Antipodean wandering albatross: satellite tracking and population study Antipodes Island 2020

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ABSTRACT

The Antipodean wandering albatross *Diomedea antipodensis antipodensis* has been in decline since 2007. The decline appears to be driven in large part by high female mortality, though reduced breeding success and increased recruitment age have exacerbated the problem.

Difficulty reaching Antipodes Island in the 2019/20 summer meant field studies were undertaken much later than usual, and the Covid19 pandemic meant less than two weeks was spent on Antipodes Island, from 15–28 March 2020. As a result, assessment of 2019 nesting success (59%) was a little coarser than previously and the chicks had all fledged before we arrived to band them. It also meant that birds which visited Antipodes Island to breed but failed early, or which left the island early after failing to find their usual breeding partner, were not recorded. This included birds wearing satellite transmitters in 2019 whose survival after their transmitters stopped working could not be verified.

Only 75 pairs nested in the study area in 2020, amongst the lowest recorded, but female survival in 2019 had increased over previous years, at least amongst non-breeding females. Breeding female survivorship in 2019 was at an unsustainable 74%, though this estimate was likely affected by the late timing of Antipodes Island fieldwork in 2020. There is so far, no evidence of the sustained improvement in female survival necessary for the population to recover.

Since 2009 there has been an estimated 1,000 “extra” deaths per year of adult albatrosses over and above their normal mortality, and if the mortality rate amongst younger pre-breeding birds is similar, then approximately 1,300 “extra” deaths per annum also occurred amongst younger birds. This suggests that since 2004 about 15,000 “extra” adults have died, and about 20,000 “extra” pre-breeding birds, of which about 70% have been female.

Forty satellite transmitters were deployed in mid-March 2020, 25 on females (10 breeding) and 15 on males (7 breeding). Half were battery-powered and the remaining 20 transmitters were solar-powered. Most of the birds were adults which had bred before, but 9 were relatively young female pre-breeders (7–11 years old). This deployment aims to identify fishing fleets with high levels of spatial and temporal overlap with Antipodean wandering albatrosses in 2020.

Analysis of the data produced by 63 satellite transmitters deployed in January 2019 identified the satellite transmitters and duty cycles which were most effective in determining the overlap of Antipodean wandering albatross and long-line fisheries in 2019. While one lightweight solar-powered and GPS equipped Rainier transmitter stayed attached longest, the heavier battery-powered TAV transmitters were on average the most durable, though these used Argos positioning which was both temporally and spatially coarser. The comparative durability of TAV tags was in part because they were attached only to fledglings, whose feathers were less worn and less likely to be moulted than the feathers on birds at other life-stages to which the rest of the tags were attached. Satellite tracking allowed detection of the capture of at least one juvenile female in fisheries bycatch on the high seas north-east of New Zealand. Juveniles, particularly females, foraged in waters further north than adults did. Lightweight solar tags should be attached to juveniles in 2021 as they are likely to keep transmitting and stay attached for longer on juveniles than on adults and because juveniles appear to overlap more with long-line fisheries than do adults.

INTRODUCTION

Antipodean wandering albatross (*Diomedea antipodensis antipodensis*) is one of two subspecies of *D. antipodensis* and is endemic to the Antipodes Islands, with approximately 99% of the population breeding there. A few pairs also nest on both Campbell Island and at the Chatham Islands. They forage mainly in the Pacific Ocean east of New Zealand, and to a lesser extent in the Tasman Sea (Walker & Elliott 2006).

They are a known bycatch in New Zealand long-line fisheries, with small numbers annually observed caught on domestic vessels (Abraham & Thompson 2015). Total potential fatalities within New Zealand's EEZ were estimated in 2018 at a mean 63 birds per annum (MPI 2019). In addition, there are substantial long-line fleets with poor observer coverage in international waters in the southern Pacific Ocean (Peatman *et al.*2019) where the birds mostly forage (Walker & Elliott 2006).

Due to the vulnerability of this long-lived and slow breeding species to any additional mortality, their survival, productivity, recruitment and population trends have been monitored during almost annual visits to Antipodes Island since 1994. In the 1990's the population increased following a major, apparently fisheries-induced, decline during the 1980's (Walker & Elliott 2005, Elliott & Walker

2005 and Walker & Elliott 2006). However, around 2006 there was a sudden drop in the size of the breeding population, and it has continued to decline since then.

This report summarises the most recent findings on the survival, productivity, population trends and at-sea distribution of Antipodean wandering albatrosses, collected during a two-week trip to the island in March 2020. Since this study began in 1994, trips to Antipodes Island have typically been of five to six weeks duration, usually starting in early January and ending in late February. The trips are timed to arrive before the previous year's chicks fledge so that they can be banded, and the success of last year's nests assessed. Departure is usually timed so that censuses can be carried out after all eggs have been laid.

This year transport problems meant that we did not arrive on the island until 15 March 2020 and left on 28 March 2020. By that time, all last year's chicks had fledged without being banded, though we were still able to assess the success of last year's breeding attempts by the condition of the abandoned nests. We only had time to census the study area, not the other two blocks which are usually censused. Mark-recapture estimates of survival and population size for 2020 will be based on many fewer re-sightings than usual and will have larger confidence intervals.

METHODS

Mark-recapture study

In summer 1994 and every year thereafter except 2006, a 29ha study area on Antipodes Island (Figure 1) has been visited to band nesting birds and record the band numbers of already banded birds. All birds found nesting within the study area are double banded with individually numbered metal and large coloured plastic bands, and since 1995, most chicks in 60% of cohorts 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 16 of the years since 1994 researchers arrived just before, at, or soon after the date at which the first chicks fledge (26 December) when more than 90% of the chicks are still present and can be banded. In 9 of the years since 1994 late trips meant up to 45% of the chicks had already fledged without being banded, and no chicks were banded in 2006 (no trip) or 2020 (very late trip).

Survival of birds in the study area is estimated with maximum likelihood mark-recapture statistical methods using the statistical software M-Surge (Choquet *et al.* 2005). For the models used in M-Surge, 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 very different probabilities of being seen on the island but similar survival rates, so the models estimate re-sighting probabilities separately for each class, but survival is estimated separately for only males and females.

Population size is estimated by multiplying the actual counts of birds in each class by its estimated re-sighting probability. 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).

Counting nests in 2 representative blocks

Since 1994, all the nests in two areas (Figure 1) additional to the study area have been counted most years. The two areas support about 14.9% of all the nests on Antipodes Island (Clarke et al. 1995, Walker & Elliott 2002a). Counts are carried out between 5 and 10 February, just after the completion of laying, and as close as possible to the same time 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 and displayed on a GPS map, 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 with spray paint and counted. All non-breeding birds on the ground are also counted, and they and most breeding birds on eggs are checked for 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, checking all nests within 10–15 m of the transect for paint marks indicating the nest has been counted.

Figure 1. Location of the Antipodean wandering albatross study area on Antipodes Island, the two census blocks and the area (shaded green) in which albatrosses do not nest.

Total number of nests on the island

The total number of pairs of wandering albatross nesting on Antipodes Island is estimated from whole island population counts done in 1994, 1995 and 1996 (Clarke et al. 1995, Walker & Elliott 2002a) and subsequent annual counts of parts of Antipodes Island. The proportion of the total population in

1994–1996 that was nesting in those parts of the island subsequently repeatedly counted is used to estimate the current total population using the following formula.

$$\hat{t}_i = \frac{t_{1994-1996}}{p_{1994-1996}} \times p_i$$

Where

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

$t_{1994-1996}$ is the mean total number of pairs counted nesting in 1994–96

$p_{1994-1996}$ is the mean number of pairs counted nesting in 1994–96 in those parts of the island that were subsequently repeatedly counted.

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 it has been found to do on Antipodes Island (Elliott & Walker 2018).

Total population size and trend

Measuring change over time in the total population of Antipodean wandering albatross is complicated by the difficulty of estimating the size of the pre-breeding population. After fledging birds don't return to the breeding island for at least three years and often for much longer, making a reliable estimate of the size of that part of the population difficult.

However, change over time in the size of the adult breeding population can more easily be calculated. Mark-recapture estimates of the number of birds breeding in the study area are much less variable than counts of nests so are used here as the basis of some population change metrics (Table 4). Each year's mark-recapture estimate of the number of breeding birds represents the number of birds recorded breeding that year, as well as the birds that have previously nested, and are still alive but are not nesting. During the 1994–1996 censuses 2.7332% of all the nests found during the censuses were in the study area, and this proportion is used here to estimate the total size of the breeding population in subsequent years. To determine whether this proportion varies over time, the number of nests in the study area was compared to the number of nests in the two other large and regularly counted blocks (MCBA and Block 32) (Table 3) using a generalised linear model with binomial errors.

To estimate the number of "extra" birds deaths—those over and above the natural mortality of a stable population—which occurred each year since the population started declining, the average mark-recapture estimate of mortality rate of breeding albatrosses in the years prior to 2005 were compared with the annual estimates since 2005 when the population was declining. The number of extra breeding birds that died each year are estimated using the formula:

$$Extra\ deaths\ of\ breeders_i = \frac{(mean\ sa\ mortality_{1996-2004} - sa\ mortality_i) \times sa\ N_{i-1}}{0.027332}$$

Where:

mean sa mortality$_{1996\text{-}2004}$ is the mean of the mark-recapture estimate of mortality between 1996 and 2004 in the study area

sa mortality$_i$ is the mark recapture estimate of mortality in year i in the study area.

sa N$_i$ is the mark recapture estimate of the number of breeding birds in the study area in year i

0.27332 is the proportion of all nests that were found in the study area between 1994–1996.

Since the breeding population is only a portion of the total population, estimation of the number of "extra" deaths amongst both breeding and mostly younger pre-breeding birds requires a comprehensive population model. In the absence of such a model for Antipodean wandering albatross, a Gibson's wandering albatross model (Francis *et al*. 2015) is used. That model found adult breeders were likely to comprise approximately 43% of the total population, so that proportion is applied here to estimate the total number of "extra" deaths amongst both adult breeding and pre-breeding Antipodean wandering albatross.

At-sea distribution

To better describe in real time the foraging range across life history stages and identify ocean areas where albatrosses might be interacting with fishing vessels, satellite transmitter tracking devices of 3 types (Table 1) were attached to 40 albatrosses between 18 and 26 March 2020. A small Migrate Technology geolocator datalogger was also attached using cable-ties to the metal leg band of each of these 40 birds. Nesting adults were tagged at their nests whilst incubating, and other adults were tagged when they visited the study area to court (Table 2).

All the satellite transmitters were attached with 12.5mm wide fabric Tesa® tape to the feathers above the spine of the bird in line with the front of the wings. For the TAV transmitters (without a solar panel) three or four strips of tape were used to fix three or four clusters of 4-10 feathers to the underside of the transmitter (Figure 2). For the solar powered transmitters, tape could not be wrapped around the transmitter because it would cover the solar panel. For these transmitters a piece of PVC plastic (cut from guttering) was used which was the same shape but slightly larger than the base of the transmitter and had three holes which lined up with the attachment points on the transmitters. This PVC base was attached to the feathers in the same way as the TAV transmitters were, and the transmitter was then attached to the PVC base using cable ties with stainless steel pawls (Figure 2).

Table 1: Satellite transmitters and GLS dataloggers attached to Antipodean wandering albatross in March 2020. Duty cycle refers to the potential number of locations obtained or estimated.

Model	Location system	Power	Data retrieval	Duty cycle	Weight (g)
Microwave Telemetry	GPS + Argos	Battery + solar	Satellite	5/day	22
GeoTrak	GPS + Argos	Battery + solar	Satellite	5/day	22
Telonics, TAV2630	Argos	Battery	Satellite	3hrs/day	35
Migrate Technology c330	GLS	Battery	At recapture	2/day	3.3

Table 2: The number, sex and status of Antipodean wandering albatross to which satellite transmitters were attached. All these birds also had a Migrate Technology GLS attached.

	Females			Males			Total
	breeders	non-breeders	Pre-breeders	breeders	non-breeders	Pre-breeders	
Microwave Telemetry		6	3	1			10
GeoTrak	4		1	2	2	1	10
Telonics TAV2630	6		5	4	3	2	20
Total	10	6	9	7	5	3	40


Figure 2: (left) a battery-powered TAV satellite transmitter taped directly to the back feathers of a female Antipodean wandering albatross (White-42E) and (right) a solar-powered GeoTrak satellite transmitter cable-tied to a PVC base which is taped to the back feathers of a male Antipodean wandering albatross (White-026).

All satellite transmitters deployed are expected to run for up to a year. This potentially allows for their recovery in the summer of 2020/21. However, some birds will not return to Antipodes Island, and many tags will fall off when the feathers they are attached to break or are moulted. Most satellite transmitters were attached to non-breeding birds which appeared to have relatively poor feather condition. Overlap of tracked birds and fishing fleets was analysed by comparing the birds' tracks with the locations of fishing boats available from the Global Fishing Watch website https://globalfishingwatch.org/map/.

RESULTS

Population Parameters

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 at an average rate of about 8% per annum for both sexes— slowly initially, then rapidly in 2002–2005 (Figure 3). After 2007 the population of breeding pairs declined, initially at about 9% per annum but in recent years the decline has abated, and the population of breeding females has been roughly stable for the last 3 years (Figure 3).

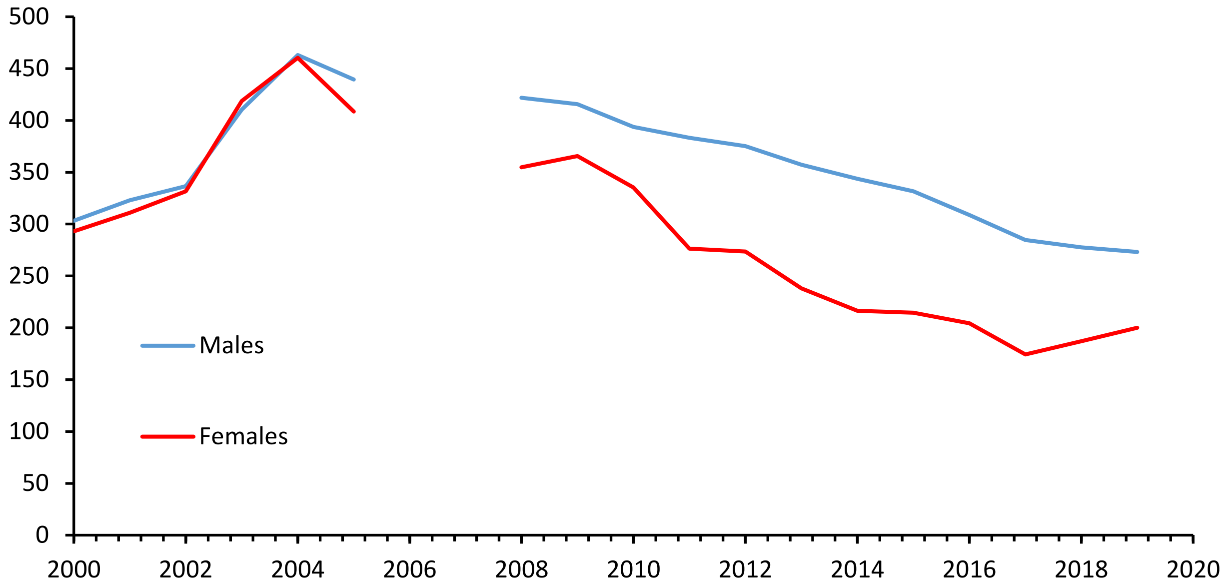

Figure 3. The number of breeding birds in the study area on Antipodes Island estimated by mark-recapture. Note: population estimates produced by mark-recapture are not reliable in the last year of data collection, so results are only up to 2019.

Survivorship

Adult survival varied around a mean value of about 0.96 up until 2004 and during this period male and female breeder and non-breeder survival was not significantly different. Since 2004 both male and female survival has declined, with female survival significantly lower and more variable than that of males (Figure 4). Since 2014 female survival has been particularly variable with both the lowest and second highest female survival occurring in that period. A five-year rolling average of female survival (Figure 4) suggests that on average female survival has been improving for the last few years.

Not only has male and female survivorship differed substantially since 2005, but the survivorship of breeding and non-breeding birds (Figures 5 & 6), and the confidence in those estimates (Figure 6) has also differed. Male breeding birds have consistently fared worse than non-breeding males since 2005, but breeding and non-breeding female survivorship has seesawed since 2005, and in 2019 the survivorship of breeding females was very low (Figures 5 & 6).

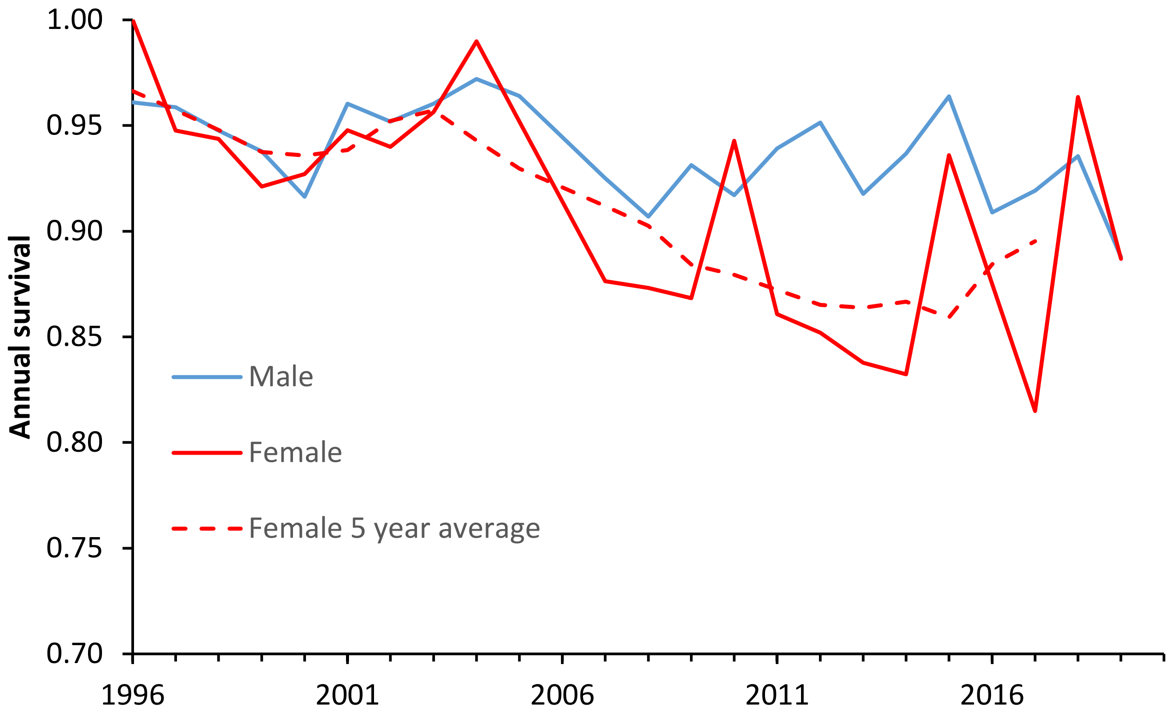

Figure 4. Estimated annual survival of male and female Antipodean wandering albatross on Antipodes Island since 1996, and five-year rolling average for females. Mark-recapture estimates of survival for 2020 are unreliable and are not presented

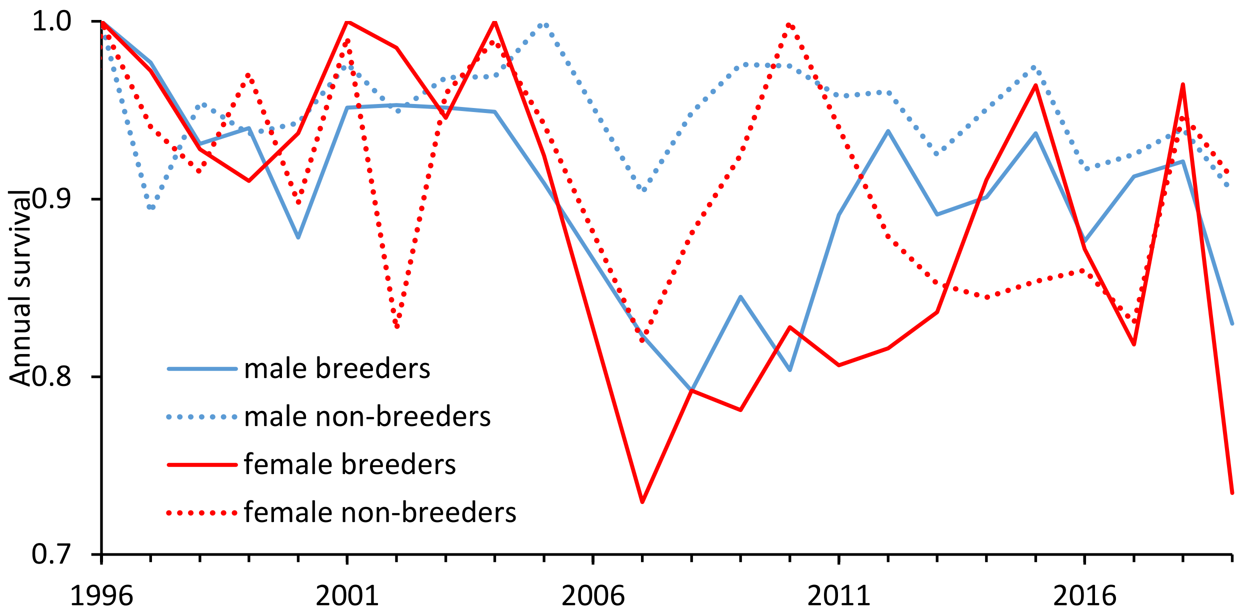

Figure 5: Estimated annual survival of male and female breeder and non-breeder Antipodean wandering albatross since 1996

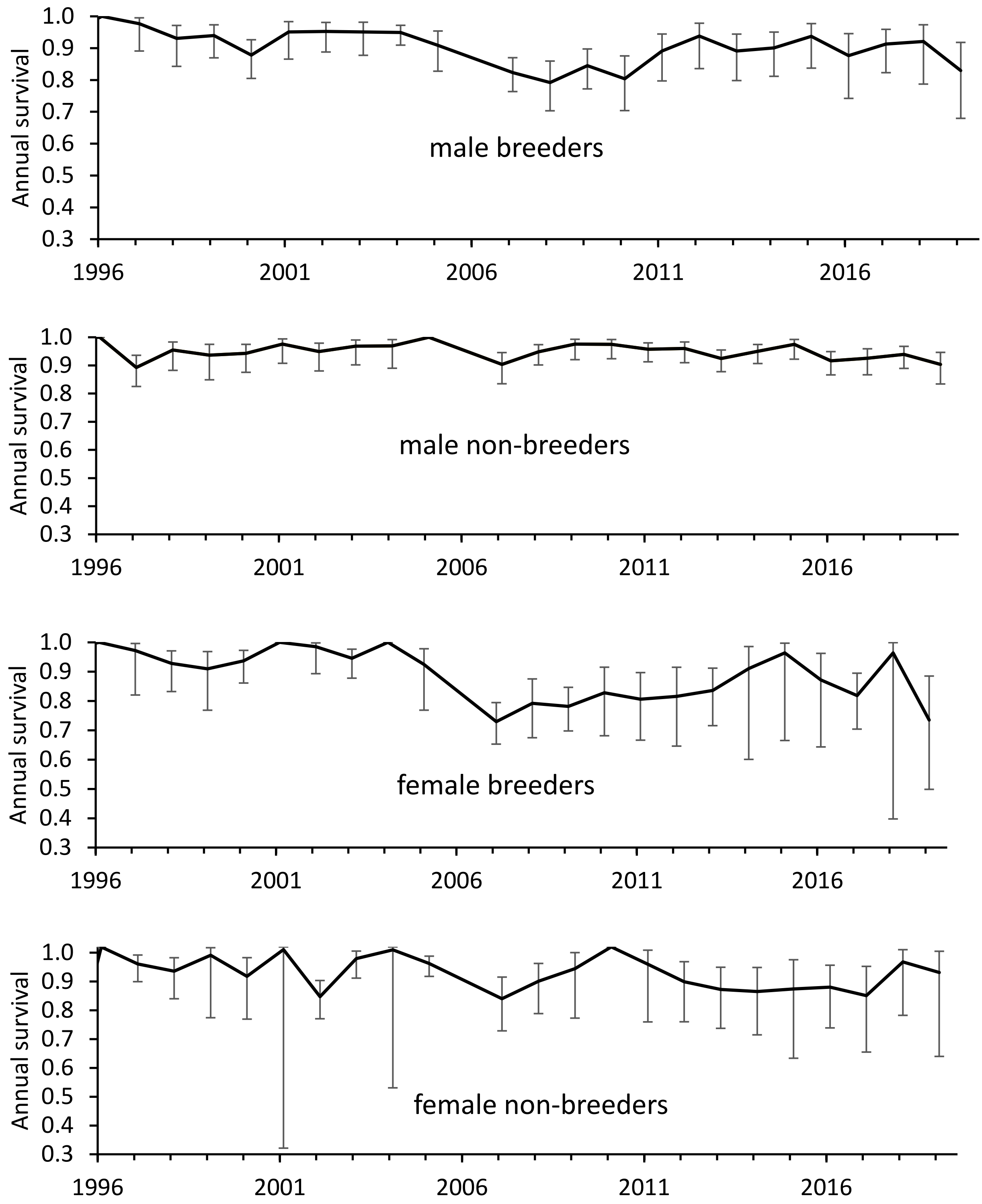

Figure 6. Estimated annual survival of male and female breeder and non-breeder Antipodean wandering albatross since 1996 with 95% confidence limits

Proportion of birds breeding

By comparing the number of nesting females in the study area with the mark-recapture estimate of the number of females in the breeding population, it is possible to estimate the proportion of females that breed each year. Before 2005 about half of the breeding females nested each year but between 2005–2010, the proportion of females that attempted to breed dropped to as low as 24%, before recovering. Since 2016 the proportion breeding has returned to pre-crash levels except in 2017 in which the low proportion breeding was a predictable response to the high nesting success in 2016.

