Population survey of Southern Buller's Albatross *Thalassarche bulleri bulleri* on the Solander Islands | Hautere, March 2024

Peter Frost[1], G. Barry Baker[2], Johannes Fischer[3] and Paul Sagar[4]

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Peter Frost[1], G. Barry Baker[2], Johannes Fischer[3], Paul Sagar[4]

[1] Science Support Service, Whanganui 4500

[2] Latitude 42 Environmental Consultants, Kettering, Tasmania

[3] Department of Conservation, Wellington

[4] 418 Pleasant Valley Road, RD21 Geraldine 7991

Corresponding author: Peter Frost (pghfrost@xtra.co.nz)

Cover: *Solander Islands from 38 kilometres away with a Southern Buller's Mollymawk superimposed*
(Photos: Peter Frost)

Executive Summary

1. An aerial photographic survey of Great and Little Solander islands was carried out on 9 March 2024, mid-way through the Southern Buller's Albatross incubation period. Overall, 6771 individuals were counted in non-overlapping zones drawn on the images: 6215 (92 %) on Great Solander, 556 (8 %) on Little Solander. Of these, 4581 individuals were associated with occupied nests, 3845 (84 %) with a sitting bird alone (no assumptions being made about whether or not the nest contained an egg); remaining 736 individuals (16 %) were in pairs, with one bird sitting. This means a further 368 occupied nests, giving an initial total of 4213 occupied nests, considered to be the minimum number.

2. Among other birds seen clearly, 583 were standing by empty nests (referred to here as occupied sites), 75 % as single birds. Loafers (145) comprised the balance of the definable birds. The status of a further 1462 individuals (22 % of the total birds counted) could not be determined directly. Assuming that their status was in the same proportions to those of the clearly observed birds, these indeterminate individuals would represent a further 1160 birds on nests, giving an overall total of 5373 occupied nests, considered the maximum number.

3. Compared with the last survey in 2016, which combined aerial survey and counts of sitting birds from vantage points, the minimum estimate would loosely imply 25 % fewer birds at nests. But with the more likely number of occupied nests being c. 5373, the falloff since 2016 might only be about 4 %.

4. Surveys of 54 occupied nests along seven short transects found only 62.3 % on average had eggs (33 nests). The rest (21 nests, 37.7 %) had birds sitting on empty nests (Sagar *et al*. 2024). The status of these latter birds is unclear. They could be pre-breeders returning to the islands prior to nesting for the first time; recent failed breeders that have not yet abandoned their nest; or breeders from previous years taking a break from breeding for some reason. Given the timing of the survey, about halfway through the incubation period, it is unlikely that any of these birds were yet to lay eggs. The proportion of birds sitting on empty nests had only previously been reported in the 2016 survey. If the 2024 ground survey is considered broadly representative of the population, then 27% fewer birds were breeding in 2024.

5. The number of birds associated with empty nests, both from the aerial survey counts and from the ground survey, together with the numerous empty nests and nest sites seen on the aerial photographs, suggests that many birds may not have bred in 2024.

6. More needs to be known about the nature of birds sitting on empty nests. If some of them are skipping breeding, and if this is occasionally widespread in the population, caution may be needed in inferring demographic trends only from changes in the number of apparently nesting pairs between two surveys.

7. The rugged nature of Great Solander Island and dense tree canopy cover in places on both islands means that some nesting birds may go undetected during aerial photographic surveys. Short-duration ground surveys are similarly limited. As a population monitoring tool, future aerial photographic surveys may be better focused on comparing counts from images taken of several clearly demarcated, more-open areas on the two islands, interspersed at longer intervals with longer-duration, more intensive, combined ground and aerial censuses of both islands, as done in the past.

1 Introduction

Southern Buller's Albatross, *Thalassarche bulleri bulleri*, nest only on two island groups globally, The Snares / Tini Heke (48° 02'S, 166° 36'E) and the Solander Islands / Hautere (46°35'S, 166°54'E), 163 km further north. Another subspecies, Northern Buller's Albatross, *Thalassarche bulleri platei*, arguably a separate species on account of its distinctly different breeding phenology, among other things, breeds on The Sisters / Rangitatahi (43°34'S, 176°49'E) and The Forty-Fours / Motuhara (43°58'S, 175°50'W), two privately owned island groups in the Chatham Islands, with a minute population breeding on Rosemary Rock (34°11'S, 172°03'E) in the Three Kings Island / Manawatāwhi archipelago.

At the last full censuses of Southern Buller's Albatross on The Snares and Solander islands, the former had 8704 breeding pairs in 2014 (Sagar 2014), around 61% of the total population, whereas the Solander Islands supported an estimated 5620 breeding pairs in 2016 (Thompson *et al*., 2017), ~39 % of the total. The population on The Snares has been the subject of a long-term demographic study since the late 1960s, with most work focused on three sub-colonies on North East island: Upper and Lower Punui Bay, and Mollymawk Bay (Sagar *et al*. 2024). Up to 2002, the combined population of North East Island and Alert Stack on The Snares grew at around 2.0 % per annum, followed by a slight apparent decline of -0.12 % per annum to 2014 (Sagar 2014). Data from the three study colonies likewise showed an annual growth rate of 2 % up to 2006, after which numbers have fluctuated but overall declined by an average -0.8 % per annum to 2019. The number of breeding pairs rose briefly in 2022 to the highest recorded, around 5 % higher than in 2006, but subsequently fell back sharply (Thompson & Sagar 2022). In the latest (2024) survey the number of breeding pairs in the sub-colonies was c. 36 % lower than in 2006 (Sagar *et al*. 2024).

The Southern Buller's Albatross population on the Solander Islands has been assessed less frequently. Between 1996 and 2002, the number of apparent breeding pairs rose from 4147 to 4912, an overall increase of 3.1 % (Sagar & Stahl 2005). Numbers rose a further 12.6 % between 2002 and 2016, when a combined ground and aerial survey recorded 5620 apparently breeding pairs (Thompson *et al*. 2017). In view of the recent declines recorded on The Snares, another census of the Solander Island population is warranted to determine if the same trend is occurring there. This is particularly pressing, given that Buller's Albatross is subject to considerable mortality due to fisheries bycatch (estimated at about 711 birds per year in New Zealand waters: Edwards *et al*. 2023, Table A3), and adult survival has declined noticeably in recent years (Sagar *et al*. 2024). Fisheries-bycatch mortality has been implicated in the decline of many other albatross species (Baker *et al*. 2007; Clay *et al*. 2019), emphasising the need to continue monitoring species at risk and finding ways to reduce that threat. The recent reassessment of the risk posed by fisheries-related mortality to New Zealand seabirds by Edwards *et al*. (2023) identified Southern Buller's Albatross as the species at greatest risk.

This report presents the results of an aerial photographic survey of Southern Buller's Albatross on the Solander Islands undertaken on 9 March 2024, about half-way through the incubation period. Although there were two field teams on the ground at the time of the aerial survey, primarily to fit satellite trackers on a selection of nesting birds, the duration of their stay—only about five hours—was too short to undertake any wide-ranging, systematic ground counts other than checking what proportion of birds on a small sample of nests around where they were working were sitting on eggs (Sagar *et al*. 2024).

