Gibson's wandering albatross: demography, satellite tracking and census

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Cover photo by Kath Walker:
Ground-counting Gibson's wandering albatrosses in Fly Square high density census block in 2011

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SUMMARY

Gibson's wandering albatross (*Diomedea antipodensis gibsoni*) have been in decline since 2005. Research into the causes of and solutions to the falling numbers of Gibson's wandering albatross includes an annual visit to the main breeding grounds on Adams Island. This report describes the results of the field programme during the 2024 breeding season. Breeding success in 2023 was close to the mean (60%) though chick development was slower and fledging later than usual. The number of nesting pairs in 3 representative census blocks in 2024 was the lowest it has been since the 2006 population crash, likely due in part to the relatively high numbers nesting the previous summer. However, there are signs the number of breeding pairs of Gibson's wandering albatross is again in decline (2016 to present) after a slow but nearly significant growth rate for the decade 2006–2015.

The satellite transmitters taped to the back feathers of 22 juvenile Gibson's wandering albatross in December 2022 remained attached for an average of 291 days with the longest lasting 540 days, much longer than transmitters on adults, presumably because juveniles delay their first moult. Juveniles were found to spend much more time than adults foraging in tropical waters north of 30 degrees (2.4% cf 0.6%), which means juveniles have greater exposure to tuna longline fishing fleets. Two of the juveniles wearing transmitters appear likely to have been caught by longliners in winter 2023, one off Queensland and one north-east of New Zealand. Twenty adult Gibson's wandering albatrosses were fitted with satellite transmitters in late December 2023, of which one breeding female was almost certainly caught in June 2024 by a Taiwanese long-liner in the mid Tasman Sea.

Drone photographs were taken of 63% of the 4,040ha of Gibson's wandering albatross breeding habitat on Adams Island, and the number of albatrosses on the ground seen in the photographs were counted. Concurrent ground calibration checks undertaken to determine the proportion of birds on the ground which had eggs ("has-egg" rate) provided a "correction factor" which varied from 30% to 88% depending on area and time of day, with an average of 54% of birds on the ground having a nest with an egg. After correction for pretend breeders and failed nests, a total of 3,348 breeding birds were counted in the 2,565ha of albatross habitat which was successfully droned, an area which in the past supported 80% of the population. Assuming the distribution of albatrosses has not changed, an estimated 4,181 pairs of Gibson's wandering albatrosses were breeding on Adams Island in 2024. A strong El Nino weather system in summer 2024 brought a constant stream of northerly fronts which were too wet, windy and misty for drone flying, and left the western and eastern extremities of Adams Island still to be droned. This will be undertaken in January 2025, when some of the already-counted parts of the island will be re-counted, to account for differences due to interannual variation.

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INTRODUCTION

Gibson's wandering albatrosses *Diomedea antipodensis gibsoni* are long-lived, slow-breeding seabirds, vulnerable to incidental capture in commercial fisheries. As such, the species is of high conservation concern (Birdlife International 2018; Robertson et al. 2021). Assessments of the risk of commercial fisheries to seabird populations (e.g. Richard et al. 2020) can be profoundly affected 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). This is the focus of this report.

Gibson's wandering albatross are endemic to the Auckland Island group. Most (94%) of the population breed on Adams Island, about 5% on Disappointment Island and a few scattered pairs (1%) on main Auckland Island make up the remainder (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 (Elliott et al. 2020). 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 (Rexer-Huber et al. 2020).

This report summarises work undertaken as part of the Department of Conservation's (DOC) Conservation Services Annual Plan 2022-23 (Department of Conservation 2022) which has the following objectives:

1. To monitor the key demographic parameters of Gibson's albatross to reduce uncertainty or bias in estimates of risk from commercial fishing.
2. To estimate the population size of Gibson's albatross.
3. To describe at-sea distribution of Gibson's albatross

The most recent findings on the survival, productivity, population size and trends and at-sea distribution of Gibson's wandering albatross collected during a nine-week trip to the island from 9 December 2023—25 February 2024 are presented.

METHODS

Mark-recapture study

A 61ha study area on Adams Island (Fig. 1) has been visited repeatedly during each season since 1991 to leg-band nesting birds and collect re-sightings of previously 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 26 of the last 34 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 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 2023). 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 dividing the actual counts of birds in each class (except sabbatical birds) by the resighting probability produced when estimating survival. Counts of sabbatical birds are always very low, so the number of sabbatical birds is estimated by multiplying the number of successful breeders in the previous season by their estimated survival. The survival estimates assume no emigration and thus underestimate survival as birds that emigrate are treated as if they died. However, wandering albatrosses have strong nest site fidelity, and 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 usually detected during the census of surrounding country (Walker & Elliott 2005). In other words, the under-estimate is small, unquantified but consistent from year to year.

Nest counts in representative blocks

Since 1998, all the nests in three census areas (Fig. 1) representative of low (Rhys's Ridge), medium (A-A) and high (Fly Square) density have been counted each year, apart from 2021 when the island was not visited. 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 transect search method is used where observers walk back and forth across the area to be counted, each within a GPS-programmed 25m wide transect. Observers search for albatrosses sitting on nests within the transect. Every bird on a nest is checked for the presence of an egg, and each nest found with an egg is marked with a dot of spray paint, recorded on the GPS, and counted. All birds whether on a nest or just on the ground are also counted. All birds are checked for leg bands, the number and location of which are recorded.

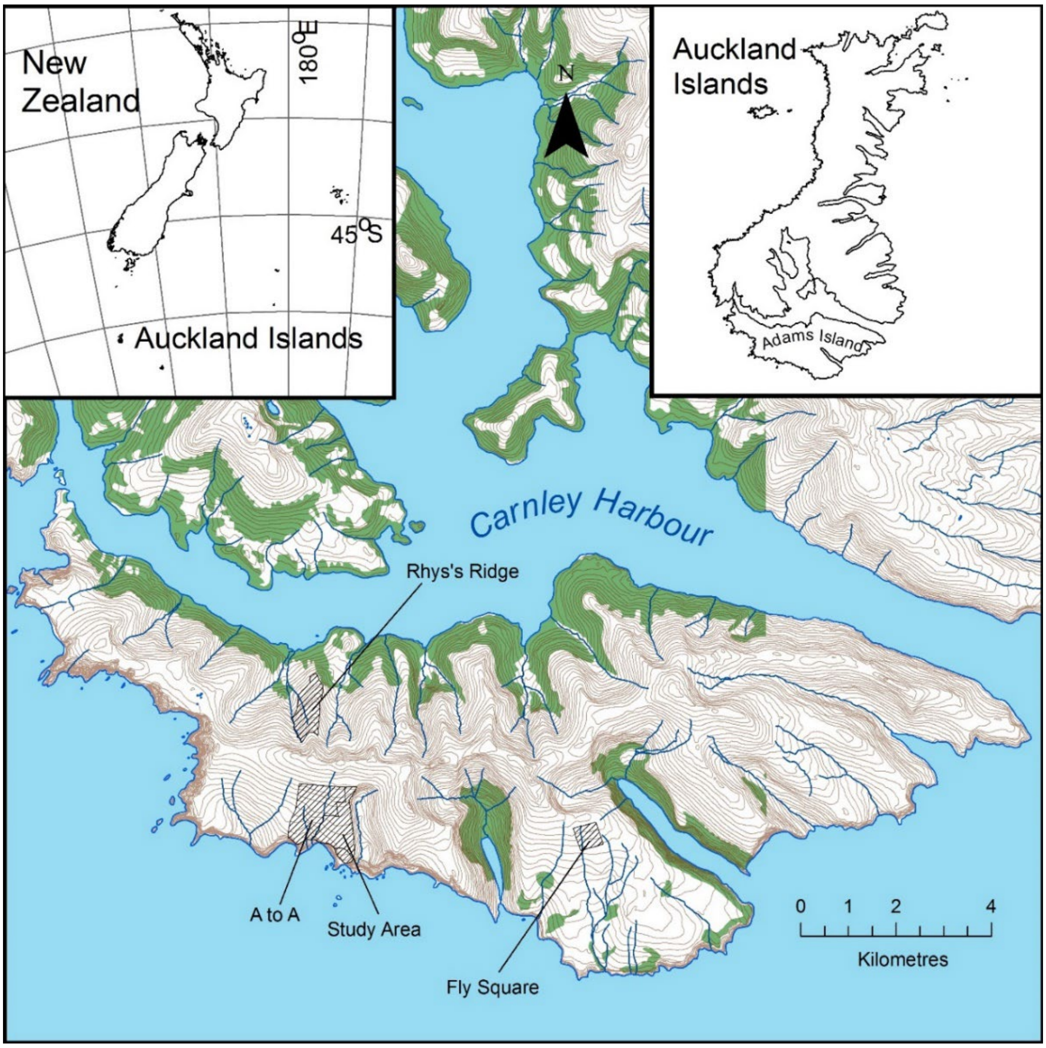

Figure 1: Adams Island, showing the Study Area (61ha) and three census areas in which counts of breeders are made (shaded): Amherst to Astrolabe (A to A; 101ha) Rhys's Ridge (67ha), and Fly Square (25ha).

Once the whole block has been counted, the accuracy of the census is checked by walking straight transects at right angles to the original transects, checking all nests within 10–15m of the transect for paint marks indicating the nest has been counted. Counts are corrected to take account of any eggs not yet laid or any failed nests at the time of counting. The corrections involve estimating the number of eggs yet to be laid and nests that are likely to have failed in each count block by interpolating the proportion of eggs laid and nests failed in the repeatedly monitored study area on the day of the count.

Rhys's Ridge, which is the smallest of the representative count blocks and the most difficult to count accurately due to its deep scrub was counted using aerial photos taken by drone in both 2023 and 2024. Both counts were corrected for birds on nests without eggs by concurrent ground transects across the upper portion of Rhys's Ridge.

Total number of nests on the island

The number of pairs of Gibson's wandering albatross nesting on the whole of the Auckland Islands each year is estimated from the corrected number of nests counted in the three blocks divided by 9.87%, which was the percentage of birds nesting in the 3 census blocks in 1997 when nests on the whole island were counted (Walker & Elliott 1999).

This estimate assumes that the proportion of the population in the three counted blocks is constant from year to year, which is supported by the relative abundance of nests in the three blocks being similar from year to year (Elliott et al. 2016).

Drone census of the whole island

This year, in addition to estimating the number of pairs nesting on the island by extrapolating from the ground counts of ~10% of the island, as described above, an attempt was made to do a whole-island census using drones. Drone census techniques developed in 2023 (Walker et al. 2023) were refined during the first few weeks of the 2024 visit and implemented from 21 January 2024 at which time 95% of eggs had been laid. The 4,040ha on Adams Island in which Gibson's wandering albatrosses had previously been seen to nest (Walker & Elliott 1999) were sub-divided into 281 x 15ha blocks for systematic aerial photography by drone. Three drones were used: a DJI Mavic 3E and two Mavic 2 Pro. Because of the different cameras and batteries on the drones the flight characteristics for the two types of drone differed, but flights for both were planned in UGCS software (https://www.sphengineering.com/flight-planning/ugcs) to obtain the same output from each drone; for a ground resolution of 1.5cm per pixel and forward and side overlaps of 65%. The Mavic 3E had a longer battery life (45 minutes) and could record images more quickly which meant it could be flown at 10m/s and still be able to store images taken at as little as 0.7 seconds apart. In contrast the Mavic 2 Pro's had only 31 minutes of battery life and had to be flown at only 7.5m/s to store images taken no less than 2.5 seconds apart. Flight plans which covered 15ha per battery for the Mavic 2 Pro's and 30 ha per battery for the Mavic 3E were made. These flight plans were a compromise: in light winds the drones could cover much more ground, but in strong winds they would be unable to complete the planned flights before their batteries went flat.

