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Population changes and biology of the Antipodean wandering albatross (*Diomedea antipodensis*)

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Abstract The Antipodean wandering albatross (*Diomedea antipodensis*) is endemic to Antipodes Island in the New Zealand subantarctic. A programme of regular census and population study was initiated on Antipodes Island in 1994 to determine the status of the species. This paper reports on field work carried out every summer from 1994 to 2005. Aspects of breeding biology are described and compared with those of other species of wandering albatross, particularly the closely related Gibson's wandering albatross (*D. gibsoni*) on Adams Island. Average annual survival over 10 years was 0.957. Productivity was measured over 11 years and averaged 0.74 chicks per nesting pair. Survivorship was similar to that in the increasing *Diomedea exulans* population on Crozet Island, and productivity higher than recorded in all other wandering albatross populations. Between 1994 and 1997, the average annual number of pairs nesting on Antipodes Island was 5136. There is evidence of population decline during the 1970s but numbers are now increasing.

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INTRODUCTION

The wandering albatrosses, with their huge wing spans and graceful soaring flight, have long been symbols of the southern oceans, and were described by Linnaeus, as *Diomedea exulans*, as early as 1758, However, until recently, almost nothing was known of the New Zealand populations, although they comprise over half of the world's wandering albatrosses (Gales 1998).

The much-studied wandering albatross (*D. exulans*) of the south Indian and south Atlantic oceans was known to have suffered population declines at all of its colonies between the 1960s and 1990s, attributed to long-line fishing in the southern oceans (Weimerskirch & Jouventin 1987; Croxall *et al*. 1990; de la Mare & Kerry 1994; Weimerskirch *et al.* 1997). There were fears the two wandering albatross taxa endemic to New Zealand, Gibson's wandering albatross (*D. gibsoni*) and Antipodean wandering albatross (*D. antipodensis*), may have suffered similarly, as both have been a regular bycatch in long-line fisheries (Murray *et al.* 1993). Wandering albatrosses are long-lived (>40 yrs), breed late (≥10 yrs) and produce a chick at two-three year intervals and, therefore, are less able to sustain increased bycatch-induced mortality than many other seabird species (Croxall & Rothery 1991; Gales 1998).

In 1994 we began a long-term study of Antipodean wandering albatross on Antipodes Island to determine population size and trends, and the key demographic parameters necessary for an understanding of conservation status. In this paper we provide estimates of breeding success and adult survival in 1994-2004 and describe population size and trends over the last 30 years.

Most Antipodean wandering albatrosses nest on Antipodes Island, but about six pairs nest on Campbell Island, about 1000 km to the south west (Gales 1998), and in 2005 a pair bred on Pitt Island in the Chatham Island group about 700 km to the north (C. Miskelly, pers comm.). Prior to 1994, most information on the species came from a study of distribution and nesting density on Antipodes Island in the summer of 1969 (Warham & Bell 1979) and from examination of dead birds caught as fisheries bycatch off the east coast of New Zealand (Murray *et al*. 1993).

The Antipodes Islands, 850 km south-east of New Zealand in the south-west Pacific Ocean, comprise one large and six smaller islands (Fig. 1). Antipodes

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Island (49° 41′ S, 178° 47′ E) is approximately 7 x 5 km (2025 ha), and comprises cliff-edged or steep coastal slopes of 100 - 200 m height and a gentler upland rising to two peaks of 366 m and 358 m near its centre. The island is mostly covered with *Poa litorosa* tussock, with only two species of low-growing woody shrub, *Coprosma rugosa antipoda* and *C. ciliata*. The steep coastal slopes are covered in 1-2 m high dense vegetation comprising tall pedestals of *Poa litorosa* intertwined with *Poa foliosa*, and the ferns *Blechnum durum* and *Asplenium obtusatum*. They are extensively burrowed by seabirds, particularly white-headed petrels (*Pterodroma lessonii*) and grey petrels (*Procellaria cinerea*). On the flatter uplands and plains, the vegetation comprises stunted and widely–spaced *Poa litorosa* with low-growing ferns and herbs in the disturbed and enriched soils around albatross nests.