2 Study Site and Methods

2.1 Study site

The Solander Islands are the eroded remnants of a previously much larger 0.40–0.15 Myr middle-late Quaternary volcanic complex lying close to the boundary of Australian-Pacific tectonic plates (GNS Science 2012; Mortimer *et al*. 2013). Geologically, the two islands are comprised predominantly of porphyritic, sharply fractured plagioclase-hornblende andesite and basalt, overlain with pyroclastic agglomerates and tuff, intermittently intruded by dykes of andesite. The resulting terrain on Great Solander | Hautere is rugged with steep cliffs bounded by only a narrow coastal terrace backing the boulder-filled beaches. The cliffs rise sharply from around the 20-m contour to at least 140 m along the South East Peninsula and up to 180–200 m in the main island block. Little Solander, lying 1.96 km due west of Great Solander, is primarily a trachyandesite half-dome intruded on the northern side by a dyke of orange tuff, with almost vertical cliffs across the southern side. The geology of the islands has been described by Harrington & Wood (1958), Mortimer *et al*.(2008, 2013) and Foley *et al*. (2013), all emphasising the islands' volcanic origin and rugged nature.

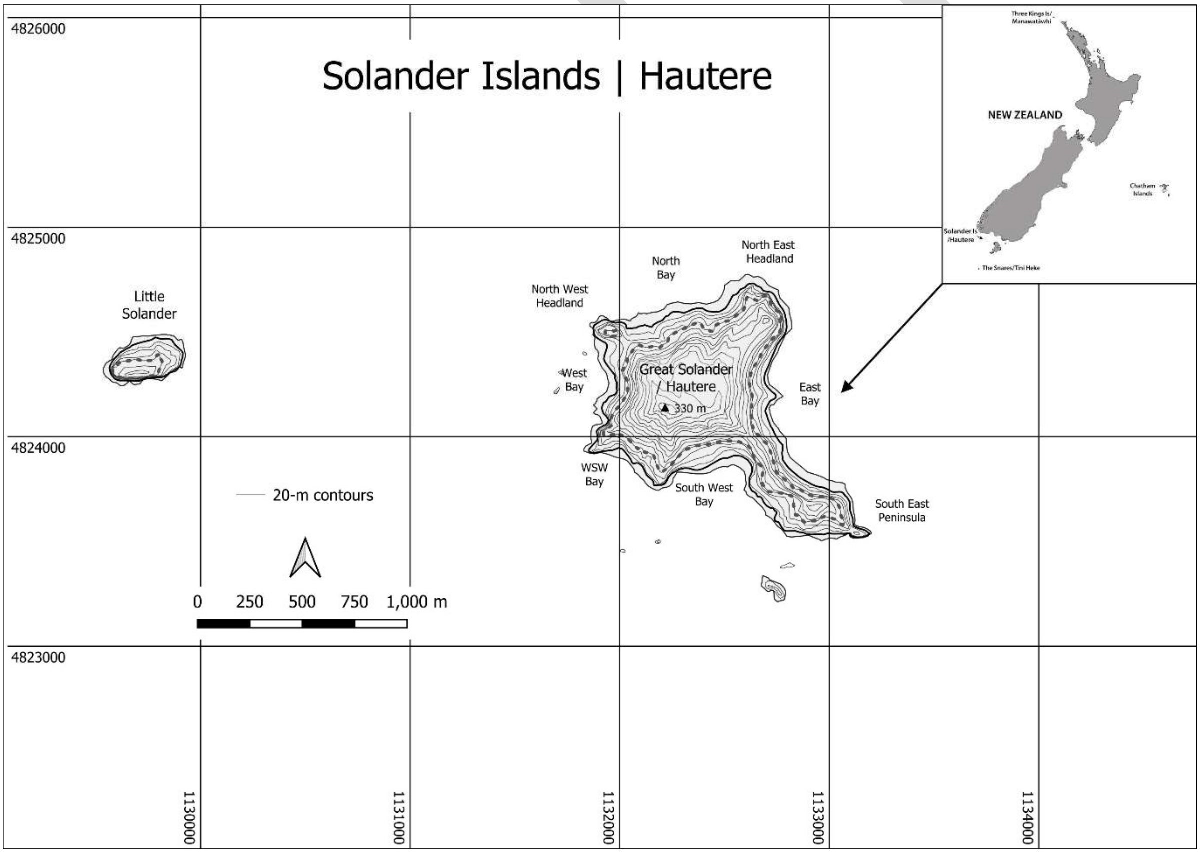

Figure 1. Location and geophysical features of the Solander Islands | Hautere, overlain with the NZGD2000 / New Zealand Transverse Mercator 1000-m grid and coordinates

Despite the steep topography and rocky slopes, both islands are well vegetated. Dense scrub, primarily of *Macrolearia lyallii* [*Olearia lyallii*], forms a compact canopy on the peaty soils of the plateau of Great Solander (Johnson 1975 [original names given in brackets]). The understory is relatively open and covered by mosses, at least 14 fern species and megaherbs such as *Azorella lyallii* [*Stilbocarpa lyallii*]. *Macrolearia* also dominates the shrub cover on deeper soils of the island's more exposed upper slopes along with *Brachyglottis rotundifolia* [*Senecio reinoldii*] and, in places on gentler slopes with more stable soils, *B. stewartiae* [*Senecio stewartiae*]. Soils are shallow or virtually absent on many of the middle to lower slopes, supporting only low-growing herbaceous plant communities, sedges and grasses such as *Poa astonii*, and the widespread megaherb, *Anisotome lyallii*. The deeper soils on the lowest slopes of the coastal platform are covered with vigorously growing *Poa foliosa*, with *Veronica elliptica* [*Hebe elliptica*], alone or with *B. rotundifolia* and *B. stewartiae*, occurring in more sheltered places and on debris fans. The vegetation of Little Solander Island is similar but apparently less diverse. *Veronica elliptica* and *B. stewartiae* occur across much of the interior of the island, replaced by an extensive, dense sward of *Poa foliosa* on the gentler slopes of the eastern half of the island, with *V. elliptica* confined to gullies and slumps (Johnson 1975). Overall, the widespread shrub cover, and even the tall swards of *Poa*, provide much cover for nesting seabirds, making it difficult to detect individuals nesting underneath the plant canopies. Outside these areas, the steep and broken topography ensures that nesting albatrosses are mostly scattered, aside from some small concentrations associated with the larger debris fans.

2.2 Aerial photography

Images were taken by GBB with a NIKON D6 camera and a VR 70–200 mm f/2.8G lens during anticlockwise circuits of both islands flown in a twin-engine, BK-117 helicopter operated by Southern Lakes Helicopters. Images were taken in Nikon RAW format (.NEF) then converted to JPG files. The Exif metadata recorded on the RAW images was transferred when the files were converted to JPG and used to extract information about each image: time when taken, lens focal length and aperture, shutter speed and ISO number. Shutter speed and ISO were preset at 1/2000s and 500, respectively. The geocoordinates and approximate altitudes from which each image was taken were recorded on the camera's GPS, enabling calculation of several flight parameters (Appendix 1: Figure A1, Tables A1 and A2). The survey lasted just 30 minutes, from 14:26 to 14:57.