Productivity

Nesting success in 2019 was 59%, roughly equal to the average since the 2006 crash, and lower than the 74% average pre-crash (Figure 7). The number of chicks produced in the study area continues to be much lower than that before the crash (Figure 7) mostly because of the much smaller size of the breeding population.

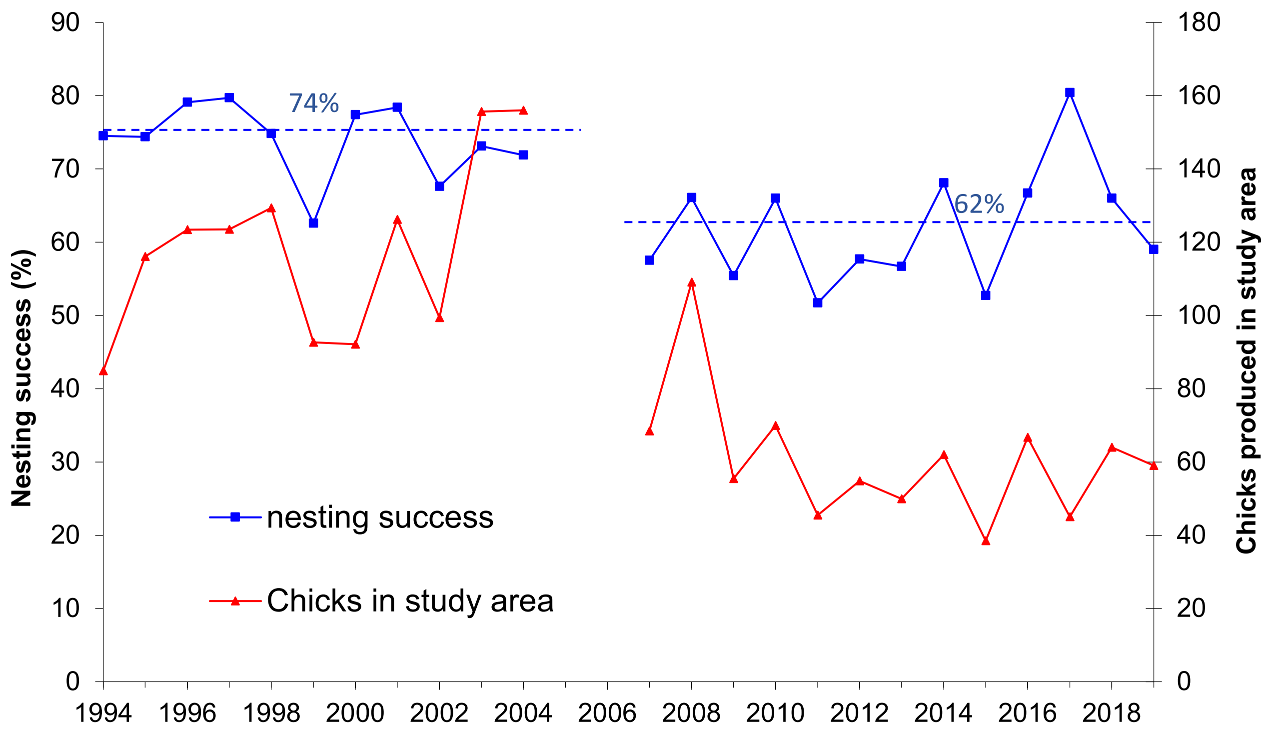

Figure 7. Nesting success and the number of chicks fledged from the study area on Antipodes Island since 1994. The dashed lines indicate average nesting success in two periods, 1994-2004 and 2007-2019.

Recruitment

The short trip in 2020 meant that we could not accurately count the number of new recruits to the breeding population, The birds responsible for the 7 nests which had failed by March 2020 had already left the island, and we did not see the second bird at a further 5 nests. However, a disproportionate number of early failures are by birds nesting for the first time, and as all 5 birds at each of the nests where only one bird was seen were new recruits, it's likely their partners were too. Assuming both partners at all 7 of the failed nests, and the other bird at the 5 nests where only one bird was seen were new breeders, a maximum of 24% of the breeding population in 2020 were new recruits. The actual number is of course unknown, and may be a little lower than this, perhaps closer to 20%. Recruitment has been relatively high in recent years (Figure 8) and is a major factor slowing the population decline.

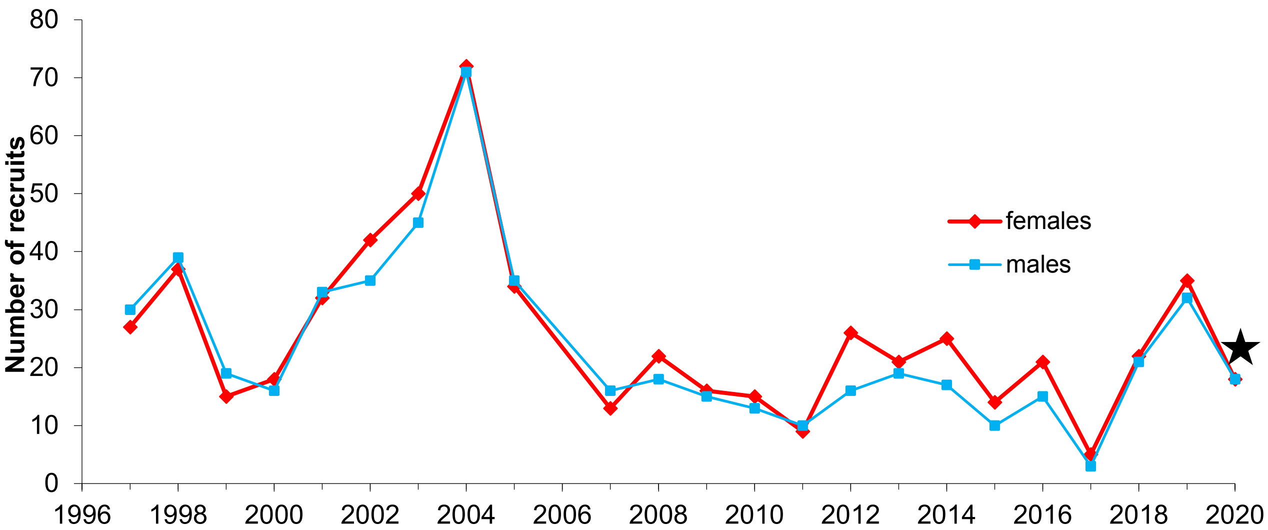

Figure 8. Number of birds recruiting to the breeding population in the study area on Antipodes Island since 1997. ★ the number of new recruits in 2020 is an estimate (see text).

82% of the known age birds that have recruited to the breeding population in the last five years were born before the sharp drop in productivity that was coincident with the population crash after 2005 and sustained thereafter. We expect that recruitment will decline in the next few years, simply because there have been relatively few chicks fledging from Antipodes Island over the last 14 years (Figure 7).

Nest counts

Only nests in the study area were counted in 2020, from which the total number of breeding pairs on the island were estimated. There were 75 nests in the study area in 2020 and an estimated 2,714 nests in total on the island (Table 3). Only the 2015 and 2017 seasons had fewer pairs nesting in the study area in the 26 years since counts began (Table 3).

After an increase between 2000 and 2005, the number of nests dropped sharply between 2005 and 2007 by about 38% (Figure 9). Since then the decline has continued but at a slower rate (Figure 9). Counts of the three areas have changed in parallel since counts were started and a generalised linear model shows no trend with time in the proportion of nests in the study area (χ^2=41,df=1, p=0.87), suggesting the changes represent an island-wide trend, and that counts from only one of the blocks (such as we did this year) will none-the-less provide a good indication of population trends over the whole island.

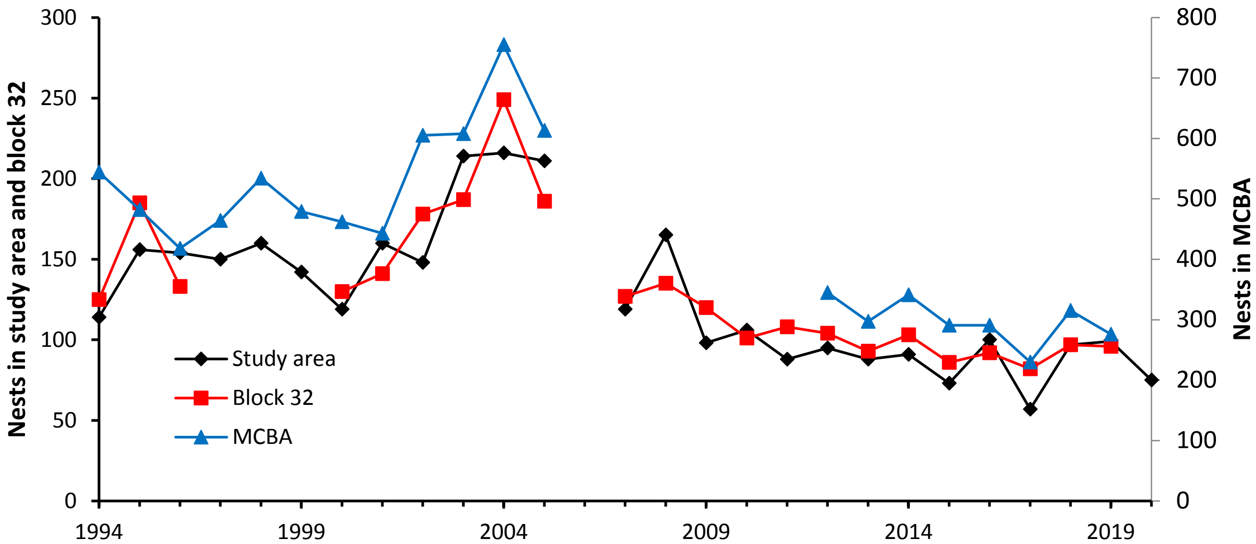

Figure 9. The number of Antipodean wandering albatross nests in three blocks on Antipodes Island since 1994

Table 3: Antipodean wandering albatross nests with eggs in February in three areas on Antipodes Island in 1994– 2020, and from the proportion nesting in those areas relative to island-wide totals in 1994–97, an estimate of the number nesting on the island in 1998–2020

Year	Study area	Block 32	MCBA	study area as % of areas counted	Total counted	Estimated nests on island
1994	114	125	544*		783	5233
1995	156	185	482*		823	5500
1996	154	133	418*	28	705	4712
1997	150		464*			5463
1998	160		534			5827
1999	142		479			5172
2000	119	130	462	20	711	4752
2001	160	141	443	27	744	4972
2002	148	178	605	19	931	6222
2003	214	187	608	27	1009	6743
2004	216	249	755	22	1220	8153
2005	211	186	613	26	1010	6750
2006						
2007	119	127				4368
2008	165	135				5327
2009	98	120				3871
2010	106	101				3676
2011	88	108				3480
2012	95	104	345	21	543	3629
2013	88	93	297	23	478	3195
2014	91	103	341	20	535	3576
2015	73	86	291	19	450	3007
2016	100	92	291	26	483	3228
2017	57	82	230	18	369	2466
2018	97	97	315	24	509	3402
2019	99	96	276	27	471	3148
2020	75					2714

* estimated (see Walker and Elliott 2002b).

Total population size and trend

The proportion of nests in the study area relative to the larger regularly counted blocks has not changed in any systematic way since 1994–96 (Table 4), and it is therefore reasonable to assume that estimates from intensively studied parts of the island are representative of the whole population.

Following the crash in 2006–8, the population continued to experience substantial losses for more than a decade. Roughly 25,500 "extra" deaths of birds of all age classes over and above that normally expected in a stable population are estimated to have occurred between 2009 and 2019 (Table 4), including nearly 11,000 breeding birds. Adult survival and hence the number of 'extra" deaths differed substantially from year to year (Table 4), but when averaged over the last 11 years (2009–

Table 4. Some mark-recapture based metrics of population size and the number of "extra" deaths over and above those expected in a stable population of adult Antipodean wandering albatrosses during the decline in the population since 2004.

	Total number of adult (breeding) birds using the Study Area[1]		Extrapolated number of adult (breeding) birds in the whole island population[2]		Adult (breeding) birds in whole island population[3]		All birds (both adult breeders & pre-breeders) in whole island population[4]	
	Males	Females	Males	Females	extra male deaths	extra female deaths	extra male deaths	extra female deaths
1996	281	287	*10270	*10483				
1997	303	309	11083	11290				
1998	318	322	11646	11797				
1999	309	308	11298	11251				
2000	303	293	11093	10726				
2001	323	311	11822	11378				
2002	337	332	12317	12131				
2003	411	419	15020	15322				
2004	463	460	16943	16844				
2005	439	409	16076	14947				
2006								
2007								
2008	422	355	15437	12985				
2009	416	366	15212	13376	316	1,094	735	2544
2010	394	335	14409	12267	528	132	1227	306
2011	383	276	14023	10113	182	1,127	423	2621
2012	375	273	13727	10004	4	1,018	9	2366
2013	357	238	13072	8710	469	1,148	1090	2670
2014	344	217	12576	7923	196	1,048	456	2436
2015	332	215	12133	7852	0	132	0	306
2016	309	204	11301	7474	520	610	1208	1418
2017	285	174	10422	6378	368	1,029	856	2393
2018	277	187	10151	6841	169	0	393	0
2019	273	200	9994	7316	650	450	1511	1045
Total					3,251	7,716	7,560	17,994
(mean)					(296)	(701)	(687)	(1,631)

[1]mark-recapture estimates from the study area.
[2]mark-recapture estimates multiplied by total number of nests / nests in the study area.
[3]mark-recapture estimates of extra deaths multiplied by total number of nests / nests in the study area.
[4]mark-recapture estimates of extra deaths multiplied by total number of nests / nests in the study area and multiplied by total number of birds / number of breeders from Francis et al. (2015).
*Based on whole island counts.

2019) a mean 701 "extra" deaths of adult females and 296 "extra" deaths of adult males (Table 4) has been occurring each year on top of the normal death rate. Even larger numbers of pre-breeders are likely to have died each year, such that in total roughly 1600 adult and pre-breeding females and 700 adult and pre-breeding males are thought to have died on average each year, over and above that expected in a stable population. At its peak in 2004 the population comprised nearly 17,000 breeding pairs, which declined to just over 7,000 pairs by 2019 (Table 4).

At-sea distribution

2019 satellite transmitter deployments

Four types of satellite tags were attached to 63 birds in January 2019 to measure their foraging ranges, identify the extent of overlap with fishing fleets, measure the incidence of fisheries mortality and to compare the effectiveness of different transmitters and different attachment methods. The fieldwork on Antipodes Island in March 2020 provided more information about the outcome of those deployments, through sightings of birds which had been tracked in 2019 and the success or failure of their nests (see below and Appendix 1).

Durability of January 2019 deployments

The length of time satellite transmitters functioned varied greatly between transmitter types.

Table 5. The durability of satellite tags attached to Antipodean wandering albatross in January 2019.

	Number of birds	Mean length of transmission (range)
Sextant Technology, **Xargos**	20	62 (0-144)
Lotek, **Pinpoint**	13	106 (12-242)
Wildlife Computers, **Rainier** S20	10	249 (76-410)
Telonics, **TAV**2360	20	301 (108-389)

TAV: 20 battery powered Telonics TAV2630 Argos satellite tags were attached in January 2019 to near-fledging chicks who were not expected to return to Antipodes Island for several years. These transmitters stopped transmitting between 24 April 2019 and 29 January 2020 (range 108–389 days) but half of them stopped in quick succession during January 2020. The most likely explanation for the synchronous stopping is flat batteries.

Xargos: 20 large prototype solar-powered, GPS and radar detecting Sextant Xargos tags were attached to adults. As a further 5 tags failed even before they were attached, equipment failure is a likely explanation for failure of 7 of the 20 tags within 2-34 days of deployment. Xargos tags were also the largest and heaviest of the tags attached and must have put a greater strain on the feathers they were attached to than other tags. Early feather breakage is probably an additional reason most these tags stopped well before other types of tags did. None of the 9 Xargos-tagged birds that were seen on the island in March 2020 still had transmitters attached so it's reasonable to conclude that they all had fallen off within 15 months of attachment.

Pinpoint: The 13 large battery powered Argos Pinpoint tags attached to adults stopped transmitting between February and October 2019 after 12–242 days although their batteries were supposed to last 400 days. They may have been unreliable, but their heavy weight, their high rounded shape and the difficulty of attachment makes it equally likely many may have fallen off prematurely due to the feathers they were taped to breaking.

Rainier: The 10 Rainier tags attached to adults failed between April 2019 and February 2020 (76-410 days after attachment). These transmitters could not fail because of flat batteries as they had solar panels but might fail if the solar panels were covered by feathers. These transmitters might be expected to last longer than the TAV tags because, although they are about the same size, they are 37% lighter, lower, and their batteries should not go flat. However, although a Rainier tag was indeed the longest lasting tag, the average length of useful deployment was longer for TAV tags. This could be either a reflection of more reliable technology in TAV tags or longer-lasting feathers on the chicks to which all the TAV tags were attached, or the obstruction by feathers of the solar panels on the Rainier tags.

<u>Fisheries interaction with birds tracked in 2019</u>

Within 6 months of attachment, 62% of all the tags had stopped transmitting, before the batteries of any of them should have gone flat. Albatross mortality is much lower than 62% and the high rate of tag loss is clearly not the result of mortality and the loss of a tag is therefore not a reliable indication of the death of a bird. Nonetheless, we carefully examined the timing, location and circumstances of the last transmission of each tag for signs that fisheries interaction might have been involved, by comparing the last fix from each with the location of fishing boats available from Global Fishing Watch (https://globalfishingwatch.org). Of the 43 tagged adults, 23 were either seen on the island in March 2020 (14 birds) or successfully raised a chick in 2019 (9 birds) (Appendix 1). Since chicks rarely fledge without 2 live parents for most of the year, we can be reasonably sure that these 9 birds, along with those we saw, survived the year. More non-breeding birds wearing transmitters may have survived the year but not been detected on Antipodes Island in summer 2020 due to our late arrival and early departure.

Rainier tags: the 10 Rainier tags deployed in 2019 offered the best opportunity to detect fisheries interaction as they provided on average 32 accurate GPS fixes per day and were very durable. Two of these 10 transmitters failed close to fishing boats. Female Green-014 failed in February 2020 about 53km from a trawler off the Chilean coast. However, after successfully rearing a chick in 2019, Green-014 would be expected to be undertaking moult at the time the transmitter stopped, so the reason transmission stopped is unlikely to be related to fisheries. The transmitter of an early-failed breeder in 2019, female White-755, stopped about 5km from a long-liner to the north of NZ in May 2019. Neither her nor her partner, nor sign of a new failed nest by this pair was seen on Antipodes Island in March 2020, as would have been expected if White-755 was still alive.

Pinpoint tags were less able to detect fisheries interactions because they produced only an average of five fixes a day and proved not very durable. None-the-less one of the 8 tags was deployed on a non-breeding female, Blue-77F and it failed about 158km from a trawler off the coast of Chile in May.

Xargos tags were potentially good detectors of fisheries interaction, as they produced accurate GPS fixes every hour and could detect radar from fishing boats. However, they were not very durable (Table 4). Two of 20 tags failed near to fishing boats. The transmitter of female non-breeder Blue-04D stopped about 21km from a trawler close to Chatham Islands in February 2019 and the transmitter had detected radar a week earlier only 50km away. The transmitter of Blue-60E a non-breeding female, had detected radar and stopped about 145km from a trawler close to the Chilean coast in late March 2019.

TAV tags were theoretically least able to detect fisheries interaction because they produced only about 5 low quality Argos fixes per day, and were attached to chicks from which corroborating evidence about survival was unavailable because they do not to return to Antipodes Island for 3 or more years after fledging. The TAV tags were, however, very durable. Two of 20 of these transmitters stopped transmitting within 130km of fishing boats. White-44J was tracked within 5km of a long-liner on 2 July 2019 and was subsequently tracked in a straight line heading for American Samoa – the same track as the fishing boat it approached. The transmitter was subsequently returned to New Zealand and the bird reported killed. Another bird, White-51J, stopped transmitting during January 2019 only 123km from a trawler NE of the Chatham Islands but this was at the time we expected the batteries to go flat.

<u>Biological information gained from 2019 deployments</u>

All flights made by birds wearing satellite transmitters in 2019 are shown in Appendix 2. From these 58 flights the following observations were made.

- Only 52% (13 of 25) of non-breeding adult albatrosses visited the Chilean coast in 2019, which contrasts to 75% (43 of 57) of the tracked non-breeding population visiting the Chilean coast between 2011and 2017, though the difference is not significant (Contingency table χ^2=2.2, df=1, p=0.14).

- Almost all (16 of 19) of the chicks wearing satellite transmitters in 2019 did not visit the Chilean coast, but rather spent all of 2019 north-east of New Zealand's North Island and in the Tasman Sea (Figure 10 and Appendix 2). While male and female fledglings foraged in similar areas, females went further north than males (4.7% of fixes from females came from north of 30°S, while only 1.4% of male fixes did). Chicks of both sexes spent more time north of 30°S than did adults (0.4% of fixes).

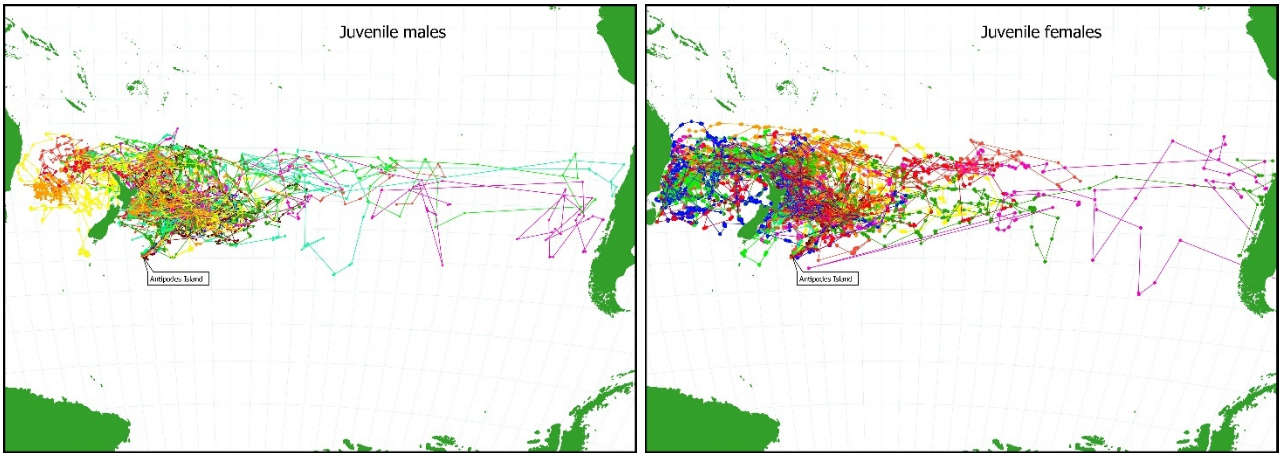

Figure 10: At-sea distribution between January 2019 and February 2020 of 10 male and 10 female Antipodean wandering albatrosses who fledged from Antipodes Island in January 2019.

- Female breeder Green-014 stopped feeding her chick on Antipodes Island about 11 November 2019, nearly 3 months sooner than female Blue-61B (20 January 2020) though her egg had been laid only a week earlier than that of Blue-61B. However, a chick successfully fledged from the nests of both these birds. As has been reported in *Diomedea exulans*, at least some males clearly take a much larger share of chick provisioning in the late stages of rearing *Diomedea antipodensis antipodensis*.

