

Status of white-chinned petrels *Procellaria aequinoctialis* Linnaeus 1758, at Bird Island, South Georgia

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Abstract: The white-chinned petrel (*Procellaria aequinoctialis*) is an abundant, widespread petrel breeding in tussock grassland at sub-Antarctic islands. Over the last decade it has been killed in large numbers in temperate and sub-tropical longline fisheries. However no data are available on the global population status. We assessed the status of white-chinned petrels at Bird Island, South Georgia by comparing the distribution and density of occupied burrows in 1981 and 1998. In both surveys white-chinned petrel burrows occurred in one-quarter of the 460–477 36-m² quadrats surveyed. The total number of burrows in each quadrat was consistent between each survey but we estimate an overall decrease of 28% in those occupied (with considerable variation between sites). Concurrent data on breeding frequency and success showed that white-chinned petrels are essentially annual breeders at Bird Island; breeding success was consistent at around 44%. Significant factors determining densities of occupied burrows were crown height and percent tussock cover (accounting for 77% of variance). The former has decreased significantly, the latter increased significantly between 1981 and 1998 but there was no relationship between white-chinned petrel occupancy rate and habitat modification due to the presence of fur seals (*Arctocephalus gazella*). This suggests that any population decline is due to factors operating away from the breeding colony, such as those attributed to fishing.

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Introduction

The white-chinned petrel (*Procellaria aequinoctialis* Linnaeus 1758) is a medium-sized petrel that nests in loose colonies in burrows in grassland. It breeds, between September and May, at ten widely spaced sub-Antarctic islands, migrating to lower latitudes during the non-breeding season. It is one of the most widely distributed petrels and probably the most abundant of the four species in the genus (Warham 1990). As many as 2 million pairs breed on South Georgia in the South Atlantic (Prince & Croxall 1983) and tens of thousands at Îles Crozet and Prince Edward Islands in the southern Indian Ocean (Jouventin *et al.* 1984, Williams 1984).

White-chinned petrels are being caught in their thousands by long-line fisheries throughout their breeding and non-breeding range (Cherel *et al.* 1996, Barnes *et al.* 1997, Catard & Weimerskirch 1999, Weimerskirch *et al.* 1999, CCAMLR 1999). There is an urgent need to evaluate their current status, assess evidence for population change and establish methods for monitoring future population trends. The absence of reliable population estimates makes the first two objectives very difficult to address at present. However at Bird Island, South Georgia, as part of a survey of distribution and abundance of burrowing seabirds, burrow densities and occupancy of white-chinned petrels were surveyed between 1978 and 1981 (Hunter *et al.* 1982). These data are, to our knowledge, the only available baseline information for breeding populations

of this species anywhere throughout its range. However, interpreting changes between then and now may be complicated by other environmental changes that have occurred at South Georgia over the last 20 years. In particular there has been substantial erosion of large areas of coastal grasslands, including those at Bird Island, by Antarctic fur seals *Arctocephalus gazella* Peters 1875 which has increased from a few thousand in the 1960s to an estimated 1.6 million by 1991 (Boyd 1993).

The aims of the present study were: (1) to provide new estimates of white-chinned petrel population at Bird Island for comparison with the results of the previous survey; (2) to assess the likely effect of habitat change on population levels and (3) to evaluate evidence of population change that might relate to increased mortality at sea.

Methods

Survey of Bird Island

A repeat of the survey by Hunter *et al.* (1982) on Bird Island (54°01'S, 38°03'W, Fig. 1) was conducted in the 1998 summer between 22 November 1997 and 5 January 1998 (summer 1995/96 is referred to as 1996, 1996/97 as 1997 and 1997/98 as 1998). In the original survey (referred to as the 1981 survey) Hunter *et al.* (1982) randomly selected sampling

