

POPULATIONS OF SURFACE-NESTING SEABIRDS AT MARION ISLAND,
1994/95–2002/03

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During the 1990s and early 2000s, populations of surface-nesting seabirds at Marion Island showed different trends, but for the majority of species numbers decreased. Reduced numbers of gentoo penguins *Pygoscelis papua*, eastern rockhopper penguins *Eudyptes chrysocome filholi*, Crozet shags *Phalacrocorax [atriceps] melanogenis* and probably macaroni penguins *E. chrysolophus* are most plausibly attributed to an altered availability of food. Decreases in numbers of dark-mantled sooty albatrosses *Phoebastria fusca*, light-mantled sooty albatrosses *P. palpebrata*, southern giant petrels *Macronectes giganteus* and possibly northern giant petrels *M. halli* may have resulted from mortality of birds in longline fisheries. However, populations of wandering *Diomedea exulans* and grey-headed *Thalassarche chrysostoma* albatrosses fluctuated around a stable level. Numbers of Subantarctic skuas *Catharacta antarctica* and kelp gulls *Larus dominicanus* breeding at Marion Island also decreased. Kerguelen *Sterna virgata* and Antarctic *S. vittata* terns remain scarce at the island. Trends for king penguins *Aptenodytes patagonicus* were not reliably gauged, but numbers probably remained stable or increased. There were large fluctuations in numbers of king penguin chicks surviving to the end of winter.

Key words: albatrosses, Crozet shag, giant petrels, kelp gull, Marion Island, penguins, population size, Subantarctic skua, terns

There are 29 species of birds that breed at the sub-antarctic Prince Edward Islands (Marion Island and Prince Edward Island), which are a South African territory in the south-western Indian Ocean (Cooper and Brown 1990). Of these, 16 species are seabirds that nest above the surface of the ground. They include four species of penguins (Spheniscidae), five of albatrosses (Diomedidae), two of giant petrels (Procellariidae), a shag or cormorant (Phalacrocoracidae), a skua, a gull and two species of terns (Laridae). All breed at Prince Edward Island, and all except the Indian yellow-nosed albatross *Thalassarche carteri* breed at Marion Island.

Of the remaining species, the lesser or black-faced sheathbill *Chionis minor* breeds at both islands, but is not strictly a seabird. It is one of two sheathbills that together constitute the family Chionidae. Sheathbills forage within seabird, especially penguin, colonies and

along the shoreline (Burger 1996) but do not feed at sea. There are thought to be some 4 000–5 500 lesser sheathbills at the Prince Edward Islands, mostly at Marion Island, where the population may have decreased since the 1970s (Huyser *et al.* 2000). There are eight species of prions and petrels (Procellariidae), two of storm-petrels (Hydrobatidae) and two of diving petrels (Pelecanoididae) that have been reported breeding in burrows in the island group. All these birds, except one of the diving petrels, are thought to breed at Marion Island (Cooper and Brown 1990). The occupation of burrows by these species makes it difficult to estimate their population sizes.

A survey of Prince Edward Island was undertaken in December 2001 to estimate populations of surface-nesting seabirds that breed there (Ryan *et al.* 2003). During 1994/95–2002/03, attempts were made to estimate sizes of populations of surface-nesting seabirds

