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Antipodean wandering albatrosses and white-chinned petrels 2024

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Final report to Department of Conservation, Conservation Services Programme

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Summary

The Antipodean wandering albatross *Diomedea antipodensis antipodensis* has been in decline since a population crash in 2005–07. Declining numbers appear to have been largely driven by high female mortality, but low chick production—with fewer birds breeding and reduced breeding success—has compounded the problem. To tease out the causes of falling numbers of Antipodean wandering albatrosses and identify the effectiveness of potential solutions, research includes an annual visit to the breeding grounds on Antipodes Island. Alongside this core annual study, we present the first stage of a two-year whole-island survey aiming to estimate the size of the Antipodean albatross population nesting island-wide. Alongside the albatross research, we are developing a mark-recapture study for white-chinned petrels. This report describes the results of the annual field programme in the 2023/24 breeding season for both Antipodean albatrosses and white-chinned petrels.

Antipodean wandering albatross. The core annual study involves mark-recapture in an intensively monitored study area and census of the annual count areas. This season's field programme allowed updates to the trend in nesting population size, survival, productivity and recruitment. There are some signs that the rate of decline is slowing. The number of Antipodean wandering albatrosses breeding has been roughly stable for the past four seasons, and female survival shows some suggestion of improving since 2014 (4-year rolling averages), although it is still highly variable year to year (from 97% in 2014 to 84% in 2019). Breeding success in 2023 at 71% approached the average pre-crash nesting success of 74%, although the mean 2006–2023 rate remains comparatively low at 62%. However, the actual number of chicks produced remains small, even in good breeding-success years, since numbers nesting remain low. Recruitment is starting to draw from the (much smaller) cohorts produced since the crash, so population numbers will soon no longer be supplemented by higher recruitment rates seen over the past decade.

The last whole-island count of nesting Antipodean albatross took place 1994–96. The first year of a two-year effort to update the whole-island estimate involved a combination of ground counts (27% of the 1,546-ha Antipodean albatross nesting distribution) and drone aerial photography for counts in orthomosaics (1,023 ha or 66% overflown). Drone counts were corrected for pretend-nesters (apparently-nesting birds with no egg) using data from concurrent nest-contents transects, and both count types were corrected for nest failures occurring before the date of count. Part of the Antipodean albatross breeding range could not be covered this first season (356 ha or 23% not counted). Numbers nesting in these not-counted areas were estimated by categorising nesting-habitat quality across the island, then extrapolating nest densities by habitat-quality class to uncounted areas. The number nesting island-wide in 2024 estimated from drone and ground counts (3,383 breeding pairs with 95% CI 3,182–3,585) is similar to the figure estimated from the annual ground count since 1997 of 15% of the island (3,307 breeding pairs), indicating that the 15% of the island chosen for annual counts remains representative of the whole island.

Trends in nest numbers and demographic parameters from the core annual study indicate that the population has been approximately stable for the last four years. However, there is so far no evidence of any sustained improvement in Antipodean wandering albatross demography, as required for the population to recover, with tentative improvements recorded here merely slowing the decline. Recommendations include ongoing mark-recapture monitoring of demographic and population-size trends; the second year of effort toward the island-wide population size estimate, to complete whole-island coverage; and research into causes of declines. More-targeted ongoing engagement is also needed to achieve better bycatch mitigation in line with ACAP best practice.

White-chinned petrel. A mark-recapture study to estimate vital rates, survival in particular, was established in late 2022. This first season of band resighting highlighted the importance of quality monitoring data:

banded white-chinned petrels were resighted at an unexpectedly low rate of only 0.243. Indeed, fewer study burrows were reoccupied than expected, and in new burrows, occupancy was lower than last year. Without quality monitoring data, we cannot yet tell whether these breeding rates are now normal for Antipodes white-chinned petrels, having shifted over the decade since the last study, or whether it has simply been a bad year. Substantial effort to grow the mark-recapture study this year mean there are now 301 banded white-chinned petrels in 156 marked burrows in the two study areas. For accurate, precise survival estimates this marked population needs building further, along with recaptures at existing marked burrows for a minimum of three years.

Keywords: Antipodes, mark-recapture, survival, productivity, population trend, drone, aerial photo-counts, Antipodean wandering albatross, white-chinned petrel

Contents

Introduction

Assessments of the risk of commercial fisheries to seabird populations can be affected profoundly by uncertainty in population size and uncertainty in demographic rate estimates, particularly adult survival (e.g. Richard et al., 2020; Walker et al., 2015). To reduce uncertainty or bias in estimates of risk from fishing, robust population status information is needed (key aspects like survival, productivity, recruitment, trends). Long-lived, slow-breeding seabirds that are vulnerable to accidental capture in commercial fisheries are the focus here: Antipodean wandering albatross *Diomedea antipodensis antipodensis* and white-chinned petrels *Procellaria aequinoctialis*.

Antipodean wandering albatross

The Antipodean wandering albatross is a biennially breeding seabird virtually endemic to the Antipodes Islands, New Zealand. A few pairs also breed on Campbell and Chatham Islands, but those make up less than 1% of the population. A sister subspecies, *D. antipodensis gibsoni*, breeds in the Auckland Islands and has morphological, distributional, and breeding timing differences with *D. a. antipodensis*. The genomics of both are currently being reviewed as part of a PhD project at Victoria University (I. Foote pers. comm.).

The New Zealand threat classification lists Antipodean wandering albatrosses as Threatened; Nationally Critical (Robertson et al., 2021), with the five qualifiers Conservation Dependent, Climate Impact, Conservation Research Needed, Island Endemic and One Location.

Since the eradication of house mice from the Antipodes Islands in 2016 (Horn et al., 2022) the island group is free of introduced mammals, and HPAI (Highly Pathogenic Avian Influenza) has not yet reached New Zealand, so the current major conservation threats to Antipodean wandering albatrosses are in the marine environment. The species forages mainly in the Pacific Ocean to the east of New Zealand, and to a lesser extent in the Tasman Sea (Bose and Debski, 2020; Walker and Elliott, 2022, 2006). In New Zealand domestic fisheries, there are some 38 Antipodean wandering albatross deaths each year (estimated annual deaths), mostly in surface or pelagic longline gear (Edwards et al., 2023). In international waters, Antipodean wandering albatrosses forage in the southern Pacific Ocean (Bose and Debski, 2020; Parker et al., 2023; Walker and Elliott, 2006) in areas where there is a large amount of surface longline fishing effort with no or very little observer coverage (Peatman et al., 2019). Antipodean wandering albatrosses are caught in those fisheries, but the lack of observer coverage and fisher-reported captures makes the overall number of annual captures of Antipodean wandering albatrosses impossible to quantify accurately.

The size of the breeding population has been followed closely since the mid-90s via both intensive monitoring for mark-recapture modelling, and via census in annual count areas (e.g. Elliott and Walker, 2018; Walker and Elliott, 2022, 2005). However, the last whole-island count of Antipodean albatrosses was 30 years ago, conducted 1994–96 (Clark et al., 1995; Walker and Elliott, 2005). We revisit the effort to obtain a new whole-island estimate, with the overall aim to ensure that trends detected via high-intensity monitoring remain representative. This is important because the Antipodean wandering albatross population has been declining since a population crash 2006–07, and is expected to continue doing so unless vital rates recover (Edwards et al., 2017; Richard et al., 2024; Walker and Elliott, 2022).

White-chinned petrel

White-chinned petrels breed on eight subantarctic islands around the Southern Ocean. Although there are an estimated 1.2 million pairs globally (BirdLife International 2023), they are listed as Vulnerable by the IUCN due to documented declines on land and at sea, and very high rates of bycatch in commercial fisheries (Barbraud *et al.* 2008; Perón *et al.* 2010; Anderson *et al.* 2011; Rollinson *et al.* 2017). Domestically, they are listed as Not Threatened (Robertson et al., 2021). The white-chinned petrel population of Antipodes is estimated at 26,400 breeding pairs (Rexer-Huber et al., 2023). A large study on Antipodes Island in 2007–11 allowed key vital rates for New Zealand's white-chinned petrels to be estimated, particularly adult survival (Thompson, 2019), but these estimates are now more than a decade old. Given continued high mortality in fisheries it is timely to re-evaluate key vital rates at Antipodes to gauge whether there have been important changes. A white-chinned petrel mark-recapture study was re-established on Antipodes Island in December 2022 (Rexer-Huber et al., 2023), specifically designed for adult survival modelling and detecting population change. Tracking devices were deployed in 2022 to see if there have been changes in the at-sea range of Antipodes white-chinned petrels since 2009–10 when the population was last tracked (Sommer et al., 2010); most remain to be recovered still.

Aims and objectives

This work aimed to understand the conservation status and estimate key demographic parameters of Antipodean albatross and white-chinned petrels.

The primary objective of this study was to update the key demographic parameters of the Antipodean wandering albatross (survival, productivity, recruitment and population trend), and to estimate the total population size of the Antipodean albatross on Antipodes Island. A secondary objective was collecting samples towards describing the diet of Antipodean wandering albatross and assessing signatures of nutritional stress. The objective of white-chinned petrel work was to update key demographic parameters (adult survival).

Additional work included collection of morphometric data from known-sex Antipodean albatrosses for taxonomic assessment, and collection of samples from a range of seabird species to screen for high-pathogenicity avian influenzas (HPAI).

Methods

Timing and logistics

Albatross and petrel research on Antipodes Island took place during 11.5 weeks over the period December 2023–March 2024, with the initial team (Edin Whitehead and Kalinka Rexer-Huber) joined by Erin Patterson and Jemma Welch at the end of January. The first 7 weeks (19 December–30 January) focused on the core annual study for Antipodean albatross (including effort on HPAI- and diet sampling and morphometrics), and on final trials to prepare for whole-island count work. During this first phase we also built on the white-chinned petrel study, resighting and banding for mark-recapture. The following 4.5 weeks (31 January–1 March) focused exclusively on whole-island Antipodean albatross nest counts.

