breeding birds during counts, environmental stochasticity and other unknown variables that are not easily quantified. Trend analysis of nine years of counts using regression splines showed no clear evidence for systematic increase or decline over the nine years of the study. Given this we do not have sufficient evidence to reject the null hypothesis of no systematic trend in the total population. The trend should be considered to be uncertain; however, the null hypothesis of a stable population remains tenable and is probably a reasonable interpretation.

1. Introduction

White-capped albatrosses *Thalassarche steadi* are endemic to New Zealand, breeding on Disappointment Island (72 000 pairs), Adams Island (100 pairs) and Auckland Island (3 000 pairs) in the Auckland Island group, and Bollons Island (50-100 pairs) in the Antipodes Island Group (Gales, 1998). Previous population estimates we have developed (Baker et al. 2014) show that most (95%) of the global population breeds on Disappointment Island, an area where access is restricted to maintain environmental values at the site.

Ground and aerial photographs were undertaken of Disappointment Island colony in 1972, 1981, 1985, 1990 and 1993 by others (Taylor, 2000) but no reports or papers have been produced from these surveys. Despite this early work the population status of white-capped albatrosses was poorly known until 2006 when we commenced annual population censuses of white-capped albatrosses breeding on the Auckland Islands using aerial photography. These population censuses have now been conducted over eight years permitting population size to be estimated and population trends determined. (Baker et al. 2014).

We have now been contracted by the Department of Conservation to conduct another aerial survey of the Auckland Islands to build on the recent population census work. Specifically, the objectives of the project were to:

1. Conduct an aerial photographic census of white-capped albatross at the Auckland Islands following the methods of Baker et al (2014), to estimate the total number of breeding pairs.
2. Provide aerial (helicopter) support for other researchers under contract to DOC to access Dundas Island from Enderby Island, and potentially other islands in the Auckland Islands group, as requested by the lead investigator(s) of that/those project(s).
3. Ensure survey flights are timed to maximise comparability to the results of Baker et al (2014), to the extent possible given weather and other logistical limitations.
4. Analyse photographs from the aerial census of white-capped albatross, following the methods of Baker et al (2014), to estimate the number of breeding pairs and determine population trend.
5. Archive all photographic data obtained for white-capped albatross in accordance with the protocols described by Baker et al (2014).

In this report we describe the methods and results used in the aerial survey undertaken in the 2014/15 (2014 hereinafter) breeding season, and consolidate these counts with the existing longitudinal dataset to determine the population trend for white-capped albatross breeding in the Auckland Islands.

2. Methods

Definitions

The purpose of this study was to estimate the number of pairs of white-capped albatrosses breeding in the Auckland Islands each year (annual breeding pairs). One problem in the literature is that the term 'breeding pair' is regularly used but this term is not defined. As this is a major source of error it is necessary to define a benchmark for what is being counted before issues of error can be addressed. In this study the following terminology is used:

Annual breeding pair – any pair of albatrosses that lays an egg in the breeding season of interest.

Loafers –birds present in a colony but which do not appear to be associated with an active nest at the time of observation. These birds may be non-breeding birds or breeding birds away from their nest, or birds that have laid an egg earlier in the breeding season and subsequently lost it through breakage or predation.

The Site

The Auckland Islands (50^0 44'S, 166^0 06'E) lie 460 km south of New Zealand's South Island, and comprise the largest island group in the New Zealand sub Antarctic. The archipelago consists of four larger islands (Auckland, Enderby, Adams and Disappointment Islands), together with a set of smaller islands (Peat 2006). Within the archipelago, white-capped albatross breed mainly on Disappointment Island, located to the west of the main

Auckland Island, with smaller colonies situated on the South West Cape of Auckland Island and on the southwest coast of Adams Island (Tickell 2000). Disappointment Island is 4 km long by up to 1 km wide, and is covered in *Poa* grassland and giant herbs, with scattered areas of shrubland and fellfield around the top of the island (Peat 2006). The island rises steeply from the sea to a plateau, with white-capped albatrosses breeding extensively on the slopes but avoiding the plateau. Birds breeding at the colonies on South West Cape and Adams Island also confine nesting to steep, tussock-covered slopes.

Biology

Despite being New Zealand's most numerous breeding albatross species, very little is known of white-capped albatross breeding biology and at-sea distribution. Birds breed in the Austral spring, commencing egg-laying in mid-November, with hatching underway by mid-January, extending into early February. Chicks are guarded for approximately three weeks, and fledge in June (Thompson et al. 2011). The breeding frequency is uncertain, however Francis (2011) reported the probability that a bird that bred in one year would also breed in the next year to be 0.63, whereas the probability that a bird that didn't breed in one year but which would breed in the next year was 0.78. These results, together with observations of birds breeding in successive years, suggests that the white-capped albatross has an intermediate breeding strategy between annual and biennial (Thompson et al. 2011).

Information on the geographical range of white-capped albatross is confounded by its resemblance to the shy albatross *Thalassarche cauta* (Double et al. 2003), and there have been no published broad-scale satellite tracking or banding studies that accurately define their at-sea distribution. However, Abbott et al. (2006) used molecular species assignment methods to distinguish 'shy-type' albatross carcasses obtained from fisheries bycatch in Australia, New Zealand, and South Africa waters, thus providing some information on the geographic distributions of these species. Although information is limited, during the breeding season *T. steadi* is thought to forage mainly within New Zealand's Exclusive Economic Zone, including around the Chatham Islands and south of the Auckland Islands (Robertson et al. 2003; Thompson and Sagar 2008; ACAP 2011; Thompson et al. 2011; Torres et al. 2011), with chick-rearing birds utilising areas off the south-east coast of Australia and around Tasmania (Thompson and Sagar 2008; Torres et al. 2011). Juveniles and non-breeding adults range throughout the waters off southern Australia and South Africa (Robertson et al. 2003; Thompson et al. 2011; Petersen et al. 2008; Thompson and Sagar 2008; ACAP 2011). Juveniles and non-breeding adults have also been reported in the south-western Atlantic Ocean off Uruguay and northern Argentina (Jimenez et al. 2009; ACAP 2011).