Every time a drone census was undertaken a ground calibration was required to allow correction for the proportion of birds seen on the drone imagery which had eggs, calculated as a 'has-egg' rate. This calibration was achieved in either of two ways:

1. Walking transects
   At the same time as the drone was being flown, a walking transect was undertaken over part of the same ground the drone was flying over, or nearby. The transect was undertaken in the same weather and at the same time of day as the drone flight. All birds encountered on the transect were recorded and every sitting bird checked to see whether it had an egg. A has-egg rate correction factor for the wider area was subsequently calculated by dividing the number of eggs found on the transect by the number of birds encountered.

2. Re-flying already ground-counted blocks
   Either just before or soon after a drone flight an additional drone flight was made over the geographically closest of either the Study Area or Fly Square where the number of active nests with eggs was known as it had previously been ground-counted. From the drone imagery all the albatrosses present could be counted and a correction factor calculated by dividing that total by the number of eggs known to be in the block.

Images taken by drones were used to construct orthomosaics using Drone Deploy (https://www.dronedeploy.com/). A separate 15 or 30 ha orthomosaic was constructed for each 1-battery-length drone flight.

A 15m x 15m grid was overlaid over the orthomosaics in the mapping software QGIS(https://qgis.org/en/site/) to aid albatross counting, with all visible albatrosses counted and their locations recorded. Each albatross detected in an orthomosaic was classified into one of four classes:

1. Sitting on a nest. Nests are mostly obvious and are recognisable from the air because they have a dark ring around the sitting bird where nesting material has been ripped out of the ground and added to the nest mound. Not all birds sitting on a nest have eggs.
2. Sitting on the ground, but with no nest visible from the air. Some birds have nests that are not detectable from above.

3. Standing. Standing birds were most often, but not always distinguishable from sitting birds in aerial photos because their legs and feet were visible.
4. Flying.

Because it wasn't possible to reliably distinguish between sitting birds, standing birds and birds on nests, all but the flying birds were summed, and the has-egg rate correction factor applied to the total number of albatrosses detected on the ground.

Collecting samples from Gibson's wandering albatross

To help determine what the diet of Gibson's wandering albatrosses had been in 2023, feathers, faecal samples and boluses were collected. Four to six feathers from 45 birds (15 chicks, 15 adult males and 15 adult females), from four birds (three adult males, one subadult female), (small balls of accumulated undigestible material, mostly squid beaks) regurgitated by 24 chicks just before fledging, were collected in late December 2023—early January 2024 from birds in the albatross study area. Sample collection was mostly in conjunction with birds being held for banding, measuring or satellite transmitter attachment.

All samples and data derived from it will be stored and managed according to protocols agreed between the Department of Conservation and Te Rūnanga o Ngāi Tahu.

At-sea distribution

To identify where adult Gibson's wandering albatrosses forage, and therefore might be interacting with fishing vessels, 20 satellite transmitters (Telonics TAV2630) were deployed in late December 2023/early January 2024. These battery-powered satellite transmitters on a duty cycle of three hours per day will transmit for a maximum of 15 months. The 35 g tags were taped onto the back feathers (Taylor 2013) of 10 females and 10 males which were sitting on eggs in the study area, or which were presumed to be about to start incubating an egg (Table 1).

Table 1: The number inferred sex and status of Gibson's wandering albatross to which satellite transmitters were attached in December 2023.

Albatross life stage	Transmitter	Female	Male	**Total**
Breeding	TAV2630	7	5	**12**
Did not breed/ failed early	TAV2630	3	5	**8**
Total		**10**	**10**	**20**

The overlap of fishing fleets and these 20 adults, plus 22 juveniles to whom satellite transmitters were attached in 2023 ,will be analysed by comparing the birds' tracks with the locations of fishing boats available from https://globalfishingwatch.org/map/, the Global Fishing Watch website.

RESULTS

Population size estimate from mark-recapture

The size of the breeding population in the study area estimated by mark-recapture was increasing up until 2005, but between 2005 and 2012 the population declined rapidly ($\lambda_{\text{both sexes combined}} = 0.955$) Fig. 2). Between 2012 and 2020 the decline slowed ($\lambda_{\text{both sexes combined}} = 0.991$), but both female and male populations showed continued gradual decreases (Fig. 2). There are no estimates of population size for 2021 as the island was not visited that year, and the population size estimates for the most recent two years are unreliable so estimates for 2012 and 2023 are not presented.

Figure 2. The number of breeding Gibson's albatrosses in the Adams Island study area between 1998 and 2020 estimated by mark-recapture. Note: population estimates produced by mark-recapture are not reliable in the last two years of data collection and no data were collected in 2021, so population size is only shown up to 2020.

Survivorship

Adult survival varied around a mean of about 96% up until 2004 and during this period male and female survival were similar (Fig. 3). Survival dropped substantially after 2005, with female survival reaching catastrophically low levels in 2005 and 2007. From 2009 onwards male and female survival has been more similar but has remained about 3% lower than it was before 2005 (Fig. 3). There are no estimates of survival for 2021 as the island was not visited that year, and survival estimates for the most recent two years are unreliable so estimates for 2022 and 2023 are not presented.

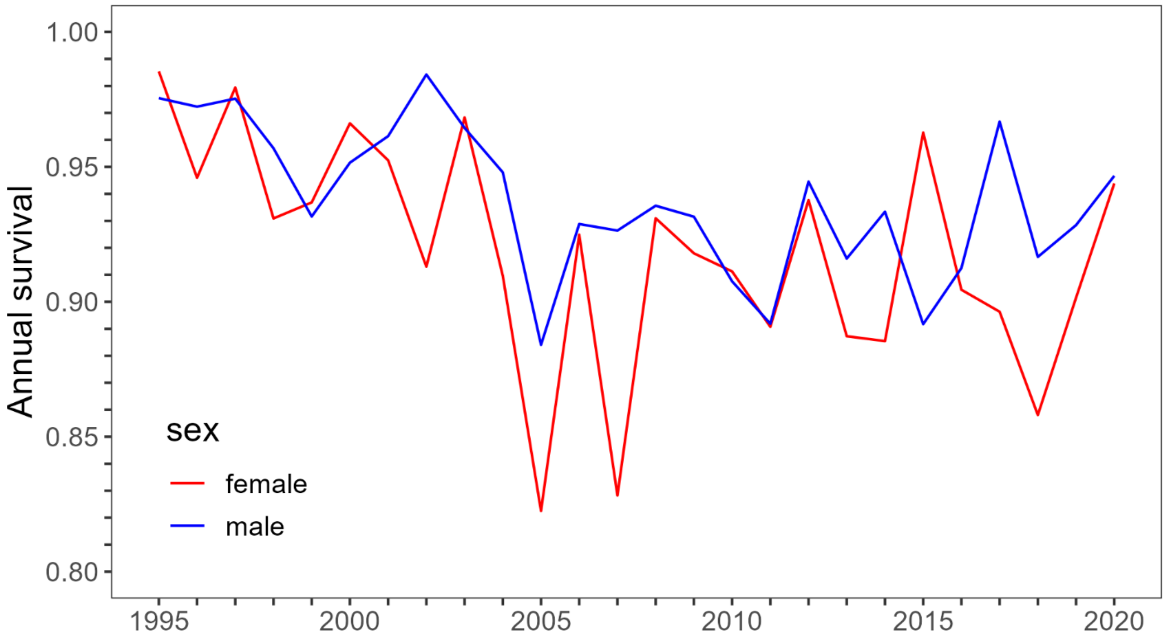

Figure 3. Annual survival of Gibson's wandering albatross in the Adams Island study area since 1995, estimated by mark-recapture. Note: survival estimates produced by mark-recapture are not reliable in the last two years of data collection and no data were collected in 2021, so survival is only shown up to 2020.

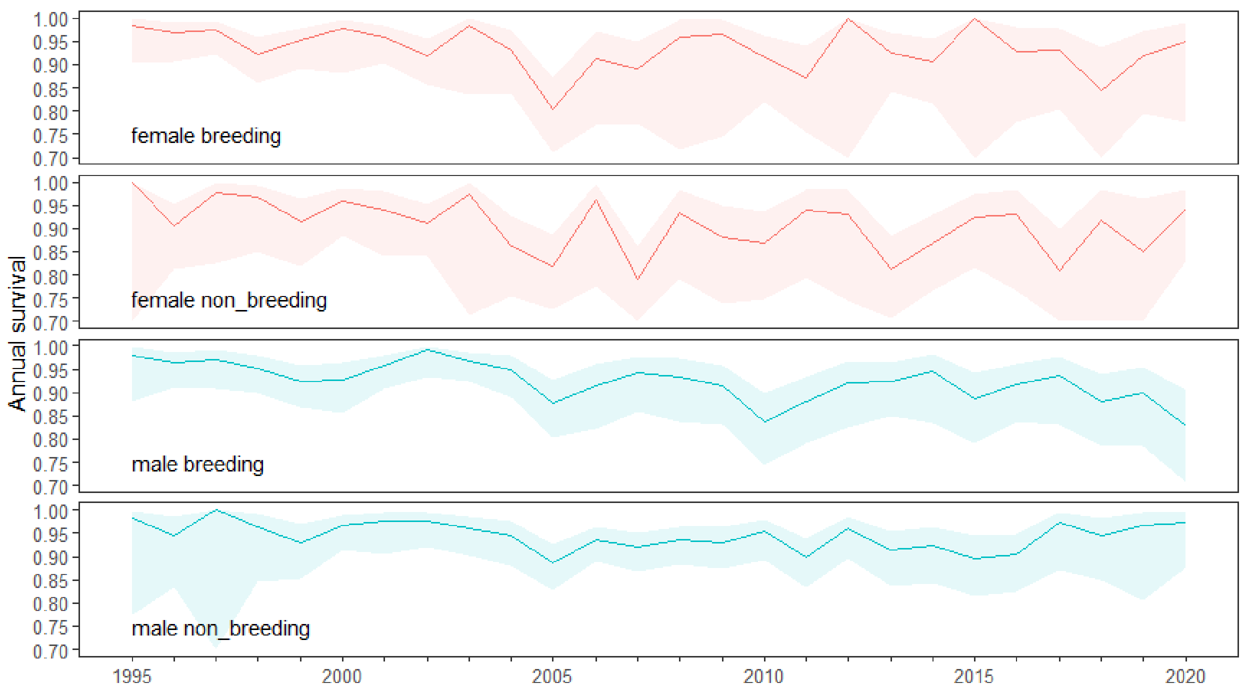

Figure 4. Survival estimated separately for breeding and non-breeding female and male Gibson's wandering albatrosses, estimated by mark-recapture with 95% confidence intervals shaded. Note: population estimates produced by mark-recapture are not reliable in the last two years of data collection and no data were collected in 2021, so survival is only shown up to 2020.