The SV *Evohe* brought EW and KRH from Bluff to the Antipodes Island 15–18 December 2023, and EP and JW were landed on Antipodes on 30 January. The researchers were picked up from Antipodes on 2 March and returned by *Evohe* to Dunedin 4 March 2024.

Antipodean albatross

Mark-recapture study

In summer 1994 and every year thereafter except 2006, a 29-ha study area on Antipodes Island (Fig. 1) has been visited to count nests, check nest contents, record the band numbers of previously banded birds, band nesting albatrosses, and band chicks just before fledging.

All nests found within the study area are marked and monitored, so that a year later the nesting outcome—failed or fledged—can be determined to estimate productivity. All Antipodean wandering albatrosses found nesting within the study area are double-banded with individually numbered metal and large coloured plastic (darvic) bands, one on each leg. Since 1995 most chicks in 60% of cohorts have also been banded. Ideally, all chicks in the study area are banded, but the proportion of chicks that are banded each year depends on the timing of the field trips, which in turn is dependent on the availability of transport. In 20 of the years since 1994 researchers arrived just before, at, or soon after the date at which the first chicks fledge (26 December) when more than 90% of the chicks are still present and can be banded. In nine of the years since 1994 late trips meant up to 45% of the chicks had already fledged without being banded, and no chicks were banded in 2006 (no trip) or 2020 (very late trip). Arrival on Antipodes for the 2024 season was 18 December 2023 so all chicks produced in 2023 could be banded.

Survival of birds in the study area is estimated using R 4.2.3 (R Core Team, 2023) and the package *RMark* v3.0.0 (Laake, 2013). For modelling, adult birds are categorised by sex and by state: non-breeders, successful breeders, failed breeders and sabbatical birds taking a year off after a successful breeding attempt. Birds in each of these states have different probabilities of being seen on the island, and potentially different survival rates, so the models test whether it is important to estimate survival rates separately for breeding and non-breeding birds as well as estimating resighting probabilities separately for each state. Specifically, we created models where survival and resighting probability varied by time, sex and breeding-status state, and tested whether:

- survivorship differed for breeders and non-breeders as well as between years and sexes;
- survivorship differed between years and sexes, but not by breeding status;
- survivorship was constant between years, by sex and by breeding status.

Annual survival and resighting probabilities were then estimated using the best-fitting model.

The number of birds in the study area in each breeding-status state (non-breeders, successful breeders, failed breeders and sabbatical birds) is estimated by multiplying the actual counts of birds in each state by their respective estimated resighting probabilities and their estimated uncertainties from the best-supported model in mark-recapture analysis. Sabbatical birds are the only state where this calculation cannot use actual in-colony counts, since the birds are not present on the island. Instead, the number of sabbatical birds is taken as the number of successful birds in the previous year multiplied by the estimated survivorship and uncertainties of successful birds. The estimated total population of birds that have bred in the study area is the sum of the estimates of all states.

The survival and resighting probability estimates assume no emigration, and even though wandering albatrosses have strong nest site fidelity, Richard et al. (2024) showed there was detectable emigration. In our models birds that emigrate then subsequently return will contribute to low detectability, and birds that permanently emigrate will contribute to low survival and these models will underestimate survival.

Trends in the mark-recapture-based estimates of population size are calculated as annual rates of population growth or decline (λ or lambda), using $\lambda = (\frac{N_{t+y}}{N_t})^{\frac{1}{y}} - 1$ where N represents the number of albatrosses, t the first year in the time series, and y the number of years in the time series.

Annual count areas

Since 1994, all the nests in two representative annual count areas (Fig. 1) additional to the study area have been counted most years. The two count blocks support about 14.9% of all the nests on Antipodes Island (Clark et al., 1995; Walker and Elliott, 2022, 2002).

Counts are carried out between 6 and 12 February, just after the completion of laying, and as close as possible each year to the same time at each place. A strip-search method is used in which observers walk back and forth across the area to be counted, each within a strip about 25 m wide marked in a map on a handheld GPS, and count all the nests with eggs in their strip. VHF contact is maintained between searchers to ensure no double-ups or gaps. Every bird on a nest is checked for the presence of an egg, and each bird found with an egg is marked by GPS. All non-breeding birds on the ground are also counted, and they and most breeding birds on eggs are checked for bands. Once the whole block has been counted, the accuracy of the census is checked by walking straight transects (validation lines) at right angles to the strips, checking that all nests within 10–15 m of the transect have a GPS point thus have already been counted.

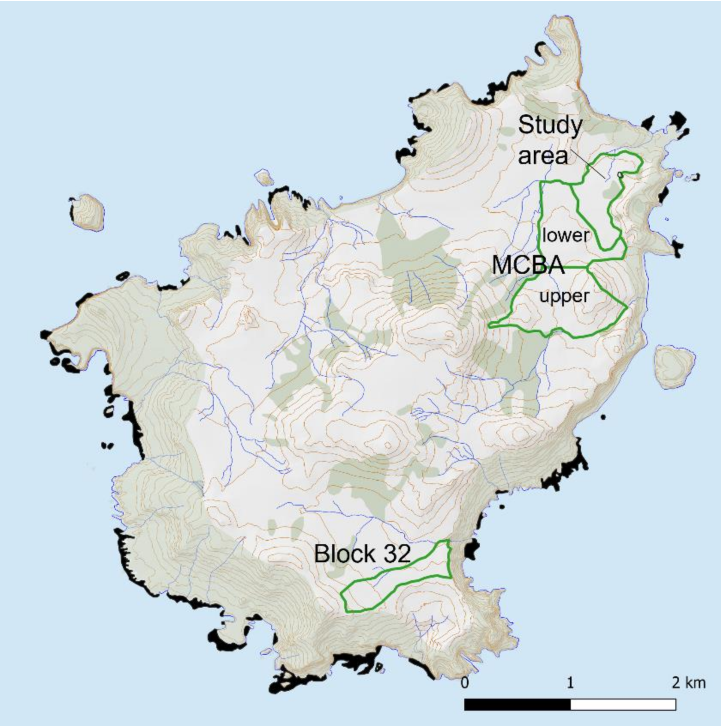

Figure 1. The core annual study for Antipodean wandering albatross takes place in the study area on Antipodes Island (top right) and in the two annual count areas. The area in which albatrosses do not nest is shaded.

By extrapolating the sample of nests counted in annual count areas, we can estimate the total number of pairs of wandering albatross nesting on Antipodes Island. This annual calculation uses the whole-island population counts of 1994, 1995 and 1996 (Clark et al., 1995; Walker and Elliott, 2005) and subsequent annual counts of parts of Antipodes Island (the study area and all or some parts of the two representative blocks described above) (Table 2). The proportion of the total population in 1994–96 that was nesting in those parts of the island counted in subsequent years is used to estimate the total number of nests on the island each year using the following equation:

$$\widehat{total}_i = \frac{pairs_i}{proportion_i}$$

Where:

$\widehat{total}_i$ is the estimated total number of pairs nesting in year *i*.

$proportion_i$ is the proportion of pairs counted nesting in 1994–96 that were in those parts of the island that were counted in year *i* (see column '% of population counted' in Table 2).

$pairs_i$ is the number of pairs counted nesting in year *i*.

This estimate assumes that the relative abundance of nests in the counted blocks is constant from year to year, which is supported by the repeated counts of the study area and census blocks on Antipodes Island (Elliott and Walker, 2018), and can be confirmed by updating counts across the whole island.

Whole-island breeding pair estimate: year 1

To estimate the number of nesting albatrosses across the whole island, we combined counts on the ground with counts in aerial photographs. Ground counts were conducted in the same blocks as for the last whole-island count but more accurately, ensuring completeness of coverage via GPS (strip-search method described above). Drones were used to cover those parts of the nesting distribution where ground counts are unlikely to be accurate; that is, areas with low nesting numbers and dense vegetation (scrub/fern) that make progress on foot very slow.

Ground counts

In 1994 when the first whole island census was undertaken, all the albatross habitat on Antipodes Island (1,546 ha) was divided into 31 blocks. Thirteen of these 31 blocks (i.e. 477 ha or 31% of the albatross grounds) which had been found to be relatively easy to count accurately on foot in 1994 were selected for ground-based nest counting in 2024. The 13 blocks were demarcated in qGIS (https://qgis.org/en/site) with 25 m swathes drawn across each block, following contours as much as possible, and adjusted using satellite imagery to avoid runs of dense *Polystichum* where albatross nests are rarely found. Resulting swathes were preloaded onto GPS. Counters searched within their swathes, recording all albatrosses present, in the manner described earlier for the annual ground counts

The number of nests counted in each block were corrected by estimating the number of eggs yet to be laid and the number of nests likely to have already failed by the count date, by interpolating the proportion eggs laid and nests failed in the repeatedly monitored study area on the same day.

Drone photography

Building on the thorough testing and workflow development in Walker et al. (2023) and Antipodes-specific trials October–January, the whole albatross nesting distribution was divided in qGIS into 143 blocks (Fig. 2). Each drone block is about 11 ha, or one battery-worth of flying time in moderate wind conditions for DJI Mavic 2 Pro.