The photographs were taken systematically from the bottom left of a scene, moving upwards more-or-less perpendicular to the top of a cliff face, ensuring that successive images overlapped vertically. The view was then shifted horizontally, before taking a parallel set to the first strip, moving down to the water's edge, maintaining vertical overlap within the image series and horizontal overlap with the preceding upwards strip. At the end of the descending strip, the view was shifted laterally again, while still retaining a degree of overlap with the previous strip, before repeating another parallel ascending and descending cycle. The aim was to ensure sufficient overlap between any image and its immediate neighbours so that photomosaics could be constructed of each cliff face. At the end of each set covering a particular face, one or more photographs were taken of the sea to indicate a move to a new position to photograph the next cliff face. The positions of the images in each set and their approximate left and right boundaries are shown in Figure A1. Although the helicopter was notionally stationary at each photographic site, in reality it was moving forward at 9.5 ± 5.2 m/s (mean ± 1 S.D.) around Little Solander Island and 4.4 ± 3.5 m/s around Great Solander Island at these sites, as can be seen in Figure A1.

Little Solander was photographed first from an average altitude of 198 m (SD ± 5 m) at focal lengths from 70–120 mm. Average distance, measured to the 100-m contour on the island, was 373 ± 52 m (range 295–429 m). The photographs covered all areas of the island at various oblique angles, with the central areas being at the lowest angle below the horizontal. This made some birds nesting under the extensive tree cover more visible for counting.

The flight around Great Solander Island started from the South-East Peninsula and proceeded anticlockwise past East Bay, around North East and North West Headlands, with North Bay in between, then around West and WSW Bays, to South West Bay. Images were taken predominantly at 135 mm focal lengths, extended to 155–185 mm when photographing the South East Peninsula from further offshore, and the plateau above 240 m. Average altitude from which the photographs were taken was 256 ± 66 m (range: 191 – 401 m), higher altitudes than those around Little Solander Island due to the higher elevation of Great Solander Island, particularly when photographing the plateau above 240 m. At the end of the circuit around Great Solander, the helicopter was flown up to 390–400 m to allow slightly less oblique photographs to be taken of the island's densely treed plateau to ensure blanket photographic coverage of the island.

2.3 Image processing

Images were first processed in Photoshop Elements 2024™, involving a combination of atmospheric correction (haze reduction), lightening shadows, darkening highlights, and enhancing midtone contrasts, all intended to heighten the visibility of the birds and other relevant features (*e.g.*, nests). Adjustments to hue and saturation, as well as sharpening some images using either Photoshop Element's Sharpen tool or Topaz Photo AI's Image Sharpen model, were made where necessary. When using Topaz Photo AI™, care was taken to ensure that no artifacts were introduced, or important small features omitted. Some images, especially those that were either over-exposed or a couple that were grossly under-exposed, were re-processed in RAW format using Nikon's NX Studio ver.1.16.1™.

After processing, series of sequential images, either single or several adjacent vertical strips, were stitched into photomosaics using Microsoft's Image Composite Editor™. Because the photomosaics overlapped to varying extents, a single count zone was demarcated in each strip, usually extending from the shoreline to the island's horizon, but occasionally to a smaller discrete area within a mosaic. Each zone was unique, abutting adjacent similarly unique zones on either side, and demarcated by lines drawn digitally on the images, connecting prominent features visible in the neighbouring mosaics (*e.g.*, rocks, fissures, bare patches, dead branches, and grass or sedge tussocks). Each line was drawn simultaneously on the two adjacent mosaics to ensure that they were identical. Some deletions and duplicates (ghosting) were noted. Ghosting was removed by redoing the stitching, using different image combinations. Obvious deletions were reinserted manually before counting.

2.4 Counting

All definite or possible Southern Buller's Albatrosses seen in each zone were counted and their status catalogued using DotDotGoose (v.1.7.0, Ersts 2024). Individuals were classed as follows:

1. bird sitting on a nest (Figure 2a – yellow dot)
2. bird sitting on a nest with presumed partner next to it (Figure 2a – orange dot)
3. bird standing on an apparently empty nest or nest site (Figure 2b – violet dot)
4. two birds standing together on an empty nest (Figure 2b – magenta dot)
5. birds not associated with a nest (*i.e.*, loafers: Figure 2c – pink dots)
6. bird present but status unknown (Figures 2d – cyan dots)
7. adult flying (recorded by not dealt with subsequently)
8. possible albatross (question mark; not dealt with further)
9. empty nest or site.

Figure 2. Examples of birds classified by behaviour: (a) occupied nests with a single bird sitting on nest (yellow dot), and two birds at nest, one sitting plus a partner (orange dot); (b) occupied sites with a non-breeding bird standing on nest (violet dot) and two non-breeding pairs at nest (magenta dot); (c) loafing birds (pink dot) together with a bird on a nest (yellow dot); (d) birds of unknown status (cyan dots)

Each category was assigned a unique colour, so that individuals or duos could be marked appropriately on a digital overlay of the scene being surveyed. DotDotGoose places a re-sizable grid onto the image being analysed. In this analysis, grid size was set at 400 x 400 pixels. The image can be magnified to whatever extent is most useful, with the grid and tally marks following suit. Each grid square was examined systematically and sequentially. Any birds seen were then categorised before moving to examine the next grid square in line. The numbers in each category were tallied automatically when birds were marked, then saved as CSV files for later analysis.

The positions of the marked birds and other relevant features were saved and could be recalled, if needed. An overlay of the image of the area, with the variously coloured marks in place, was saved as a PNG file, providing a useful overview of where the birds were, and whether there was any clustering of activity in particular sites (Figure 3).

2.5 Ground survey

Seven short non-random transects were surveyed in South West Bay and North Bay concurrently with the aerial survey (Sagar *et al*. 2024). Together, the surveys lasted 66 minutes (the times taken to complete each section were not always recorded) and covered a total of c. 2 km (data from GPS GPX files). The transects were not randomly selected and sampling was largely opportunistic. The aim was to establish what proportion of birds on nests were actually incubating eggs as opposed to sitting on empty nests. If these results are considered representative of the larger population, they could be used to adjust the aerial counts downwards so as not to overestimate the actual number of breeding pairs.

2.5 Data analysis

Data analysis was reasonably straightforward because each count zone was unique and non-overlapping. The number of apparently active nests (N_{obs}) was simply the sum of all birds seen sitting on nests and the number of nests with two birds present (a sitting bird plus partner). In what follows, these are referred to as occupied nests, without any implication that this necessarily means the presence of an egg. We simply cannot tell from the aerial photographs the number of actual breeding pairs (*i.e.,* birds incubating). In contrast, sites where one or two birds were present but standing on or next to an obviously empty nest are referred to here as occupied sites, with the occupants assumed to be non-breeders.

In addition, in each zone, there were birds whose status could not be determined confidently (status unknown (U)). At least some of these would likely have been present at a nest. The number of additional occupied nests was estimated as the product of U and two probabilities from the observed proportions of birds clearly seen at nests: (1) the probability that a bird was present at an occupied nest ($p[nest_{occ}]$); and (2), given that some of the birds at occupied nests were partners, the conditional probability that an individual associated with such nests was actually sitting ($p[sitting \mid nest_{occ}]$). That is, the number of additional occupied nests was $N_{add} = (U) * p[nest_{occ}] * p[sitting \mid nest_{occ}]$, and the estimated total number of occupied nests $N_{obs} + N_{add}$.

To express the uncertainty in the counts for each island, 95 % confidence limits (CL) were calculated for the totals of each category in each of the five areas on Great Solander and for Little Solander overall. These confidence limits were calculated using the *poisson.exact* function in the R package *exactci* (Fay 2017). This corresponds to the exact central confidence interval of Garwood (1936), widely used for calculating this parameter in a one-sample case; here, the number of counts in each category. This assumes they follow a Poisson distribution, in which the mean and variance of a sample are the same (Baker et al. 2013).