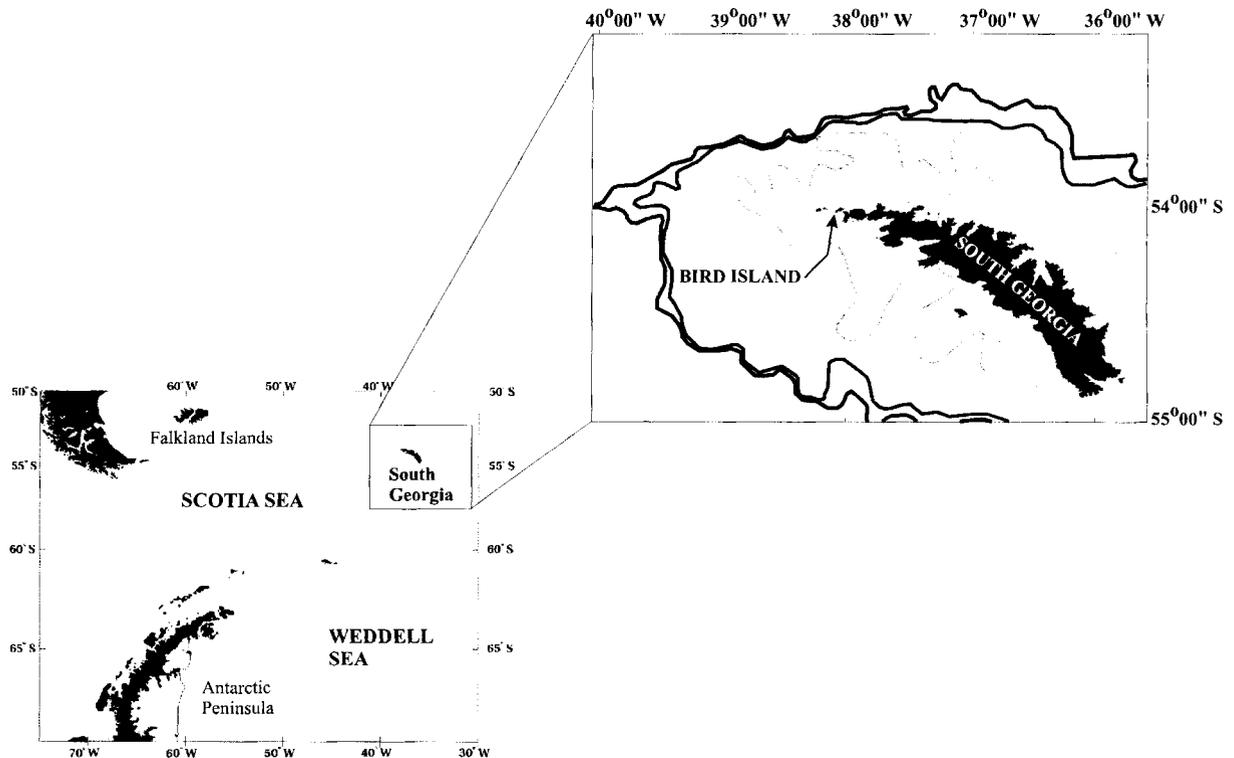


Fig. 1. Location of Bird Island, South Georgia in the South Atlantic.

quadrats within a 60 m x 60 m grid covering the entire island (which is *c.* 500 hectares in area). To locate quadrats within the grid, two adjacent sides of each square were divided into 4 m sections. Two numbers between 0 and 15 (adjusted to 0–14, i.e. 15 sections for the 1998 survey) were selected from a random number table to give the coordinates of the centre of the quadrat to be sampled. Each quadrat was defined using orange nylon string, 3.385 m in length, attached to a stake placed at the coordinates and used to describe a radius of a circle with an area of 36 m². In the repeat survey it was not possible to locate exactly the original grids but approximate locations (within *c.* 50–100 m) could be identified from detailed site descriptions. Once the site was located, a similar grid was marked out and the same coordinates from the original survey were used. Thus those quadrats surveyed in 1998 were not an exact repeat of Hunter *et al.* (1982) but were located within 50–100 m and in a similar habitat. Due to the relatively restricted areas and habitats in which white-chinned petrels nest at Bird Island, Hunter *et al.* (1982) additionally selected some non-random quadrats in areas considered to represent their optimum habitat. In the resurvey, if the coordinates of these non-random samples were recorded on the original data-sheets, then the same coordinates were used in 1998; if not then quadrats were located in the centre of each grid square.