- When relieved on her nest after laying an egg, female breeder White-315, flew speedily to the Chilean coast, quickly turned around and came directly back to Antipodes Island. Her nest would have failed by then as she had been away about 6 weeks, but she spent about a week making short local flights around Antipodes Island, presumably to reconnect with her mate, before finally leaving the island for good that year. It was previously unknown that such lengthy connections to an abandoned nest would exist.

2020 satellite transmitter deployments

All but one of the 40 transmitters attached in 2020 were still transmitting as of 1 May 2020 (Fig 11).

Of the 15 non-breeding females to which we attached satellite tags in 18–26 March 2020, nine had not been recorded back in the albatross study area since they fledged. One of the nine was 7 years old and the others 10 or 11 years old. They and the remaining six non-breeding females had noticeably more worn feathers than did breeding birds, and it is unknown how much this might affect the longevity of the satellite transmitter attachment.

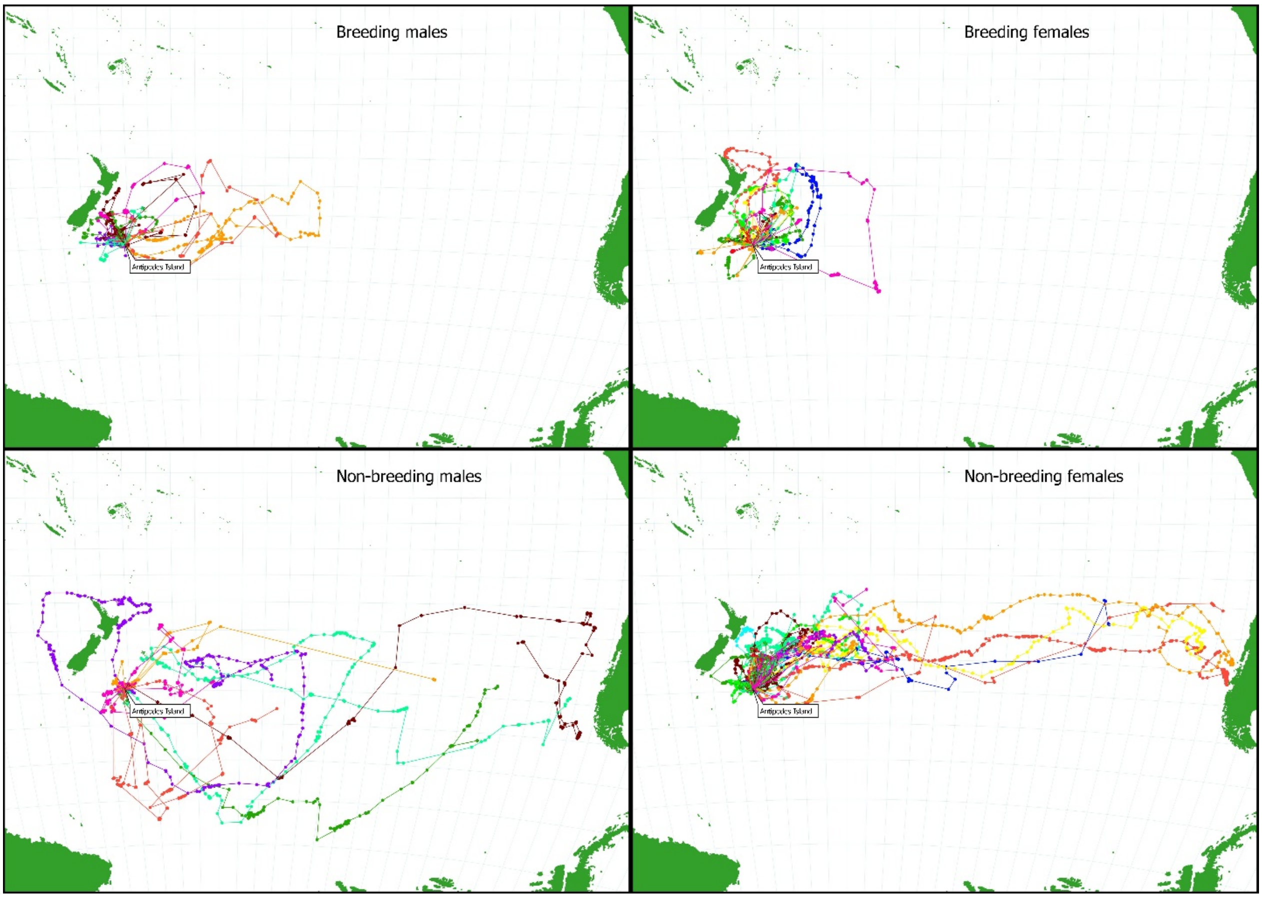

Figure 11. Satellite tracking of 15 female and 8 male non-breeding and 10 female and 9 male breeding Antipodean wandering albatrosses from 26 March to 30 April 2020

DISCUSSION

Population trends

The number of breeding Antipodean wandering albatrosses, as estimated by both nest counts and mark-recapture, has been declining since 2005, though the rate of decline has slowed in recent years. At 75 pairs, the number of birds breeding in the study area in 2020 was third only to 2015 (73 pairs) and 2017 (57 pairs) as the lowest number ever recorded. While the low number of pairs nesting in 2020 is of concern, mark-recapture estimates are a much better indicator of population change than are simple counts of nests, and mark-recapture suggested that in 2019, the Antipodes Island population might have stabilized.

This change is attributable to improving female survivorship, and high recruitment to the breeding population in the last few years. Both these improvements are fragile. Although female survivorship has on average improved over the last few years, the survivorship of both breeding and non-breeding females recorded in 2017 was very low (82% and 83% respectively), and in 2019 the survivorship of breeding females was extremely low (74%). The latter should be treated with caution though, as it might be an artefact of the late and short field trip to Antipodes Island in 2020.

The recent levelling off in rate of decline of nesting pairs is driven mainly by a wave of recruitment of birds that hatched in “the good years’ before 2005. In 2019 40% of nesting females were new recruits and in 2020 about 25% were; on average these birds were 18 years old. However, over the next few years the supply of pre-breeding birds will inevitably shrink. After 2005, far fewer pairs each year nested and nesting success fell by around 10% (Figure 7).

While it is possible to calculate the number of “extra” deaths, over and above normal mortality which occurred in the period 2009–2019 (25,500 birds, 11,000 of them adult breeders) when the decline rate was slowing, it is harder to estimate the numbers of “extra” deaths which occurred during the period when the decline was at its steepest as Antipodes Island wasn’t visited in 2006— the only year missed in the last 26 years. If we conservatively assume that birds died at the same rate between 2005 and 2008 as they have subsequently we estimate that roughly 35,000 “extra” birds died over and above normal mortality since 2004, 15,000 of them adults and 20,000 of them pre-breeding birds, of which about 70% are females. The loss of an estimated 700 males and 1600 females annually during the last 15 years has led to a strong sex imbalance in the surviving population.

A feature of the decline period in Antipodean wandering albatrosses has been the high numbers of female birds “choosing” not to breed. In 2005–2010, the proportion of females that attempted to breed dropped as low as 28% but since 2016 returned to between 40 and 80%, a similar pattern to that recorded in closely-related Gibson’s wandering albatross (Figure 12). The low numbers nesting in 2020 suggest the situation has not fully returned to pre-crash state. Just why the proportion of females breeding declined in 2005–2016 and began returning to normal is unclear. That the same change was occurring in Gibson’s wandering albatross at much the same time (Figure 12) suggests that oceanic conditions both west of New Zealand where Gibson's wandering albatross primarily forage and east of New Zealand where Antipodean albatross mainly forage (Walker & Elliott 2006) were suboptimal in 2005–2016 and have since improved.

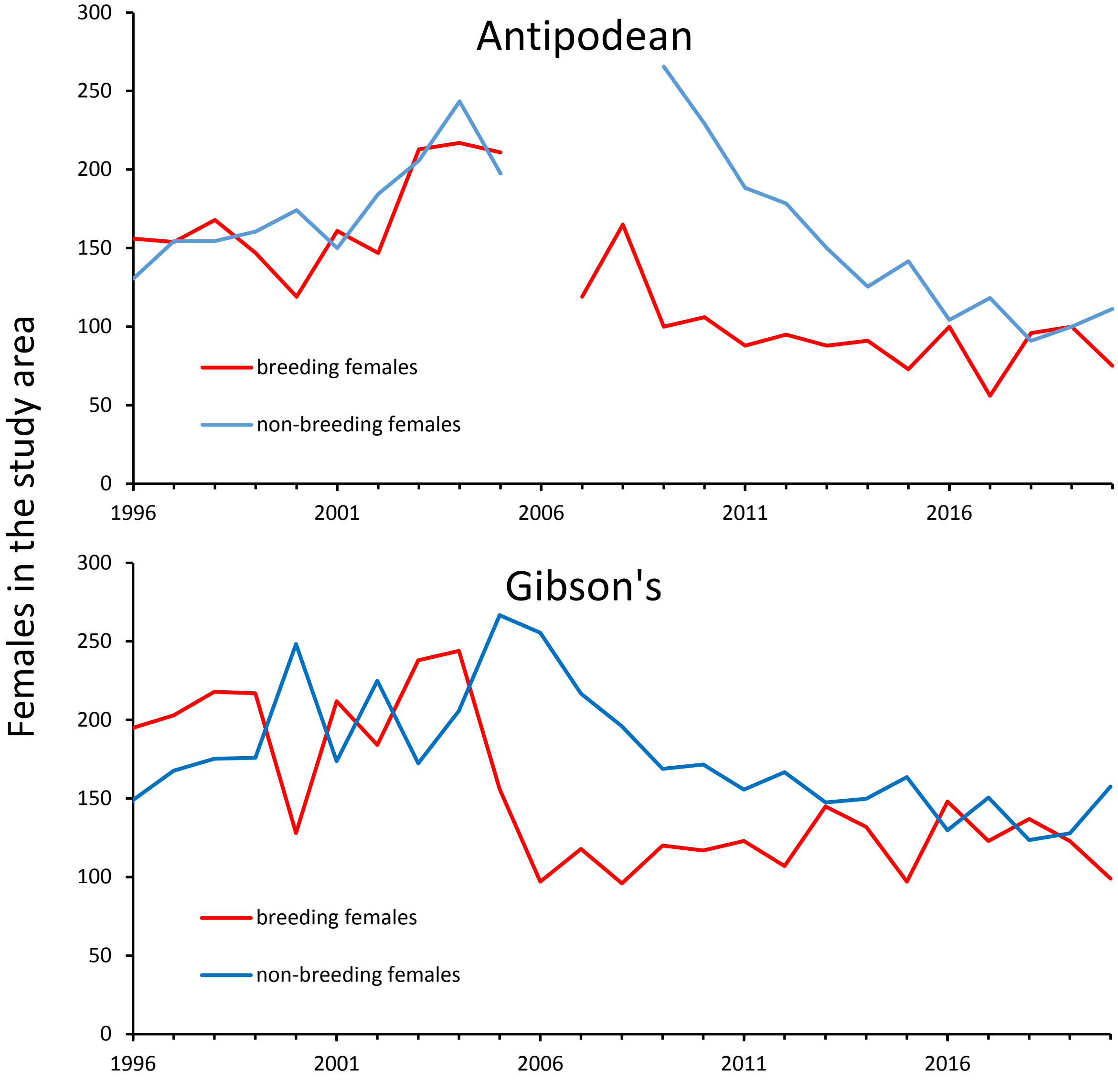

Figure 12. The proportion of female Antipodean wandering albatross (top) and Gibson's wandering albatross (bottom) breeding (red line) or not breeding (blue line) in the study area on Antipodes and Adams Island respectively in 1996–2020.

However, despite that similarity, the survivorship (Figure 13) and trajectory of the Antipodean wandering albatross population has been different to that of Gibson's wandering albatross (Figure 14).

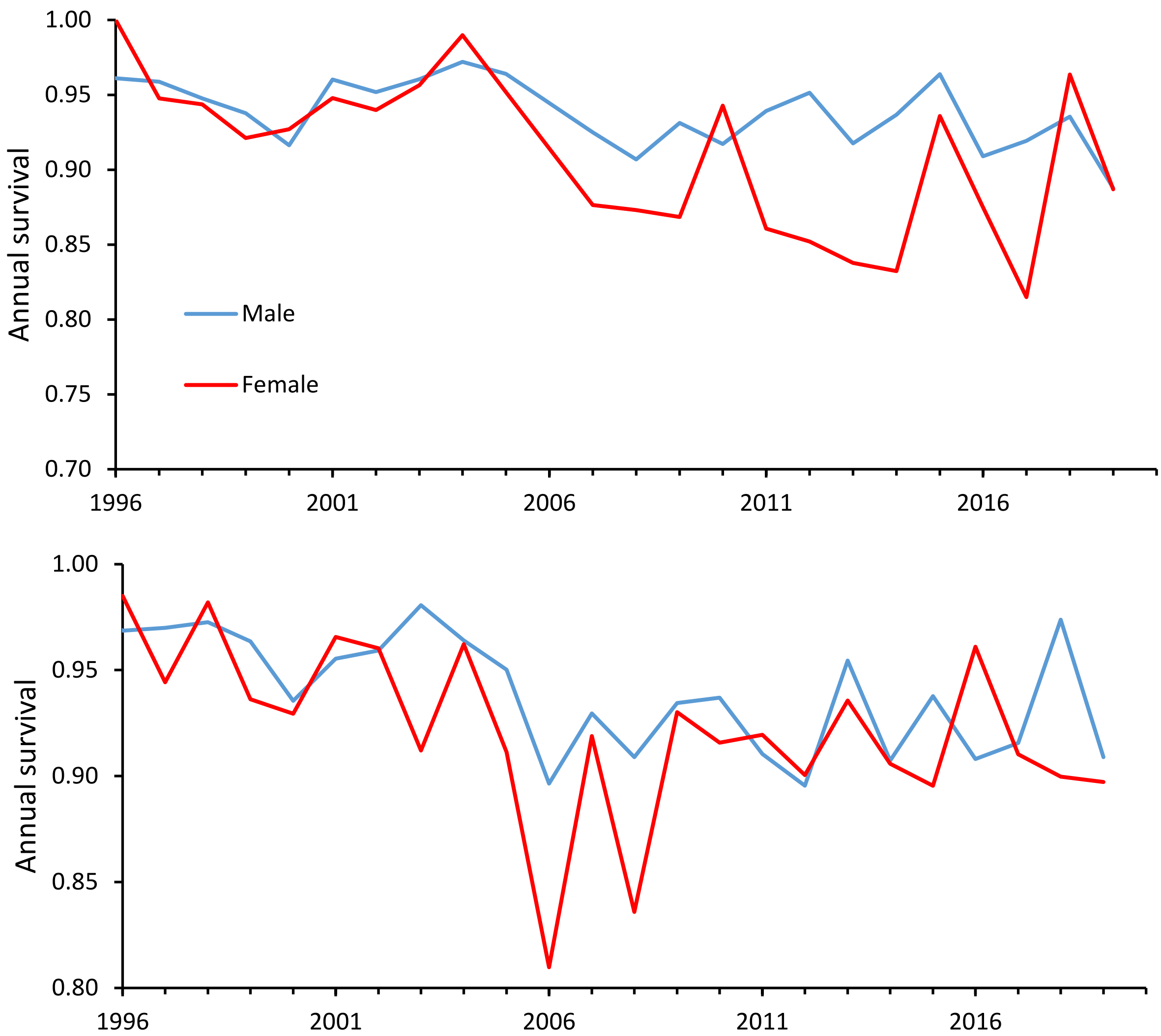

Figure 13. Survival of male (blue) and female (red) Antipodean (top) and Gibson's (bottom) wandering albatrosses in 1996–2019. Gibson's wandering albatross data from Rexer-Huber et al. 2020. Note that as Antipodes Id wasn't visited in 2006, survival estimates for Antipodean wandering albatross in 2006 and 2007 were estimated from the survival over a 2-year period and then equally apportioned amongst the 2 years.

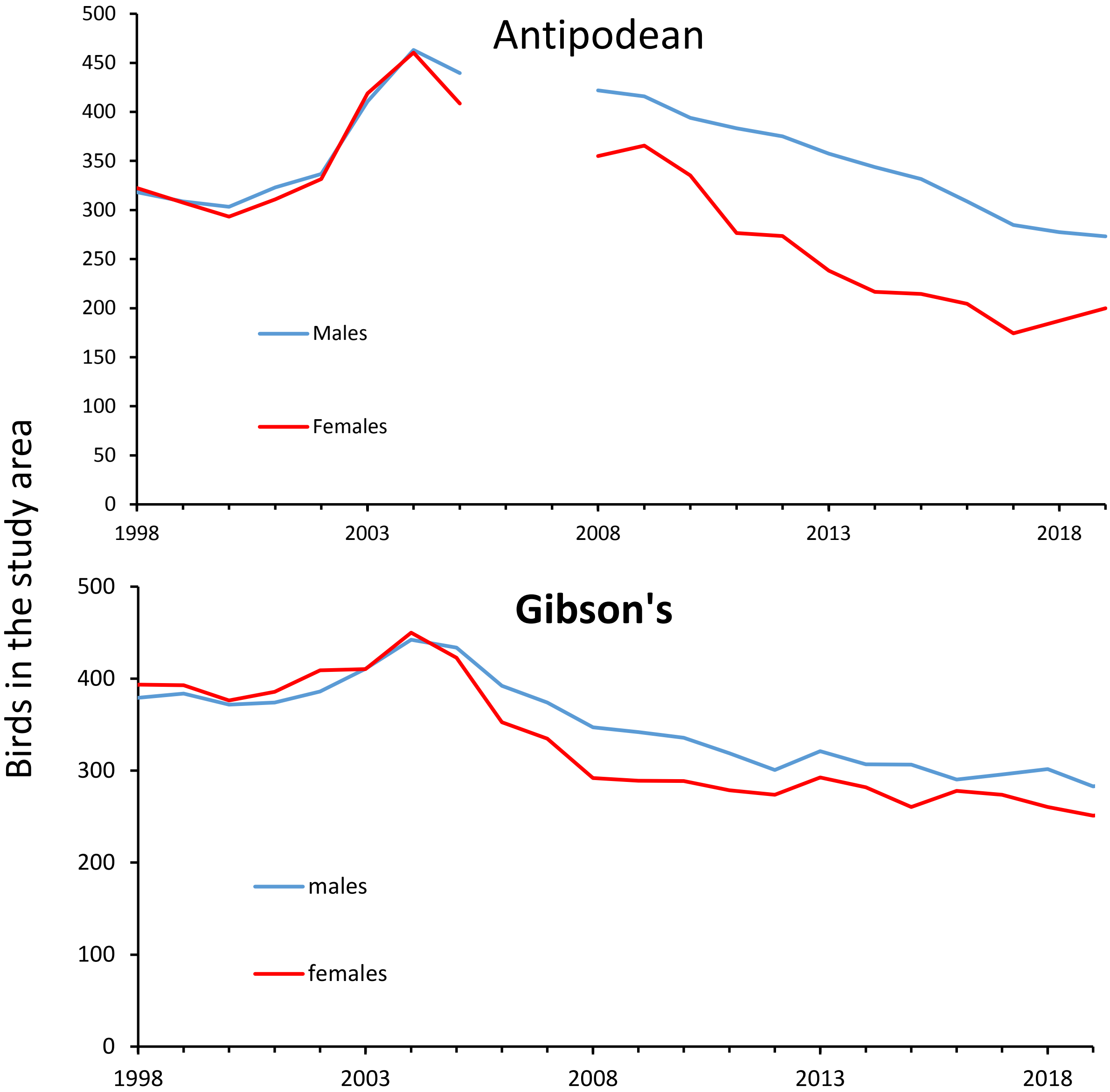

Figure 14. The number of breeding pairs of Antipodean (top graph) and Gibson's wandering albatrosses in the study areas on Antipodes and Adams Island respectively in 1998–2019 estimated by mark-recapture. Data for Gibson's albatross from Rexer-Huber et al. 2020.

Tracking the birds at-sea

Extensive satellite tracking of both male and female Antipodean wandering albatross showed many fledglings spent time in the Tasman Sea where most Gibson's wandering albatross forage, and little in the coast off South America, at least in 2019. If this happens in other years, it may help explain some of the similarities in their demography's.

The confirmed death of one juvenile female (White-44j) in a long-line fishery in the most northern waters used (26.6° south), and the use of the same area by 3 of the other 8 female juveniles but none of the male juveniles tracked in 2019 suggests that a fisheries-induced sex bias in survival might begin soon after fledging driven by differences in overlap with high seas fisheries. Juveniles, particularly females, spent more time in more northerly waters than did adults (Appendix 2). Little was previously known of the at-sea distribution of juvenile Antipodean wandering albatross; this sample suggests they overlap more with long-line fisheries which are more extensive in northern than southern waters than do adults. Any impact of this is unknown, as survival not been measured in juveniles.

During the last two visits to Antipodes Island we have deployed 6 different types of satellite transmitters and have reached some conclusions about their suitability for assessing interaction between the birds and fishing fleets. Most of the likely interaction between Antipodean wandering albatrosses and fishing boats occur in the winter (Elliott & Walker 2018) so transmitters that stay functioning and attached for at least 5 months provide better information than those that fail or fall off before then.

The large and heavy Xargos and Pinpoint transmitters were the least durable and the Pinpoint transmitters also provided very few fixes. When working at their best, the Xargos transmitters provided the best data stream of all the transmitters and included radar detections as well as very frequent GPS fixes. However, unless Xargos transmitters could be made lighter and more reliable, they mostly do not transmit for long enough to be useful for Antipodean wandering albatross.

The TAV2630 Argos satellite transmitters were on average the most durable, though the best performing solar tag lasted longer. It may be worth experimenting with reducing the transmission schedule of the TAV tags to see if they can last a little longer, but they may fall off through moulting or feather breakage before the batteries expire. TAV tags produce only relatively inaccurate doppler shift fixes which will provide less accurate data for assessment of fisheries interaction than GPS fixes.

The three solar-powered GPS tags, one each from Microwave Telemetry, GeoTrac and Wildlife Computers, have very similar specifications. Only Wildlife Computers Rainier S20 tags have been attached for long enough to assess their durability, but the similarity between the shape and weight of these three tags and the way they were attached means they should stay attached for the same length of time: only their reliability might vary. The longest lasting of all the transmitters deployed was a solar-powered Rainier S20, though the average durability of these tags was a little less than that of TAV tags.

Two issues with solar-powered tags require further work that might improve their durability: feathers obscuring solar panels and balancing power use and data collection and transmission schedules. Some tags have the solar panels obscured by feathers which means they transmit intermittently and perhaps fail. This might be fixed using “tape outriggers” (Department of Conservation, no date) to hold potentially problematic feathers out of the way. Solar-powered transmitters that are programmed to collect GPS fixes and transmit data frequently, quickly exhaust their small batteries and must shut down while their batteries are re-charged. When programmed in this way they produce intermittent data streams. Such transmitters can be programmed with conservative GPS collection and transmission schedules which means that there are no breaks in the data stream, but less data is produced. The optimum GPS collection and data transmission schedule for Antipodean wandering albatrosses will need to be found by trial and error.

Regardless of the transmitters used, the age and breeding history of birds is likely to affect the duration of transmitter attachment. Different ages and classes of birds are at different stages of the moult cycle and transmitters fall off when the body feathers they are attached to are moulted. Most knowledge of moult is of primary rather than body feathers (Prince *et al*. 1997), but the following principles are probably applicable to assessment of how long a transmitter would stay attached. Birds expecting to breed arrive on Antipodes Island in summer with feathers in good condition, having moulted in their sabbatical year, and won’t moult again until their breeding attempt is over. In contrast birds visiting the island just to court will already be in various stages of moult. Juveniles ready to fledge are in the best condition of all the birds present in January with a complete set of new feathers which they won’t begin to moult for some time (starting ~6 months later for body feathers and several years later for primaries and secondaries) (Prince *et al.* 1997).

To date, the more expensive lighter solar-powered GPS transmitters have been attached exclusively to older birds, particularly breeders, early-fail breeders or keeping-company birds. This is because there is a reasonable chance of seeing such birds again before the transmitter falls off, so tags could potentially be redeployed. However, so far none have been recovered.

