Salvin's albatross population trend at the Bounty Islands, 1997-2011

Salvin's albatross population at the Bounty Islands

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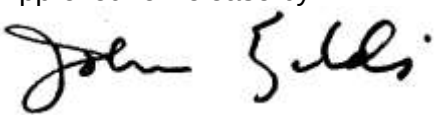

John Zeldis

Executive summary

The Bounty Islands supports about 98.5% of the breeding population of the endemic Salvin's Albatross (*Thalassarche salvini*), but the population had not been counted using methods that can be replicated. Therefore, until now there has been no means to determine population trends over time. To estimate population trend and examine the accuracy of ground counts we completed a whole-island survey of Salvin's Albatross breeding at Proclamation Island, Bounty Islands, New Zealand in November 1997. Repeat counts using the same methods completed in November 2004 and November 2011 suggested that the numbers of Salvin's Albatross nests on Proclamation Island declined by 14% between 1997, and 2004, by 13% between 2004 and 2011, and overall by 30% between 1997 and 2011. Counts of nests on Depot Island decreased by 10% between 2004 and 2011.The scale of change measured in the Salvin's Albatross population on Proclamation and Depot Islands requires urgent investigation of the population and foraging biology of this nationally vulnerable New Zealand endemic species. We recommend that future ground counts be undertaken about 14 September (at the end of egg laying), so reducing any effects of prior breeding failure on estimated totals.

1 Introduction

Salvin's Albatross (*Thalassarche salvini*) is endemic to New Zealand, with the main breeding population at the Bounty Islands. These albatrosses have been recorded as bycatch in New Zealand trawl fisheries in relatively high numbers, and have been identified as at potential risk from the impacts of such commercial fisheries (Richard et al. 2011). Little is known about Salvin's Albatrosses, with most knowledge coming from the small population at the Snares Western Chain (Sagar et al. 2011).

In November 1978 the first scientific expedition to camp on the islands reported that Salvin's Albatrosses were breeding on eight islets in the group with a total estimated population of 76,352 breeding pairs (0.5 pairs per m^2) (Robertson & van Tets 1982). The population estimate was derived by estimating the nesting density and multiplying by the area of the island covered by nesting birds. Subsequently, commercial fishing operations were recognised as the major factor in the decline of albatross populations (Bartle 1991; Brothers 1991; Croxall & Gales 1998; Gales 1998) and this lead to a flurry of albatross population studies being established. Among these studies were those reported here. The first of these was planned, funded and implemented in 1997-98 by Gerry Clark, Environmentalist and Master Mariner, primarily to establish population monitoring of the breeding populations of Salvin's Albatross, Erect-crested Penguin (*Eudyptes sclateri*), Fulmar Prion (*Pachyptila crassirostris*) and Bounty Island Shag (*Leucocarbo ranfurlyi*). The Bounty Islands were visited again in 2004 and 2011 to repeat and expand the 1997 work.

The purpose of this report is to determine the population size and trend of breeding Salvin's Albatrosses based on data collected on Proclamation Island during the period 1997-2011, and on Depot Island during the period 2004-2011.

2 Study area

The Bounty Islands (47º 45'S, 179º 03'E) are 760 km east of New Zealand, and are comprised of 22 bare granite outcrops with a total area of 135 ha, exposed to the full force of the southern ocean (Peat 2003; Taylor 2006). They are spread in three groups over 4.5 kilometres of ocean. The largest is Depot Island which is 800 m long and 50 m high; the highest point is on Funnel Island at 73 m above sea level (Figure 2-1) (Taylor 2006).

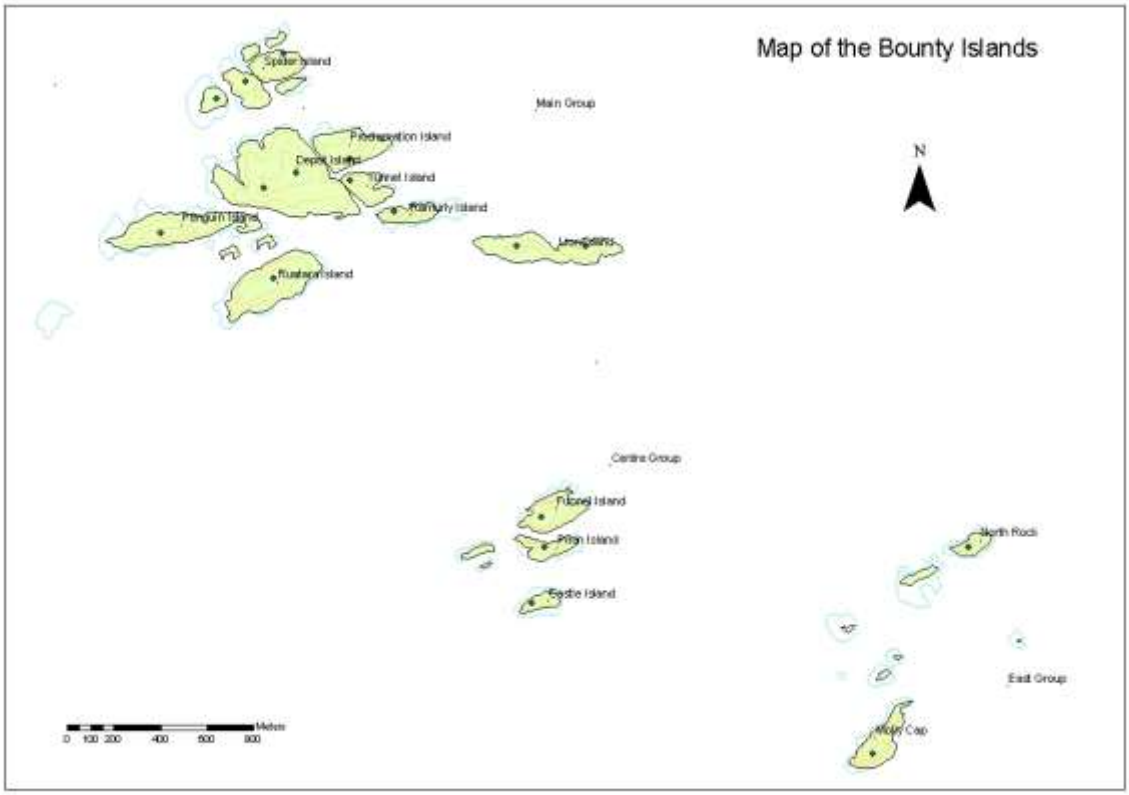

Figure 2-1: Bounty Islands, showing the location of island groups and islands.

The islands sit atop the Bounty Plateau continental crust extending south and east of New Zealand (Adams 1981, 1985). The shallow shelf waters and the sharp relief of the Plateau edge mix the Antarctic Circumpolar Current and northern subtropical waters that are deflected by the New Zealand landmass (Belkin & Gordon 1995; Chang & Gall 1998; Murphy et al. 2001). The resulting high productivity supports the summer breeding of seven seabird species and the largest known breeding population of New Zealand fur seal (*Arctocephalus forsteri*) (Robertson & van Tets 1982; Peat 2003).

