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2018 Aerial survey of Salvin's albatross at the Bounty Islands

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1. Introduction

Salvin's albatrosses *Thalassarche salvini* is an abundant albatross species present throughout the year on all continental shelf areas around New Zealand (J.A. Bartle pers. comm. in Gales 1993). The species roams widely in winter, moving eastwards across the South Pacific to the waters off the west coast of South America (Chile and Peru), where it has been observed throughout the Humboldt Current System between 7-42°S, most frequently over the continental slope (Spear et al 2003; ACAP 2009). Small numbers of non-breeding adults regularly fly across the Tasman Sea to south-east Australian waters but is scarce in the southern Indian Ocean (Jouventin 1990; ACAP 2009). Salvin's albatross is only a rare vagrant to the South Atlantic, though small numbers are present in the shelf waters of South Africa (Marchant and Higgins 1990).

This species is essentially endemic to New Zealand, breeding mainly on the Bounty Islands and the Western Chain of The Snares. Other breeding sites include The Pyramid in the Chatham Islands, where two occupied nests were reported in 1995 (Croxall and Gales 1998), and Ile des Pingouins in the Crozet archipelago (Indian Ocean) where four breeding pairs were recorded in 1986 (Jouventin 1990) but birds no longer appear to be present. The total breeding population was estimated to be approximately 32,000 pairs in 1998 (ACAP 2009), with 98.5% of the population concentrated on the Bounty Islands (Amey and Sagar 2013).

The population status of this species is poorly known (ACAP 2009). Counts completed on The Snares in October each year over the period 2008-2010 ranged from 1,100 to 1200 breeding pairs (Sagar et al 2011). In 1978, Robertson and van Tets (1982) estimated there were 76,000 pairs in the Bounty Group (Taylor 2000) based on nest densities and the area occupied on each island. Analysis of ground counts of Salvin's albatross nests on Proclamation Island (Bounty Islands) in November 1997 (Clark et al. 1998), November 2004 (de Roy & Amey 2004) and November 2011 showed that the numbers of breeding Salvin's albatrosses declined by an estimated 30% between 1997 and 2011 (Amey and Sagar 2013). Similarly, on Depot Island there was an estimated decrease of 10% in the numbers of breeding pairs between 2004 and 2011 (Amey and Sagar 2013).

In 2010 and 2013, Baker et al (2012, 2014) completed an aerial survey of the Bounty Islands and photographed all albatross colonies. They estimated the total count of nesting Salvin's albatrosses to be 31,786 annual breeding pairs (95% CI 31,430 — 32,143) in 2010 and 39,995 (95% CI 39,595 — 40,395) annual breeding pairs in2013. These studies represented the first complete population surveys of Salvin's albatross on the Bounty Islands.

We have now been contracted by the Department of Conservation to conduct another aerial survey of the Bounty Islands. The objectives of this study are:

1. Satellite mapping of Bounty Islands to allow area of occupancy to be quantified.
2. Aerial photographic survey to estimate total number of breeding pairs and area of occupancy

2. Methods

The Site

The Bounty Islands (47^0 44'S, 179^0 02'E) are a group of bare rocky islands situated 659 km south-east of New Zealand's South Island. They are the smallest island group in the New Zealand sub-Antarctic, and cover only 135 ha in total area. The entire group spans about 4.5 km from east to west, and three km from north to south. The archipelago consists of 22 small islets in three groups (West, Centre and East Groups: Figure 1). All the islands are comprised of coarse biotite granite, with some finer-grained variations, and are the eroded remnants of a ridge of buckled and uplifted basement rock (Taylor 2006). Within the archipelago, Salvin's albatross reportedly breed on ten Islands – Proclamation, Tunnel, Depot, Ruatara, Penguin, Ranfurley, Lion and Spider Islands in the West Group; Funnel Island in the Centre Group; and Molly Cap in the East Group (Tickell 2000). However, Baker et al (2014) did not find birds nesting on Ranfurley and Lion Islands. Most of the albatross colonies are mixed colonies and contain extensive numbers of erect-crested penguins *Eudyptes sclateri* (Robertson and van Tets 1982).