Antipodes Island is one of the world's least modified islands. It has been inhabited for short periods only by sealers, shipwrecked castaways and researchers. Although farm cattle, sheep and goats, and some trees and grasses, were deliberately introduced in the late 1800s (Warham & Johns, 1975), they quickly died out and the only lasting additions to the biota are a few weedy herbs (Godley 1989), house mice (*Mus musculus*), and some birds self-introduced from New Zealand (Warham & Bell 1979).

Antipodean wandering albatrosses do not breed amongst the tall vegetation on the steep coastal slopes, or amongst the tall *Polystichum vestitum* fern on poorly drained parts of the upland. However, the remaining 1062 ha of the island is all occupied by nesting albatrosses, effectively comprising one large colony. This contrasts with most other wandering albatross populations where colonies occur in discrete habitat patches or on separate islands.

METHODS

From 1994 to 2005 we visited Antipodes Island every summer between December and March. In a 29 ha study area near the north end of the island (block 1 in Fig. 1), we banded all nesting albatrosses and mapped and marked their nests. In 1994-1997 birds were banded only with a numbered stainless steel band, but during 1998-2005 all metal-banded birds were also fitted with a coloured plastic band engraved with large numbers which could be read from a distance. The coloured bands increased the chances of band recoveries and reduced the need for catching birds.

Adult wandering albatrosses show strong fidelity to their colony and nest site (Inchausti & Weimerskirch 2002) and their survival can be calculated from annual checks for banded birds in the study colony. However, the birds' deferred breeding strategy (Tickell 1968) complicates measurement of adult survival. Birds that fail in their nesting attempt during or soon after incubation usually return to breed in the following season, but most successful breeders and those that fail after incubation, usually wait at least a year before attempting to breed again. A few birds do not return to the breeding island for three or four years. Estimates of adult survival were calculated from banding and recovery data using the multi-strata formulation of Brownie *et al.* (1993) and Hestbeck *et al.* (1991) implemented in the program MARK (White & Burnham 1999). Details of this method are described in Elliott & Walker (2005). We used AIC (Burnham & Anderson 2002) to determine whether our data supported different survival estimates for male and female albatrosses.

Breeding success was compared at three different and widely separated sites (study area 29 ha, Pipit Peak 19 ha, Block-32 21 ha; Fig. 2) by counting the number of nests containing eggs in early-mid February, just after laying was completed, and by counting the number of chicks present in December just before they commenced fledging. The number of chicks which finally fledged was only measured in the study area where the marked nest sites were re-visited at the end of the season and again the following summer to look for dead banded chicks who failed to fledge. Differences in breeding success between years and between sites were examined by logistic regression.

From 1998, all newly constructed nests present in the study area at the beginning of the breeding season were marked, mapped, and checked every one or two days to determine the timetable of egg laying, the length of incubation shifts, and the nest failure rate during incubation.

Nest site fidelity was assessed in 1996 by searching for the last nest used by birds breeding in the study area and measuring, with compass and tape measure, the distance and direction moved between nest sites.

To determine the current size of the Antipodean wandering albatross population, the island was divided into 36 blocks separated by topographical features (Fig. 1). Thirty-one of the 36 blocks contained nesting albatrosses. In 1994 (Clark *et al*. 1995), 1995 (Amey *et al*. 1995) and 1996 (this paper) nests with eggs in all the albatross-occupied blocks were counted during February. In 1997, only 17 of the 31 blocks were counted. Within each block two - four observers spread out so that they were 20 - 25 m apart, and walked in parallel lines through the block, zigzagging where necessary to cover all the ground. Observers on the outside marked the edges of the counted strip with fluorescent tape or spray paint so that the same ground was not counted twice. In 1994 and 1995 each nest was marked with a spot of paint to show it had been counted.

To determine population trends, nests in three of the blocks were counted annually from 1997 (study

