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

Draft Report

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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 a fortnight 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 whilst close to boats 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.

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 65 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 without GPS their location data was poorer.

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 1 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 caught on observed 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, presumably fisheries-induced, decline during the 1980's (Walker & Elliott 2005, Elliott & Walker 2005 and Walker & Elliott 2006). However, about 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

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 last 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

Details of the methods used, study area locations and earlier results are given in Walker & Elliott 2005, Elliott & Walker 2005 and Walker & Elliott 2006. In brief, summer visits are made to Antipodes Island and all birds found within or near a 29 ha "study area" (Figure 1) are checked for bands. An attempt is made to identify both birds at every nest in the study area, and any breeding birds that have no bands are banded. All nests are labelled and mapped, the outcome of the previous year's nesting attempts is assessed, and the chicks banded. This data enables calculation of survivorship, productivity, recruitment, and attendance on the breeding grounds.

In addition, the number of active nests in 3 different parts of Antipodes Island (Figure 1) comprising 14.9% of all the nests on Antipodes Island (Walker & Elliott 2002a) are usually counted each year. A short trip to the island meant that only the nests in the study area were counted in 2020.

Survival is estimated from the banded birds with mark-recapture statistical methods using the statistical software M-Surge (Choquet *et al.* 2005), and populations size is estimated from the actual counts of birds and the sighting probabilities produced when estimating survival.

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.

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 we used a piece of PVC plastic (cut from guttering) 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. Interactions 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 as 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).

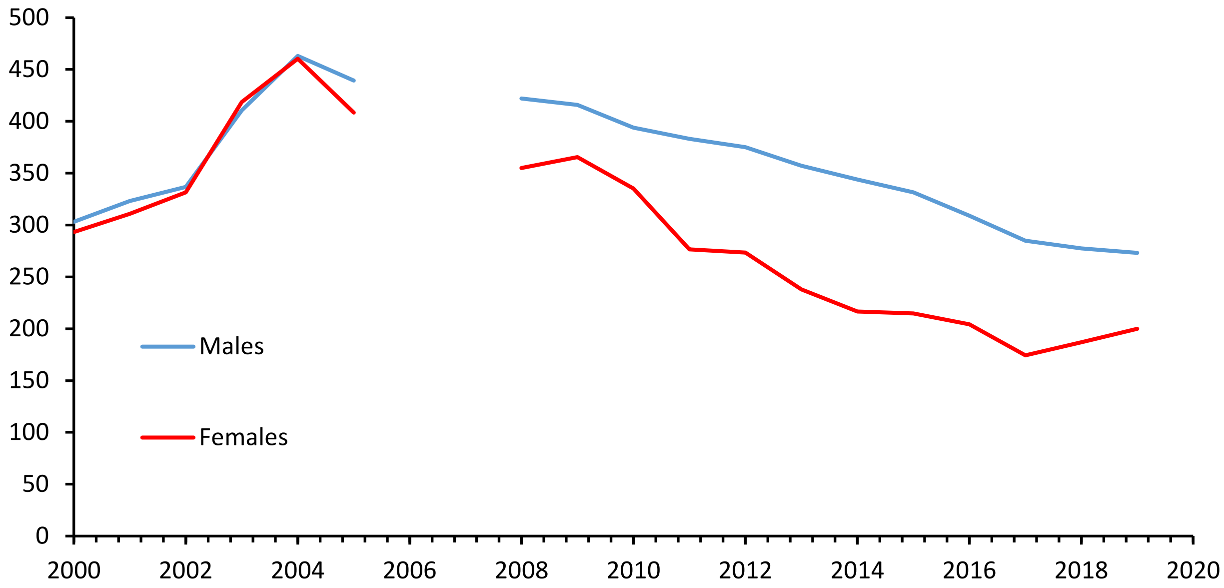

Figure 3. The number of breeding birds in the study area on Antipodes Island estimated by mark-recapture. Note: population estimates produced by mark-recapture are not reliable in the last year of data collection, so results are only up to 2019.

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 2nd highest female survival occurring in that period. A five-year rolling average of female survival (Figure 5) suggests that on average female survival has been improving for the last few years.

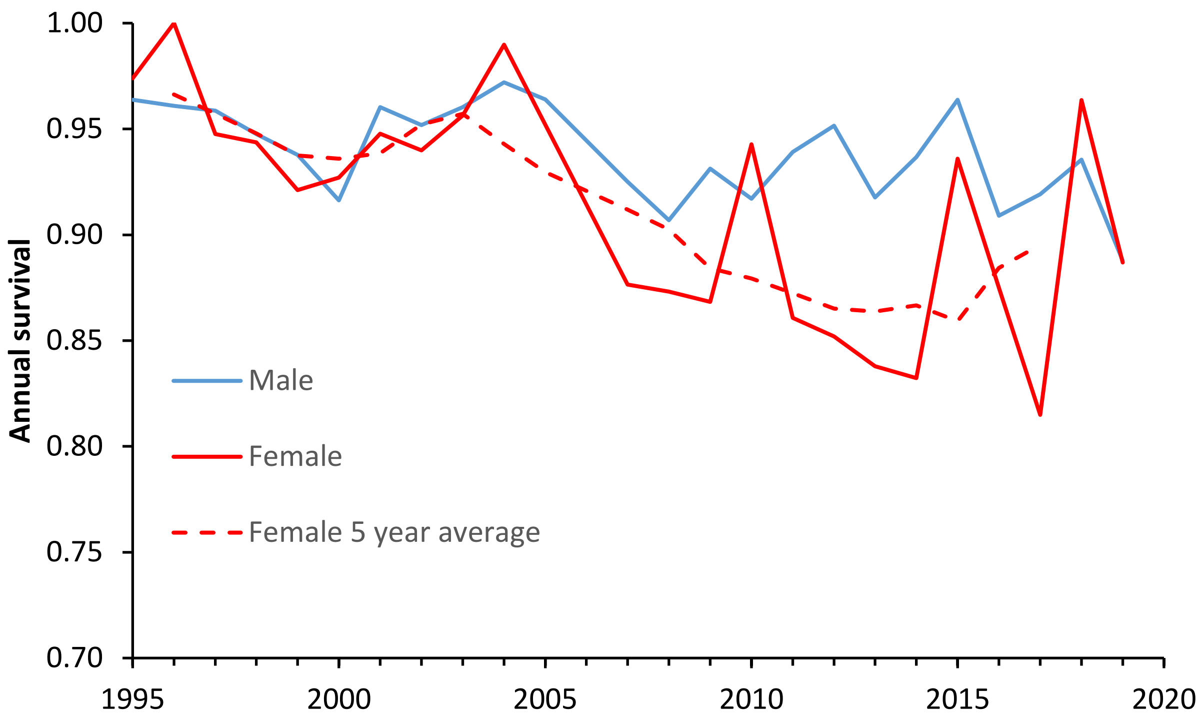

Figure 4. Estimated annual survival of male and female Antipodean wandering albatross on Antipodes Island since 1995, and five-year rolling average for females. Mark-recapture estimates of survival for 2020 are unreliable and are not presented

Not only has male and female survivorship differed substantially since 2005, but the survivorship of breeding and non-breeding birds, and the confidence in those estimates has also differed (Figure 5). 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).

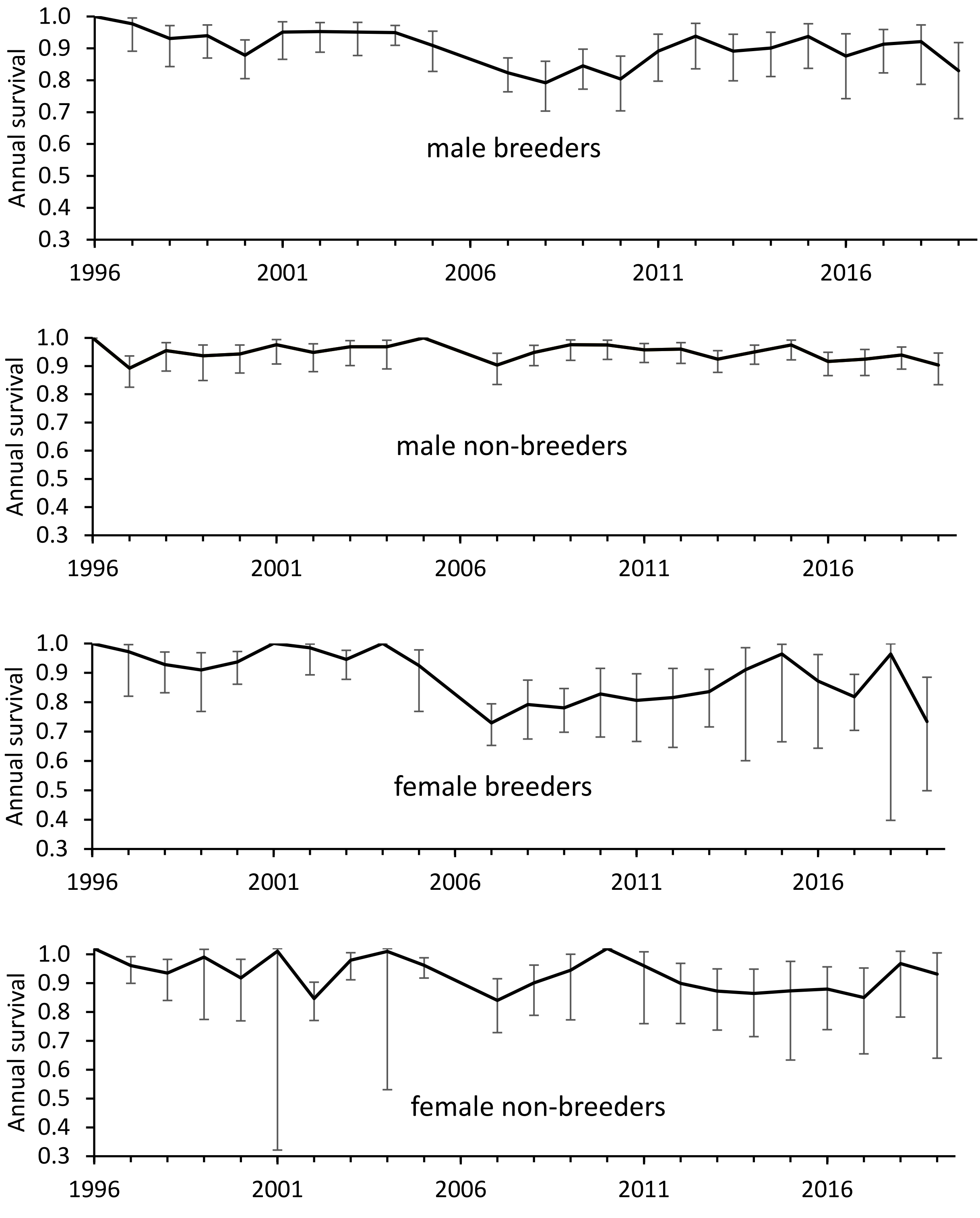

Figure 5. Estimated annual survival of male and female breeder and non-breeder Antipodean wandering albatross since 1995 with 95% confidence limits

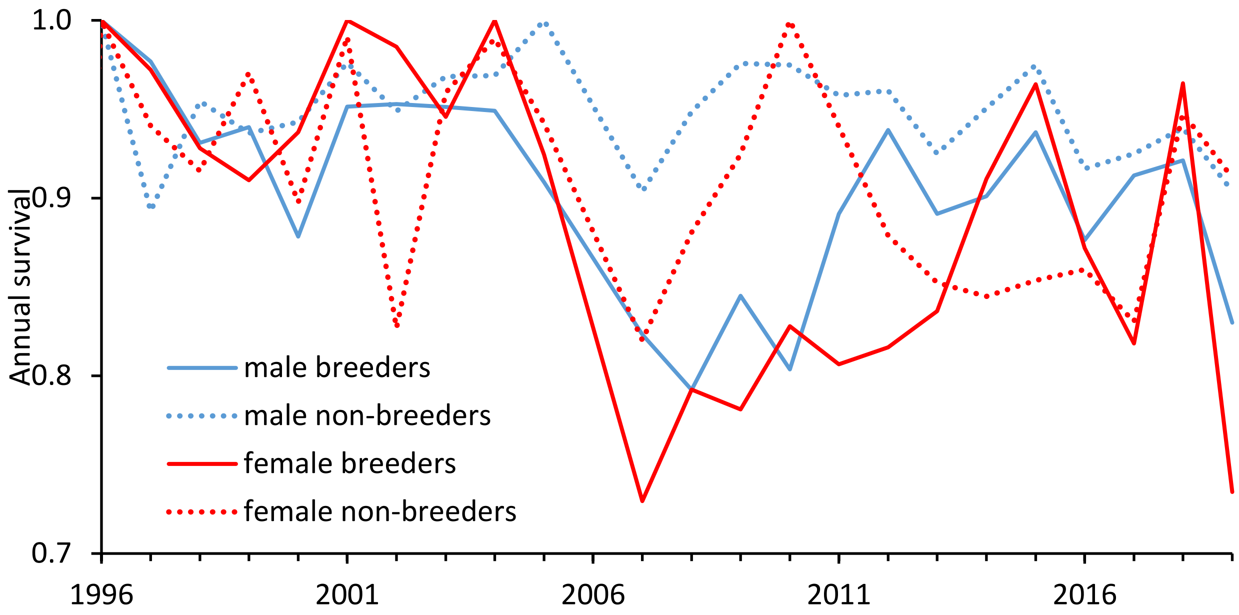

Figure 6: Estimated annual survival of male and female breeder and non-breeder Antipodean wandering albatross since 1995

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.

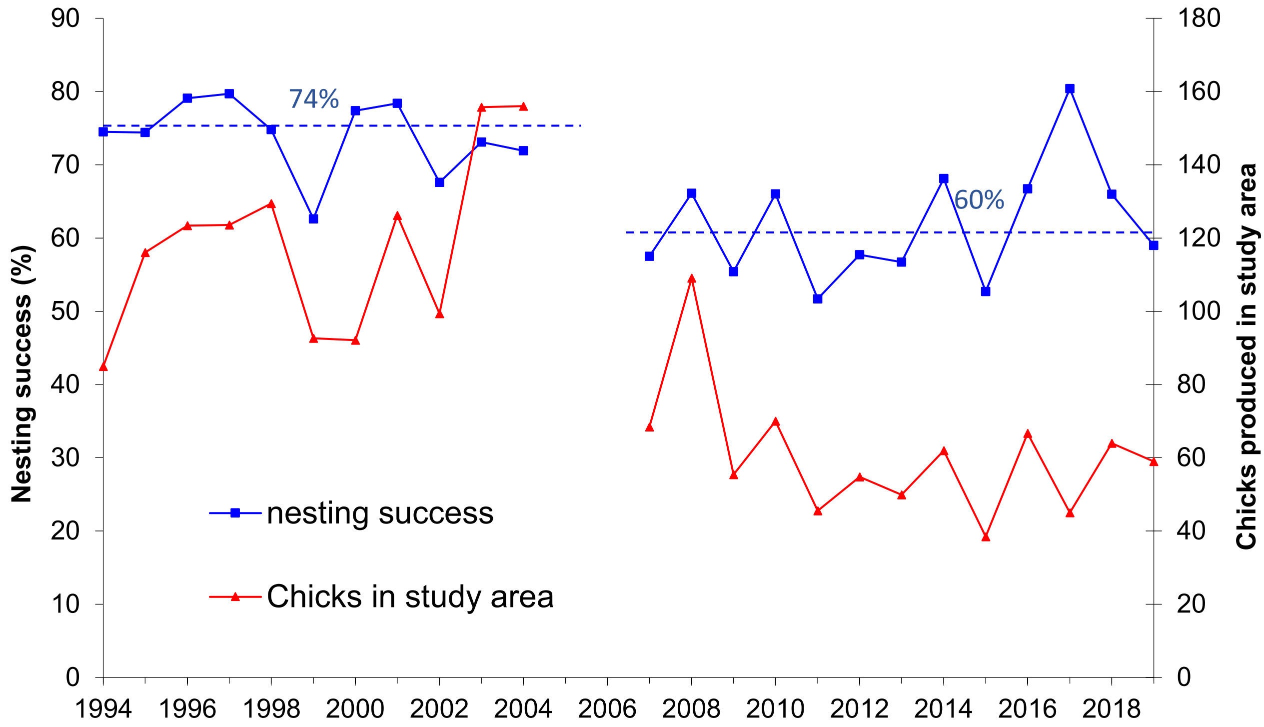

Figure 7. Nesting success and the number of chicks fledged from the study area on Antipodes Island since 1994. The dashed lines indicate average nesting success in two periods, 1994-2004 and 2007-2016.

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 6) 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. Note 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, 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.

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	Subtotal	MCBA	Total counted	Estimated nests on island
1994	114	125	239	544*	783	5233
1995	156	185	341	482*	823	5500
1996	154	133	287	418*	705	4712
1997	150			464*		5463
1998	160			534		5827
1999	142			479		5172
2000	119	130	249	462	711	4752
2001	160	141	301	443	744	4972
2002	148	178	326	605	931	6222
2003	214	187	401	608	1009	6743
2004	216	249	465	755	1220	8153
2005	211	186	397	613	1010	6750
2006						
2007	119	127	246			4368
2008	165	135	300			5327
2009	98	120	218			3871
2010	106	101	207			3676
2011	88	108	196			3480
2012	95	104	199	345	543	3629
2013	88	93	181	297	478	3195
2014	91	103	194	341	535	3576
2015	73	86	159	291	450	3007
2016	100	92	192	291	483	3228
2017	57	82	139	230	369	2466
2018	97	97	194	315	509	3402
2019	99	96	195	276	471	3148
2020	75					2714

* estimated (see Walker and Elliott 2002b).