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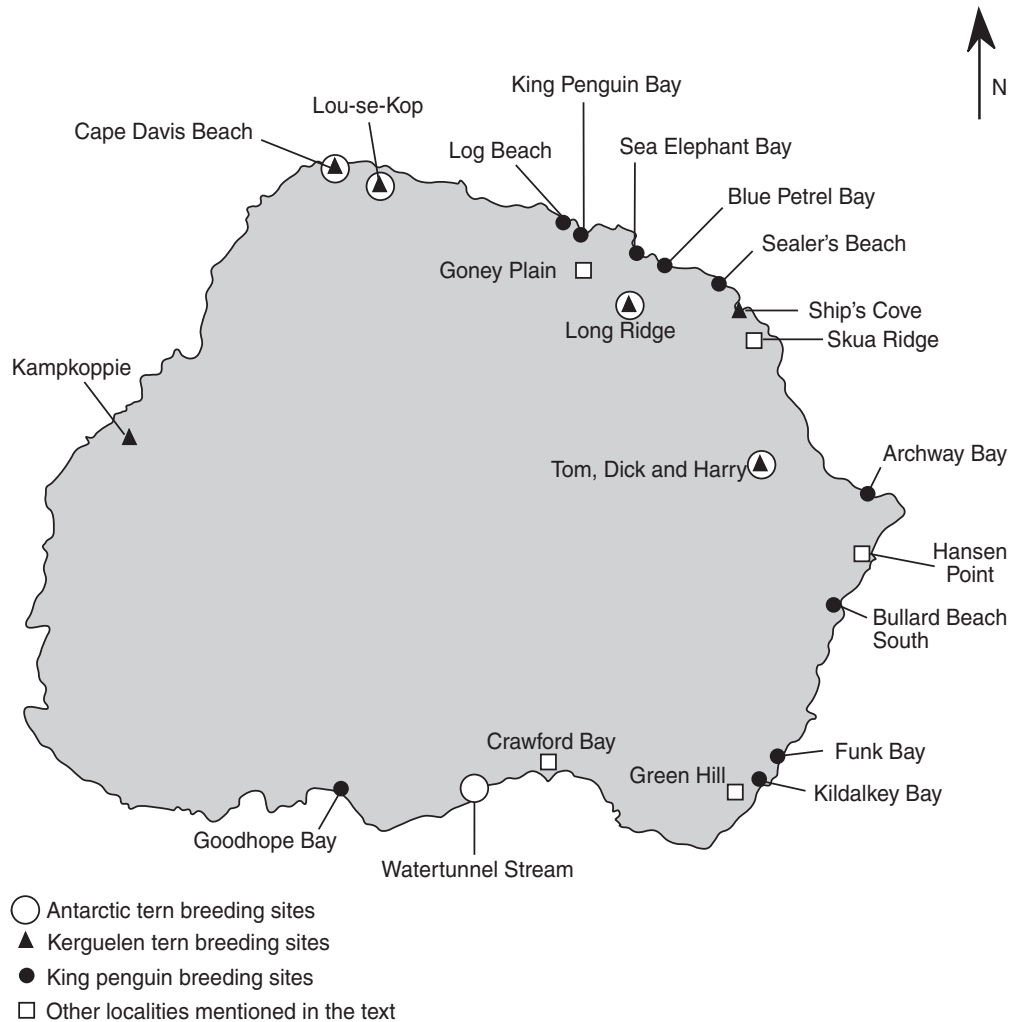


Fig. 1. Localities where king penguins, Antarctic terns and Kerguelen terns bred successfully at Marion Island, 1992/93–2002/03

at Marion Island. This paper collates, and in some instances updates, information reported separately for gentoo penguin *Pygoscelis papua* (Crawford *et al.* 2003c), macaroni penguin *Eudyptes chrysolophus* (Crawford *et al.* 2003a), eastern rockhopper penguin *E. chrysocome filholii* (Crawford *et al.* 2003b), wandering albatross *Diomedea exulans*, grey-headed albatross *Thalassarche chrysostoma* (Nel *et al.* 2002a), northern giant petrel *Macronectes halli*, southern giant

petrel *M. giganteus* (Cooper *et al.* 2001) and Crozet shag *Phalacrocorax [atricaps] melanogenis* (Crawford *et al.* 2003d). Additionally, it provides estimates of population size for king penguin *Aptenodytes patagonicus*, dark-mantled sooty albatross *Phoebastria fusca*, light-mantled sooty albatross *P. palpebrata*, Subantarctic skua *Catharacta antarctica*, kelp gull *Larus dominicanus*, and Antarctic *Sterna vittata* and Kerguelen *S. virgata* tern. Estimates of population size are com-

pared with estimates provided for the 1980s (Cooper and Brown 1990) and some earlier periods.

MATERIAL AND METHODS

King penguin

At Marion Island (290 km², 46°52'S, 37°51'E), an extended egg-laying period, variations in timing of breeding in consecutive years and an irregular breeding schedule make counting of king penguins difficult (van Heezik *et al.* 1995). The egg-laying period lasts from late November to late February (du Plessis *et al.* 1994), with timing of breeding of individual birds largely dependent on whether the previous season was spent breeding and, if so, whether the outcome was a success or a failure (Weimerskirch *et al.* 1992, van Heezik *et al.* 1994). The fledging period of chicks is prolonged by a winter period of fasting (June–September), when chicks are fed infrequently or not at all. Therefore, it is not possible for adults to fledge chicks in time to breed early in the following season, and late breeding usually follows a successful breeding season. However, birds that were unsuccessful or failed to breed in the previous season are able to breed early (Weimerskirch *et al.* 1992, van Heezik *et al.* 1994, 1995). It is considered that repeated monthly counts of adults are necessary to yield a reliable estimate of population size. Peaks in numbers of adults at four colonies have been obtained between December and March (van Heezik *et al.* 1995). In the present study, it was not possible to undertake repeated counts of adults in this early period of breeding. Instead, counts of chicks that survived the winter fast were made in September or October.