Field Work

On 25 October 2018 we chartered a fixed-wing aircraft from Kiwi Air Ltd to conduct a return flight to the Bounty Islands group. The aircraft, a twin turboprop Reims F406, was piloted by Cole Bennetts, and carried photographer Barry Baker. The aircraft had been modified to permit photography to be undertaken through two co-located port holes installed in the floor on the right-hand side of the machine.

The flight was conducted in mid-October to coincide with the mid-incubation period of the albatross breeding cycle and the presence of a team of scientists on the Bounty Islands. At this time, it was anticipated that birds would have completed egg laying and that most of birds that attempted to breed in 2018/19 would still be attending active nests.

We selected a weather window for the operation that predicted clear flying conditions with minimal low-level cloud. Photography was timed to occur between 11.00 to 14.00 hours. Although there is little information on the behaviour of breeding Salvin's albatrosses, information from the closely-related shy *Thalassarche cauta* and white-capped albatrosses *T. steadi* indicates that at this time of the breeding cycle the ratio of incubating to loafing birds is high as most loafers are at sea during the middle of the day (Baker et al. 2018).

We left Dunedin at 12.45 hours and arrived at the Bounty Islands at 14.34 hours. On arrival the weather around the Bounty Islands was overcast but fine with a cloud base of 6,000 feet. Winds were light south-westerly blowing 10-55 knots on the water and at 30 knots at our flight height of 1,200 feet. Conditions for photography were excellent and we were able to obtain clear photographs of most colonies at least once during several photographic passes of the various islands.

We approached Molly Cap first (East Group), and then proceeded to photograph Funnel Island (Centre Group) systematically until all known albatross sites were photographed. Other stacks and islands in these two groups were also inspected to ensure no albatrosses were present. While we had hoped to photograph all islands and stacks in the Bounty Group, irrespective of whether or not albatrosses were known to nest on them, our time in the air over the Bounty Islands was limited to a maximum of 75 minutes because of fuel constraints, and it was not possible to achieve this. All photographs were taken through the rear floor port while both the co-located front port was also open. This allowed the photographer to view the terrain as the aircraft was approaching an island, which provided a few seconds to line up the camera. Nonetheless, when coupled with a minimum aircraft speed of 120 knots at time (aircraft speed 120 knots plus wind speed 40 knots) and the close proximity of some of the islands to each other, considerable concentration by both the pilot and photographer was required to be sure that all colonies had complete photographic coverage before we ran out of air time over the islands.

Photography of the main West Group was undertaken by flying a series of parallel transects over the entire Group and commencing with a line running c.45 degrees from the SW end of Ranfurley Island. The initial line was selected visually with subsequent lines established through the use of the TracMap Flight Pro GPS guidance system (http://www.tracmap.com/aviation/), established in the baseline program, where regular parallel lines are flown without boundaries defined. The transects flown were spaced at 100 m centres and ran across the West Group from south-east to north-west, to define and accurately fly the series of transects. The transects were set up to ensure that the 100m centre lines would provide an overlap tolerance of at least 20% (20 m) side overlap (between flying tracks) and 50% (45 m) frontal overlap (with respect to the flight direction)[1], and maintaining as much as possible a constant height over the terrain under the following flight and photographic specifications:

- Flight height 1200 ft agl;
- Ground speed 120 knots;
- Camera and lens: full-frame Digital Single Lens Reflex Camera (Nikon D800) and Nikon 70-200 mm f2.8 lens set at 70mm photo extension.
- Shutter speed 1/2500 sec, camera operated in shutter priority mode to maintain shutter speed.