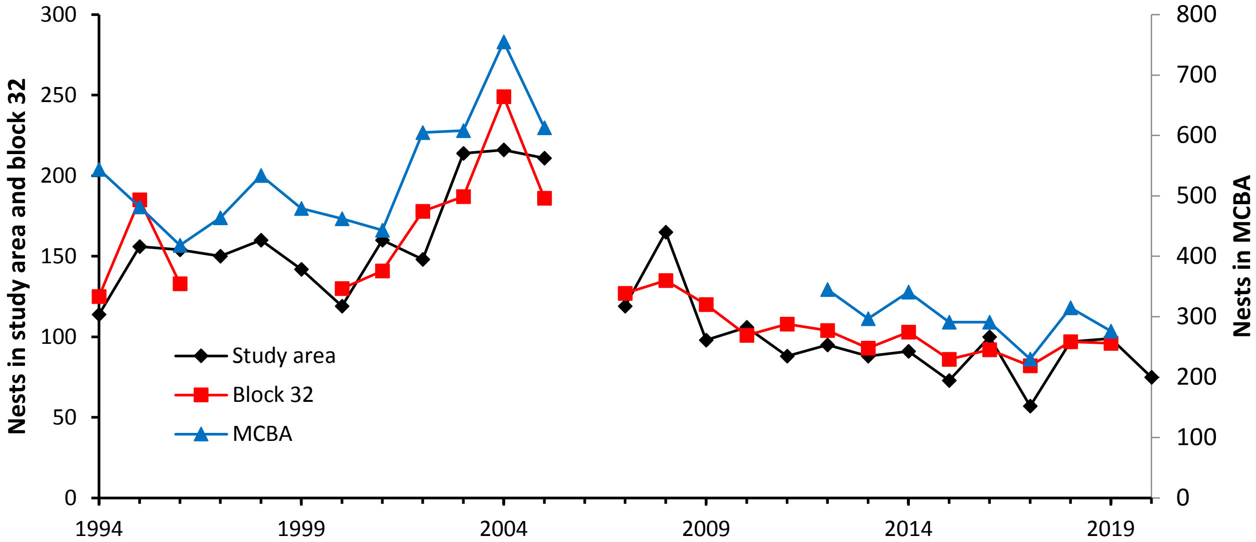

Figure 9. The number of Antipodean wandering albatross nests in three blocks on Antipodes Island since 1994

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 4. 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. The manufacturers specifications suggest these transmitters should have gone flat during November 2019, though half of them lasted considerably longer. This is likely because the manufacturers calculated battery life on the assumption of colder temperatures than the Antipodean wandering albatross wearing them experienced.

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.

Fisheries interaction with birds tracked in 2019

Within 6 months of attachment, 62% of all the tags had stopped transmitting, before the batteries of any of them should have gone flat. Such a high rate of tag loss is clearly not the result of mortality and the loss of a tag by itself is therefore not a reliable indication of the death of a bird. None-the-less, 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 transmitters failed within 100km of a fishing boat. Female Green-014 failed in February 2020 close to 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 may be unrelated to fisheries. The transmitter of an early-failed breeder in 2019, female White-755, stopped close to 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 Blue-77F, a non-breeding female, failed within 160km of 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). Three failed near to fishing boats. The transmitter of female non-breeder Blue-04D stopped within 21km of 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 within 100km of a trawler close to the Chilean coast in late March 2019. The transmitter on Blue-68E, a breeding female, stopped when she was within 40km of a long-liner, 3000km east off East Cape in April 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 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.

Biological information gained from 2019 deployments

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 adult albatrosses visited the Chilean coast in 2019, in contrast to the great majority of the tracked non-breeding population doing so in 2011–2017, but not quite as small a proportion as in 2018.

- 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).

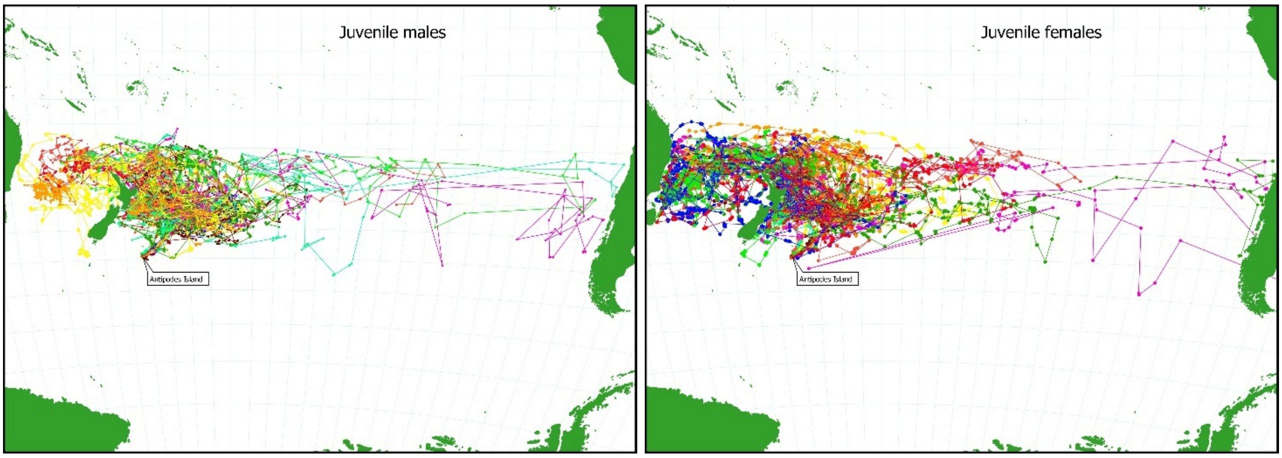

Figure 10: At-sea distribution between January 2019 and February 2020 of 10 male and 10 female Antipodean wandering albatrosses who fledged from Antipodes Island in January 2019

- 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).

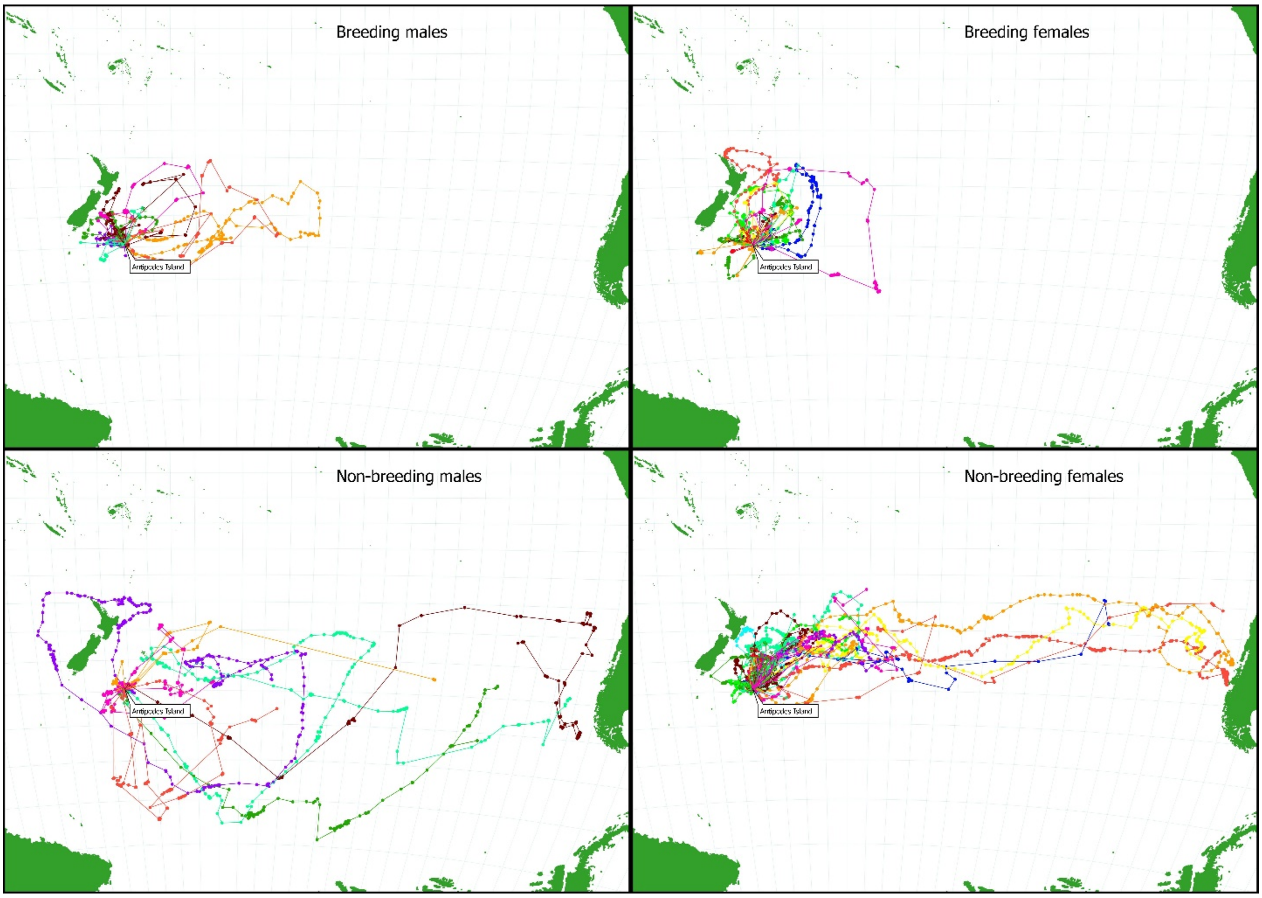

Figure 11. Satellite tracking of 15 female and 8 male non-breeding and 10 female and 9 male breeding Antipodean wandering albatrosses from 26 March to 30 April 2020.

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.

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).

A feature of the decline period in Antipodean wandering albatrosses has been the high numbers of 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.

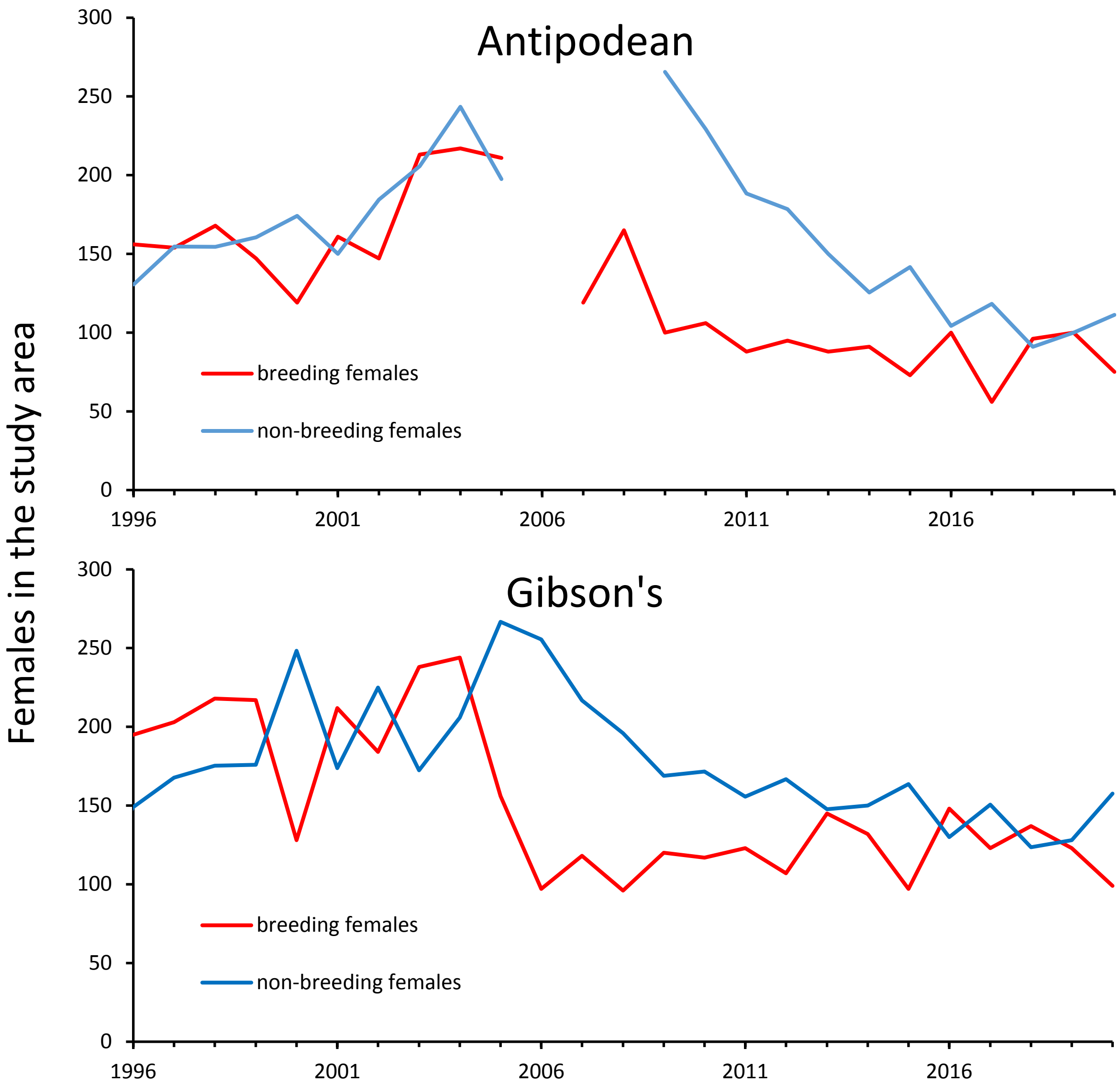

Figure 12. The proportion of female Antipodean wandering albatross (top) and Gibson's wandering albatross (bottom) breeding (red line) or not breeding (blue line) in the study area on Antipodes and Adams Island respectively in 1996–2020.

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).

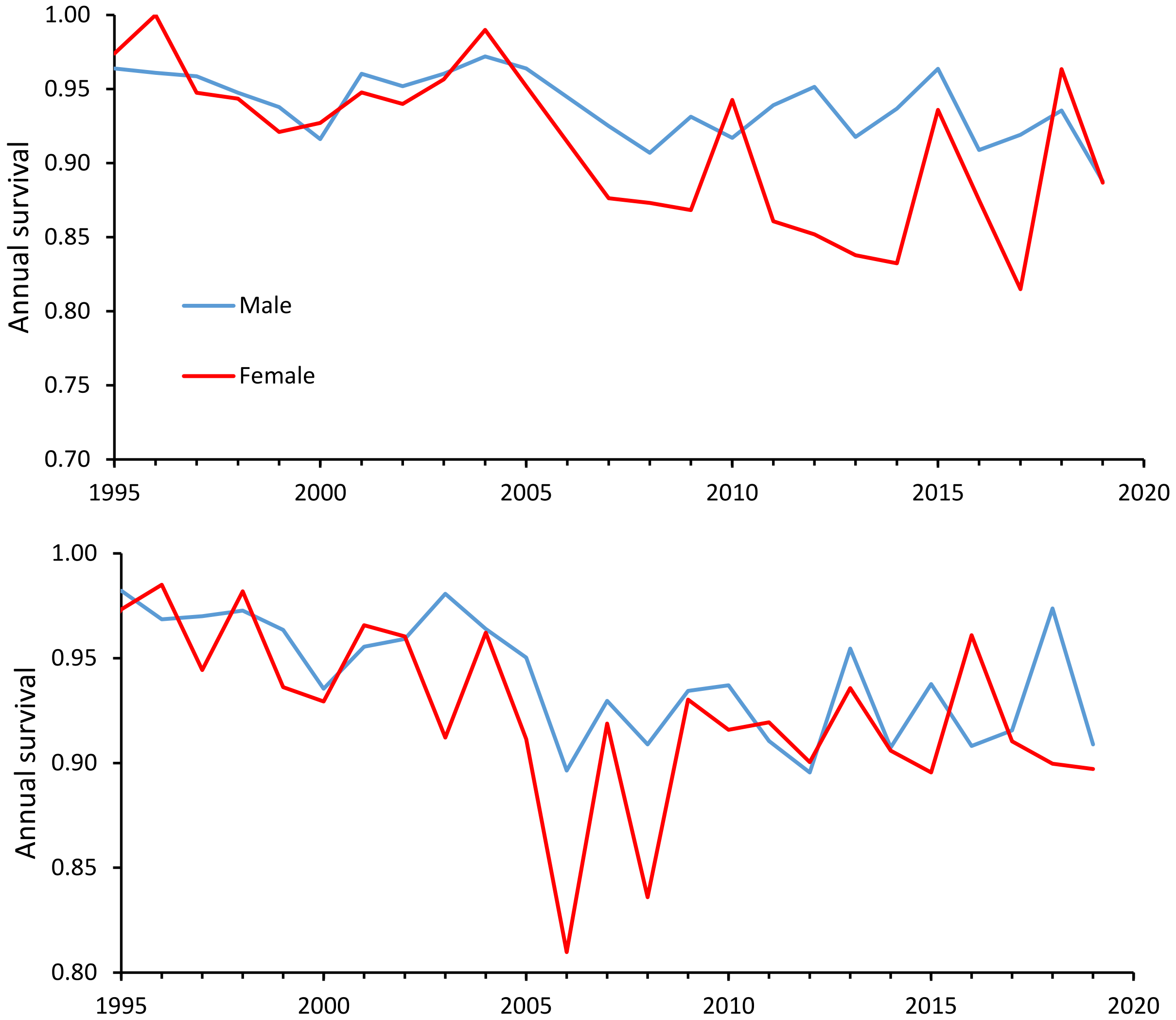

Figure 13. Survival of male (blue) and female (red) Antipodean (top) and Gibson's (bottom) wandering albatrosses in 1993–2019. Gibson's wandering albatross data from K. Rexer-Huber & G. Parker pers. comm. Note that as Antipodes Id wasn't visited in 2006, survival estimates for Antipodean wandering albatross in 2006 and 2007 were estimated from the survival over a 2-year period and then equally apportioned amongst the 2 years.

