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Gibson's albatross and white-capped albatross in the Auckland Islands 2021–22

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Final report

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Summary

This report details the mark-recapture methods and findings for Gibson’s albatross and white-capped albatross at the Auckland Islands. We present data on the size of the Gibson’s albatross nesting population on Adams Island in 2022 and update estimates of survival, productivity, and recruitment and foraging range to help identify causes of current population size and trends. For white-capped albatrosses the focus is on estimating adult survival, documenting a study set up to quantify productivity, and drone trials to assess the suitability of drones for quantifying the breeding population size.

Gibson’s albatross. The survival rate of adult females and males has recuperated somewhat from the dramatically low survival rates recorded 2006–08. However, at 92% the 10-year average survival rate for both sexes remains 4% lower than before the population crash in 2005, and is probably incompatible with population recovery given limited chick production. Nesting success and chick production for the 2020 and 2021 cohorts could not be determined since we could not visit the island in 2021. Mark-recapture models have shown a gradual but steady continuing decline in the Gibson’s albatross breeding population. This is now starting to be reflected in the trend of nest counts as well: estimated island-wide nest numbers showed slow improvement 2008–13, but these gains have stalled with a current growth rate or lambda of 1.1. The island-wide estimate of Gibson’s albatross nests in 2021–22 (4,434 nests) remains half the size of the pre-crash nesting population. Transmitting GPS trackers were fitted on 39 breeding birds, along with 23 GLS loggers. Together, survival, breeding numbers and recruitment show the slow Gibson’s albatross population recovery recorded over the decade 2007–16 has stalled.

White-capped albatross. Banded white-capped albatrosses were resighted at a rate of 0.25 in the study colony of 679 banded birds. Adult survival was estimated as 89% (95% CI 86–91), taking into account different detection rates of nesting birds and those not on nest during colony visits. This is similar to but more precise than the last estimate in 2020 (90%, 86–93). Ten nest cameras were deployed to take time-lapse images of 61 active nests, which should provide data on productivity and refine our understanding of breeding-season timings. Drone trials indicate that animal responses to a small drone are minimal, and the photographs obtained from programmed-grid overflight at 30–70 m over nests are suitable for counting apparently nesting birds. Nest contents of apparently nesting birds were also quantified and whole-colony ground counts conducted, illustrating that ease of fitting in drone survey—and the ground-truthing needed to refine the accuracy of later counts from images—around other colony work.

Keywords: Adams, Disappointment, mark-recapture, survival, productivity, population trend, drone, aerial photo-counts

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Introduction

Assessments of the risk of commercial fisheries to seabird populations (e.g. Richard *et al.* 2020) can be affected profoundly by uncertainty in population size and uncertainty in demographic rate estimates, particularly adult survival (Walker *et al.* 2015). To reduce uncertainty or bias in estimates of risk from fishing, robust information is needed on key aspects of biology (survival, productivity, recruitment, trends). Long-lived, slow-breeding seabirds that are vulnerable to accidental capture in commercial fisheries are the focus here: Gibson's albatross *Diomedea antipodensis gibsoni* and white-capped albatross *Thalassarche steadi*. Both are species of high conservation concern (BirdLife International 2018a; BirdLife International 2018b; Robertson *et al.* 2021).

Gibson's wandering albatrosses are endemic to the Auckland Island group. About 95% of the population breed on Adams Island, with small numbers on Disappointment Island and a handful on main Auckland Island (Elliott *et al.* 2020). They forage largely in the Tasman Sea, but also along the continental shelf off southern and south eastern Australia and off eastern New Zealand (Walker & Elliott 2006). Gibson's albatross survival, productivity, recruitment, and population trends have been monitored during annual visits to Adams Island since 1991. In the 1990s the population slowly increased following a major, presumably fisheries-induced, decline during the 1980s (Walker & Elliott 1999; Elliott *et al.* 2020). However, between 2004 and 2006 there was a sudden 68% drop in the size of the breeding population, from which recovery has been very slow. The Gibson's wandering albatross population is still less than half of its estimated size in 2004, having lost the gains slowly made through the 1990s (Walker *et al.* 2017; Rexer-Huber *et al.* 2020a).

The white-capped albatross is also endemic to New Zealand, with ~95% of the population breeding on Disappointment Island (Baker *et al.* 2014; Walker *et al.* 2020). White-capped albatrosses are caught in incidental bycatch in commercial fisheries in New Zealand, with an estimated 6,961-13,785 (95% CI) killed 2002–2019 in predominantly trawl, but also surface longline and bottom longline fisheries (MPI 2022). There have been improvements in bycatch mitigation in New Zealand commercial fisheries, but bycatch in New Zealand 2015 – 2019 is estimated at 362 – 731 (95% CI) white-capped albatrosses per annum (MPI 2022). There is a particularly high bycatch rate in the Auckland Island squid fishery (MPI 2022). White-capped albatrosses are also caught in substantial numbers in fisheries off South Africa despite substantial reductions in captures since the late 1990s (Ryan *et al.* 2002; Watkins *et al.* 2008; Francis 2012; Rollinson *et al.* 2017). Mortality in high seas fisheries remains largely unknown.

A white-capped albatross study area was established on Disappointment Island in January 2015 (Thompson *et al.* 2015) and data suitable for estimating demographic parameters like adult survival and for population trend assessment was collected annually until 2020 (Parker *et al.* 2017; Rexer-Huber *et al.* 2018; Rexer-Huber *et al.* 2019; Rexer-Huber *et al.* 2020a). Estimates of white-capped albatross numbers have so far been based on aerial photographs from helicopter, interpreted to estimate the number of nesting birds present, starting in 1985, then most years 2006 to 2017 (Baker *et al.* 2014; Baker *et al.* 2018; Walker *et al.* 2020). Aerial helicopter photographs were also taken in 2019 but these have not been interpreted yet (Rexer-Huber *et al.* 2019). Tracking data are collected at the Disappointment Island study area to build on existing knowledge about the at-sea range of white-capped albatrosses (Thompson & Sagar 2008; Thompson *et al.* 2009; Torres *et al.* 2011). Breeding success remains essentially unknown for white-capped albatrosses. A trial of nest cameras in 2018 suggested that productivity may be worryingly low, with only 29% of chicks fledging (Rexer-Huber *et al.* 2019).

In 2020–21 this work could not take place due to DOC cancelling the work programme. DOC again cancelled the work programme in 2021–22, but we continued the work independently (not under contract to DOC), collecting information to understand the species' conservation status and estimate key demographic parameters. Here the following specific aims and objectives are addressed:

- Gibson's albatross research aimed to build on estimates of survival, productivity and recruitment at Adams Island, and provide information on the size and trend of the population. We also deployed 39 transmitting GPS trackers and 23 GLS loggers to track movements at sea of Gibson's albatrosses.
- The white-capped albatross component focused on collecting resight data from the study colony on Disappointment Island and estimating adult survival. Secondary objectives were to assess the utility of drones for aerial photographic survey monitoring, and to deploy time-lapse nest cameras to estimate productivity and timings (fledging dates, colony return dates).

Methods

Timing and logistics

Seabird research in the Auckland Islands took place over the period January–February 2022, conducted by the same two-person team throughout. Five and a half weeks were spent on Adams Island (6 January–14 February) for Gibson's albatross research, focusing on population monitoring and tracking. After that, two days were spent on Disappointment Island 15–16 January for research on white-capped albatross.

The SV *Evohe* brought us from Bluff to the Auckland Islands, delivering us to Adams Island on 6 January. The researchers were picked up from Adams on 14 February and transferred to Disappointment Island at first light 15 February. Approaching high winds meant we had to be picked up 7 pm the following day. *Evohe* returned us to Bluff 20 February.