Two sets of photographs were taken. Photographs to be used in compiling photo-montages (see below) were taken using a Nikon D800 digital camera and an image-stabilised Nikon 70— 200mm F2.8 zoom lens. Additional photographs were also taken with a Nikon D500 digital camera and a Nikon 300mm f4 PF telephoto lens at each of the island groups to assist in determining the proportion of albatrosses to penguins in mixed-species colonies,

[1] Note that side overlap relies on the ability of the pilot to accurately fly transects with precision, and frontal overlap is under the control of the photographer.

and to provide information on the number of non-breeding birds present in the colony —we refer to these photographs as 'close-up photos'.

The aerial photography of all albatross colonies was completed by 15.45 hours and we then departed the Bounty Islands, arriving back at Dunedin airport at 17.45 hours. A total of approximately 450 digital photographs were taken during the survey flight. All photographs of colonies were taken as raw images and subsequently saved as fine JPG format files. The full flight path and altitudes were recorded using a GPS receiver and have been downloaded and archived along with the photographs. The entire set of photographs were subsequently replicated to ensure that three complete back-up sets existed on portable hard drives and stored in three different locations. A full collection of photographs and details of the flight path have been submitted to the Department of Conservation.

Counting protocol

The photographs were used to construct photo-montages of each transect flown. From these we then produced a complete series of overlapping images that covered the entire area of the islands where albatrosses are nesting.

We used protocols initially developed for aerial censuses of Chilean albatross colonies (Arata et al, 2003; Robertson et al. 2007) and refined in our surveys of white-capped albatross in the Auckland Islands (Baker et al. 2018). Photographic montages of each transect and, where necessary, of each island, were constructed from overlapping photographs using the image editing software package ADOBE PHOTOSHOP (http://www.adobe.com/). Counts of all Salvin's albatrosses on each montage were then made by magnifying the image to view birds and using the paintbrush tool in PHOTOSHOP to mark each bird with a coloured circle as they were counted. To assist with counting we used MOUSECOUNT software (http://www.kittyfeet.com/mousecount.htm) and a hand held click counter. Once all birds had been counted on a photo-montage, the file was saved to provide an archival record of the count. Each single bird was assumed to represent a breeding pair. While most birds were alone at nest sites (apparently occupied sites – AOSs), we also counted instances when two birds were sitting close together (i.e. inside the pecking distance that defines the minimum distance between nests) and assumed to both be members of a nesting pair. In this situation, both birds were counted, and the number of pairs recorded. The number of pairs was subsequently deducted from the total number of birds to derive an estimate of AOSs. annual breeding pairs. This estimate was subsequently refined to account for birds that were shown from a more detailed analysis of the close-up photos to be loafing in the colony i.e. standing with no egg apparent or sitting with no nest visible. Ground counts that defined the proportion of nests that contained eggs, and the proportion of loafing birds in the colony were also used to refine the estimate of annual breeding pairs.

Counts of photo montages were undertaken by one observer only. Previously we have undertaken multiple counts of photomontages from Auckland Island censuses to estimate counter variability associated with miscounting and misidentifying white spots on the ground as birds (Baker et al. 2018). These count data were statistically modelled by Poisson regression, a special case of a Generalised Linear Model (McCullagh and Nelder, 1989), with observer and area as fixed effects. After allowing for both mean observer and mean area differences, there was no evidence to suggest that our model and data were incompatible, based upon regression diagnostics and model checking. There was also no evidence of a difference between observers and hence an observer bias. We have no reason to believe that data collected from the Bounty Islands should have different distributional properties to our Auckland Island data and so we assume the current data are also compatible with a Poisson model. Thus, we present raw counts only and assume the deviation is estimated as the square root of the count, a property of the Poisson model. The estimated confidence intervals represent counter variability only, and do not take into account other sources of counting error (discussed in detail in Baker et al. 2018).