For each sample, habitat information, following that described by Hunter *et al.* (1982), was recorded. The aspect and slope was measured with a compass and inclinometer and

percent tussock grass (*Paradiachloa flabellata* Lam.) cover and mean crown height recorded. The degree of fur seal activity was classified from 0–6 (category 7 was not needed as no areas completely devoid of tussock were surveyed), namely: (0) seals absent, (1) seals occasionally present but no signs of damage to tussock, (2) seals present nearby, but no damage, (3) some shoots permanently flattened, (4) shoots flattened and some erosion of tussock crowns and between clumps, (5) tussock crown erosion occurring on all clumps, (6) heavy erosion on and between tussocks but active growth still occurs on clump fringes. All potential white-chinned petrel burrows were examined acoustically for occupancy. This involved playing taped vocalisations of white-chinned petrels down the burrow to elicit a response from an occupying bird (Berrow 2000). If there was no response, a 3-m length of flexible wire was used to try to locate the nest chamber via the burrow entrance. If a bird was present then it would often vocalise when disturbed; however it was not possible to locate all nest chambers. If a bird was present, the nest was checked for an egg. The status of each burrow was classified following Hunter *et al.* (1982) as: (1) incomplete excavation, (2) unused but suitable for excavation, (3) tunnel entrance or chamber iced up, (4) flooded, (5) collapsed, (6) no indication of breeding but signs of use in current season, (7) unused in present season but indications of breeding activity in previous seasons. Burrows were recorded as occupied if: (1) bird calls from burrow, (2) evidence of egg (including cold or broken), (3) excavated by a skua, after Hunter *et al.* (1982). The 1998

survey was completed during the incubation period and thus determining occupancy through the presence of chicks, as used by Hunter *et al.* (1982) was not necessary.

Survey data from both years were read into ArcInfo (version 7.21), a GIS mapping and analysis package. Maps of habitat changes were then constructed using the GRID module of Arc/Info.

Breeding success

The success of the breeding attempt was monitored in a sample of burrows during 1996 ($n = 38$) and 1998 ($n = 48$). The nest chamber of some of these burrows ($n = 15$ and $n = 21$) could be reached by hand or with a short flexible wire whereas for others an observation window was dug above the nest chamber and filled with a plug of earth and covered with a wooden board. Breeding success was determined by inspecting these burrows every two days prior to incubation until an egg was laid and again towards the end of chick rearing. Birds that reared a chick to fledging were classified as successful whereas birds losing their egg or their chick were recorded as unsuccessful. Hatching success was defined as the proportion of eggs laid that hatched, fledging success as the proportion of chicks fledged from those eggs that hatched and overall breeding success as the proportion of chicks fledged from eggs laid.

Breeding frequency

All birds found in 29 burrows were ringed during summer 1996 and their identities and reproductive performance recorded in each of the following two years. Both partners were ringed in four additional burrows in 1997 and monitored in 1998. The definition of breeding success follows that described above. Breeding frequency was defined as the proportion of birds breeding again in subsequent seasons and was calculated using recaptures in subsequent years (summers 1997 and 1998). Non-breeding birds include those not recorded in a summer or those occupying a burrow but not associated with an egg. Burrows were checked between two and five times during pre-breeding and early incubation to record both breeding partners. Following Chastel (1995), as petrels are strongly faithful to their nest site and breeding partner, a bird not recorded in a particular year was assumed to have bred if its usual partner was identified as a breeder and if these birds bred together the following year.

Results

The density of burrows in different habitats were calculated at 24 locations around Bird Island (see map in Hunter *et al.* 1982). Large areas of Bird Island were not surveyed as they are unsuitable (rock, scree and moss) for breeding (Hunter *et al.* 1982); thus the distribution reflects only locations with potentially suitable breeding habitat.

Distribution and density of white-chinned petrels

During 1978–81, 26.3% of the 460 quadrats surveyed on Bird Island had occupied white-chinned petrel burrows present (Fig. 2a). In 1998, 17 additional quadrats were surveyed, resulting in a total sample of 477 (Fig. 2b), with occupied burrows occurring in 25.3% (Table I). The distribution of occupied quadrats in both surveys was similar.