Within sexes, survival differs between breeders and non-breeders (Fig. 4). Non-breeding females have generally 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. 4).

Productivity

Breeding success was estimated as 60% in 2023 (Fig. 5, blue line); much lower than the 74% recorded in 2022 but not far below the 63% mean pre–2005 crash. The development of chicks in the 2023 season was slower and fledging later than it had been in recent years. Nesting success has been gradually rising since 2011, as has the number of chicks produced, but the latter remains lower than pre-2005 since fewer birds are breeding (Fig. 5, red line).

Figure 5. Gibson's wandering albatross nesting success and the number of chicks fledged from the study area on Adams Island since 1991.

Nest counts and estimate of nest numbers on Adams Island

The number of pairs nesting in the three representative census blocks in 2024 was the lowest it's been since 2008 (Fig. 6, Table 2). The total number of breeding pairs across the island as extrapolated from the numbers counted in the three representative blocks was accordingly also low (Table 2), with a possible gradual decline since 2016, after a slow but nearly significant rate of increase in the previous decade (Fig. 7). In 2024 there were an estimated 3,653 breeding pairs on Adams Island, considerably fewer than in 2023, and the lowest number since 2006 and 2008, which were the worst years of the population crash (Fig. 7, Table 2). In the study area a notable number of pairs that were expected to lay, did not in the end do so; that is pairs which had bred successfully in 2022 and were present at the start of the 2024 breeding season but did not breed after all.

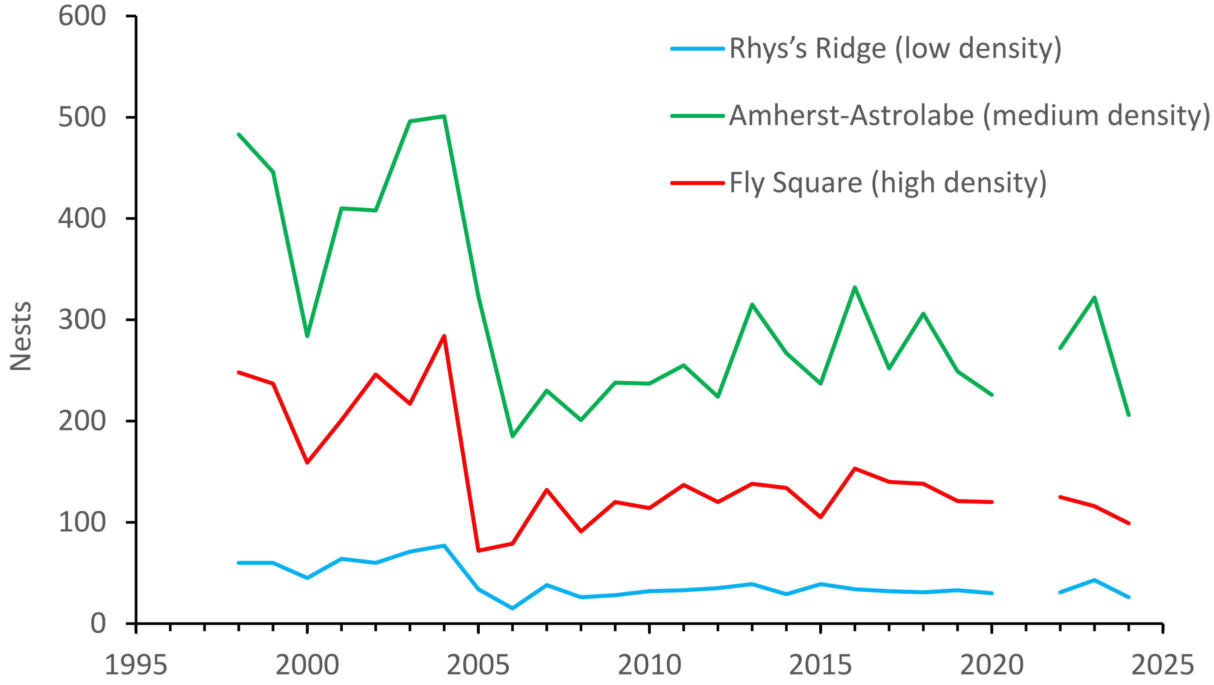

Figure 6. The number of Gibson's wandering albatross nests in three census blocks on Adams Island 1998–2024

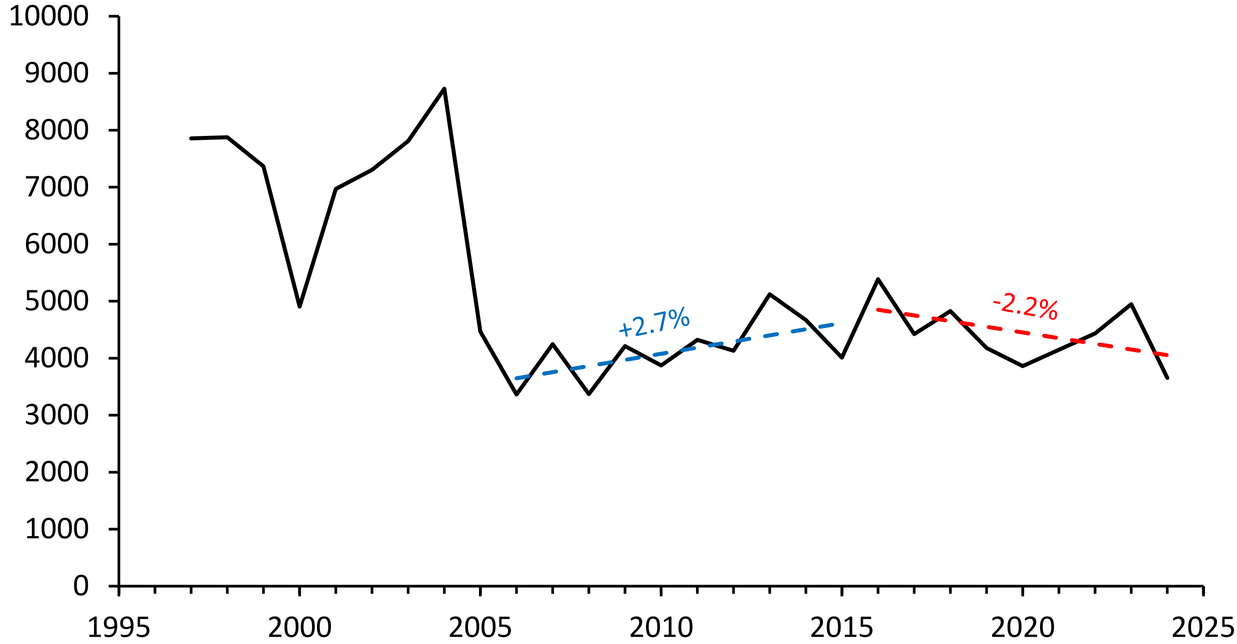

Figure 7. Total Gibson's wandering albatross nests across Adams Island 1997–2024. The estimated number of nesting pairs on the island is based on annual counts in the three census blocks, taking account of the number of failed nests and unlaid eggs at the time of counting, extrapolated using the proportion (9.87%) relative to island-wide nest totals in 1997 when the last whole island count was undertaken. The positive rate of growth 2006-2015 (dashed blue fitted line) is nearly significant while the negative rate 2016-2024 (dashed red fitted line) is not.

Table 2. Gibson's wandering albatross nests with eggs in late January in three census blocks on Adams Island, 1998–2024. 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 (the correction factor applied each year is the ratio between the 5th and 6th columns). Estimated total is the estimated number of nests on the island, based on the proportion (9.87%) 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 counted	Total corrected for unlaid eggs and failed nests	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
2023	43	322	116	481	501	4947
2024	26	206	99	331	370	3653

Drone census of nesting Gibson's albatross across Adams Island

The aerial census of Gibson's albatross was undertaken between 18 January and 25 February 2024. Persistent windy, wet and/or claggy weather in February greatly reduced the number of days in which drones were able to be flown, so 80% of all blocks were flown in 8 of the 20 days 18 Jan–6 Feb, with the remaining 20% flown in just 4 suitable days out of the 19 days 6–25 Feb.

Of the 4,040ha of albatross nesting habitat on Adams Island, 2,654ha (66%) was eventually photographed after deteriorating weather forced multiple visits to many sites. Most of the completed blocks were in the central part of the island, those being the only blocks which could be reached in the short periods of time between bad weather fronts. In total 184 of the 281 census blocks were flown and orthomosaics created from the images. A technical problem with one of the drones meant that the orthomosaics produced from some blocks were too blurry for albatrosses to be counted. Although this problem was eventually solved, there was insufficient time to re-fly 6 of the blurry blocks, so the final tally was 178 blocks (2,565ha, 63%) flown, processed into orthomosaics and counted (Figure 8).

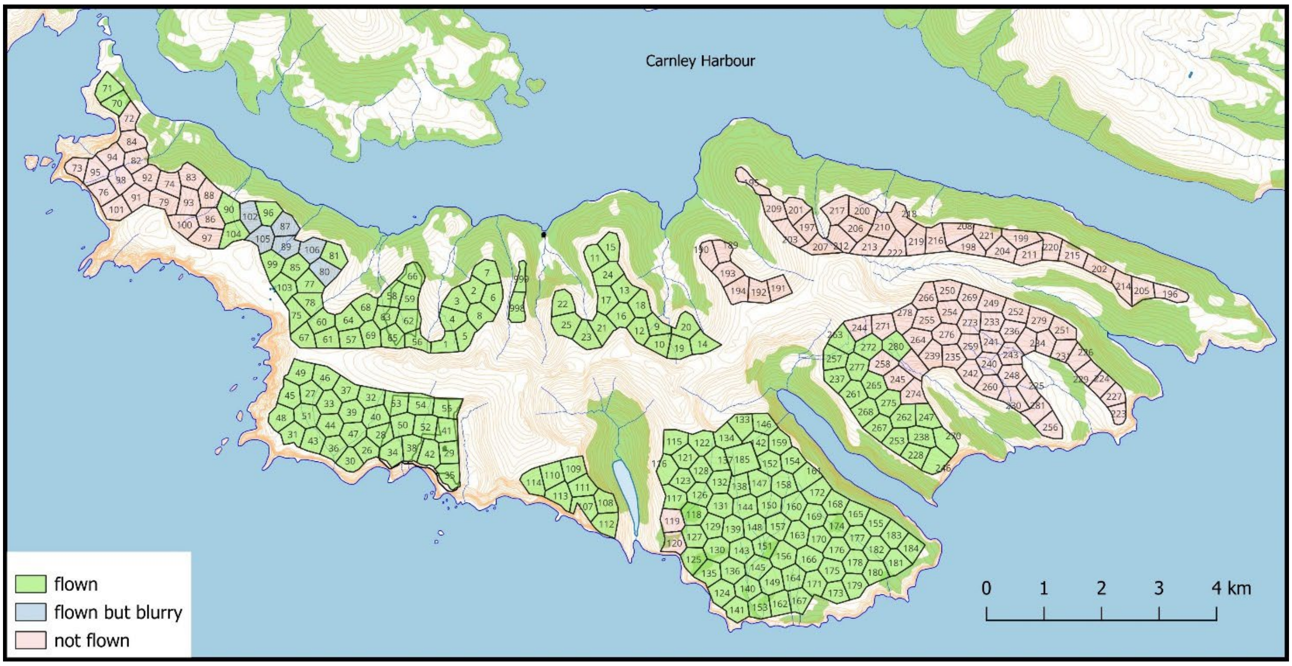

Figure 8. The 4,040ha of Gibson's wandering albatross nesting habitat (coloured areas within black borders) on Adams Island over which drone flight plans were prepared in 281 x 15ha blocks (black polygons with block number) and either not flown (pink); flown, processed into orthomosaics and counted (green); or flown, processed but too blurry to count (blue).