Ground counts

Ground counts of nesting Salvin's albatrosses were undertaken by a NIWA ground team on Proclamation Island on 22 October 2018, a few days before the aerial photography was undertaken, to determine the proportions of nests containing eggs and non-breeding birds present in the colony (Sagar et al. 2018). Four transects were completed on three occasions. The process involved an observer walking along counting birds on nests with an egg, birds on a nest without an egg (apparently incubating) and loafers (birds not associated with a nest), all within 1 m either side of the line being walked. The length of each transect was determined by the density of nests and the level of disturbance observed – an attempt was made to count at least 30 active nests per transect, but the count was terminated if loafers became disturbed and began to walk ahead of the observer. Transects

were undertaken at 1025, 1215, and 1330 hours with each of the 12 transects (three time periods x four observers) being unique (Sagar et al. 2018).

Satellite mapping of Bounty Islands to allow area of occupancy to be quantified

We used the photomontages developed to count albatrosses on each of the islands in the Bounty Island archipelago to define a boundary of the Area of Occupancy for each island. The presence of nesting albatrosses shows as a series of yellow dots (each dot representing the position of a breeding bird) scattered over each island. From these photo-montages we identified the areas on each island where the breeding colonies occurred. We then compared these images with geo-referenced orthophotomaps of the islands created using the GIS Software package (QGIS) and layers available on line, drawing polygons to define each colony. The size of each colony was estimated using the QGIS terrain morphometry tools. Because the shape of the polygons drawn affected the measurement of the area of occupancy, we repeated this exercise three times and report the AOO as the mean estimate for each island. The GIS base maps developed would also be suitable for mapping colonies based on counted images from 2010 and 2013, but this was not undertaken because the angle the photographs were taken in those years was more lateral (65-70^{o}) than directly overhead (90^{o}), leading to parallax differences and hence interpretation error.

The use of Google earth photos, originally considered for this component, was rejected as photos for the Bounty Islands were not ortho-rectified to account for spatial error associated with data interpretation and the inaccuracies inherent in the datasets.

3. Results

Counts

In October 2018 we estimated the total count of nesting Salvin's albatrosses (Apparently Occupied Sites) in the Bounty Islands to be 60,419 (59,927— 60,911), based on raw counts. These counts have been adjusted downwards to account for the presence of 3,069 birds assessed as being the partners of incubating birds. The total raw count for all islands was 57,350 (95%CI 56,871 — 57,829) nesting Salvin's albatross pairs (Potential Occupied Sites) (Table 1).

Analysis of 15 close-up photographs randomly selected from Molly Cap, Funnel Island and the Main Group of islands (5 closeups from each group) showed that in October 2018, 72% of the birds visible in the photographs were sitting on nests (Molly Cap: 284 of 395, or 0.72; Funnel: 270 of 388, or 0.70; Main Group: 297 of 406, or 0.73; Table 2). Because of the rocky nature of the islands and lack of nesting material available we were unclear of the status of almost half (0.49) of the birds visible in the close-up photos (Table 2).

The ground counts at Proclamation Island indicated that the mean proportion of breeding birds (i.e. birds occupying a nest site containing an egg) on Proclamation Island between 10:25 and 13:30 h on 22 October 2018 was 0.47 (range 0.41-0.52) (Table 3; Sagar et al. 2018), somewhat lower than the ground counts undertaken at a similar time of year in 2013 (mean 0.74; range 0.71 — 0.77; 23 October 2013; Baker et al. 2014). The proportion of birds assessed as apparently occupying sites was 0.65 (range 0.56-0.78) (Table 3).

Estimated annual counts for all breeding sites in the Bounty Islands were adjusted to account for the presence of non-breeding birds. The estimates of annual breeding pairs derived from this process differed greatly, depending on the source of the correction factor used:

- close up photos (Table 2) 41,723 (95% CI 41,315 — 42,132) (Table 1);
- ground counts on Proclamation Is. 26,955 (95% CI 26,626 — 27,283) (Table 1);

Table 1. Raw and estimated counts of Apparently Occupied Sites (equivalent to annual breeding pairs) of Salvin's albatrosses in the Bounty Islands in October 2018. Raw counts of AOSs were adjusted utilising correction factors developed from close-up photos (Table 2) and ground counts on Proclamation Island (Table 3). For the close-up counts the correction factors were 0.696, 0.719 and 0.732 for Funnel Is., Molly Cap and all other islands, respectively. For the Proclamation Island ground counts the correction factor was 0.47.