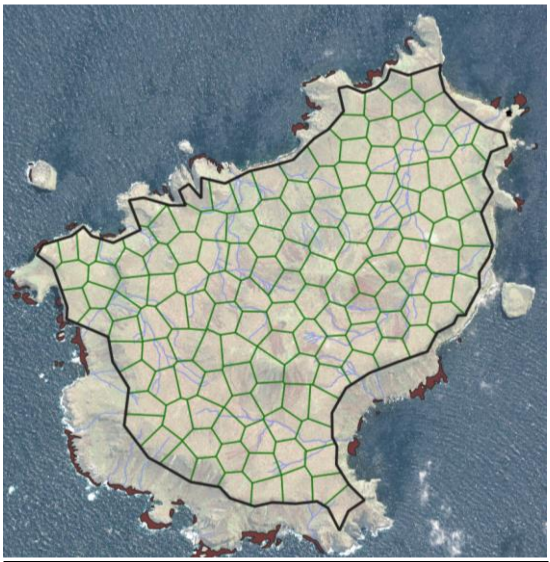

Figure 2. Drone blocks (green polygons) for coverage of Antipodean wandering albatross nesting distribution (bold line)

Drone flight was programmed individually for each block in the flight planning software UgCS (https://www.ugcs.com) to obtain overlapping nadir photographs of the entire area at an appropriate resolution (1.4 cm/px obtained via flight no faster than 7 m/s, taking a photo every 17.88 m in order to get 65% front and side overlaps; typically ~50 m flight height).

To fly a block, the pilot and ground-truthing team rushed to a take-off point when a weather window opened. Photography in areas not ground-counted was prioritised where possible, to maximise the overall area of nesting habitat covered, but substantial parts of the ground-counted areas were also overflown for direct comparison. In practise, destinations for drone flight were determined by wind and fog; areas somewhat sheltered from the day's wind direction, and areas below the low-cloud layer. Some practicalities of drone flight on Antipodes are discussed in Appendix A.

Best-practise drone use around wildlife requires careful assessment of the risk of adverse effects on animals (Borrelle and Fletcher, 2017; Hughes et al., 2018; Mustafa et al., 2018; Rexer-Huber and Parker, 2020). No concerning animal responses were seen during trials in 2022 and 2023 when using these small drones in areas where Antipodean albatross nest (authors' unpubl. data). Nonetheless, we monitored carefully for animal responses to the drone during all flights, particularly during takeoff and landing when drones come nearer to animals on the ground.

A major assumption involved in aerial-photo nest counts is that all apparently incubating birds are breeding (nest contents bias). Because a highly variable proportion of birds that look like they are incubating do not in fact have an egg (range 16–29% last year, Parker et al., 2023), we focussed on collecting nest-contents data concurrent with drone photography. During drone flights, the ground-truther(s) collected concurrent nest-contents data; either in transects across the area being droned, or as part of ground-count swathes (when drone overflight overlapped temporally and spatially). Nest contents of all apparently-nesting albatross (sitting on nest mounds in incubation/brooding posture, ANA) were recorded. The nest correction factor for a given area is calculated as the proportion of ANA that are sitting on egg there at the time it is overflown calculated (has-egg rate); that is, as

$$has\ egg\ rate = \frac{n\ on\ egg}{total\ \mathrm{ANA_{ground}}}$$

where total $\mathrm{ANA_{ground}}$ is $total\ \mathrm{ANA_{ground}} = n\ on\ egg + n\ on\ empty$

The has-egg rate variance (lower and upper 95% confidence intervals) are calculated using a t-distribution instead of a normal distribution to reflect small sample sizes.

Drone-photo counts

To check coverage and image quality, orthomosaics were made on-island (Drone Deploy; https://www.dronedeploy.com). Between 104 and 448 photos were required to cover each block (mean 245 photos), each taking on average an hour to upload for cloud-processing. Resulting orthomosaics were 1.3–1.9 gb in size. Eighty-eight blocks had full coverage, with composite images of suitable quality (not clag-affected).

Orthomosaics were each counted in qGIS, overlaying the drone block boundaries and a 15-m grid for count accuracy. Image quality was good enough to allow an experienced observer to differentiate apparently nesting albatrosses (ANA, or birds that look like they are incubating) to be distinguished from albatrosses *not* on nests (sitting or standing). Finally, drone-photo nest counts were clipped to exclude areas ground-counted, to ensure no nests were counted twice. Counting the albatrosses in orthomosaics took 10 days.

To estimate the number of breeding pairs in each block in 2024, the number of albatrosses counted on the orthomosaics were adjusted to account for pretend-breeders and earlier nest failures. That is, the drone-photo count of apparently-nesting albatrosses ($\mathrm{ANA_{drone}}$) in each block was corrected with the "has-egg" rate at the time photos were taken to provide the number of active nests at the time the block was droned. The number of earlier nest failures (active nests multiplied by the nest-failure rate in the study area up to the date the block was photographed) was then added to the number of active nests:

$$active\ nests = \mathrm{ANA}_{\mathrm{drone}} \times has\ egg\ rate$$
$$breeding\ pairs\ 2024 = active\ nests + (active\ nests \times failure\ rate)$$

Finally, the total number of pairs breeding across all drone-count areas in 2024 is estimated as the sum of 2024 pairs from all drone blocks.

Nesting-habitat quality extrapolation

The Antipodean albatross breeding range could not be covered in entirety this first season: 356 ha (23% of the 1,546-ha breeding distribution) was not overflown or ground-counted. To estimate the number of pairs breeding in not-counted areas, we categorised nesting-habitat quality across the island in every drone block, then extrapolated to uncounted blocks—or parts of blocks—nest densities by habitat-quality class.

Nesting habitat was classed as low, medium or high in a subjective assessment based on impression of relative nesting albatross abundance when transiting through areas. Using the number of breeding pairs in each counted block in 2024 as above (failure-rate and nest-contents corrected) and the GIS-derived area of each block, we calculated average nest density for each habitat-quality class. Average densities were applied to the area (or part-area) of all blocks lacking count data (not counted on the ground or overflown by drone) then summed to reach a not-counted areas nest estimate.

Antipodean wandering albatross samples and measures

Diet: feathers. For a new approach to assess changes in diet and stress during the non-breeding period that is in development, using corticosterone and stable isotope analysis (Brendon Dunphy, University of Auckland), feather samples were taken from 20 fledglings, 12 adult females and 14 adult males. Birds were mainly sampled in areas where they are not regularly visited to minimise research impacts on study-area birds.

Diet: feces. For an ongoing effort to understand the diet of Antipodean wandering albatrosses using genetic identification of prey species detected in their faeces (Karen Middlemiss, DOC), fresh fecal material was collected opportunistically during albatross work. Diet is expected to vary with age and breeding status, so most samples were collected in the study area from banded birds.

All diet samples and data from them will be managed and stored with the kaitiakitanga and rangatiratanga of Kāi Tahu in the forefront, as set out by a sample and data management agreement between the Department of Conservation and Te Rūnanga o Ngāi Tahu.

Taxonomy: standard measures. Contributing toward re-assessment of the Gibson's and Antipodean wandering albatross taxonomy, we took standard wandering albatross measures from known-sex Antipodean albatrosses. The same protocol was used as for Gibson's albatrosses to enable direct comparison. 19 females and 20 males were measured. This work is part of a paper being progressed by Kath Walker.

HPAI screening. Samples toward a HPAI-screening study were collected from 4 skuas, 12 giant petrels, 9 white-chinned petrels and 11 Antipodean albatrosses. Each individual had both cloacal and choanal swabs taken. In one case a large tick was also sampled from a giant petrel, and another also had fresh feces collected. The team working on penguins ensured that the penguin species were also included in the screening effort. HPAI screening samples were kept chilled until they could be taken off Antipodes in January by Thomas Mattern, who delivered them directly to Gemma Geoghegan at Otago University.

White-chinned petrels

The mark-recapture study of white-chinned petrels that was started in 2022 to follow trends in demographic parameters (especially survival) was developed further, marking more study burrows in the two established study areas (Fig. 3).

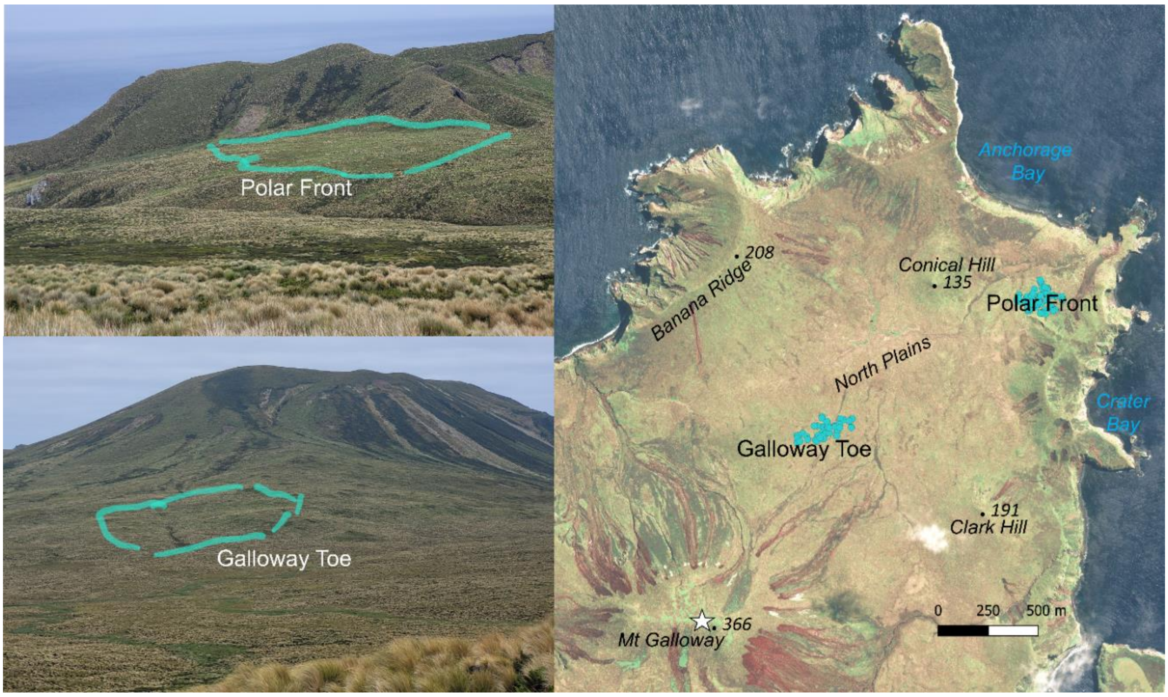

Figure 3. White-chinned petrel study areas on Antipodes Island (in blue). Top left: Polar Front area viewed from Conical Hill. Bottom left: Galloway Toe area from Banana Ridge.