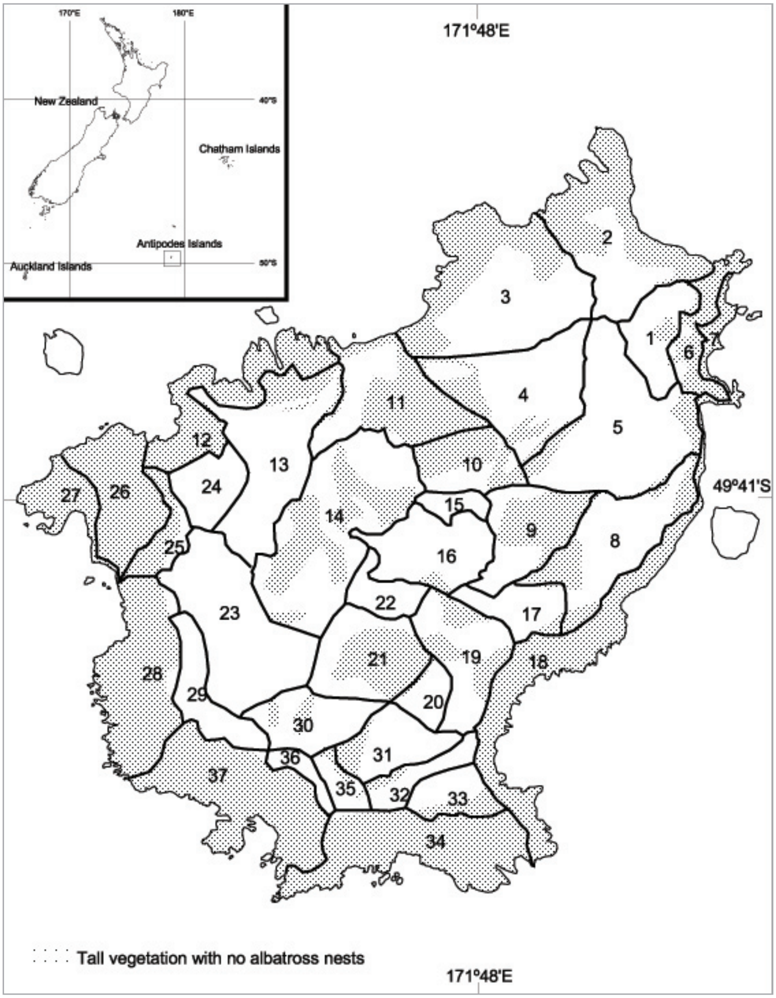

Figure 1 Antipodean wandering albatross census blocks on Antipodes Island.

area, MCBA and Block 32; Fig.2). These three blocks were chosen because they had large populations and sufficiently clear boundaries to ensure exactly the same areas were counted each year. To minimize the variation in census totals caused by early egg loss, we carried out the counts around the same dates each year (between 5 and 19 February) and as soon after completion of laying as possible.

Since 1997 the accuracy of each year's ground counts was assessed. During the counts a spot of paint was sprayed next to each nest. When the count of the block was completed, counters walked once more through the block in straight lines at approximately right angles to the routes previously taken. During this walk they checked each nest within 15 m of the line walked and recorded the number of painted and unpainted nests encountered.

To determine changes in the size of the albatross population between 1969 and 2004, we attempted to repeat several of the methods used to assess the albatross population prior to our study. During 1978, 1096 chicks were banded on Antipodes Island, and an estimate that these chicks comprised half the chicks present on the island (Bell 1979) was later used to estimate the total population at the time (Clark *et al*. 1995). During each island-wide albatross census in 1994-96, we checked all birds for bands and recorded the location of any found in order to recover and map the distribution of the survivors of those 1096 chicks. Since wandering albatross show strong natal site fidelity, the distribution of surviving chicks should give an indication of the areas and proportion of the total population which were banded in 1978, as this information was not recorded by the banders.

In February 2004, we repeated the 1969 ground-truthing of vantage point counts in two small areas in the north of the island. Firstly we counted all the occupied nests visible through binoculars from

Table 1 Estimated annual survival rates of Antipodean wandering albatross (± standard error), 1995 - 2004.

Year	survival
1995	0.998 (0.005)
1996	0.984 (0.006)
1997	0.957 (0.009)
1998	0.956 (0.009)
1999	0.951 (0.010)
2000	0.913 (0.012)
2001	0.955 (0.010)
2002	0.935 (0.011)
2003	0.955 (0.008)
2004	0.969 (0.007)
Mean	0.957 (0.007)

Table 2 Breeding success (number of chicks fledged per breeding pair) of Antipodean wandering albatross in three areas on Antipodes Island between 1994 and 2004 (number of nests in brackets). See Fig. 2 for location of areas.