Information from the closely-related shy albatross indicates that during the early incubation period the ratio of incubating to non-breeding birds is high as most non-breeders are at sea during the middle of the day (Barry Baker unpublished). This assumption was subsequently confirmed by observations at the South West Cape colony in November-December 2007 (Paul Sagar and David Thompson unpublished), although photographic evidence indicates the number of non-breeding birds was higher during January counts (see below).

Field Work – White-capped albatross

Field work for previous years (2006-2013) has been previously described in Baker et al. (2014). Every year from 2006/07 (hereinafter 2006) to 2013/14 (2013) we chartered a helicopter from Southern Lakes Helicopters Company to conduct a return flight to the Auckland Islands group. The aircraft, a single-engined Squirrel AS350B3, was piloted by either Chris Green, Richard Hayes or Mark Deaker (Southern Lakes Helicopters Company). On board was Barry Baker (photographer and project coordinator), a back-up photographer, a flight logistics manager and a Department of Conservation representative.

From 2006 to 2010 flights were conducted in December to coincide with the early incubation period of the breeding cycle. At this time it was anticipated that birds would have just completed egg laying (M. Double unpublished; P. Sagar unpublished), and hence most birds that attempted to breed would still be attending active nests. The dates of our previous visits to the Auckland Islands were 16 December 2006, 13 December 2007, 14 December 2008, 3 December 2009 and 15 December 2010. For logistical reasons the counts since 2011 were undertaken in January (11 January 2012, 14 January 2013 and 20 January 2014. The 2014 counts were undertaken on 14 January 2015 (Disappointment Island, SW Cape) and 18 January 2015 (Adams Island). The timing of January counts is not ideal with respect to the breeding cycle of white-capped albatross, as although hatching would not have commenced, some nests could be expected to have failed and those breeding birds may have abandoned their breeding sites.

For all flights we selected a weather window for the operation that predicted clear flying conditions with minimal low-level cloud. At the time of the 14 January 2015 flight the weather around the Auckland Islands was calm and fine. We were able to obtain clear photographs of the Disappointment Island and South West Cape colonies, but did not photograph the very small Adams Island colony until 18 January. Weather conditions during all flights are shown below:

Date	Weather conditions encountered during photographic survey
16/12/2006	calm and fine, no cloud
13/12/2007	calm and fine, minimal cloud
14/12/2008	calm and overcast, cloud base over 1,200 metres. On a couple of occasions light showers encountered
3/12/2009	calm but overcast, cloud base 600 metres. Light showers and sea fog encountered during flight over Disappointment Island, obstructing visibility of the top of the island on occasions.
15/12/2010	calm and fine, minimal cloud
11/01/2012	calm and fine, minimal cloud
14/01/2013	calm and fine, minimal cloud
20/01/2014	wind gusting to 40 knots, overcast, cloud base 1500 metres
14/01/2015	calm and fine, minimal cloud

Photography was timed to occur between 1100 to 1600 NZDT when we assumed most loafers would be at sea (see *Biology*, above).

On 14 January 2015 we left Enderby Island (Auckland Islands) at c.1200 NZDT with the door on the port side of the helicopter removed, and approached Disappointment Island at c.1210 NZDT. We conducted two circuits to provide the images that were used to count the breeding birds on the island, which were taken using a photo-extension of 70 mm. Additional photographs using maximum photo-extension (200 mm or 300mm) to assist in determining the proportion of empty nests and non-breeding birds in the colonies were also taken. The survey of Disappointment Island was completed by c.1315 NZDT and we then proceeded to the smaller white-capped albatross colony at South-West Cape on Auckland Island which was photographed between 1327—1340. Adams Island was photographed on 18 January 2015 at 1600 NZDT.

For the photography, two photographers were positioned on the port side of the aircraft which permitted each to take photographs of the island simultaneously. All photographs were taken through the open port side of the aircraft using Nikon D300 or D800 digital cameras and image-stabilised Nikkor 70— 200 mm F2.8 and 18—200 mm zoom lenses, or a 300 mm F2.8 telephoto 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 perpendicular to the land surface. The focal length of the zoom lens was not adjusted within each pass sequence over the island. From the circuits of the island we produced a complete series of overlapping images that covered the entire area of the island where albatrosses were nesting. The two photographers took approximately 1,500 digital photographs each during the survey flight. All photographs of the colony were taken as NEF raw files and subsequently saved as fine JPG files. The survey photographs of Disappointment Island were taken at an altitude of about 400 metres, well above the minimum limit of 300 m recommended by DOC. Most photographs were taken with the zoom lens set at a focal length of 70 mm. The close-ups were taken using the

300 mm telephoto lens. The entire sets 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 collection of photographs will also be submitted to the Department of Conservation on the completion of the contract. As an interim measure, a copy of all photographs of white-capped albatross colonies was submitted to DOC Southland (Ms Sharon Trainor) for on passing to DOC Wellington.