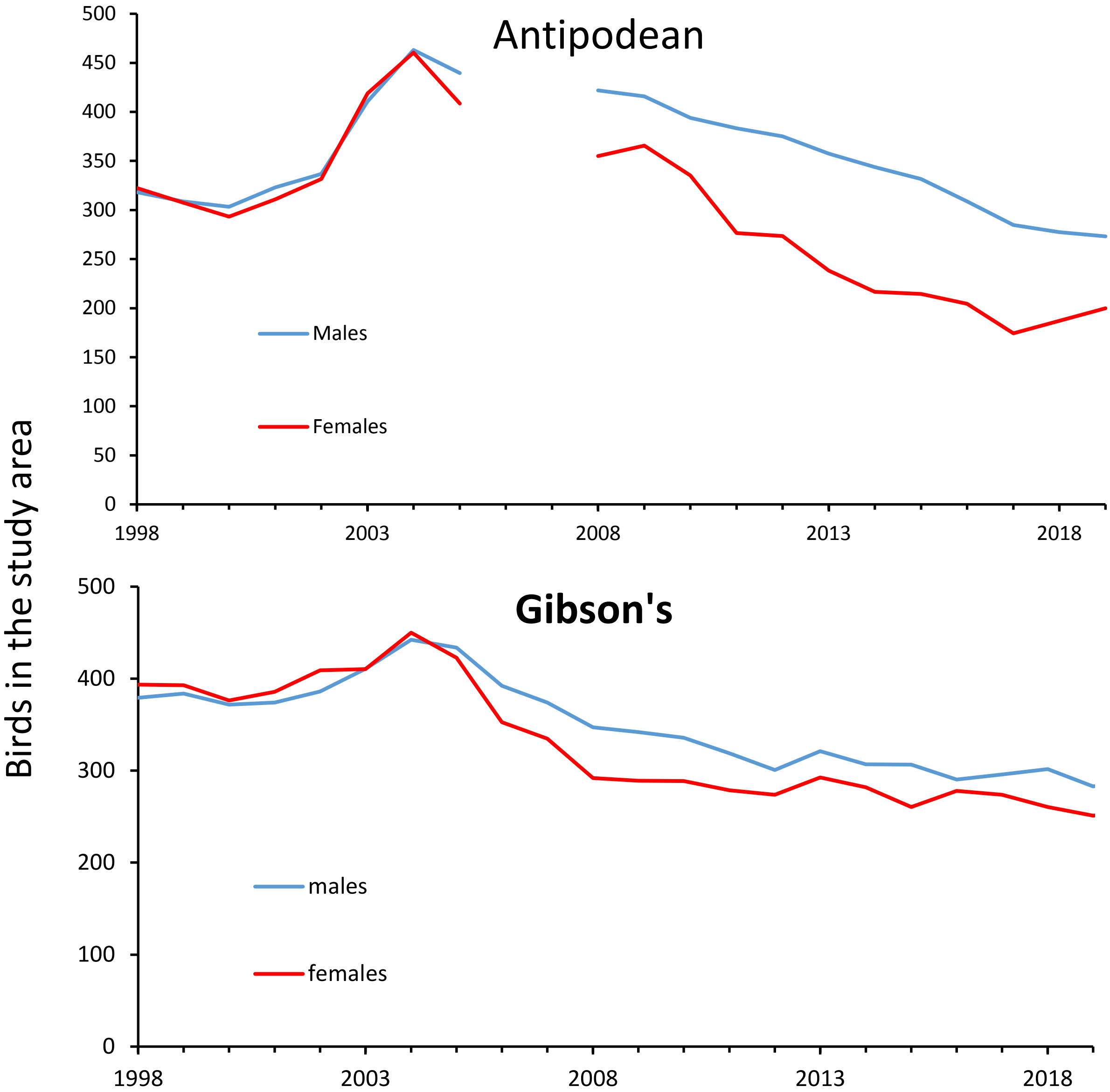

Figure 14. The number of breeding pairs of Antipodean (top graph) and Gibson's wandering albatrosses in the study areas on Antipodes and Adams Island respectively in 1998–2019 estimated by mark-recapture

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. 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 is 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. The optimum transmission schedule can only be found through trial and error. 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.

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.

ACKNOWLEDGEMENTS

Many thanks to Katie Clement-Seelye for her exhaustive work organizing passage to Antipodes Island, in the most difficult of circumstances (no available boats). Thanks too, to Sally Paterson and Peter Burling of Live Ocean, and Janice Molloy of Southern Seabird Solutions for their help searching for a suitable boat. We thank the Department of Conservation staff in Invercargill for their logistic support getting the expedition away (twice) and Nathan McCrorie (skipper) and the crew of *Tranquil Image* for safe passage to and from Antipodes Island. Transport, field work and 8 solar satellite transmitters were funded by the Department of Conservation, 20 battery-powered satellite transmitters were funded by the Ministry of Primary Industries, and many donors to the charity "Live Ocean" funded 12 solar satellite transmitters. We thank Igor Debski (Department of Conservation) and William Gibson (Ministry of Primary Industries) for their help organizing these satellite transmitters, and Samhita Bose with help analysing the datalogger and transmitter data.

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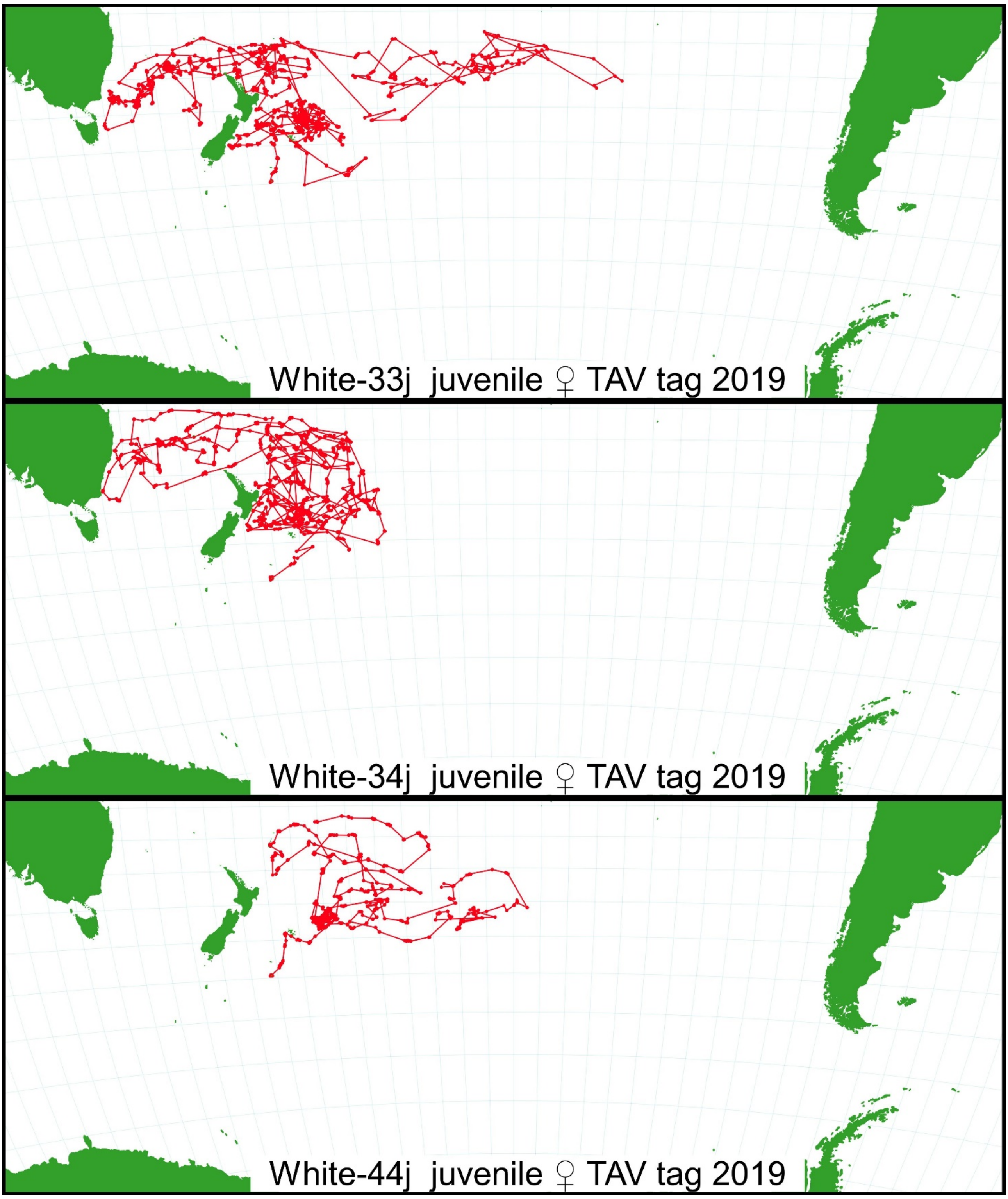
Appendix 1: Calculating the likelihood that the cessation of signals from birds wearing satellite transmitters attached in Jan– Feb 2019 was fisheries-related, as assessed by presence of the birds back on Antipodes Is in March 2020, or the successful fledging of their 2019 chick, and the proximity to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

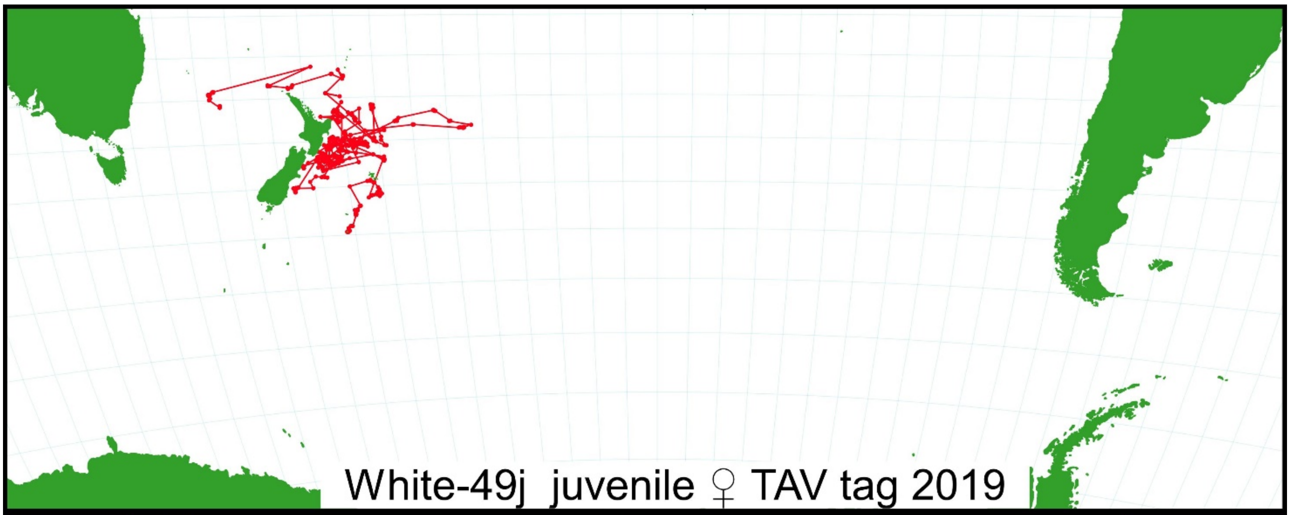
Appendix 2: Locations from 58 Antipodean wandering albatrosses of different ages and life stages tracked between Jan 2019 –Feb 2020. Mean (and range) days tracked for each tag type is TAV=301 (108–389), Rainier=249 (76–410), Pinpoint=106 (2–242). Xargos=62 (0–144)

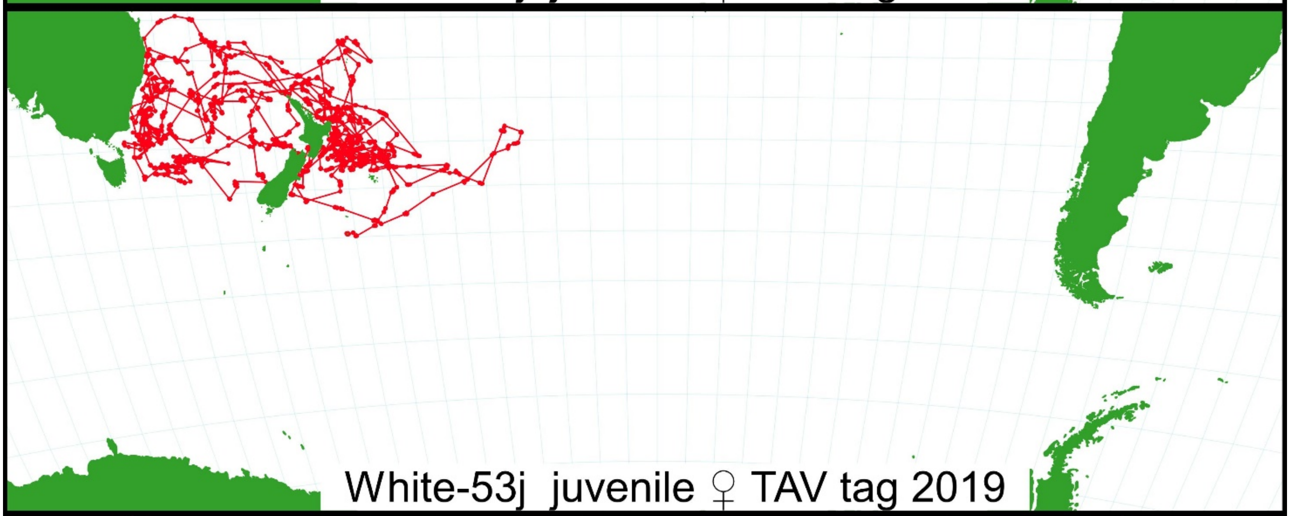
Fledgling females

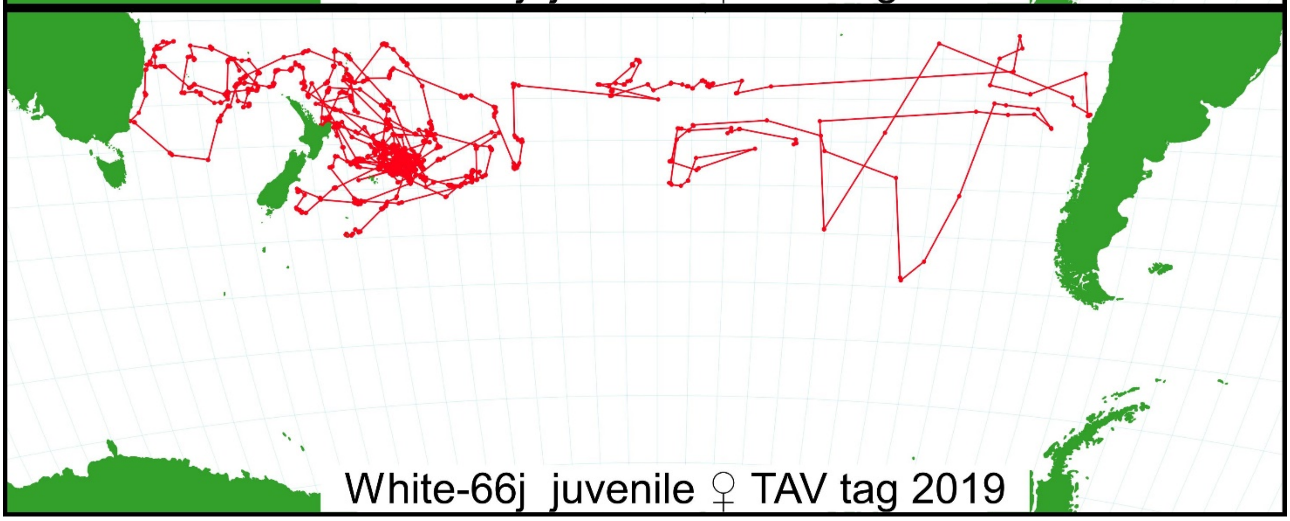


Fledgling female W-44j was caught by long-line fishing boat on 2 July 2019 at 27 °south