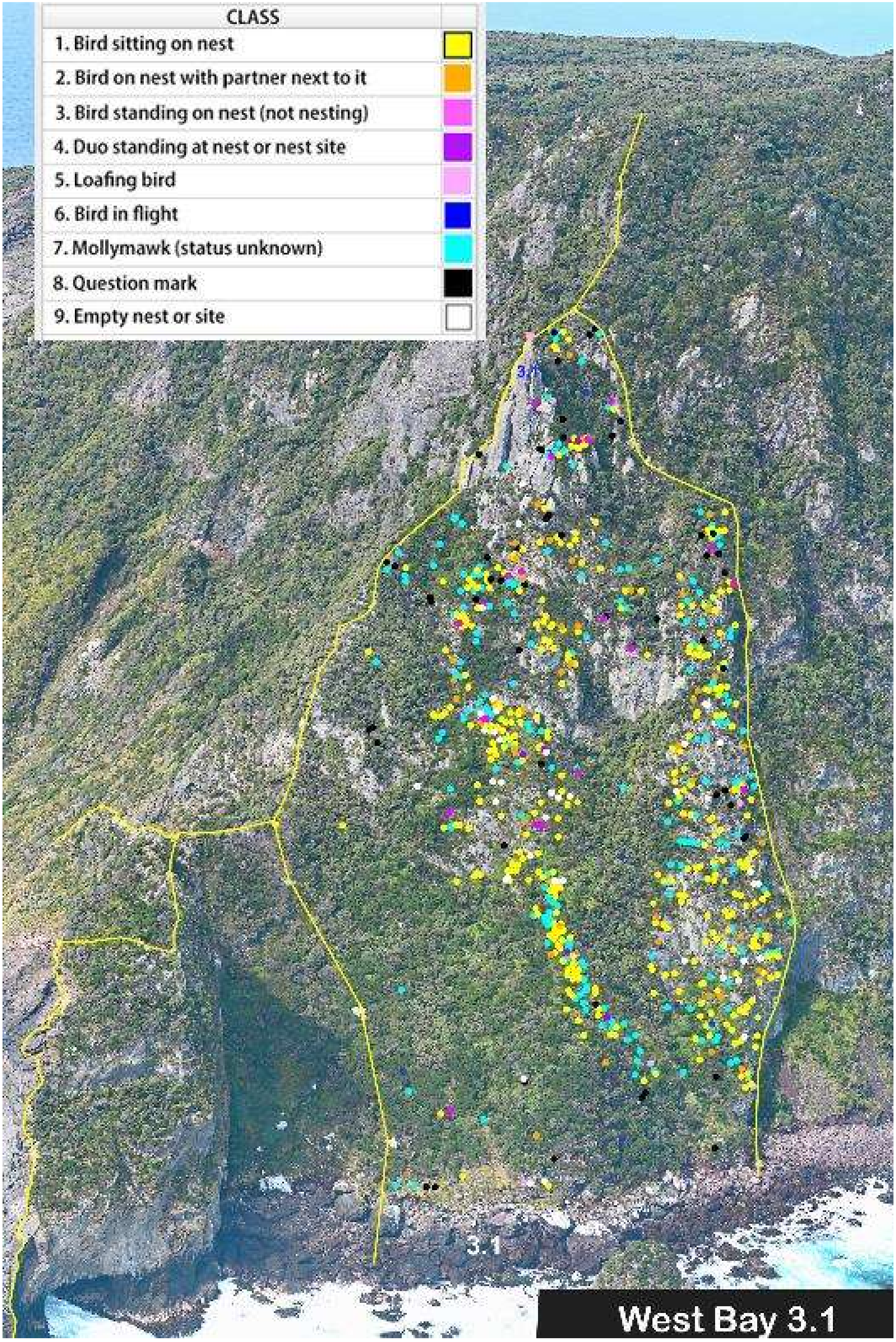

Figure 3. DotDotGoose overlay showing the locations of 394 Southern Buller's Albatross on nests and 284 other individuals identified in West Bay Area 3.1. The yellow line marks the boundary of this and adjacent areas. The thickness of the boundary lines and size of the symbols have been considerably enlarged for illustrative purposes

3 Results

3.1 Great Solander

At least 3,873 nests occupied by Southern Buller's Albatross (95 % CL, 3722–4030) were counted on Great Solander Island, consisting of 3537 single birds sitting on nests plus 336 nests with two birds present—one sitting, the other alongside and assumed to be its partner—just under 9 % of the total (Table 1). In addition, there were 1356 birds whose status was indeterminate, around 22 % of all individuals counted on the ground. Some of these unknown individuals would likely also have been associated with an occupied nest. Assuming these indeterminate birds were in the same proportion as the observed singles and pairs at such nests, then the total estimated number on Great Solander was 4953 (95 % CL, 4774–5148) (Table 1). Overall, 6215 individuals were counted on the ground on Great Solander (including loafers and birds of indeterminate status). Of these, 5383 (87 %) were birds at occupied nests. The balance (832 individuals, c. 13 %) were non-breeding birds either standing at a nest site but not incubating (659 or c. 10 %) or not obviously associated with a nest at all ('loafer': 173 or c. 3 %).

Occupied nests were distributed all around the island (Figure 4). Although the area of each of the five zones into which the island has been partitioned in earlier studies is unknown, planar measures of area suggest that the number of occupied nests observed in each zone is not simply a function of its size. South West Bay, with 1228 occupied nests (31.7 % of the total), supported proportionately more observed occupied nests per unit area (69), than either North Bay (1113, 28.7 %) or West Bay (559, 14.4 %), with 59 and 55 occupied nests per unit area respectively. East Bay (694 occupied nests, 17.8 %) and WSW Bay (279 occupied nests, 7.2 %) supported proportionately the least, 40 and 27 occupied nests per unit area, respectively. The picture does not change substantially if the total occupied nests (*i.e.,* those including the fraction of indeterminate birds assumed to be on nests) are considered.

This assessment does not include those birds that might have been nesting on the tree-covered plateau or were undetected under plant cover elsewhere. Those visible under trees close to the edge of the plateau were accounted for in the area counts but no birds were seen in images of the plateau above c. 240-m contour taken at the end of the regular survey. This area is densely vegetated, primarily with *Macrolaria lyalli* and *Brachyglottis stewartiae* (Johnson 1975). The areas of apparent greatest concentrations of occupied nests are shown in Figure 4. These were generally more open areas: gentler slopes with shallow soils; talus; or grassy areas (*e.g.*, eastern end of Little Solander; lower slopes of South West Bay, Great Solander).

3.2 Little Solander

A total of 340 occupied Southern Buller's Albatross nests (95 % CL, 297–389) were counted on Little Solander Island, comprising 308 single birds sitting on nests plus 32 others (9 % of the total) accompanied by a second bird, assumed to be the partner (Table 1, Figure 2a). But there were also 106 birds whose status could not be determined (Figure 2c, d), 19 % of all 556 individuals seen on the ground. Assuming that these indeterminate individuals include some birds on nests, and that they occur in the same proportion as those counted directly, the number of occupied nests overall was estimated to be 420 (367–480). Of the remaining birds (including that proportion of birds whose status was indeterminate), 84 (15 %) occupied sites as non-breeding birds—standing not sitting on the nests—with a further 12 individuals as apparent outright loafers (Table 1).