Early Ground counts

In earlier years ground counts were undertaken within a week of the 2007 and 2008 aerial counts. They have been reported on in more detail in earlier reports e.g. Baker et al. (2014), but the methods used in these studies are described briefly below.

At Disappointment Island counts of occupied nests were undertaken in 2008 by two observers to determine the proportion of birds sitting on nests without an egg. All occupied nests encountered 1 m either side of a randomly placed transect were inspected and the presence of eggs recorded. These counts were undertaken on 9 December 2008 between 1200 and 1230 NZDT.

At South West Cape, Auckland Island, counts were conducted in 2007 and 2008 by three observers who independently recorded the number of birds sitting or standing on nests, the number of pairs (partners accompanying an incubating bird), and the number of non-breeding birds present in four well defined areas of the colony. Counts were made every hour between 1030 and 1630 NZDT.

Ground counts on Disappointment Island in 2015

The National Institute of Water and Atmospheric Research (NIWA) were commissioned to undertake ground truthing of aerial survey by transect counts. This work was undertaken on Disappointment Island on 6 and 10 January, 2015, which was 4-8 days before the aerial survey was undertaken. The results of this work have been reported separately (Thompson et al. 2015), but are also included in this final report.

Ground-truthing was carried out at three white-capped albatross colonies: an area to the north of Castaway Bay, an area towards the south coast of Disappointment Island and an area below the summit ridge facing northwards (Thompson et al. 2015 and Figure 2 1 therein). Within each area, a member of the field team walked slowly along a transect, contouring across the slope, recording the number of birds sitting on a nest with an egg (incubating), the number of birds sitting on a nest without an egg (apparently incubating), the number of birds standing or sitting upright on a nest without an egg and the number of birds 'loafing' and not on a nest. Birds were recorded within approximately 2 m either side of the transect line, and those on empty nests recorded as either sitting or standing were categorised when first observed (Thompson et al. 2015).

Trend analysis

To assess population trend in total counts we used an appropriate Generalised Linear Model (Nelder and McCullough 1989) where the response was specified as an over dispersed Poisson distribution and the link was logarithmic. To allow for possible non-linear trend effects we used regression splines with a single knot at 2010.

Trend analyses were also run using software program TRIM (TRends and Indices for Monitoring Data; Pannekoek and van Strien 1996). TRIM is a freeware program, developed by Statistics Netherlands and is the standard tool used by the Agreement for the Conservation of Albatrosses and Petrels (ACAP) to analyse trends.

3. Results

Aerial counts

In 2014 we estimated the total count of nesting white-capped albatrosses to be 100,341 (95%CI 99,707 — 100,975) for Disappointment Island (Table 1); 4,881 (4,741 — 5,021) for South West Cape, Auckland Island (Table 2); and 206 (177— 235) for Adams Island (Table 3). Of these, 3,477 (3,359—3,595), 140 (116— 164) and 13 (6—20) birds were assessed as being the partners of incubating birds at Disappointment Island, South West Cape and Adams Island, respectively. Therefore, we estimate that there were 96,864 (95%CI 96,242 — 97,486), 4,741 (4,603 — 4,879) and 193 (165— 221) annual breeding pairs at Disappointment Island, South West Cape and Adams Island, respectively, in 2014, based on the raw counts, giving a total for these sites of 101,798 (101,160 — 102,436) breeding pairs (Table 4).

Analysis of 15 close-up photographs randomly selected showed that in 2014 most (420 of 462, or 90.9%) of the birds visible in the photographs were sitting on nests (Table 5). Twenty six (5.6%) were clearly not associated with a nest, 13 were the mates of birds sitting on nests, and we were unclear of the status of a further three birds. Across four years of close-up counts for years 2007-2010, 3,939 of the 3,993 visible birds (99%) were sitting on nests, while 54 birds (1%) were not associated with nests (Table 6). Across four years of close-up counts for years 2011-2014, 3,383 of the 3,902 visible birds (87%) were sitting on nests, while 519 birds (13%) were not associated with nests (Table 6). The proportion of non-breeding birds during the last four years ranged from 6-22%.

These results indicate that when counts were carried out in 2006-2010 (December, early incubation) there were few non-breeding birds in the colony, but in 2011-2014 (January, late incubation period) more non-breeders were present. These differences were taken into account when assessing population trends (see below).

Also apparent in the close-up photographs were a large number of empty nests. For the eight years 2007 to 2014 we counted a total of 2,943 empty nest pedestals compared with 7,322 occupied nests in the randomly selected close-ups each year (29% unoccupied).

Ground counts

Ground counts of nests inspected on the ground on Disappointment Island on 9 December 2008 showed that 447 occupied nests (93.5%) contained eggs and 31 (6.5%) were empty.

At SW Cape ground counts in 2007 and 2008 confirmed the impression provided by the close-up photos that few non-breeding birds are generally present in the colony during December counts at the time of day that the aerial photography was undertaken. From 84 observations, ≤ 2% of birds present were non-breeders on 86% of observations, and ≤ 5% on 97% of the total observations. The maximum number of non-breeders present at any one time was 10%.

Ground counts undertaken by Thompson et al. (2015) showed that of a total of 1,449 birds in the colony, 1,127 (78%) were sitting on nests and the remaining 322 (22%) were clearly loafing. Of those birds sitting on nests, 909 (81%) were incubating eggs and 218 birds (19%) were sitting on empty nests. Only 909 birds (63%) were actively nesting (on eggs), while 540 (37%) of the total of 1,449 birds present were loafing. The findings of the January 2015 ground counts are summarised below from Thompson et al. (2015).