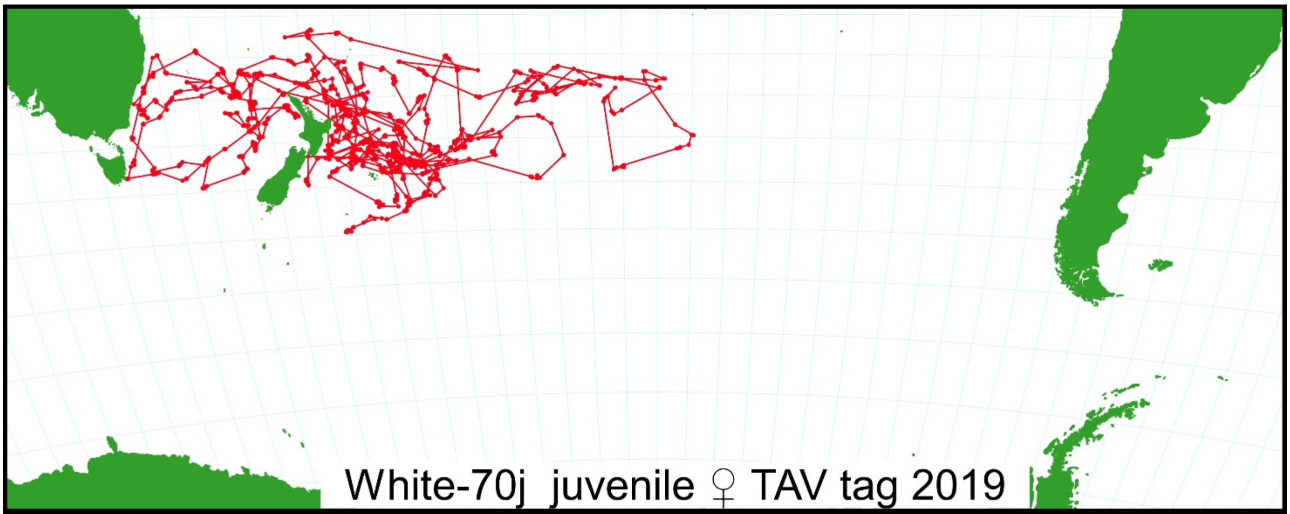
Fledgling females

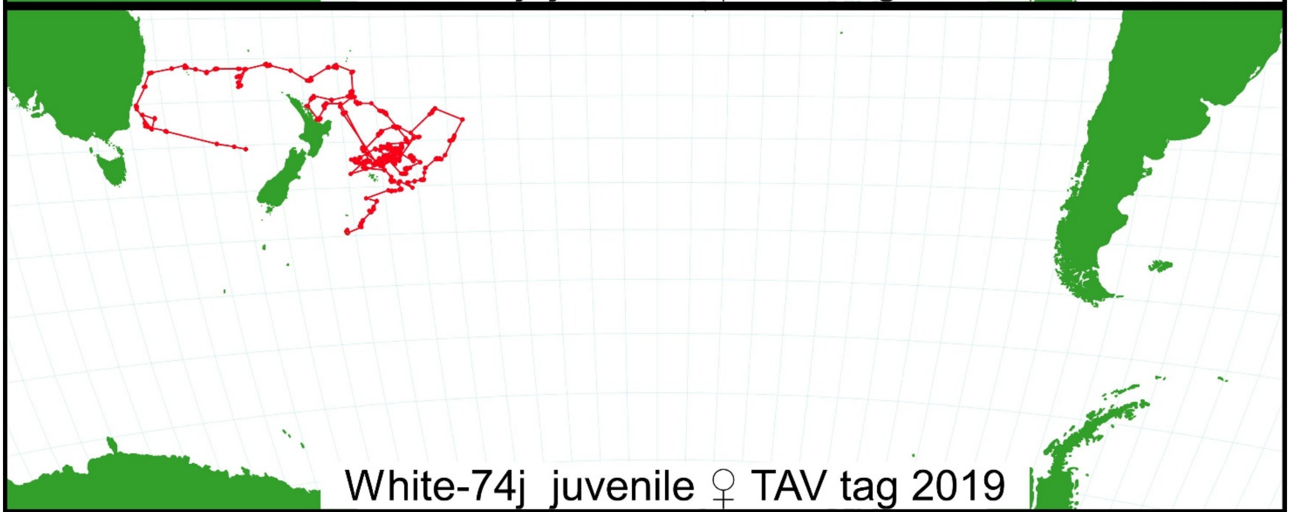


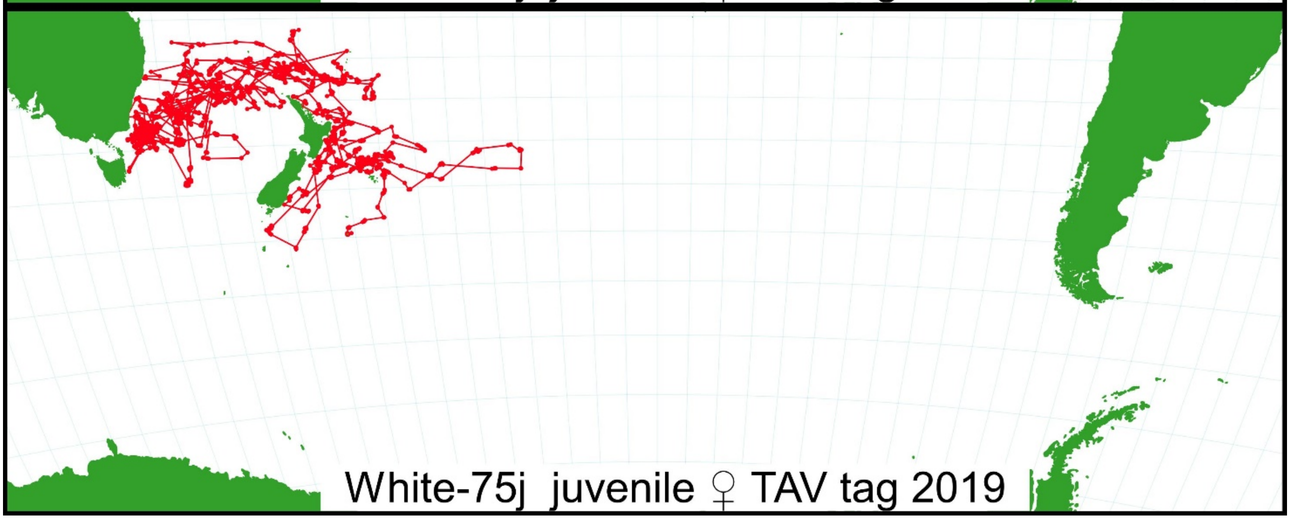




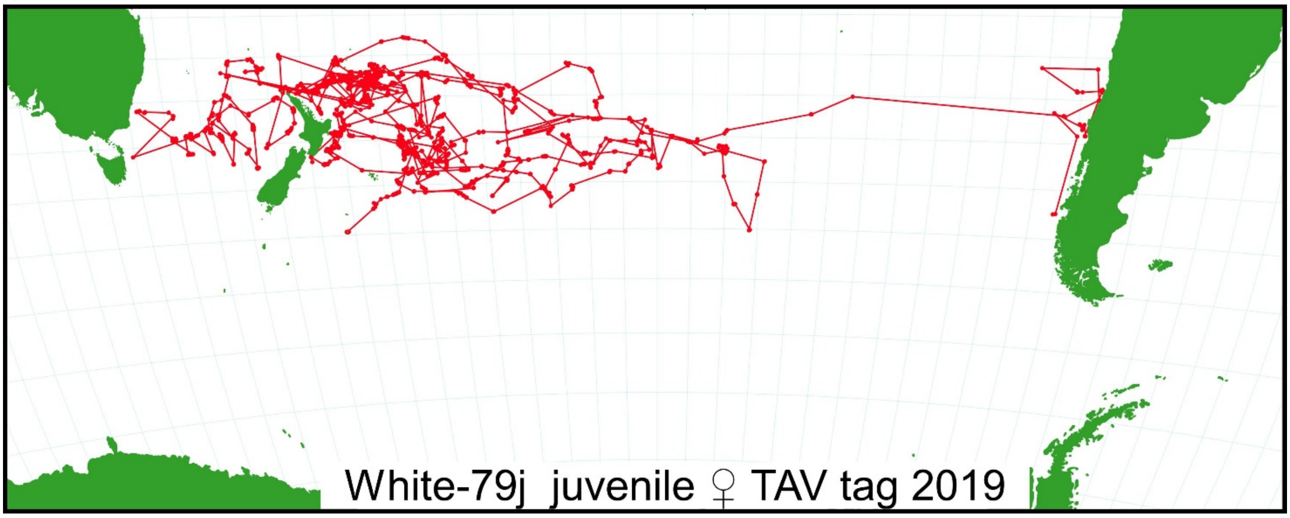
Fledgling females



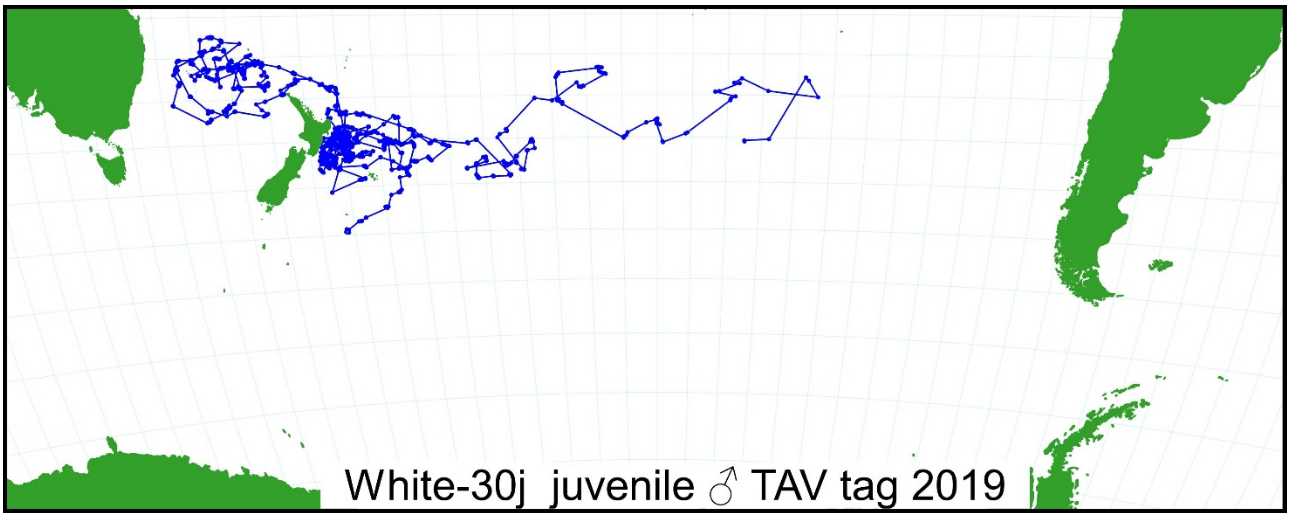


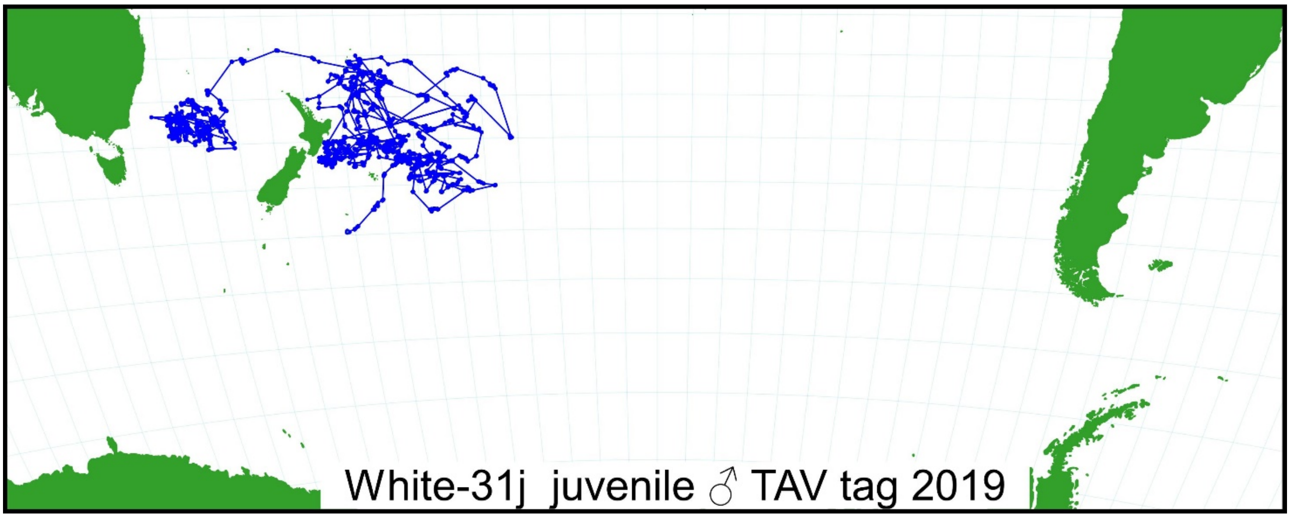


Fledgling female

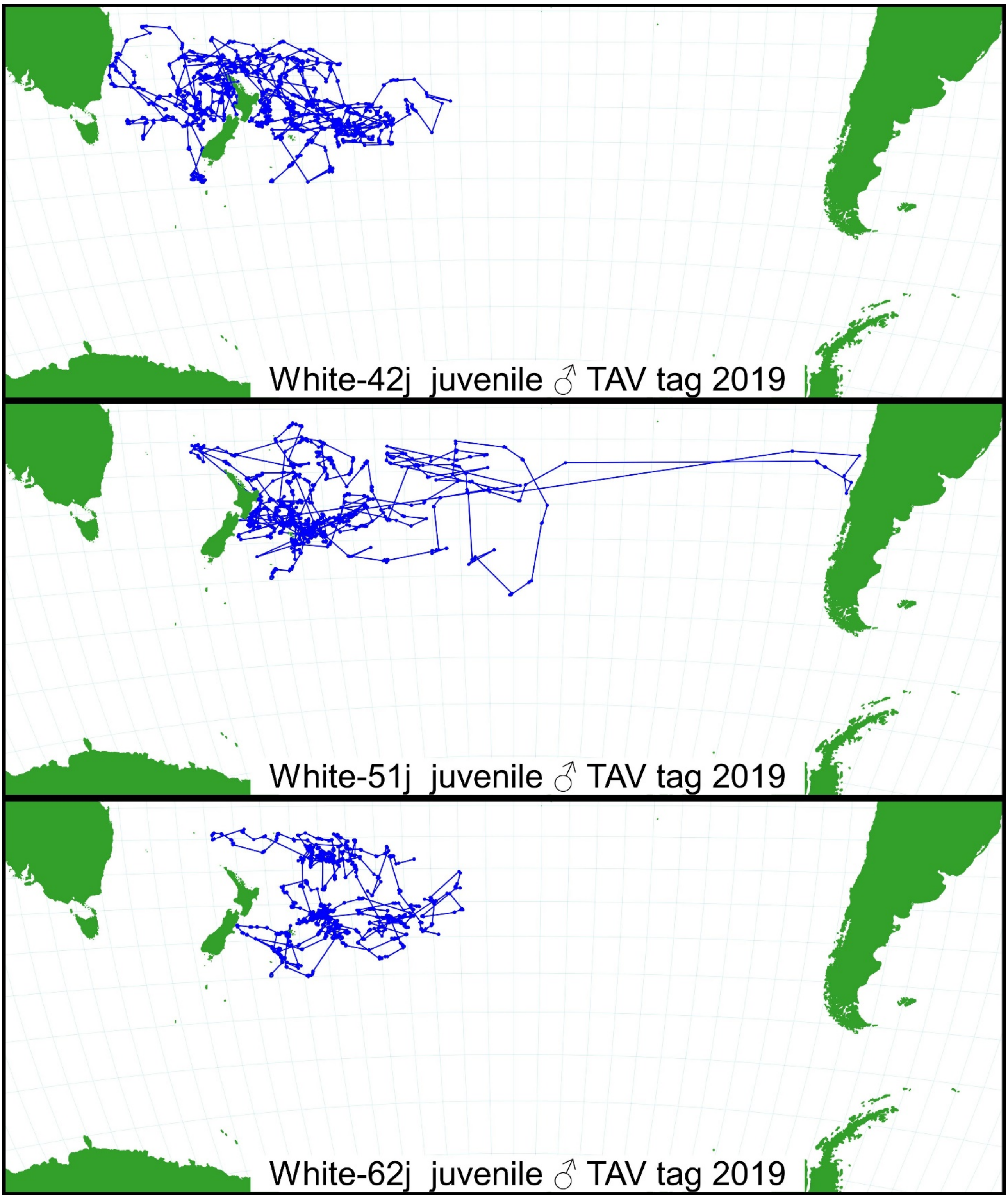


Fledgling males

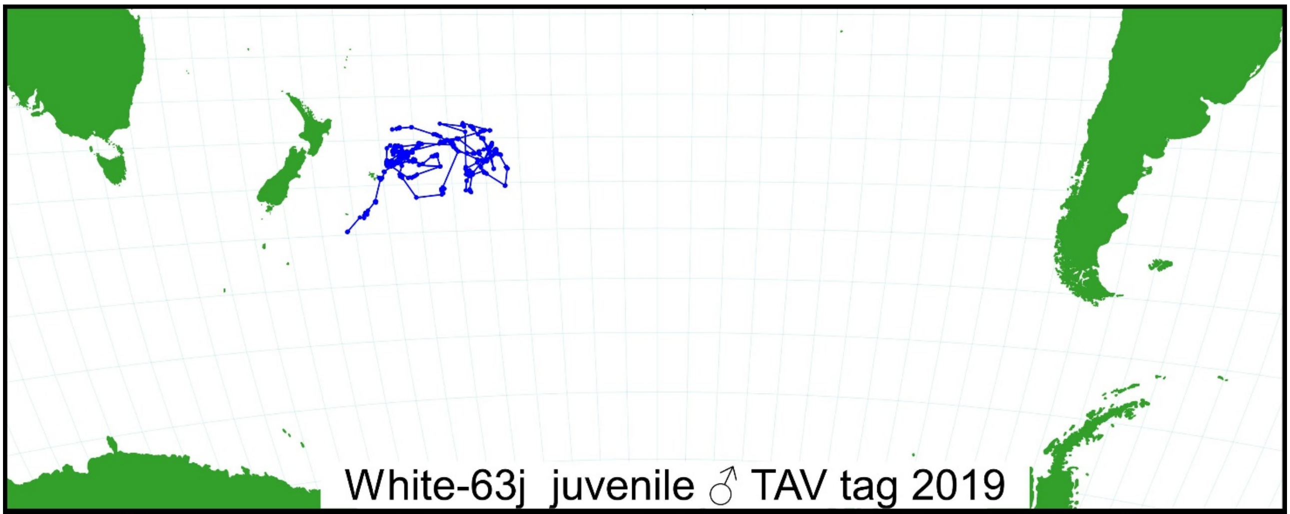


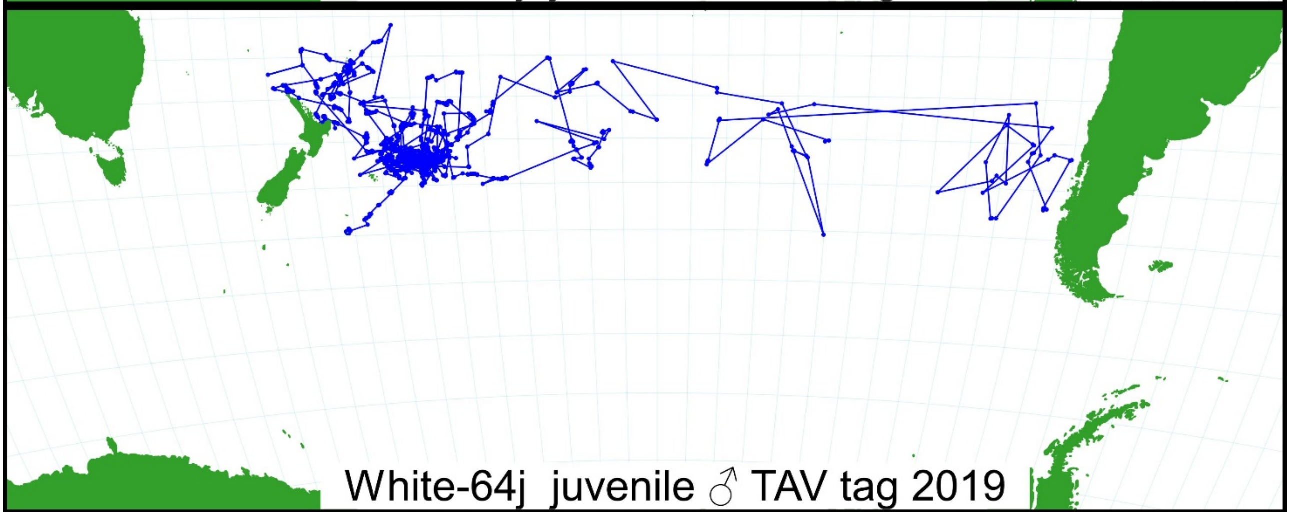


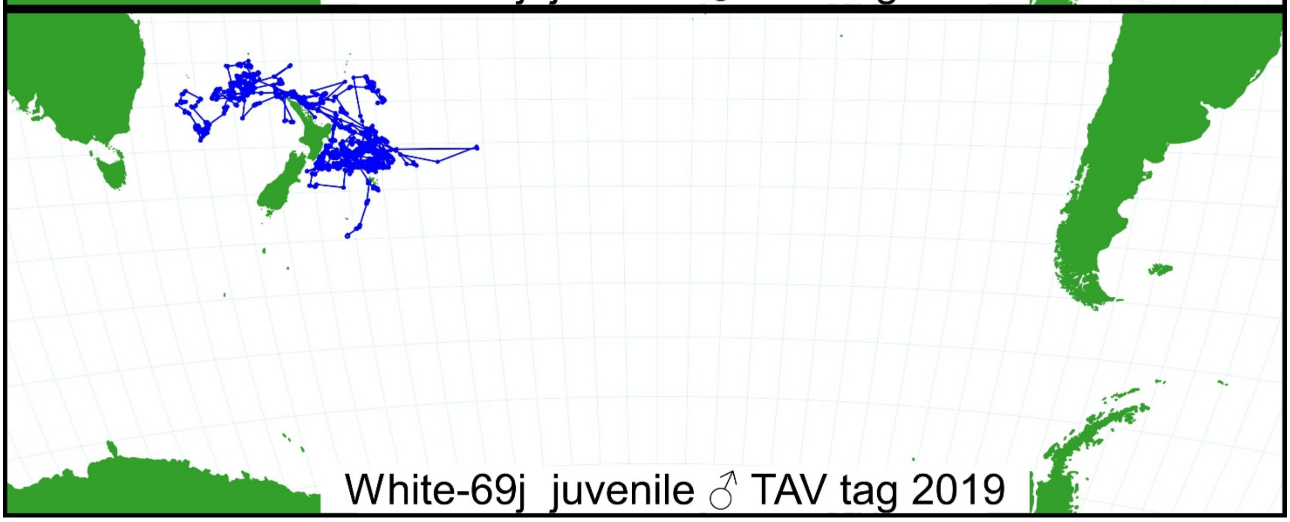
Fledgling males



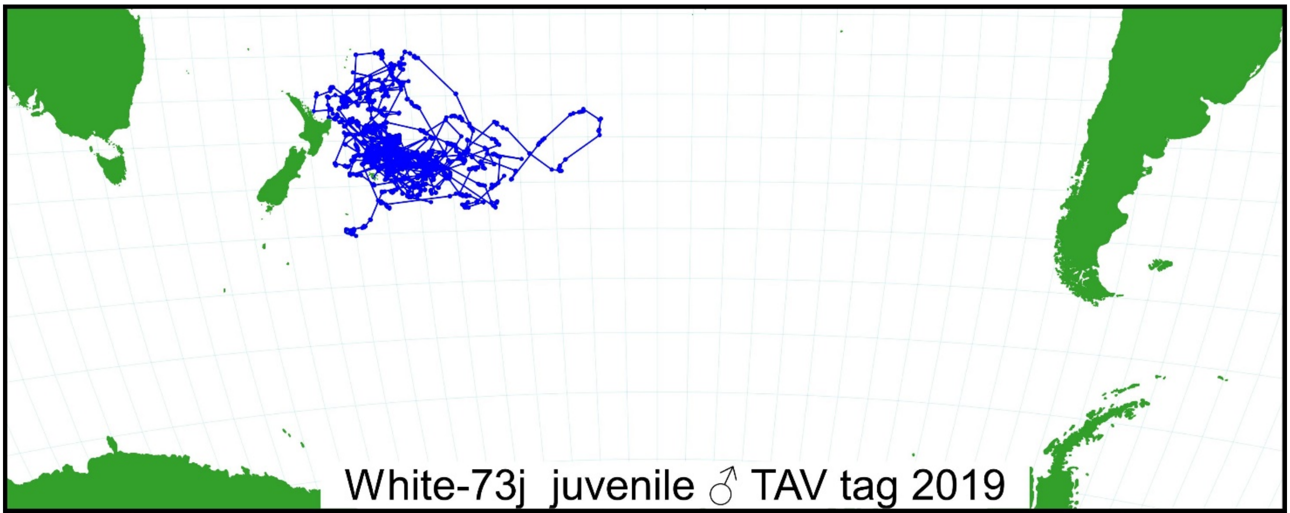
Fledgling males

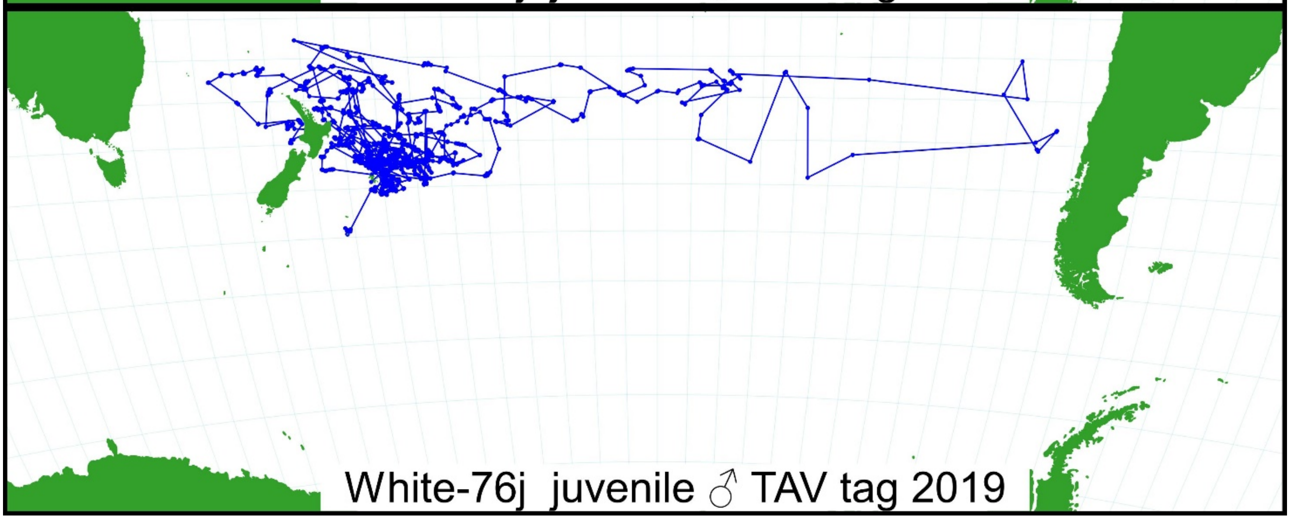