Table 1. Summary of the numbers of Southern Buller's Albatross on the Solander Islands counted from aerial photographs taken on 9th March 2024. The 95 % confidence limits are shown below each count in grey text

	Great Solander					**Great Solander (total)**	**Little Solander**	**Solander Islands (total)**
	1 East Bay	**2 North Bay**	**3 West Bay**	**4 WSW Bay**	**5 SW Bay**			
Bird sitting on nest	654	1007	497	260	1119	3537	308	3845
	605–706	*946–1071*	*454–543*	*229–294*	*1054–1187*	*3288–3801*	*275–344*	*3563–3968*
Duo at nest, one sitting	40	106	62	19	109	336	32	368
	29–54	*87–128*	*48–79*	*11–30*	*90–131*	*265–422*	*22–45*	*287–408*
Bird standing on nest	98	97	39	23	130	387	48	435
	80–119	*79–118*	*28–53*	*15–35*	*109–154*	*311–479*	*35–64*	*346–478*
Duo standing on nest	20	14	6	1	23	64	10	74
	12–31	*8–23*	*2–13*	*0–6*	*15–35*	*37–108*	*5–18*	*42–93*
Loafing bird (not associated with nest)	27	36	12	13	47	135	10	145
	18–39	*25–50*	*6–21*	*7–22*	*35–63*	*91–195*	*5–18*	*96–171*
Status unknown (U)	297	412	274	96	277	1356	106	1462
	264–333	*373–454*	*243–308*	*78–117*	*245–312*	*1203–1524*	*87–128*	*1290–1539*
Known occupied nests	**694**	**1113**	**559**	**279**	**1228**	**3873**	**340**	**4213**
	634–760	*1033–1199*	*502–622*	*240–324*	*1144–1318*	*3722–4030*	*297–389*	*4055–4376*
$p(nest_{occ})$	***0.816***	***0.883***	***0.908***	***0.887***	***0.857***	***0.866***	***0.827***	***0.863***
	0.787–0.845	*0.861–0.903*	*0.875–0.935*	*0.837–0.919*	*0.834–0.876*	*0.839–0.889*	*0.786–0.864*	*0.834–0.887*
$p(sitting \mid nest_{occ})$	***0.946***	***0.913***	***0.900***	***0.936***	***0.918***	***0.920***	***0.914***	***0.920***
	0.934–0.956	*0.904–0.922*	*0.887–0.913*	*0.915–0.956*	*0.909–0.927*	*0.909–0.913*	*0.896–0.931*	*0.908–0.931*
Estimated total occupied nests[1]	**923**	**1445**	**783**	**359**	**1446**	**4953**	**420**	**5373**
	847–1005	*1342–1550*	*710–863*	*309–414*	*1345–1554*	*4774–5148*	*367–480*	*5166–5566*
Total birds counted on ground[2]	**1196**	**1792**	**958**	**432**	**1837**	**6215**	**556**	**6771**
	1049–1367	*1613–1995*	*831–1109*	*351–540*	*1653–2048*	*5868–6586*	*456–680*	*6407–7158*

Note 1. Total apparently nesting pairs are the sum of birds seen sitting on nests ('known apparently nesting pairs') and the proportional allocation of birds whose status could not be determined (U) calculated as U*$p(nest_{occ})$*$p(sitting \mid nest_{occ})$. See text for further details.

2. Includes birds whose breeding status is unknown.

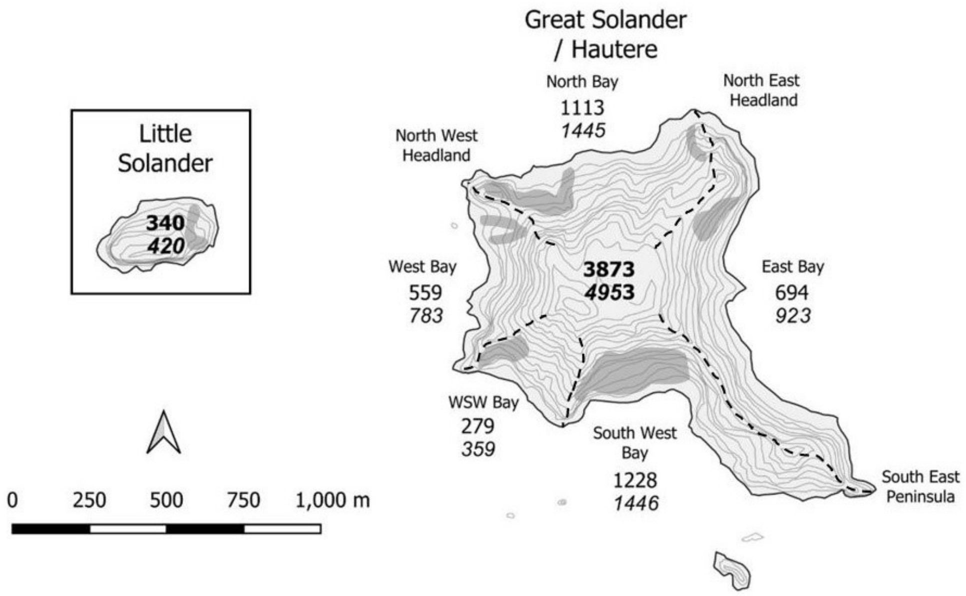

Figure 4. Distribution of occupied nests of Southern Buller's Albatross on the Solander Islands, as counted on aerial photographs taken on 9 March 2024 (regular font), with those estimated after accounting for birds seen in the images but initially unclassified ('status unknown') in italic font. The shaded areas show the general locations of the denser concentrations of birds occupying nests.

Non-breeding individuals—loafers and birds occupying nest sites but evidently not nesting—made up c. 14 % of all 6771 birds visible on the ground in the aerial images of both islands (*i.e.*, 928 individuals, including a proportion of indeterminate birds: Table 1). Loafers, birds not obviously associated with a nest but sitting or standing instead on ridges, prominent rocks or grass tufts (Figure 2c), comprised 20 % of these non-breeding birds on the two islands.

In addition, 1739 unoccupied nests and vacant nest sites—obvious large hollows in slopes with apparently excavated material around the entrance (Figure 5)—were also noted on the islands, c. 24 % of all observed nests and nest sites (including the unoccupied ones). The actual numbers are undoubtedly higher because some were probably missed. Whether these were failed or abandoned nests, or just ones that had not been reoccupied in the current season is not known.

The counts of the number of occupied sites do not take account of birds sitting on empty nests. From 54 nests checked along seven short transects in South West Bay and North Bay, the average percentage with birds sitting on eggs was 62.3 % (95 % CL 54.9–69.6 %, 33 nests); the balance (21 nests, 37.7 %) were occupied by birds sitting on empty nests (Sagar *et al*. 2024).

3.3 Other species

Fourteen Australasian Gannets/Tākapu, *Morus serrator*, were seen on Little Solander Island, 11 on the northern slope of the island, on vegetation debris fans just below the tree line (Figure 6), one among rocks on the western edge, and two on a bluff jutting out of the south-west corner of the island. The latter two appeared to be sitting on nests, although in March nests would be expected to have large chicks. Other species noted included nine Fiordland Crested Penguins/Tawaki, *Eudyptes pachyrhynchus*, on the shore of Great Solander Island; one Brown Skua/Hākoakoa, *Stercorarius antarcticus*; two Weka, *Gallirallus australis*, one on each island; and at least 12 Southern Black-backed Gulls, *Larus dominicanus*, and 17 Red-billed Gulls, *Chroicocephalus novaehollandiae*.