The cheaper, heavier, battery-powered transmitters with lifespans of around 14 months were deployed exclusively on fledglings in 2019, as fledglings are not able to be re-caught for at least 3–5 years and were expected to have a high initial natural mortality rate. Mortality in fledglings in their first few months has been low; they are likely to have the longest lasting feathers; and they seem to forage further north than adults and thus overlap more with long-line fisheries (Elliott & Walker 2018). For these reasons, light-weight solar tags that last for many years and are light enough to not break feathers are arguably more suitable for fledglings. Tracking young birds between the ages of 2 and 5 can only be undertaken with archival geolocator tags which stay on the birds until they return to the island. A programme of deployment of these tags on young birds is planned for 2021.

RECOMMENDATIONS

1. The trend of declining survival, impending shortage of recruiting birds and ongoing reduced productivity make monitoring the population size and trend of Antipodean wandering albatross, and research into the cause of decline, a high priority.

2. To maximize returns from the large investment in satellite telemetry of Antipodean wandering albatross in 2020, researchers should be on Antipodes Island from mid-late December to recover solar transmitters from 7 birds breeding in 2020, and to improve estimates of survival of birds, including those whose transmitters stopped close to fishing boats.

3. Field work on Antipodes Island next summer should extend into March to maximise the chance of recovering the 40 GLS attached in 2020, many to younger birds who don't attend Antipodes Island till later in the breeding season.

4. Any solar tags available should be attached to fledglings as they are likely to stay attached much longer than they do on adults, can transmit as long as they are attached unlike the battery-powered tags used on juveniles so far, and because preliminary data show juveniles at more risk from fisheries than adults.

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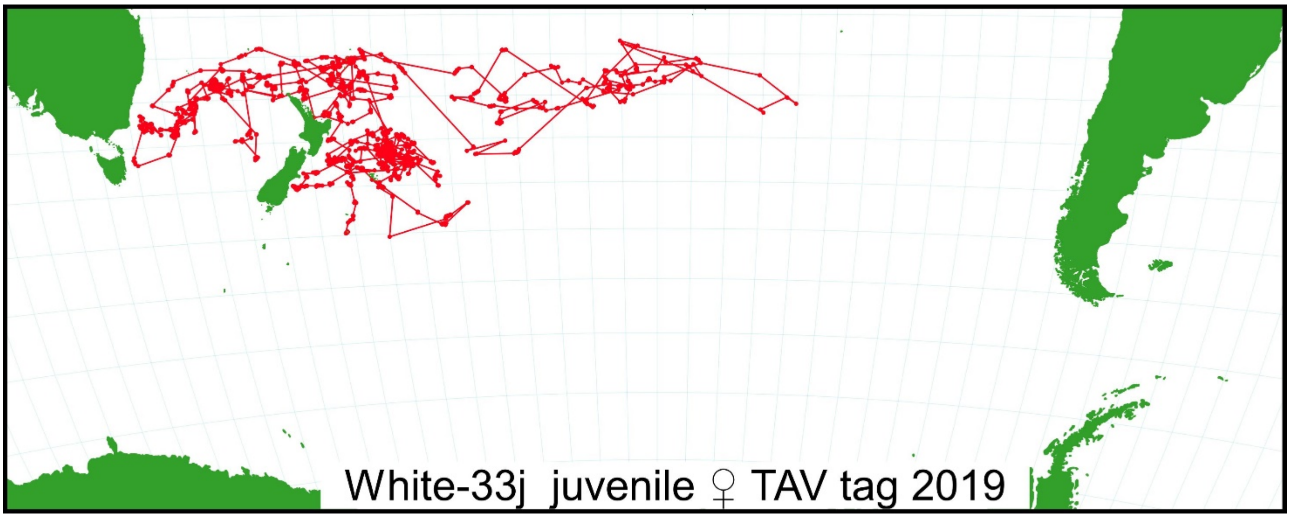
Appendix 1: Calculating the likelihood that the cessation of signals from birds wearing satellite transmitters attached in Jan– Feb 2019 was fisheries-related, as assessed by presence of the birds back on Antipodes Is in March 2020, or the successful fledging of their 2019 chick, and the proximity to vessels when the transmitter stopped.

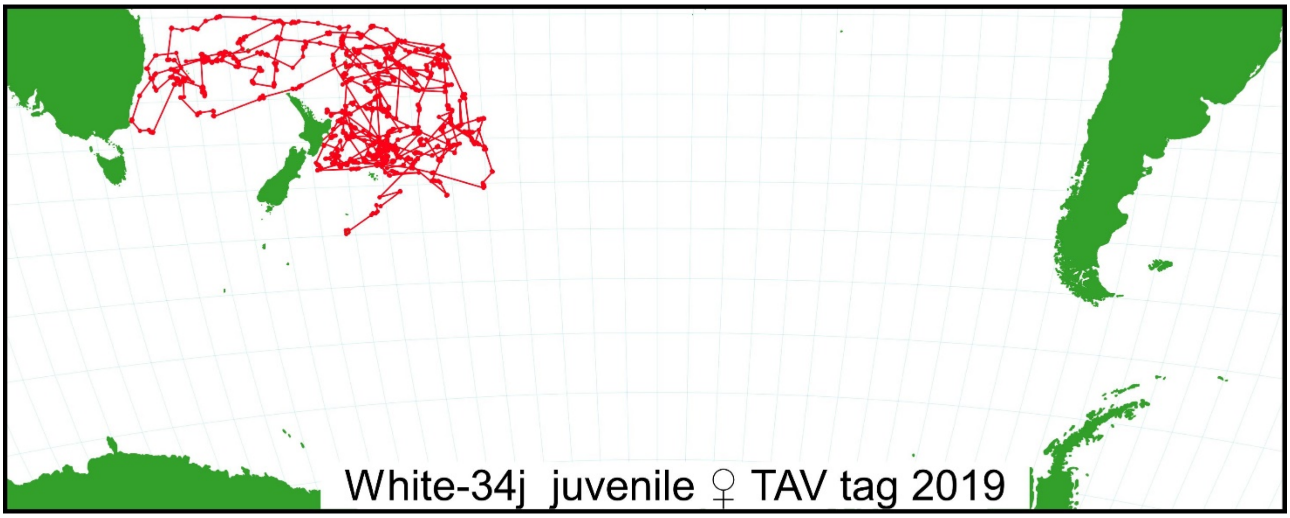
Name	Sex	Status	Device type	Last date & time location received	Days tag on	Alive on island 2020	2019 nest success	Alive after tag stopped	Km from boat
Blue-26g	Female	breeder	Pinpoint	14/02/2019 16:28	16		no		290
Blue-10g	Female	breeder	Pinpoint	6/05/2019 12:56	97		no		335
Blue-25g	Female	breeder	Pinpoint	17/08/2019 13:07	200		yes	yes	396
Blue-77f	Female	non-breeder	Pinpoint	16/05/2019 8:49	106				160
White-639	Male	non-breeder	Pinpoint	1/07/2019 8:10	140	yes		yes	26
White-55b	Male	non-breeder	Pinpoint	2/10/2019 10:25	242				348
White-638	Male	non-breeder	Pinpoint	4/06/2019 6:19	122				355
Orange-656	Male	non-breeder	Pinpoint	12/05/2019 12:07	100				417
White-561	Male	non-breeder	Pinpoint	28/05/2019 12:03	119				443
Blue-734	Male	non-breeder	Pinpoint	23/03/2019 18:56	50	yes		yes	701
White-416	Male	non-breeder	Pinpoint	4/05/2019 7:02	91				738
Blue-71e	Male	non-breeder	Pinpoint	10/05/2019 16:55	89				1240
Blue-848	Male	non-breeder	Pinpoint	14/02/2019 4:31	12				
Green-014	Female	breeder	Rainier	8/02/2020 14:53	393		yes	yes	38.3
Blue-33d	Female	breeder	Rainier	11/06/2019 5:21	140		yes	yes	281
Blue-94d	Female	breeder	Rainier	2/10/2019 20:45	256	yes	no	yes	304
Blue-61b	female	breeder	Rainier	25/02/2020 7:54	410		yes	yes	336
Blue-929	Female	breeder	Rainier	6/04/2019 20:47	76		yes	yes	365
White-755	Female	failed breeder	Rainier	19/05/2019 14:36	125		no		91
Blue-22d	Female	failed breeder	Rainier	18/12/2019 4:22	343		no		407
Blue-90e	Female	non-breeder	Rainier	19/07/2019 14:32	184	yes		yes	212
White-201	Female	non-breeder	Rainier	4/09/2019 6:08	240	yes		yes	240
Blue-07b	Female	non-breeder	Rainier	2/12/2019 20:27	322				679
White-939	Female	breeder	Xargos	17/06/2019 4:00	139		yes	yes	19
Blue-68e	Female	breeder	Xargos	5/04/2019 9:14	67		no		40
White-315	Female	breeder	Xargos	24/04/2019 8:57	85	yes	no	yes	49
Blue-70d	Female	breeder	Xargos	19/02/2019 10:00	34		yes	yes	721
Blue-47f	Female	breeder	Xargos	4/05/2019 3:29	96		no		1168
Blue-23g	Female	breeder	Xargos	28/01/2019 8:00	0	yes	no	yes	
Blue-14g	Female	breeder	Xargos	20/02/2019 21:00	24		yes	yes	
White-038	Male	breeder	Xargos	22/06/2019 6:44	144	yes	no	yes	617
White-251	Male	breeder	Xargos	5/02/2019 11:12	7		no		
Blue-69b	Male	breeder	Xargos	11/02/2019 4:31	13		yes	yes	
White-870	Male	failed breeder	Xargos	19/03/2019 20:00	49	yes	no	yes	84
Blue-04d	Female	non-breeder	Xargos	11/02/2019 10:10	13				21
Blue-60e	Female	non-breeder	Xargos	27/03/2019 5:00	61				101
White-953	Female	non-breeder	Xargos	24/04/2019 22:00	85				386

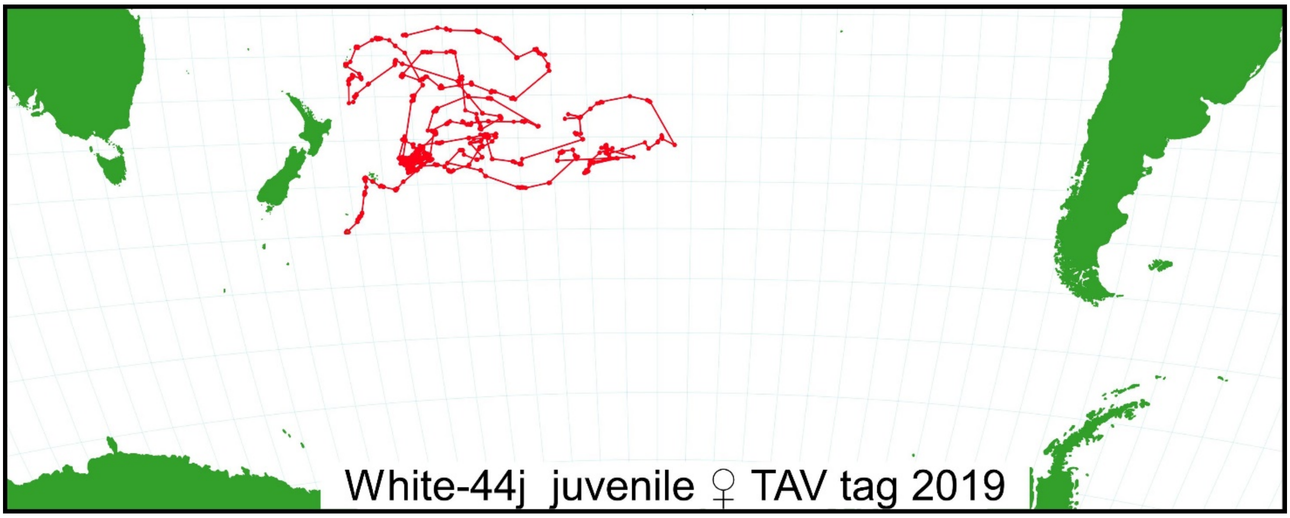
White-570	Female	non-breeder	Xargos	1/05/2019 3:00	91	yes	yes	472
White-462	Female	non-breeder	Xargos	9/05/2019 5:00	104			551
Blue-11e	Female	non-breeder	Xargos	13/04/2019 20:00	77	yes	yes	1163
White-58d	Female	non-breeder	Xargos	28/01/2019 14:00	2	yes	yes	
White-585	Female	non-breeder	Xargos	20/05/2019 9:00	123	yes	yes	
Blue-857	Male	non-breeder	Xargos	3/03/2019 20:00	34	yes	yes	659
White-44j	Female?	juvenile	TAV	30/06/2019 0:00	175			75
White-49j	Female?	juvenile	TAV	27/04/2019 9:53	111			108
White-75j	Female?	juvenile	TAV	28/01/2020 0:00	389			257
White-33j	Female?	juvenile	TAV	10/01/2020 9:58	371			356
White-74j	Female?	juvenile	TAV	30/05/2019 20:44	147			419
White-34j	Female?	juvenile	TAV	10/09/2019 9:12	247			525
White-70j	Female?	juvenile	TAV	22/10/2019 8:41	289			539
White-79j	Female?	juvenile	TAV	31/12/2019 7:59	361			615
White-53j	Female?	juvenile	TAV	28/01/2020 7:00	387			761
White-66j	Female?	juvenile	TAV	25/01/2020 6:03	384			1830
White-51j	Male?	juvenile	TAV	24/01/2020 7:36	383			123
White-73j	Male?	juvenile	TAV	28/01/2020 9:49	388			217
White-42j	Male?	juvenile	TAV	29/01/2020 20:17	389			258
White-82j	Male?	juvenile	TAV	2/09/2019 9:33	239			278
White-63j	Male?	juvenile	TAV	23/04/2019 9:42	108			306
White-30j	Male?	juvenile	TAV	2/10/2019 7:38	271			671
White-31j	Male?	juvenile	TAV	18/01/2020 8:31	379			719
White-76j	Male?	juvenile	TAV	11/12/2019 9:09	339			908
White-69j	Male?	juvenile	TAV	11/10/2019 20:51	280			1022
White-64j	Male?	juvenile	TAV	25/01/2020 18:07	385			1480

Appendix 2: Locations from 58 Antipodean wandering albatrosses of different ages and life stages tracked between Jan 2019 –Feb 2020. Mean (and range) days tracked for each tag type is TAV=301 (108–389), Rainier=249 (76–410), Pinpoint=106 (2–242). Xargos=62 (0–144)

Fledgling females

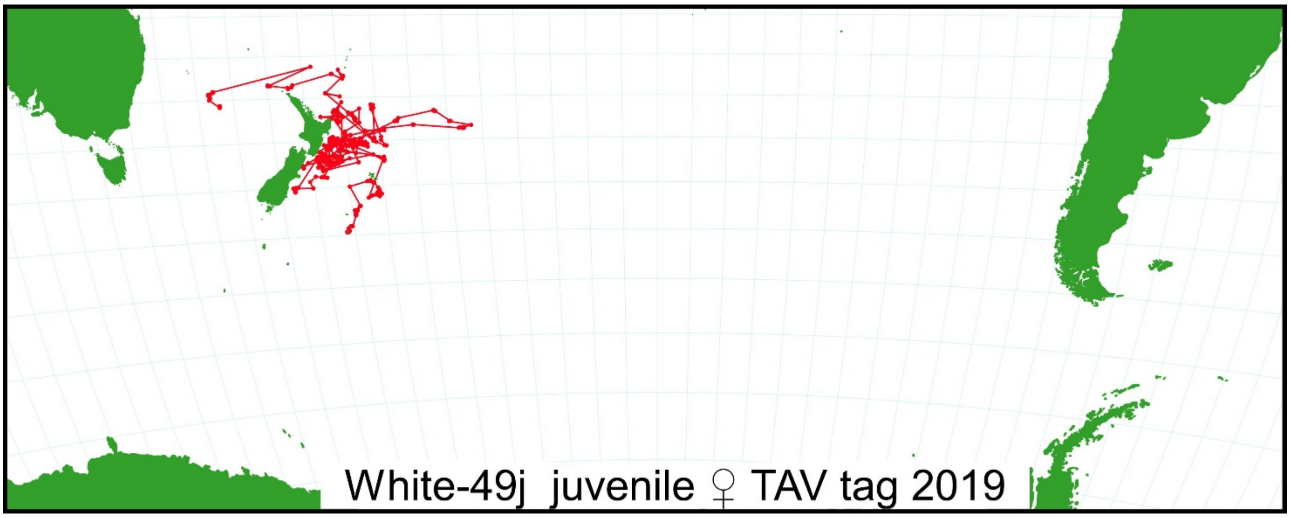


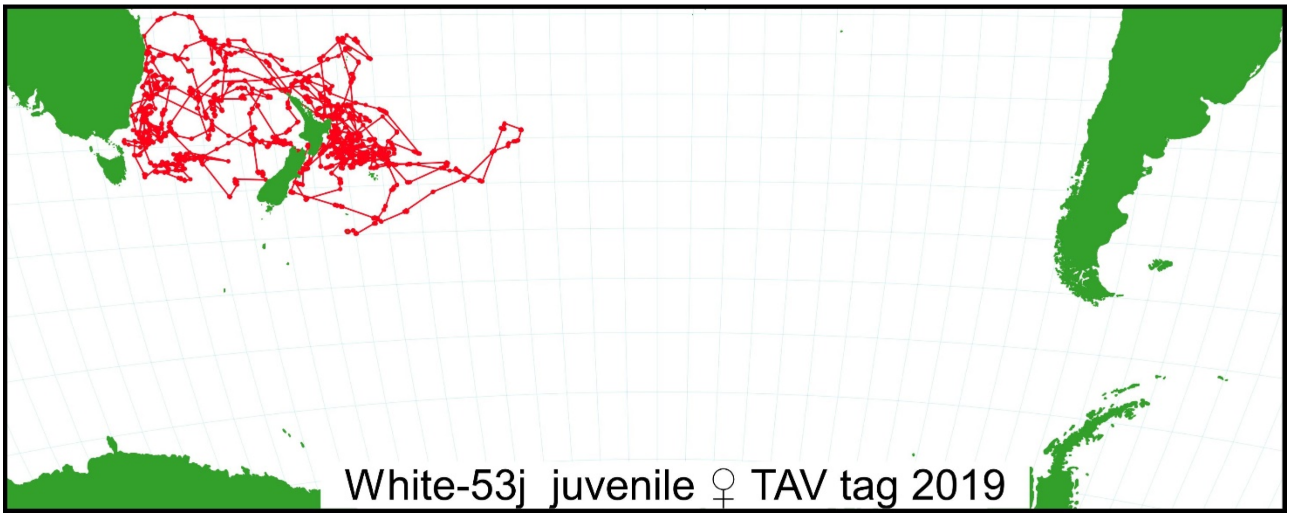


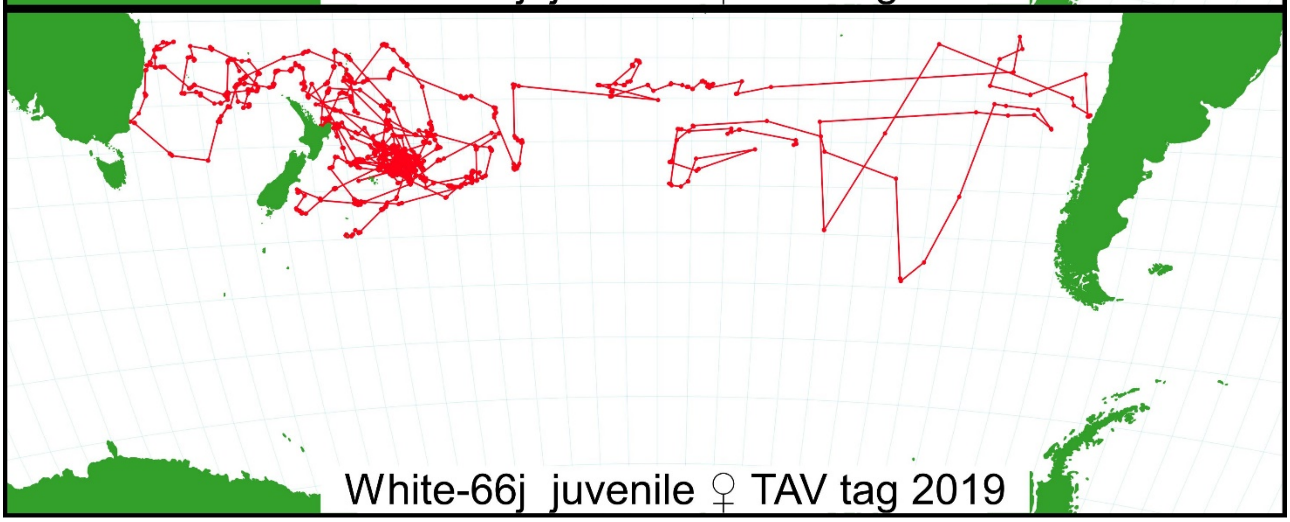


Fledgling female W-44j was caught by long-line fishing boat on 2 July 2019 at 27 °south