Between 1981 and 1990, king penguins were recorded breeding at 15 localities at Marion Island, and they moulted at another two localities (van Heezik *et al.* 1995). In September or October, large numbers of chicks (c. 8 500–15 000) were present at Kildalkey Bay and King Penguin Bay (Fig. 1). There were fewer than 4 000 chicks at each of the other colonies (van Heezik *et al.* 1995).

From 1992 to 2002, there was successful breeding at 10 localities. At Kildalkey and King Penguin bays, the numbers of chicks present in September or October were estimated by counting the numbers in subsections, estimating the proportion of the overall area of the colonies covered by the subsections and dividing the counts by the proportion. Sometimes photographs were taken from surrounding vantage points to assist in this procedure. At the eight smaller colonies, numbers of chicks were counted using a tally counter. Natural

features or prominent birds were used to divide the colonies into smaller groups of birds, which were counted separately and the results summed. In 1999, the numbers of chicks at the colony at Archway Bay were counted three times on 11 occasions between 1 July and 21 November. On each occasion, the coefficient of variation (*CV*) was computed to provide an indication of the accuracy of the counts.

Sooty albatross species

Coastal counts were undertaken of occupied nest sites of dark-mantled and light-mantled sooty albatrosses each year from 1996/97 to 2002/03. At Marion Island, dark-mantled sooty albatrosses breed only at coastal sites and along Grey-headed Albatross Ridge (Fig. 2a), but light-mantled sooty albatrosses also breed inland (Berruti 1979, Fig. 2b). Therefore, in 1997/98, 2001/02 and 2002/03 the search for nests of light-mantled sooty albatrosses was extended inland. The areas covered included all breeding sites reported by Berruti (1979) and subsequent field personnel. In all years except 2001/02, counts were undertaken in late November and December, when most birds of both species are incubating (Berruti 1979). In 2001/02, the counts were conducted from 18 to 31 December.

Dark-mantled sooty albatrosses breed once every two years, but about 89% of failed breeders breed again the following year (Marchant and Higgins 1990). If it is assumed that about 42% of breeders fail (Weimerskirch and Jouventin 1998; about 65% failed at Marion Island in 1974/75 – Berruti 1979), it is possible to estimate the overall number of pairs breeding at Marion Island in years *t* and *t*+1 ($B_{t,t+1}$) as

$$B_{t,t+1} = N_t + N_{t+1} - 0.89 \cdot 0.42 \cdot N_t \quad ,$$

where N_t = number of pairs breeding in year *t* (taken to be the number of occupied nests counted in year *t*). Such estimates were made for the six pairs of breeding seasons from 1996–1997 to 2001–2002.

Light-mantled sooty albatrosses also are able to lay again in the following season if their breeding attempt fails, but they breed only every second year if successful (Marchant and Higgins 1990). Assuming that a similar proportion of failed breeders will re-lay in the following season and breeding failure to be 65% (Weimerskirch and Jouventin 1998; breeding failure was 69% at Marion Island in 1974/75 – Berruti 1979),

$$B_{t,t+1} = N_t + N_{t+1} - 0.89 \cdot 0.65 \cdot N_t \quad .$$

This relationship was used to estimate the overall number of breeding pairs at Marion Island in 2001–2002 and 2002–2003, the only successive years for