The islands are the major breeding location of the endemic Salvin's Albatross, Erect-crested Penguin, Fulmar Prion and the only breeding location of the Bounty Island Shag. Salvin's Albatrosses and Erect-crested Penguins nest in mixed colonies covering most areas above wave height on eight islands in the group. Fulmar Prions breed in rock crevices and the Bounty Island Shags nest on small ledges on steep cliffs above the water. Snares Cape Pigeons *(Daption capense australe)*, Antarctic Terns (*Sterna vittata*) and Black-backed Gulls *(Larus dominicanus)* also nest on the islands (Robertson & van Tets 1982).

3 Methods

3.1 Timing of visits

The timing and a brief description of the studies undertaken on Salvin's Albatrosses at the Bounty Islands are shown in Table 3-1.

Table 3-1: Timing of visits to the Bounty Islands and a summary of work on Salvin's Albatross undertaken.

Year	Dates on the islands	Travel	Salvin's Albatross work undertaken
1978	7 to 20 Nov	HMNZS *Waikato*	Population estimate - density based
1997	31 Oct to 17 Nov	*RV Totorore*	Attempt to repeat 1978 counts
	9 Dec to 6 Jan		Proclamation Island 8-block count
			Nest monitoring in study area (hatch date, egg loss attendance)
			Investigator disturbance
2004	12 to 17 Nov	*Mahalia*	Proclamation Island 8-block count
			Depot Island count
			Funnel Island count
			Location and boundaries of blocks and colony areas defined by GPS
2011	11 to 14 Nov	*RV Tiama*	Proclamation Island 8-block count
			Depot Island count
			Location and boundaries of blocks and colony areas defined by GPS

3.2 Ground counts

3.2.1 Repeating 1978 census

The aim of the 1997 expedition was to repeat the counts of nesting Salvin's Albatrosses and Erect-crested Penguins that had been completed in November 1978 to assess if there had been any change in the population sizes of these species. Before travelling to the islands a thorough review of the 1978 trip report was made and C. J. R. Robertson, who had conducted the 1978 counts, was contacted to discuss the methods used. Unfortunately, little detail was contained in the report and given the time that had elapsed since, C.J.R. Robertson was unable to recall the exact methods.

The 1997 trip was timed to cover the same period as the 1978 expedition and using the photographs in the 1978 report an attempt was made to identify areas of different densities of breeding birds that had been counted then. We sampled areas from 5 m^2 to 20 m^2 in an attempt to replicate "a few small areas" that had been sampled in 1978 (Robertson & van Tets 1982). However, we were not confident that any of the areas we sampled were those used in the 1978 estimate and due to the high variability in the density figures we recorded, we decided that the best way to "average" the variability in density was to complete a whole-island count of nesting birds. In this way variation in density caused by edge effect,

topography, and fur seal numbers would not bias the sample and the technique would be repeatable, comparable and afford greater accuracy.

3.2.2 Proclamation Island

In November of 1997, 2004 and 2011, Proclamation Island was divided into the same eight blocks using natural geographic features (Figure 3-1) and the boundaries marked with stock marker for the duration of each visit. All nesting Salvin's Albatrosses within the eight blocks were counted to give a whole island census for Proclamation Island. In 1997 the boundary between blocks 7 and 8 was in a different position than in 2004 and 2011. Therefore, it is not appropriate to compare counts of these blocks in 2004 and 2011 with the counts made in 1997 unless the totals for the two blocks are combined. In 2011 block 8 was not counted due to time and weather constraints.

Figure 3-1: Proclamation Island census blocks.

3.2.3 Depot and Funnel Island

In 2004 additional study sites were established on Depot Island (Figure 3-2 and 3-3) and Funnel Island (Figure 3-4). On both islands a discrete area, clearly defined by natural features was marked with stock marker. Both Salvin's Albatrosses and Erect-crested Penguins within the marked area were counted using the same methods as on Proclamation Island. Considerations in selecting the sites were representativeness of bird densities to elsewhere on that island, ease of relocating and recognising the site in future by geographical features, and the ability for future counts to be undertaken in a single day visit to the island.

Counts on these islands were made to establish if nest densities were the same on each island, to add robustness to the population monitoring. Changes in the population may manifest as a change in nest density and/or the extent of the area covered by birds. It is also possible that favoured sites or islands carry maximum densities of breeding birds and that changes in the population occur initially and more rapidly at less favourable sites. Monitoring several islands increases the likelihood of detecting disparate population change.

On Depot Island the west and north boundaries of the block are not as easy to distinguish as the other boundaries. A series of point to point photographs were made to assist relocating the boundary on the ground in future. The numbers in Figure 3-4 are prominent ground features that were numbered with stock marker then photographed viewing the next consecutive number, the photographs clearly show the painted block boundary. In 2011 albatross and penguin nests on Depot Island were counted for a second time, but sea conditions did not enable Funnel Island to be revisited and so no count was made there.

On Funnel Island the count site was delineated by a small saddle/seepage area straddling the island from a small gut at the base of the northern finger through the low ground to the southern side culminating in a sheer gut (Figure 3-4). We attempted to divide the island into a smaller block along the ridgeline but had difficulty finding an obvious delineation. The count of the whole western end took 4 hours 15 minutes, a sub total of the area south of the ridgeline has been included in italics but as this boundary is difficult to relocate the whole western end should be recounted in future unless time is restricted

3.2.4 Census methods

Each block was systematically searched by two people, one checking Erect-crested Penguins and the other Salvin's Albatrosses for the presence of an egg or chick. Salvin's Albatross nests were counted where an albatross (with or without an attendant partner) was incubating an egg or brooding a chick. No nests with an abandoned egg or chick were recorded. In most cases the egg or chick could be seen as the albatross repositioned itself in response to the approach of the counter, otherwise the stance of the albatross generally indicated if it was incubating. Most birds not incubating sit with wings folded higher on their back than do incubating birds, and they are more likely to stand up completely when approached. When the breeding status was unclear from these indicators the bird was gently lifted to confirm if an egg or chick was present. After being counted each nest was marked with a spot of stock marker spray on the ground close-by, a different colour was used from that used to mark penguin nests.

While counting occupied nests an attempt was made to count and where possible mark with stock marker birds not incubating an egg. These "Loafers" include pre-breeders prospecting for mates, failed breeders and off duty mates of breeders. Loafers are highly mobile and often flocked ahead of the advancing counters making them difficult to mark. Their numbers fluctuated with time of day, weather conditions and time of season. Nesting birds are often unable to be distinguished from Loafers in aerial photographs. Therefore, Loafer counts assist in the interpretation of aerial photographic counts.

The majority of Salvin's Albatrosses were also checked for a leg band. All bands were recorded if possible and the bird marked with stock marker so that they were not recaptured during the same visit.