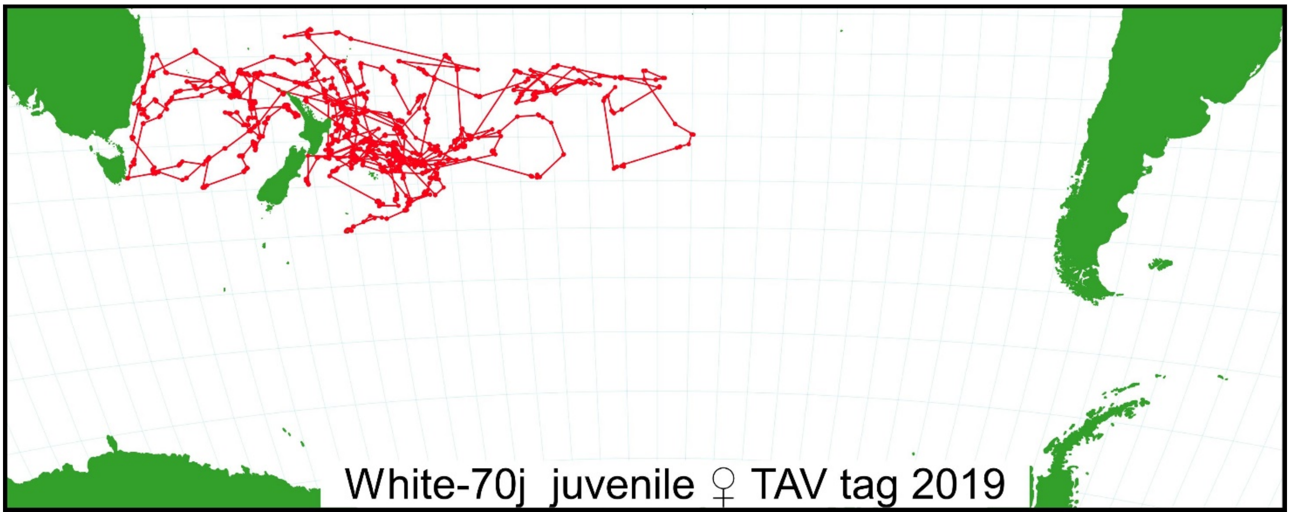
Fledgling females

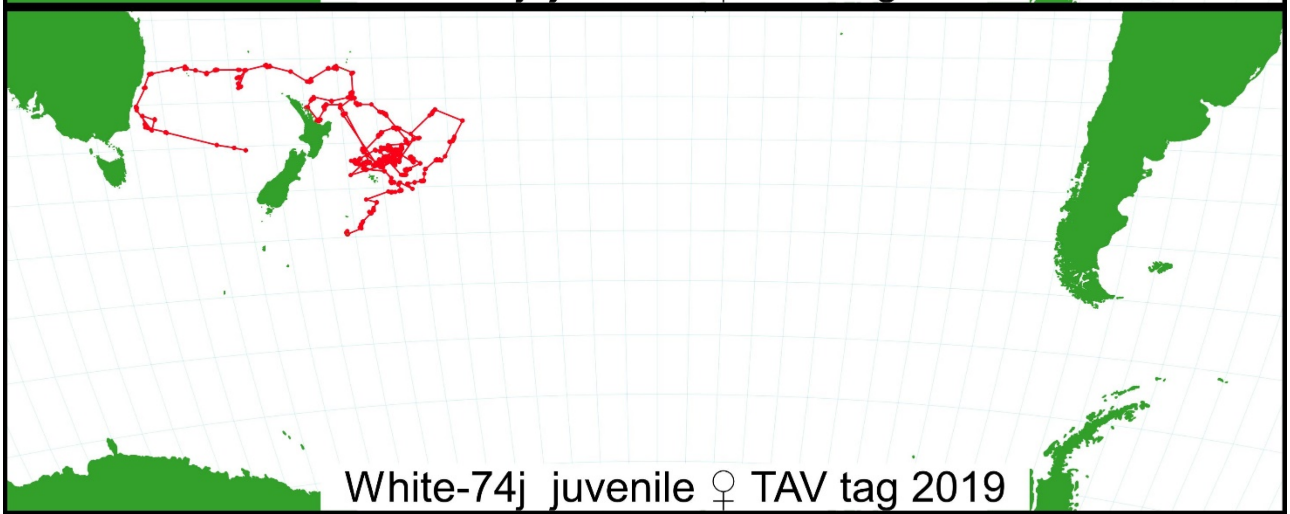


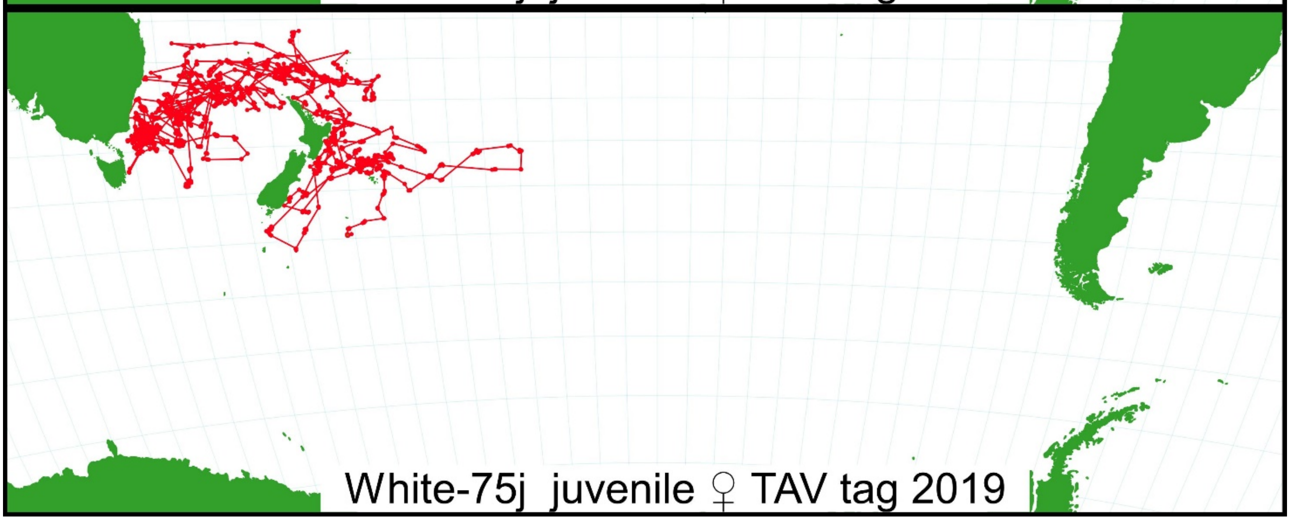




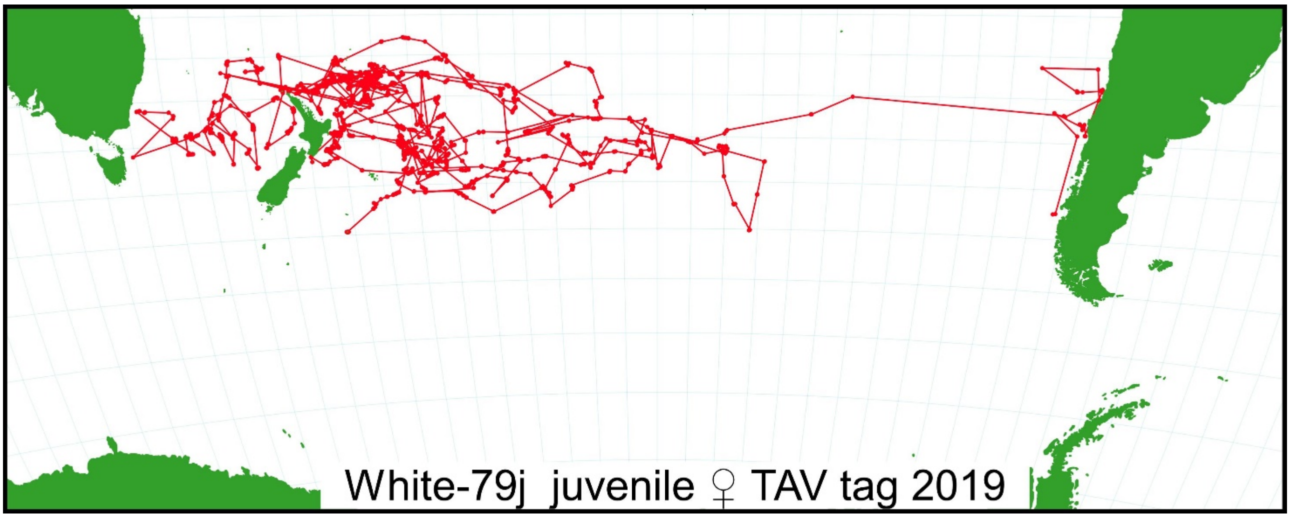
Fledgling females



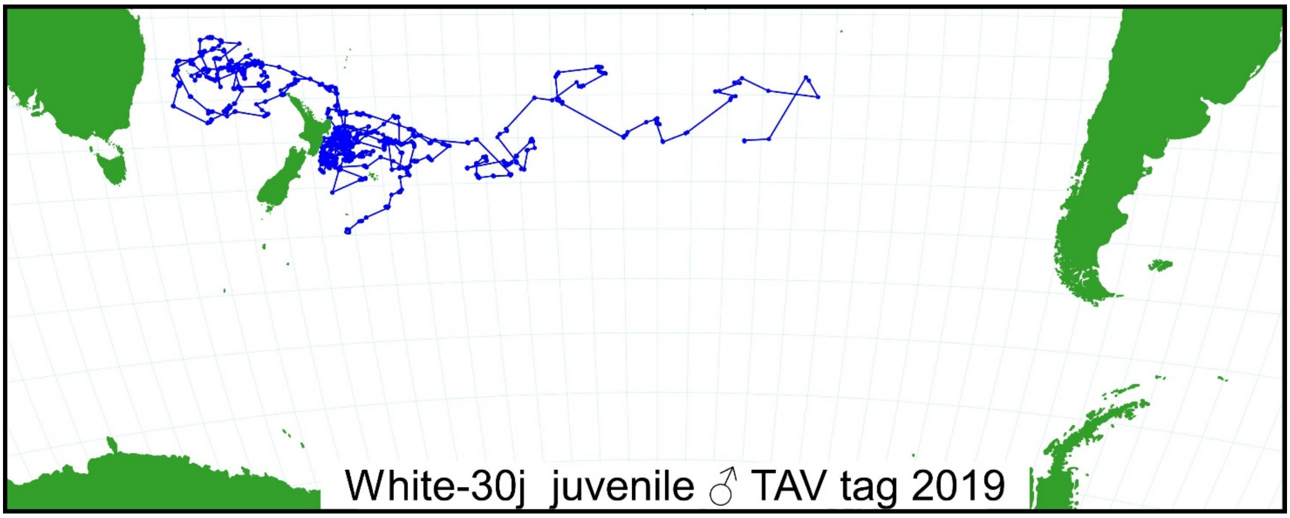


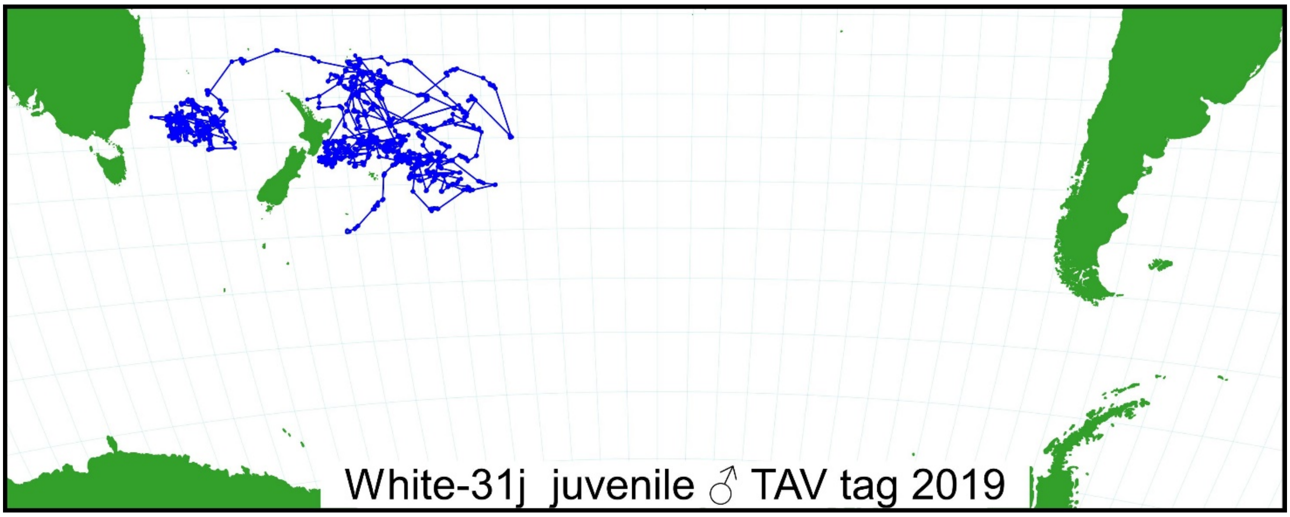


Fledgling female

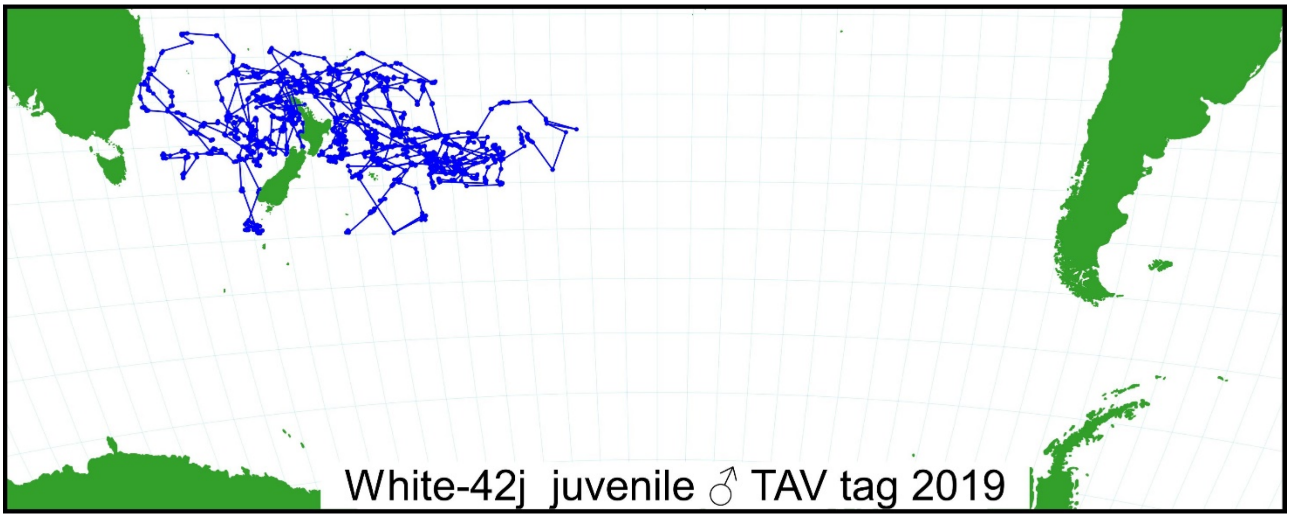


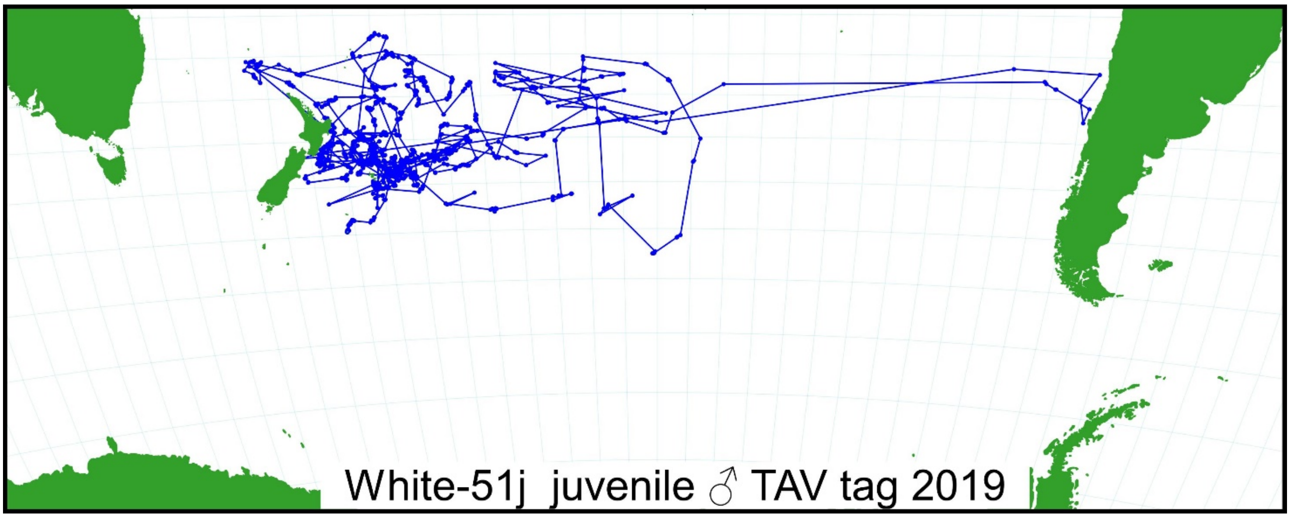
Fledgling males

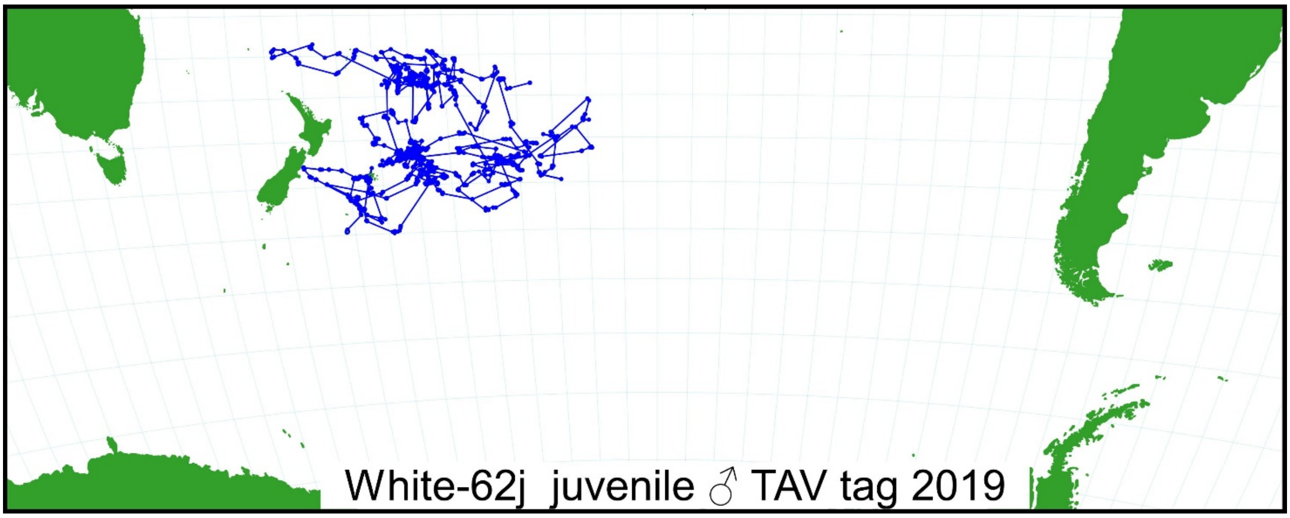




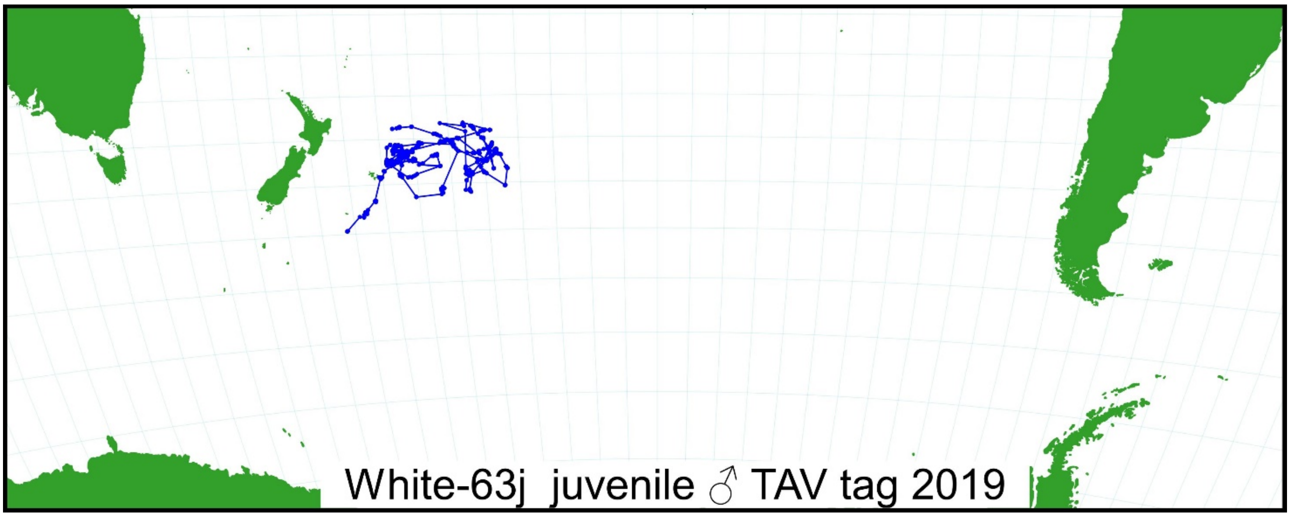
Fledgling males

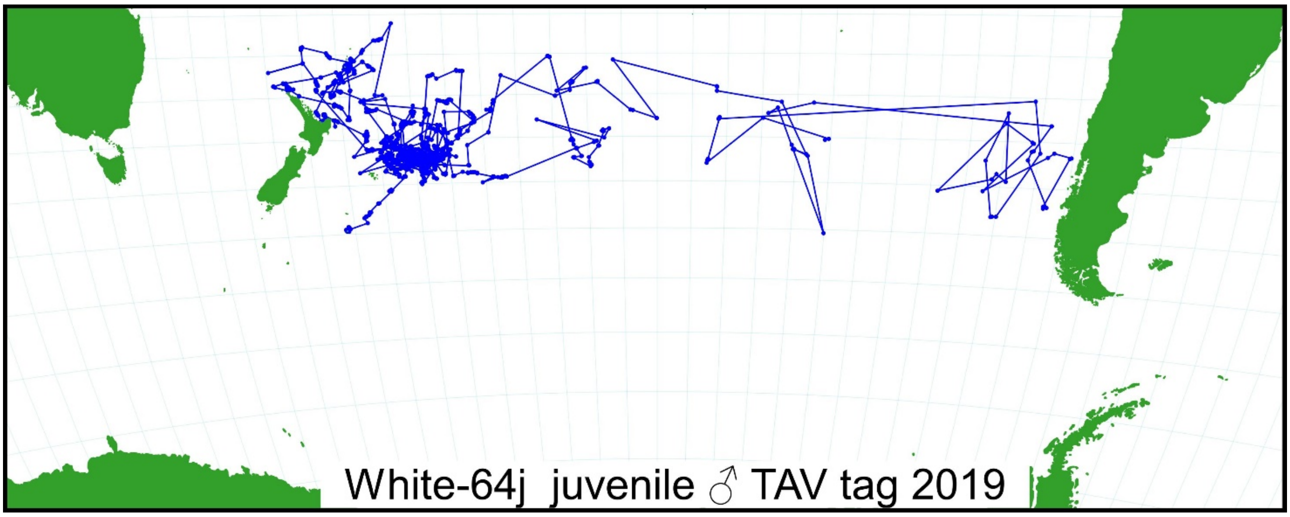


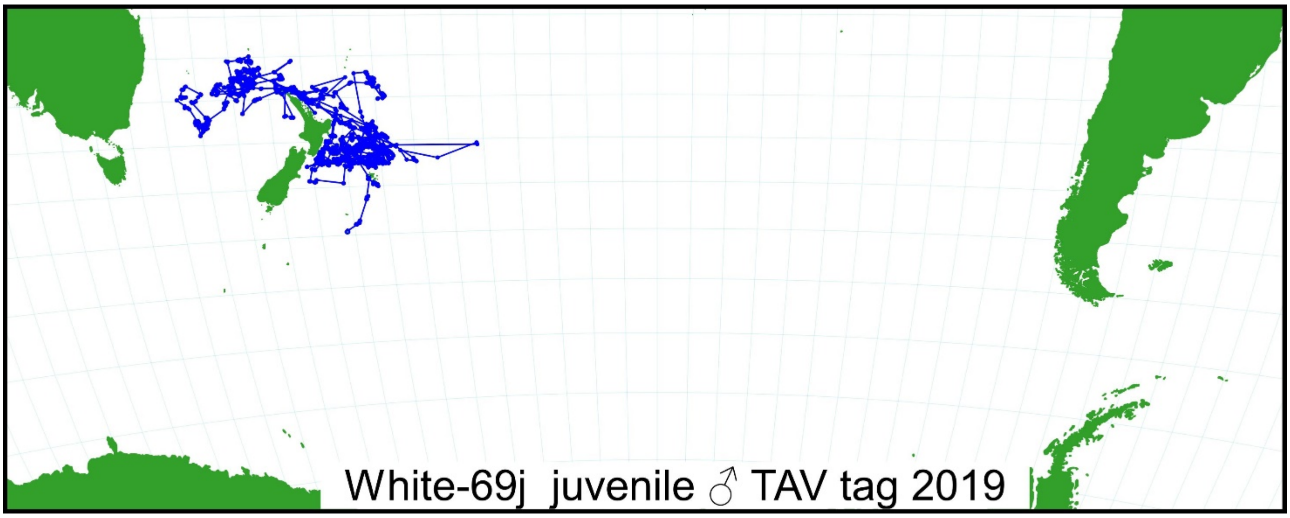




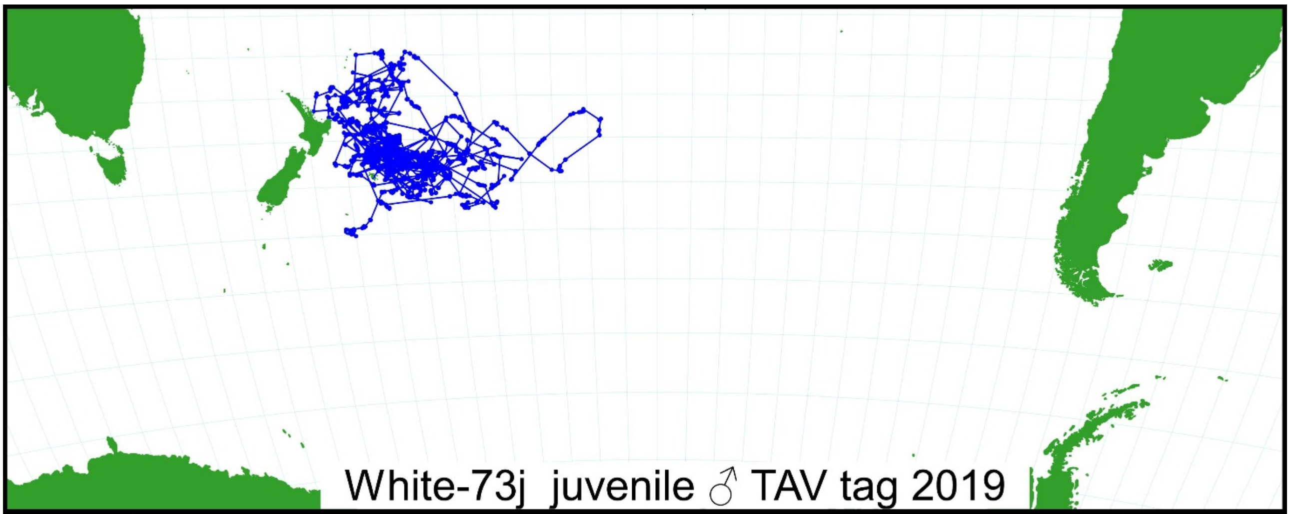
Fledgling males

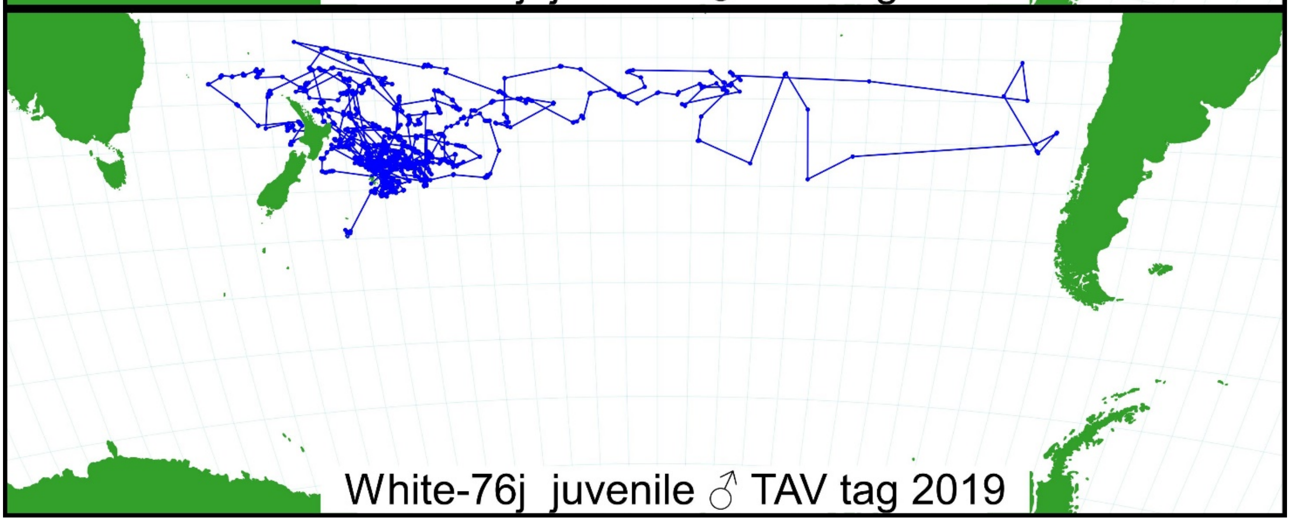




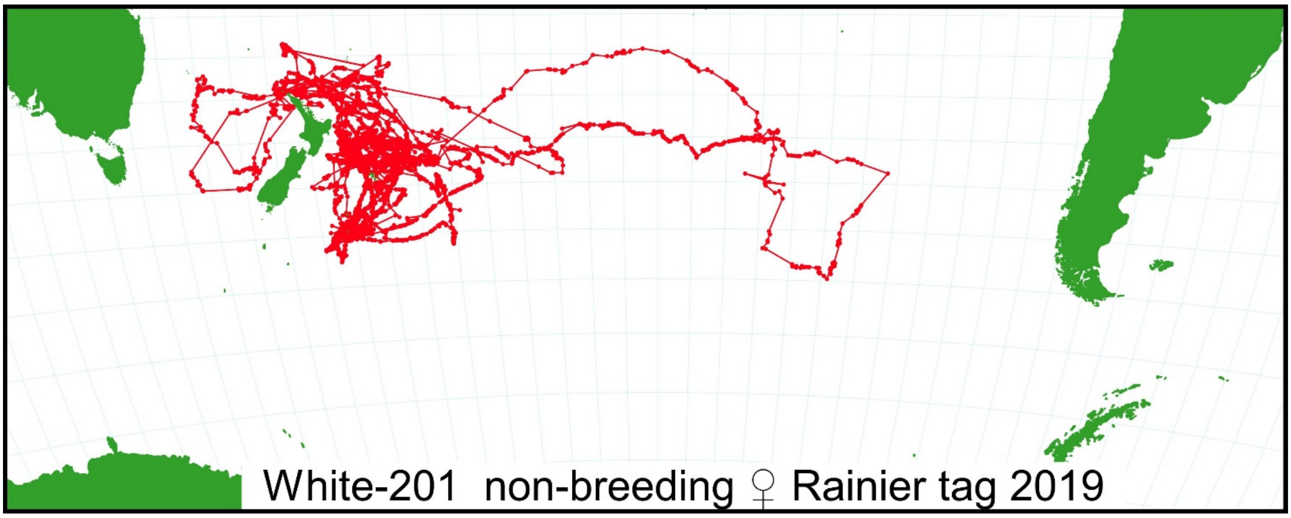


Fledgling males