Year	Study area	Pipit Peak	Block 32
1994	0.745 (110)		
1995	0.744 (156)		
1996	0.791 (148)		
1997	0.797 (148)		
1998	0.748 (163)		
1999	0.626 (139)		
2000	0.774 (115)	0.646 (82)	0.769 (130)
2001	0.784 (162)	0.754 (69)	0.715 (144)
2002	0.676 (148)	0.657 (108)	0.589 (185)
2003	0.731 (216)	0.663 (104)	0.732 (190)
2004	0.719 (221)	0.733 (116)	0.773 (251)
Mean	0.740	0.691	0.716

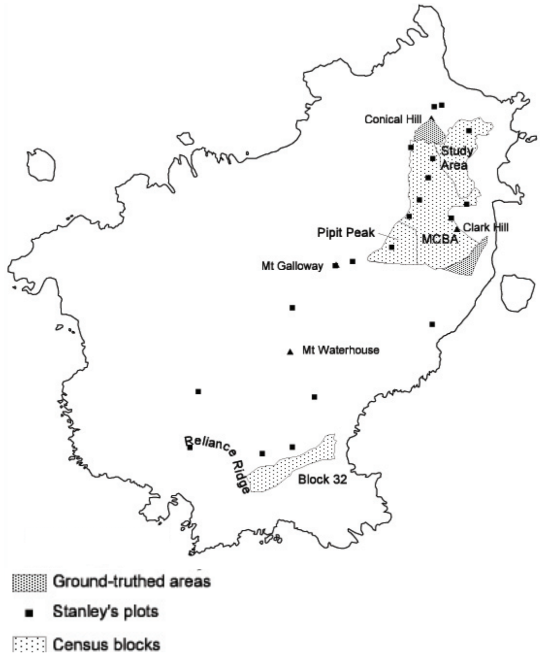

Figure 2 Location of Antipodean wandering albatross study areas; trend-count assessment areas (MCBA, Block 32, Study Area); productivity assessment areas (Study Area, Pipit Peak, Block 32); vantage-point (Conical Hill, Clark Hill) and ground-count sites for ground-truthing in 1969 and 2004; and Stanley's nest-density plots on Antipodes Island.

the summit of Clark Hill and Conical Hill (Fig. 2), then carried out a thorough ground search of those areas. In mid-February 2004 we also attempted to repeat a 1969 assessment of the density of albatross nests with eggs in 20 x 929 m^2 quadrats in a range of albatross nesting habitat (Fig. 2). We determined the approximate position of each of the original 20 sites from notes on the location, landform and vegetation made in 1969 and placed four new quadrats within 60 m of this point. The numbers of nests in quadrats in 1969 and 2004 were compared using a generalised linear model with Poisson errors. We were assisted in the identification of the 1969 ground-truthing and quadrat sites by R. H. Taylor, who helped select the original vantage points, and still had the field notes describing the quadrat-count sites.

RESULTS

Survival

Our data did not support separate estimates of male and female survival, but there was considerable inter-annual variation in survival (Table 1). The estimated average annual survival for both sexes combined was 0.957 (± *se* 0.007).

Breeding success

The mean breeding success (the number of chicks fledged per breeding pair) in the study area between 1994 and 2004 was 0.74 (Table 2). Breeding success measured at the start of the fledging period was found to vary little from final fledging success, allowing a comparison of productivity in the intensively researched study area with that in infrequently visited Block 32 and Pipit Peak.

Changes in productivity in the three areas were similar (Table 2). Logistic regression of the last five years of data showed that there was a significant difference in breeding success between years (*deviance* = 21.47, df = 4, p = <0.001), but no significant difference between sites (*deviance* = 5.04, df = 2, p = 0.080).

In each year 1996 - 2003, the median egg-laying date was in the interval 23 - 26 January; first eggs were laid on 7 January, and the last on 17 February. Mean egg loss between early January and early February was 5% (range 4 - 9%). In 1997 the mean duration of the first male incubation shift was 11.6 days (n = 214) and in 1998, 13.5 days (n = 143).

Few birds re-used the same nest in their next breeding attempt: 6% of failed breeders (n = 49), and no successful breeders (n = 62). The remainder moved on average 18.5 m ± 1.07 (range 4 - 77 m, n = 108): distances moved by successful and failed nesters were not significantly different (Wilcoxon rank sum test W = 1644, p = 0.18).

Population size and trend

The total number of pairs attempting to breed on Antipodes Island in 1994, 1995 and 1996 was 4635, 5757 and 5146 respectively ($\bar{x}$ = 5180). A partial count in 1997 found number breeding to be similar to that of 1966 (Table 3).