Date	Start	End	Bird sitting on egg	Bird sitting on empty nest	Total birds on nests	Loafing - standing on empty nests	Loafing birds, not associated with nests	Total loafers	Total birds	Total Nests
6-Jan-15	NR	NR	122	30	152	32	17	49	201	184
10-Jan-15	10:00	10:20	119	39	158	22	20	42	200	180
10-Jan-15	12:00	12:20	113	24	137	4	2	6	143	141
10-Jan-15	14:00	14:20	128	13	141	3	4	7	148	144
10-Jan-15	16:00	16:20	126	27	153	27	20	47	200	180
10-Jan-15	10:00	10:45	100	36	136	29	43	72	208	165
10-Jan-15	10:00	10:55	154	33	187	59	31	90	277	246
10-Jan-15	12:48	13:08	47	16	63	0	9	9	72	63
Totals			909	218	1,127	176	146	322	1,449	1,303
%			0.81	0.19		0.55	0.45			
					0.78			0.22	1.00	

Trend Analysis

Count data over nine years show strong inter-annual fluctuations, a characteristic we have observed for many other seabird species (e.g. Congdon et al. 2007). This variability would encompass counting error, the presence

of non-breeding birds during counts, environmental stochasticity and other unknown variables that are not easily quantified.

Estimated annual counts for all three breeding sites in the Auckland Islands (Table 4) were adjusted to account for the presence of loafing birds (Table 6), as determined by aerial close-up photos, giving adjusted estimates of annual breeding pairs of 116,025, 90,036, 96,118, 73,838, 76,119, 92,692, 102,273, 74,031 and 95,894 for each year from 2006 to 2014 inclusive. These adjusted figures were used as inputs into models used for assessment of population trend.

Trend analysis for all sites combined using regression splines showed no clear evidence for systematic increase or decline over the nine years of the study. Given this we do not have sufficient evidence to reject the null hypothesis of no systematic trend in the total population (Figure 4); the null hypothesis of a stable population remains tenable.

Using TRIM for all sites combined and analysing nine years of data (2006 to 2014 breeding seasons), the stepwise procedure for selection of change points indicated significant change points in all years ($p < 0.01$ for Wald tests). The population size estimates computed from the model indicate an average growth rate of -1.73% per year ($\lambda = 0.9827 \pm 0.001$; assessed by TRIM as a moderate decline.

4. Discussion

Comparison of Annual Photographic Counts

Our study provides the first complete estimate of the number of annual breeding pairs and population trend of white-capped albatrosses at the Auckland Islands. When the raw counts are adjusted for the presence of loafing birds, as determined from aerial close-up phots, the estimated number of annual breeding pairs over the last nine years has ranged from a high of 116,025 annual breeding pairs in 2006 to a low of 73,838 in 2009, with mean estimated number of annual breeding pairs of 90,781. These numbers exceed the early published estimates of Gales (1998) and Taylor (2000) (70 000 and 70-80 000 pairs, respectively).

Two aspects of the counts were notable. Firstly, the count patterns at both Disappointment Island and South West Cape were very similar in every year (Figure 4). The ratio between counts at South West Cape and Disappointment Island has ranged from 0.049 to 0.062 (mean 0.058). This would not be necessarily expected, and provides evidence that both populations are impacted equally by the same ecological and environmental influences. Under resource constraints, annual monitoring of the smaller South West Cape colony could serve as a useful proxy for the population as a whole. Secondly, the number of loafers in the colonies increased greatly as incubation progresses, as has been observed for other albatross species (Tickell 2000). Evidence from the close-up photographs across nine years indicates that the number of loafing white-capped albatrosses at Disappointment Island was very low early in the incubation period (<2% for all December counts), but higher later in the breeding season (7%, 15% , 22.3% and 5.8% for January counts in 2011, 2012, 2013 and 2014 respectively). Information gained from ground counts in 2007, 2008 and 2014 support this observation. This has implications for the timing of future counts, as it is desirable that this parameter is measured each year, particularly when counting is undertaken later in the breeding season. While acknowledging that helicopter availability in the Auckland Islands is always likely to have some influence on the timing of future counts, it is recommended that future counts are timed for mid-December, if logistically feasible.

Trend analysis

Population size estimates computed from the TRIM model indicate an average growth rate of - 1.73 % per year ($\lambda = 0.9827 \pm 0.001$); assessed by TRIM as moderate decline. We note, however, that a simple linear trend analysis, as performed by TRIM is not well suited to a data set with high inter-annual variability. Trend analysis using regression splines is more appropriate to such data sets, and showed no evidence for monotonic decline over the nine years of the study, therefore providing insufficient evidence to reject the null hypothesis of no trend in the total population. While a population trend is uncertain, the null hypothesis of a stable population remains tenable.

Sources of error in photographic census, and the value of ground-truthing

As for any wildlife survey method, aerial photography must contend with sources of sampling error. The observed strong inter-annual fluctuations in the count observed in this study would encompass counting error,

the presence of loafing birds during counts, environmental stochasticity and other unknown variables that are not easily quantified.

Ground-truthing has been used in other photographic censuses of albatross colonies to estimate the bias associated with birds loafing in colonies, birds sitting on nests without an egg, and to identify areas where nests may be obscured from the air by topographical features (Robertson et al. 2007). The information gained from ground surveys has then be used to estimate the total number of breeding pairs from the total number of birds counted.