New study burrows within the existing study colony areas (Galloway Toe and Polar Front, Fig. 3) were identified by first using a burrowscope to find whether burrows were occupied, and for assessment of their suitability as long-term study burrows. Some burrows were excluded if the nest chamber was too far beneath the surface to reach by access plug, or too shallow to withstand regular checks over time without being damaged by the investigator. Burrow marking methods from last season were left unchanged since there were no issues with finding already-marked burrow tags or hatches again after a year's absence. That is, burrows were all marked with blue cattle tags wired to the substrate near the burrow entrance, with small access plugs to reach the nest chamber (cut by hand saw) in almost all marked burrows.

The existing study burrows were checked for returned banded birds, some of which were fitted with tracking devices last year. In all cases—existing and new marked burrows—burrows were revisited every 5–7 days (based on the observed changeover routine at this time of year) for a quick inspection by burrowscope to check for a newly-returned mate lacking twink from handling, until the mate was found and also banded.

Results

Antipodean albatross

Mark-recapture modelling

A range of mark-recapture models were compared using AICc (Table 1). Antipodean albatrosses in the colony are seen in different states (non-breeders, successful breeders, failed breeders, and sabbatical birds taking a year off after a successful breeding attempt). The best supported multi-state model showed that survival rate differs over time and by sex, with resighting probability differing over time between states and sexes, and the probability of transitioning from one state differs between states, sexes and over time (model 1 in Table 1). Models not distinguishing survival of females and males had poorer fit to the data (model 2, Table 1). There was less support again for distinguishing survival for breeding and non-breeding birds (model 2, Table 1).

Table 1: Comparison of the top models of Antipodean albatross survival (S). All models have detection probabilities (p) and transitions (Psi) that vary with time, sex and state { p(~-1 + time:sex:stratum)Psi(~-1 + time:sex:stratum) }, where strata are the following states: breeders, successful breeders, failed breeders, and sabbatical birds.

Model	npar	AICc	ΔAICc
1. Survival varies with time and sex { S(~-1 + time:sex) }	466	39859.98	0.000
2. Survival varies with time { S(~-1 + time) }	437	39880.97	20.99
3. Survival varies with time, sex and for breeding and non-breeding birds { S(~-1+time:sex:breed) }	524	39889.83	29.85

Survival

Adult survival varied around a mean of about 95.9% up until 2004 and during this period male and female breeder and non-breeder survival was not significantly different. Since 2004 annual survival of both males and females has declined, with female survival significantly lower and more variable than that of males (Fig. 4). Since 2014 female annual survival has been particularly variable with both the lowest and second highest female survival occurring in that period. When that volatility is smoothed by calculation of 4-year rolling averages, average female survival appears to have increased since 2010 to approach male survival rates. However, although average female survival has reached 92.1% (most recent 4-year average), this remains lower than the pre-crash average of 95.9% (Fig. 4).

Not only have male and female survival rates differed substantially since 2005 (best-supported survival-by-sex model), but survival of breeding and non-breeding albatrosses has differed, along with confidence in those estimates (Fig. 5; survival-by-sex-by-status model). Male breeders have fared worse than non-breeding males since 2005, while breeding and non-breeding female survivorship has see-sawed since 2005 (Fig. 5).

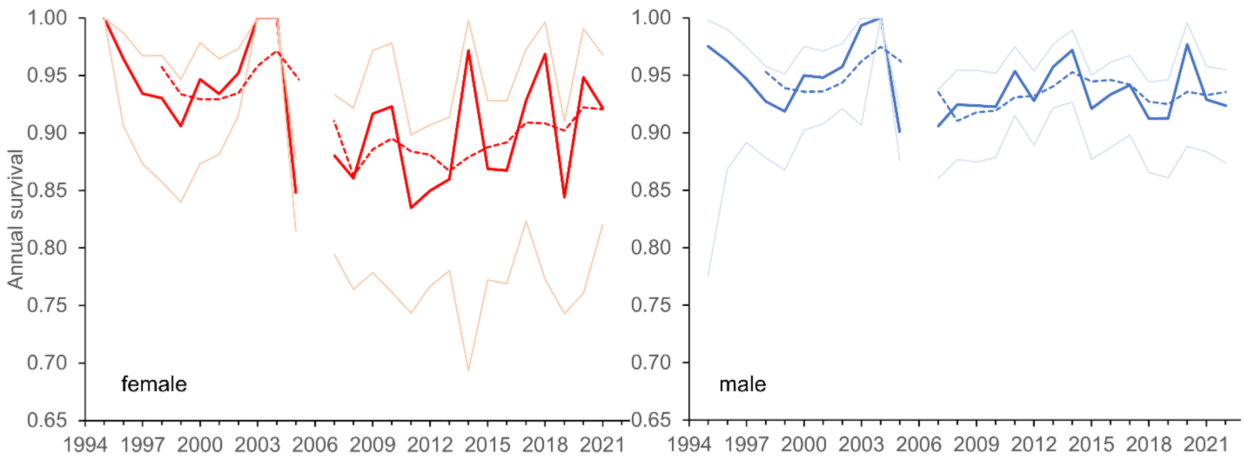

Figure 4. Estimated annual survival of female (red, left) and male (blue, right) Antipodean wandering albatross on Antipodes Island since 1996. Dashed lines represent 4-year rolling means; pale lines show lower and upper 95% lower and upper confidence limits. Estimates from the best-supported survival-by-sex model. Mark-recapture estimates are not reliable for the last two year’s data, so results for 2022 should be taken with caution and for 2023 are not presented.

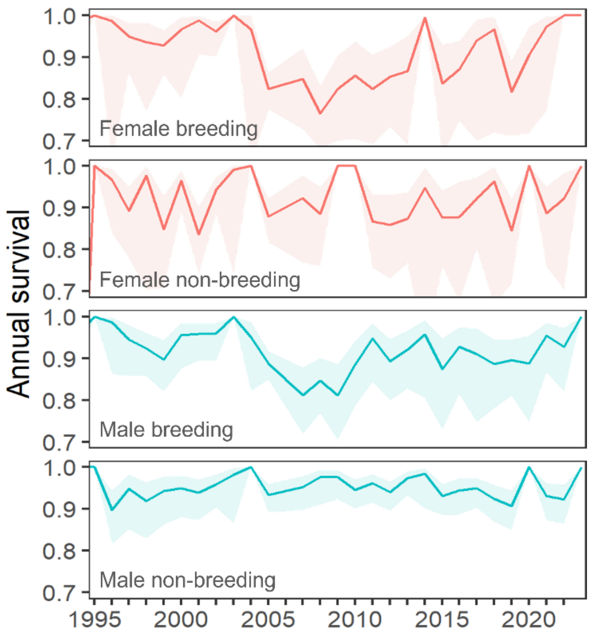

Figure 5. Estimated annual survival of breeding and non-breeding male and female Antipodean wandering albatross since 1996 with 95% confidence limits (shaded). Confidence intervals were not estimated when survival estimates were 1. Estimates from the survival-by-sex-by-status model. Mark-recapture estimates are unreliable for the last two years' data, so results for 2023 should be taken with caution and for 2024 are not presented.

Population size trend from mark-recapture

The size of the breeding population in the study area estimated by mark-recapture (Fig. 6) was increasing up until 2005 at an average rate of about 4.4% per annum for both sexes (1996–2005). The increase was initially slow, then rapid in 2002–2005. After 2007 the population of breeding pairs declined, initially very rapidly with an average 2008–2012 of -3.2% per annum. In recent years the rate of decline has abated to an average of -1.3% per annum decline for both sexes (2013–2022), and the population of breeding females has been roughly stable for the last three years (Fig. 6).

The sex ratio before 2005 was about 1:1 but for the following decade averaged 1.5 times as many males as females (average 2008–2018). The sex ratio appears to have improved a bit since 2019, sitting around 1.3 times as many males as females for four successive years.

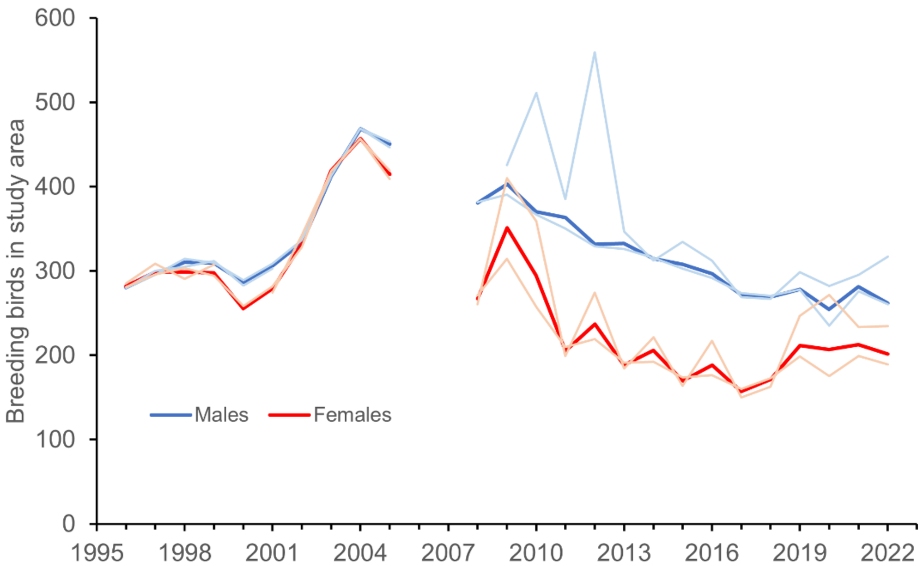

Figure 6. The number of breeding female (red) and male (blue) Antipodean wandering albatross in the study area on Antipodes Island estimated by mark-recapture. Pale lines show lower and upper 95% lower and upper confidence limits. Note: population estimates via by mark-recapture are not reliable for the last two year's data, so results are only up to 2022

Productivity

Nesting success in 2023 was 71%. Nesting success has been higher in the two most recent cohorts than it has been for several years. However, this spike has not improved the average nesting success since the 2006 crash; the current average remains 63%, notably lower than the average pre-crash nesting success of 74% (blue in Fig. 7). The number of chicks produced in the study area continues to be much lower than that before the crash (red in Fig. 7) mostly because of the much smaller size of the breeding population.