Numbers of nests counted annually were similar during most of the study, but rose sharply during 2002 – 2004 (Table 4). Validation of our counts showed we undercounted, on average, by 1.5% except in the study area where repeated visits located all nests. Although there were similar increases in later years in the number of nests in all three blocks, analysis of variance of regressions of the logarithms of the counts against time showed that there was a significant increase only in the study area and MCBA (Table 5).

In 2004, there were 26 nests counted from the vantage point on Conical Hill but 44 nests found in the subsequent ground count; at Clark Hill 27 nests seen from the vantage point and 33 found during the ground count. Thus, vantage point counts recorded 68.8% of the pairs actually nesting.

During whole island censuses in 1994, 1995 and 1996, recoveries of chicks banded in 1978 were concentrated in the north-east of the island in blocks 1, 4, 5, 8, 17, with a few in blocks 2, 3, 15, 22, 36. Since most birds return to nest close to their natal area (unpubl. data), these recovery data provide a rough map of the areas where banding occurred in 1978. This area encompassed about one-third of the albatross breeding population.

We compared nest densities in 2004 with those recorded in 1969 (Wareham & Bell 1979). Fifteen nests contained eggs in the 20 quadrats in 1969 (0.75 nests/quadrat; 8.07 nests/ha). In 80 quadrats established adjacent to those of 1969 (see Methods), 50 nests contained eggs (0.63 nests/quadrat; 6.73 nests/ha). This difference was not significant ($F_{1,98}$ = 0.371, p = 0.5425). As the number nesting in 2004 was higher than previously during our study, and as the number varied greatly in consecutive years, we also compared the density of nests in eight quadrats measured on the North Plains in 1969 with that in the 106.347 ha North Plains census block 5) during the five consecutive years the latter was counted during the mid 1990's. The 1969 nest density (9.42 nests/ha) was higher than in each of the later years ($\bar{x}$ = 4.6 nests/ha, range = 4.0 - 5.2).

Table 3 Number of pairs of Antipodean wandering albatross on eggs in 31 census blocks (see Fig. 1) on Antipodes Island in February, 1994-96, and the number of pairs in 17 census blocks in February 1997. The total number of pairs present in 1994-96 in the 17 blocks counted in 1997 is given in brackets.

Census Block	1994	1995	1996	1997
1	114	156	158	150
2	115	126	138	125
3	105	166	131	154
4	260	363	307	321
5	553	490	425	472
6	26	20	19	Not counted
8	268	339	314	279
9	50	68	61	112
10	77	106	72	98
11	29	81	62	Not counted
13	301	385	297	350
14	483	553	567	Not counted
15	73	114	80	65
16	242	344	300	275
17	160	210	152	184
19	194	232	250	197
20	80	108	84	73
21	129	168	146	Not counted
22	128	119	173	151
23	463	527	497	Not counted
24	159	175	159	152
26	5	10	7	9
28 & 29	124	224	201	Not counted
30	114	125	132	Not counted
31	126	173	123	Not counted
32	125	185	133	Not counted
33	85	129	90	Not counted
34	0	0	15	Not counted
35	17	28	31	Not counted
36	30	33	22	Not counted
Total	4635 (2884)	5757 (3511)	5146 (3108)	(3167)

DISCUSSION

Adult survival and productivity

At 0.957, average annual adult survival of *D. antipodensis* during 1994 - 2002 was similar to that of *D. gibsoni* on Adams Island (unpubl. data), the same as for the slow-growing population of *D. exulans* on Crozet Island during 1986 - 1993 (0.956; Weimerskirch *et al*. 1997), but higher than for the declining population of *D. exulans* on South Georgia during 1988 - 1993 (0.92; Croxall *et al*. 1998).

Over the same period average annual productivity of *D antipodensis* was higher (0.74 fledglings/nesting pair) than for *D. gibsoni* (0.63; unpubl. data) or *D. exulans* on Crozet Island (0.685; Weimerskirch *et al*.1997) or South Georgia (0.68;

Croxall *et al.* 1998). The most intensively studied area recorded slightly higher productivity than two other sites. This suggests that intensive population monitoring does not affect productivity.