Island	Number of birds	Pairs	Apparently Occupied Sites	Adjusted count - close-up photos	Adjusted count - ground truthing
Molly Cap	5,202	281	4,921	3,538	2,313
Funnel Is	5,855	339	5,516	3,845	2,593
Ruatara	7,065	363	6,702	4,906	3,150
Proclamation Is	6,702	366	6,336	4,638	2,978
Spider Island	5,317	288	5,029	3,681	2,364
Depot Island	23,677	1,150	22,527	16,490	10,588
Penguin Is	1,507	81	1,426	1,044	670
Tunnel Is	5,094	201	4,893	3,582	2,300
Castle	0		0	0	0
Lion	0		0	0	0
Total	60,419	3,069	57,350	41,723	26,955
SE	246	55	239	204	164

Table 2. Counts of 15 randomly selected close-up photographs taken at Funnel Island, Molly Cap, and the Main Group of islands (5 close-ups from each) in the Bounty Islands in October 2018, showing the proportion of birds assessed as attending apparently occupied nest sites (AOSs).

Island	Incubating - Apparently Occupied Sites	Loafer	Pair on nest	Unknown	Total birds	Total incubating + loafer	proportion AOSs
Funnel	270	118	12	448	848	388	0.696
Main Group	297	109	24	333	763	406	0.732
Molly Cap	284	111	10	414	819	395	0.719
Bounty Is totals	851	338	46	1195	2430	1189	0.716

Table 3. Ground counts of Salvin's albatross at Proclamation Island showing the nesting status of birds encountered along 2m wide transects over three time periods, 22 October 2018. Table 4 from Sagar et al. (2018).

Time	Transect	Apparently Occupied Sites (AOOs)		Loafers	Total birds	Proportion Apparently Occupied Sites	Proportion Loafers	Proportion AOSs containing eggs	Proportion of birds breeding
		Nest with egg	Empty nest with bird on						
10:25	1	42	7	39	88	0.56	0.44	0.86	0.48
	2	50	20	31	101	0.69	0.31	0.71	0.50
	3	47	20	37	104	0.64	0.36	0.70	0.45
	4	26	16	16	58	0.72	0.28	0.62	0.45
12:15	1	43	19	23	85	0.73	0.27	0.69	0.51
	2	33	16	14	63	0.78	0.22	0.67	0.52
	3	32	12	28	72	0.61	0.39	0.73	0.44
	4	30	14	26	70	0.63	0.37	0.68	0.43
13:30	1	38	6	31	75	0.59	0.41	0.86	0.51
	2	32	5	25	62	0.60	0.40	0.86	0.52
	3	36	22	30	88	0.66	0.34	0.62	0.41
	4	30	12	31	73	0.58	0.42	0.71	0.41
		439	169	331	939	0.65	0.35	0.72	0.47

Estimates of Area of Occupancy

The total mean estimated Area of Occupancy of Salvin's albatross in October 2018 was 18.371 ha (range 18.343-18.371; Table 4).

4. Discussion

Aerial survey is an effective method of rapidly assessing the population size of Salvin's albatross in the Bounty Islands, and our raw counts of birds ashore of 42,826 (95% CI 42,212–43,240) in October 2010, 53,893 (95% CI 53,429–54,357) in October 2013, and 60,419 (95% CI 59,927–60,911) in October 2018, represent the first complete population surveys of the species on the archipelago. Our photo coverage of all colonies was high, particularly so for the 2018 survey, and we are confident very few birds were missed. Areas where our coverage was incomplete in 2010 were on Molly Cap, Tunnel, Proclamation and Penguin Islands, and details of this are provided in our earlier report (Baker et al 2012). These difficulties would have biased the counts overall, but we conservatively estimate the accuracy of our counts would be within 1,000 pairs of the true figure and would certainly have not been responsible for the substantially larger counts for 2013 and 2018.