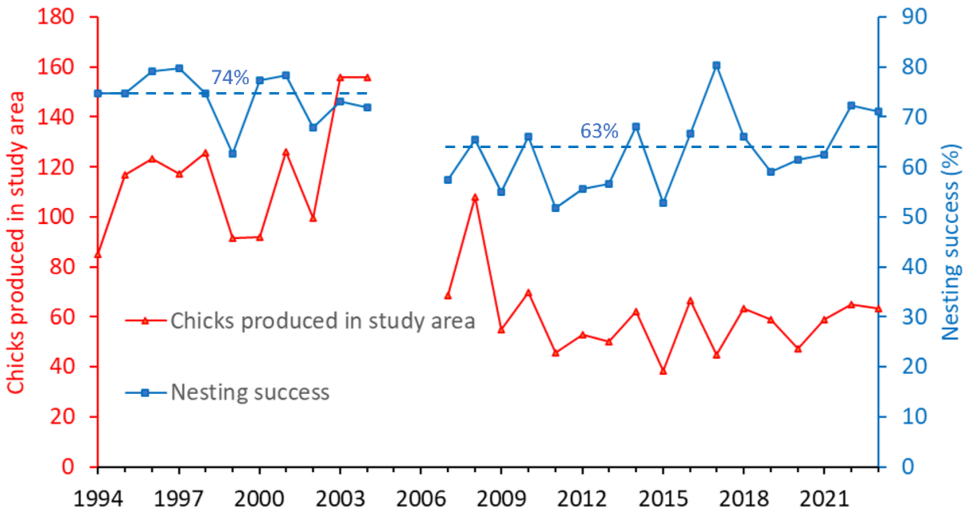

Figure 7. Nesting success and the number of chicks fledged from the study area on Antipodes Island since 1994. The dashed lines indicate average nesting success in two periods, 1994–2004 and 2007–23.

Recruitment

The number of birds breeding in the study area for the first time—that is, recruiting into the breeding population—has remained steady, on average, since 2007 (Fig. 8), despite the declining number of breeding pairs over that period. The average age of known-age recruits (breeding for the first time) in 2024 was 14 years (range 10–22), so many of the new recruits hatched before the population crash in 2006.

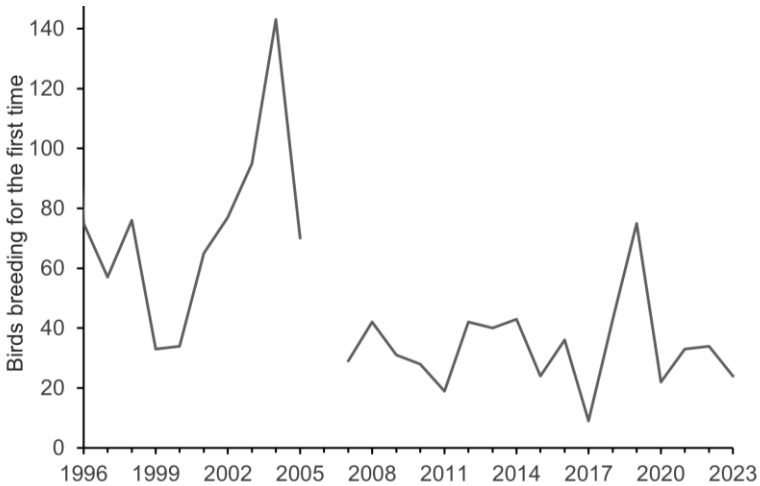

Figure 8. Recruitment of Antipodean wandering albatrosses. Numbers recruiting, or breeding for the first time, in the study area on Antipodes Island.

Population size trend from annual count areas

Nests were again counted in the study area, Block 32 and MCBA (Fig. 1) in 2024. From these counts the total number of breeding pairs on the island were estimated (Table 2). After an increase between 2000 and 2005, the number of nests dropped sharply by about 38% between 2005 and 2007 (Fig. 9). In the following decade this reduction slowed, and since 2017 the numbers of pairs nesting have remained fairly similar from year to year (Fig. 9). There is no sign of recovery.

Table 2: Antipodean wandering albatross nests with eggs in February in three annual count areas on Antipodes Island in 1994–2023. The estimated number nesting on the island in 1998–2024 is based on the proportion nesting in those areas relative to island-wide totals in 1994–97. For 2024, we also show corrected counts (*italicised*), corrected using nest-failure rates from the intensively-monitored study area for direct comparison with large-scale ground and drone estimates

Year	Study area	Block 32	MCBA total	Lower MCBA†	% of population counted	Total counted	Estimated nests on island
1994	114	125	544*		15.0	783	4635
1995	156	185	482*		15.0	823	5757
1996	154	133	418*		15.0	705	5148
1997	150		464*		12.1	614	5074
1998	160		534		12.1	694	5736
1999	142		479		12.1	621	5132
2000	119	130	462		15.0	711	4740
2001	160	141	443		15.0	744	4960
2002	148	178	605		15.0	931	6207
2003	214	187	608		15.0	1009	6727
2004	216	249	755		15.0	1220	8133
2005	211	186	613		15.0	1010	6733
2006							
2007	119	127			5.6	246	4393
2008	165	135			5.6	300	5357
2009	98	120			5.6	218	3893
2010	106	101			5.6	207	3696
2011	88	108			5.6	196	3500
2012	95	104	345	145	15.0	544	3627
2013	88	93	297	127	15.0	478	3187
2014	91	103	341	130	15.0	535	3567
2015	73	86	291	124	15.0	450	3000
2016	100	92	291	97	15.0	483	3220
2017	57	82	230	85	15.0	369	2460
2018	97	97	315	136	15.0	509	3393
2019	99	96	276	107	15.0	471	3140
2020	75				2.8	75	2679
2021	94	89		124	9.6	307	1906
2022	90	74	274	113	15.0	438	2920
2023	90	87	310	112	15.0	487	3247
2024	88	80 (*84*)	296 (*324*)	121	15.0	461 (*496*)	3093 (*3307*)

* estimated (see Walker & Elliott 2002)

† Lower MCBA is a subarea of the overall MCBA count block, shown to enable comparison when only a part-count of MCBA was possible

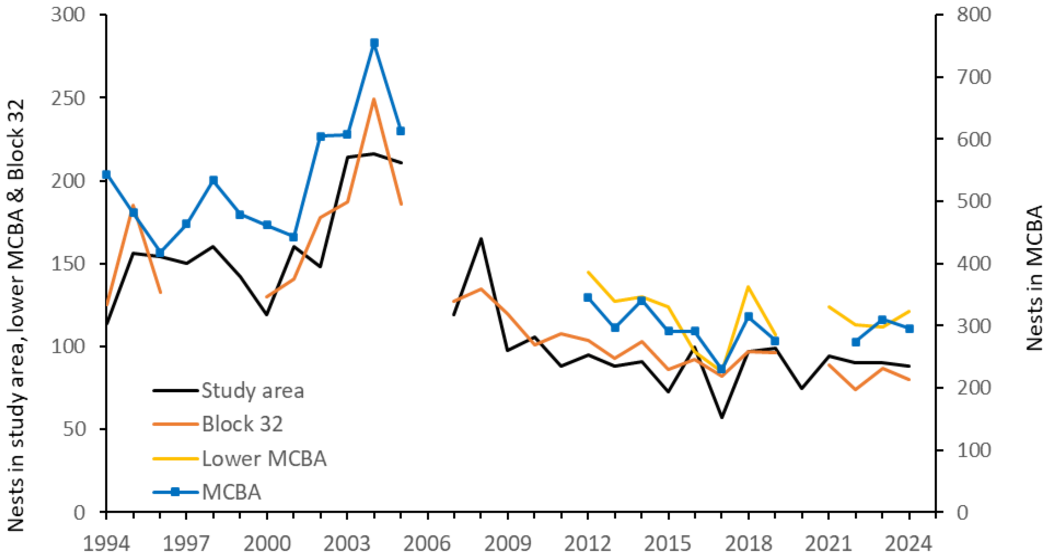

Figure 9. The number of Antipodean wandering albatross nests in three areas on Antipodes Island since 1994. The MCBA subarea 'lower MCBA' is shown to enable comparison in years when only a part-count of MCBA was possible.

Whole-island breeding-pair estimate

Ground-count estimate

Albatross nests were counted exhaustively in 420 ha on foot, which took three people nineteen days from 2–28 February. In these areas 2,344 Antipodean albatrosses on the ground were counted, of which 1,315 were sitting on eggs (Fig. 10, Table 3). Validation lines to check count accuracy showed 2 out of 98 nests on the validation lines had been missed, comprising a 2% undercount of nests. This is in line with the 1.5% undercount in Walker and Elliott (2005), so we have not corrected for this.