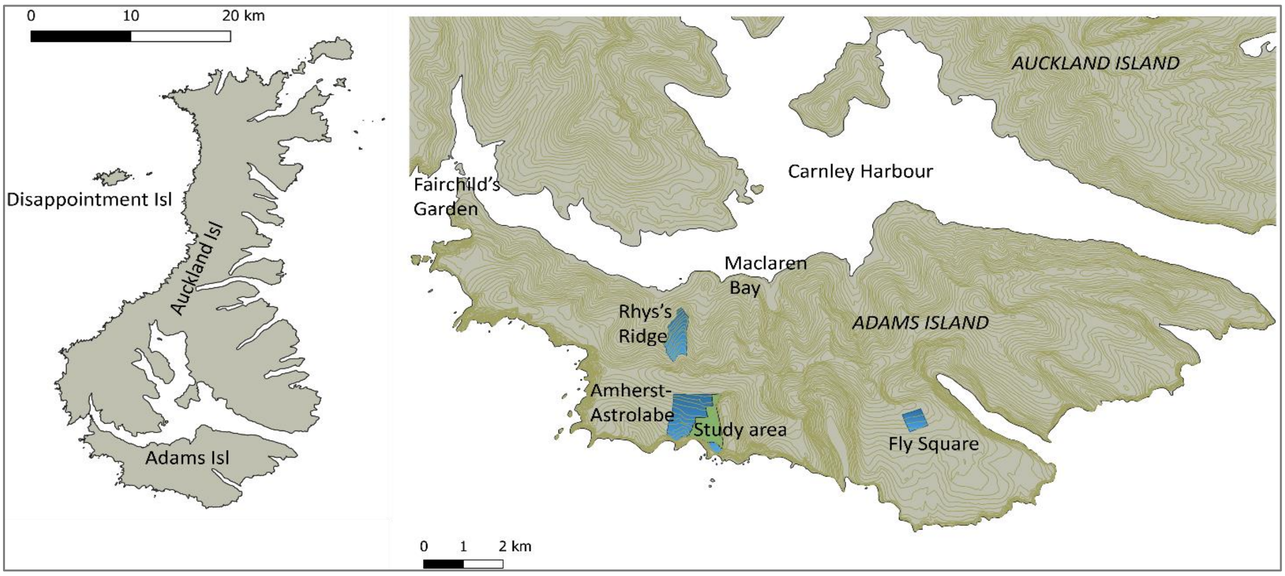

Figure 1. Auckland Island group (left) with inset of Adams Island at right. Areas in blue are representative nest-count blocks for Gibson's albatross, and the Gibson's study area is shown in green.

Gibson's albatross

Mark-recapture study

Since 1991, a 61 ha study area on Adams Island (Fig. 1) is visited repeatedly each season to leg-band nesting birds and collect resightings of already banded birds. The wider areas around the study area (within a kilometre) are visited less frequently and any banded birds are recorded. All birds found nesting within the study area have been double-banded with individually numbered metal bands and large coloured plastic bands, and since 1995 most of each year's chicks have also been banded. The proportion of chicks that are banded each year depends on the timing of the research field trips which in turn is dependent on the availability of transport. In 24 of the last 32 years researchers have arrived at, or soon after, the time at which the first chicks fledge and more than 90% of the chicks were still present and were banded. In the other eight years researchers either did not arrive (2021) or arrived late when most chicks had already fledged and were therefore not banded.

Survival is estimated from the banded birds with maximum likelihood mark-recapture statistical methods using the software package MARK via the R package RMark (White & Burnham 1999; Laake 2013; R Core Team 2021). For the models, adult birds are categorised by sex and by breeding status: non-breeders, successful breeders, failed breeders, and sabbatical birds taking a year off after a successful breeding attempt. Birds in each of these classes have quite different probabilities of being seen on the island but similar survival rates, so the models estimate resighting probabilities separately for each class, but survival is estimated separately only for males and females, and for breeding and non-breeding birds.

Population size is estimated by multiplying the actual counts of birds in each class by the resighting probability produced when estimating survival. The survival estimates assume no emigration which is appropriate because wandering albatrosses have strong nest site fidelity, a pair's separate nesting attempts are rarely more than a few hundred metres apart, and birds nesting at new sites within a few hundred metres of the study area are detected during the census of surrounding country (Walker & Elliott 2005).

Nest counts in representative blocks

Since 1998, all the nests in three census areas (Fig. 1) have been counted each year (apart from 2021). The three areas support about 10% of the Adams Island albatross breeding population and represent high density nesting habitat (Fly Square), medium density (Astrolabe to Amherst including the 61 ha mark-recapture study area) and low-density habitat (Rhys's Ridge).

Counts are carried out between 23–31 January just after the completion of laying, and as close as possible to the same date at each place in each year. A strip search method is used where two observers walk back and forth across the area to be counted, each within a strip about 25 m wide programmed on a GPS, and count all the nests with eggs in their strip. Every bird on a nest is checked for the presence of an egg, and each nest found with an egg is marked by GPS and counted. All non-breeding birds on the ground are also counted, and they and most breeding birds on eggs are checked for leg bands, the number and location of which are recorded. Once the whole block has been counted, the accuracy of the census is checked by walking straight transects at right angles to the strips, marking all nests within 10–15 m of the transect by GPS and checking later to ensure the nest has been counted.

Counts are corrected to take account of any eggs not laid or any failed nests at the time of counting. These corrections are based on the repeated monitoring of nests in the study area.

Total number of nests on the island

The number of pairs of Gibson's wandering albatross nesting on the whole of the Auckland Islands was estimated from a whole-island population count done in 1997, followed by repeated counts of parts of Adams Island, including the count in 2022. The proportion of the total population in 1997 that was nesting in those parts of the island that were subsequently repeatedly counted was used to estimate the total population using the following formula:

$$\hat{t}_i = \frac{t_{1997}}{p_{1997}} \times p_i$$

Where

$\hat{t}_i$ is the estimated total number of pairs nesting in year *i* ;

t_{1997} is the total number of pairs counted nesting in 1997;

p_{1997} p_{1997} is the number of pairs counted nesting in 1997 in those parts of the island that were subsequently repeatedly counted; and

p_i p_i is the number of pairs counted nesting in year *i* in those parts of the island that are repeatedly counted.

This estimate assumes that the proportion $\frac{t_i}{p_i}$ is constant from year to year, which is true when the pattern of distribution of nests remains the same from year to year, as confirmed on Adams Island (Elliott *et al.* 2016).

Foraging range

To identify where Gibson's albatrosses might be interacting with fishing vessels, satellite-transmitting GPS trackers were deployed, building on the information from twelve trackers deployed in January 2019. In January 2022, Telonics devices (TAV2630) were fitted on 29 breeding Gibson's albatrosses and ICARUS devices on another ten birds. These complement geolocator loggers (GLS, Migrate Technology) (Fig. 2 left) that archive light data until device recovery, which have been used since 2009 to monitor Gibson's albatross foraging range. This season 23 GLS were available, so all 10 ICARUS-carrying birds received a GLS and the remaining 13 GLS were fitted on TAV-carrying birds.

Figure 2. *Left:* GLS logger and solar-powered ICARUS tag. *Right:* Tracker fitted on Gibson's albatross

Trackers were deployed on breeding birds in the study area between 28 January and 6 February 2022. Satellite-transmitting trackers were attached to back feathers (Fig. 2 right) and GLS loggers fitted onto the bird's metal leg band.