To obtain an estimate of the proportion of nests missed or double counted in each block on completion of a block count, transects were walked at 90 degrees to the general count direction. The person who had previously counted albatrosses now checked penguin nests and the penguin counter checked albatross nests 2 m either side of the line walked. The total number of nests counted was recorded as well as nests that were unmarked or had been counted more than once. The percentage of birds missed and/or over-counted was calculated for each block and this figure applied to give an adjusted count for individual blocks.

3.2.5 Study area

On 29 October 1997 a study area measuring 10 m by 20 m was established on Proclamation Island (Figure 3-1). The area was subdivided into 5 m squares and can be readily relocated using natural ground features. When the study area was established there were 86 Salvin's Albatross nests, each with a single egg close to hatching. All nests were marked with a numbered tag.

Due to the high numbers of Salvin's Albatross in the study area the sub area of six squares "A" to "F", containing 70 Salvin's Albatross nests was monitored daily from 31 October to 17 November 1997 to record pipping (i.e. when the eggshell was starred or had a small hole broken – the first sign of a chick hatching), chick hatching dates, and the rate of nest failure. All nests containing an egg in the complete study area were monitored on 1, 5, 14, 17 November 1997.

All Salvin's Albatross nest pedestals in the study area not containing an egg, were counted on 1 Nov 1997 to estimate the number of Salvin's Albatross nests lost before the start of the study. Most nest pedestals persist throughout (and between) breeding seasons. The presence of recent renovations, guano and down as indicators and the fact they had not been dismantled for use by other pairs indicated that all the nest pedestals in the study area had been used during the 1997 season.

3.2.6 Control area and investigator disturbance

A control area measuring 20 m by 10 m was established on 5 November 1997. The control area was established primarily to monitor the impact of investigator disturbance in the study area where daily visits ranged from two to eight hours duration. The control area was distant from but similar in topography and aspect to the study area and was left as undisturbed as possible.

Three visits were made to the control area, the first to set the area up and again on 14 November 1997 before our departure from the island; a third visit was made on 3 January 1998 at the end of the expedition. On each visit all Salvin's Albatross nests with eggs within the control area were counted. Each nest received a small mark of stock paint on the ground beside the nest to indicate it had been counted, different coloured paint was used for each count. When the control area was established on 5 November, the area contained 64 Salvin's Albatross nests with a single egg. All empty Salvin's Albatross nest pedestals in the control area were counted on the first visit to the area.

The number of Salvin's Albatross nest losses in the study area were compared to the number of Salvin's Albatross nest losses at the control area over the same time period to

assess whether investigator disturbance in the study area had affected the breeding success in the study area. Results were tested using a Pearson's Chi-square 2-sided exact test.

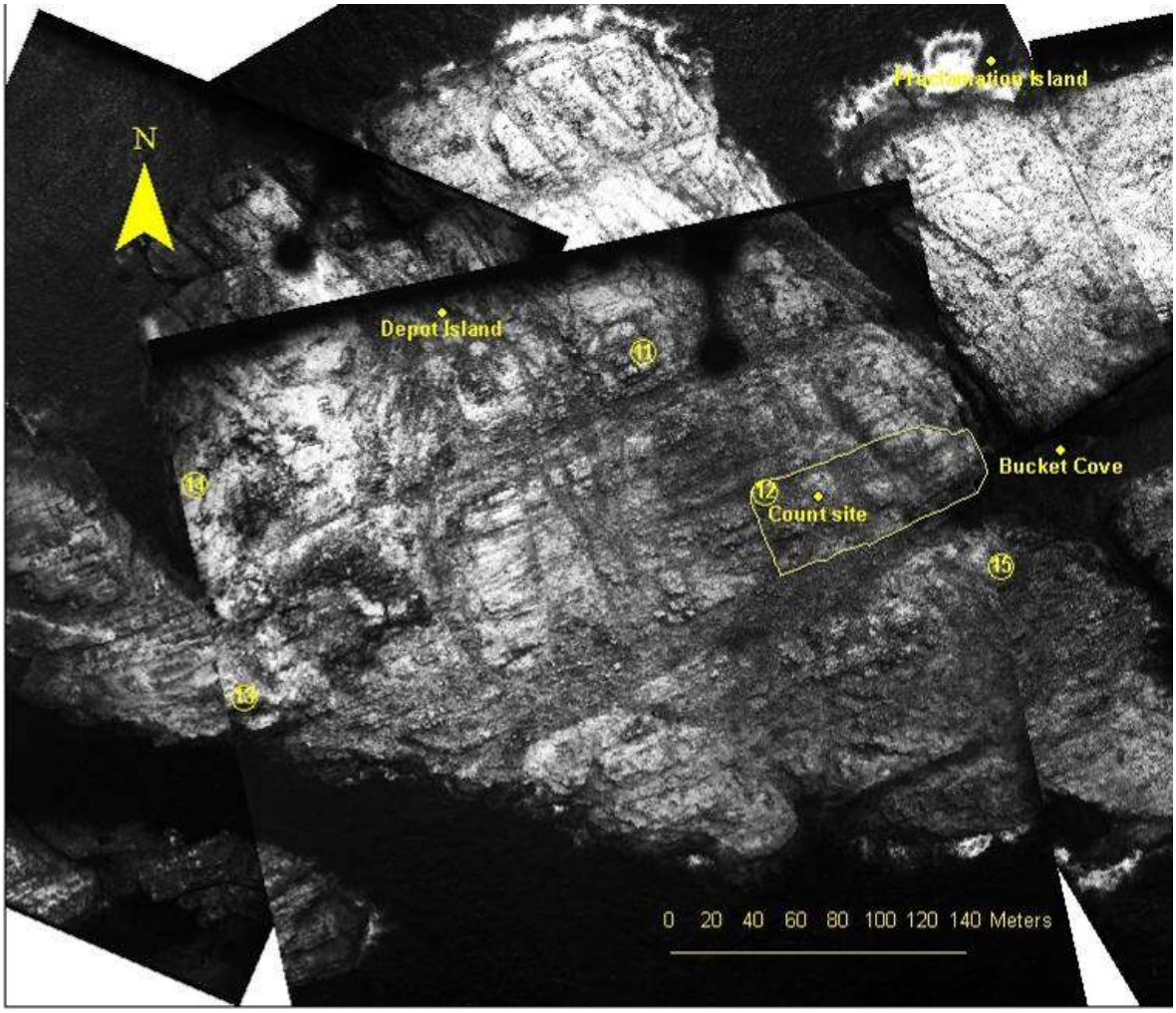

Figure 3-2: Depot Island showing the location, size and scale of the count site.