Nest numbers counted in February are corrected for breeding failures earlier in the season, using data from regular checks of the intensively monitored study area (Table 3). Allowing for nest failures occurring before each area's count date, there were a total of 1,388 pairs breeding in ground-counted areas in 2024.

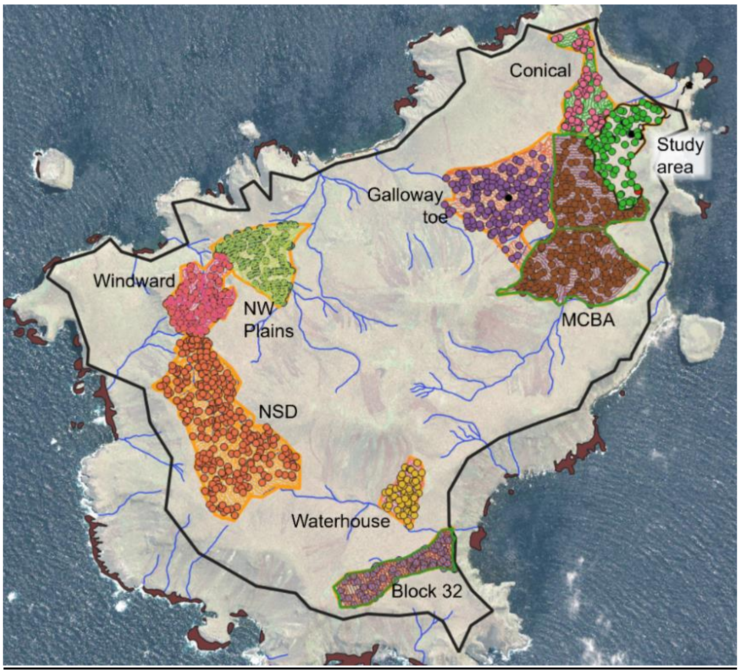

Figure 10. Antipodean wandering albatross ground counts February 2024. Coloured dots – active nests at time of count; Bold black line – extent of albatross nesting distribution.

Table 3: Antipodean wandering albatross breeding pair estimate from ground counts of 420 ha or 27% of the albatross nesting habitat on Antipodes Island

Area	Area (ha)	**N nests**	Total adults counted	Date range	Failure rate to date	2024 nesting pairs
MCBA	92.3	**296**	594	2-5 Feb	0.08-0.12	**324**
Block32	24.6	**80**	205	9-Feb	0.06	**84**
Conical Hill	25.7	**69**	169	7-8 Feb	0.06-0.07	**74**
Galloway Toe	54.4	**169**	324	11-16 Feb	0.05	**177**
Waterhouse	12.3	**59**	86	15-Feb	0.05	**62**
SW Plains	58.1	**114**	184	18-Feb	0.05	**119**
NSD	92.5	**312**	612	21-28 Feb	0.05	**326**
Windward	29.7	**128**	170	27-Feb	0.05	**134**
Study Area	30.2	**88**		throughout		**88**
TOTAL		**1315**	2344			**1388**

Drone photography

During the window of time for the whole-island counts (from 5 February, once egg-laying is complete, to the team's pickup on 2 March), westerly low cloud and clag dominated. Only 3 days were suitable for drone flight for most of the day; in most cases, we had to use windows of only a few hours of suitable flying conditions before the clag descended. In practise this meant a lot of standby, rushing for windows, and sitting watching the clag layer hoping for it to lift. Nonetheless, 96 of the 144 blocks or 1,024 ha were overflown at least once (Fig. 11), covering ~67% of the albatross nesting area.

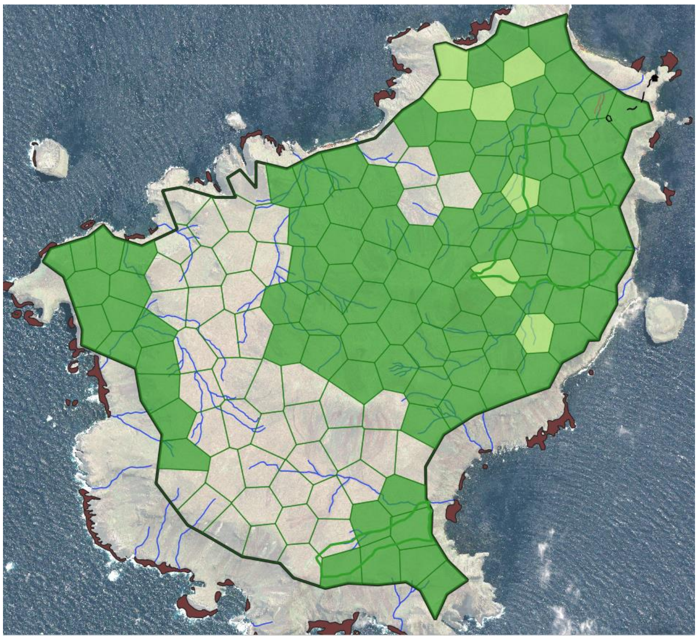

Figure 11. Drone coverage (green shading) of Antipodean wandering albatross nesting distribution (bold line) February 2024. Green-outlined polygons – drone block boundaries; Green fill – blocks with high-quality (complete coverage, no clag or blur issues); Light green fill – blocks to be re-flown (images clag-affected or blurred); No fill – blocks with no aerial imagery yet.

Drones have potential to disturb wildlife, so we monitored carefully for animal responses throughout all drone flights. There were no signs of obvious disturbance to wildlife during overflight. Animal responses were limited to head-tilting to watch the drone during the last stages of descent (birds on nest in 10–15 m radius). The most active response was one occasion where a bird standing 5 m away from drone landing walked away as the drone descended. In flight, there was just one close encounter; the drone flew within meters of an albatross, which veered gently around the drone. The drone was also investigated by skuas in flight on four occasions; flying to within ~10 m to look and then leaving (3 occasions) or following for ~1 min then leaving (once).

Nest-contents data collected during drone overflight showed that on average 69.8% of apparently-nesting albatrosses had eggs (has-egg rate), with the rest being birds with no egg that appeared to be incubating. However, the has-egg rate ranged widely from 49% to 87% across the 21 distinct days and areas checked (median sample size 70 nests), and not in a predictable way (e.g. becoming smaller as the breeding season progresses) (Table 4). The variability and unpredictability of the has-egg rate highlights the importance of nest-contents checks being concurrent with drone overflight of a site to keep estimated nesting numbers as accurate as possible.

Table 4: Nest contents of apparently-nesting Antipodean wandering albatross in 2024

						Has-egg rate (bird on egg / ANA)	
Date	Descript	Type	Bird on egg	Bird on empty nest	ANA (apparently nesting albatross)	Has-egg rate	95% CI has-egg rate
2-Feb	MCBA (Clark Hill, mid MCBA)	swathes	114	40	154	0.7403	0.675–0.806
4-Feb	MCBA (Pipit Peak, top MCBA)	swathes	35	16	51	0.6863	0.4–0.972
5-Feb	MCBA lower	swathes	121	72	193	0.6269	0.524–0.73
7-Feb	Perpendicular Head to Conical Hill	swathes	41	20	61	0.6721	0.521–0.824
8-Feb	Clark Hill and top MCBA	transects	30	12	42	0.7143	0.516–0.912
9-Feb	Block 32	swathes	80	72	152	0.5263	0.418–0.635
11-Feb	Galloway toe	swathes	52	28	80	0.6500	0.608–0.692
12-Feb	Ramparts, Sectoides Stream to Orde Stream	transects	39	13	52	0.7500	0.653–0.847
12-Feb	Galloway toe	swathes	54	31	85	0.6353	0.552–0.719
14-Feb	Galloway toe	swathes	40	15	55	0.7273	0.512–0.942
15-Feb	Main route east direction Mt Waterhouse	transects	10	3	13	0.7692	–
15-Feb	Waterhouse	swathes	59	11	70	0.8429	0.737–0.948
16-Feb	Galloway toe	swathes	23	24	47	0.4894	0.318–0.661
21-Feb	Central Platau en route to NSD	transects	11	4	15	0.7333	–
22-Feb	NSD south of camp, across Dog	swathes	97	54	151	0.6424	0.545–0.739
23-Feb	NSD west of Carex Burn	swathes	69	23	92	0.7500	0.624–0.876
24-Feb	Study Area	SA round	89	21	110	0.8091	0.742–0.877
26-Feb	Mt Galloway north and south flanks	transects	37	18	55	0.6727	0.663–0.683
26-Feb	NSD side of Mt Waterhouse	swathes	38	18	56	0.6786	0.616–0.741
27-Feb	Windward, north end NSD	swathes	136	20	156	0.8718	0.801–0.943
28-Feb	NSD wrapup	swathes	47	23	70	0.6714	0.508–0.835

Drone-photo nest estimate

Overall, 3,983 Antipodean albatrosses were counted across all drone photographs, including all those standing or sitting and obviously not nesting, as well as those albatrosses apparently nesting. Excluding those apparently-nesting albatrosses already counted in ground-count areas (871 apparently-nesting albatrosses, ANA), drone-only areas had 1,895 ANA. Only four blocks contained no nests, with up to 82 ANA per block. Corrected with the data from concurrent nest-contents inspections (Table 4), an estimated 1,332 albatrosses were on eggs in February. Then accounting for nest failures before the drone-photo date, we calculate that there were 1,399 breeding pairs in the 2024 season in the drone-only areas (7 per block, up to 62 breeding pairs per block).

Summed across drone blocks, an estimated 1,399 (95% CI 1,264–1,534) Antipodean albatross were breeding in the drone-only areas in 2024.