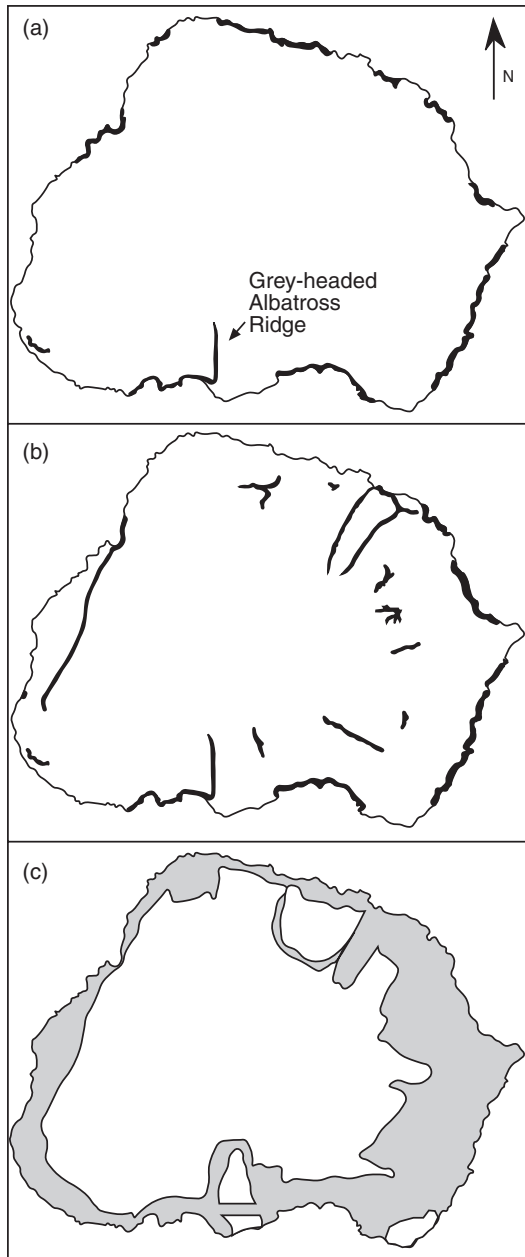


Fig. 2. The distributions at Marion Island in 1997/98 of active nests of (a) dark-mantled and (b) light-mantled sooty albatrosses. Those portions of Marion Island that were searched for active nests of Subantarctic skuas are shaded in (c)

which complete counts of numbers of occupied nests are available.

Subantarctic skua

Numbers of breeding pairs of Subantarctic skuas were estimated at Marion Island from counts of active nests or mobbing behaviour used to identify breeders when nests were not found. Surveys were undertaken from 19 November to 13 December 1997 and from 18 to 31 December 2001. At Marion Island, eggs are laid between 23 October and 19 December, with 70% laid from 2 to 14 November (Williams 1980). The area searched on each of the surveys is shown in Figure 2c and, based on the observations of Hunter (1990), was thought to include the entire breeding population.

Kelp gull

Numbers of active nests of kelp gulls were counted at Marion Island in January of each year between 1998 and 2001, from 18 to 23 December 2001 and in January 2003. At Marion Island, egg laying by kelp gulls is confined to December (Williams *et al.* 1984). A nest was considered active if occupied by an adult or an egg.

Terns

Numbers of breeding pairs of terns were counted or estimated on surveys conducted around Marion Island in November–December and January–February of 1996/97–2000/01 and 2002/03. In 2001/02, searches were made for nests from 18 to 23 December. Eggs of Antarctic terns have been found at Marion Island in February (Berruti and Harris 1976). At Kerguelen and Crozet islands laying is from late December to mid January (Higgins and Davies 1996). Eggs of Kerguelen terns have been found at Marion Island in October (Rand 1954) and recently fledged young have been seen in February (Berruti and Harris 1976). Most adults seen at the Prince Edward Islands from 28 August to 16 September 1984 were paired, and courtship feeding and display flights were observed (Ryan 1987). At Kerguelen Islands, laying is from late August to mid December, depending on weather conditions; at Crozet Islands, it is from early October to early January (Higgins and Davies 1996).

Areas where terns were seen, or where they had been recorded breeding in earlier years, were searched for nests; the numbers of nests were recorded. A nest was deemed to be active if it contained eggs or if fresh faeces were found nearby. Numbers of chicks and fledglings were counted and each taken to repre-

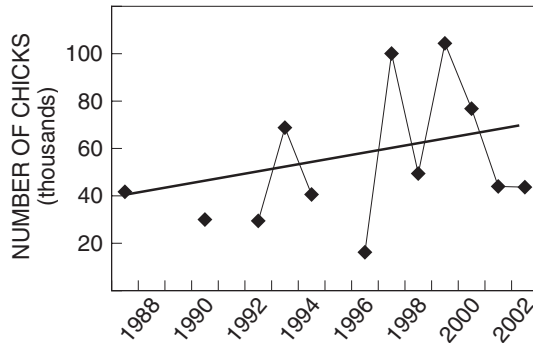


Fig. 3. Overall numbers of post-winter chicks of king penguins counted at Marion Island, 1987–2002, showing the linear trend

sent one nest. For Antarctic terns at South Shetland Islands, 0.93 chicks hatched per nest (Higgins and Davies 1996). For Kerguelen terns at Crozet Islands, 0.78 and 0.24 chicks hatched and fledged per nest respectively (Higgins and Davies 1996). Where adults at nests or chicks could be positively identified, the nests were allocated to the species concerned. In other instances, the number of pairs allocated to each species was determined from the ratio of the species in birds seen overhead. Sometimes nests were not found but breeding was almost certain because adults continually mobbed the observer. In such instances the number of adults was counted and halved to estimate the number of breeding pairs (Ryan 1987).