The following likely sources of bias and identifiable components of variability in using aerial survey techniques, can be identified, some of which can be addressed with ground truthing, and some of which cannot. These include:

1. The total number of active nests will be overestimated due to the presence of loafing birds and birds sitting on nests without eggs. For black-browed albatross colonies in Chile, Robertson et al. (2007) estimated that nearly 12% of birds attending a colony fell into one of these two categories. Simultaneous ground-truthing revealed that 5% of the birds photographed were loafing in the colony and a further 7% were sitting on empty nests. In this study we have identified that the proportion of loafers varied greatly between December counts undertaken at the end of egg-laying/ early incubation period, and a month later when incubation was well advanced and a number of nesting birds are likely to have failed. The size of these errors would differ depending on the time of day and stage of breeding that surveys were conducted.

We have chosen to use the evidence on the proportion of loafers present in colonies, derived from close-up photographs and ground counts to deflate the raw counts to estimate the number of annual breeding pairs. However, it could be equally valid to inflate counts to some degree using this data, as a loafer may be a failed breeding bird, particularly so when birds are sitting on nests without eggs. As such, our estimates of annual breeding pairs should be considered to be conservative. We also recognise that ground-truthing data assessing the proportion of birds sitting on empty nests will not reliably provide a correction factor relevant to determining annual breeding pairs, as a bird sitting on an empty nest may have laid and subsequently lost its egg, may be yet to lay, or simply be a non-breeding loafer.

2. Differences between observer counts will generate variability in the count, as will misidentification of birds in mixed species colonies. Fortunately, our analyses suggest that the error associated with our counts was no larger than the intrinsic error expected in count data, and there were no other species nesting amongst the white-capped albatross colonies.

3. Poor stitching of the photographs will generate variability in counts. Omission or double-counting of albatrosses near stitch lines due to parallax has been considered a problem in other studies (Robertson et al. 2007). For the counts at all breeding sites in the Auckland Islands the nature of the terrain was such that we are confident that on most stitch lines no such errors occurred. On most images the ridge lines were easily defined and we are confident that birds were not missed or double counted. Where it was difficult to draw these lines any error would not have exceeded two hundred birds in total across all stitched images in any year.

4. Ground-truthing may permit identification of 'detection error' in areas where nests may be obscured from the air by topographical features such as jumbled rock substrate, but this is unlikely to have been a problem for the Auckland Island sites. Note however, that in some cases where site topography is uneven, it is possible to miss small colonies in ground counts that may be readily observed from the air (Robertson et al. 2007; G. Robertson unpublished).

While ground-truthing may improve the accuracy of population estimates derived from aerial surveys, it needs to be recognised that the timing of aerial and on-ground counts needs to synchronous if meaningful correction factors are to be developed. In any albatross colony, nests fail after laying as eggs are broken or become buried in the mud-nest pedestals. In the closely related shy albatross, some birds may continue to attend nests for some time after eggs are lost or broken. However, as the time-lag between an aerial and on-ground count increases, the relativity between estimates derived from both counts is likely to decrease. Access to many sub-Antarctic islands is often difficult for both logistic and financial reasons, and the uncertainty associated with access may provide a valid reason to rely on aerial counts for estimating population size at sites where it is feasible to do so. As advocated by Robertson et al. (2007) and used by Arata et al. (2003) and in this study, the use of high resolution digital photographs and subsequent magnification on a monitor to enhance the images

of individual birds, can provide improved information on posture and behaviour that may enable breeding birds and loafers to be separated.

Despite the strong inter-annual fluctuations, the data are useful for tracking change in the white-capped albatross population since they have been collected at roughly the same time of the breeding cycle (incubation), allowing inferences about long-term trends to be made. This information should provide a statistical basis for making decisions about management of these populations.

Conservation implications

The remoteness of breeding sites and difficulty of access has previously constrained development of a comprehensive estimate for size of the breeding population of white-capped albatross (Croxall and Gales 1998; Taylor 2000). While attempts have been made at times over the last 20 years to conduct counts at Disappointment Is and South West Cape, where the bulk of the global population breeds, details of these have never been published and it is difficult to assess the methodology used, the time of year counts were made, the completeness of the counts, and any population trend beyond the data I have collected.

With only the reputedly small colony on Bollons Island (Gales 1998; Tennyson et al. 1998; Robertson 1975) not counted in this study, our estimates represent the first reliable population estimate for this species. These estimates indicate that global population is currently c.90 000 annual breeding pairs, which is much larger than previously thought. This may be the result of sustained population growth since the 1970s, or simply reflect inaccuracy of the earlier counts in a population that is stable.

In a global review of fisheries-related mortality of shy and white-capped albatrosses Baker et al. (2007) estimated that 8 000 white-capped albatrosses were killed each year as a result of interactions with trawl and longline fisheries in the Southern Ocean. This level of estimated mortality highlights the need to continue to acquire accurate population estimates and trends for white-capped albatross populations to assess the impact of fisheries operations on this species. While uncertainty still exists around the population trend, ongoing annual monitoring is recommended to build on the existing data set, clarify the population's status and provide certainty around the sustainability of current levels of fishing mortality.