Analysis of new tracking data is not attempted here since daily location data continues to be transmitted (satellite-transmitting devices), bird's final breeding status (succeeded, failed) is not yet known (to be determined from colony inspection Jan 2023), and GLS data are not available yet (loggers to be collected 2023). However, data from devices that stopped working were reviewed to assess whether any trackers stopped working close to a fishing boat. Overlap of tracked birds and fishing fleets up to 8 July 2022 was analysed by comparing the birds' tracks with the locations of fishing boats available from the Global Fishing Watch website https://globalfishingwatch.org/map (following Elliott & Walker 2020).

White-capped albatross

Mark-recapture study

Resightings of banded white-capped albatrosses were collected at the study colony in Castaways Bay on Disappointment Island (Fig. 1). All white-capped albatross nests and loafing birds in the study area were checked for bands. Nesting birds checked were marked with stock marker on the breast. Incubating white-capped albatross are flighty, so we maintained best-practise release techniques (Rexer-Huber *et al.* 2018). A buffer of ~50 m around the study area was checked in case banded birds had moved outside the study area. No new birds were banded to add to the study since we were only on the island for a single day.

Survival of white-capped albatrosses in the study area was estimated with maximum likelihood mark-recapture statistical methods similar to those used for Gibson's albatross. Models categorised adult birds by observed state (S birds sitting on a nest with egg or chick, and L birds standing in the colony whose breeding status is unknown), reflecting that birds in each of these classes are expected to have quite different probabilities of being seen on the island but similar survival rates. Annual survival is estimated, but time-varying annual survival is not attempted since exploratory analyses in 2020 showed that at that point, the data were not yet adequate for estimating time-varying annual survival rate for such a long-lived species (Rexer-Huber *et al.* 2020a). With a year missing from the dataset (2021), this is not yet expected to have changed substantively. Models therefore estimated annual survival using the complete dataset when testing the influence of other parameters (resighting probability, state).

Drone trial

White-capped albatross colonies can be difficult to access on foot, so for whole-island population estimates, aerial photographic methods are valuable (Walker *et al.* 2020). Aerial photographs have been taken from helicopter annually from 2007 to 2017 (Baker *et al.* 2014; Baker *et al.* 2018) and again in 2019 (Rexer-Huber *et al.* 2019). Using a drone as the platform for aerial photographs potentially offers some logistical benefits, but has not been tested at white-capped albatross colonies. Assessing the suitability of drones for aerial photographic survey monitoring of wildlife requires, first, careful trial to ensure a drone does not cause undue disturbance at that site (Parker & Rexer-Huber 2021). Then can follow assessment of whether the image quality obtained *under those flight constraints* is suitable for counts (Rexer-Huber & Parker 2020).

Building on other studies assessing the response of *Thalassarche* albatrosses to drones (in New Zealand, grey-headed, Campbell and Salvin's albatrosses) (Rexer-Huber *et al.* 2020b; Rexer-Huber & Parker 2020), animal responses were the first part of the trial. Animal responses before, during and after drone flight were monitored with a dedicated observer with binoculars supporting the drone pilot. The drone was a DJI Mavic

2 Pro (high-quality Hasselblad camera, 20MP 1" CMOS sensor), flown manually for disturbance trials using the DJI Go4 drone interface. Animal response trials were conducted in two stages; launch and ascent (a careful and slow launch and hover then slow ascent to 30 m flight height), then overflight (initial hover at target flight height then if no reaction, progress to a slow flight in a steady and straight transect). Filming with an DSLR camera was used for a record of responses through all stages.

Once minimal disturbance risk had been established, aerial photographs of the Castaways colony area were taken. Photography occurred 15:30 to 16:30 hrs, so loafers were returning to the colony; established procedures are for aerial photography 11:00–16:00 hrs when most loafers are thought to be at sea (Baker *et al.* 2014; Baker *et al.* 2018). Two ways to capture images by drone were tested: diagonally into colony, and programmed grid. Photographs looking diagonally into the colony face, to align with photos from helicopter which were taken roughly perpendicular to colonies, were taken during manual flight. Grid flights were programmed in PIX4Dcapture to flight height 30 m above launch, camera angle nadir, with generous front and side overlap (80% and 72%, respectively). During grid flight the drone maintains the same height, but in these steep colonies the slope drops away such that nests were 30 m below the camera at the top edge of the colony but 70 m below camera on the lower edges of the colony. Monitoring of animal responses continued throughout diagonal and programmed-grid flights.

Two assumptions are involved when counting nests in aerial photographs: that every nest present is visible in the photograph (detection bias), and that all apparently incubating birds are breeding (nest contents). To quantify detection bias, or detectability of nests in drone photographs, ground-truthing was conducted by counting every nest in the area at the time photos were taken. Nest contents of all birds that are apparently nesting (sitting on nest mounds in incubation/brooding posture) were also recorded, and the proportion of apparent nesters that are truly breeding calculated (nest correction factor).

Drone photographs were stitched into photomosaics, either panorama (diagonal photographs, Microsoft ICE) or orthomosaic (programmed grid photos, Dronedeploy). Birds in the aerial images were counted using dotdotgoose (Ersts 2019). Count categories distinguished loafing birds from those apparently nesting (AON, apparently on nest).

Nest cameras

Wildlife cameras (Bushnell Enduro) to record time-lapse images, at hourly intervals during daylight hours, were deployed in the Castaways Bay colony. Ten cameras were deployed at seven sites in the study colony to optimise colony coverage, secured to waratahs. Cameras were placed to ensure there was no overlap between cameras' field-of-view, and all active nests in each camera's view were recorded to aid image processing later (Fig. 3). Cameras are currently recording at 61 active nests total (4–10 active nests per camera).

Figure 3. Example field-of-view of time-lapse nest cameras in white-capped albatross colony. Active nest visible in field-of-view of each camera circled

Data from these cameras will be suitable for estimating chick success for the 2022 cohort (number of chicks fledged out of the number hatched), since most chicks were recently hatched. These cameras will also provide better data on phenology (mean fledging dates, the period the colony is empty, and the mean date of first return), building on information from the trial in 2018 that followed only a small number of nests (Rexer-Huber *et al.* 2019).

To estimate breeding success (number of chicks fledged out of the number of eggs laid)—not just chick success—cameras will need to continue in place for another year after this deployment. The current cameras would need to last for a full year to follow the start of the 2023 cohort from lay in October 2022; have batteries and SD cards replaced; and remain in place for the remainder of the breeding season through to August 2023.

Results

Gibson's albatross

Population size estimate from mark-recapture

Mark-recapture resighting probabilities and survival estimates are used to correct the actual counts of birds in the study area to estimate the full study area breeding population. The population in this area was increasing up until 2005, but between 2005 and 2012 the population declined rapidly. Since 2012 the decline has slowed, but both female and male populations show continued gradual decreases (Fig. 4).

The size of the total population including pre-breeding birds (as opposed to the total number of breeders) can be estimated using the modelling techniques of Francis et al. (2015), but this is beyond the scope of this report.