Not all the birds counted were nesting, and we were fortunate in having a field team on Proclamation Island around the time of the 2013 and 2018 flights to provide ground counts of the proportions of nesting and loafing birds (Baker et al. 2014). This provided a correction factor that accounts for birds 'loafing' in colonies and birds sitting on nests without an egg. The proportion of loafing birds (birds not associated with a nest) in the colonies was high (17% and 35%, 2013 and 2018, respectively) and this but this may be normal at this stage (mid-incubation period) for this species. Robertson et al (2007) estimated that nearly 12% of black-browed (*Thalassarche melanophyris*) and grey-headed (*T. chrysostoma*) albatrosses attending a colony were loafers during the early incubation period. Baker et al (2018) found that few non-breeding birds are generally present in white-capped albatross (*T. steadi*) colonies during ground counts in the early incubation period. 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%. Analysis of close-up photography taken over seven years in the same study showed that the proportion of non-breeders in the early

incubation period ranged from 3-4% but was higher during mid-incubation (three-year mean 17%, range 10-24%). Laying dates of Salvin's albatrosses at the Bounty islands are not known, but in 1997 the mean hatching date of 48 eggs was 14 November (Clark et al 1998). Therefore, assuming a similar incubation period to the closely related shy albatross (*Thalassarche cauta*) of 73 days (Hedd and Gales 2005), the mean laying period of Salvin's albatrosses at the Bounty Islands would be early-mid September (Debski and Hjörvarsdóttir 2017). Consequently, the timing of our aerial survey would be mid-incubation, when the proportion of loafers ashore was higher than that expected earlier in the incubation period.

Table 4. Mean estimates of Area of Occupancy (AOO) of Salvin's albatross breeding colonies on 8 islands in the Bounty Islands in October 2018. Areas were estimated by drawing polygons to define each colony on geo-referenced ortho-photomaps based on photo montages of each island and calculating the size of each colony using the GIS Software package QGIS. Mean estimates are derived from three estimates for each island.

Island	1	2	3	Mean
	Min		Max	(Ha)
Molly Cap	1.069	1.079	1.103	1.084
Funnel Is	1.594	1.423	1.572	1.530
Ruatara	2.13	1.989	2.161	2.093
Proclamation Is	1.692	1.821	1.867	1.793
Spider Island	1.719	1.859	1.87	1.816
Depot Island	8.035	7.768	7.86	7.888
Penguin Is	1.127	1.142	1.012	1.094
Tunnel Is	0.977	1.11	1.133	1.073
Totals	**18.343**	**18.191**	**18.578**	**18.371**

The proportion of birds apparently occupying sites in 2018 estimated from the close-up photos was consistent with that determined by the ground count (71.6 % and 65%, respectively), providing evidence that this parameter can be estimated with reasonable certainty from aerial photography.

Perhaps most surprising was the difference in the number of apparently occupied sites that contained eggs between 2013 and 2018 —90% and 72%, respectively; and the total number of breeding birds ashore for these years —74% and 47%, respectively. This is unlikely to be attributed to differences in the timing of breeding, as the ground counts for 2013 and 2018 were undertaken at a similar time in the breeding season, one day apart —23 October 2013 and 22 October 2018. A more likely explanation would be inter-annual differences in oceanic conditions that may have led to early nest failures in 2018 or a late decision by many birds to suspend breeding.