Ground-truthing, either by transect counts or by re-flying of already ground-counted blocks, showed considerable variation in the ratio of birds on the ground incubating an egg to all birds on the ground, the 'has-egg' rate, ranging from 0.35 to 0.88. They varied not just with area but with time of day, with the counts undertaken in the morning generally having the least inflation of the number of birds with eggs by birds without eggs (Table 3). On average 54% of birds on the ground had a nest with an egg (has-egg rate), with the rest being birds either sitting or standing without an egg.

Table 3. Birds and eggs counted during walking-transects or from calibration flights of ground counted blocks

Date, time	Place (census blocks)	Type	Bird on egg	Bird without egg	Total birds on ground	Has-egg rate (Bird on egg / total birds on ground)
18 Jan, am	Study Area (41, 55)	flight	10	4	14	0.71
21 Jan, am	Magnetic & Rhys's Ridges (1-3, 5-8, 56, 59, 62)	transect	12	18	30	0.40
24 Jan, pm	Study Area (29, 35, 42)	flight	65	34	99	0.66
25 Jan, pm	Survey Bay (57, 69, 77, 103)	transect	5	3	8	0.63
28 Jan, am	Maclaren & Fleming ridges (22, 25)	transect	7	1	8	0.88
28 Jan, pm	Maclaren & Fleming Ridges (11, 13, 15, 17, 21, 23, 24)	transect	6	11	17	0.35
2 Feb, am	Fly Square (185)	flight	99	76	175	0.57
2 Feb, pm	Fly Square (185)	flight	99	115	214	0.46
6 Feb, am	Fly Square (185)	flight	99	78	177	0.56
6 Feb, pm	Fly Square (185)	flight	99	108	207	0.48
12 Feb, am	Study Area (29, 41)	flight	31	13	44	0.70
17 Feb, am	Study Area (29, 35, 41)	flight	53	23	76	0.70
21 Feb, pm	Fairchild's (70, 71)	transect	3	4	7	0.43
25 Feb, am	Rowley's (237,247,257,261,262,265,270,272,275,277)	transect	23	35	58	0.40
Total			**611**	**523**	**1134**	**0.54**

Data from regular visits to the study area produced correction factors to account for failed nests and yet-to-be-laid eggs starting from 0.874 on 24 January, rising to 0.878 on 2 February and declining to 0.826 on 25 February. These changes fit the breeding phenology: eggs were still being laid on 24 January, so the correction factor increased, but by the time egg laying had finished some nests had already failed so the correction factor never reached 1.00 and subsequently declined after all eggs had been laid but nests continued to fail.

In total 5,559 Gibson's wandering albatrosses on the ground were counted in the orthomosaics (Fig. 9). Once correction factors were applied (for the proportion of birds on the ground which were not on an egg (Table 3) and for the proportion which had yet to lay or had failed at the time of counting), a total of 3,348 pairs were estimated to be nesting within the 63% of the island's albatross habitat censused in 2024. In 1997, the areas counted in 2024 contained 79.4% of the number of nests counted. Assuming the pattern of distribution of nesting birds on the island has remained unchanged since 1997, then the drone census suggests there were 4,181 Gibson's wandering albatross pairs nesting on the island in 2024.

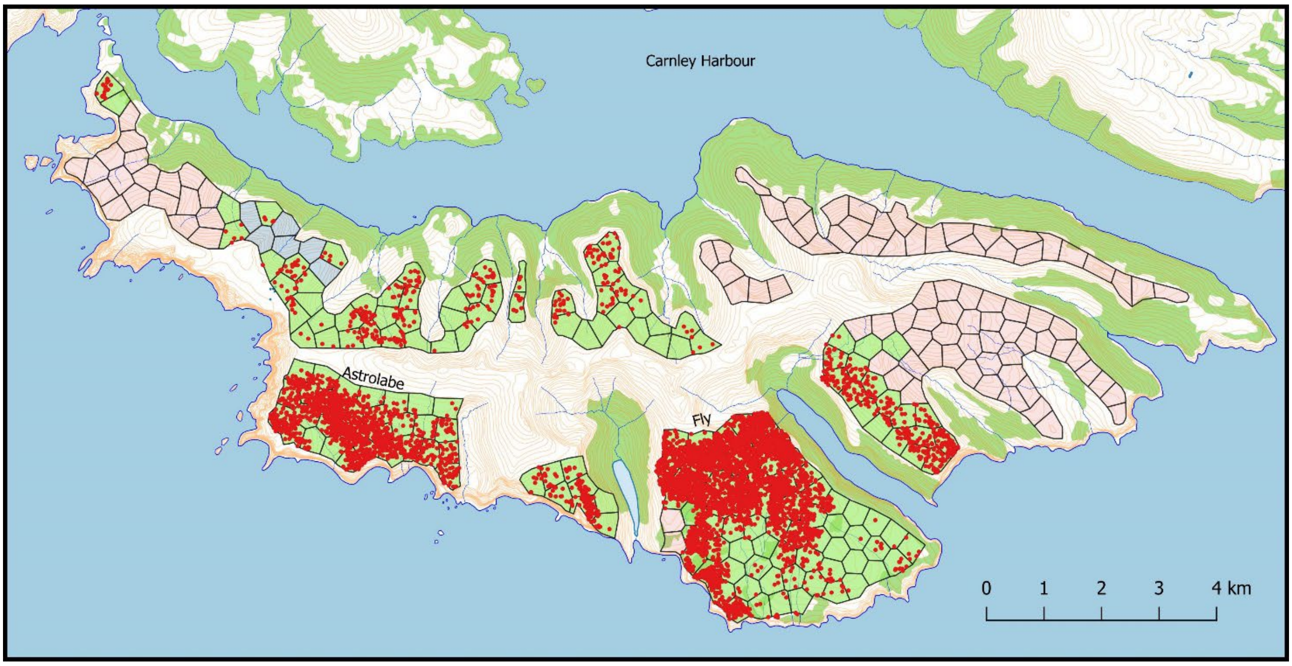

Figure 9. The location of 5,559 Gibson's wandering albatross (solid red dots) on the ground counted from drone photos of 178 blocks (green polygons) of the albatross habitat on Adams Island in January and February 2024. The remaining 103 blocks (pink and blue polygons) are still to be photographed.

At-sea distribution of juveniles in 2023

The average time to failure of 22 transmitters attached to juvenile albatrosses in December 2022 was 290 days, with the first two failures after only 28 days and 94 days at sea and the last one failing on 10 June 2024 after 540 days. The two early-failing transmitters are likely to have been caused by the death of the juvenile females wearing them due to poor condition or inexperience in the difficult early weeks after fledging. During the winter and early spring of 2023, several young females may have been accidentally killed in fisheries bycatch. On 19 July 2023 the transmitter being worn by Black-85H stopped when the bird was north of North Cape within 36 km of Taiwanese long-liner *Kinemaru No. 135*. On 15 September 2023 the transmitter on Black-78H stopped when the bird was over the Mooloolaba seamount east of Queensland, within 20 km of Australian long-liner *Emnicus*.

The foraging distribution of the juveniles tracked in 2023 (Fig.10) was more northern and eastern and less south-western than the distribution of adults (compare Fig. 10 with Figs 11 & 12). Of the 35,000 fixes received from juveniles in 2023, 2.4% were north of 30°S whereas only 0.6% of the 76,000 fixes received from adults in 2019–2024 were north of 30°S. One juvenile, Black-83H, foraged as far north as 22°S, just south of Tonga. There appeared to be a greater concentration of activity around the Chatham Rise amongst juveniles than adults, though much of this activity was by only two young females.

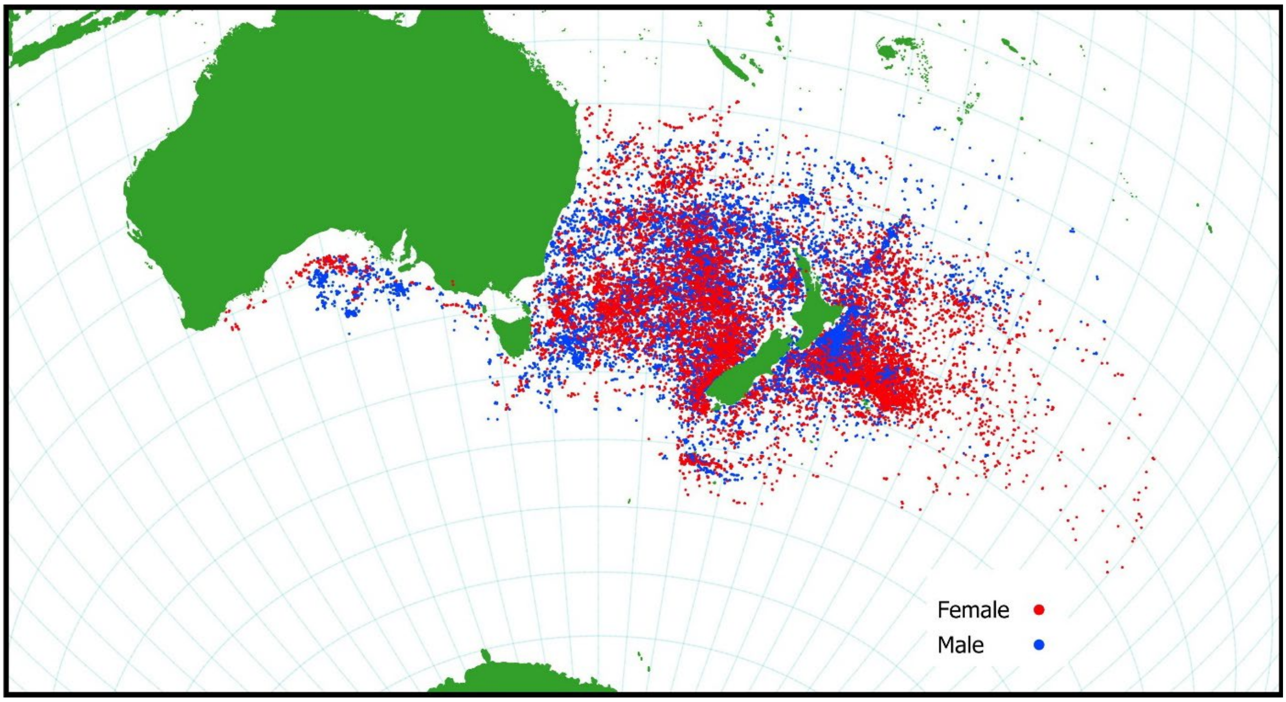

Figure 10. Satellite fixes from 22 juvenile Gibson's albatross tracked between December 2022 and June 2024.

At-sea distribution of adults in 2024

Of the 20 satellite tags attached to adults in December 2023 and January 2024, 13 were still transmitting in mid-August 2024 (Fig. 9). Overlaying the location of each bird at the time of its final satellite transmission and the location of fishing vessels via Global Fishing Watch strongly suggested the breeding female Red-99J was caught in the mid-Tasman on 11 June 2024 by the Taiwanese long liner *Fong Chun* as her satellite transmitter abruptly stopped transmitting only 200 metres from this vessel.