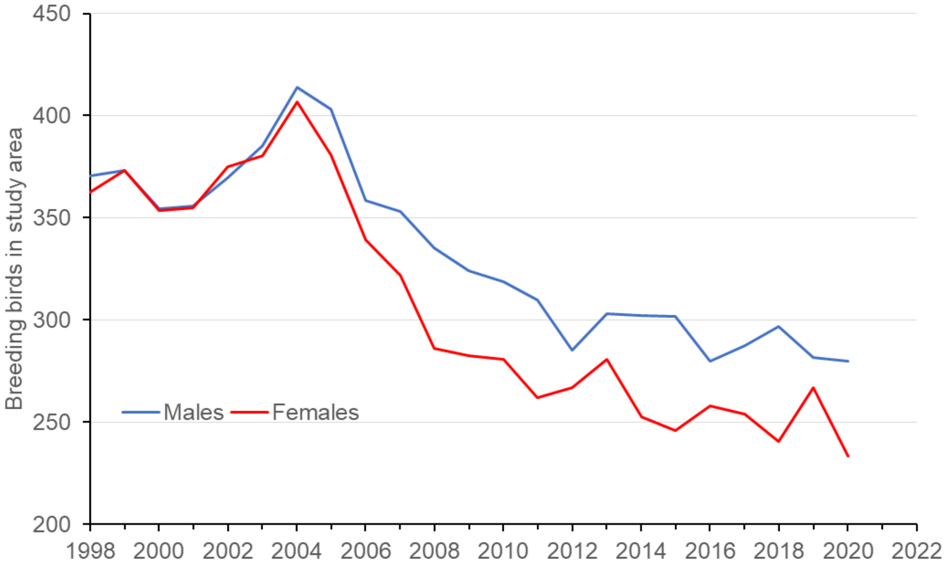

Figure 4. The number of breeding Gibson's albatrosses in the Adams Island study area estimated by mark-recapture. Note: mark-recapture population estimates are not reliable in the last year of data collection, so we show only results up to 2020

Survival

Adult survival varied around a mean of about 96% up until 2004 and during this period male and female survival were not notably different. Survival dropped substantially after 2005, with female survival reaching catastrophic lows 2006–08 (Fig. 5). Female survival has improved substantially since then, and the last five years of data show some indications of a positive trend in survival. However, survival of 92% (10-year average 2010–19, both sexes) remains markedly lower than the 96% average prior to the crash (1994–2003).

Within sexes, survival often differs between breeders and non-breeders (Fig. 6). Non-breeding females generally have had lower annual survival rates than breeding females, particularly since 2013. In contrast, non-breeding males have generally had similar or slightly better survival than breeding males (Fig. 6).

The best-supported model for Gibson's albatross survival remains the male-female model (lower AIC than the one distinguishing breeders and non-breeders; males and females: 281053.8 vs. males and females x breeders and non-breeders: 281123.6). Nonetheless, it is valuable to consider those years when breeding females have vastly different survivorship than non-breeding females.

Productivity and recruitment

Because the colony could not be visited in 2021, there are no final breeding success data for 2020 and the 2021 breeding success could also not be determined on the current visit (lacking data on numbers nesting at the start of the season). When last estimated, in 2019, breeding success was 56% (Rexer-Huber *et al.* 2020a).

The number of birds breeding for the first time in the study area appears to have plateaued since 2014, following the big decline in 2005–06 (Fig. 7). This season 27 females and 20 males joined the breeding population. Recruitment appears to have been better than in 2020, when both female and male recruitment was particularly low (8 and 9, respectively), but 2022 figures will have been inflated by birds that actually joined the breeding population in 2021, when researchers were not there to record it (although only recruits whose breeding attempt failed last year will have returned this year).

Many of the birds recruiting to the breeding population now are chicks fledged since the population crashed in 2006. Thus, even if young birds have high survival rates, the number of birds reaching breeding age will be low because of the low numbers of birds breeding since 2006.

Nest counts and whole-island estimate of nest numbers

The three blocks in which nests have been counted since 1998 were counted again in late January 2022, from which the total number of breeding pairs on the island were estimated. Counts were corrected to take account of as-yet unlaid eggs and nest failures at the time of census (Elliott *et al.* 2016).

The number of nests across the island dropped sharply 2004–06 by about 46%. Since then, the data showed slow growth of nest numbers 2007–16 with annual growth rate or lambda of 1.4, but with recent years' data this recovery stalled (lambda of 1.1 2007–22) (Fig. 8, 9). Across the island there are now an estimated 4,434 nests (Fig. 9, Table 1).

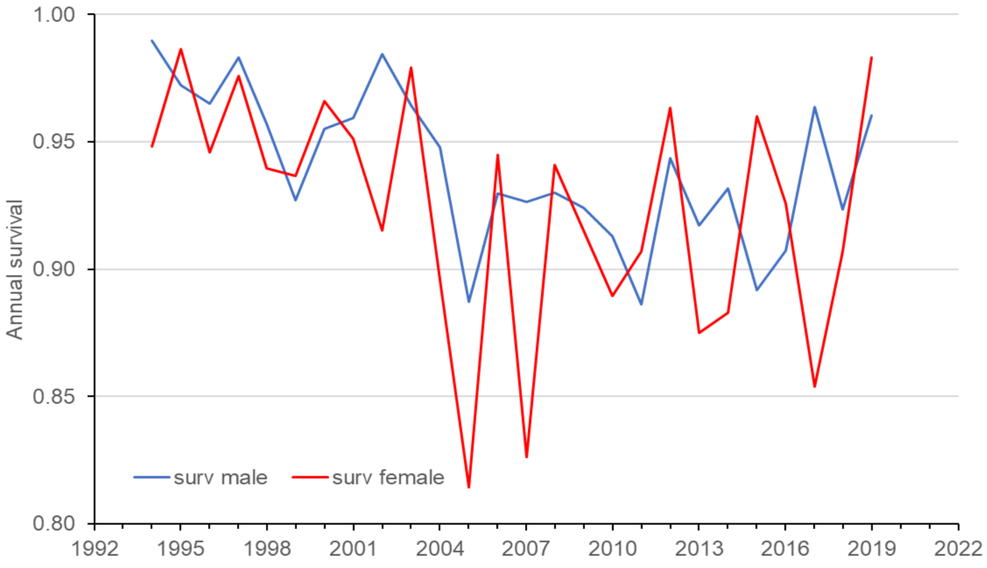

Figure 5. Annual survival of Gibson's albatross in the Adams Island study area since 1993, estimated by mark-recapture. Mark-recapture estimates of survival for 2020 are unreliable, being affected by lack of data from 2021, so not presented

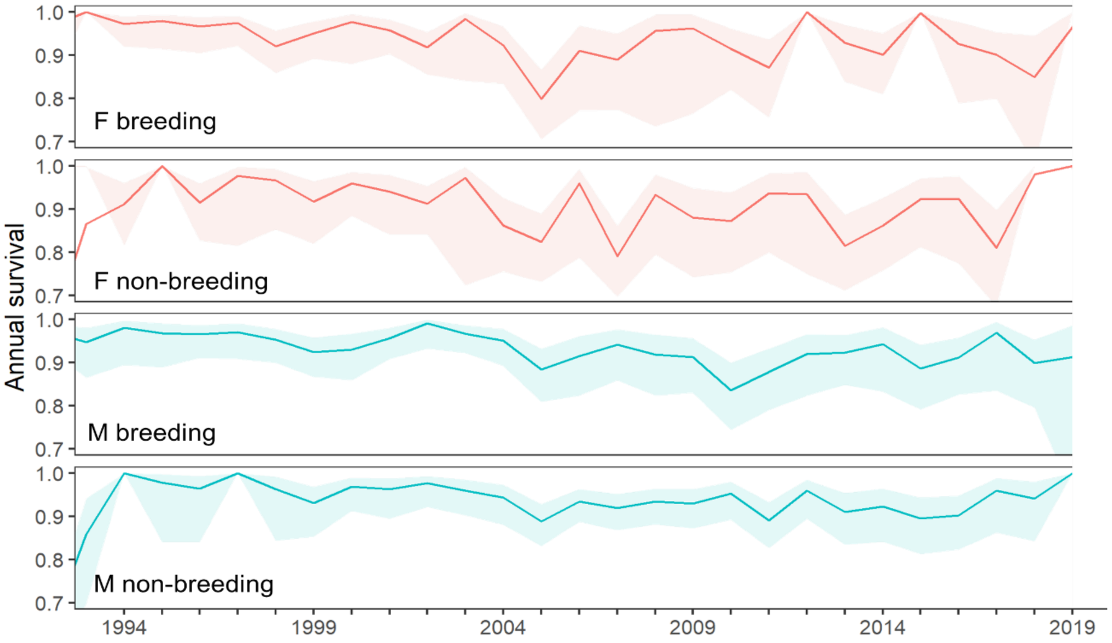

Figure 6. Survival estimated separately for breeding and non-breeding female (top two panels) and male (bottom two panels) Gibson's albatrosses, estimated by mark-recapture