While we have adjusted our raw counts in 2018 to account for the proportion of AOSs determined by the close up photos, and the proportion of birds ashore that were found to be occupying a nest site which contained an egg, determined by ground truthing, we have not calculated and compared estimates of annual breeding pairs across the three years of survey data. The great difference between the proportion of AOSs that contained eggs in 2013 and 2018 makes it unsafe to assess trend without additional data. At this stage it is probably best to use the raw counts as an index of abundance and assess trend using these data, an approach adopted by Robertson et al. (2016) for Chilean albatross colonies where it was not feasible to obtain data on the proportion of breeders and loafers.

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7. Figures

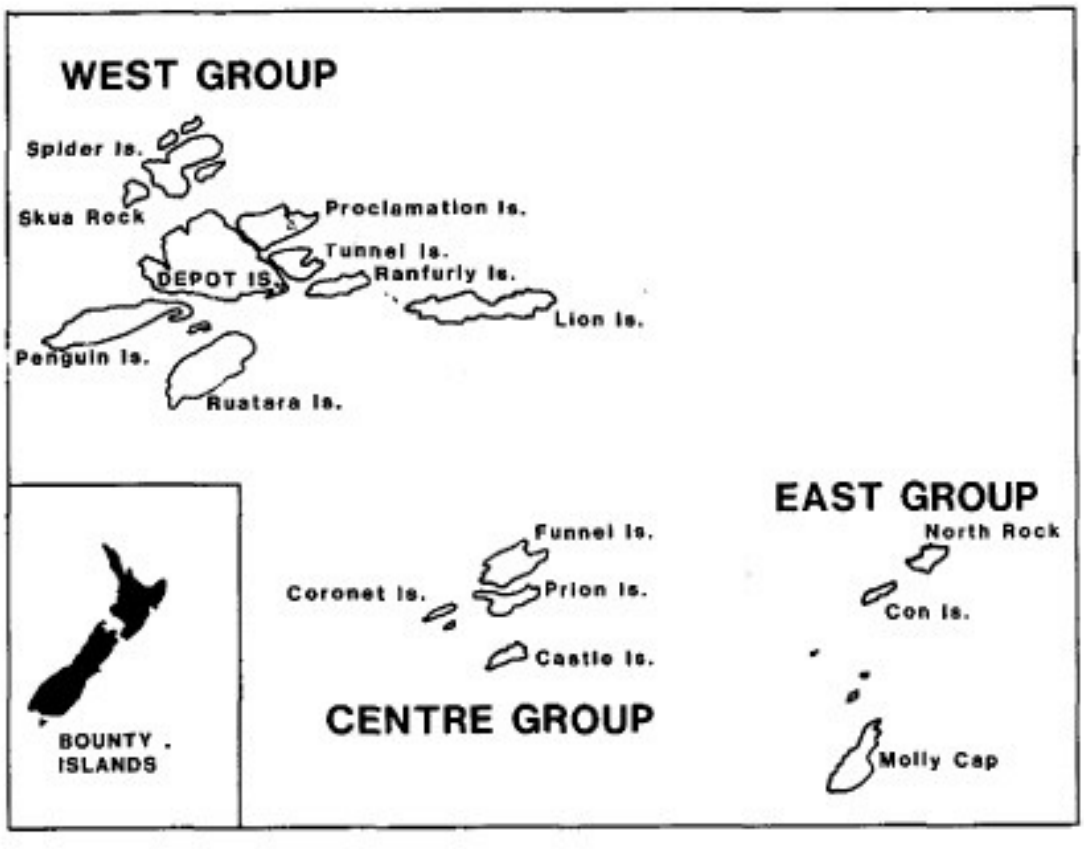

Figure 1. Map showing the Bounty Islands and their location relative to New Zealand (from Robertson and van Tets 1982). Salvin's albatross nest on Molly Cap, Funnel, Spider, Depot, Proclamation, Tunnel, Ruatara and Penguin Islands.