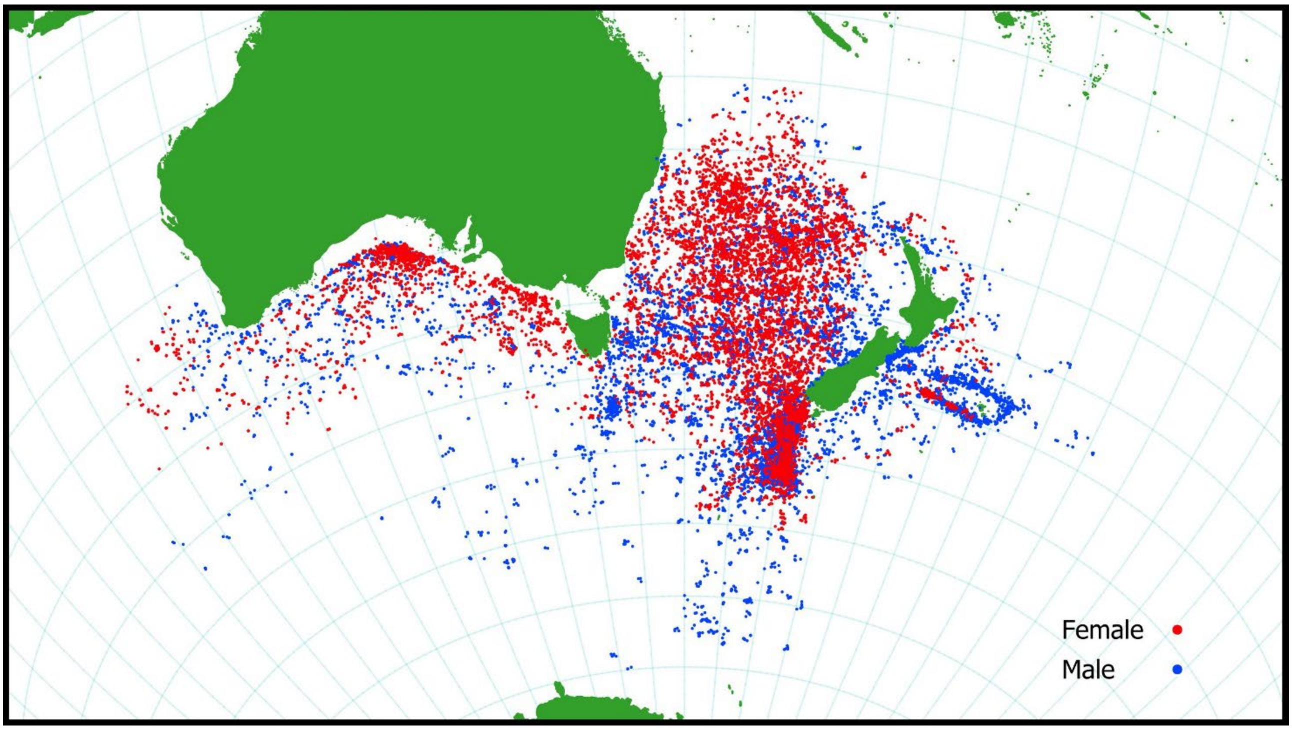

Figure 11. Satellite fixes from 20 adult Gibson's albatross tracked between December 2023 and August 2024.

In January–August 2024 there was more use by adult females of the Great Australian bight and the shelf break off South Australia (Fig. 11) than was recorded in adult females tracked by satellite at the same time of year, January–August, in the period 1994–2022 (Fig. 12).

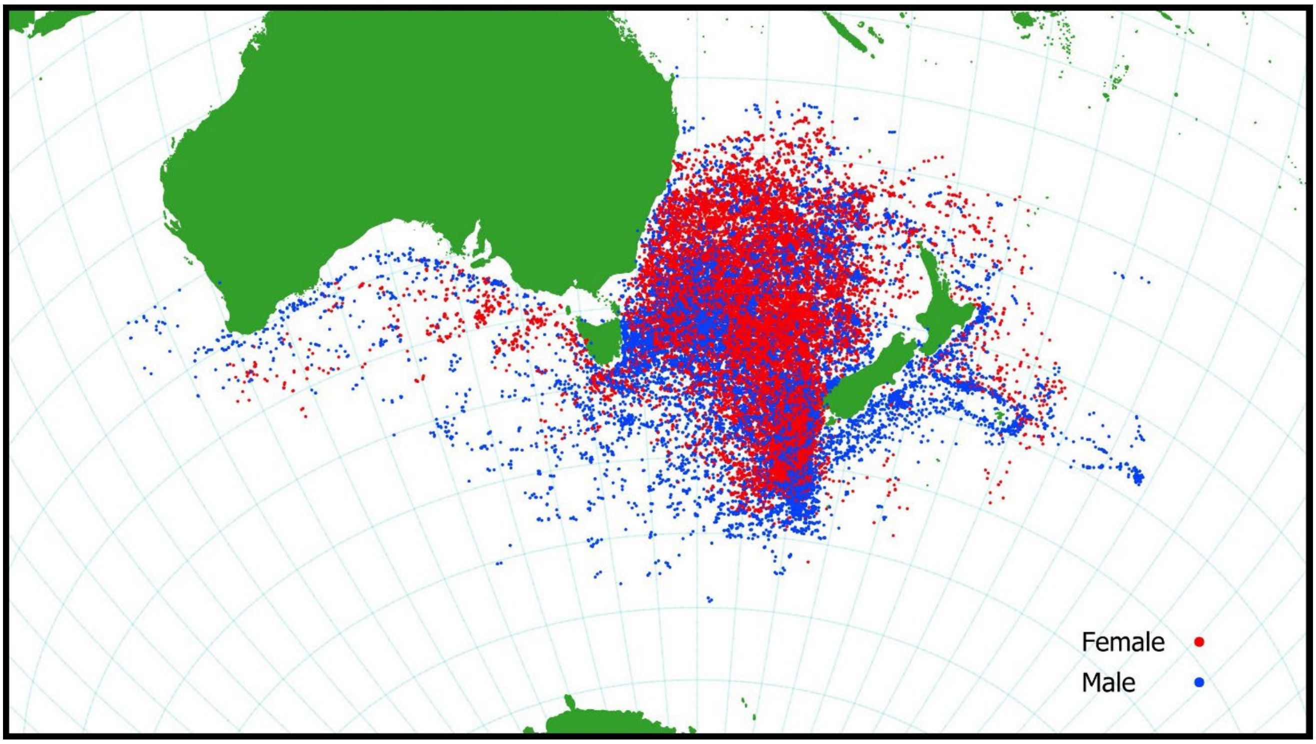

Figure 12. Satellite fixes from 125 adult Gibson's albatross tracked in January–August between 1994 and 2023.

DISCUSSION

Population trajectory

The number of Gibson's wandering albatross pairs breeding in 2024 were the lowest since 2006 and 2008, the worst two years of the population crash. This in part will be the result of high numbers breeding in 2023, and unfavourable conditions at sea in mid-late 2023, judging from the late departure of chicks from Adams Island in December 2023, and the number of pairs who arrived on Adams Island for the 2024 breeding season but departed without breeding. As well as reflecting annual variation, the low numbers in 2024 may indicate a new period of decline. In the decade following the 2005 population crash, the number of breeding pairs grew at a nearly significant rate, but since 2016 has started to fall (Figs 6, 7; Table 2). While it will take a few more years to be sure there is really a new decline, such a decline has been anticipated given Gibson's albatross demography.

Demographic factors influencing population trajectories are increasingly well understood (Walker et al. 2023). The slow increase in the number of nesting Gibson's wandering albatrosses between 2006 and 2015 can be attributed to a recovery in the proportion of females breeding. Prior to 2006 about half the adults bred, but in 2006 this dropped to less than 30% and then between 2006 and 2012 it recovered to close to pre-2006 levels (Elliott et al. 2018). Once the proportion of females breeding returned to around normal, however, further increase in the number of nests could only arise from increased recruitment and survival, and the slow decline since 2016 is likely partly the result of a shrinking pool of new recruits. Wandering albatrosses start breeding at about 12 years old, so most birds joining the breeding population now were produced during the 2006–2012 period when chick production was very low (Fig. 5).

Survival of female Gibson's wandering albatrosses also showed a slowly declining trend between 2016 and 2020 (Fig. 3). Although survival gradually improved between 2006 and 2015, the most recent estimates of adult female survival (82% in 2019, 94% in 2020) remain substantially below the average pre-crash survival rate and is low for such a K-selected species (Weimerskirch & Jouventin 1987; Véran et al. 2007). The most recent mark-recapture estimates of population size indicate that the population is declining, not stable as nest counts had formerly suggested. Unfortunately, the data gap in 2021 is still preventing the provision of any reliable survivorship estimates since 2020. Survivorship estimates by mark recapture are unreliable and not usually presented for at least one and usually two years immediately prior to the most recent measurement, so normally only the 2022 survival estimate would have been presented here. However, in the absence of knowledge as to the breeding status of the birds in 2021, the 2022 and 2023 estimates lack credibility and are not comparable with earlier data, so one more year is needed before an updated survival estimate can be calculated.

Richard et al. (2024) developed a population model for the closely related Antipodean wandering albatrosses (from here, the Richard model) and this model was explored to assess its suitability for estimating survival and population size of Gibson's wandering albatrosses. However, close inspection of the Richrd model revealed it assumed the detectability of adult male and female albatrosses was the same, whereas analysis using program Mark showed that in both Gibson's and Antipodean wandering albatrosses, detectability of sexes is substantially different, with female detectability lower than that of males. As a result, survival estimates made using the Richard model will be biased. While it is possible to modify the Richard model to incorporate separate estimates of male and female detectability, this has not yet been done as it offers no substantial advantages over the program Mark approach used in this study since 2005 (Elliott & Walker 2005). One potential advantage of the Richard model is that it estimates the survival of pre-breeding birds. However, program Mark can also make these estimates, though this capacity has only infrequently been used in this study. The Richard model uses Bayesian methods in the program STAN (Carpenter et al. 2017) but in the absence of informative priors these methods produce very similar results to the maximum likelihood methods implemented in program Mark. Thus, there seems no particular reason to favour using the Richard model over the Mark models used in the past, and the Mark models run more quickly. However, the Richard model has one great advantage in provision of a Graphical User Interface for exploring the likely future effect of changes in albatross productivity and survival(https://docnewzealand.shinyapps.io/Antipodean_albatross_IPM/).

At sea distribution

The discovery in 2023 that juvenile Gibson's wandering albatross spend much more time than do adults in tropical waters north of 30° S (2.4% of time, compared to 0.6%) is in line with patterns in Antipodean albatross and other species of wandering albatross. This is concerning given the intensity of long line fishing activity in these tropical waters during winter months. Juvenile Gibson's wandering albatrosses also appear to spend more time northeast of New Zealand than do adults, in a zone in which a relatively high rate of capture of young Antipodean wandering albatross had previously been recorded (Walker & Elliott 2022). Three female Gibson's wandering albatross (two juveniles and one breeding adult) wearing satellite transmitters may have been captured by long-line vessels fishing for tuna. The adult female Red-99J, whose capture seems the most certain being only 200m from a Taiwanese vessel when her transmitter stopped, was foraging in the mid Tasman Sea, while the potential capture of juvenile Black-85H occurred north-east of New Zealand and the other juvenile Black-78H off the coast of Queensland. Given the small number of Gibson's albatross fitted with satellite transmitters in 2023 (22 juveniles) and 2024 (20 adults), to suspect 3 met early deaths in fishing equipment is concerning.