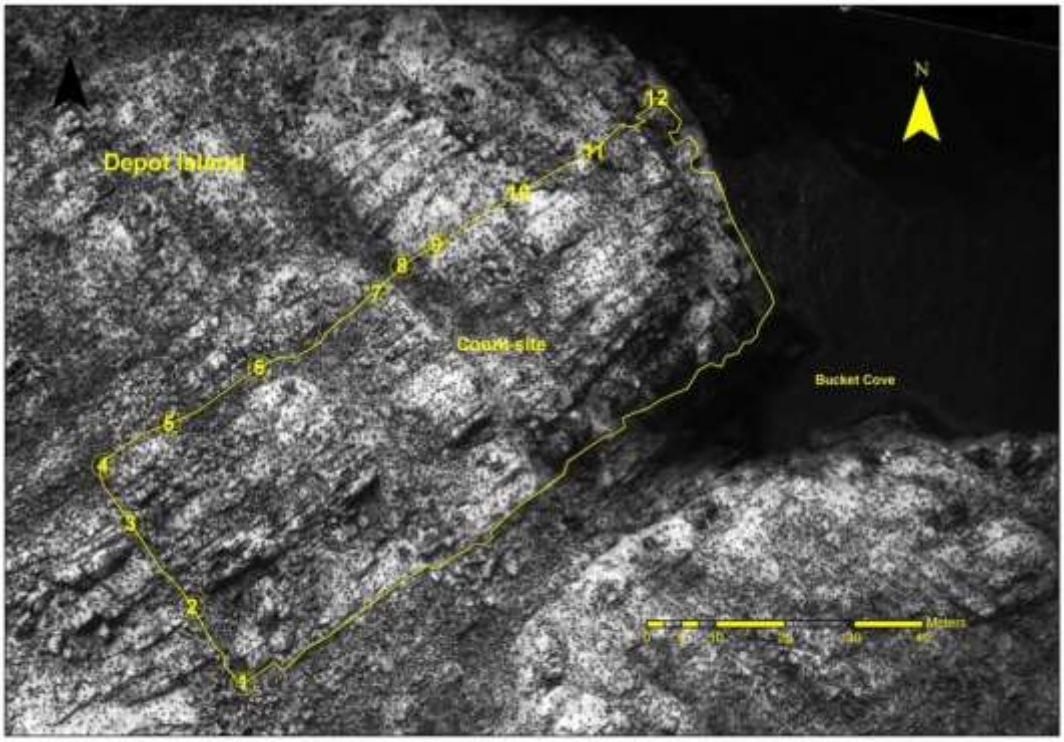

Figure 3-3: Location of numbered feature in photographs of Depot Island count site to aid relocating the count boundary in future.

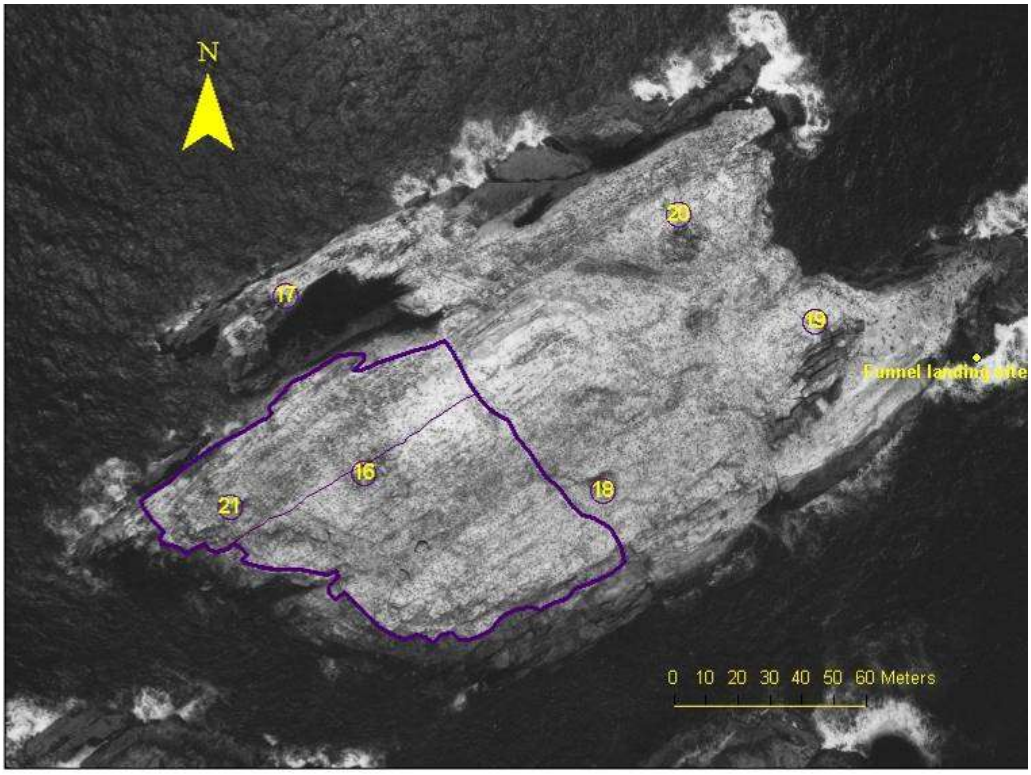

Figure 3-4: Funnel Island showing the location of the study area and landing site. The numbers are the locations of the GPS control points.

4 Results

4.1 Ground counts

4.1.1 Proclamation Island

The results of the ground counts are shown in Tables 4-1 to 4-4. The results of the transect counts show that very few nests were missed or double counted during the ground counts, and so in all years the adjusted totals are <1% greater than the total number recorded during the initial ground count. .

Table 4-1: Counts of Salvin's Albatrosses on Proclamation Island 12-16 November 1997.
Total nests, all nests containing an egg or a chick. A negative number indicates that the nest had been counted twice in the ground count.

		Albatross					
1997	Date	Ground count		Transect count		TOTAL	Count time
Proclamation blocks		Total Nests	Total Loafers	Un-marked	Marked	Adjusted nest total	hh:mm
1	12/11/1997	344	308	0	120	**344**	3:00
2	16/11/1997	150	131	1	99	**152**	1:05
3	13 & 14/11/1997	413	105	0	98	**413**	2:55
4	14/11/1997	406	185	1	100	**410**	2:35
5	14/11/1997	332	75	1	100	**335**	1:46
6	15/11/1997	289	114	1	100	**292**	1:10
7	15/11/1997	697	382	1	103	**704**	3:15
8	16/11/1997	420	218	-1	107	**416**	3:11
TOTAL (Blocks 1-8)		**3051**	**1518**	**4**	**827**	**3065**	**18:57**

Table 4-2: Counts of Salvin's Albatrosses on Proclamation Island 15-23 November 2004. Total nests, all nests containing an egg or a chick. A negative number indicates that the nest had been counted twice in the ground count.

		Albatross					
2004	Date	Ground count		Transect count		TOTAL	Count time
Proclamation blocks		Total Nests	Total Loafers	Un-marked	Marked	Adjusted nest total	hh:mm
1	19/11/2004	263	398	1	120	**265**	2:00
2	18/11/2004	99	130	0	28	**99**	:50
3	18/11/2004	414	176	1	82	**419**	1:45
4	23/11/2004	312	408	2	100	**318**	1:15
5	23/11/2004	253	263	1	100	**256**	1:15
6	19/11/2004	216	136	0	100	**216**	0:48
7	16/11/2004	400	249	-1	103	**396**	1:57
8	15&16/11/2004	665	156	0	107	**665**	5:50
TOTAL (Blocks 1-8)		**2622**	**1916**	**4**	**740**	**2634**	**14:50**

Table 4-3: Counts of Salvin's Albatrosses on Proclamation Island 14 November 2011. Total nests, all nests containing an egg or a chick. Block 8 was not counted.