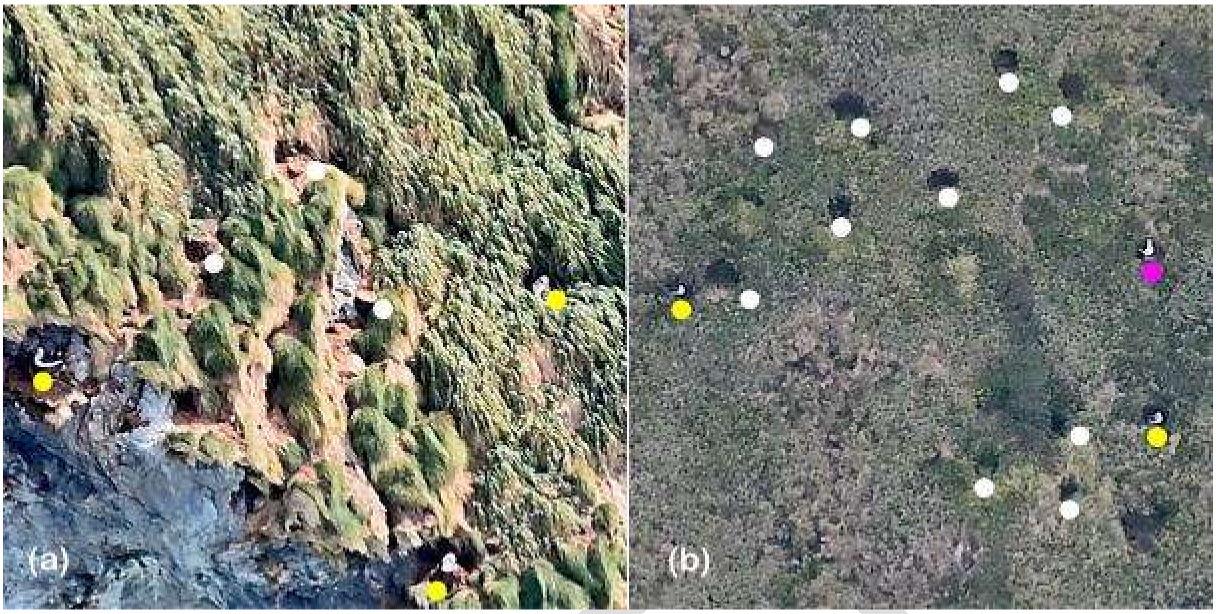

Figure 5. Examples of (a) empty nests (white dots) and (b) vacant nest sites (white dots) on Little Solander Island and above SW Bay, Great Solander Island, respectively. Occupied nest sites are marked yellow dots in both images; a single bird standing on an empty nest is marked with a violet dot in (b).

Figure 6. Four Australasian Gannet (bright green triangles) and six sitting Southern Buller's Albatross (single birds on nest—yellow dots; two birds at a nest, one sitting—orange dot) on the north face of Little Solander Island

4 Discussion

A total of 4213 occupied nests of Southern Buller's Albatross were counted initially on the aerial images taken of the Solander Islands in March 2024: 3873 (92 %) on Great Solander and 340 (8 %) on Little Solander. A single bird was sitting on just over 91 % of these nests; the rest had two birds present, presumed to be a sitting bird and its partner. The proportions of single-occupant nests was similar on the two islands. Of all the individuals seen on the islands whose status could be determined, 4209 (89 %) on Great Solander and 372 (85 %) on Little Solander were associated with occupied nests, either as single sitting birds or as partners alongside them. The remaining classified individuals were either non-breeding single birds or duos at nest sites but without any evidence of nesting (583 or 11 % of the total for both islands), or apparent loafers (145, c. 3 %).

In addition, however, there were a further 1462 birds that were not seen well enough to be categorized initially ('Status unknown'), just under 22 % of all 6771 birds counted: 1356 (93 %) on Great Solander and 106 (7 %) on Little Solander. Some of these would most likely have been on nests, either as single birds or as partners of sitting birds. Assuming that the proportion of individuals on nests among these indeterminate birds was about the same as those observed among the classified birds, then a further 1160 occupied nests (1080 on Great Solander and 80 on Little Solander) can be added to the observed number, giving 5373 occupied nests overall: 4953 on Great Solander and 420 on Little Solander (Figure 4). These numbers likely include some birds sitting on empty nests but exclude any nesting birds completely obscured from view by the vegetation. We know nothing about the nature of these birds nor if the noted percentage of false positives (c. 38 %: Sagar *et al*. 2024) in a small sample of 54 nests examined concurrently with the aerial survey is more widely applicable. Nevertheless, if only 62 % of the 5373 estimated occupied nests on the Solander Islands in 2024 actually had birds incubating eggs, and assuming that no nesting birds were overlooked under the tree canopies, then the number of nests with an egg would have only been c. 3347.

How does this compare with counts from previous surveys (Table2)? Those involved a mix of ground counts, in which individual nests were visited and tallied; vantage-point counts through binoculars, in which presumably the number of birds sitting on empty nests could not be fully determined; and counts of birds on nests visible on aerial photographs, where birds sitting on empty nests were indistinguishable from incubating birds (Sagar *et al*. 1999; Sagar & Stahl 2005; Thompson *et al*. 2017). In 1996 and 2002, the number of birds present with and without eggs in those colonies that could be reached on foot was recorded (Sagar *et al*. 1999; Sagar & Stahl 2005), but no details were given, so the extent to which they were finally incorporated is unclear. In 2016, the proportion of birds sitting on a nest with an egg was recorded in two separate surveys of 49 and 74 nests near the western end of North Bay on Great Solander Island. It was 0.82 in both cases (Thompson *et al*. 2017). Applying this to the overall count of 5620 nesting birds in 2016 gave a total of 4,579 incubating birds (Thompson *et al*. 2017). The adjusted count for 2024—3347—is 27 % less, implying a sharp falloff in breeding numbers, for whatever reason.

Because a correction for birds sitting on empty nests was not obviously applied to the counts in 1996 and 2002, Thompson *et al*. (2017) handled their final 2016 assessment similarly. Treating the unadjusted counts of occupied nests as population indices, therefore, the 1996–2024 counts suggest that c. 36 % more birds were occupying nests on the Solander Is in 2016 than in 1996. In contrast, there were 4 % fewer birds occupying nests in 2024 compared with the population in 2016 (based 5373 occupied nests, the maximum estimate for 2024). No assumptions are being made here about whether or not the birds were sitting on eggs or empty nests.