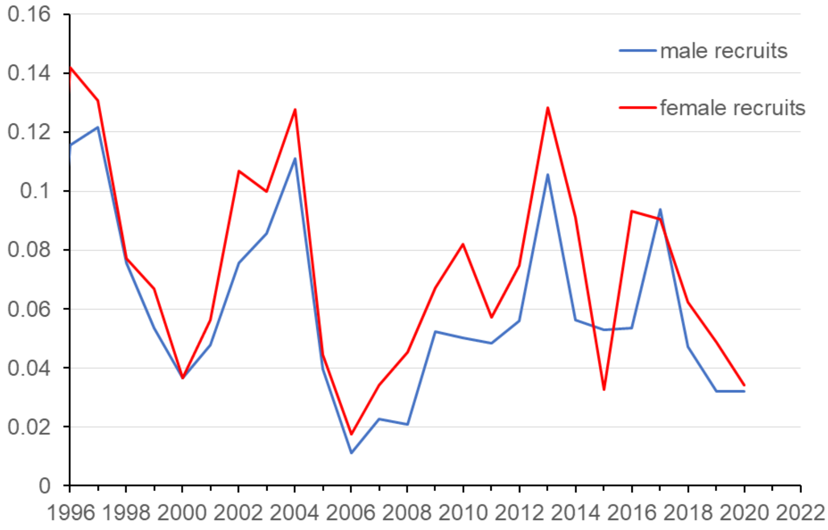

Figure 7. Recruitment rate: number of Gibson's albatross breeding for the first time in the study area on Adams Island since 1996, out of the number breeding in the study area estimated by mark-recapture

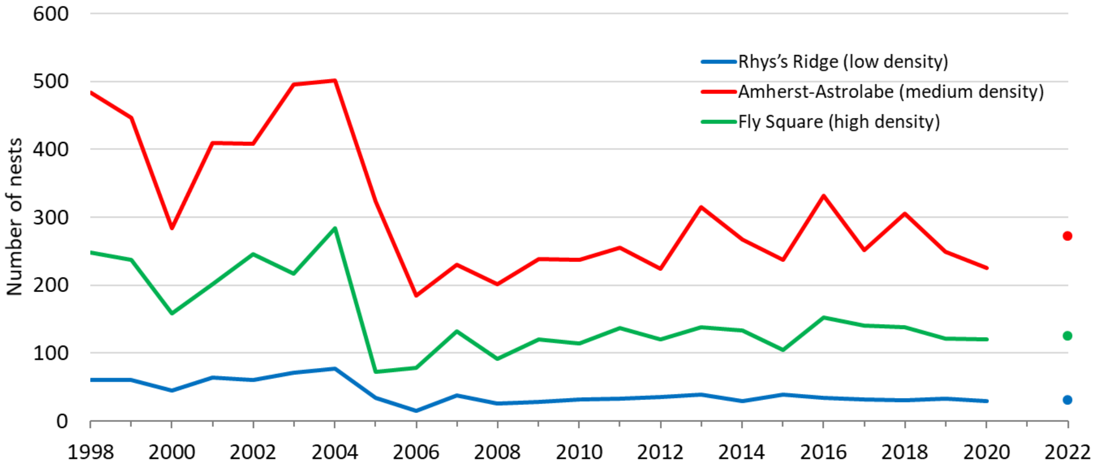

Figure 8. The number of Gibson's wandering albatross nests in three census blocks on Adams Island 1998–2022

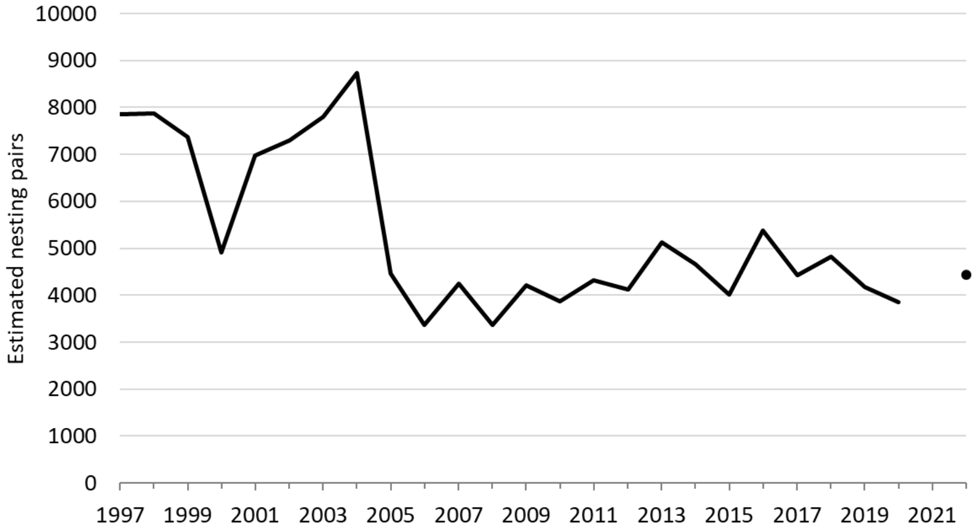

Figure 9. Total Gibson's albatross nests across Adams Island 1997–2022. The estimated number of nesting pairs on the island is based on annual counts in the three census blocks, taking account of the number of failed nests and unlaid eggs at the time of counting, and corrected by the proportion of the total population in 1997 that was nesting in those three counted blocks

Table 1. Gibson's wandering albatross nests with eggs in late January in three census blocks on Adams Island, 1998–2022. Corrected total is the estimated number of nests in the three blocks taking account of the number of failed nests and unlaid eggs at the time of counting. Estimated total is the estimated number of nests on the island, based on the proportion nesting in the three counted blocks relative to island-wide totals in 1997 when the last whole island count was undertaken

Year	Rhys's Ridge (low density)	Amherst-Astrolabe (medium density)	Fly Square (high density)	Total No. of nests	Corrected total	Estimated total
1997					796	7857
1998	60	483	248	791	798	7875
1999	60	446	237	743	746	7367
2000	45	284	159	488	497	4904
2001	64	410	201	675	706	6969
2002	60	408	246	714	740	7303
2003	71	496	217	784	791	7809
2004	77	501	284	862	884	8728
2005	34	323	72	429	452	4467
2006	15	185	79	279	341	3363
2007	38	230	132	400	430	4245
2008	26	201	91	318	341	3371
2009	28	238	120	386	426	4211
2010	32	237	114	383	392	3872
2011	33	255	137	425	438	4323
2012	35	224	120	379	418	4131
2013	39	315	138	492	519	5120
2014	29	267	134	430	473	4669
2015	39	237	105	381	406	4010
2016	34	332	153	519	545	5385
2017	32	252	140	424	448	4424
2018	31	306	138	475	489	4827
2019	33	249	121	403	423	4180
2020	30	226	120	376	391	3861
2021	No count					
2022	31	272	125	428	449	4434

Gibson's albatross foraging range

Thirty-nine Gibson's albatrosses were fitted with trackers. Transmission of fixes is ongoing, except for the ICARUS trackers; support for the ICARUS platform (which transmitted via the International Space Station) ceased in March 2022, so no further data is expected from these trackers.