Acknowledgements

Over the years this project has been funded by the Department of Conservation's Conservation Services Programme, and the Ministry of Primary Industries. The support of Martin Cryer of the New Zealand Ministry of Primary Industries, Richard Wells of the DeepWater Group, and Igor Debski and Pete McClelland of DOC during the development of the project was greatly appreciated. We are also grateful for the efforts of Brent Beavan, Pete McClelland, Sharon Trainor and Doug Veint for facilitating permits to visit and work in the Auckland Islands over the years. Photographic and logistical support was provided by Simon Childerhouse, Rachael Alderman, Graham Robertson, Mike Double and Luke Finley. Southern Lakes Helicopters and pilots Sir Richard 'Hannibal' Hayes, Mark Deaker and Chris Green safely transported us to and from the Auckland Islands and provided an excellent photographic platform for the study. We also thank Paul Sagar, David Thompson, Leigh Torres, Graham Parker and Kalinka Rexer-Huber of NIWA for conducting ground-truthing counts on South West Cape and Disappointment Island, and to David Thompson and Paul Sagar for freely sharing information from their ecological study of white-capped albatrosses. The support of Nathan Walker and Susan Waugh of the then NZ Ministry of Fisheries, and Graham Robertson and Mike Double of the Australian Antarctic Division, during the development and implementation of this research, was greatly appreciated.

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Table 1. Counts of nesting white-capped albatrosses, made from photomontages of Disappointment Island, Auckland Island, 14 January 2015.

Area	Counts		
	Total birds	**Pairs**	**Occupied nests**
1	757	21	736
2	2,852	85	2,767
3	883	41	842
4	72	3	69
5	1,515	44	1,471
6	19,940	597	19,343
7	2,731	129	2,602
8	1,524	30	1,494
9	1,443	62	1,381
10	214	9	205
11	856	33	823
12	8,629	308	8,321
13	2,164	92	2,072
14	9,558	311	9,247
15	12,034	529	11,505
16	11,391	377	11,014
17	17,674	632	17,042
18	1,372	54	1,318
Castaway a	58	2	56
Castaway b	4,674	118	4,556
TOTAL	100,341	3,477	96,864
SE	316.77	58.97	311.23

Table 2. Counts of nesting white-capped albatrosses, made from photomontages of South West Cape, Auckland Island, 14 January 2015.

Area	Counts		
	Total birds	**Pairs**	**Occupied nests**
1	2,075	59	2,016
2	357	16	341
3	702	15	687
4	85	2	83
5	23	1	22
6	95	1	94
7	38	1	37
8	25	0	25
9	226	5	221
10	522	12	510
11	733	28	705
TOTAL	4,881	140	4,741
SE	69.86	11.83	68.85

Table 3. Counts of nesting white-capped albatrosses, made from a photomontage of the Adams Island colony, 18 January 2015.

Area	Counts		
	Total birds	**Pairs**	**Occupied nests**
1	206	13	193
TOTAL	206	13	193
SE	14.35	3.61	13.89

Table 4. Annual breeding pairs of white-capped albatrosses in the Auckland Islands in December 2006-2010 and January 2012-2015, with 95% Confidence Intervals, and counts adjusted to take into account the proportion of loafers in colonies, as determined by aerial 'close-up' counts from Disappointment Island.

Island	2006	2007	2008	2009	2010	2011	2012	2013	2014
Adams	**-**	**79**	**131**	**132**	**117**	**178**	**215**	**184**	**193**
LCI		61	108	109	95	151	186	157	165
UCI		97	154	155	139	205	244	211	221
Disappointment	**110,649**	**86,080**	**91,694**	**70,569**	**72,635**	**93,752**	**111,312**	**89,552**	**96,864**
LCI	109,984	85,493	91,088	70,038	72,096	93,140	110,645	88,953	96,242
UCI	111,314	86,667	92,300	71,100	73,174	94,364	111,979	90,151	97,486
SW Cape, Auckland	**6,548**	**4,786**	**5,264**	**4,161**	**4,370**	**5,846**	**6,571**	**5,542**	**4,741**
LCI	6,386	4,648	5,119	4,032	4,238	5,693	6,409	5,393	4,603
UCI	6,710	4,924	5,409	4,290	4,502	5,999	6,733	5,691	4,879
Total Auckland Islands	**117,197**	**90,945**	**97,089**	**74,862**	**77,122**	**99,776**	**118,098**	**95,278**	**101,798**
LCI	116,512	90,342	96,466	74,315	76,567	99,144	117,411	94,661	101,160
UCI	117,882	91,548	97,712	75,409	77,677	100,408	118,785	95,895	102,436
Proportion loafing birds	0.01	0.01	0.01	0.01	0.01	0.07	0.13	0.22	0.06
Adjusted count	116,025	90,036	96,118	73,838	76,119	92,692	102,273	74,031	95,894

Table 5: Counts of 15 randomly selected close-up photographs taken at the Disappointment Island colony in January 2015.

Photo ID	Image	Incubating	Loafer	Unknown	Pairs	Empty nest
1	4214	39	4	0	2	16
2	4218	38	2	0	0	17
3	4221	19	0	0	1	3
4	4224	28	0	2	0	12
5	4227	10	0	0	0	5
6	4231	15	1	0	0	13
7	4234	20	1	0	1	8
8	4238	46	2	0	3	19
9	4240	26	1	0	1	6
10	4243	17	0	0	0	4
11	4245	40	1	0	2	10
12	4247	11	3	0	0	9
13	4249	20	3	0	0	12
14	4250	51	0	0	0	21
15	4252	40	8	1	3	11
Total		420	26	3	13	166

Table 6. Summary of counts of randomly selected close-up photographs taken each year at Disappointment Island in December 2007-2010 and January 2012-2014.