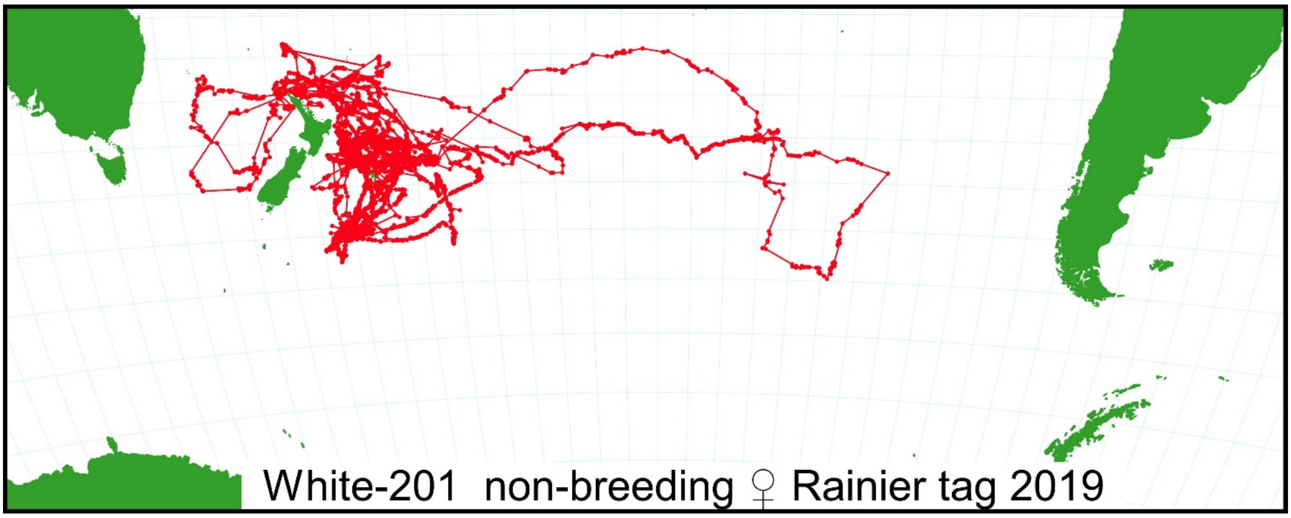


Fledgling males

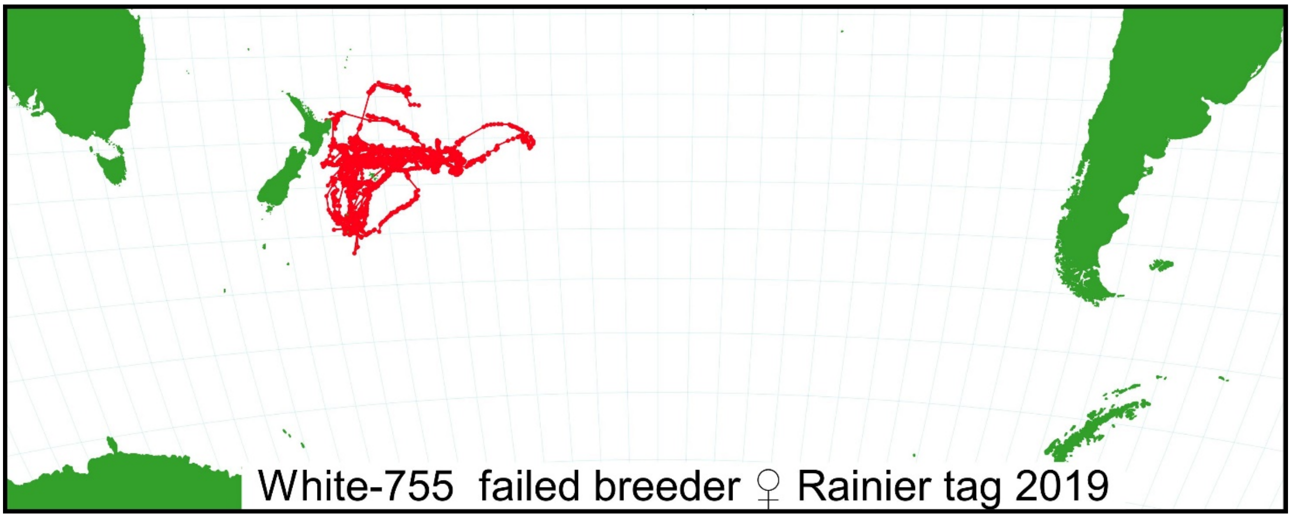




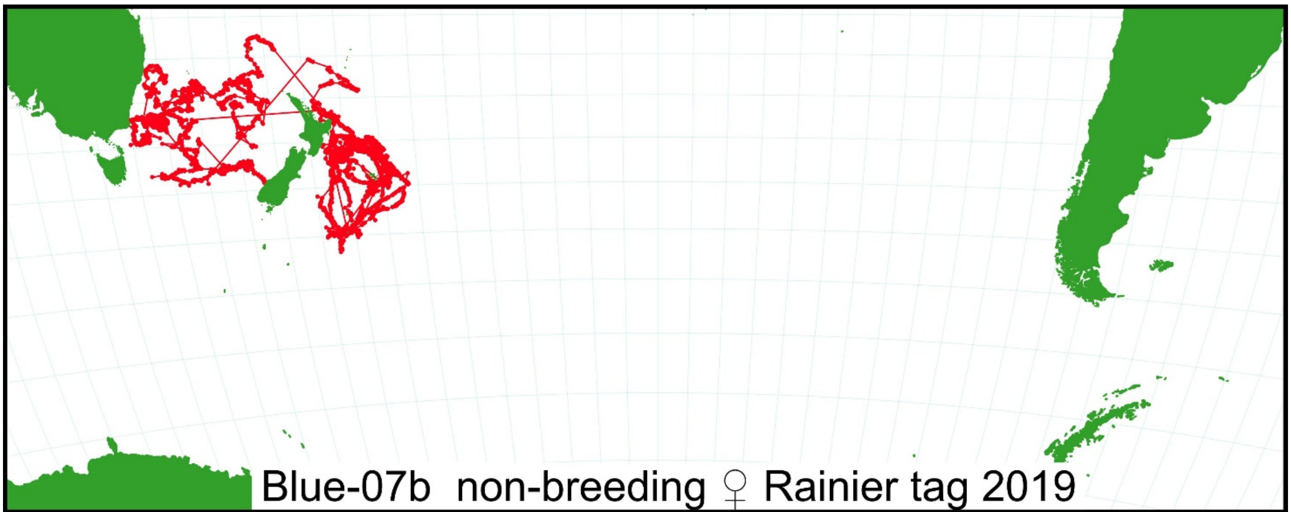
Non-breeding and failed breeding females.

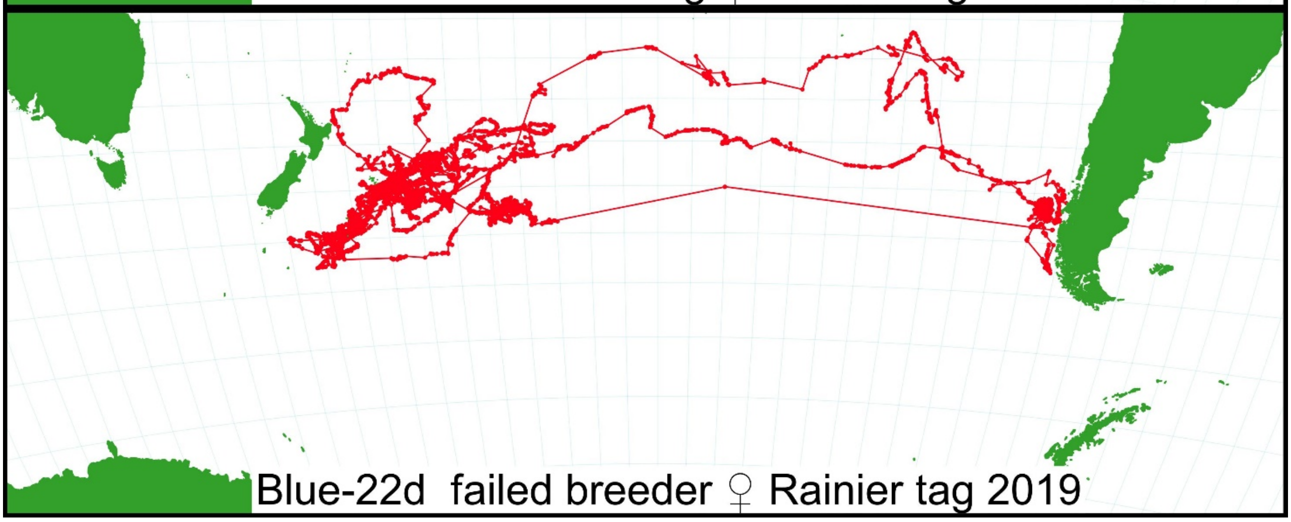


Non-breeding and failed breeding females.

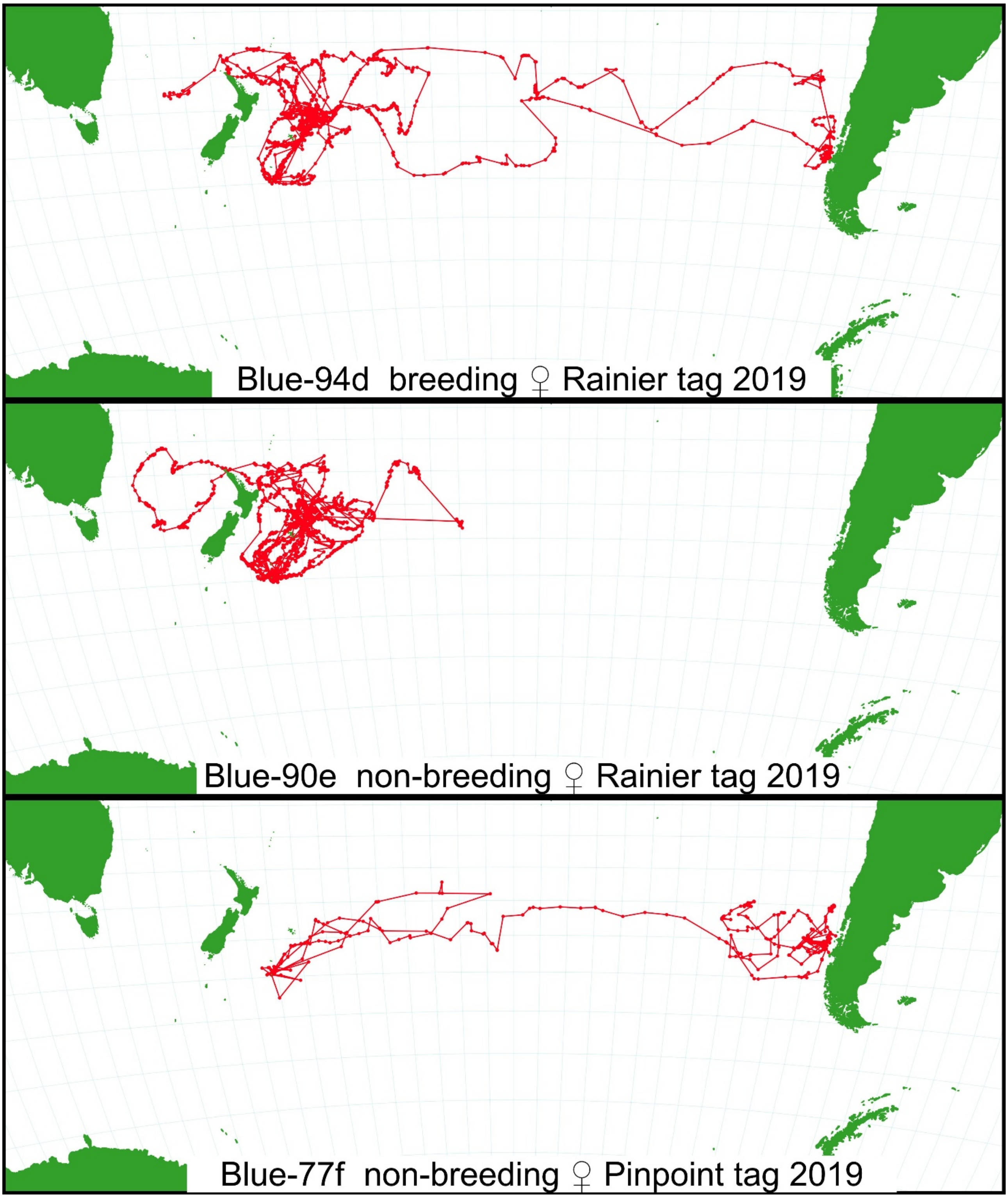


Female White-755 repeatedly returned In Jan-April to her failed nest on Antipodes I to court her mate but was likely killed on 19 May 2019 when her transmitter stopped close to a long-line vessel over a seamount on the Louisville Ridge North-East of New Zealand’s East Cape