Previous tracking from 2019 highlighted that it was informative to separate tracking data into birds whose breeding attempt failed during the tracking period, and those that continued incubation and chick provisioning throughout. In January 2023 final breeding outcomes for the 2022 tracked cohort can be determined, so analyses of the tracking data is best left until that information is available.

Meanwhile, trackers that stopped working are inspected, to see where they stopped relative to nearby fishing effort at that time. Of the 29 Telonics TAV 2360 satellite tags deployed, 13 had stopped transmitting by July.

Of those, nine stopped when within 250 km of a trawler or longliner, but there was no evidence that any had been killed by the fishing boats.

Genetic work: sampling

Blood samples were collected for genetic work to be conducted by Imogen Foote (Victoria University of Wellington), for comparison with Antipodean albatross. Blood was taken from 55 Gibson's albatrosses from four different colonies (Fig. 10), ensuring sufficient distance between birds to reduce the likelihood of sampling close relatives (at least 300 m apart, based on median dispersal distances). Blood samples from each bird were split between two different storage media to maximise quality of the samples, and carried to a freezer as soon as possible.

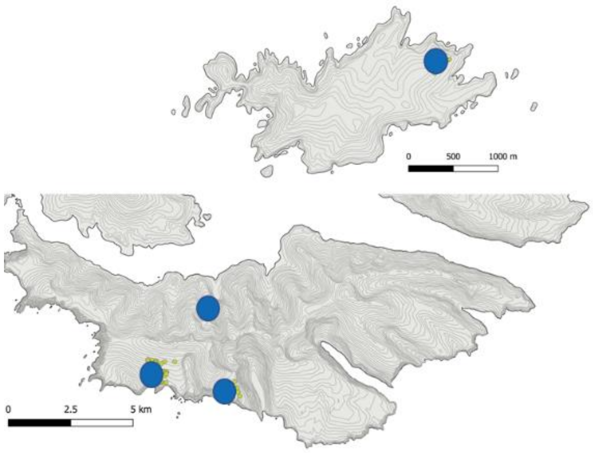

Figure 10. Gibson's albatrosses blood sampling for genetic work. Samples were collected from four colonies (blue points): Disappointment Isl (*top*) and Astrolabe, north ridge and Mt Dick colonies on Adams Island (*bottom*)

White-capped albatross

Mark-recapture study

A total of 173 banded white-capped albatrosses were resighted over the 2-day visit to Disappointment Island in 2022, giving a resighting rate of 0.25 (Table 2). The short visit also made the interval between nest checks even shorter than usual (24 hrs between checks), which reduces the turnover of birds and so fewer new band resightings to contribute to the tally of resighted birds. However, the visit's timing in mid-February meant very quick changeovers at nest, which somewhat balanced the very short visit. 70% of banded birds seen on the second check were new arrivals, not present the day before. No banded birds were seen outside the original banding area.

No new albatrosses were banded to add into the study, with band resightings, drone trial and nest camera deployment prioritised. Banding was limited to giving metal-only birds a numeric darvic band (4 birds) or band repairs (2 darvic band repairs). The study colony has had 679 birds banded, including the 36 birds banded in the study area in 1993 and 2008 (Fig. 11).

Table 2. White-capped albatrosses banded and resighted in subsequent years on Disappointment Island 2015–2022

	2015	2016	2017	2018	2019	2020	2021	2022	Total
Banded	150	83	160	128	122	0	-	0	679
Resighted from previous years	na	32 of 150	56 of 233	130 of 393	191 of 557	175 of 679	-	173 of 679	
% resighted	na	21%	24%	33%	34%	26%	-	25%	
Duration of work (days)	3 †	3 †	2.5	2.5	2.5	0.5	-	2 †	

† Duration includes ground-truthing work

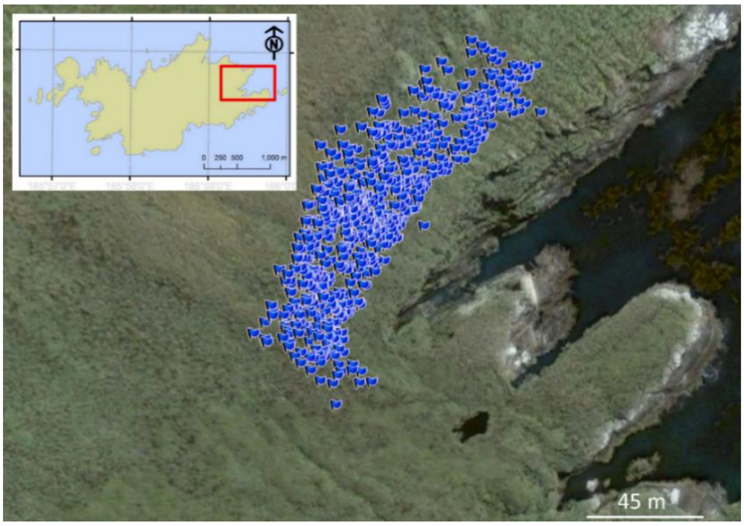

Figure 11. White-capped albatross study area in Castaways Bay, Disappointment Island. Blue flags are banding locations of white-capped albatrosses 2015 to present

Survival estimates

White-capped albatrosses in the colony are seen in different states (S sitting on egg or chick; L loafing or standing in colony). The best supported multi-state model showed that survival rate is the same for both states but that resighting probability differs between states and over time, and the probability of transitioning from one state differs between states and over time. Estimates from this model, accounting for the differing resighting probabilities of states, give annual survival as 0.89 (95% CI 0.86–0.91).

If we do not account for observed state (standard CJS model), the best-supported model estimated annual survival with resighting probability varying over time. Under this model, estimated annual survival was 0.90 (95% CI 0.85–0.93) for the period 2015–22. This estimate is less precise than the multi-state model above, suggesting the multi-state models provide the more useful estimate.

Drone trial

Animal response trial. Animal responses to the drone were minimal at this time of year. There was little response by white-capped albatrosses on the ground to the drone's presence during launch and landing. Albatrosses on the ground (nesting or loafing in colony) apparently ignored the drone when it was >5 m away; while the drone was closer (launch or land) albatrosses watched it closely but did not otherwise move. This was true for loafing birds (e.g., Fig. 12 left) as well as those nesting.

The airspace immediately above the colony was relatively busy when we conducted drone trials (Fig. 12 right). Albatrosses in flight were visibly aware of the drone and avoided it, and the drone avoided albatrosses too: in one case the drone detected an albatross in its collision-avoidance sensors, paused in mid-flight, then carried on its flightpath once the albatross was no longer in its sensors. Some seabirds approached within 10–20 m to look at the drone in flight then either kept going (Northern giant petrel) or followed at a distance (white-chinned petrels). Skuas were present but did not come to investigate the drone; this may not be the case, though, during the breeding season when their territorial airspace is actively guarded.

Figure 12. Animal disturbance trial for drone use at Disappointment Island. *Left*: white-capped albatross watching drone descend to land (sitting on empty nest). *Right*: birds flying in relatively busy airspace above white-capped albatross colony ~15:30 hrs saw and stayed clear of drone (yellow arrow)

Overall this trial indicates that a drone can be flown safely and without undue disturbance to the wildlife in these dense colonies on Disappointment Isl. However, response to a drone may differ by time of year/breeding stage, and potentially with busyness of the airspace, so any future drone deployment for white-capped albatrosses should again cautiously assess animal responses before conducting aerial photographic monitoring.