	Albatross				
14 November 2011	Ground count		Transect count		TOTAL
Proclamation block	Total Nests	Total Loafers	Un-marked	Marked	Adjusted nest
1	285	271	0	38	**285**
2	84	55	1	25	**87**
3	311	120	1	39	**319**
4	295	129	0	52	**295**
5	235	113	0	48	**235**
6	147	79	0	100	**147**
7	336	280	3	59	**352**
TOTAL (Blocks 1-7)	1693	1047	5	361	**1720**

Table 4-4: Comparison of adjusted totals of ground counts of Salvin's Albatross nests in November 1997, 2004 and 2011 on Proclamation Island and 2004 and 2011 on Depot Island.

	Salvin's Albatross Nests								
Block	**1997 Ground count**	**2004 Ground count**	**2011 Ground count**	**Difference between 1997 & 2004**		**Difference between 2004 & 2011**		**Difference between 1997 & 2011**	
Dates	**12-17 Nov**	**16-24 Nov**	**14 Nov**						
				n	**%**	***n***	**%**	***n***	**%**
Depot I♦		720	648			-72	-10		
Proclamation									
1	344	265	285	-79	-23	20	8	-59	-17
2	151	99	87	-52	-34	-12	-12	-64	-42
3	413	419	319	6	1	-100	-24	-94	-23
4	410	318	295	-92	-22	-23	-7	-115	-28
5	335	256	235	-79	-24	-21	-8	-100	-30
6	292	216	147	-76	-26	-69	-32	-145	-50
7*	704	396	353	-59	-5	-43	-11		
8*	416	665							
TOT 1-6	*1945*	*1573*	*1368*	*-372*	*-19*	*-205*	*-13*	*-577*	*-30*
TOT 1-7		*1969*	*1721*			*-248*	*-13*		
TOT 1-8	*3065*	*2634*		*-431*	*-14*				
Total Depot and Proclamation(1-7)		*2689*	*2369*			*-320*	*-10*		

♦Study area on Depot set up in 2004

*Different block boundary used in 1997 - combine blocks 7 & 8 for comparisons

Estimated adjusted whole-island totals of the numbers of breeding pairs decreased from 3065 in 1997 to 2634 in 2004, a decline of 14% (Table 4-4). Likewise, estimated adjusted totals of breeding pairs in Blocks 1-7 decreased from 1969 in 2004 to 1721 in 2011, a decline of 13%. Whilst for the period 1997 to 2011 estimates of adjusted total numbers of breeding pairs in Blocks 1-6 decreased from 1945 to 1368, a decline of 30%. Coincidentally, each of the periods 1997-2004 and 2004-2011 is seven years, and so these represent estimated declines of 2.00% per annum between 1997 and 2004 and 1.86% per annum between 2004 and 2011.

4.1.2 Depot and Funnel Islands

The results of counts on Funnel and Depot Islands are shown in Table 4-5. As on Proclamation Island the transect counts indicated that a minimal number of nests had been missed during the ground counts, and so the adjusted estimated totals are the same (Funnel and Depot Islands in 2004) or very similar (Depot Island 2011) to the ground count totals.

Table 4-5: Counts of Salvin's Albatrosses on Funnel Island (November 2004) and Depot Island (November 2004 and 2011) count blocks. Total nests, all nests containing an egg or chick.

	Date	Ground count		Transect count		TOTAL	Count time
		Total Nests	Total Loafers	Un-marked	Marked	Adjusted nest	hh:mm
Funnel Is.	22/11/2004	1206	579	0	107	**1206**	4:15
Funnel Is.(subset, area south of the ridgeline)	22/11/2004	800	356				
Depot Is.	21/11/2004	720	465	0	100	**720**	4:00
Depot Is	11/11/2011	641	203	2	194	**648**	4:00

Estimated adjusted whole-island totals of the numbers of breeding pairs in the count block on Depot Island decreased from 720 in 2004 to 648 in 2011, a decline of 10% (Table 4-4), an average decline of 1.3% per annum during this period.

4.2 Study area

4.2.1 Date of egg laying

Daily nest monitoring in the 1997 study area recorded the hatching dates for Salvin's Albatrosses, with an estimated mean hatching date of 14 November and an estimated range of 2-26 November (Table 4-6, Figure 4-1). Shy Albatrosses *Thalassarche cauta* are closely related to Salvin's Albatrosses and have an incubation period of 73 ± 1 days (Hedd & Gales 2005). There are no published studies on the incubation period for Salvin's Albatrosses, and so we assume an incubation period of 73 days. Therefore, the end of egg laying for Salvin's Albatrosses is likely to be 14 September, 61 days prior to the 14 November census date.

Table 4-6: Summary of pipping and hatching dates for Salvin's Albatross nests on Proclamation Island study area.

	Pipping date	Hatch date	Time to hatch (days)
n	48	48	31
mean	11/11/97	14/11/97	4
min	31/10/97	2/11/97	1
max	22/11/97	26/11/97	5