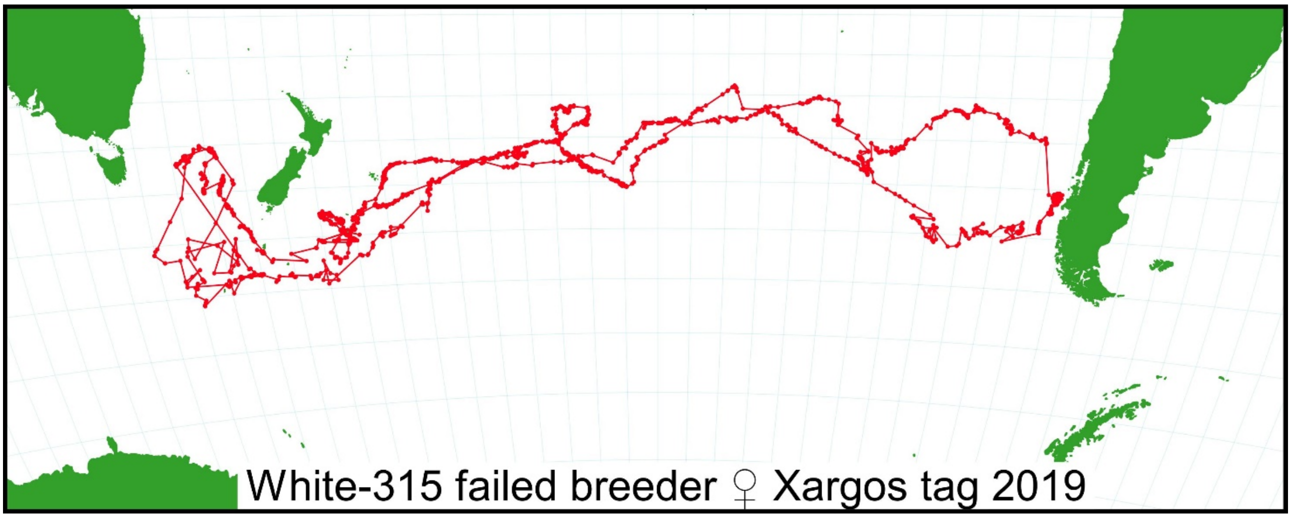




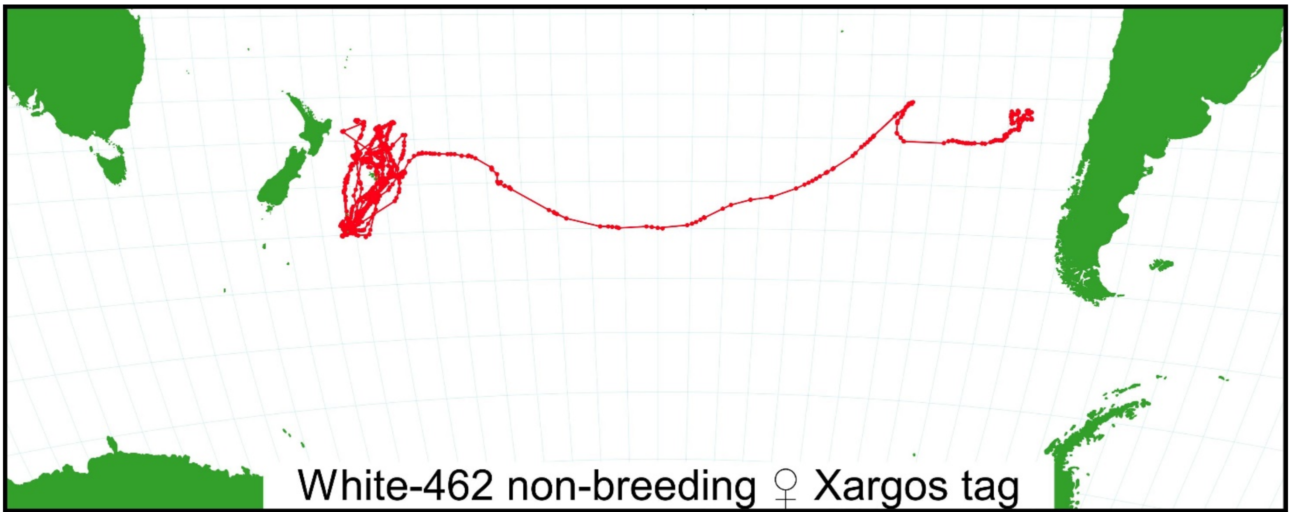
Non-breeding and failed breeding females.

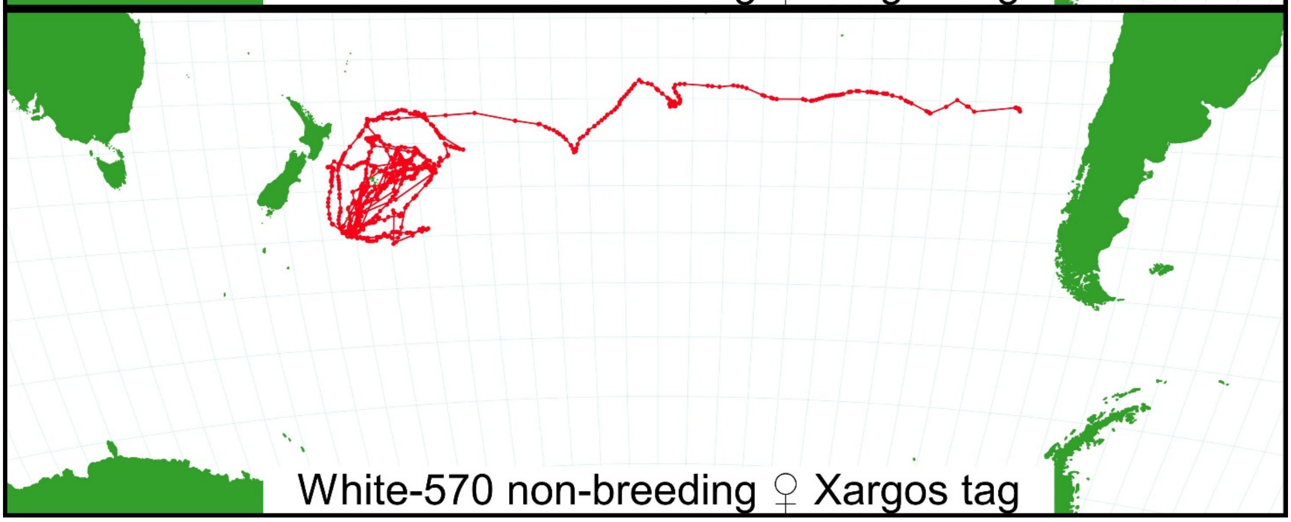


Non-breeding and failed breeding females.

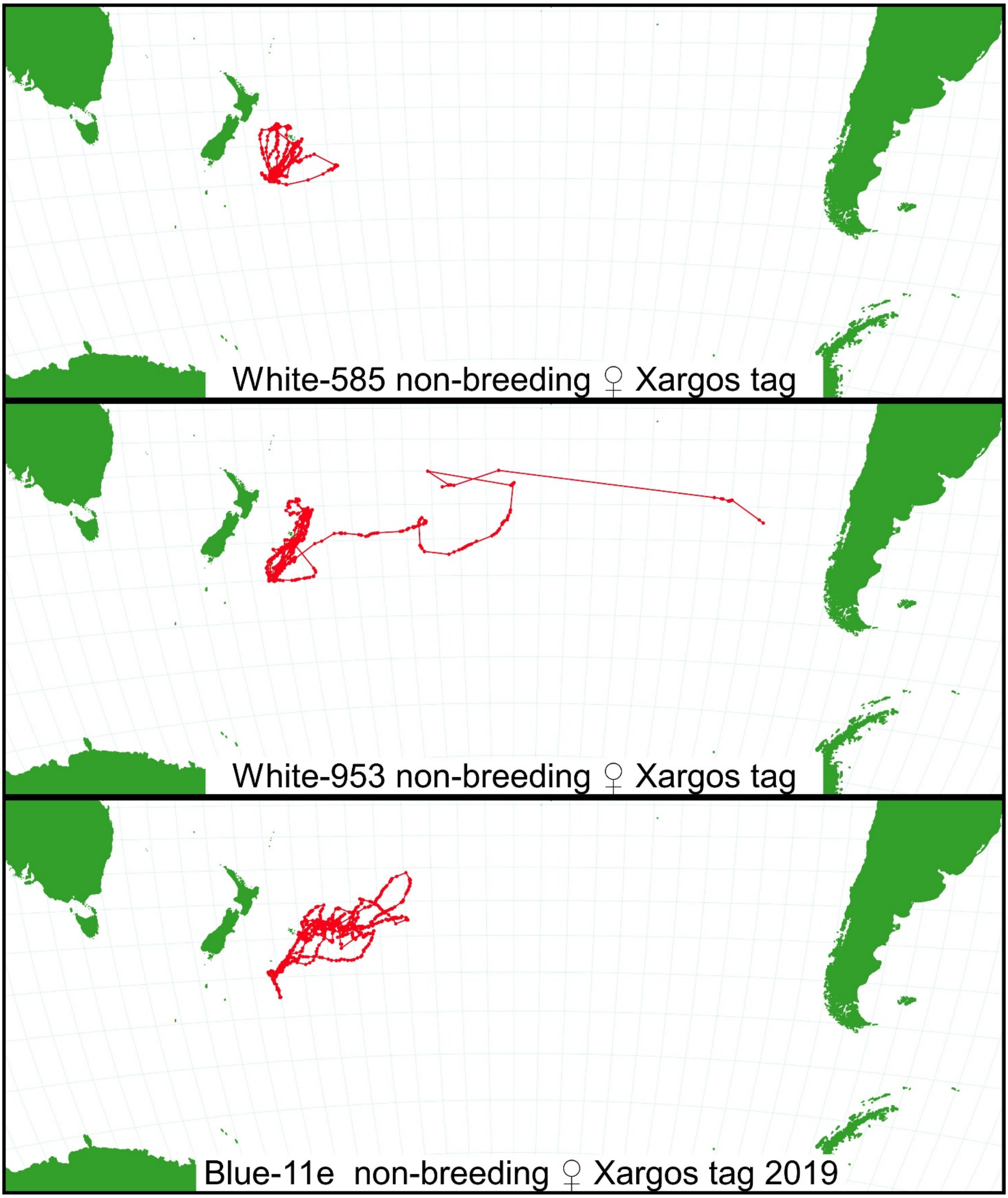


Female white-315 deserted 2 Feb as soon as relieved at the nest after egg-laying, flew to Chilean coast & returned to nest on 26 March, made several short trips away from nest, then finally completely abandoned nest & foraged in Tasman Sea before tag stopped 23 April 2019

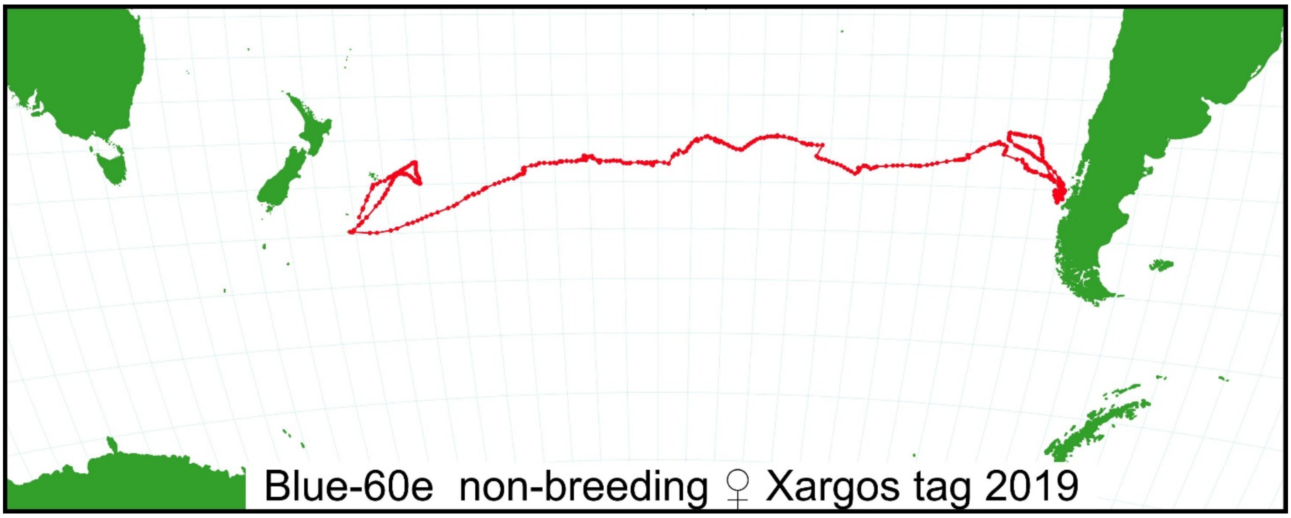




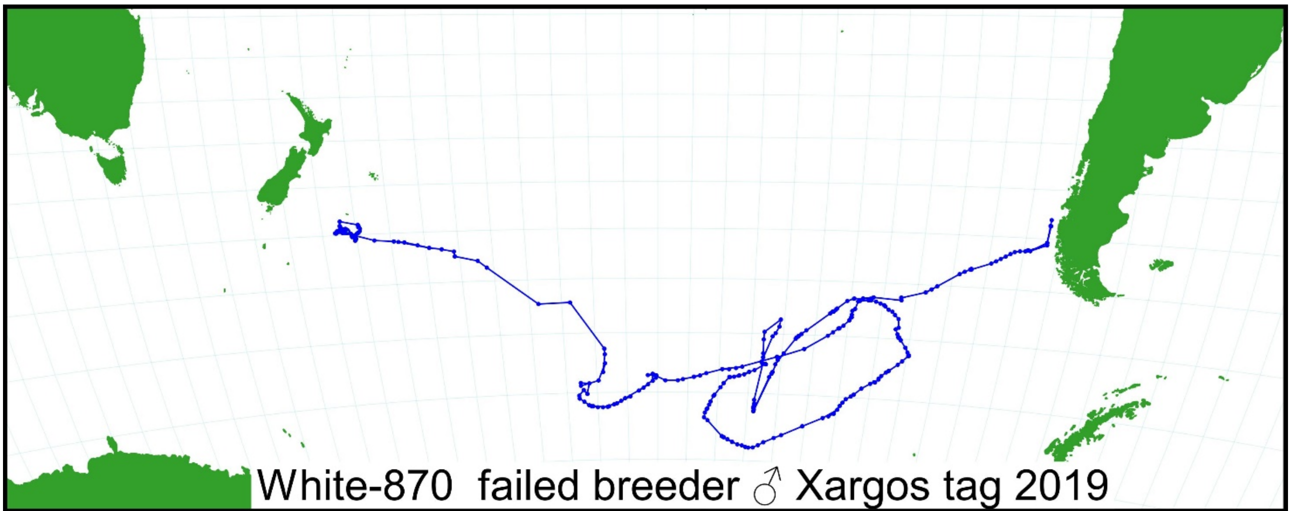
Non-breeding and failed breeding females.

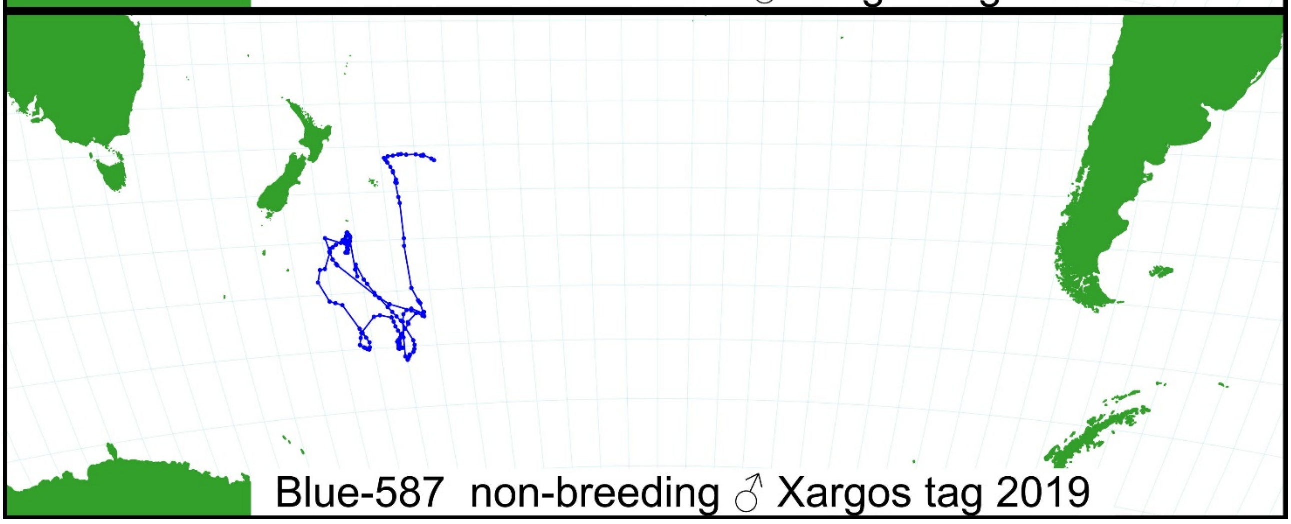


Non-breeding and failed breeding females.