Breeding biology

Egg-laying started a little earlier (7 January) than previously thought, as did fledging (4-6% departed by 4 January in average years and 17% in good years). Nearly all chicks have fledged by the end of January. Early reports, based on brief day visits, included comments that on 1 February 1888 "the wandering albatross... had just begun to lay" (Reischek 1889); and "we found them just beginning to lay on the 17th January" (Capt. Fairchild quoted in Chapman 1891), and "they lay in mid-January" (Bailey and Sorensen 1962, re-quoted in Warham & Bell 1979). The first major ornithological expedition on the island for any length of time appeared unaware that the majority of chicks had already departed by the time they arrived on the island on 28 January, as they commented "in late January and early February 1969, some chicks were still in down but most were well feathered and some probably flew by the end of January" (Warham & Bell 1979). The unsuspected absence of large numbers of chicks may have contributed to their underestimation of the total size of the breeding population (discussed later).

Despite these earlier-than-anticipated arrivals and departures, we found the breeding season of Antipodean wandering albatross to be later than that of most other wandering albatross species. Their median laying date was three weeks later than *D. gibsoni* on nearby Adams Island, and three - four weeks later than *D. exulans* on South Georgia, Crozet, Kerguelen and Marion Islands (Marchant & Higgins 1990). Only *D. amsterdamensis* in the Indian Ocean lays later (mid-February - mid March; Jouventin *et al.* 1989).

D. antipodensis are much less likely to re-use the same nest site in successive seasons than *D. exulans*, and, to a lesser extent, *D. gibsoni*. On South Georgia, 20% of *D. exulans* re-used the same nest (Tickell 1968) while on the Crozet Islands 23.3% of successful breeders and 37.9% of failed breeders did so (Marchant & Higgins 1990). On Adams Island 1.25% of breeding *D gibsoni* and 18% of failed breeders re-used the same nest site in successive seasons (Walker & Elliott 1999). By comparison, no successful *D. antipodensis* breeders and only 6% of failed breeders re-used the same nest. In addition, the average distance moved between subsequent nesting attempts is greater for *D antipodensis* (18.8 m) than for *D. exulans* on South Georgia (7 m; Tickell 1968), but less than *D. gibsoni* (22 m; Walker & Elliott 1999).

Possible explanations for this difference in re-use of nests include the availability of nesting material and the density of nesting birds. Nesting material is probably more abundant on Antipodes and Adams Islands, as both islands have a warmer climate and are more densely vegetated than the breeding grounds of other wandering albatross species. An abundance of nesting material may also be the reason virtually all albatross chicks on Antipodes Island make at least one new nest near the natal nest, and spend the last few months before fledging on these, whereas they only occasionally build such nests on the Crozet Islands (Voisin 1969).

Nest density on Antipodes Island (5.5 – 8.5 nests/ ha) lies between that at South Georgia (39.7 nests/ ha; Tickell 1968) and at Crozet Island (<1.5 nests/ ha; Weimerskirch & Jouventin 1987), so site availability is unlikely to influence re-nesting behaviour.

Population size and trends

Over the three seasons in which all the albatross nests on Antipodes Island were counted (1994-96), an annual average of 5180 pairs nested. As about 60% of the breeding population is present in any one season (unpubl. data), the total breeding population

Table 4 Number of pairs of Antipodean wandering albatross breeding each year 1994-2005 in parts of Antipodes Island. See Fig. 2 for locations of counted areas. * indicates an estimate based on the proportion of birds in Block 5 but not in MCBA in 1998 (see text for details).

Year	Study area	Block 32	Block 5	MCBA
1994	114	125	553	544*
1995	156	185	490	482*
1996	154	133	425	418*
1997	150		472	464*
1998	160		543	534
1999	142			479
2000	119	130		462
2001	160	141		443
2002	148	178		605
2003	214	187		608
2004	216	249		755
2005	211	186		613

Table 5 Growth rates calculated by regression and significance tests for Antipodean albatross nest counts in 3 areas on Antipodes Island. * - significant at the 5% level.

Area	Growth rate	*F*	*df*	*p*
Study area	1.042	10.168	1,10	0.010*
MCBA	1.031	6.804	1,10	0.026*
Block 32	1.035	4.184	1,7	0.080

of *D. antipodensis* then was about 8600 breeding pairs. Over the period of our study the population increased between 3 – 4% per annum (Table 5).