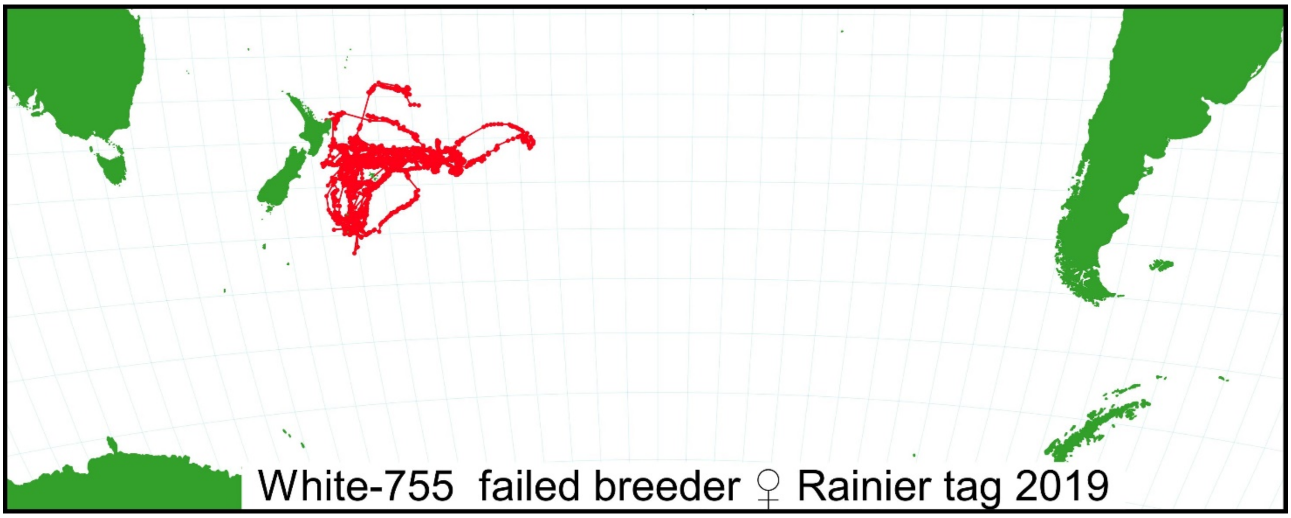




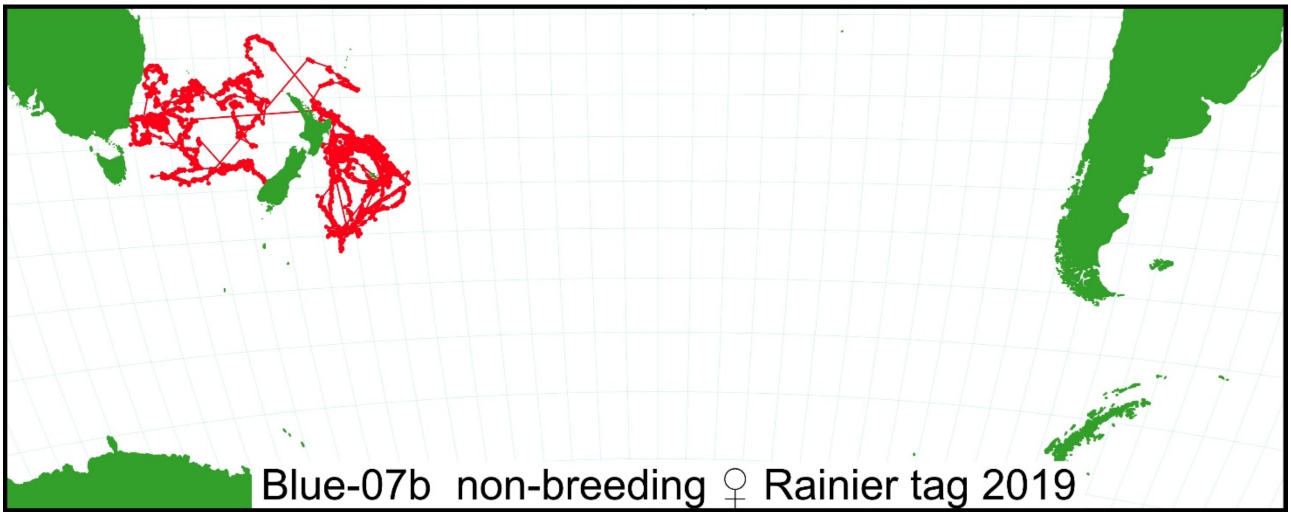
Non-breeding and failed breeding females.

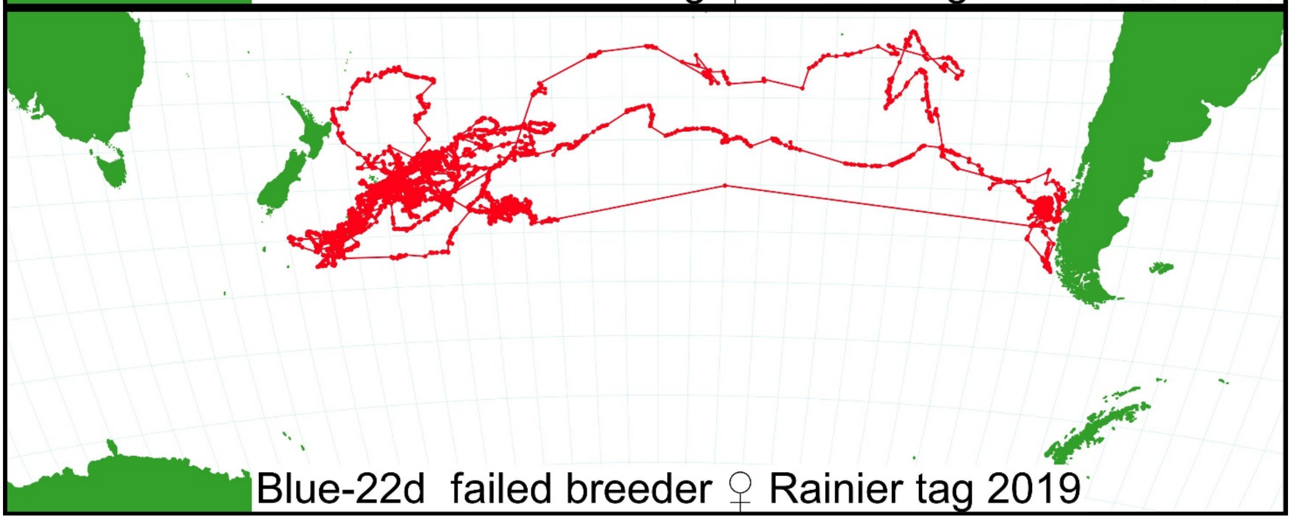


Non-breeding and failed breeding females.

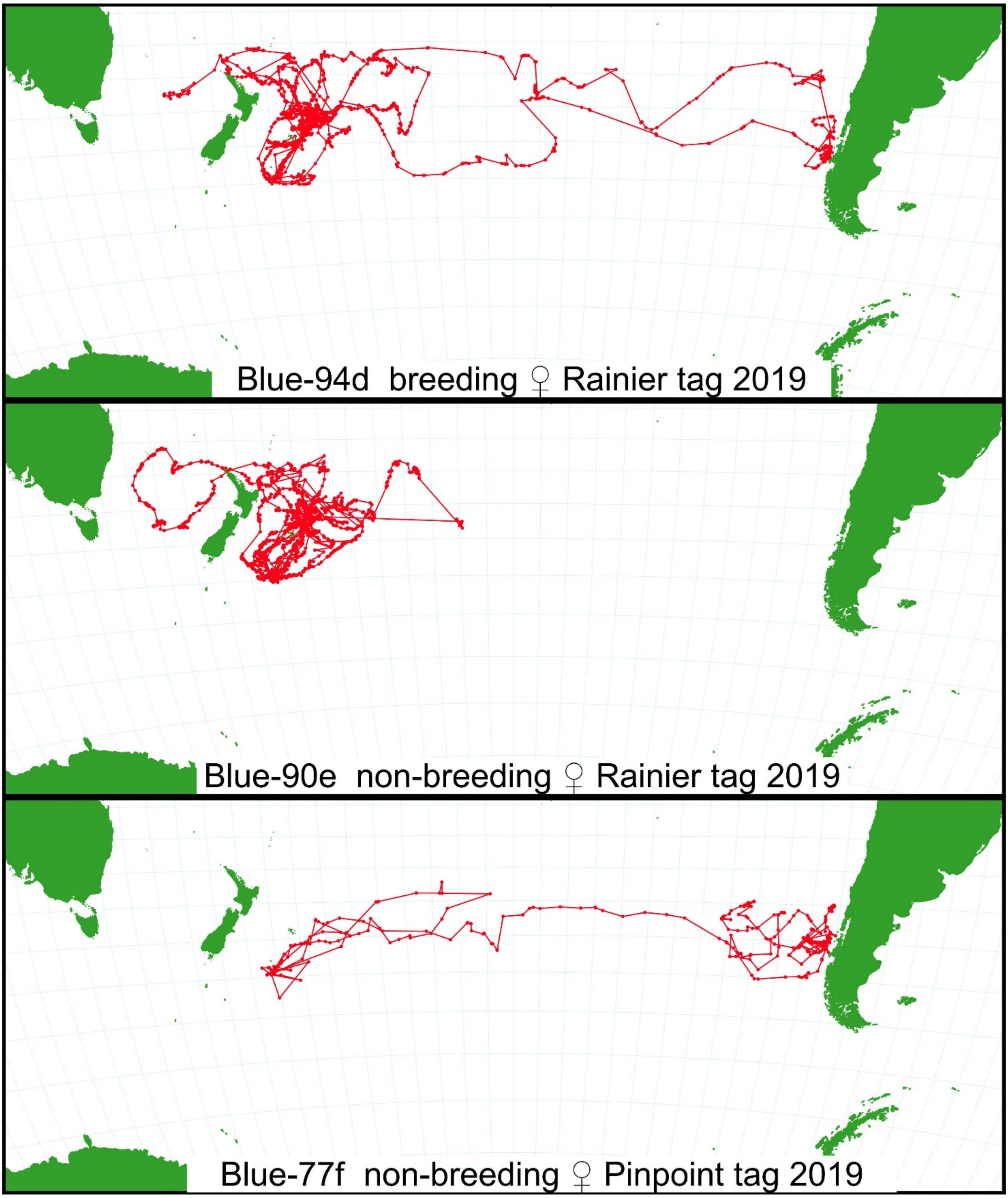


Female White-755 repeatedly returned In Jan-April to her failed nest on Antipodes I to court her mate but was potentially killed on 19 May 2019 when her transmitter stopped close to a long-line vessel over a seamount on the Louisville Ridge North-East of New Zealand's East Cape

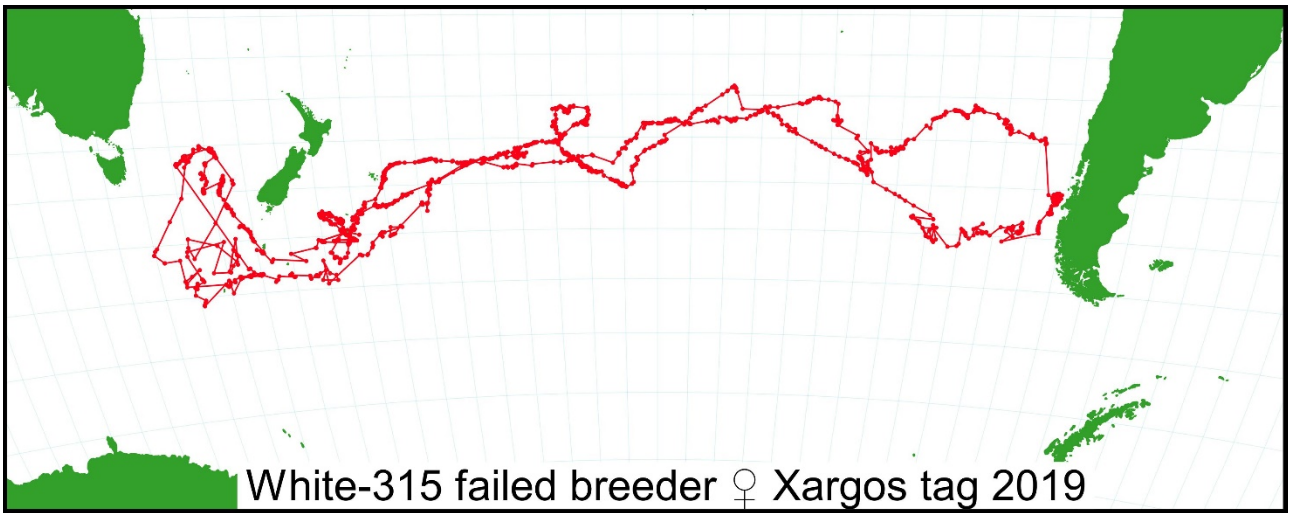




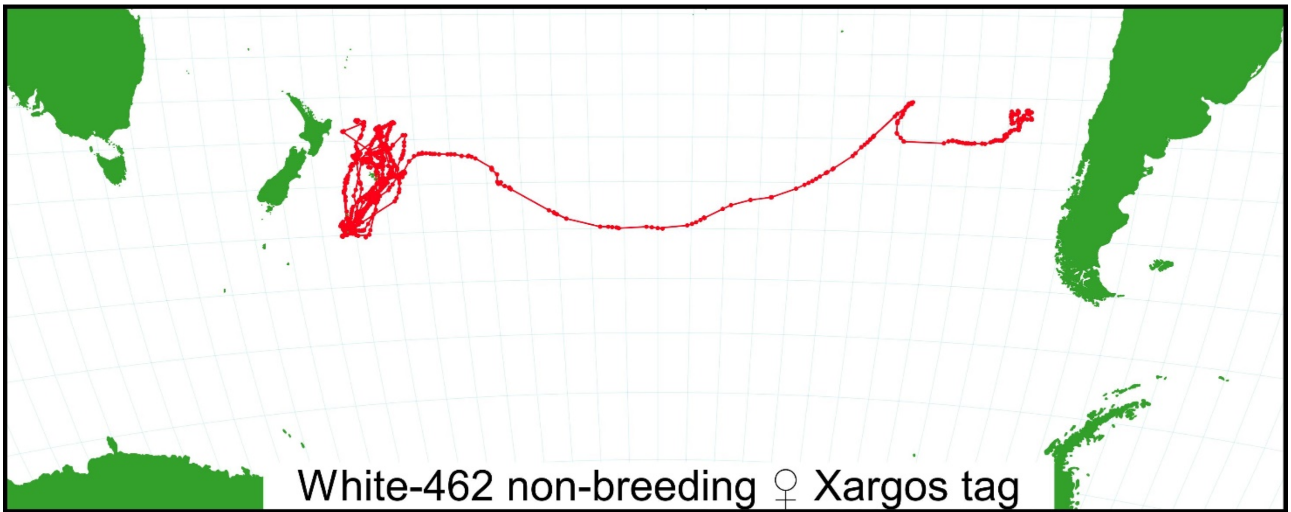
Non-breeding and failed breeding females.

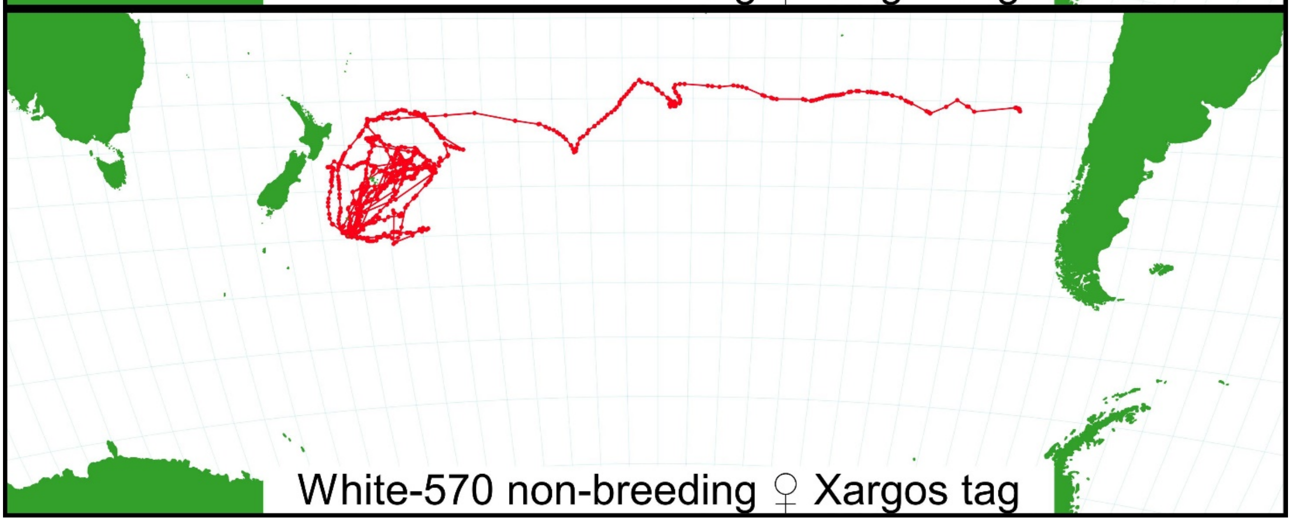


Non-breeding and failed breeding females.