Most quadrats had no burrows (74.7% in 1981 and 73.5% in 1998) which emphasizes the clumped nature of white-chinned petrel distribution at Bird Island. The proportion of quadrats with occupied burrows ranged from 0% to 76% in both surveys but the frequency distributions (data were log x transformed) between surveys (Fig. 3) were statistically similar (Kolmogorov-Smirnov test, $D = 0.15$, NS). There was no difference ($t_{423} = 0.34$, NS) in the total number of burrows (occupied and unoccupied) per quadrat (4.9 ± 0.3 in 1981 and 4.5 ± 0.3 in 1998 ($t_{423} = 1.07$, NS) only those quadrats with burrows analysed) but there were significantly fewer occupied in 1998 (2.2 ± 0.2) compared to 1981 (3.0 ± 0.2) ($t_{423} = 3.11$, $P < 0.01$, on transformed data), representing a 28% decrease. Changes were unevenly distributed with some areas showing increases (Fairy Point +127%) and others decreases (Top Meadows and Cobblers -46% and -43%) but only at Cobblers Mound and Round How were changes between surveys significant (Mann-Whitney U -test, $P < 0.05$) (Table I).

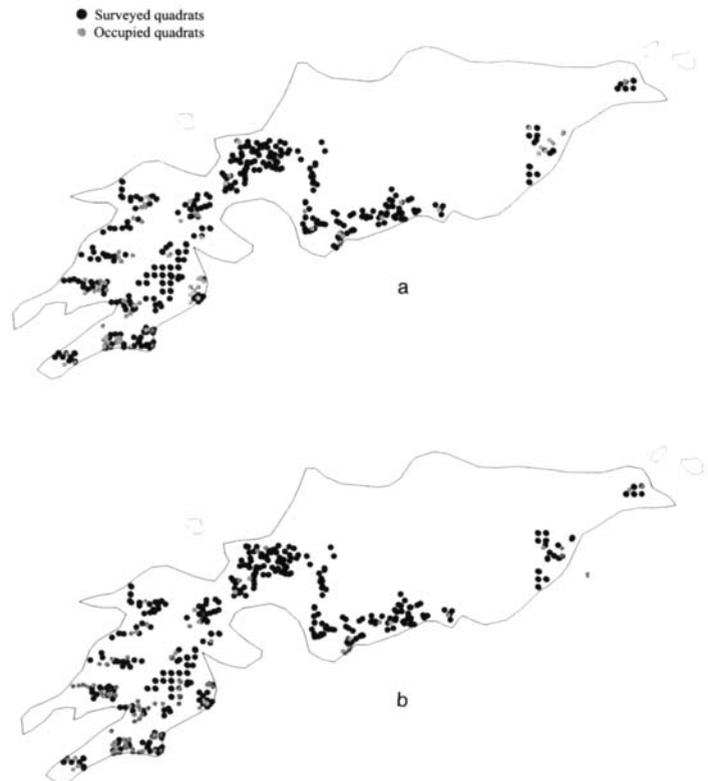


Fig. 2. Distribution of surveyed and occupied quadrats in a. 1979–81 and b. 1998.

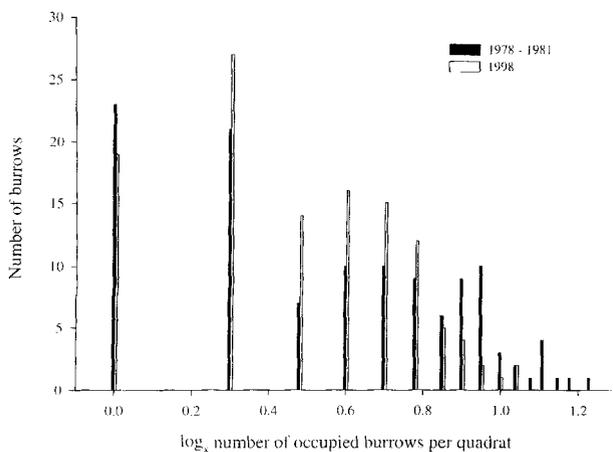
Table I. Proportion of occupied burrows, mean crown height (cm \pm s e) of *Paradioclocha flabellata* and the damage attributed to seals (\pm s e) at each site surveyed. Damage attributed to seals was scored 0 (absent) to 6 (heavy erosion).