Year	On Nest	Not sure	Not on nest	Pairs	Total Birds - breeding status known	Empty nests	Total nests
2007	805	21	4	5	809	326	1,131
2008	1,590	20	29	22	1,619	438	2,028
2009	937	23	13	5	950	633	1,570
2010	607	16	8	2	615	343	950
2011	1,007	31	77	19	1,084	291	1,298
2012	1,096	63	169	17	1,265	n/a	663
2013	860	24	247	29	1,107	504	1,364
2014	420	3	26	13	446	166	586
Totals	**7,322**	**201**	**573**	**112**	**7,895**	**2,943**	**10,265**

Figure 1. Boundary of photographic montages 1 to 8 and Castaway Bay, Disappointment Island

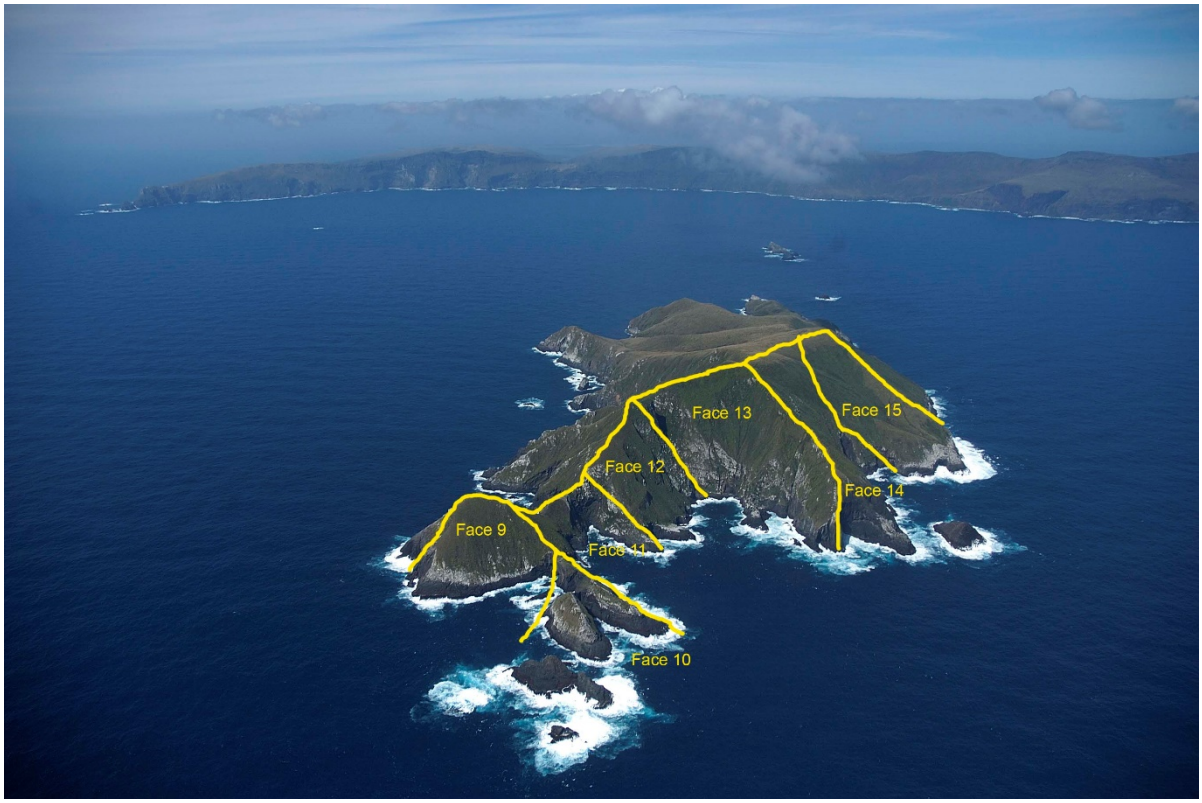

Figure 2. Boundary of photographic montages 9 to 15, Disappointment Island