Habitat-quality extrapolation

Despite best efforts, 356 ha (23% of the 1,546 ha breeding range) lacked count data by the time the team were picked up from the island; that is, had not been overflown by drone or counted on the ground. Taking the average nest densities in low-, medium- and high-quality nesting habitat (Table 5) and applying these to blocks not counted (area of the part of a block not counted, or of the whole block in 18 cases) suggested that there were 2 to 38 nests in 2024 in each of the not-counted blocks (median 14 nests). Summed across not-counted areas, an estimated 597 pairs (531–662 pairs) are thought to have been breeding in the not-counted areas in 2024.

Table 5: Antipodean wandering albatross nest density in each nesting-habitat quality class

	n	Mean density (nests†/ha)	95% CI density (nests/ha)
Low	27	0.31	0.203–0.409
Medium	22	1.32	1.167–1.479
High	47	3.12	2.835–3.408

† Nests are the 2024 breeding pair estimate (nest-contents and failure-rate corrected) for each block

Whole-island breeding pair estimate

In the 2024 season, aerial and ground methods together gave an overall coverage of 1,190 ha counted, or 77% of the 1,546 ha albatross nesting distribution. Adding corrected ground and drone-photo counts together gives an estimated 2,787 breeding Antipodean albatrosses in these 1,190 ha in 2024.

Using nest densities by habitat-quality class, we estimate that a further 597 (531–662) albatrosses were breeding in uncounted areas (not covered by drone or ground-count methods) this year.

Taken together, this suggests an island-wide population of 3,383 (3,182–3,585) pairs of Antipodean albatrosses breeding in 2024.

White-chinned petrels

The mark-recapture study of white-chinned petrels that was started in 2023 was improved with another 66 burrows marked, bringing the study to 156 marked burrows containing 301 banded birds. Effort was comparable to last year though yield was slightly down; we scoped 552 burrows at least once this year, marking 12 new burrows/100 explored, while 564 burrows were scoped at least once in 2023 at a hit-rate of 16 marked burrows/100 explored.

Burrows were revisited until the mate was also banded, or the chick was left alone in the burrow when brooding ended. This approach meant most pairs have both birds banded, with a mate outstanding from only 20 burrows. The brood-end date, from which chicks were alone in the burrow, was 30 January (median from ten records 29 Jan–1 Feb).

Existing study burrows were checked for returned white-chinned petrels with bands, with 41 of the 169 birds banded last year recovered. This rate of return of 0.243 is lower than expected, since white-chinned petrels are annual breeders and birds were breeding when banded. Indeed, only 27% of 2023 study burrows were reoccupied this year. Those 66 study burrows with no sign of breeding this year either failed earlier in incubation, leaving no detectable eggshell remains, or did not return to breed this year at all.

Birds were not missed because they had shifted to other (unchecked) burrows. All burrows in the area around marked study burrows were also checked, and only one case of burrow switching was detected (a pair found in a burrow 10 m from where they bred last year, although with no sign they were breeding there this year). Burrow-shifting appears minimal, thus cannot explain the low reoccupancy (rate of return to last year's breeding burrows.) It is also unlikely to be a study-related effect, since burrow occupancy was lower in new (unmarked, non-study) burrows than it was last year at the same time (17% in December 2023, cf 30% in December 2022).

Six GLS were recovered of the 16 deployed last year, giving at-sea movements for the full annual cycle. The analysis of data from these devices will be covered elsewhere.

Discussion

Antipodean wandering albatross

Population size trends

After an extended period of decline starting in 2005, the number of breeding-age Antipodean wandering albatrosses has been roughly stable over the last four to five years. This is seen in annual nest counts and confirmed in the estimates derived from mark-recapture, a method that is more sensitive to changes in the population than are simple counts of nests.

Although a stable breeding population is preferable to one that is declining, stable is not enough for Antipodean wandering albatrosses. Simulations in 2021 predicted that without intervention to the current situation, the breeding population will decrease from ~3,300 pairs to 400 breeding pairs after 30 years (Richard, 2021). Even incorporating recent improvements in female survival (five-year average to 2022), the simulation models indicated that without other intervention, improvements are not great enough to cause population increase (Walker & Elliott 2022). Without recovery of key demographic vital rates to pre-crash levels, population projections show that numbers will continue to decline (Edwards et al., 2017; Richard et al., 2024). This is seen in wandering albatrosses elsewhere: an albatross population can only grow when survival, breeding and success probabilities are higher than the long-term means (Pardo et al., 2017). A scenario where numbers do not decline further but remain stable at the current low does not provide resilience against future rapid significant change of the type already seen in both Antipodean and Gibson's wandering albatrosses (Elliott and Walker, 2020, 2014; Richard et al., 2024). Without a subsequent increase in the size of the breeding population after a population decline, each sharp drop is a step to a smaller population. Small populations are vulnerable to stochastic events, for example landslips (~12% of Antipodes Island slipped in 2014), or disease like HPAI.

Securing the population and halting the projected decline logically requires an increase in the size of the Antipodean wandering albatross breeding population, but there is no indication of such an increase in nesting numbers. Even taking into account birds absent because they are on breeding sabbatical, different detection rates for breeding and non-breeding birds, and different survival rates (using data from the mark-recapture study), no growth in the breeding population is detectable. Indeed, it is now 20 years since the breeding population was last increasing (in the 2004 season).

Contributing factors

Several factors together explain the state of the Antipodean wandering albatross population: low survival rates, differing between males and females; a skewed sex ratio with attendant behavioural change; suboptimal recruitment, and productivity.

Of these, productivity and recruitment have improved or are stable. In 2023 productivity approached the average pre-crash nesting success of 74%. It is encouraging that the 2023 rate was the third-highest nesting success recorded for 17 years, although the average rate remains lower than before at 63%. However, more-normal looking productivity rates cannot change that the actual number of chicks produced each year is still much lower than before the 2005 crash, because the breeding population remains lower than in 1995 when this fine-scale population study began.

Recruitment—the number of birds breeding in the study area for the first time—has remained (on average) steady since 2007, despite the declining number of breeding pairs over that period. In other words, the rate of recruitment has been higher, which has been an important factor in slowing the population decline (Elliott and Walker, 2020). The recruitment age is getting younger, with females recruiting at an average age of 18 years in 2019 and 2020, and 15 years in 2022 (Elliott and Walker, 2020; Walker and Elliott, 2022). Most of these birds hatched around or just before the 2005–07 population crash. This is worrying because after 2005 far fewer chicks were produced, so the supply of birds available to recruit into the breeding population—buttressing breeding numbers—is now expected to shrink.

Sex ratio

The Antipodean wandering albatross population now features a markedly skewed sex ratio. The sex ratio before 2005 was about 1:1, as typical for the great albatrosses, but for the following decade the ratio averaged 1.5 times as many males as females. Now there are about 1.3 times as many males as females in the Antipodean wandering albatross population (average 2019–22). The behavioural consequences of this long-term male excess (for example, greater aggression between males disrupting or pre-empting male-female courtship) have unknown effects, but if courtship to stabilise a pair bond is indeed disrupted or pre-empted by these interactions, we expect that pair formation—and therefore productivity—would be affected.

Survival

A skewed sex ratio is the logical outcome when survival rates for males and females become different. Before 2004 survival rates were similar for male and female Antipodean wandering albatrosses, varying around a mean of 95.9%, but since then female survival has been much lower and more variable than male survival. Survival rates for females varied before the 2005 crash, but since have roughly doubled in variability. This likely simply reflects the spatial and temporal variability of fishing effort, such that bycatch some years occurs at higher rates.

At 89.6% average female survival over the last decade (since 2011) remains 6% lower than the average in the decade before the population crash, and further spikes in female mortality would drive further decline and prevent recovery. However, since 2014, the occasional year with relatively high female survival appears to be slowly pushing upward the average (4-year rolling averages, to smooth the spikes and detect change), closing the gap between male and female survival rates. However, as discussed above, when the most-recent five-year average of female mortality was used in the simulation model developed in 2021 (Richard, 2021; Walker and Elliott, 2022), the improved female survivorship seen to date was not great enough to cause population increase in the Antipodean wandering albatross without other intervention.

Overall Antipodean wandering albatross survival rates are 92.5%, considering females and males together, which are low for such a K-selected species (Véran et al., 2007; Weimerskirch and Jouventin, 1987). Wandering albatross populations from four island groups in the South Atlantic and Indian oceans had survival rates of 96% and 97% recorded when population numbers were stable, and survival rates between 84% and 92% when numbers were declining (Cuthbert et al., 2004; Pardo et al., 2017; Weimerskirch and Jouventin, 1987).

Whole-island breeding pair estimate: year 1

To contribute to the bigger picture for Antipodean wandering albatrosses, this first of two years of whole-island census used a drone to supplement ground-counts of nests. Building on over a decade of planning and several years of targeted method testing and workflow development (Rexer-Huber et al., 2020; Walker et al., 2023; Walker and Elliott, 2022), we conducted comprehensive, fully repeatable counts underpinned by technologies that allow a more accurate picture of the number of breeding pairs than was possible in whole-island count of the 1990s (GIS and GPS to ensure areas not missed, drone for full coverage of areas very difficult to cross on foot).

Importantly, we find that the number of breeding pairs estimated via large-scale ground counts and drone-photo counts (3,383 pairs, 95% CI 3,182–3,585 pairs) is similar to the number estimated via the annual monitoring approach (extrapolation from annual count of ~15% of the nesting area, 3,307 pairs). This confirms that the annual count areas have remained representative of island-wide trends over the last 30 years of monitoring. The similarity between the two estimates for 2024 also validates the approach used for the annual estimate, showing that it remains a relevant cost-effective way to provide accurate annual estimates to follow the trend of the island-wide breeding population. Although the estimates do not match perfectly, the extrapolation would be considered high accuracy on the ACAP population survey accuracy scale, since it is within 10% of the large-scale ground and drone estimate (ACAP, 2009). While it may be tempting to compare the estimate here with that from the mid-90s, we caution against doing so. Method changes since the last whole-island count—that is, introducing a drone and using GIS and GPS-driven ground counts—will have changed detection rates to an unknown extent, so comparison with the 1994–96 whole-island count would not be meaningful.