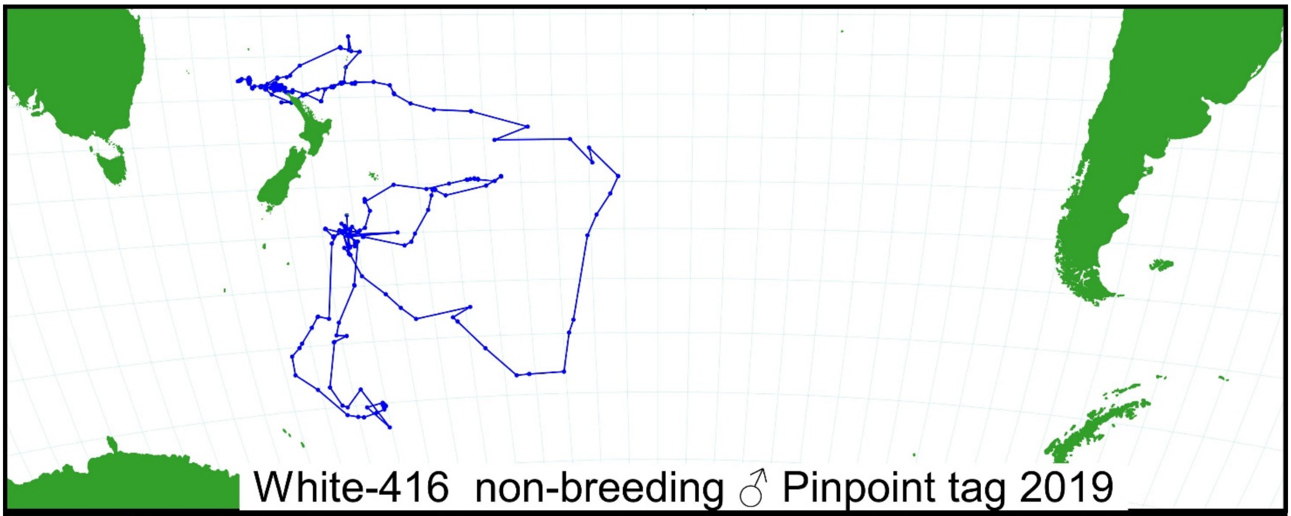


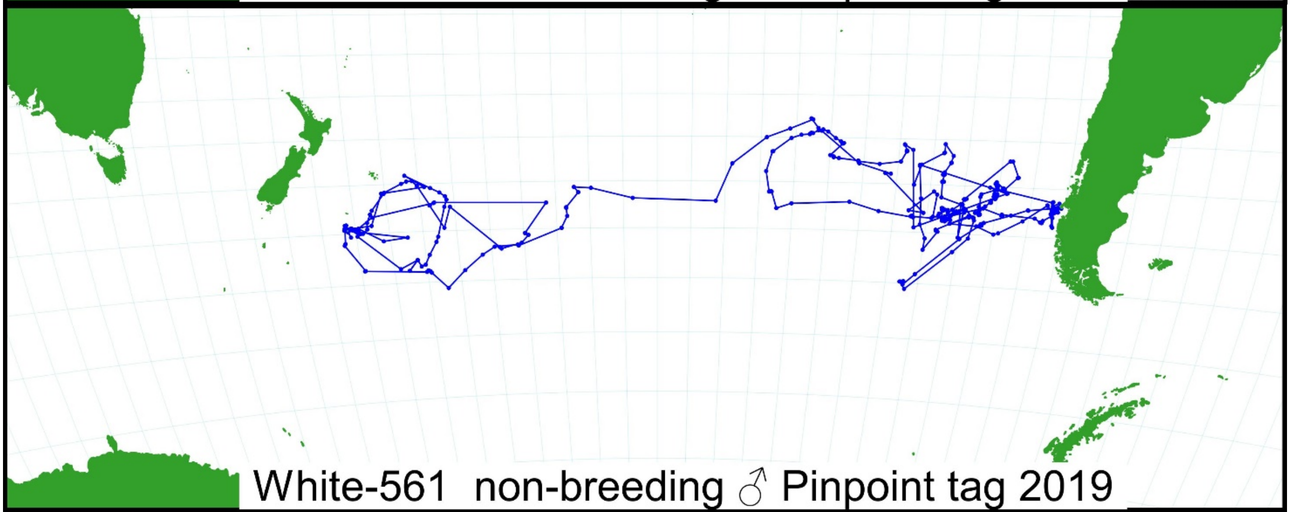
Non-breeding and failed breeding males

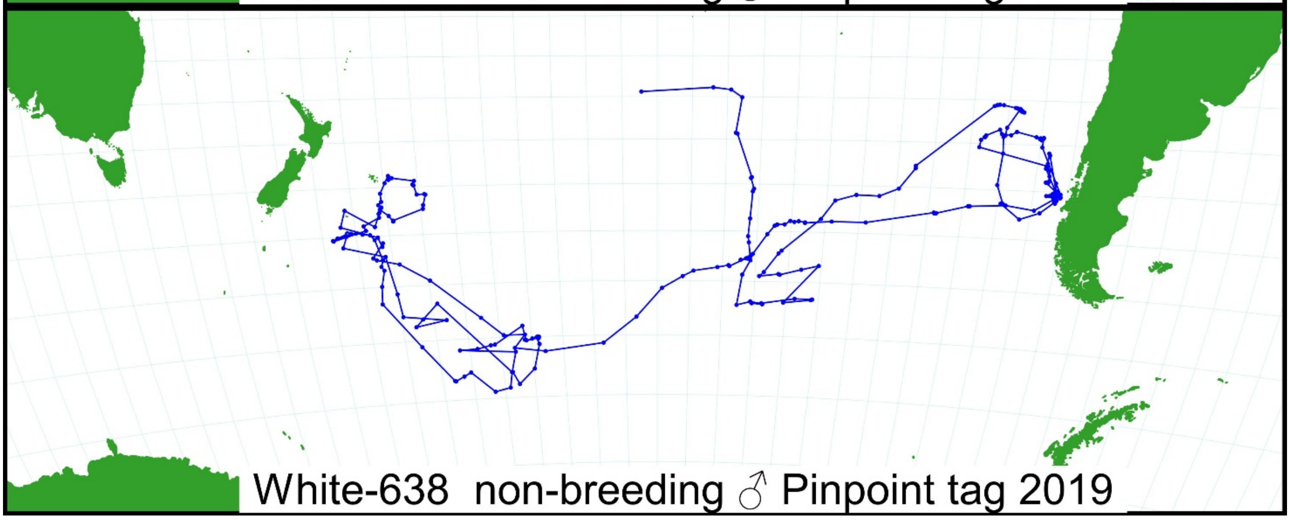




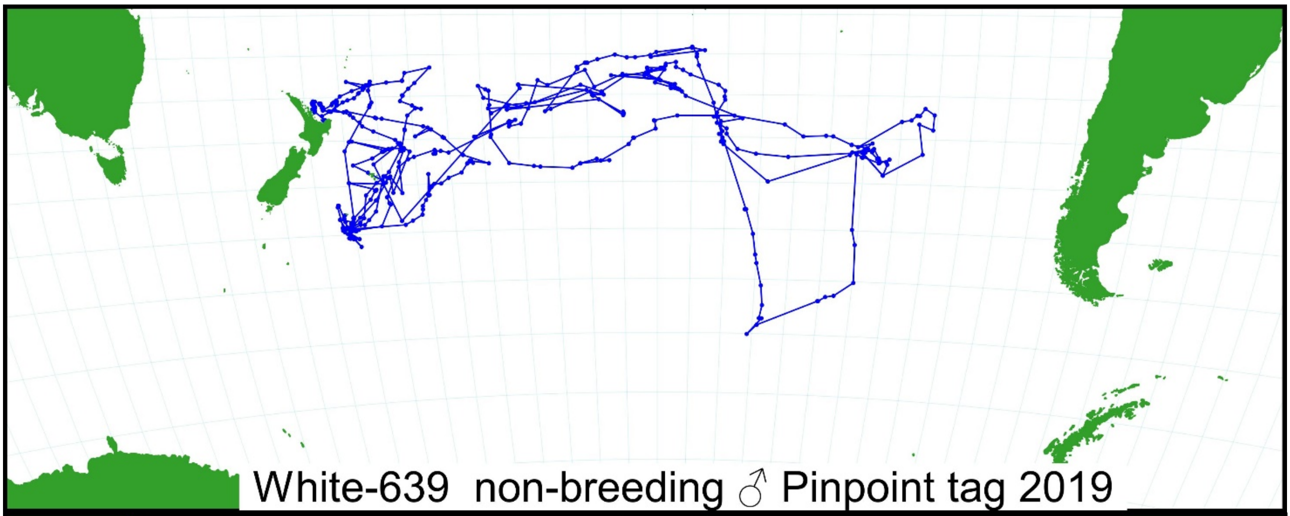
Non-breeding and failed breeding males

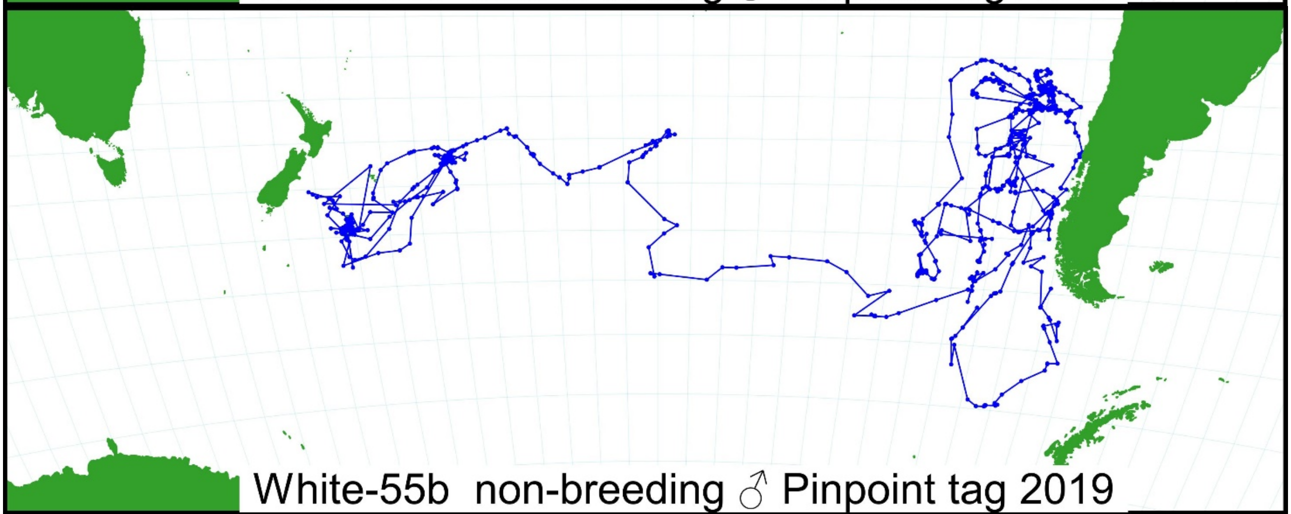


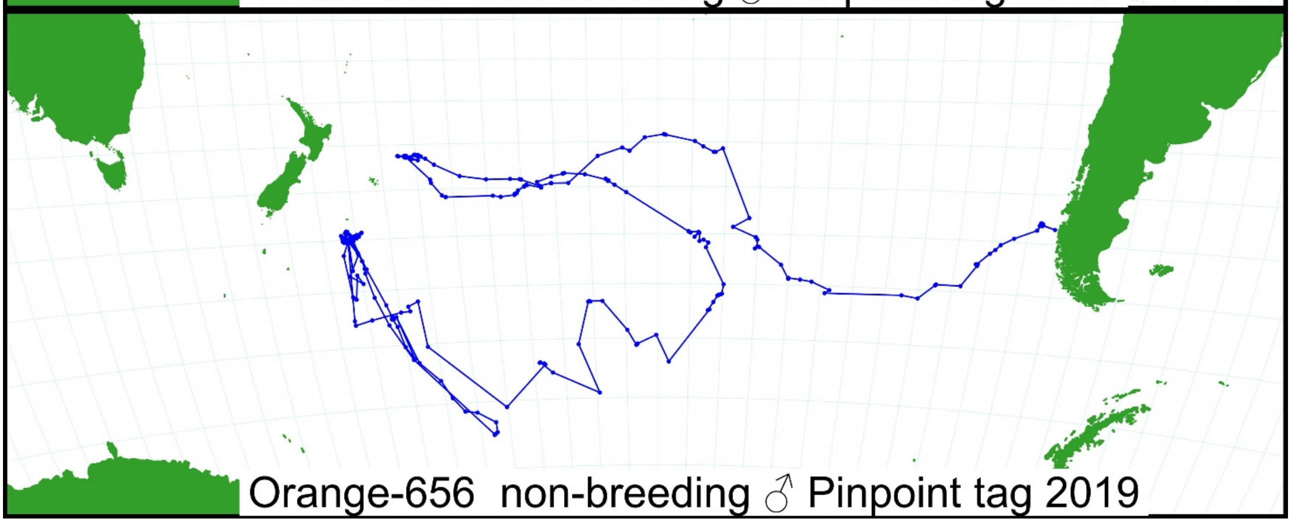




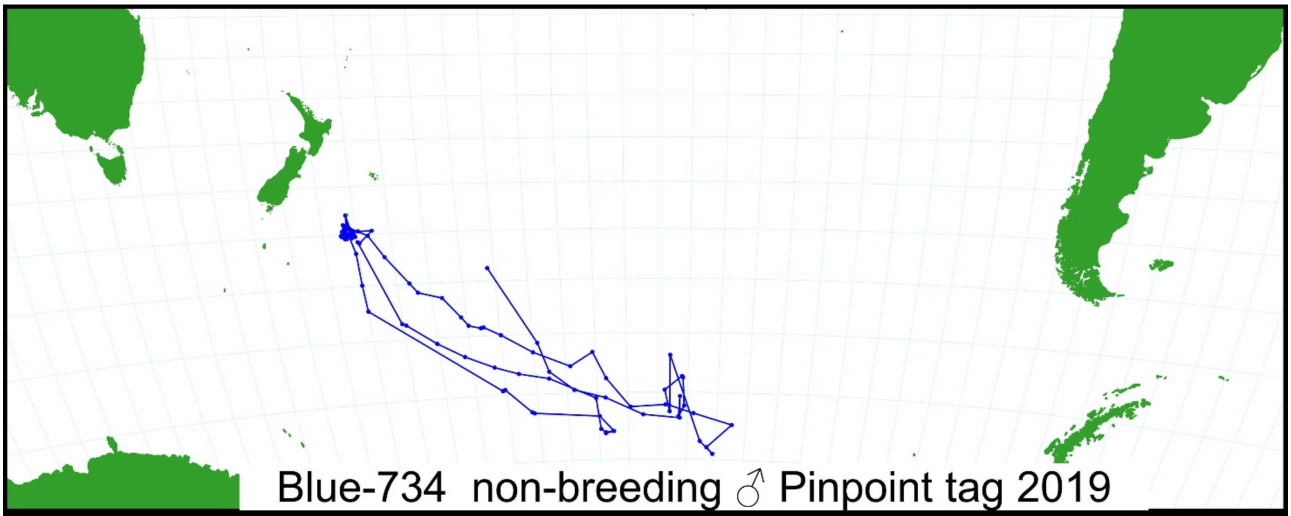
Non-breeding and failed breeding males

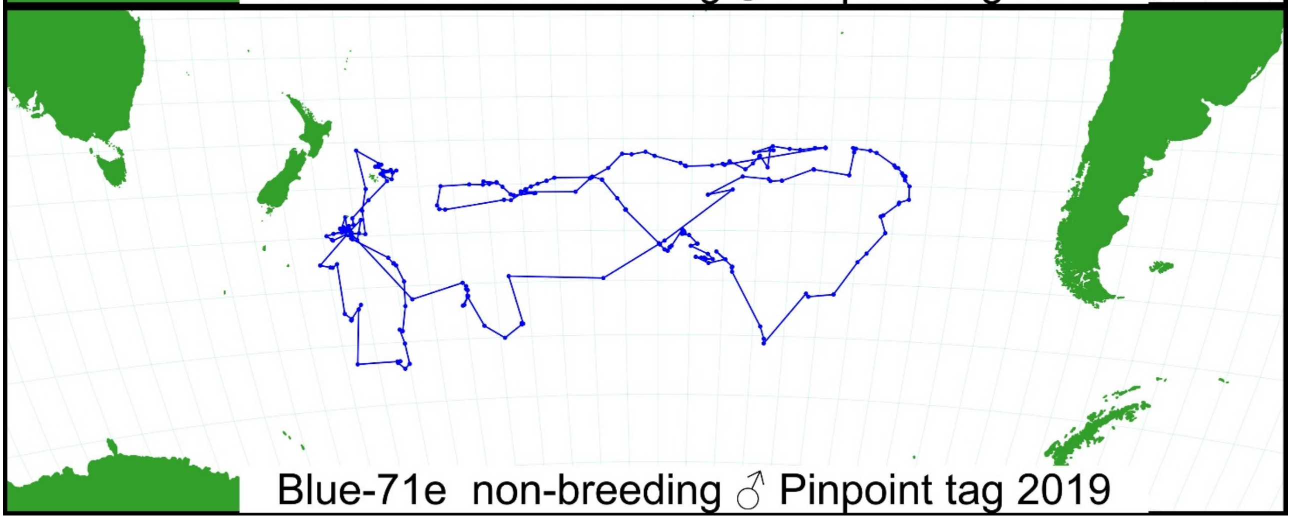




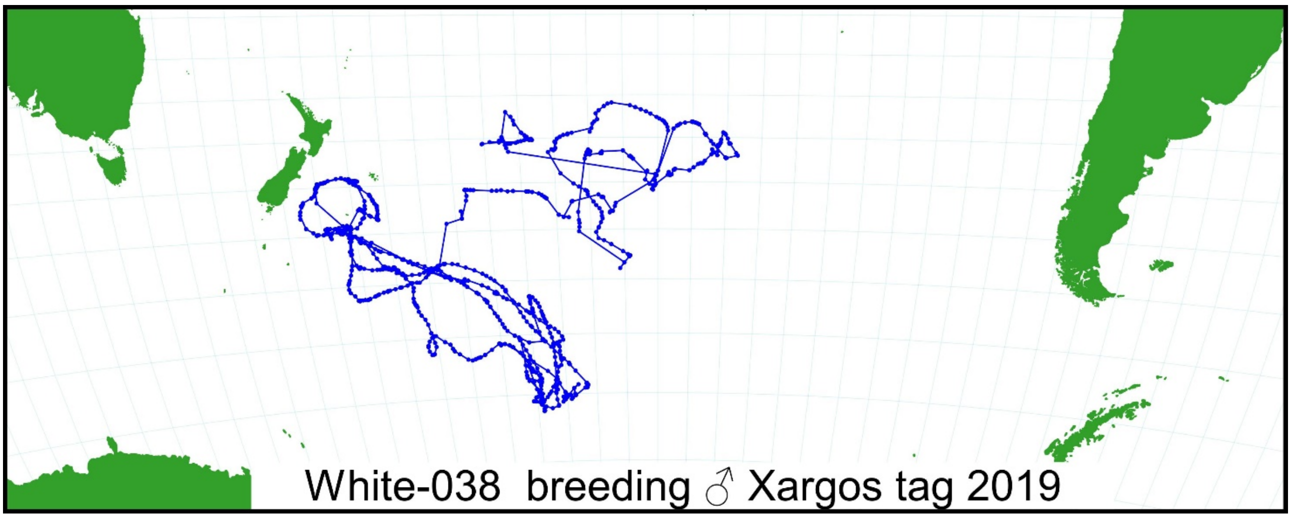


Non-breeding and failed breeding males