Image suitability. Aerial photographs of the Castaways study area were taken 15:30–16:30 hrs on 15 February. Pickup from island was to occur shortly after the trial, so there was little scope for fine-tuning coverage or flight height (for example, testing a lower flight height to compare image quality with the 30 m flown), but 788 useful photos were obtained. Both diagonal-view and programmed-grid photo types could be stitched into photomosaics with good coverage of the whole study colony (e.g., top left panel in Fig. 13).

Assessing images for quality, grid overflight images are of a quality suitable for counting nesting white-capped albatrosses (Fig. 13). This is not just the case at the top of the colony, where nests were 30 m below the camera (top right, Fig. 13), but also for images of the lower edge of the colony where nests are some 70 m below the camera (bottom right, Fig. 13). Diagonal photos (perpendicularly into the colony) are of poorer quality, such that it is expected to affect counting accuracy (bottom left, Fig. 13). This is because diagonal photos were taken from greater distance to avoid missing areas when flying manually (rather than on a programmed flight path).

Figure 13. Overview and quality of drone images of white-capped albatross colonies. Panels are enlarged sections of image composites. Clockwise from *top left*: study area orthomosaic from drone images (programmed-grid at 30 m flight height), overlaid on publicly available satellite images. *Top right*: grid-flight at top of colony, 30 m above nests (zoom 51%). *Bottom right*: grid-flight at bottom of colony, ~70 m above nests (zoom 100%). *Bottom left*: manual flight for diagonal into colony, showing same area as top left (zoom 194%)

Counts in the orthomosaic from the programmed-grid flights gave 63 loafers, 608 AON, 32 chicks (and one nest with only an egg in the cup). Ground-truthing counts of every nest showed there were 520 nests in the colony at the time photographs were taken. Comparing ground- and aerial counts, nest numbers were overestimated in aerial counts by some 14%. Loafing birds are expected to have been the primary cause of inflated AON numbers; that is, loafers mis-identified as AON since image quality was not quite good enough to be confident of a bird's substrate (on a nest or not?). Another factor to note is that the count boundary will not have corresponded exactly to the study area boundary (in this trial, there was no time to place physical boundary landmarks visible in drone). Correcting the total of 704 birds counted in photographs by 0.85 (the proportion actively breeding of all birds present in ground counts) gives an estimate of 595 breeding pairs in aerial images. Again, the 13% difference between this corrected estimate and numbers on the ground (520 nests) suggests that more loafing birds were present when aerial photos were taken than during ground counts.

The finding that aerial counts were less-accurate than ground counts in this trial is helpful to direct how the method can be refined in future aerial work. The boundary of a ground-count area needs physical landmarks visible in drone counts, and a lower flight height is needed to improve image count accuracy so that loafers can be identified with more confidence. If future aerial photographs are taken at a lower flight height so image quality is better, enabling loafers to be excluded from AON, then AON could simply be corrected for nest contents. (Nest contents checks showed that of 293 apparently nesting birds, 90% had an egg/chick at the time of these flights. The aerial photo-count could therefore be multiplied by 0.90, to get a more-accurate estimate of the number of breeding pairs.)

Discussion

Gibson's albatross

The demography of Gibson's albatross had showed gradual improvement following the population crash in 2006, but these gains now appear to have levelled out.

Survival has improved, overall, after a period of markedly low survival recorded during the population crash where adult females were particularly affected. However, adult survival of 92% remains substantially below the average pre-crash survival rate, and is low for such a K-selected species (Weimerskirch & Jouventin 1987; Véran *et al.* 2007). A consequence is that numbers of breeding birds in the study population continue to gradually but steadily decline. Island-wide nest numbers increased slowly 2008–13 but these gains have stalled to a growth rate (lambda) of 1.1. In other words, trends in nest numbers are starting to catch up with trends apparent for more than a decade in the overall/complete study population, highlighting the importance of mark-recapture modelling in detecting whole-population trends that raw nest counts may not be able to capture (Bakker *et al.* 2018). The rate of new birds entering the breeding population is no longer increasing the way it was immediately post-crash (2006–13). Unfortunately nesting success data from both 2020 and 2021 breeding cohorts is now lacking, since researchers were not able to visit the colony in 2021. Up to 2019, nesting success had been at or above pre-crash levels for four years running (Rexer-Huber *et al.* 2020a).

Together, survival, recruitment and productivity shed some light on the slow increase then stasis in the number of breeding birds on the island. Although nesting success had shown recovery (to 2019 at least), the number of chicks produced remains much lower than it used to be, since the breeding population is still substantially smaller than before 2005 and annual adult mortality remains higher. Wandering albatrosses start breeding at about 12 years old, so most birds joining the breeding population now were produced during a period when chick production was very low. Further, the trend to recruiting at a younger age may have already depleted the pool of birds available to recruit. Along with adult mortality remaining high, this is likely to continue to limit population recovery.

It is unclear what has changed in the last five to six years to stall the (albeit slow) population recovery recorded over the decade 2007–16, other than diminishing recruitment from a small pool of birds. Why do breeding numbers remain depressed? The southern oscillation index (SOI) may have had an influence, since a lower proportion of the population choose to breed during La Niña (Elliott *et al.* 2018) and moderate La Niña conditions persisted for much of 2016–18 (Bureau of Meteorology 2020). However, this is not the whole explanation, since in 2019 the SOI reverted to a moderate El Niño under which a higher proportion should choose to breed, yet particularly low breeding numbers were seen (Fig. 14).

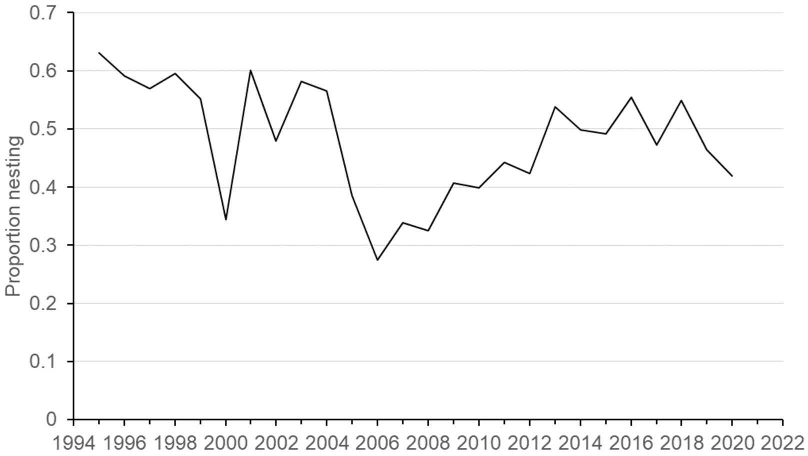

Figure 14. Gibson's albatross nesting rates 1995–2020. Number of females choosing to nest as a proportion of the full population of breeding females in the study population

Another possibility is some change in overlap of Gibson's albatross at sea with fishing fleets that results in greater risk of mortality. This could occur, for example, if the foraging range shifts into a heavily fished zone, or if fishing effort increases in the albatross foraging areas. Full tracking sets from the 2022 cohort are not available yet, but tracking data from 2019 showed little clear change in foraging range compared to the known distribution (Walker & Elliott 2006; Walker *et al.* 2017; Rexer-Huber *et al.* 2020a). If there was a change in mortality risk in that period, the change is subtle. Nonetheless, subtle effects can be masked by pooled data, so survival was estimated separately by breeding status. In recent years non-breeding females have had markedly lower annual survival rates than breeding females. Tracking data in 2019 showed the foraging range of breeding and non-breeding females to be different (Rexer-Huber *et al.* 2020a), but followed only a few non-breeding females for less than a year. The much larger sample of birds tracked in 2022 will be valuable to assess where the range of non-breeding females differs from breeding females, together with concurrent assessment of fishing effort in the central Tasman Sea and Australian Bight, where Gibson's albatross forage (Walker & Elliott 2006).