Table 2. Comparison between the number of Southern Buller's Albatross occupying nests on the Solander Islands in 2024 and those counted in earlier years. Both counted (min.) and estimated (max.) figures are given for 2024, the latter taking account of the proportion of birds whose status was not determined initially, but which were later estimated to be occupying nests. These figures do not take account of the proportion of nests with birds that may have been sitting on empty nests (see text for details)

Year	1996 [1]	2002	2016	2024	
Date (ground survey)	16–22 Feb	22 Feb–8 Mar	25–29 Feb	9 Mar [2]	
Date (aerial survey)	15 Feb	20 Feb	29 Feb	9 Mar	
Area / Source	Sagar *et al*. 1999	Sagar & Stahl 2005	Thompson *et al*. 2017	This study (min.)	This study (max.)
Great Solander	3885	4579	5280	3873	4953
1. East Bay	*709*	*876*	*666*	*694*	*923*
2. North Bay [3]	*1086*	*1162*	*778*	*1113*	*1445*
3. West Bay	*387*	*489*	*829*	*559*	*783*
4. WSW Bay [4]	*306*	*362*	*481*	*279*	*359*
5. SW Bay [5]	*1397*	*1690*	*2536*	*1228*	*1446*
Little Solander	262	333	340	340	420
Solander Is total	**4147**	**4912**	**5620**	**4213**	**5373**

Notes

[1] Corrected figures to account for missed colonies (see Sagar & Stahl 2005)

[2] Sagar *et al*. (2024)

[3] Referred to as North East to North West Headland in earlier reports (Sagar *et al*. 1999, Sagar & Stahl 2005, Thompson *et al*. 2017)

[4] Referred to as West Bay to South West Bay in earlier reports

[5] Referred to as South West Bay to South East Peninsula in earlier reports

What is known about those birds in a colony sitting on empty nests? The phenomenon is reasonably widely recognised in albatrosses and petrels (Robertson *et al*. 2008; Baker *et al*. 2015, 2023; Thompson *et al*. 2017, Walker *et al*. 2020; Bell *et al*., 2023; Parker *et al*. 2023), albeit not often measured comparably or reported clearly. Some could be pre-breeders, returning to the islands prior to nesting for the first time in a later year ('tryers'). Such birds clearly have not yet entered the breeding population and should rightly be discounted. Others sitting on empty nests could be recent failed breeders that have not yet abandoned their nest but are continuing to occupy their site to prevent it being taken over by pre-breeders looking for a site to occupy. Detecting failed breeders should be possible during a ground survey provided egg shells (and chick carcasses) remain in the nest, but for how long? In this regard, failed Southern Buller's Albatross breeders on The Snares remained in their colonies for up to three months following failure (Stahl & Sagar 2006). Not accounting for failed nesters risks underestimating the current season's breeding population.

Some non-breeding birds could even be breeders from the previous year, but which are taking a sabbatical for some reason, yet remain tied to their nest site, again perhaps to prevent it being usurped. A wide range of seabirds are known to skip breeding for a year or more, obligately so in large albatrosses that take almost a year to complete their annual breeding cycle but intermittently in others (Crawford & Dyer 1995; Mougin *et al*. 1997; Bradley *et al*. 2000; Jenouvrier *et al*. 2003; Giudici *et al*. 2010; Sanz-Aguilar *et al*. 2011; Cubaynes *et al*. 2011; Weimerskirch *et al*. 2015; Cruz-Flores *et al*. 2021). This accords with life-history theory, which predicts that long-lived, late-maturing, slow reproducing species may forego a current breeding opportunity in circumstances that might otherwise compromise long-term survival and future breeding prospects (Jouventin & Dobson 2002; Dobson & Jouventin 2010). Birds taking a sabbatical are clearly part of the wider breeding population. Ignoring them surely underestimates its size.

To determine the proportions among these possibilities in non-breeders requires knowing something about each individual or at least a statistically valid sample of such birds. Identifying which birds may be taking a sabbatical and which are pre-breeders—birds marked as fledglings years earlier and known not to have bred before—should be possible in long-term population studies with individually marked birds. For example, in 2002 on The Snares, when almost half the birds present in study plots were non-breeders, 80 % of them were pre-breeders (Stahl & Sagar 2006). From that long-term study, 16 % of birds breeding in one year did not breed the next and 7% missed breeding in two consecutive years (Francis & Sagar 2012), close to the outstanding balance of 20 % non-breeders recorded in the study colonies in 2002.

The foregoing discussion emphasises the uncertainty around numbers obtained from aerial photographs and their interpretation. Whereas aerial photographic surveys are often the only means of monitoring populations of large surface-nesting seabirds on remote, nearly inaccessible islands, they clearly have limitations (Wolfaardt & Phillips 2013). Apart from biases or errors introduced while compiling and analysing the images, other include not all birds present necessarily being detected, photographed or counted. Some birds may be sitting on empty nests, for some reason, and among birds not on nests, it is nearly impossible to distinguish among mates of breeding birds, non-breeders, pre-breeders and failed breeders, as discussed above. For failed breeders, much depends on the timing of the survey relative to the start of nesting, because the number of failures increases over time. That varies among surveys (Table 2). How long it takes failed breeders to abandon their nests completely for that season is also not know. Neither is necessarily constant from year to year, so the incidence of birds sitting on empty nests in one year cannot be used to adjust the numbers of birds counted in earlier or later years.

Overall, caution may be needed in inferring too much about demographic trends just from the number of breeding pairs in a particular year, however measured or assessed. To do otherwise is to imply that adult breeders should always breed, either annually or biennially depending on their inherent nature, regardless of circumstances, and that any change represents a real change in the status of that population. The possibility that some individuals may occasionally forego breeding, for whatever reason, needs wider recognition and, if true, then more needs to be known about the circumstances in which this happens, not only for individuals but also at a population level if this deferral of breeding is occasionally widespread.

5 Recommendations

1. Given the extent of tree cover on the Solander Islands, under which numerous pairs of Southern Buller's Mollymawk appear to nest, many probably undetectable in aerial photographs, long-term population monitoring through aerial photography alone at this site is questionable. Instead, if aerial photography is the only feasible regular monitoring tool, it should be focused on those areas where the birds are more visible, such as the more open, densely occupied ones shown in Figure 4. For interannual surveys, boundaries need to be agreed on, using stable features such as prominent rocks and ridges as marker points and boundaries, to ensure consistency in the areas being monitored over time. Comparing time-series of counts of occupied nests in such areas may give a clearer picture of population trend. These could be complemented at longer intervals by multi-day, whole-island censuses, on the ground and from the air, as done in the past.
2. More needs to be known about birds sitting on empty nests. Up to now, attention in ground-based surveys has focused almost entirely on documenting the proportion of birds on nests with eggs. Those sitting on empty nests are treated as a homogenous set, often lumped with floaters, and written off as non-breeders. On the contrary, they may comprise failed breeders, pre-breeders and, perhaps, birds taking a sabbatical for some reason. More considered reporting and clearer use of terms would help (Baker *et al*. 2023).
3. We need a better understanding of the extent of skipped breeding among mature birds ('breeding sabbaticals') and circumstances leading to it (*e.g.*, poor physical condition; divorce from or death of a partner). If the number of non-breeding mature birds varies substantially through time, this may compromise the interpretation of aerial survey counts through the presence of both false positive errors (birds present but not breeding) and false negative ones (birds absent but still part of the breeding population).