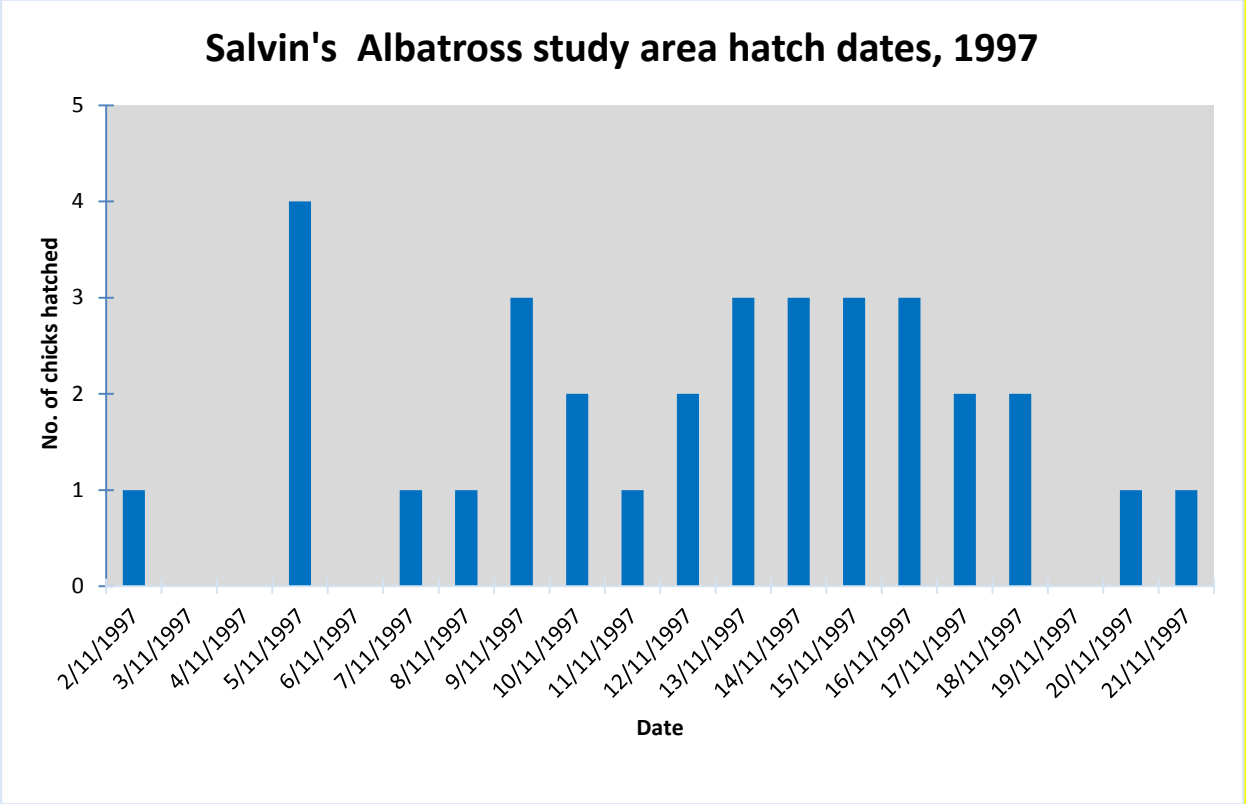

Figure 4-1: Hatch dates for Salvin's Albatrosses in Proclamation Island study area, November 1997. Includes estimated hatch dates for 5 intact eggs and 13 pipped eggs at end of study.

4.3 Investigator disturbance

When the study area was established on 31 October 1997 the whole area contained 86 Salvin's Albatross nests and the subsample of blocks A-F contained 70 nests (Table 4-7). Daily monitoring of the subsample saw numbers drop to 48 by the end of leg 2 of the expedition and to 43 by the end of leg 3 of the expedition on 3 January 1998. The rates of nest loss in the study area and control area are summarised in (Table 4-7)). In the study area the start date is 31 October (70 nests) and in the control area it is 5 November (64 nests), the end date for both sites is 3 January 1998. The different time periods in the study and control areas are compared to cover the period of visitation to the study area. Ideally the study colony and control area would be established on the same day. There was no significant difference in the number of Salvin's Albatross nests lost in the study and control areas (χ^2 1.64, p>0.05, 1df).

Table 4-7: Numbers of Salvin's Albatross nests in the study and control areas on Proclamation Island, November 1997 to January 1998. Counts of `All nests' include those estimated to have failed prior to the count plus those still containing an egg or a chick.

		Date of nest visit								
		1/11	5/11	31/10	1/11	5/11	14/11	17/11	3/01	3/01
Block name	5 x 5	All nests	All nests	Nests with egg /chick	Nests with egg /chick	Nests with egg /chick	Nests with egg /chick	Nests with egg /chick	Nests with egg /chick	Chicks alive at end of study
Study	A	13		11	9	8	7	6		
Study	B	15		14	13	13	12	12		
Study	C	8		7	7	5	5	5		
Study	D	14		12	11	10	9	8		
Study	E	14		12	12	11	8	8		
Study	F	17		14	12	10	9	9		
Study	G	6		5	4	4	4	4		
Study	H	16		11	10	10	10	10		
Sub-tot A-F		***81***		***70***	***64***	***57***	***50***	***48***	***43***	***61.4%***
TOTAL		**103**		**86**	**78**	**71**	**64**	**62**		
Control	I		19			13	12			
Control	J		15			7	6			
Control	K		16			11	11			
Control	L		12			6	6			
Control	M		7			6	3			
Control	N		8			5	5			
Control	O		9			9	6			
Control	P		8			7	5			
TOTAL			**94**			**64**	**54**		**46**	**71.9%**

- *Only overall count available*

In a separate exercise we counted the numbers of occupied (i.e. those containing an egg or a chick) and empty nests in the study colony on 14 November 1997 and 2011. We assumed that each empty nest represented a failed breeding attempt and that the average date of laying was 14 September, and so estimated the daily rate of egg loss each year by dividing the percentage of empty nests by 61 (the estimated number of days elapsed since laying). This resulted in estimated nest losses/day of 0.62% and 0.34% (Table 4-8).

Table 4-8: Counts of Salvin's Albatross in the study area on Proclamation Island 14 November 1997 and 2011, with estimated daily loss since end of laying.

Date	Salvin's Albatross nests in study area on Proclamation Island						
	Egg	Pipped egg	Chick	Active nests (study squares G & H)	TOTAL	Empty nest	Nest loss/day from 14 Sept
14 Nov 1997	16	13	21	13	**64**	39	0.62%
14 Nov 2011	43	15	40	0	**98**	26	0.34%

5 Discussion

These results provide the first estimate of the population trend of Salvin's Albatrosses breeding at the Bounty Islands, as well as presenting information about the timing of hatching, breeding success and the effects of investigator disturbance.

5.1 Ground counts

Overall, on Proclamation Island the numbers of breeding Salvin's Albatrosses declined by an estimated 30% between 1997 and 2011. Similarly, on Depot Island there was an estimated decrease of 10% in the numbers of breeding pairs between 2004 and 2011.

Inter- and intra-block figures on Proclamation Island show a similar pattern, with all of blocks 1-6 declining 17-50% between 1997 and 2011. Over the 1997 to 2004 period only block 3 showed a slightest increase of 1% while all but combined blocks 7 & 8 decreased by more than 22%. From 2004 to 2011 the numbers of breeding Salvin's albatrosses increased only in block 1 (8%) with numbers in the other blocks declining by 7-32%.

The main potential errors associated with ground counts include missing or double counting of nests and including loafers in the count. However, in the present study the effects of missing or double-counting nests were taken into account by undertaking transect counts made by a different observer to record the missed or double counted nests. The results of the transect counts showed that this source of error was minimal and highly unlikely to have affected the accuracy of the ground counts. An additional major error could arise if loafing birds were included in the count of breeding birds. In the present study the contents of each nest were identified as either an egg or a chick, and so taken to represent a breeding pair. Counts of loafers included birds occupying empty nests and were recorded separately. These were not used when estimating the breeding population, thereby eliminating this potential source of error.

Salvin's Albatrosses are annual breeders (Sagar et al. 2011) and the average length of incubation among *Thalassarche* species is 68 – 73 days (Tickell 2000). The only published studies of the laying and incubation period within the shy albatross group are for Shy Albatrosses *T. cauta* which has an incubation period of 73 ± 1 day (Hedd & Gales 2005). Assuming a 73-day incubation period mean egg laying for Salvin's Albatrosses at the Bounty Islands would be on 2 September with most eggs being laid between 24 August and 14 September. Therefore, the optimal time to conduct a Salvin's Albatrosses census would be about the end of the egg laying period (14 September) because at this time all eggs have been laid and few nests are likely to have failed.