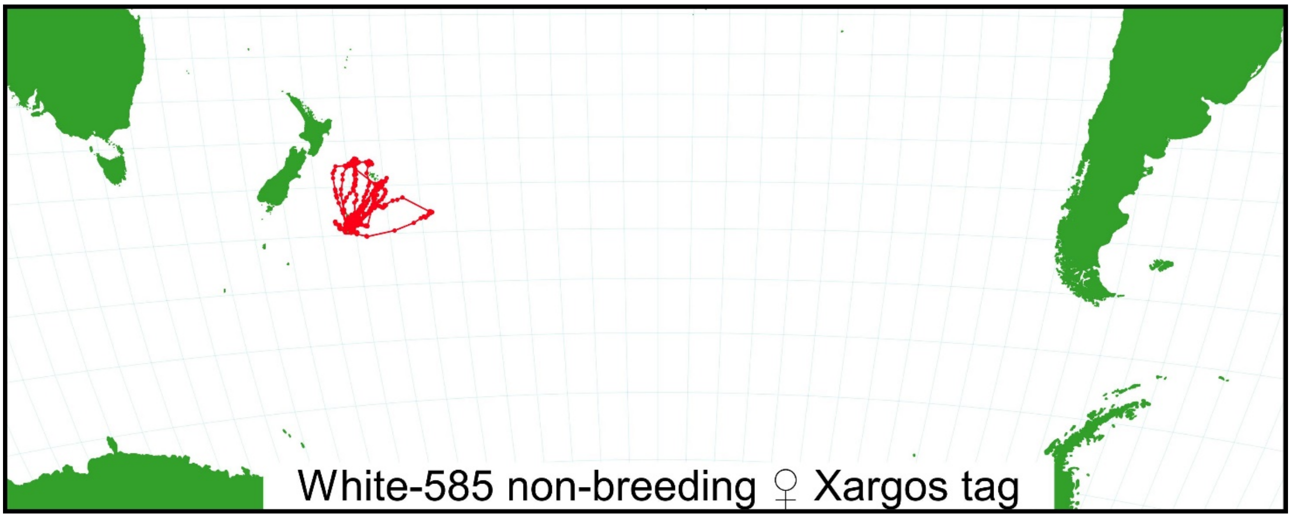


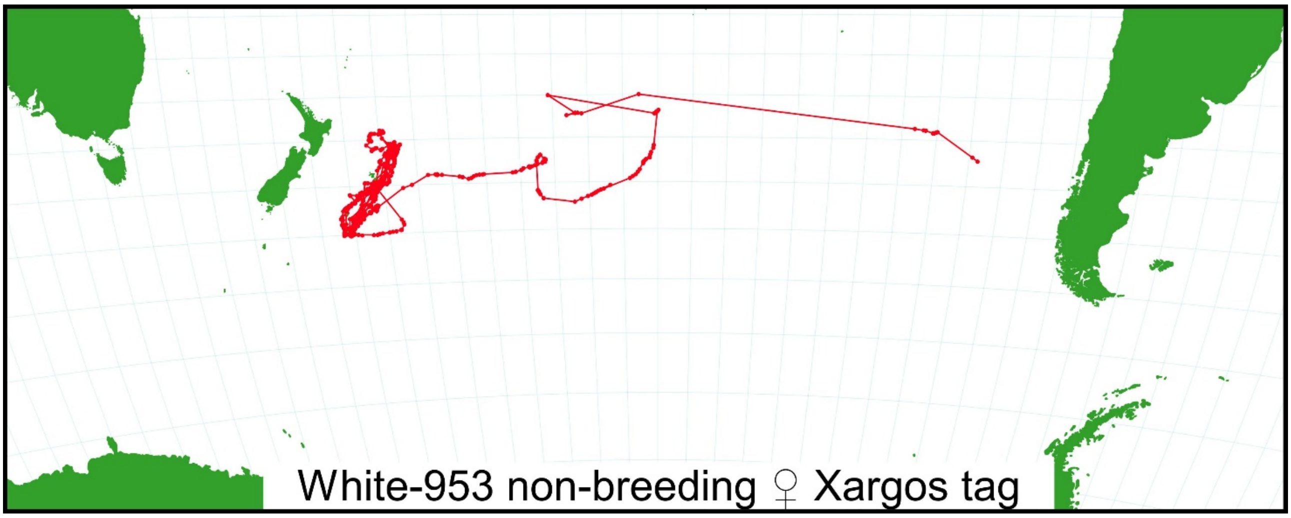
Female white-315 deserted 2 Feb as soon as relieved at the nest after egg-laying, flew to Chilean coast & returned to nest on 26 March, made several short trips away from nest, then finally completely abandoned nest & foraged in Tasman Sea before tag stopped 23 April 2019

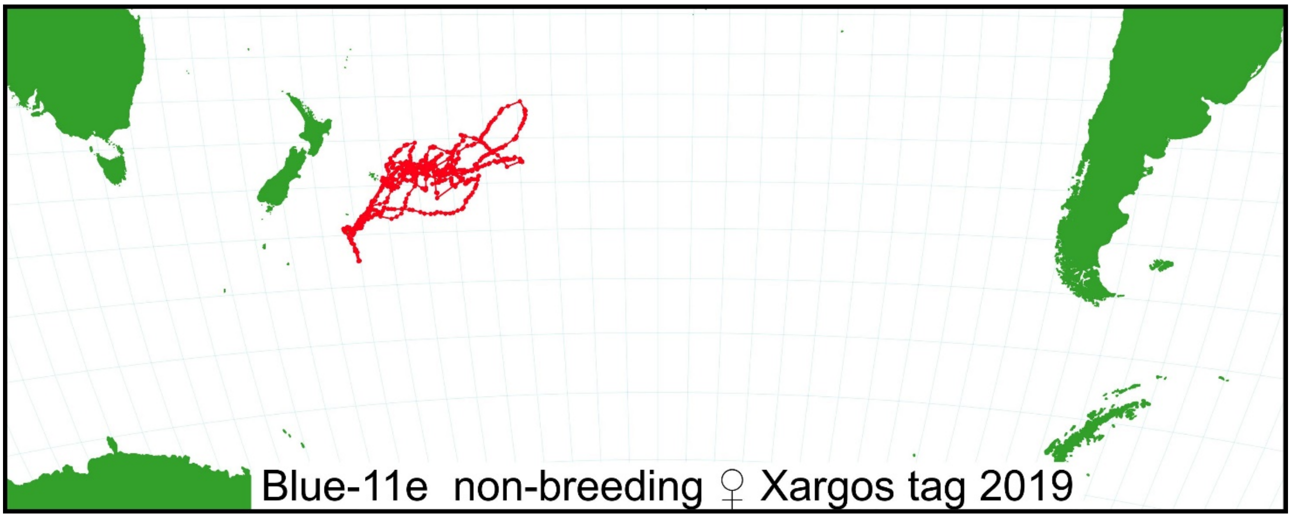




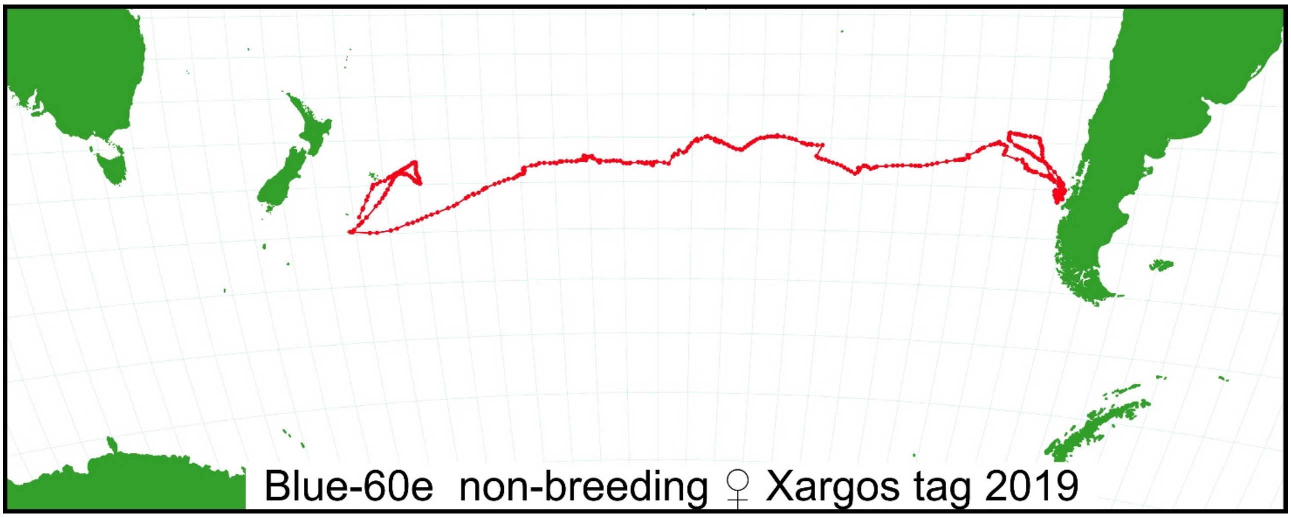
Non-breeding and failed breeding females.



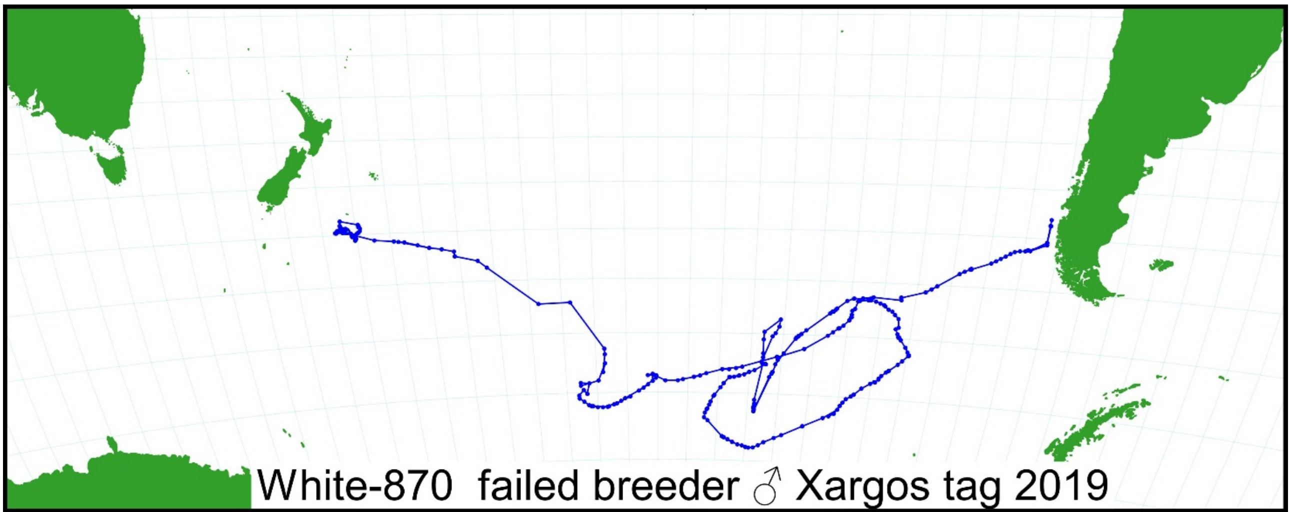


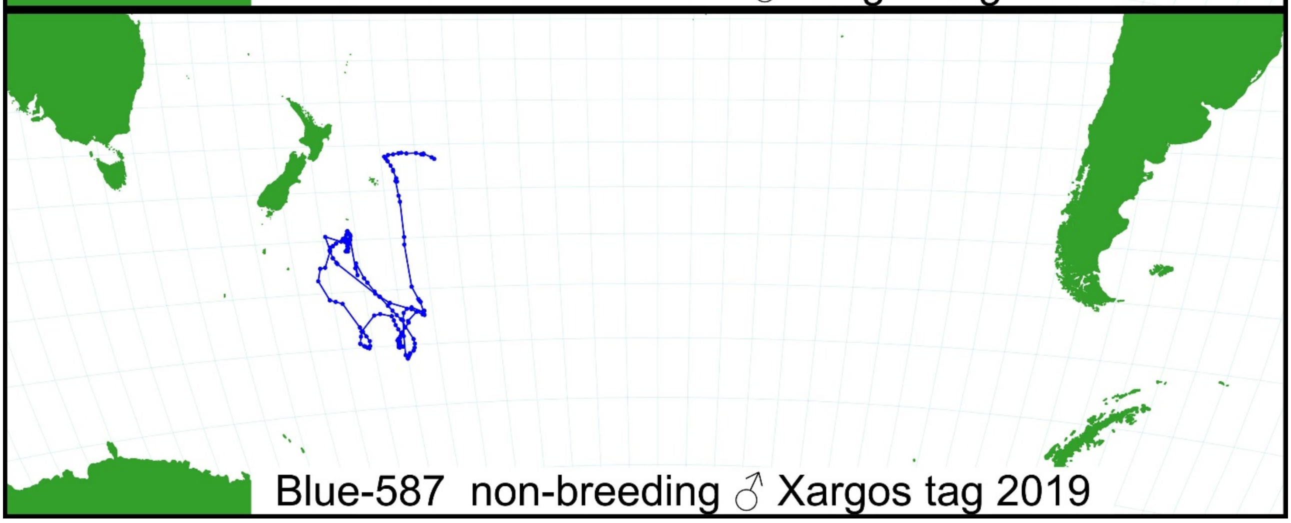


Non-breeding and failed breeding females.