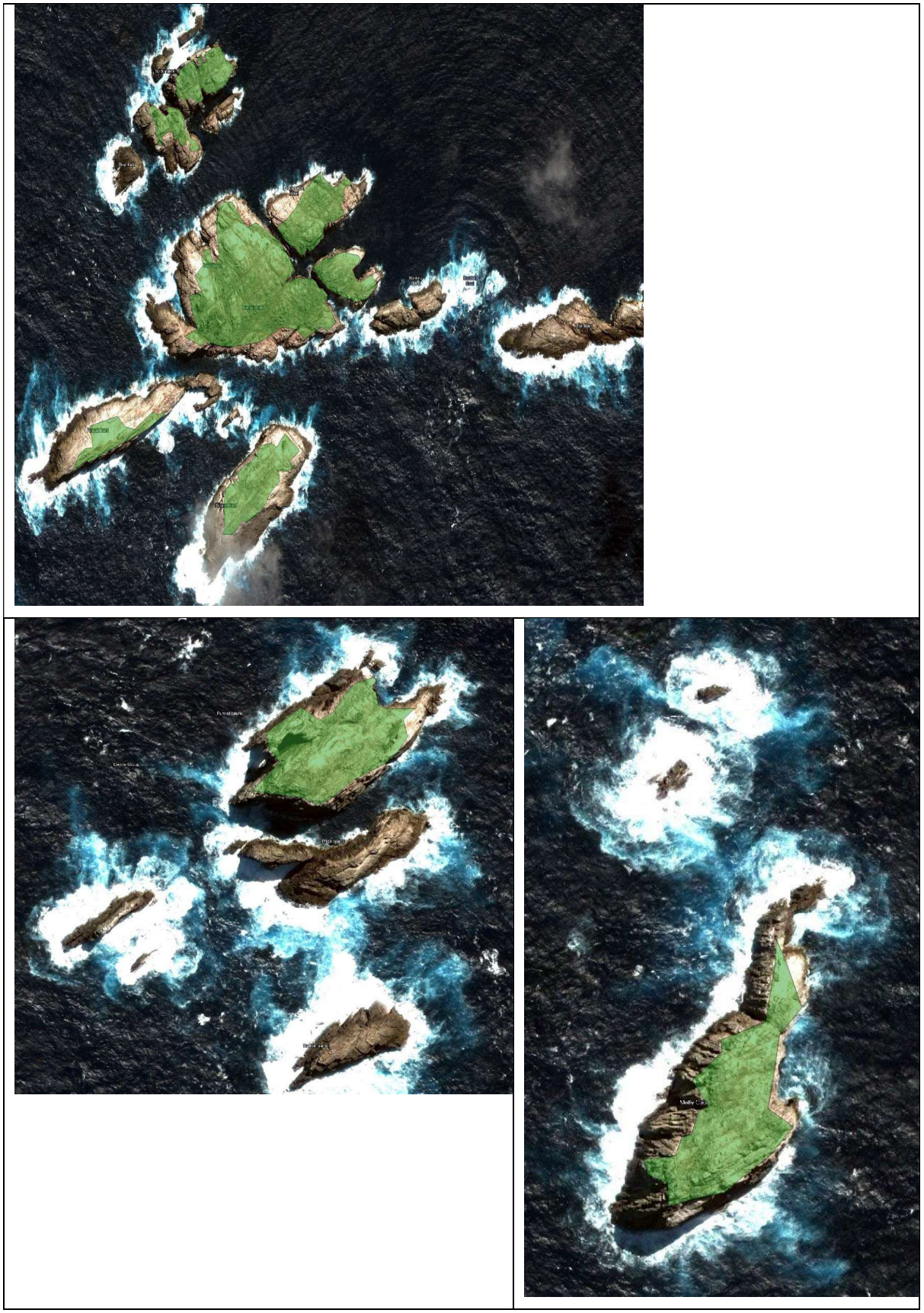

Figure 2. Area of Occupancy (green shading) of nesting Salvin's Albatross on the Bounty Islands in October 2018. Main or West Group of Islands (top panel), Funnel Is. (Centre Group —bottom left panel), Molly Cap (East Group —bottom right panel).