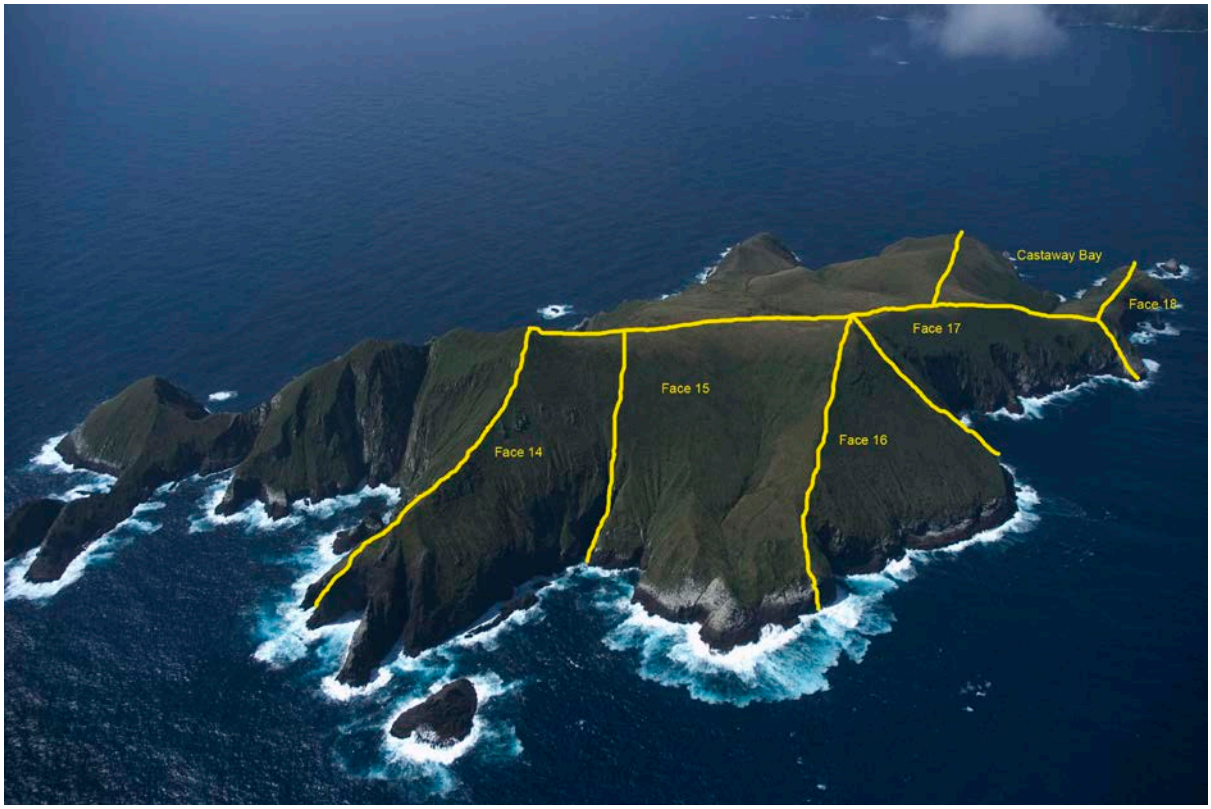

Figure 3. Boundary of photographic montages 14 to 18 and Castaway Bay, Disappointment Is.

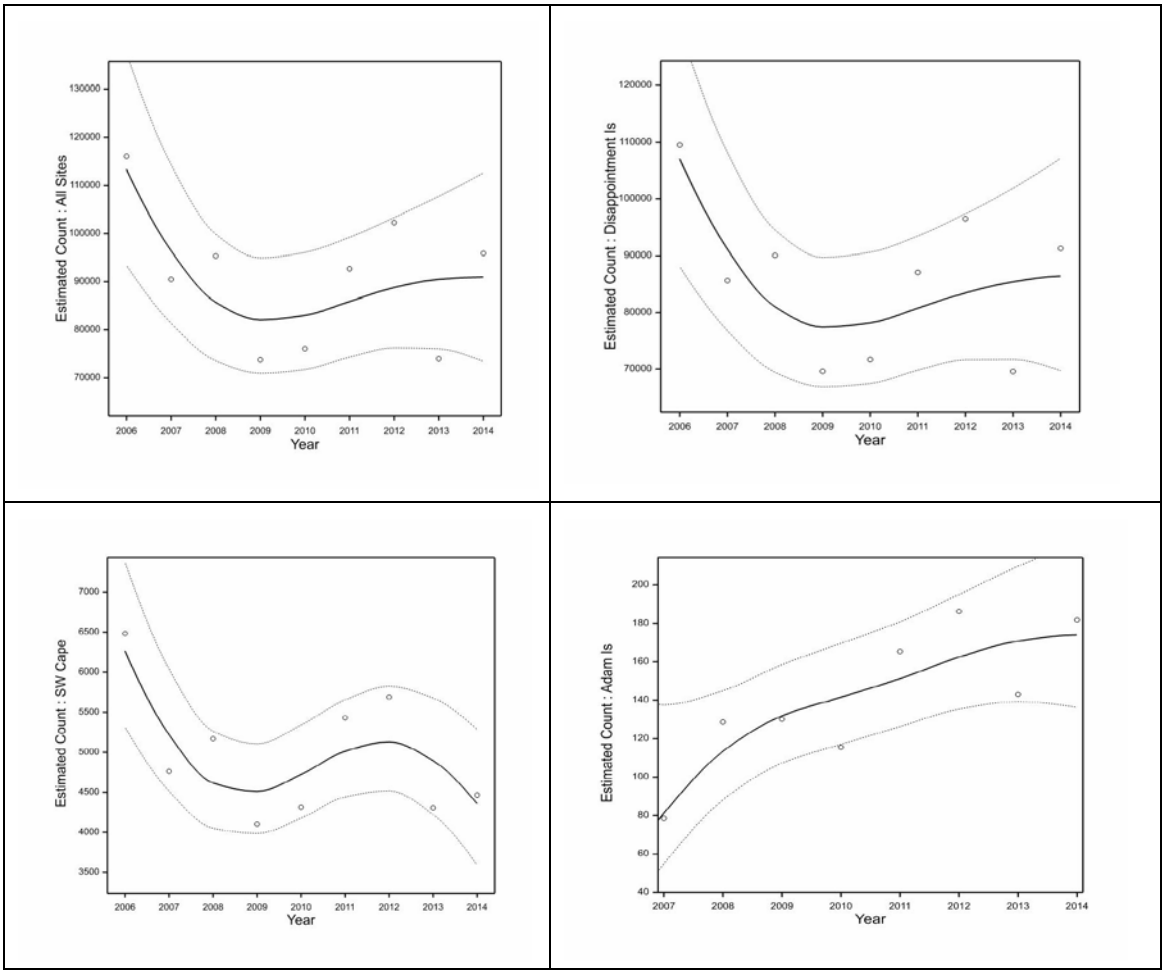

Figure 4.Data points (total counts as adjusted for the presence of loafing birds), regression trend line with associated 85% confidence intervals for annual breeding pairs of white-capped albatross at three sites in the Auckland Islands. Non-overlap of the 85% CI between any two points infers significance at P=0.05. Note that scale differs on the Y axis. Top left panel - All sites; top right panel - Disappointment Is, bottom left panel - SW Cape; bottom right panel – Adams Is.