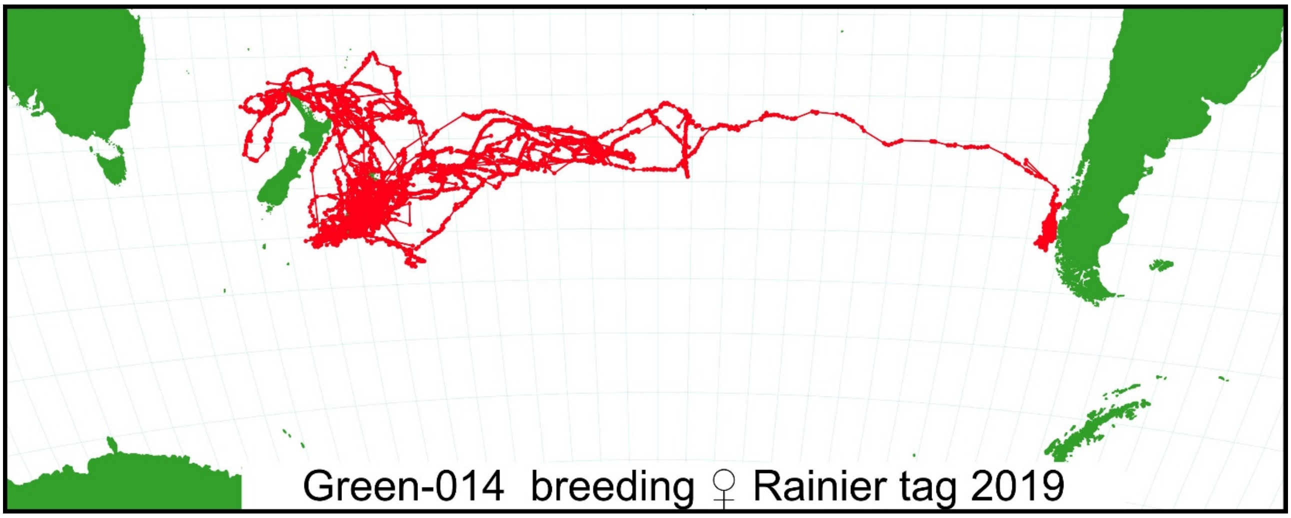




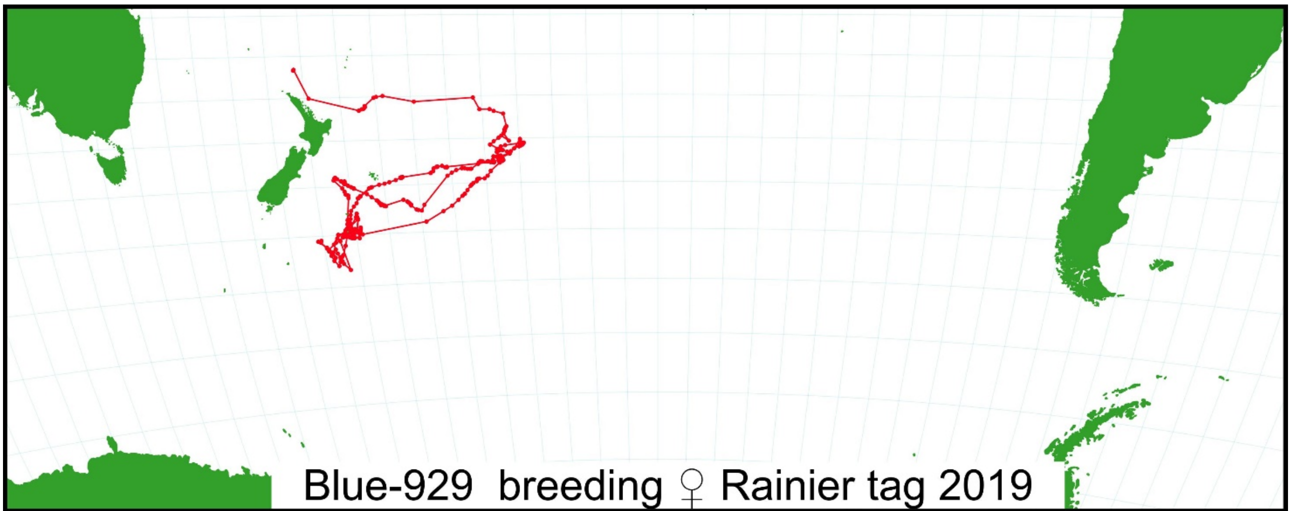
Breeding male

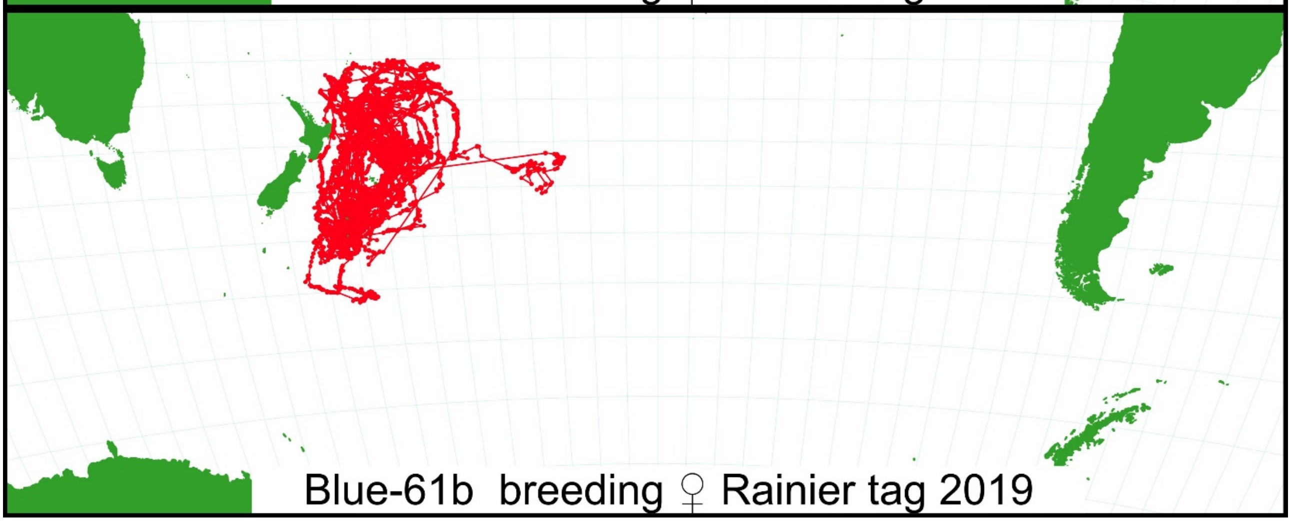


Breeding females

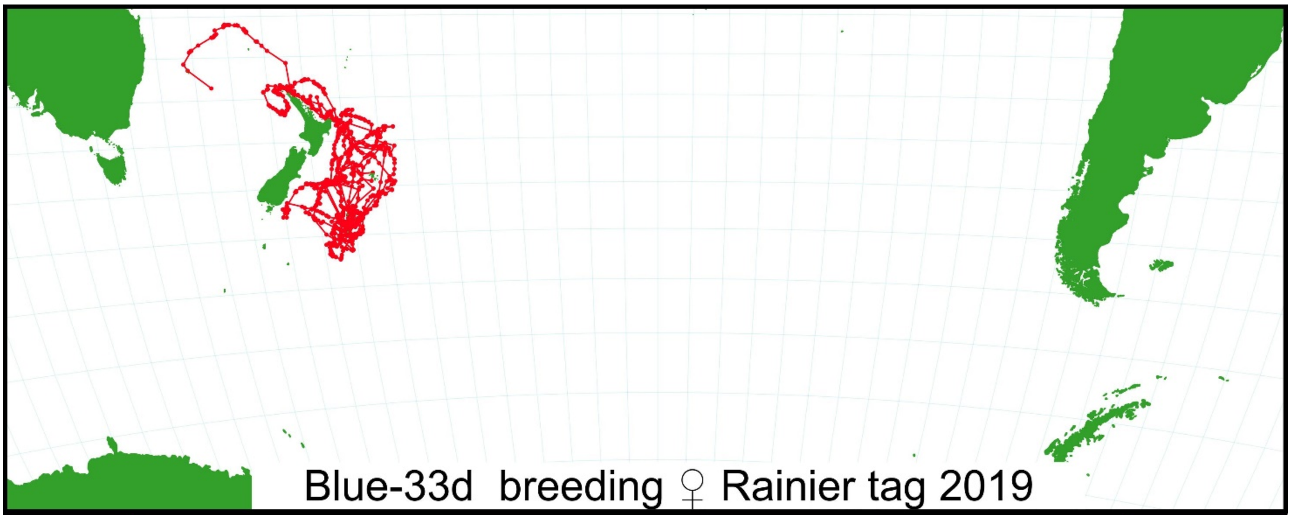


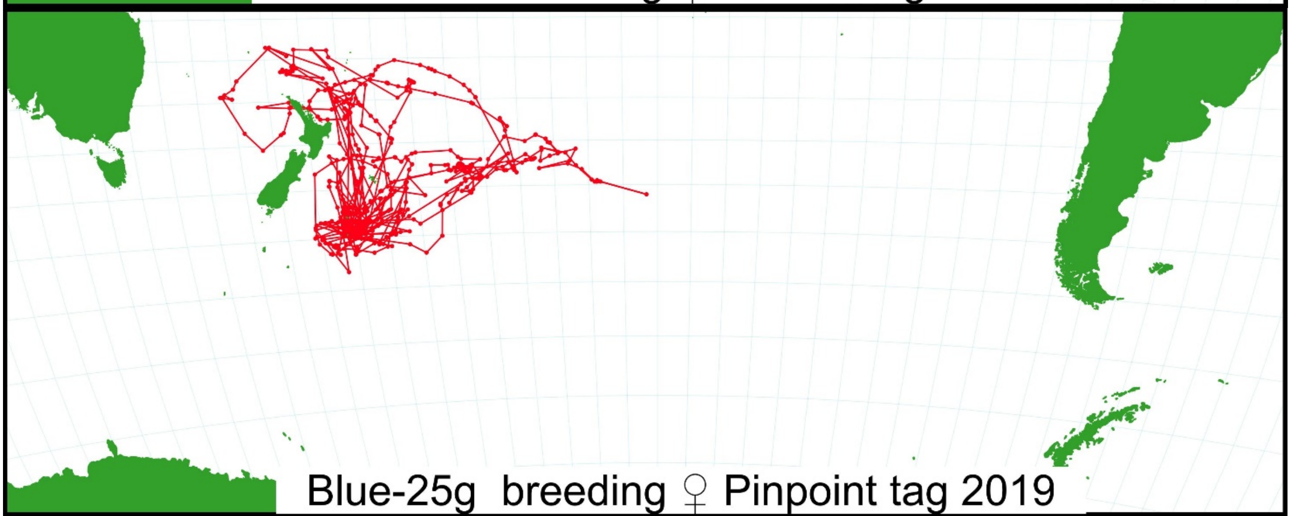
Green-014 successfully bred Jan–11 Nov, then leaving mate to complete chick rearing. went to coast off Chile till tag dropped off 8 Feb 2020

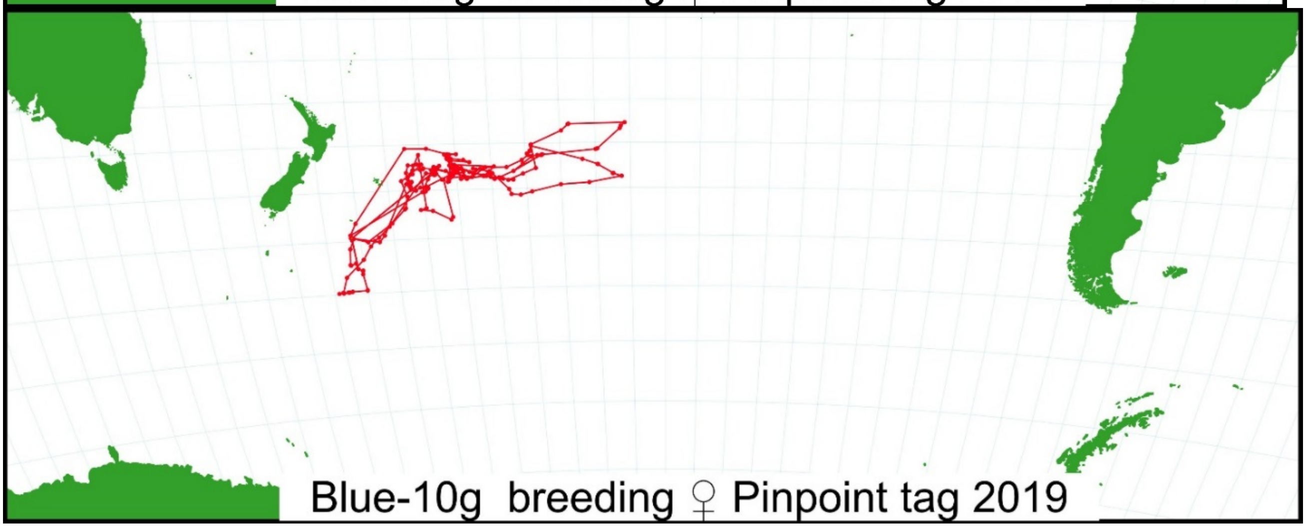




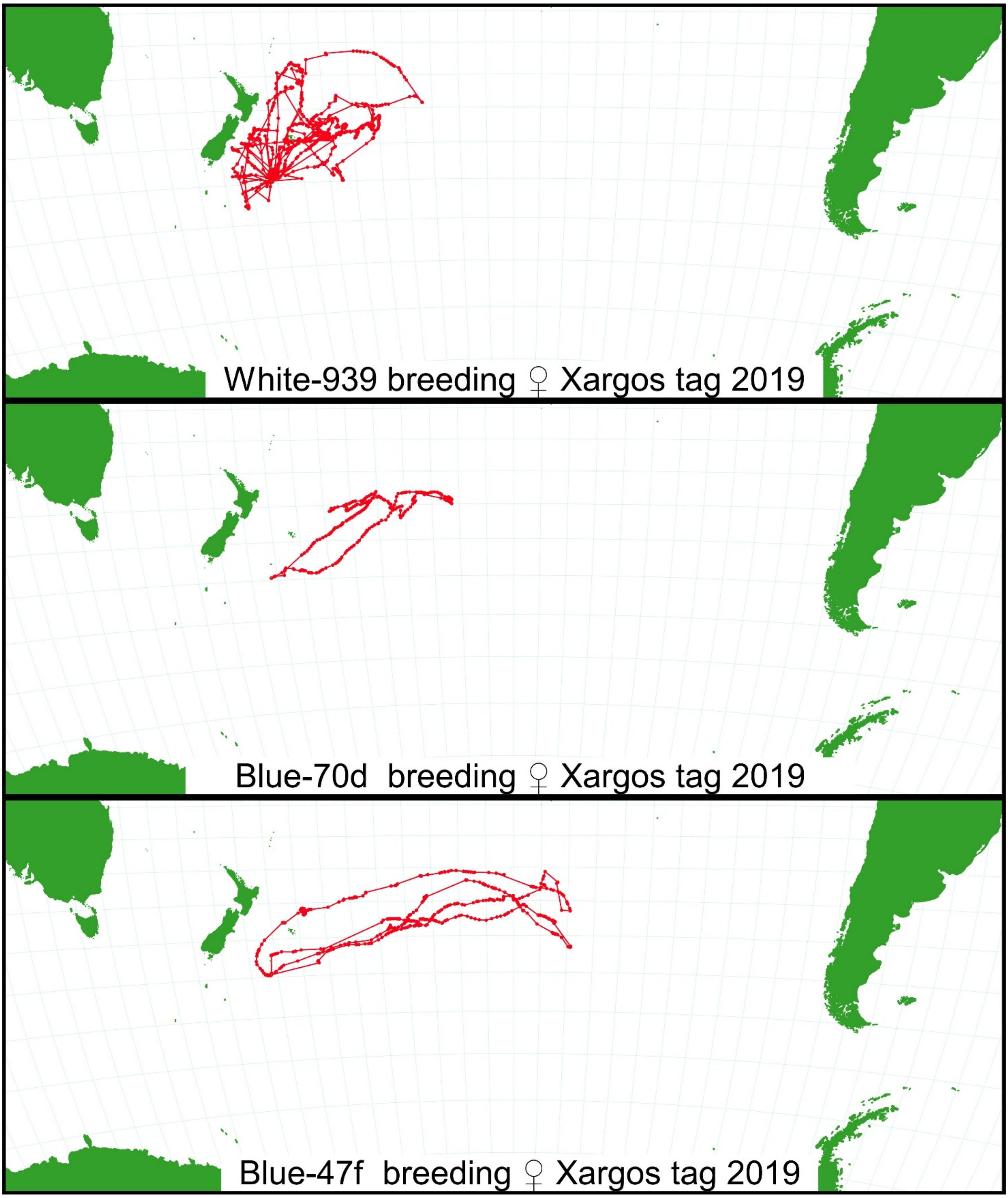
Breeding females







Breeding females



Breeding females