Site	1978-81			1998			change in occupancy
	% occupied (n)	Mean crown height	Seal damage	% occupied (n)	Mean crown height	Seal damage	
Bird Sound	29 (48)	18.8 \pm 3.3	2.4 \pm 0.4	36 (46)	31.7 \pm 1.8	3.7 \pm 0.3	24%
Bottom Meadow	50 (14)	44.4 \pm 5.1	0.1 \pm 0.1	52 (18)	30.6 \pm 3.5	0	4%
Cobblers Mound	32 (6)	52.1 \pm 6.6	0	18 (7)	47.9 \pm 10.5	1.6 \pm 0.5	-43%*
Dank Fen	0 (3)	8.8 \pm 5.1	1.5 \pm 1.0	0 (4)	7.5 \pm 2.5	1.8 \pm 0.5	0%
Everman	100 (14)	48.9 \pm 3.6	3.9 \pm 0.6	67 (15)	41.3 \pm 2.4	4.8 \pm 0.2	-33%
Fairy Point	22 (10)	48.5 \pm 2.6	0.3 \pm 0.3	50 (10)	44.0 \pm 4.3	0.5 \pm 0.5	127%
Farewell	50 (10)	36.9 \pm 3.6	0	46 (11)	46.0 \pm 5.2	0	-8%
Goldcrest Point	42 (18)	34.7 \pm 3.0	0	38 (24)	44.8 \pm 3.2	0	-10%
Gony	48 (46)	38.8 \pm 2.8	2.4 \pm 0.4	59 (50)	38.9 \pm 2.6	3.5 \pm 0.3	23%
Johnson	42 (30)	35.4 \pm 3.0	3.0 \pm 0.6	49 (28)	51.5 \pm 3.7	3.2 \pm 0.3	17%
Molly Hill	0 (22)	47.3 \pm 2.7	1.7 \pm 0.4	36 (26)	32.8 \pm 3.5	1.6 \pm 0.5	0%
Molly Meadows	100 (1)	45.3 \pm 5.1	0.8 \pm 0.8	58 (4)	33.3 \pm 3.3	0	-42%
Molly Ridge	45 (14)	49.3 \pm 4.4	0.7 \pm 0.5	61 (16)	61.7 \pm 6.6	1.1 \pm 0.5	36%
Mount Cwm	54 (42)	36.1 \pm 1.7	5.2 \pm 0.3	73 (22)	40.0 \pm 5.8	4.6 \pm 0.3	35%
Natural Arch	0 (8)	41.0 \pm 5.8	4.4 \pm 0.9	0 (9)	-	-	0%
North Valley	59 (76)	17.4 \pm 1.6	1.9 \pm 0.3	41 (76)	36.1 \pm 1.5	3.3 \pm 0.2	-30%
Pearson	47 (8)	44.5 \pm 3.7	4.2 \pm 0.9	38 (10)	39.0 \pm 7.1	6.0 \pm 0.0	-19%
Round How	37 (17)	38.9 \pm 2.5	5.2 \pm 0.3	41 (20)	43.5 \pm 3.9	4.6 \pm 0.1	11%*
Sooty Creek	33 (6)	14.4 \pm 9.6	0	0 (6)	33.3 \pm 9.9	0	-100%
Square Pond	40 (7)	45.4 \pm 4.9	3.7 \pm 0.7	57 (7)	42.9 \pm 4.2	4.7 \pm 0.2	43%
Tonk Ridge	52 (9)	37.7 \pm 6.2	0	33 (7)	26.7 \pm 4.9	0	-37%
Top Meadows	54 (29)	25.2 \pm 4.0	0	29(25)	26.1 \pm 3.4	0	-46%
Wanderer Ridge	18 (19)	26.4 \pm 4.2	1.2 \pm 0.5	0 (23)	27.1 \pm 2.5	4.3 \pm 0.4	-100%
Wanderer Valley	0 (13)	16.4 \pm 3.2	2.4 \pm 0.8	0 (13)	23.8 \pm 2.9	2.1 \pm 0.6	0%
Mean (Total)	26.3 (460)	37.4 \pm 0.8	2.2 \pm 0.1	25.3 (477)	32.7 \pm 0.9	2.6 \pm 0.1	-6% \pm 10