Size of the breeding population

A drone-based census of all 4,040ha of albatross habitat on the island was challenging, as anticipated, given the very large size of Adams Island, its height and elongated shape combined with near-continuous misty, wet, and windy conditions in the tussock and fellfield in which most Gibson's albatross nest.

Despite these challenges, drone coverage of 63% of the albatross habitat was achieved, including the two largest and densest colonies, Fly Basin and Amherst Basin. As the drone blocks matched the ground census blocks used in 1997 it was possible to determine that the 2,565ha of albatross habitat droned in 2024 supported just under 80% of the population in the last whole island census in 1997. On the assumption that the number of pairs nesting in 2024 in the area which was unable to be droned had the same proportionate decrease since 1997 as the 63% of the island which was droned, an estimated 4,181 pairs were nesting on Adams Island in 2024.

While it may be tempting to compare this estimate with that from 1997, and subsequent estimates based on the 1997 count (Table 2), we caution against doing so. Method changes since the last whole-island count, most obviously the use of drones, satellite imagery and GPS, will have changed detection rates to an unknown extent, so comparison with the 1997 whole-island count would not be meaningful.

The use of satellite imagery and drones in 2024 brought the discovery of an area of albatross habitat seaward of dense scrub near Cape Thomson which was unknown so not counted in the 1997 census. Drones were also key to locating many widely scattered albatross nests hidden in the extensive scrub-filled southern portion of Fly Basin, many of which would have been missed in 1997 as it was counted from vantage points with binoculars.

Conversely, in 2024 albatross census via drone-derived aerial photographs brought with it a major new source of error: its inability to distinguish birds on eggs from birds on the ground without an egg, an error only partially moderated by concurrent ground-truthing. Ground-truthing revealed 54% of Gibson's wandering albatrosses on the ground were breeding birds incubating an egg, and this has-egg rate varied substantially from 35% to 88% between sites, and when repeated at the same sites, by date and time of day (Table 3).

On the island's northern slopes which support only sparse albatross populations, transect-based ground-truthing was used and it was difficult to get large enough samples there to not be strongly affected by chance. On the southern slopes where populations were denser, repeat droning of either the

Study Area or the Fly Square census block which had been intensively ground-counted were used instead of transects, and gave higher sample sizes (Table 3). With the relatively modest level of ground-truthing undertaken, the representativeness of the areas chosen for ground-truthing was sometimes an issue; that is exposed windy areas with short tussock often contain a higher proportion of courting than breeding birds, and in taller more sheltered tussock zones, the reverse. This was particularly noticeable on Rowley's Ridge where a transect made on the more exposed eastern slopes found many birds on the ground, very few of which were on an egg (42 birds, 9 of them on eggs), while at the same time on a transect in deeper tussock on the western side of the same ridge there were fewer birds but almost all birds encountered were on an egg (16 birds on the ground, 14 of them on eggs). Whether a transect was representative or not of the range of nesting densities in a block was to some extent a matter of chance.

Planning is underway to complete the drone-based whole island census in mid-late January 2025, focussing first on the 1,475ha of Gibson's wandering albatross nesting habitat which was not photographed in 2024. Most of the 103 x 15ha blocks involved are at the far eastern or far western end of Adams Island so success will be dependent on suitable weather coinciding with boat transport availability. As the number of pairs breeding varies from year to year, often substantially, some of the areas counted in 2024 will be re-censused in 2025 to provide an index of the differences in albatross numbers due to interannual variation. Most blocks which remain to be counted are on northern or western facing slopes which are less favoured by the albatrosses so support only 20% of the population, despite comprising 37% of all the areas used by Gibson's albatross. That the majority of the population have been censused is fortunate, given resource constraints limit the extent of re-census /overlap possible in 2025. In other words, successful census in 2024 of the extensive gentle southern-facing slopes in which the largest proportion of the Gibson's wandering albatross population nest in the dense Astrolabe and Fly colonies has limited the problem caused by splitting the census over two years.

Performance of the new drone census technique

The census of Gibson's wandering albatross on Adams Island was undertaken at the same time as a similar census was being undertaken on Antipodes Island of Antipodean wandering albatross(Rexer-Huber et al. 2024), and some key differences in results provide useful information as to the situations where this drone-based technique works best. There is a considerable disparity in size and shape of the two islands, with large, elongated Adams Island containing 4,040ha of mostly high altitude (250–450m asl) albatross habitat (368 x 15ha drone count blocks), while small and compact Antipodes Island contains 1,546ha of mostly low altitude (100–350m asl.) albatross habitat (143 x 11ha drone count blocks). Despite this disparity in size, about the same number of breeding pairs are present on both islands, with those on Antipodes Island spread rather evenly across the whole island, and much more patchily on Adams Island. These geographic characteristics affected the drone census in several ways.

On Adams Island ground-truthing of drone-photographed census blocks suggested a lower proportion of albatrosses present had eggs than did ground-truthing on Antipodes Island (Adams I. mean 54%, range 35-88%; Antipodes I. mean 70%, range 49-87%). However, this difference was more apparent than real. To ensure coverage was achievable in the time available, drones were programmed on very large Adams Island to fly at a greater height than on smaller Antipodes Island, making it more difficult, particularly for inexperienced counters, to determine on the resultant drone photos from Adams Id if birds were standing or sitting, let alone sitting on a nest. As a result, the Gibson's albatross uncorrected count was simply of all "**birds on the ground**". A lower drone height was set on Antipodes Island primarily to provide enough resolution to be able to spot female Antipodeans, which unlike Gibson's, have very dark plumage. A single very experienced observer counted all the Antipodes drone photos. As a result, the Antipodean albatross uncorrected count was of "**apparently nesting birds**", as those standing or sitting but not on a nest were able to be identified and excluded from the initial count, so that a smaller proportion of the those that were included were pretend breeders.

On Antipodes Island the whole island count of 3,383 breeding pairs in 2024 was close to the estimate of 3,101 pairs made from extrapolation of annual ground counts in 15% of the island, whereas on Adams Island the whole island count of 4,181 in 2024 was considerably higher than the estimate of 3,653 pairs made from extrapolation of annual ground counts of 10% of the island. The apparently higher accuracy of the 2024 Antipodes Island census is probably real and due to nearly 50% of the count coming directly from high quality ground-based census and only 50% from drone counts with their associated pretend-breeder error. In contrast, on Adams Island only 9% were high quality ground counts and 91% drone counts so the opportunity for variation due to chance was much higher. In addition, the original 1997 count on Adams Island was likely less accurate than that on Antipodes Island, simply because the comparatively large scale and difficult physical nature of Adams Island makes finding every albatross extremely hard to achieve.

Although there is error inherent in drone counts, this does not mean that drone census is unsuited for counting the number of breeding pairs on Adams Island. Drone-related error is probably of a similar scale, just of a different type, to that affecting ground-counts of such a big and inhospitable island.

RECOMMENDATIONS

Although the demography of Gibson's albatross gradually improved in the decade following the 2005–06 crash, over the last 8 years this improvement has stalled, with the population at best stable but showing signs of decreasing. Monitoring the size of the population and its structure and trend on Adams Island remains a priority, as does more tracking to better understand the overlap and interaction of Gibson's albatross with long line fishing fleets to help understand causes of population changes.

Population **trends** are best assessed from the mark-recapture study, and from the counts of parts of the island that are easy to census accurately and have been repeatedly censused.

To obtain an updated population **size** estimate, census of the nesting population on Adams Island using drones showed the technique worked well and should be completed next summer

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REFERENCES

BirdLife International 2018. *Diomedea antipodensis*: BirdLife International: The IUCN Red List of Threatened Species 2018: e.T22728318A132656045. https://www.iucnredlist.org/species/22728318/132656045(accessed 6 May 2023).

Carpenter B, Gelman A, Hoffman MD, Lee D, Goodrich B, Betancourt M, Brubaker MA, Guo J, Li P, Riddell A 2017. Stan: A probabilistic programming language. Journal of Statistical Software 76.

Department of Conservation 2022. Conservation Services Programme Annual Plan 2022/23. Wellington, Department of Conservation. 99 p. (Accessed 23/May 2024) https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/plans-and-submissions/202223/final-csp-annual-plan-2022-23.pdf

Elliott G, Walker K 2005. Detecting population trends of Gibson's and Antipodean wandering albatrosses. Notornis 52(4): 215.

Elliott G, Walker K, Parker G, Rexer-Huber K 2016. Gibson's wandering albatross census and population study 2015/16. Wellington., Report on CSP Project 4655, Department of Conservation. 19 p.

Elliott G, Walker K, Parker G, Rexer-Huber K 2018. Gibson's wandering albatross population study and census. Unpublished Report for the New Zealand Department of Conservation (16 p)

Elli**ott GP, Walker KJ, Parker GC, Rexer-Huber K, Miskelly CM 2020.** Subantarctic Adams Island and its birdlife. Notornis 67(1): 153–187.

Laake JL 2013. RMark: an R interface for analysis of capture-recapture data with MARK. https://apps-afsc.fisheries.noaa.gov/Publications/ProcRpt/PR2013-01.pdf (accessed 6 May 2023).

R Core Team 2023. A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/(accessed 23 Maty 2024).

Rexer-Huber K, Elliott G, Walker K, Thompson D, Parker G 2020. Gibson's albatross and white-capped albatross in the Auckland Islands 2019–20. Wellington, Prepared by Parker Conservation for Department of Conservation. 30 p. (Accessed 23 May 2024) https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/reports/final-reports/pop2017-04-auckland-island-seabirds-research-final-report-2019-20.pdf

Rexer-Huber K, Whitehead E, Parker G, Patterson E, Walker K, Welch J, Elliott G 2024. Antipodean wandering albatrosses and white-chinned petrels 2024. Prepared by Parker Conservation for the Department of Conservation. 30 p.

Richard Y, Abraham ER, Berkenbusch K 2020. Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006-07 to 2016-17. New Zealand Aquatic Environment and Biodiversity Report 237. Wellington, Ministry for Primary Industries. 57 p.

Richard Y, Berkenbusch K, Crawford E, Tornquist M, Walker K, Elliott G, Tremblay-Boyer L 2024. Antipodean albatross multi-threat risk assessment. New Zealand Aquatic Environment and Biodiversity Report No. 332.62 p.

Robertson HA, Baird KA, Elliott G, Hitchmough R, McArthur N, Makan T, Miskelly C, O'Donnell CF, Sagar PM, Scofield RP 2021. Conservation status of birds in Aotearoa New Zealand, 2021. Department of Conservation, Te Papa Atawhai. 43 p.

Véran S, Gimenez O, Flint E, Kendall WL, Doherty Jr PF, Lebreton J-D 2007. Quantifying the impact of longline fisheries on adult survival in the black-footed albatross. Journal of Applied Ecology 44(5): 942–952.