Rates of nest loss prior to our counts are unknown. However, if we assume that all empty nests counted in the study area in 1997 and 2011 represented failed breeding attempts and that the failure rate was then constant between 14 September (end of egg laying) and 14 November (census date), the failure rate is estimated to be 0.62% nests/day in 1997 and 0.34% nests/day in 2011 (Table 4-8). Therefore, given that the rate of nest failure in 1997 was almost twice that of 2004 any adjustments made for these estimated rates of nest failure would result in even higher rates of estimated overall population decline. However, because the estimated failure rates were not verified it is not appropriate to make this comparison.

Table 5-1: Breeding success in *Thalassarche* species at different sites over multiple years.

Albatross species	Site	Years studied	% breeding success		
			mean	s.e.	range
Black-browed (*T. melanophris*)	South Georgia[1,5]	20	29%	5%	0-63%
Grey-headed (*T. chrysostoma*)	South Georgia[1,5]	20	39%	4%	5-60%
Black-browed (*T. melanophris*)	Kerguelen[2]	16	63%	10%	50-90%
Yellow-nosed (*T. chlororhynchos*)	Amsterdam Island[2]	10	25%	18%	0-60%
Campbell (*T. impavida*)	Campbell Island[3]	6	66%	12%	51-84%
Grey-headed (*T. chrysostoma*)	Campbell Island[3]	6	40%	20%	16-70%
Black-browed (*T. melanophris*)	Macquarie Island[4]	6	46%	4%	33-58%
Grey-headed (*T. chrysostoma*)	Macquarie Island[4]	6	55%	4%	43-74%
Bullers (*T. bulleri*)	Snares[6]	8	71%	-	-

[1](Prince et al. 1994), [2](Weimerskirch and Jouventin 1997), [3](Waugh et al. 1999a), [4](Terauds 2003), [5] (Croxall et al. 1997), [6](Sagar et al. 2000)

In 1997 nest failure in the study area was measured over the duration of the study. Nest failures were 1.85%/day between 31 October and 17 November 1997 (hatching), then dropped to 0.22% /day between 17 November 1997 to 3 January 1998 (brooding and post-guard), averaging 0.60% /day for the combined time. These figures demonstrate the potential variability of nest loss rate within a season and the likelihood that breeding success is variable between seasons also.

Trends in breeding success of other *Thalassarche* species have been documented at Bird Island (Tickell & Pinder 1975; Prince et al. 1994; Croxall et al. 1999;), Isles Crozet ((Weimerskirch et al. 1986; Weimerskirch & Jouventin 1997), Macquarie Island (Terauds 2003) and Campbell Island (Waugh et al. 1999b), over multiple seasons. Breeding success was highly variable both between and within species, with large inter-seasonal variations in breeding success at individual breeding sites (Table 5-1).

In some studies breeding success was correlated with environmental variation affecting prey concentration and production in the foraging zones of the breeding birds (e.g., Prince et al. 1994; Croxall et al. 1999; Waugh et al. 1999a; Terauds 2003) and stochastic events at the breeding site (Tickell 2000). In these studies the timing of breeding failure was variable with rates of eggs hatched to chicks fledging also showing fluctuations between and within species and individual sites. The variation was driven by the timing of fluctuations in the marine and terrestrial environments that affect the overall breeding success (Tickell 2000).

Because of the variable rates of breeding failure the timing of counts is important if estimates are to be compared across years. In this study the Salvin's Albatross nest counts were undertaken in early to mid-November and coincided with the peak of egg hatching (mean hatch date 14 November). The level of nest failure before this time could only be estimated by assuming that each empty nest represented a breeding failure that season. However, this needs to be verified because although in colonies of some other albatross species there are a proportion of nests in which no eggs are laid in any given season (e.g., Buller's albatross *T. bulleri* Sagar & Warham 1998), on the Bounty Islands some abandoned nest pedestals are

dismantled to refurbish the pedestals of neighbouring pairs (J. Amey, pers. obs).Therefore, as counts were completed within the same week in November in all three years we did not take account of assumed prior nest failures, but compared estimated numbers of nests active at the time.

Complexity in population parameters within a single seabird species have been recorded in other albatross species both between and within sites (Prince et al. 1994; Sagar et al. 1999). It was for these reasons that monitoring sites were established on Depot and Funnel Island in 2004. Unfortunately, the Funnel Island site was unable to be visited in 2011 but the Depot Island study site showed 10% fewer Salvin's Albatrosses breeding in 2011 than in 2004, thus providing additional evidence to support the trend estimated for Proclamation Island.

Given the rare and regulated visits to the Bounty Islands and the absence of introduced plants and animals, the apparent population decrease is unlikely to be due to land-based factors (Taylor 2000). However, the increase in New Zealand fur seal activity on Proclamation Island may contribute to breeding failure as nesting Salvin's Albatrosses are disturbed or displaced. However, the situation regarding fur seals is not straight forward. For example, although Blocks 1, 3 and 5 had the least seal activity and also had some of the smaller decreases in the numbers of albatrosses, our estimated declines of 17, 25 and 30% respectively are unlikely to be the effect of early breeding failure alone. Also, it should be noted that in the study colony we estimated higher daily failure rates (0.62%/day) in 1997 than in 2011 (0.34%/day), when fur seal numbers and so activity would assumed to be higher.

During the late 1980s commercial fishing operations were recognised as one of the major factors influencing albatross populations (Bartle 1991; Brothers 1991; Gales 1998; Croxall & Gales 1998). The 2%/annum rate of decline measured at the Bounty Islands is similar to fisheries induced declines in other albatross species (e.g., Prince et al. 1994, Weimerskirch & Jouventin 1997, Weimerskirch et al. 1997a, Prince et al. 1998). Being long lived and slow breeding, albatross species are vulnerable to even small increases in adult mortality.

The findings were the catalyst for population studies of many of the 14-24 albatross taxa (Croxall & Gales 1998; Brooke 2004) including a study of Salvin's Albatrosses at the Snares Western Chain from 2008 to 2010. This study found an estimated adult survival probability of 0.967 which is among the highest recorded for any species of annual breeding albatrosses (Sagar et al. 2011).

5.2 Previous estimates

5.2.1 Ground counts

During November 1978 the density of Salvin's Albatross pairs (=nests) on Proclamation Island was estimated to be 0.5/m^2. The breeding areas of birds on each of the islands where they occurred were then plotted from visual mapping and aerial photographs and from these the total population was estimated to be 76,352 pairs (Robertson & van Tets 1982). A ground count of nests on Proclamation Island in November 1997 found 3062 breeding pairs (Clark et al. 1998) whereas Robertson & van Tets (1982) estimated that there were 8656 nests there in November 1978. In addition, by multiplying estimated area of suitable nesting habitat (139,780 m^2) by the average nest density (0.22 /m^2 the total population of Salvin's Albatrosses on the Bounty Island in November 1997 was estimated at 30,752 pairs (Taylor

2000). However, this estimated area of suitable nesting habitat has now been superseded by more accurate area measurements from geo-rectified aerial photographs; these will be reported elsewhere. Unfortunately, the 1978 and 1997 expeditions used different base maps for calculating areas of the islands, and so resulted in different estimates of the area of suitable nesting habitat (Taylor 2000). This confounds the reliability of direct comparisons between the 1978 and 1997 population estimates to the extent that they cannot be supported. Given that the methods of estimating the population size in 1978 are insufficiently known to allow them to be replicated, we recommend that our 1997 methods and estimate be used as the baseline against which future ground counts are compared.