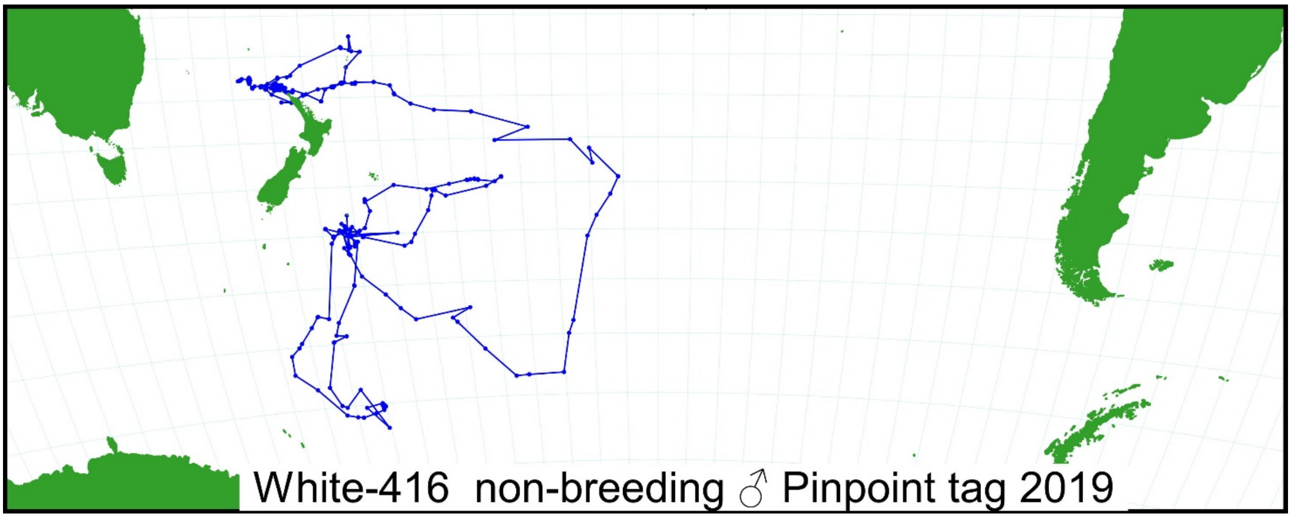


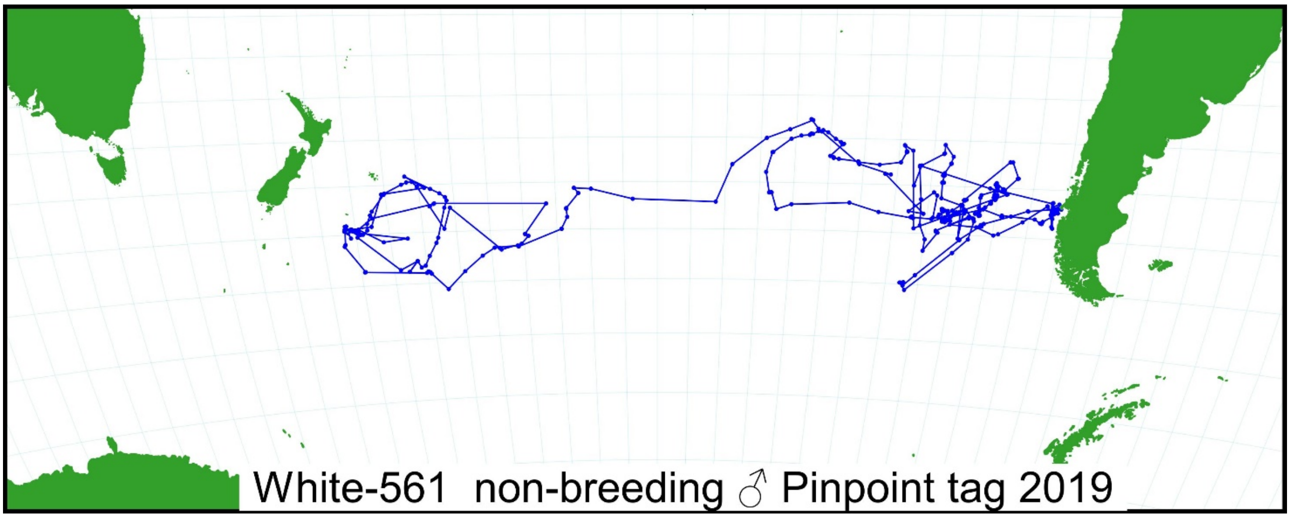
Non-breeding and failed breeding males

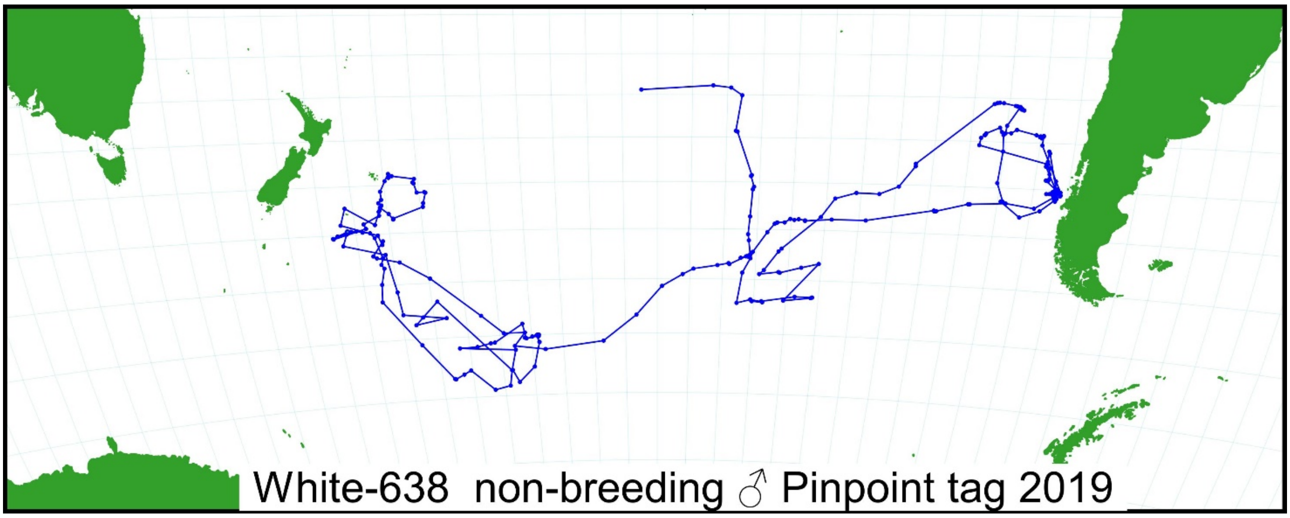




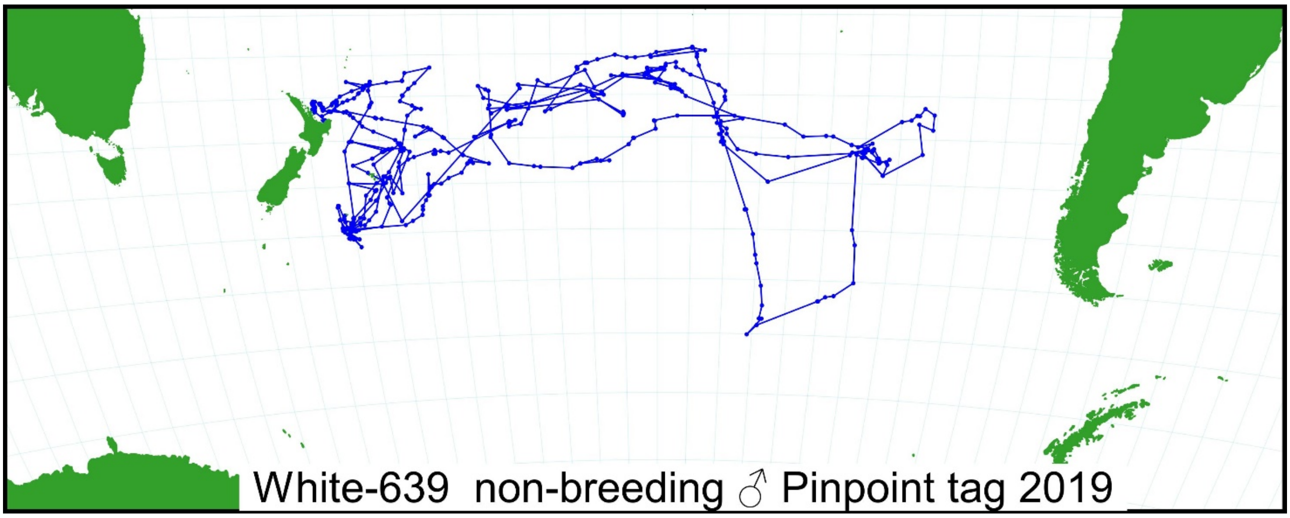
Non-breeding and failed breeding males

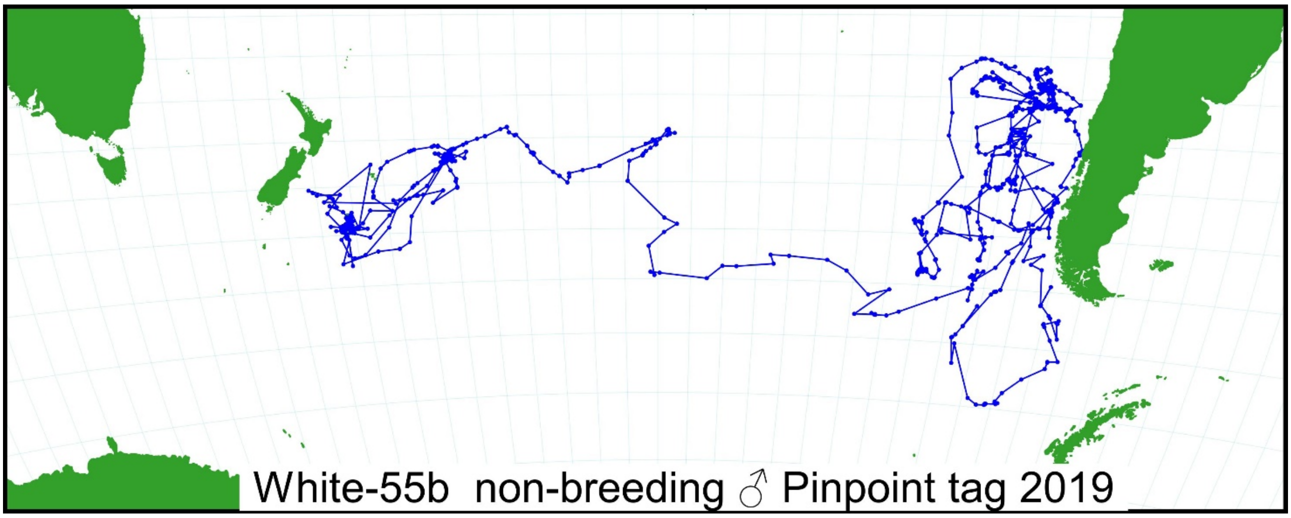


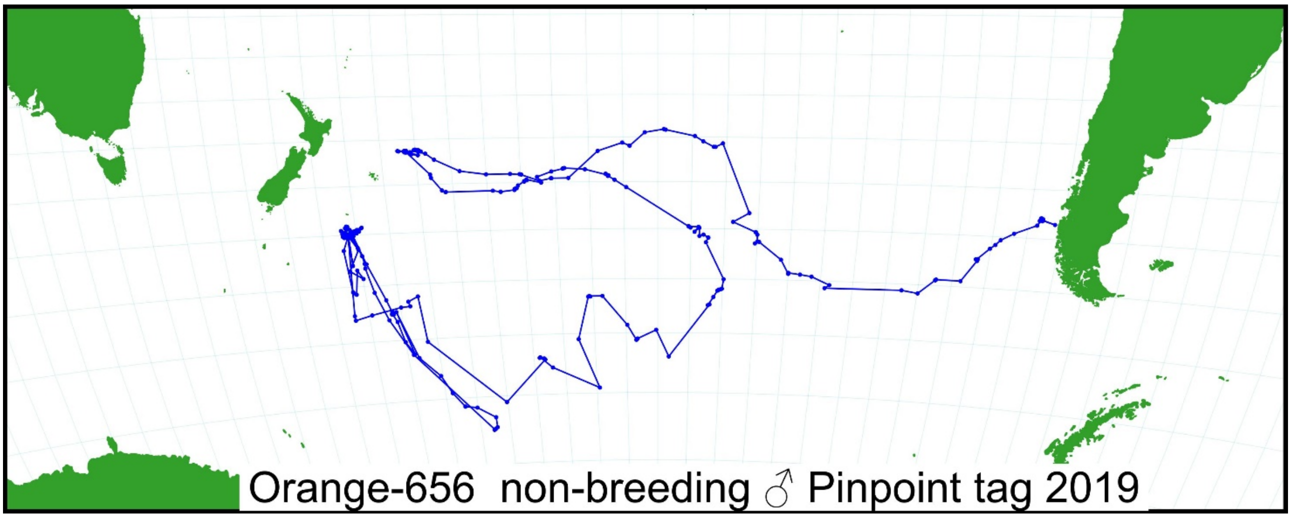




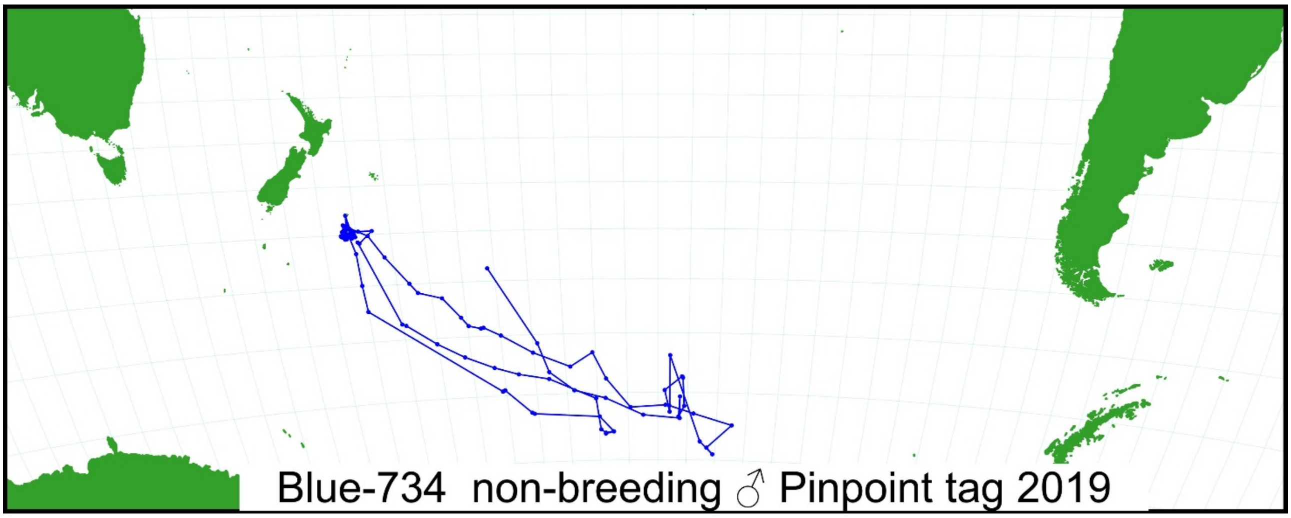
Non-breeding and failed breeding males

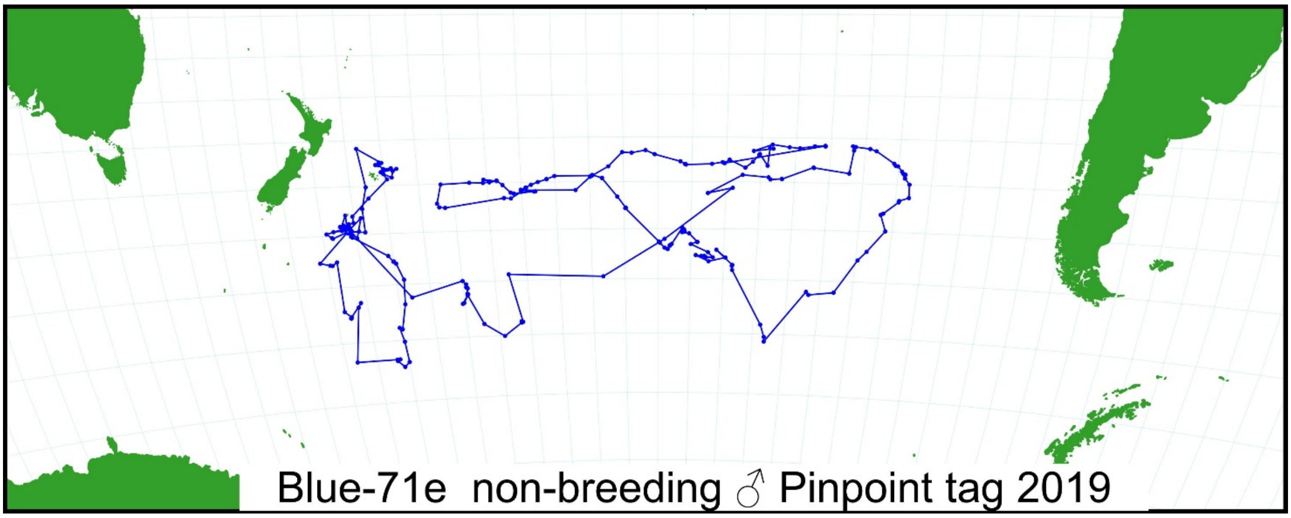




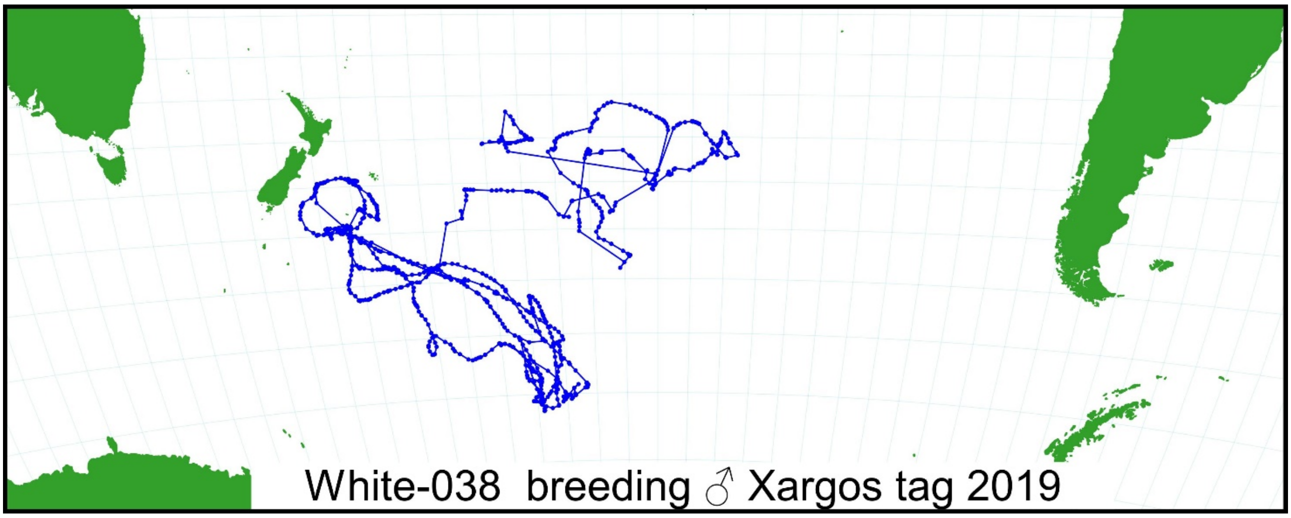


Non-breeding and failed breeding males

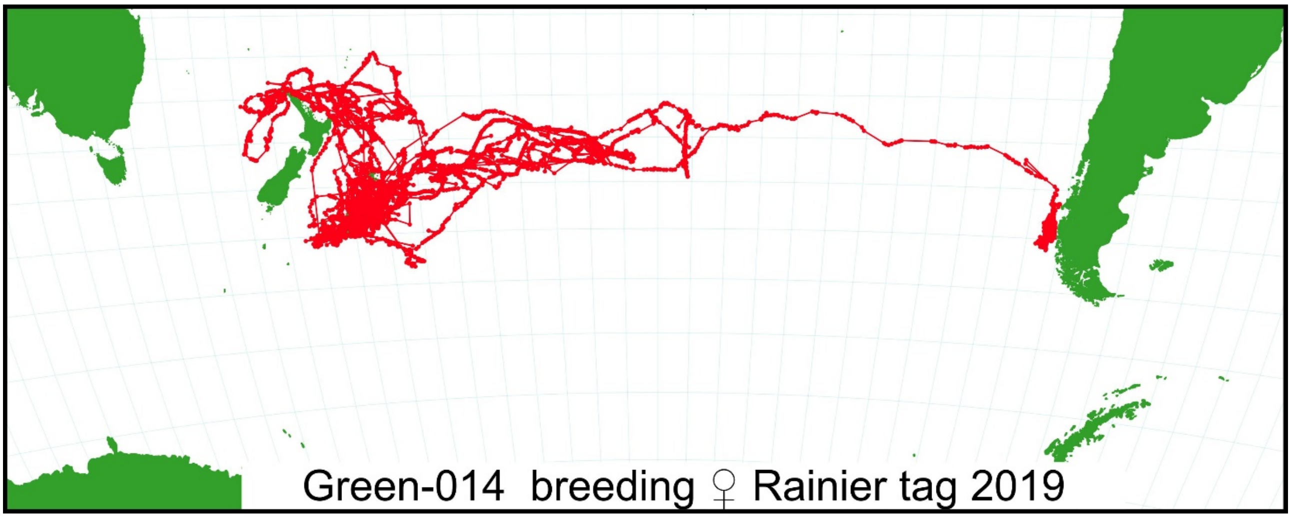




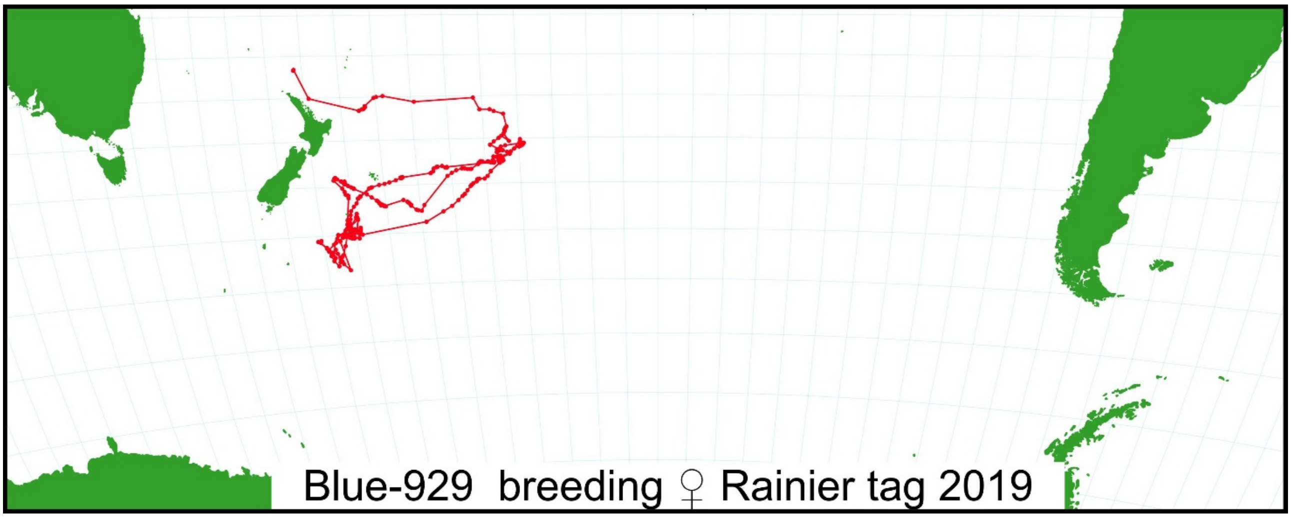
Breeding male

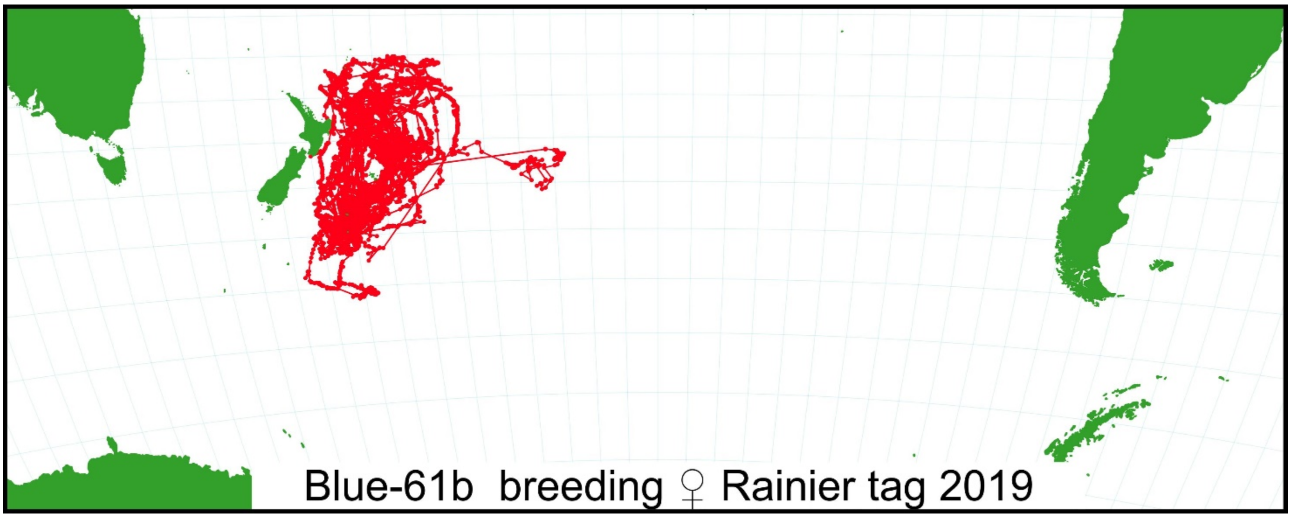


Breeding females

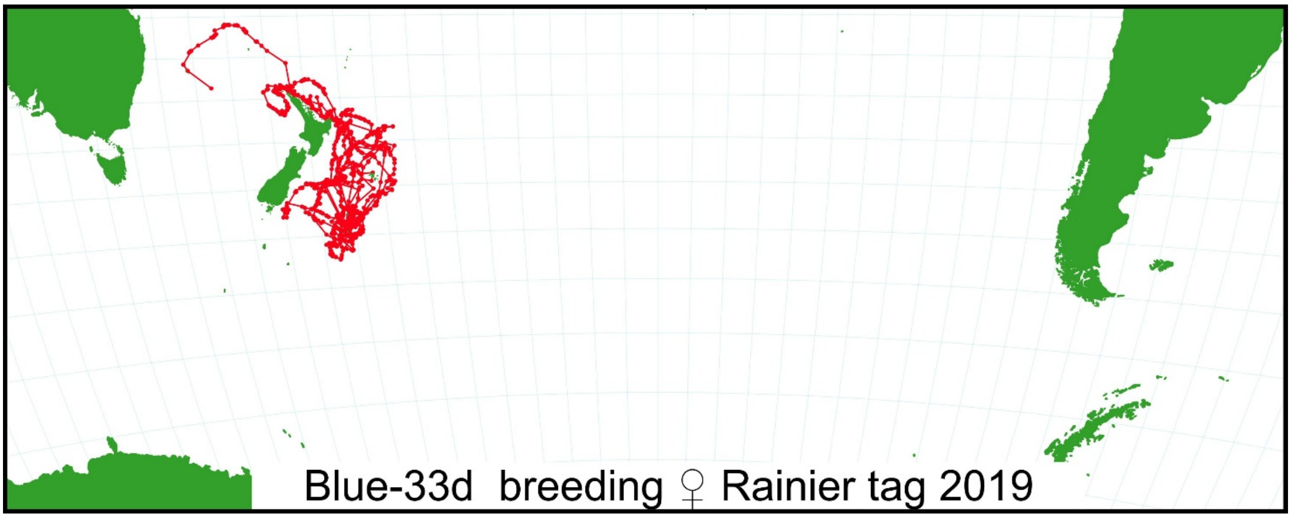


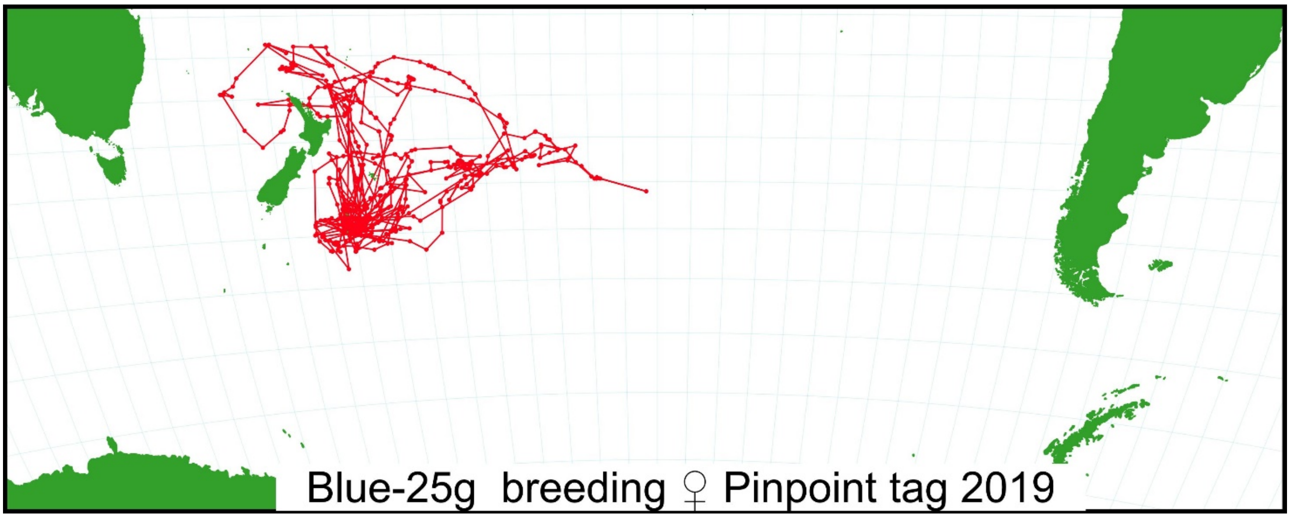
Green-014 successfully bred Jan–11 Nov, then leaving mate to complete chick rearing. went to coast off Chile till tag dropped off 8 Feb 2020

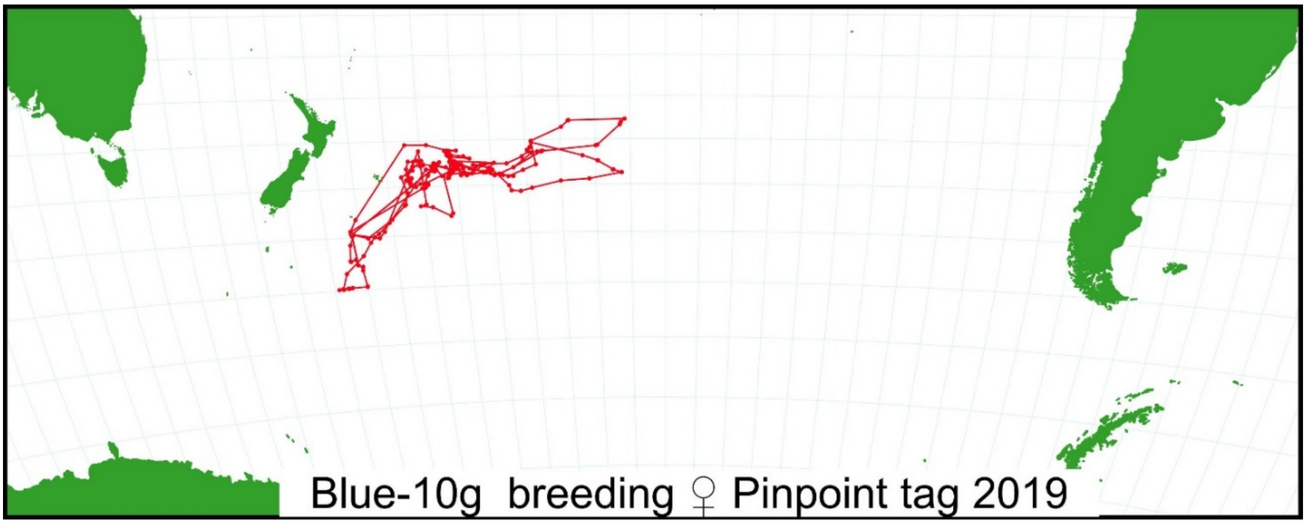




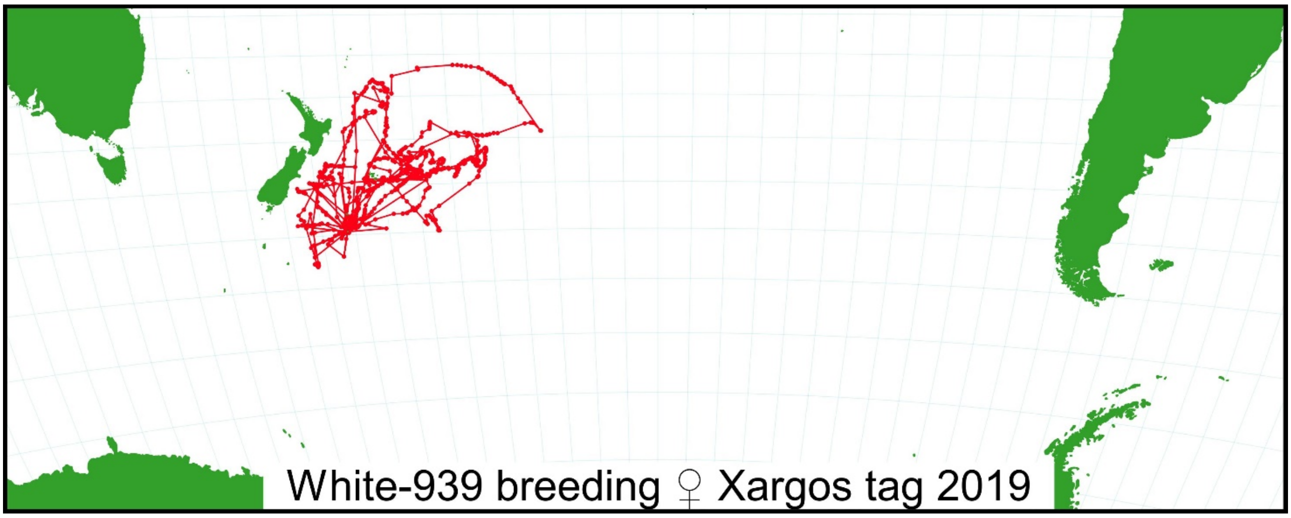
Breeding females

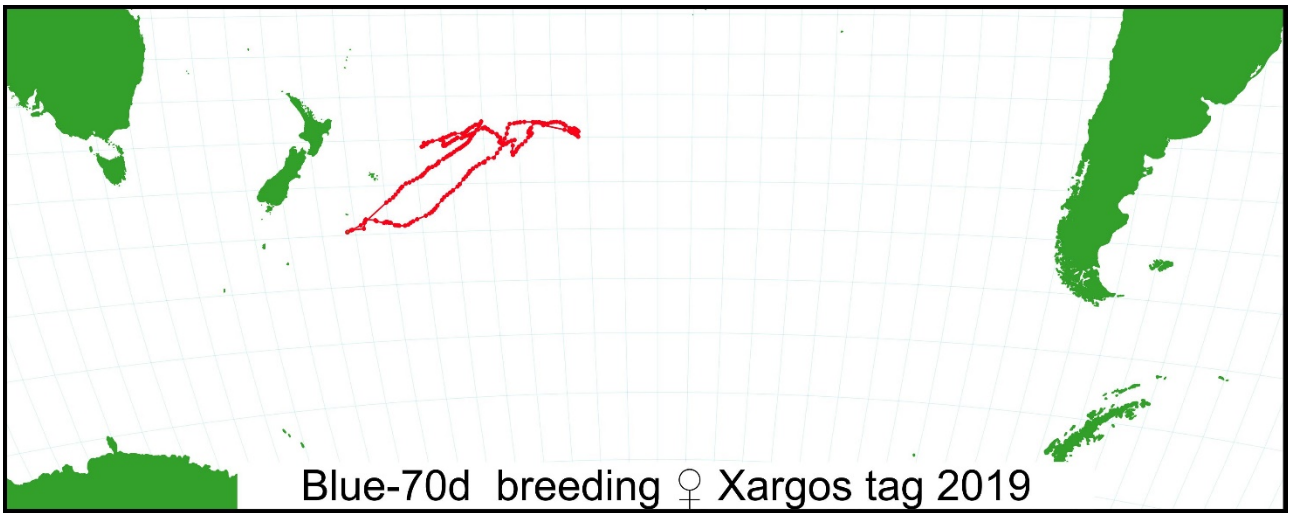


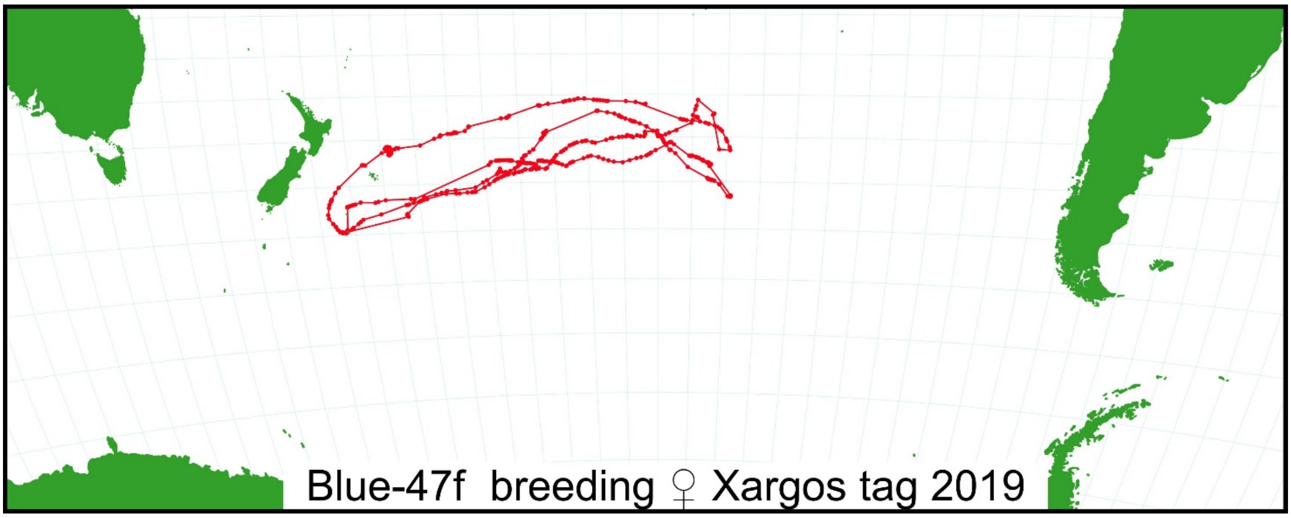




Breeding females







Breeding females