Walker K, Elliott G 1999. Population changes and biology of the wandering albatross *Diomedea exulans gibsoni* at the Auckland Islands. Emu-Austral Ornithology 99(4): 239–247.

Walker K, Elliott G 2005. Demographic parameters of Gibson's albatross (*Diomedea gibsoni*). Wellington, Conservation Services Programme, Department of Conservation. 32 p.

Walker K, Elliott G 2006. At-sea distribution of Gibson's and Antipodean wandering albatrosses, and relationships with longline fisheries. Notornis 53(3): 265–290.

Walker K, Elliott G 2022. Antipodean wandering albatross satellite tracking and population study on Antipodes Island in 2021 and 2022.

Walker K, Elliott G, Rexer-Huber K, Parker G 2017. Gibson's wandering albatross population study and census. Wellington, Department of Conservation. (Accessed 23 May 2024) http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-conservation-services/reports/gibsons-albatross-adams-island2017-finalreport.pdf

Walker K, Elliott G, Parker G, Rexer-Huber K 2023. Gibson's wandering albatross: population study and assessment of potential for drone-based whole-island census. Wellington, Department of Conservation. (Accessed 23 May 2024) https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/reports/202223-annual-plan/pop2022-08-gibsons-albatross-final-report.pdf

Walker N, Smith N, Sharp B, Cryer M 2015. A qualitative review of New Zealand's 2013 level two risk assessment for seabirds. New Zealand Fisheries Science Review 2015/1. Wellington, Ministry for Primary Industries. 53 p.

Weimerskirch H, Jouventin P 1987. Population dynamics of the wandering albatross, Diomedea exulans, of the Crozet Islands: causes and consequences of the population decline. Oikos 315–322.

White GC, Burnham KP 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46(sup1): S120–S139.

APPENDIX 1: LESSONS ON EFFICIENT LARGE-SCALE FIELD USE OF DJI MAVIC 2 PRO AND MAVIC 3E DRONE

Note these lessons do not include any of the standard CAA Rule 101 requirements, as it is assumed that drone pilots will already know and abide by these rules.

1. Preparation

Getting hardware

- If working remotely, take **back-up units of key equipment** e.g. generator (for charging drone batteries) and Starlink unit (for internet to e.g. upload footage for stitching while in the field).
- Take enough drone **batteries** and gang **chargers** to allow for 2 full consecutive days of work in weather windows, so you aren't limited by inability to re-charge all drained batteries before the second day.

In 2024:

  - Each Mavic 2 Pro (hereafter "M2") was able to fly ~1.5 15ha blocks per fully charged battery on a calm day, and ~0.5 of a 15ha block per battery on a very windy day.
  - The Mavic 3E (hereafter "M3") was able to fly ~2 15ha blocks per fully charged battery on a calm day, and ~1 15ha block per battery on a very windy day - but note in 2024 the M3 was used to fly the most distant blocks, so this includes more travel time than the M2 numbers above.
  - We had 23 M2 batteries and 8 M3 batteries, but only the charger capacity to charge 6 M2 batteries and 1 M3 battery simultaneously.

If we arrived home at 2130 hours after a long day having fully drained the batteries, we weren't able to charge all the batteries in time to take them up the hill by 0800 the next day.

- For each drone, take into the field:
  - 1 **powerbank** with PD (Power Delivery: means it can charge the controller fast enough to keep ahead of the batteries being drained)
  - 2 **USB-A to micro-USB-B** cables
  - 2 **USB-A to USB-C** cables
  - 1 set of spare **rotor blades**
  - 1 **SD card** for the drone and at least one spare (64GB was adequate for M2 flying up to 15 8ha blocks, but at least 128GB recommended for M3 flying up to 8 30ha blocks. Note card also needs to have a read/write speed fast enough to maintain constant photo rate)
  - 1 (~500 GB) **SD card** for a mobile phone, if you're using mobile phones as backup field data storage

  - 1 USB-C **SD card reader** (for use in a mobile phone) and ideally a spare
  - 1 **mobile phone** with required **apps** (e.g. DJI Go, UGCS) downloaded on it. Have some additional backup phones across the team with the required apps downloaded in advance
  - Sufficient **drone batteries** for the day's work
- We recommend taking an **anemometer** to collect accurate and detailed information on wind speed limits for flying drones (see *Planning a day's fieldwork* section below).
- **Safety glasses** are recommended for pilots if field conditions (e.g. ubiquitous tall tussock) require launching the drone from your hand and catching it at the hover.

Getting software and data inputs

- Download **software** – we used a combination of DJI Go 4, UGCS, Drone Deploy and QGIS. DO NOT set either DJI Go 4 or UGCS (or another drone app) as the default to open when you plug in the controller, otherwise it can be difficult to access the other drone apps.
- Make sure you have an adequate **Digital Elevation model** (DEM) – you need a **local copy** of it in case you lose internet access e.g. if Starlink unit breaks.
- Check you have suitable **subscription** to the software e.g. a Drone Deploy subscription that will allow you to upload the quantity of data you expect to collect.
- Set up a **system for managing data**, including flight planning, collected footage, stitching, and orthomosaic analysis progress and results. In 2024 we used an MS Excel spreadsheet with macros to check a data storage folder for the existence of folder/file names for each orthomosaic and count results, and automatically update the spreadsheet accordingly.

Making flightplans in QGIS

- We used **QGIS** (https://qgis.org/en/site/) geographical information system software and **UGCS** (https://www.ugcs.com) mission planning software to plan flights.
- A video explaining the workflow is accessible at https://1drv.ms/v/s!AiNWzBTALBEMhdATJU89-oLmsG6dtw?e=E8Hzei
- The steps in the process are:

1. In QGIS, draw a **polygon** delineating the area in which albatrosses nest, with a projected coordinate reference system e.g. EPSG: 3788 NZGD2000 / Auckland Islands TM 2000, and with an attribute field for the polygon's **area in hectares**
2. Calculate the area of the polygon and divide by **15** (or other size as appropriate, in 2024 15 ha was the size of each block for an M2, and two of these could be combined to create a 30 ha block for an M3) to get the **number of flight plans** that will be needed to cover the block.
3. Generate a large number of random points (>1000) inside the overall albatross habitat area polygon using the **random points in a polygon tool**.

4. Use the **k-means clustering tool** to cluster the random points into the number of flight plans you want to produce (as calculated in step 2).
5. Use the **aggregate tool** to aggregate the k-means clustered points according to their Cluster_ID.
6. Use the **centroids tool** to calculate the centroids of those clustered points.
7. Use the **generate voronoi polygons tool** to create polygons around the centroids with a buffer of 150-200%.
8. Use the **clip tool** to clip the voronoi polygons by the original albatross habitat area polygon to create polygons of approximately 15 ha to use as the boundaries of flight plans.
9. Convert the 15 ha polygons to a raster using the **convert map to raster tool**. Set map units per pixel to 1 and select "make background transparent". Set the extent to the extent of the clip layer you created in step 8.
10. **Export the raster as a tiff file**. Tick "Rendered Image" and use the CRS EPSG 4326 WGS84.
11. Then leave QGIS and open **UGCS**. Create a **new mission** and give it a useful name (i.e. one that relates to the location of the flight plan blocks you're going to populate it with)
12. Create a **new route** within the mission and give it a name that relates to the flight plan block you're going to make. Select the correct drone type, and **set "Action on loss of RC" to "continue"**.
13. Import the **tiff file** of the 15 ha block polygons. Click on the "map options" icon near the top right. Click "map layers". Click "add" and give it a useful name. Click on the name of the map you've just created and click on "upload". Navigate to the tiff file you just made and it will upload. Click on the "set overlay" arrow and it will add the tiff file to the map as an overlay.
14. Use the **photogrammetry tool** to create a flight plan by drawing a polygon just outside the boundaries of one of the 15 ha block polygons.

Don't get too close to **cliff edges** (due to DEMs being less accurate at these locations, leading to collision detection requiring a manual take-over which wastes a lot of battery and risks losing the drone).
Avoid including areas that aren't necessary to include, to save on batteries (e.g. any areas that aren't albatross habitat).

15. Give the flight plan **appropriate specifications**. In 2024 we used:
    - 1.5cm resolution
    - Adaptive bank turns
    - 65% overlaps
    - 7.5m/s flight speed
    - No overshoots
    - Altitude mode AGL
    - Camera by distance

Make sure you set the **flight speed** correctly! This is very important – double-check! The default setting is much less than the maximum, so uses far more battery life and field time. The flight speed for an M2 should be 7.5m/s when taking pictures, and 15m/s when travelling to/from the starting point.
Make sure to set it to **continue with the task if the drone loses contact with the controller** (e.g. due to rocky outcrops between pilot and drone), if this is appropriate for the site and task.
Consider if you want to set it to return to home once task is complete. In 2024 we set it to **hover once task was complete but return to home when battery was due to run out**, so that if it still had battery left after a task we could upload a new route while it hovered and send it off without wasting battery returning it to home, but this might not always be appropriate.

16. Add **take-off and landing waypoints** as per the video linked above. Put them in a likely place, though their exact location doesn't matter, they're only included so that you can factor "commute" distances into the flight length.
17. Once the flight plan has been calculated, for M2s check that its flight length does not exceed **20 minutes** (including the flight time to get to and from a takeoff point) and that it has fewer than **99 waypoints**. This is not a concern for M3s. You can manipulate the flight length and number of waypoints by adjusting the flight direction and changing the AGL tolerance.

Factor in **predominant wind**, **topography**, and where drone **pilot** is likely to stand (Make flightplans with start point furthest away (e.g. bottom of slope) so that if the drone runs out of battery partway through, it is closer to where pilot is likely to be standing so less battery is wasted coming home and then getting back to the restart point).

18. **Delete the takeoff and landing points**.
19. **Upload the route to phones** being used for drones and all back-up phones: connect the phone (with UGCS for DJI app downloaded on it) and computer to the same wi-fi network (this can be the phone used as a hotspot), then plug the phone into the computer with a USB cable. Open the UGCS for DJI app on the phone and click on the 3 dots in the bottom bar. Click on the UGCS server tab, scroll to each flight plan and click on the '…' icon, then on 'Make available offline'. After a flight plan has downloaded it should appear under the 'Local' tab
20. Double-check that each phone has **local copies** of the flight plans saved on the phone itself: open UCGS app, click on 'Open route' icon, click on 'Local' tab and check if the necessary flight plans are listed. If they are not, repeat the process in step 19.

Note if you've already downloaded a flight plan to a phone and that flight plan is then altered in the desktop UCGS software, the local copy will need to be deleted from the phone and the new version downloaded.

Initial one-off drone set-up

- Set up the controller to **disable superfluous buttons**, so that you don't accidentally make the drone do things you don't want it to do (e.g. making the camera point upwards without realising it by fumbling the controller with cold hands in thick gloves).
    - Some can be disabled in the app (e.g. DJI Go) or set to an innocuous setting that won't matter if you bump it on.
    - Others might need to be taped over with electrical tape (e.g. in 2024 the M2 controller wheel on the right was taped over).
- Set the app (e.g. DJI Go, UGCS) **settings** as you want them, including focus method, ISO, shutter speed, footage type, storage location (store to SD card, not internal storage as this isn't big enough).