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Appendix

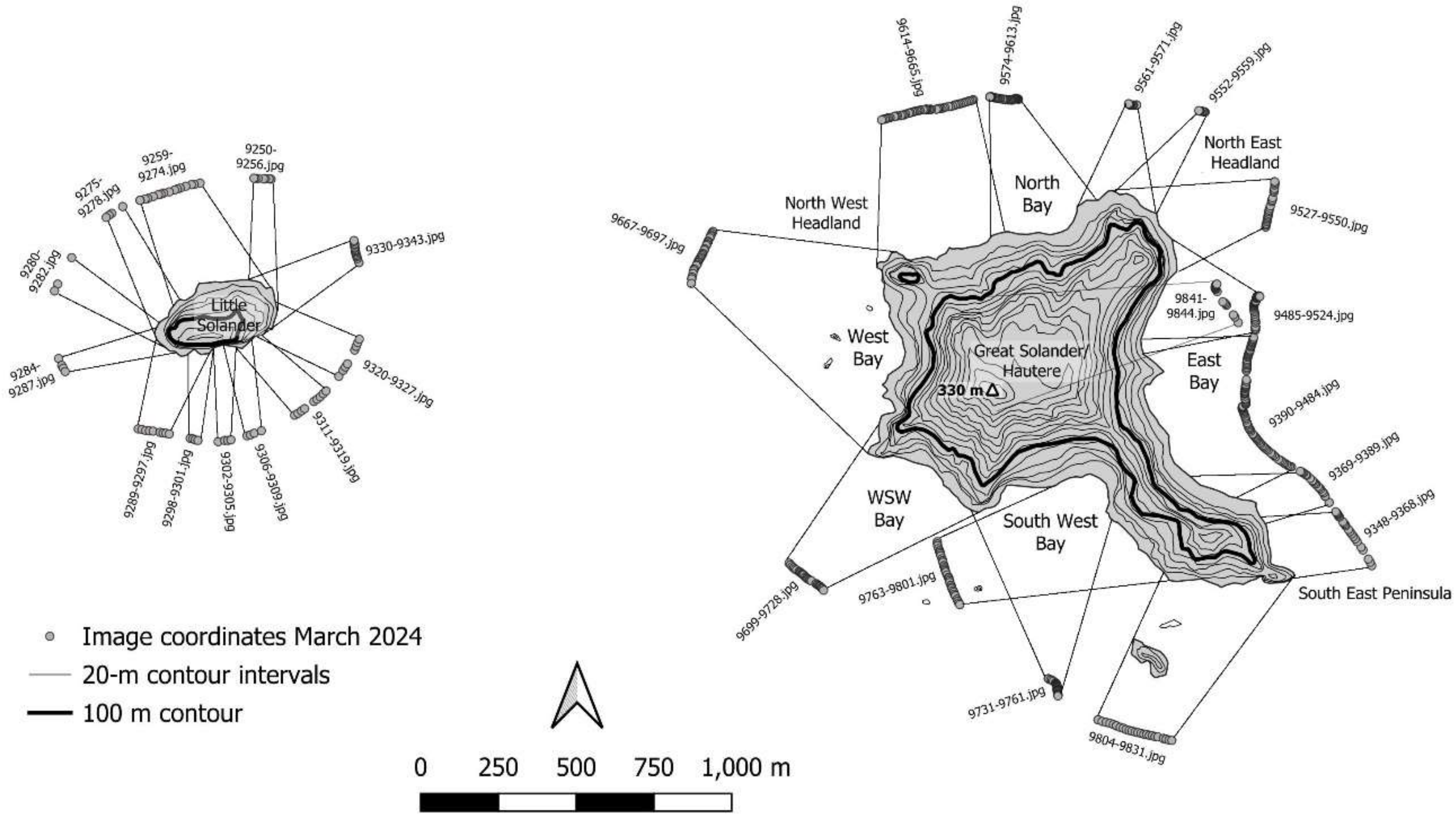

Figure A1. Locations from where the various image sets were taken during the 9 March 2024 aerial photographic survey of the Solander Islands, together with their fields-of-view. The 100-m contour is emphasised.

Table A1. Flight and photographic parameters associated with the different image sets taken and analysed during the aerial photographic survey of Little Solander Island, 9 March 2024, 14:27:12 – 14:31:22 (NZST). All images taken at 1/2000s (ISO 500) with a Nikon D6 camera and a VR 70-200 f/2.8 G lens

Island	Image set	Duration (s)	Distance moved (m)	Mean air Speed (m/s)	Focal length (mm)	Aperture	Mean GPS altitude (m)	Mean distance to 100-m contour (m)
Little Solander	9250-9256	00:11	55.2	5.0	70	F4.0	198	429
Little Solander	9259-9274	00:22	201.1	9.1	95	F4.0	193	414
Little Solander	9275-9278	00:04	63.6	15.9	95	F4.0	193	410
Little Solander	9280-9282	00:02	120.3	60.2	110	F4.0	199	389
Little Solander	9284-9287	00:04	47.0	11.8	120	F4.0	205	357
Little Solander	9289-9297	00:10	101.4	10.1	120	F3.2	203	295
Little Solander	9298-9301	00:04	26.1	6.5	120	F3.2	201	305
Little Solander	9302-9305	00:04	41.6	10.4	120	F3.2	200	313
Little Solander	9306-9309	00:03	48.8	16.3	120	F3.2	198	305
Little Solander	9311-9319	00:11	128.0	11.6	120	F3.2	200	321
Little Solander	9320-9327	00:11	136.6	12.4	120	F3.2	194	369
Little Solander	9330-9343	00:15	73.5	4.9	120	F3.2	199	426
Overall	Total/*Mean*	04:10	2577.3	*9.5*	70-120		*198*	*373*
	Standard Deviation			*5.2*			*5*	*52*

Table A2. Flight and photographic parameters associated with the different image sets taken and analyses during the aerial photographic survey of Great Solander Island/Hautere, 9 March 2024, 14:34:48 – 14:57:15 (NZST). Camera, lens, shutter speed and ISO were the same as for Little Solander Island (Table A1)

Island	Image set	Duration (s)	Distance moved (m)	Mean air Speed (m/s)	Focal length (mm)	Aperture	Mean GPS altitude (m)	Mean distance to 100-m contour (m)	Mean distance to 240-m contour (m)
Great Solander	9348-9368	00:28	208.9	7.5	135	F2.8	199	320	956
Great Solander	9369-9389	00:25	138.6	5.5	135	F2.8	197	274	794
Great Solander	9390-9484	01:50	494.7	4.5	135	F2.8	203	337	553
Great Solander	9485-9524	00:43	122.9	2.9	135	F2.8	191	323	566
Great Solander	9527-9550	00:25	149.6	6.0	135	F3.5	219	388	726
Great Solander	9552-9559	00:08	21.2	2.7	135	F4.5	196	411	782
Great Solander	9561-9571	00:11	28.0	2.5	135	F4.5	199	378	705
Great Solander	9574-9613	00:46	97.8	2.1	135	F5.6	306	525	666
Great Solander	9614-9665	00:55	305.0	5.5	135	F5.6	318	529	692
Great Solander	9667-9697	00:33	182.8	5.5	135	F4.5	327	644	856
Great Solander	9699-9728	00:32	142.5	4.5	135	F3.5	327	558	725
Great Solander	9731-9761	00:32	72.9	2.3	135	F3.5	365	603	859
Great Solander	9763-9801	00:40	216.3	5.4	185	F3.5	209	312	498
Great Solander	9804-9831	00:24	247.0	10.3	185	F3.5	212	588	1045
Great Solander	9838-9844	00:10	84.2	8.4	155	F4.0, F13.0	401	244	479
Great Solander	9846-9855	00:09	28.0	3.1	155	F4.0	390	184	455
Overall	Total/*Mean*	22:27	8776.2	*4.4*	135-185		*256*	*431*	*709.8*
	Standard deviation			*3.5*			*66*	*130*	*165.8*