A final possibility is that nothing has changed: the population has declined continually since 2004, as illustrated by mark-recapture estimates, and apparent improvements in nest counts were simply an artefact of nest counts being a less-powerful method to detect population change than mark-recapture methods (Bakker *et al.* 2018; Elliott & Walker 2020).

While the conservation status of Gibson's wandering albatross remains of concern, monitoring the size of the population and its structure and trend on Adams Island remains a priority.

White-capped albatross

Survival. The current survival rate estimate for white-capped albatross—0.89 (95% CI: 0.86–0.91)—is low for albatross species (Véran *et al.* 2007). Adult survival was similarly low when last estimated two years ago (0.90, 95% CI: 0.86–0.93) (Rexer-Huber *et al.* 2020a). The only other estimate for white-capped albatross was higher but less precise (0.96, 0.91–1, from a small Southwest Cape study) (Francis 2012). With more resighting visits and more banded birds in the Disappointment study estimates are expected to be more precise, and as the dataset improves over time the precision of estimates are improving (Roberts *et al.* 2015; Rexer-Huber *et al.* 2018; Rexer-Huber *et al.* 2020a).

Within the same study, a more-precise survival estimate can be obtained by accounting for observed state (whether birds were actively breeding, or just seen loafing/standing in colony) (Rexer-Huber *et al.* 2020a). The probability of detecting loafing birds differs from that for breeding birds, as for Gibson's albatrosses. Unlike Gibson's albatrosses, though, short visits to the white-capped albatross colony mean that the actual breeding state of loafers remains uncertain. Loafing birds may in fact be breeding, so until researchers can be present at the island for long enough (a full changeover interval) to be sure that both mates have been checked on all nests, it is not possible to be sure that loafers present are not breeding. At late incubation/brood-guard, the changeover interval is at its shortest in albatrosses, so the extra time on the island required may not be significant.

Adult survival is estimated here using the whole white-capped albatross recapture dataset. Time-varying demographic parameter estimates, such as those following changes over time in Gibson's albatrosses, require a longer dataset than is currently available. This is not unexpected, since population dynamics of long-lived slow-breeding animals logically requires longer time periods. Continued resighting visits to this white-capped albatross study colony should soon provide a dataset with the power to detect and follow changes over time in survival, as well as in population size and trend.

Timing. Timing in mid-February appears to be optimal for resighting work in white-capped albatross colonies. Turnover of birds was high (70% of banded birds not present the previous day), maximising the chance of seeing bands; most nests contained small chicks (95% of nests), which are less delicate than eggs so less vulnerable to damage by parents (Parker *et al.* 2017); and the chick was still being brooded at most nests (98%), so parents are present to be resighted.

Nest cameras. A nest camera trial in 2018 followed only a few nests through to fledging, but suggested that breeding success may be worryingly low. Chick success, or the survival of a chick from hatching to fledging, was 29% (Rexer-Huber *et al.* 2019), and breeding success (survival from egg lay to fledging) will be lower than chick success. Nest cameras deployed in a Salvin's albatross colony provided good data for estimating breeding success and even daily nest survival rates (Rexer-Huber *et al.* 2021), so a similar broad deployment of cameras on white-capped albatrosses should provide better data on productivity. The timing of white-capped albatross breeding (lay ~October to fledging July–August) (Rexer-Huber *et al.* 2019) means cameras must be deployed across two years, given annual visits are typically in January–Feb.

Drone trial. Aerial counts complement data collection from the study colony (trends in survival, productivity etc) by providing the context of trends in overall nest numbers (Walker *et al.* 2020). The drone trial here showed that a drone is feasible as a platform for aerial counts. Birds flying in the busy airspace over the colony saw and avoided the drone, and no disturbance was detected in the dense multispecies colony when the drone was overhead. Similarly, there was no response from white-capped albatrosses at Southwest Cape to drone overflight as low as 70 m (R. Sagar pers. comm. May 2022). Image quality is sufficiently crisp for counts of albatrosses in the area, even at the lowest edge of the colony where nests were 70 m (not 30 m) below the drone.

Good data were collected to assess the accuracy of aerial photo-counts. A full ground-count of all nests in the study area (520 nests when photographs were taken), compared to the photo-count of nests in that area, showed that nest numbers were overestimated in aerial photo-counts. Nevertheless, this trial has provided useful proof of concept, and steps for better drone image capture to improve photo-count accuracy. Drone photo capture should be at a lower flight height, and the ground-count boundary marked to be visible in aerial photos so corrected counts are as accurate as possible. Ground-count accuracy checks are clearly not feasible at all sites, but study area ground-truthing checks could then be used to correct aerial counts from other areas/times when no concurrent ground-truthing was possible.

If a drone can be flown lower in future work on white-capped albatrosses, image quality could improve to the point where apparently-nesting birds can be distinguished from loafing (not on nest) birds (see Parker & Rexer-Huber 2020). In that scenario, a nest-contents correction becomes useful, accounting for 'pretend breeders' or 'triers' by quantifying the proportion of apparently-incubating birds that are actually breeding. At 90% in 2022, the proportion of apparent-nesters actively breeding was better than the 81% recorded in 2015 and 70% in 2016 (Parker *et al.* 2017). This is not unexpected, though, since nest-contents correction is known to vary significantly between years (Walker *et al.* 2020).

Because a drone can be flown by a team already present on the ground, in suitable weather windows around study colony work, combining drone and mark-recapture work would be markedly cheaper than helicopter methods alone, and provide higher quality data to guide management. Drone methods could be scaled up to photograph all breeding sites (periodic whole-island estimate), but are obviously suited for more regular overflight of representative monitoring colonies identified by Baker *et al.* (2018) (Castaways B and the Southwest Cape waterfall colony, being colonies at which the trend over time followed the overall trend).

Recommendations

Gibson's albatross

The gradual improvements in the demography of Gibson's albatross over more than a decade following the crash in 2005–06 appear to have stalled. The breeding population size has declined, as illustrated by mark-recapture that accounts for their biennial breeding status and absences, and recruitment and nest counts have levelled off. With more than a decade of low chick production and annual mortality remaining high for a K-selected species (and higher than it used to be), the conservation status of Gibson's wandering albatross remains of concern. Monitoring the size of the population and its structure and trend on Adams Island remains a priority.

White-capped albatross

A resighting rate of 25% in 2021 is lower than achieved in previous years, the result of a short island visit. Future visits should again take place in mid-February when mate changeovers are most frequent, but over at least five days to increase resighting rates and provide some contingency for poor weather. Longer visits would help improve survival estimates by improving the confidence in assigning state (breeding/non-breeding) to birds seen. More resightings are needed to allow estimation of time-varying annual parameters like survival rates, population size and population rate of change.

To maximise the productivity data that time-lapse cameras can provide, batteries and SD cards should be replaced on next visit (Feb 2023) and cameras left in place, to capture the full 2022–23 breeding season from October to August (Rexer-Huber *et al.* 2019).

To develop drone-based aerial monitoring of population size, the next step is to refine flight height so that nesting birds are reliably distinguishable from loafing birds, and scale up drone coverage to whole-island level. Simultaneous ground counts are needed to quantify nest contents and aerial photo-count accuracy at a subset of sites. Ideally, aerial photography would occur in early Dec before many egg failures occur.

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