The settings we used in 2024 were:

- Focus method: autofocus – continuous (AF-C)
- ISO: 100
- Shutter speed: 1/1000
- Aperture: auto
- Storage location: SD card
- Footage type: still photo

Planning a day's fieldwork

- Make an **IMG or KML file of all the flight block boundaries** and download it to field team's GPS devices or phone apps respectively, so that drone pilots and ground-truthers in the field can easily see where they are in relation to the blocks. If you want to see the names of the blocks then make sure there are fields in the KML with the headings "name" and "id" (must be in lower-case) that contain the names of the blocks.
- **Check the forecast** weather conditions for:
    - **Wind** – strong wind and gusts can: make it impossible to fly, increase the risk of blurry footage or gaps in the footage, rapidly drain batteries, increase the risk of crashing and damaging drones, and increase the risk of injury to pilots (if the wind catches a rotor blade of a drone that's turned off, that rotor can unexpectedly and suddenly spin as fast as if the drone were running).

We found that if fieldworkers were getting buffeted around by wind then it was too strong to fly. Low wind speeds are ideal, but even when the drones were constantly displaying "high wind speed" or "dangerous wind speed" warnings they still produced good footage.

The top-tier warning was "max rotor speed reached", at which point drones started drifting off course and miscalculating how much battery it would take to return home if they would be flying against the wind.

We found that the M3 could cope well with stronger wind speeds than the M2s, however strong winds still affected it. If a drone is struggling to return to home automatically due to strong winds, it can help to manually take over and fly it lower to the ground where the wind speed is somewhat lower.

We recommend taking an anemometer and recording more detail about the local wind speeds that drones can and cannot be flown in – we didn't have one so cannot be any more specific about wind limits.

- **Rain** – even light drizzle can damage the drone and will likely void its warranty. On Adams Island, any cloud producing light drizzle would generally reduce visibility to the point where drone footage wasn't useful anyway.
- **Cloud base** – we soon learnt that even if there was no wind or rain, the cloud base could still thwart flying if it was too low. We used the Windy weather forecasting app to predict cloud base.

- Factoring in the forecast, travel time, drone type and batteries available, agree on **how many blocks** to fly, **which pilot will fly which blocks**, and roughly **where the pilots will fly them from**.

The closer to a block a pilot is, the less battery will be wasted flying to and from the start point. We tended to either stand at points where 3 or 4 blocks met or start at a block at one end of a line of blocks and walk along the line while flying the drone (see section *2. Flying in the field*).

- If you have a combination of different drone types available, plan how to use them effectively. We generally used the Mavic 3 for the most distant or awkward-to-reach blocks, since it had the power and battery longevity to be safely flown further away from the pilot than the M2.
- Come up with a **back-up plan** for if the weather changes unexpectedly, e.g. have a backup set of flight plans downloaded that are on a different aspect of the terrain and/or at a different elevation.

Pre-fieldwork daily drone and accessory preparation

- **Charge drone batteries the evening immediately before the day of use** to get 96-100% charge.

If batteries are charged but then sit unused for a day or more (e.g. because plans change due to weather), they can drop to ~86% while still indicating a full charge. This is enough to significantly reduce the area that can be flown per battery, and some battery chargers will not recognise that such batteries aren't fully charged so will not top them up to 100%.

To address this, deliberately discharge any such batteries (e.g. by flying the drone at base) until they start indicating that they aren't fully charged, then recharge them to 100% the evening immediately before day of use.

- **Charge powerbank**.
- **Charge mobile phone** (and any spares) to 100% and check the necessary **flight plans** are stored on it locally.

- **Turn phone onto flight mode to make the battery last.**
- Check that all footage from previous days of fieldwork has been copied off the drone SD card and backed up, then **insert the SD card into the drone and format it** within DJI Go.
- Check drone case has:
  - A **micro-USB-B cable** and a **USB-C cable** (each drone team should have a spare of each type)
  - Spare **rotor blades**
  - An **SD card reader** (each team should have a spare)
  - A spare drone **SD card**
  - A **powerbank**

2. Flying in the field

To fly a block with an M2

- Unfold drone, take off **protective camera bubble**, check it has a **fully charged battery** and an **SD card** inserted, and sit it in a position where the **camera gimble** is not touching anything and has room to rotate when the drone is later turned on.
- Unfold the controller, **insert joysticks**, connect it to **powerbank** so it starts charging, and connect the **USB-A to USB-C cable** to the controller but don't connect the phone just yet.

Keep the controller connected to the powerbank as much as possible, even when walking between locations without a drone in the air - we found it was the device that drained batteries the most rapidly.

- Take **phone** out of its cover if it has one, make sure it is ready to go (turned on, screen unlocked, no apps open), then fit it into controller but don't connect it to the cable yet.
- When everything is ready to go, **turn the drone on and turn the controller on**. Once they've connected, check the drone battery charge is as expected.
- Connect the **phone** to the controller and **open DJI Go**. Check **settings** are still the way you want them (they sometimes change for no apparent reason).
- Close out of DJI Go, then **unplug the cable and reconnect** it. **Open UGCS**.
- If you get a 'compass error' warning, we found it didn't affect our flying so could ignore it – this might not always be the case.
- Click on '**Load route'** icon and scroll to the correct flight plan and download it starting at the first point.
- Wait for the route to completely load, then hold the drone by its body up above you and well away from anyone's face and **turn the camera to face downwards**. We had to hold the drone due to ubiquitous deep tussock and backpacks not being adequate launch pads; if you have a flat surface to launch from then doing so is somewhat safer.

- Check no birds are about to fly into the airspace above you, then click on '**Launch'** icon and gently let go of drone as it takes off from your hand.
- As the drone nears its starting point at the correct flight height above ground, **half-click on the 'Take photo' button on the controller to manually focus the camera** without actually taking a photo. This helps avoid blurry photos if the autofocus plays up, because you've manually set the focus to be approximately correct for the block.
- Keep an eye on the footage to **check for blurriness** as the drone progresses. If it appears blurry, again half-click on the button on the controller to manually focus the camera.
- When the drone has finished flying the block, click on '**Home'** icon to bring it back to you. You can take over and manually fly it back to you if that's more efficient or you've moved from the original Home point (see tips below).
- Carefully **catch the drone** at the hover keeping your own and anyone else's face well clear. If vegetation and terrain conditions allow you to land the drone, it is safer to do so.
- Turn the drone and then the controller off. Take out the SD card and **copy the footage** on it into: A. a new folder in the drone SD card named after the block the footage is from, and B. a new folder in the backup SD card in the phone also named after the block. Then delete the footage from the DCIM folder. Note that it works best to "unmount" the SD card from your phone before detaching the SD card reader; if you just pull it out then often it doesn't recognise it the next time you insert it. If the SD card reader is not recognised, restart your phone.

Be very careful not to send the tiny SD card flying when trying to insert it into spring-loaded tiny slots! Rather tricky things to find in thick vegetation…

- Some tips and tricks we learnt:
    - It works well for one pilot to **fly two drones at the same time from a stationary location**, but we recommend separating the launch times by at least 5 minutes so if one drone has problems at the end of its flight you aren't trying to wrangle two drones home at the same time.

You need to keep a close eye on both controllers, and it is safest to fly two at once when weather conditions are good so you're unlikely to have any drone dramas (e.g. running out of battery mid-flight, drifting off course, struggling to come home etc).

-
    - If a drone finishes one block and still has ample battery left, you can simply **upload the next block's flightplan to the drone while it is still hovering in the air at the end point** of the flightplan, then click 'Launch' and it will fly off to the next block – you don't need to land it.

However, it is then likely to run out of battery partway through the next block and return, so you need to pay very close attention to the controller to see which waypoint to send it back to with a fresh battery to complete the block without creating a gap in the footage.

- Once you've launched a drone to fly a block, you can then **walk towards the point from where you want to fly the next block while it is flying**, to save time and battery. However, although some drones will allow you to change the 'Home' point while the drone is flying to the location you have moved to, the M2 does not.

You will need to pay close attention to where the drone and 'Home' points are relative to your location, so that **when the drone runs low on battery and starts flying to the now-incorrect 'Home' point you can take over and manually fly it to your new location**.

You will also need to keep monitoring the controller screen and the drone while walking – ok in tussock, not so suitable in e.g. scrub!

Be warned that **the controller icon that shows you where you are on the controller screen can occasionally disappear** without warning. You need to always know where the drone is in relation to you in reality, don't just rely on the screen!

It is safest if you can keep yourself between where the drone is and the original 'Home' point since it will then have to fly over you when going 'Home', but this isn't always possible.

We only flew a single M2 drone while walking, not two, because of the increased risk since you can't simply tell it to come back to you automatically. This may not be a problem with other drone models.

- When the weather was good (light winds) we used a combination of uploading blocks at the hover and walking from one block to the next, as described above, to string together lines of blocks that made use of every last bit of each drone battery and didn't waste potential flying time by having the drone in our backpacks while walking between blocks.
- Infrequently we would get a warning message along the lines of "Unable to load route due to take-off position being outside elevation model" when we tried to load a route. The solution we found was to move around - usually ~50m was enough but on one occasion we needed to move a few hundred metres. We assumed it was caused by a discrepancy between the DEM and reality, so this is another plug for getting a high-quality DEM for your site.

3. Post-fieldwork routine

- **Charge batteries fully if you're going to use them again tomorrow**, otherwise store them until the day before they are going to be used again then charge them fully.

If they have **over 20% charge** then store them as-is, but if they have **less than 20% charge** then charge them to at least 60% before storing them.

- **Copy all the footage** to your base footage storage and backup systems, then **format drone SD card in the drone** to clear it for next use.
- **Upload the footage to Drone Deploy** or another stitching provider:

    - Open Drone Deploy, add a project and name it after the block you are uploading. You could instead create one overarching project and later add multiple maps for all the blocks, but in 2024 we found it easiest to keep track of which blocks were bring processed by having each block be a separate project.
    - Click on 'upload' to upload the images collected by the drone. Depending on various factors (other users, size of images, etc) this will take at least one hour for a 15ha block. You can upload multiple blocks at once, but this won't reduce the overall time taken – each one will be completed more slowly.
    - When uploading is complete, it will then take several more hours for the footage to be processed into an **orthomosaic**.
    - When the orthomosaic is complete, click on 'map', name the map, and click 'export' to export it as a **geotiff**. Use a 'tiled' image and the maximum resolution possible. If the file is deemed too big, go back to 'maps', and crop the map into two (or more) sections and download them separately, ensuring there is an overlap. Exporting takes about 20-30min. If you entered your email address, you will receive an email when the download is ready.
- Process footage, e.g. in QGIS. We found that DOC's "high-spec" laptops were able to process footage at twice the speed of normal DOC laptops, due to being able to more rapidly re-load the high-resolution footage every time the map view is shifted.

4. Ground-truthing tips

- Go where the albatross are to maximise the number of albatross you can check on the ground, instead of following strict transects.
- Make sure you ground-truth the same aspects as the drone coverage, e.g. if you're flying blocks with both NE and NW aspects then don't only do ground-truthing in NE aspect areas.
- Ground-truthing is quite slow relative to drone flying – with one person on each task (especially if the pilot is flying two drones at the same time) you tend to not be able to ground-truth every block that is flown – aim to get as representative a sample as possible while also maximising the number of birds checked by avoiding areas with hardly any albatross present.
- Try to ground-truth blocks as close as possible in time to when they're flown