* $P < 0.05$, Mann-Whitney U-test

The results from the 1998 survey were used to investigate potential effects of habitat selection. The number of occupied burrows in each quadrat was regressed, using a least-squares multiple regression, on % tussock cover, crown height, slope, aspect and damage attributed to the presence of seals as factors. The regression was significant ($F_{5,434} = 12.4$, $P < 0.01$) with crown height ($t_8 = 6.30$, $P < 0.01$) and % tussock

($t_8 = 3.59$, $P < 0.01$) being the two most important determinants, accounting for 61.8% and 15.3% of the variance respectively. Aspect was also significant, accounting for 12.4% of the variance ($t_7 = 2.16$, $P < 0.05$). Highest densities were recorded on slopes of around 30° but this is strongly influenced by availability.

**Fig. 3.** Number of occupied burrows per quadrat (quadrats with no burrows not shown).**Table II.** Breeding success and causes of mortality of white-chinned petrels during 1996 and 1998 summers at Bird Island, South Georgia.

	1996	1998
Number of eggs	38	48
Infertile	1	3
Flooded/ collapsed	3	3
Abandoned	3	3
Disturbance	2	3
Unknown	3	7
Number of chicks hatched	26 (68.4%)	29 (60.4%)
Eaten by skuas	2	4
Starvation	0	1
Unknown	7	3
Chicks fledged	17 (65.5%)	21 (72.4%)
Overall breeding success	44.7%	44.0%

Habitat modification due to fur seals

There was a significant increase between 1981 and 1998 in % tussock cover (72.7% in 1981 to 77.4% in 1998, $t_{423} = 5.19$, $P < 0.05$) and a significant decrease in mean crown height (32.7cm in 1998 from 37.4cm in 1981, $t_{423} = 4.34$, $P < 0.01$); there was also a significant increase in damage to tussock attributable to seals (paired t -test, $t_{425} = 5.56$, $P < 0.01$) (Table I). Increases in seal damage were concentrated in four main areas (Fig. 4a). Sites where decreases in tussock cover (Fig. 4b) and crown height (Fig. 4c) were recorded were more widespread but increased cover and crown height were also recorded in sites with increased seal damage. The greatest changes in burrow occupancy occurred at Gony, Round How, Top Meadows and Natural Arch (Table I) but there was no significant correlation between changes in occupancy rate at each site and changes in seal damage ($F_{1,22} = 1.34$, NS) or crown height ($F_{1,22} = 0.08$, NS) between the two surveys.

Breeding success

The breeding success and causes of mortality during 1996 and 1998 are shown in Table II. Hatching success was greater in 1996 (68.4%) but fledging success was lower, resulting in similar overall breeding success (44%). The majority of egg losses in both years was attributed to flooded, collapsed and abandoned burrows with infertility and disturbance slightly more important in 1998. Four chicks were known to be eaten by brown skuas *Catharacta lonnbergi* Mathews 1912 in 1998 compared to two in 1996.

Breeding frequency

Of the 29 burrows monitored over two years, birds in 20 (69.0%) returned to breed in successive years. Four burrows were monitored between 1997 and 1998 and all birds bred in successive years, resulting in a total of 72.7% breeding in successive years. In the remaining burrows, one pair skipped a year between breeding attempts and five pairs (15.1%) changed their partners, one after a successful breeding attempt but whether the partner died or "divorce" occurred is not known. Three pairs changed partners after a breeding failure, one after the nest collapsed due to human disturbance; for one pair the outcome of the breeding attempt could not be determined.

Discussion

Breeding frequency and success of white-chinned petrels

The overall breeding success of white-chinned petrels at Bird Island (45% in 1996, 44% in 1998) is consistent with data from the same site in 1986 (50%; Hall 1987) and is typical of burrowing Procellariiformes (Croxall 1984). Breeding frequency at South Georgia (73%) is similar to the 81%



Fig. 4. Distribution of changes in a. damage attributable to the presence of seals, b. % tussock cover and c. crown height.

reported during a larger study on Îles Crozet by Chastel (1995). This 8% difference represents only a difference of three pairs in the present study. We can safely conclude that white-chinned petrels at South Georgia, as at Îles Crozet, are essentially annual breeders.