Has the population size varied significantly since the islands were first discovered? On seldom-visited Antipodes Island, this has proved very difficult to determine. All early references to wandering albatrosses on Antipodes Island come from visitors travelling on government vessels searching for shipwrecked sailors. The first account was that of Captain Fairchild of the steamer *Hinemoa* who visited the Antipodes Islands on 18 March 1886. He noted "the whole island is covered with coarse grass, and there is a considerable tract of level land, which in March was frequented by thousands of albatrosses" (Fairchild 1891). The most informative account comes from Chapman (1891), who visited Antipodes Island on 17 January 1890 and noted "at Antipodes Island ….the albatroses (sic) were enormously plentiful". He climbed from Anchorage Bay to the summit of Mt Galloway and found "a great deal of flat land up there, which was literally alive with albatroses. Young, black birds were very common; ...The albatrosses were building nests everywhere, and numbers of them were billing and cooing and gathered in large flocks as at Adam's Island…….They were as numerous as geese in a farmyard…The season was decidedly backward as compared to the other islands; we only got three eggs and altogether only about twenty were found….With such a number of nests I am sure that a month later a thousand could be gathered in the same time. On this island we found young albatroses standing about the old nests quite low down on the plain, but they were far more numerous on the hill".

It was not until 1969 that the first attempt to estimate albatross numbers was made; during a six-week expedition to the island, B. Bell and R. Taylor counted all albatrosses (except those in large gams) visible from the island's high points. Ground searches showed that counts from these vantage point counts detected only about two-thirds of the birds actually present, and that only about one-third of the birds on the ground were breeding. After adjusting their vantage point counts accordingly, they concluded about 1000 pairs were then breeding (Warham & Bell 1979). During the same expedition, R. Stanley's counts of active nests within 20 x 929 m^2 plots across a range of albatross nesting habitat across the island (wrongly described as only on the North Plains by Warham & Bell (1979)) recorded a nest density of 8.07 nests/ha, but no attempt was made to extrapolate this density across the island as a check on the census results.

Bell (1979) noted, following a visit in 1978, that "further studies of wandering albatross showed the population to be bigger than estimated earlier". This re-assessment arose from the banding of 1096 chicks in only a portion of the island. The 1096 chicks banded represented "probably about half the number of chicks present at the end of the 1978 breeding season" (Clark *et al*. 1995), suggesting about 2300 breeding pairs nested that year (allowing for early failures), or 2.16 nests/ha. However, judging from the distribution of recoveries during 2004 of the cohort banded in 1978, banding only occurred over about one third of the breeding grounds. This indicates there may have been *c*.3800 pairs breeding that year, or 3.6 nests/ha.

Two further population estimates, using the same strip-search technique we used, were made; Clark *et al*. (1995) recorded 4522 albatross nests with eggs in 1994 and Amey *et al*. (1995) 5757 nests in 1995.

Re-assessment of 1969 counts

In 1994, the counters attempted to repeat the vantage point counts undertaken in 1969, but found the proportion of birds seen from vantage points to be very variable (13 - 87%) and much lower ($\bar{x}$ = 26%) than in 1969 (67%), making comparisons difficult. Our study shed more light on this discrepancy. In 2004, when we repeated the 1969 ground-truthing at exactly the same sites (Conical Hill and Clark Hill), we found the proportion of birds overlooked (68.8%) was similar to that in 1969. It seems the 1969 comparison was made in two small sites in easy open country where few nests were obscured, and which were close to suitable vantage points. In contrast, the 1994 comparison was made over the whole island and included many areas where large numbers of nests were obscured by vegetation and topography and the only available vantage points were at considerable distances from the count areas. We consider the 1994 ground-truthing provides a more accurate figure.

If the number of birds counted from vantage points over the whole island in 1969 (1867) is adjusted using the index derived from whole-island comparisons of vantage point and ground counts in 1994 (26% of the birds present seen), the total number of birds on the island in 1969 was *c*.7200 (*cf.* 6121 in 1994). Both the 1969 and 1994 vantage point counts included all non-breeders except those in large gams, so these totals are not directly comparable with the whole-island ground-count totals of breeding pairs in 1994-1996. A remaining complication is that the 1969 ground-truthing found only one-third of birds on the ground were breeders, whereas annual ground-counts throughout the 1990's consistently found two-thirds of all birds on the ground were breeding birds. The 1969 figure may be an error, or simply a chance result of a small sample made late afternoon on a windy day when many non-breeders were ashore.