5.2.2 Aerial counts

On 12 October 2010 digital photographs were taken during an aerial survey of the Bounty Islands and from these an estimated 41,100 Salvin's Albatrosses were counted (Baker et al. 2012). However, because many albatross nests on the Bounty Islands have no substantial pedestal in many cases it was not possible to determine if birds were sitting on a nest or resting on the rocks (Baker et al. 2012). Therefore, the estimated total included an undetermined proportion of loafers. For this reason it is not appropriate to compare the ground counts reported here with the estimate made from aerial photographs.

5.3 Importance of the Bounty Islands

Numbers of Salvin's Albatrosses at the Snares Western Chain were estimated to be 1100-1200 annual breeding pairs during the period 2008-2010 (Sagar 2011), while the main breeding population, an estimated 30,752 breeding pairs in 1997, is at the Bounty Islands (Taylor 2000). Elsewhere, in the New Zealand region, two occupied nests have been reported from The Pyramid in 1995 and a chick in 2006, and one chick from the Forty-Fours in 2007 (ACAP 2010). Four breeding pairs were also recorded on Iles des Pingouins in the Crozet archipelago in 1986 (Jouventin 1990). Therefore, the Bounty Islands support an estimated 98.25% of the total breeding population of what is essentially an endemic species.

The scale of change measured in the Salvin's Albatross population both on Proclamation Island and Depot Island requires urgent investigation of the population and foraging biology of this nationally vulnerable New Zealand endemic species.

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Appendix A Band recoveries for Salvin's Albatross, Bounty Islands 28 October to 17 November 1997.

Date	Band No.		Block No.	Breeding status	Comments
28/10/1997	O	14124		Loafer	
28/10/1997	O	14129		Loafer	
28/10/1997	O	14133		Loafer	
28/10/1997	O	14203		On egg	
28/10/1997	O	14237		Loafer	
28/10/1997	O	14333		On egg	
28/10/1997	O	14355		Loafer	
28/10/1997	O	14466		Loafer	
28/10/1997	O	14483		Loafer	
29/10/1997	O	14154		Loafer	
29/10/1997	O	14159		Loafer	
31/10/1997	O	14252		Loafer	
5/11/1997	O	14205		Loafer	
5/11/1997	O	14224		Loafer	
5/11/1997	O	14275		Loafer	
8/11/1997	O	14291		Loafer	
9/11/1997	O	14334		Loafer	
12/11/1997	O	14132	1	Loafer	
12/11/1997	O	14211	1	On egg	
12/11/1997	O	14264	1	Loafer	
12/11/1997	O	14266	1	Loafer	
12/11/1997	O	14296	1	Loafer	
13/11/1997	O	14338	3	Loafer	
14/11/1997	O	14309	4	Loafer	Edge of control area
14/11/1997	O	14310	4	Loafer	
14/11/1997	O	14325	4	LOAFER	
14/11/1997	O	14486	4	Loafer	South of 1978 camp
14/11/1997	O	14489	4	Loafer	South of 1978 camp
14/11/1997	O	14565	5	On chick	
14/11/1997	O	14591	5	Loafer	
14/11/1997	O	19527	5	On chick	
14/11/1997	O	19549	3	On egg	Bottom of block 4
14/11/1997	O	19562	4	On egg	
15/11/1997	O	14515	7	Loafer	
15/11/1997	O	14563	5	On chick	Bottom edge of block 6
15/11/1997	O	14583	5	On chick	Bottom edge of block 6
15/11/1997	O	14586	5	On chick	Bottom edge of block 6
15/11/1997	O	14589	5	On chick	Bottom edge of block 6
15/11/1997	O	19505	5	On chick	Bottom edge of block 6
16/11/1997	O	14420	2	Loafer	North of 1978 camp site

Appendix B Band recoveries for Salvin's Albatross, Bounty Islands 12 - 17 November 2004.

Date	Band number		Block No.	Breeding status	Comments
15/11/04	O	14285	1	On broken egg	
15/11/04	O	14483	3	Loafer	
15/11/04	O	14452	2	Loafer	
16/11/04	O	14515	7	Nest with chick	
17/11/04	O	14452	2	Loafer	
17/11/04	O	14316		Nest with chick	
17/11/04	O	14324		Loafer	
18/11/04	O	14416	2	Nest with chick	
18/11/04	O	14408	2	Nest with chick	
18/11/04	O	14361	3	Loafer	
19/11/04	O	14237	1	Nest with chick	
19/11/04	O	14133	1	Nest with chick	
19/11/04	O	14145	1	Loafer	
19/11/04	O	14288	1	Loafer	
19/11/04	O	14115	1	Loafer	
19/11/04	O	19150	1	Loafer	
19/11/04	O	14380	1	Loafer	
19/11/04	O	14205	1	Nest with chick	
19/11/04	O	14211	1	Nest with chick	
19/11/04	O	19522	6	Loafer	
19/11/04	O	14560	6	Nest with chick	
20/11/04	O	14338	1	Nest with chick	
20/11/04	O	14479	1	Loafer	
20/11/04	O	14483	3	Loafer	
20/11/04	O	14211	1	Nest with chick	Partner O-14217
20/11/04	O	14217	1	Nest with chick	Partner O-14211
20/11/04	O	14275	1	Loafer	

Appendix C Band recoveries for Salvin's Albatross, Bounty Islands 11 - 14 November 2011

Date	Band number		Block No.	Breeding status	Comments
14/11/2011	O	14133	1	Loafer	Adjusted sprung band
14/11/2011	O	14140	1	On chick	Adjusted sprung band
14/11/2011	O	14154	1	On egg	
14/11/2011	O	14176	1	Loafer	Band removed - embedded deeply in leg
14/11/2011	O	14217	1	On egg	Band good
14/11/2011	O	14237	1	On chick	Band good
14/11/2011	O	14285	1	On chick	Adjusted sprung band
14/11/2011	O	14296	1	On chick	
14/11/2011	O	14374	3	Loafer	
14/11/2011	O	14390	1	On chick	
14/11/2011	O	14433	4	Loafer	
14/11/2011	O	14560	6	Dead	Old carcass
14/11/2011	O	14569	6	On chick	
11/11/2011	O	19407	Depot	On egg	
14/11/2011	O	19529	3	On egg	Adjusted sprung band
14/11/2011	O	19532	6	On egg	Adjusted sprung band
14/11/2011	O	19564	3	On chick	Adjusted sprung band
14/11/2011	O	19583	4	Loafer	