As anticipated, pretend-breeders—birds on nest with no egg—have potential to greatly affect the accuracy of aerial photo-counts. We found that 30% of apparently-nesting Antipodean wandering albatrosses were actually pretend-breeders with no egg, varying substantially by site from 13% to 51%. Nest-contents sampling this season was more comprehensive than ever before (21 distinct days/areas checked, median 70 nests per sample). While the variability was higher than during preliminary work for Antipodean albatrosses (range across sites 16–29%, Parker *et al.* 2023), this is more likely due to wider sampling this season, since similarly wide variation in the proportion of pretend-breeders was found in drone trials on Gibson's wandering albatrosses in 2023 (20–53%) (Walker et al., 2023) and for both Gibsons and Antipodean albatrosses in 2015 (Walker and Elliott, 2015). Therefore, to ensure numbers of breeding pairs are not overestimated, a correction of aerial photo counts for the proportion of albatrosses on empty nests is clearly vital. But we see that a single nest-contents correction factor is inappropriate (e.g. average of sampling across sites, or over time), given the variability in pretend-nester rates between sites and among years at the same sites (Gibson's, Antipodeans). Instead, nest-contents checks should be concurrent with the photography they are applied to, to reduce the error introduced to aerial photo-counts as much as possible, making estimated nest numbers as accurate as possible.

Key areas to address in the second year are the different breeding cohort, and coverage. As biennial breeders, a (mostly) different cohort of Antipodean albatrosses breed each year, so two successive counts would better account for these expected year-on-year differences. Secondly, completing whole-island coverage will be important to acquire count data from all parts of the albatross distribution. The year-1 push to maximise the ground-counted area required substantial personnel time, which in turn meant drone coverage of the island was reduced. The density-by-habitat extrapolation approach applied to uncounted areas (no count data of either type in 23% of albatross distribution) enabled a whole-island estimate for year 1. However, the assumptions and biases introduced by using this approach (subjective habitat-quality assessments to extrapolate density) are best avoided when possible. The year-2 goal is therefore to obtain whole-island coverage to have direct data on nesting numbers from all parts, to obtain an estimate as accurate and precise as possible.

White-chinned petrels

A mark-recapture study focused on estimating vital rates, survival in particular, established on Antipodes in 2022 now comprises two study areas with 301 banded white-chinned petrels in 156 marked burrows. This is a good push toward a marked population large enough for survival estimates that are accurate and precise enough to detect important population changes.

This first season of band-resighting checks highlighted the need for quality monitoring data. A startlingly low rate of study burrows were reoccupied this year (27%, compared to the 44–68% recorded in the 2007–11 study; NIWA unpubl. data), but we cannot yet tell if this is the new normal for Antipodes white-chinned petrels (having shifted over the decade since the last study), or whether it has just been a bad year. Burrow-shifting appears minimal, so birds were not missed because they had switched to other (unchecked) burrows; nor is it likely to be a study-related effect, since burrow occupancy was also lower this year than at the same time last year (17%, compared to 30% in December last year) in new, unmonitored burrows. It seems that a higher proportion than expected either failed during early incubation or did not attempt to breed this year at all. Antipodes white-chinned petrels overwinter in the Humboldt current system, and other seabirds that depend on the Humboldt current had poor breeding rates in 2023–24 (e.g. Humboldt penguins, T. Mattern pers. comm). If there was indeed poor winter feeding last year in the Humboldt, as likely occurred given the big El Niño shift in 2023 which would have weakened the current system there (https://www.ncei.noaa.gov/access/monitoring/enso/soi) we speculate that fewer white-chinned petrels would have been in good enough condition to attempt to breed this year. Supporting this, we observed a notable number of breeders with worn, poor-condition plumage unlike what we usually see on early- to mid-incubation birds.

Important next steps are recaptures at existing marked burrows to start building a capture history dataset, and to build the number of marked burrows within the study areas to reach at least 400 banded birds. Secondarily, control burrows to assess investigator disturbance should be marked (no banding), with a nest failure check at the end of a given trip across all marked burrows to allow comparison of failure rates in study and control burrows.

We anticipate that marked burrows will need to be visited for at least three years before band resighting data start giving useful estimates of survival, given the nature of mark-recapture studies for long-lived seabirds like white-chinned petrels. To illustrate, the 366 white-chinned petrels banded and resighted 2007–11 yielded annual survival estimates of adequate precision after four years of banding and resightings (Thompson 2019).

Recommendations

Antipodean wandering albatross

Overall, some gradual improvements in Antipodean wandering albatross demography appear to have slowed the rate of population decline over the past four years. However, this slowing is fragile, being underpinned by tentative improvements in female survival—which is vulnerable to large fluctuations year to year—and driven by high recruitment rates from before the crash that cannot be sustained since recruitment is starting to draw from the (much smaller) cohorts produced since the crash. While the improvements detected are welcome, on their own they are insufficient to halt the population decline and secure the species, merely slowing the continued decline of Antipodean wandering albatrosses.

With nest numbers in stasis, more than a decade of low chick production, annual mortality remaining high for such a K-selected species, and impending shortage of recruiting birds, the situation for

Antipodean wandering albatross is concerning. Monitoring the trends in population size and demographic parameters and research into causes of declines remain a high priority.

For effective population size/trend monitoring and research into causes, we recommend:

- Focusing the second year of island-wide nest counts on drone coverage to gain complete whole-island coverage for counts. For the most accurate, reliable estimate (ensuring breeding pair numbers are not overestimated), ground-count effort should prioritise numbers of nest-contents checks concurrent with drone overflight, since this is the most influential variable. Regular study area checks to detect breeding failures should be maintained, even though this is a less influential factor.
- Ongoing intensive effort to monitor the marked population to ensure consistency and continuity in the dataset with most power to detect trend.
- Ground counts of the core annual count areas be conducted as usual to keep trend-monitoring uninterrupted, but also for two years of direct assessment of the ratio to whole-island estimate.
- Island-wide nesting population estimate be repeated every 10–15 years to ensure the intensively-monitored part of the population remains representative.
- Other potential issues (pollution, diet changes) be explored further.

White-chinned petrels

Ongoing mark-recapture will enable robust trend estimation over time, provided the study is large enough, small enough, and goes for long enough: large enough to provide accurate, precise estimates of vital rates; small enough for thorough, intensive monitoring effort to be feasible; and be continued for long enough to yield robust survival estimates.

Continued effort is needed in the two white-chinned petrel mark-recapture areas established here to build the population of marked birds to be large enough for survival estimates to be useful, with ongoing annual effort for at least three years to collect the crucial resightings data that underpin survival rate estimates.

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Appendix A: Drone process practicalities

Single-day coverage. On good days we learned that a single pilot with a single DJI Mavic 2 Pro drone can fly 14 blocks in a day, including travel time between bocks. Coverage would be improved with two drones flown concurrently by a pilot, but preferably by two pilots working separate areas.

Timing. This season the weather shifted after the first week of February to be more dominated by clag-producing conditions than in January. Although the timing of nests counts is ideally after all eggs are laid (i.e. from the 2nd week February), drone work likely needs to start earlier to take advantage of the more settled conditions in January (if those do indeed occur). If drone flight starts before all eggs are laid, eggs not yet laid at the time of drone flight can be accounted for using the same regular study area nest checks, interpolated as for nest-failure rate correction.

Launch position. In steeper areas or areas containing bluffs, drone launch had to be from near the upper elevation. In practise that meant some blocks in steeper country could only be flown one at a time, compared to those over plains and plateaus where 3–4 blocks could be flown from a given takeoff point before needing to move.

Wind. In moderate- to high windspeeds, more than one battery was required to complete a programmed flight with enough power to return-to-home RTH partway through a flight and resume the programmed flight after battery replacement. Typically the flight software warned of dangerous wind conditions in just light to moderate winds, when the drone performance seemed unaffected. Flight could continue with surprisingly strong winds (30–35 kn based on forecast in Windy, actual speed unknown as no anemometer). Even areas where the drone was visibly pushed off its flight path did not end up with imagery gaps, so the 65% front- and side-overlaps are sufficient to account for substantial drone deviation. However, up to two batteries are needed to complete coverage of such blocks when persisting into the wind. The main issues found when flying in very strong winds were around bluffs (gusts shunting drone into bluffs) and on return-to-home: when RTH trajectory was into a strong head-wind, the calculation of battery required for safe RTH proved insufficient, meaning the drone ran out of battery before reaching the pilot. So if flying in strong winds, be aware that more batteries are required, and plan the takeoff point so the RTH path is not into a headwind.

Focus. At programmed flight speeds a high shutter speed proved necessary. We settled on shutter priority 1/1000. Despite this, a few flights returned blurred images, or parts blurred (typically the first ~10–30 images). The simplest fix was to press the focus button (usually top right on controller) as the drone approached the start of its programmed lines, when returning with a new battery, and occasionally in between.

Nadir. Even if programmed in UgCS, for some reason the camera did not tilt to 90° to take nadir photos; this needed to be done manually between takeoff and the start of the programmed flight (left-hand roller on controller).

Orthomosaic counting. Allow ~30–40 min per block. A GIS-capable laptop required if counting via qGIS, given the size of the orthomosaics. Dotdotgoose is much smaller and 'lighter' but DOC computers require special support from the DOC tech support team to run the dotdotgoose.exe.