In a direct replication of Stanley's plots we recorded only 6.73 nests/ha over the island, whereas there had been 8.07 nests/ha in 1969 (Wareham & Bell 1979). If Stanley's nest density estimate is applied to all 1062 ha of albatross habitat on the island, there would have been 8570 nests in 1969. These nest density comparisons overcome most of the problems of the vantage point counts; no nests will have been missed because the quadrats were very small, and they were not confounded by non-breeding birds since only in both 1969 and 2004 only nests containing an egg were counted.

Population trend

The adjusted census totals and nest density counts indicate a breeding population on Antipodes Island in 1969 of 5000 - 8000 pairs, many more than thought to be present at the time (Wareham & Bell 1979). Judging from the number of chicks banded on the island in 1978 from about a third of the population, there may have been *c*.3800 breeding pairs in 1978 (Bell 1979). The population during the whole island counts in the mid 1990's averaged 5180 pairs and, during 2001 - 2004, the population increased. From these data can we deduce past population change?

Chapman's (1891) descriptions convey an impression of a large and dense population of albatrosses on the island. Wareham & Bell (1979) convey a similar impression with comments of "abundant on Antipodes", and "Even from offshore the number of birds seen leaving and flying to the island showed the population of this albatross was a large one".

We conclude that the albatross population on Antipodes Island decreased between 1969 and 1994, but that some time before, or about, 1994 it began to increase again. The nest density recorded in 1969 (8.07 nests/ha) is significantly greater than has been recorded subsequently, and the density estimate derived from the 1978 counts (3.6 nests/ha) gives an indication of the possible magnitude of change. However, too many assumptions are required in the comparison of whole island counts to confidently estimate the magnitude of change which seems to have occurred over the last 30 years. Our best estimate comes from the direct comparison of nest density counts in 1969 and 2004, which suggest there was a decline in the order of 50%. However, because only 20 plots were counted in 1969, even this estimate should be treated cautiously. The apparent increase between 2001 and 2004 is too sudden, too rapid and too brief to be sure yet that it constitutes sustained population increase.

Explanations for population change

There are a number of possible causes of these population changes, though none of them relate to the breeding grounds. There have been no deleterious changes to Antipodes Island over the last 100 years, with very few human visits, no land disturbance and a continuance of its predator-free status. However, there have almost certainly been changes in the marine environment which reflect climatic variability.

During the 19th and early 20th Centuries, clusters of large icebergs were common in some years in New Zealand waters, including near Antipodes and Chatham Islands, but since 1948 no icebergs have been reported near New Zealand. In 1887, 17 icebergs including four stranded ashore were seen at Antipodes Island (Brodie & Dawson 1971). These observations indicate the types of changes in oceanographic conditions that can occur in the Southern Ocean.

The low albatross productivity and survival recorded in this study in 1999 (Tables 1,2) was probably caused by abnormally warm sea temperatures during the La Niña phase of the El Niño - southern oscillation event, as it also affected other wandering albatross species in the southern oceans (Schaffer *et al*. 2001). However, while this may have delayed the start of albatross population growth in the late 1990s, such a single season event would not explain any larger scale decline between the 1970s and 1990s.

Bycatch of albatrosses in the southern blue-fin tuna fishery provides the best explanation for the probable decline of albatrosses since the late 1960s and their recovery in the 1990s. Southern blue-fin tuna fishing started in the oceans around New Zealand in the 1960s and reached its peak in the 1970s (Murray *et al.* 1993). Since the late-1980s the fishing effort has declined (Tuck *et al.* 2003), and there has been a gradual adoption of bycatch mitigation techniques by fishers. Antipodean wandering albatrosses have been caught by fishers off the east coast of New Zealand (Murray *et al.* 1993; Robertson *et al.* 2004), and probably off Chile also. The declines in other wandering albatross populations have been linked to a bycatch-induced reduction in annual survival (eg., Croxall *et al*. 1997; Weimerskirch *et al*. 1997).

This study highlights the difficulties of detecting real population change in a long-lived, biennially-breeding species by general counts which have large margins of error (the early counts) or are dependant on a long time frame (the latter counts). However, it also indicates the importance of devising reliable monitoring methods and maintaining a commitment to using them, as the conservation of these birds is not assured simply by protecting their breeding islands.

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