Nature of population change

Although we report an overall significant decrease of 28% in occupied between 1978–81 and 1998 surveys it is possible that this could reflect much poorer conditions for breeding in 1998 compared to 1978–81, particularly as 1998 was a year of poor breeding success for penguins and seals at Bird Island (Reid *et al.* 1999). However we believe that the difference in white-chinned petrel populations between years is real because:

- a) the 1998 surveys were conducted only during incubation,

whereas the 1978–81 surveys were carried out throughout the whole breeding season, giving rise to potentially lower values due to the absence of birds which had failed prior to the survey. Given that 30–40% of breeding attempts fail during incubation (Hall 1987, Table II) this bias could be quite substantial,

- b) both 1978 and 1981 (during the previous survey) were also years of poor breeding success for krill-eating seabirds and seals at Bird Island (Croxall *et al.* 1988),
- c) the breeding success of white-chinned petrels was no lower in 1998 than in 1986 and 1996 (Hall 1987, this study), both years of average-to-good breeding success of other seabirds at South Georgia (Croxall *et al.* 1988, 1999, Reid *et al.* 1999),
- d) Breeding rate (frequency) was not diminished in 1998 compared with 1997, suggesting that just as many birds turned up to breed in 1998 as in the previous year.

These data tend to confirm earlier suggestions (Hall 1987, Berrow & Croxall 1999) that breeding population size and breeding success of white-chinned petrels are not greatly influenced by events in years of low krill availability. This may reflect the very varied diet of white-chinned petrel, with krill not accounting for more than 40%, even in years of high availability (Croxall *et al.* 1995, Berrow & Croxall 1999) and the vast foraging range of this species (Berrow *et al.* in press) which exceeds that even of the South Georgia albatross species.

Overall, therefore, we do not believe that the 28% lower estimate of burrow occupancy in 1998 is due to a temporary reduction in the breeding population; if anything we suspect the 1981 survey to be an underestimate, because of the extended survey period.

Causes of population change

The breeding habitat of white-chinned petrels on Bird Island, South Georgia is similar to that described by Schramm (1986) for white-chinned petrels breeding at Marion Island in the Indian Ocean. White-chinned petrels bred in relatively restricted areas and habitats, largely determined by the size and density of tussock. Tussock growth is promoted by the richness and depth of soil, both of which are enhanced by the nutrients and activities associated with the presence of seabird colonies (Smith 1985).

Seals have substantially modified the habitat on Bird Island through erosion of tussock (Bonner 1985) and this modification is still occurring. Thus the presence/activities of seals was recorded in 56% of samples in 1981 and 67% in 1998; an increase of 11%. If habitat modification was adversely affecting breeding white-chinned petrels then we may expect a change in the distribution of occupied burrows on the island, with fewer petrels where seal damage has increased.

However, the area of potential breeding habitat for white-chinned petrels was similar in 1981 and 1998. Despite some deterioration of habitat quality caused by Antarctic fur seals, there was no significant effect on petrel burrow occupancy rate. We are unable, therefore, to attribute the changes in abundance of white-chinned petrels at Bird Island to changes in breeding habitat or, indeed, to any other factors operating directly on the terrestrial environment. We can only infer that the most likely explanation for the population decrease is as a result of incidental mortality associated with long-line fisheries both around South Georgia and in petrel wintering areas around South Africa and South America (Weimerskirch *et al.* 1999, Berrow *et al.* in press). The current estimated levels of mortality (CCAMLR 1999 2000) are such that continued population decrease would be predicted over the next 5–10 years. The survey and monitoring procedures we have used should be appropriate for most, if not all, breeding sites of this species. It is urgent to obtain realistic estimates of white-chinned petrel breeding populations for other sub-Antarctic islands, particularly in the Indian Ocean and to repeat the South Georgia survey in a few years time.

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