Identification of Antarctic and Kerguelen terns is difficult when encountering the species for the first time (Berruti and Harris 1976). Different observers were stationed in the field at Marion Island each year and took varying amounts of time to become familiar with identification of the two species. Therefore, identifications were most certain for birds at nests. Observers sometimes found it difficult to be sure of the identification of birds seen overhead, especially in rainy weather. On occasion, observers considered that the number of Antarctic terns may have been underestimated and the number of Kerguelen terns overestimated.

For each species and locality, the number of pairs breeding was assumed to be the maximum number estimated for the locality in the particular season.

Other species

Information was collected on breeding populations of wandering albatross, grey-headed albatross, southern giant petrel and northern giant petrel in 2001/02 and

2002/03 to update that presented by Nel *et al.* (2002a) and Cooper *et al.* (2001). As before, counts of the first three species were made shortly after egg laying was complete. For northern giant petrel, the count in 2001/02 between Skua Ridge and Hansen Point (Fig. 1) and the entire count in 2002/03 were undertaken shortly after egg laying was complete. However, in 2001/02 the count for the remainder of the island was undertaken from 18 to 23 December, 2–3 months later than the other counts. These December counts were adjusted to account for earlier breeding failure by assuming a breeding success of c. 60% to the large chick stage (Cooper *et al.* 2001). For all four species, all known breeding localities were covered including those for giant petrels reported by Hunter (1990). Additionally, extensive searches were made for northern giant petrel farther inland.

RESULTS

King penguin

Numbers of king penguin chicks in September or October estimated for different localities at Marion Island between 1981 and 2002 are listed in Table I. Estimates were made at all breeding localities in 12 years between 1987 and 2002 and showed considerable fluctuation, ranging from 16 000 in 1996 to more than 100 000 chicks in both 1997 and 1999 (mean 54 000, *SD* 28 000). The linear trend indicated an increase in the number of chicks with time, but this was not significant (Fig. 3, $n = 12$, $r = 0.353$).

On average, the two largest colonies at Kildalkey Bay and King Penguin Bay together held 80% of the chicks. The numbers estimated for those two colonies were significantly positively correlated over time ($n = 12$, $r = 0.758$, $p < 0.005$). There was a significant increase in numbers of chicks estimated for Bullard Beach South ($n = 18$, $r = 0.614$, $p < 0.01$) and a significant decrease in numbers at Goodhope Bay ($n = 15$, $r = -0.680$, $p < 0.01$).

In 1999, the *CV* on counts at Archway Bay was between 0.4 and 6.8% ($n = 11$, mean 2.5%) for average numbers of chicks ranging from 916–1 230. The estimate of the overall number of post-winter chicks was dominated by the large numbers at Kildalkey Bay and King Penguin Bay, for which a higher *CV* would be applicable. It is likely that the *CV* on the overall estimates is of the order of 10%.

Sooty albatross species

Numbers of dark-mantled sooty albatrosses counted at

Table 1: Estimates of the number of chicks of king penguins surviving to the end of winter at different breeding localities at Marion Island and overall, 1981–2002. Information for 1981–1990 from van Heezik et al. (1995)

Locality	Number of chicks																		
	1981	1982	1983	1984	1986	1987	1988	1989	1990	1992	1993	1994	1996	1997	1998	1999	2000	2001	2002
Archway Bay	479	618	578		1 132	812	473	1 725	1 775	584	600	652	364	1 285	1 054	1 160	1 017	1 075	1 059
Bullard Beach South	50	50	81		188	118	77	320	80	104	329	111	10	532	273	298	290	454	243
Funk Bay			157		207	248	131	330	80	151	246	220	67	90	136	163	145	168	121
Kildalkey Bay						15 194			14 500	15 000	20 160	22 000	7 100	38 738	13 965	34 055	22 011	23 671	17 386
Goodhope Bay				2 500			2 216	3 684	1 210	1 000	1 237	1 328	154	1 985	739	823	861	564	8 40
Log Beach						1 907		1 500	750	1 276	2 424	1 283	425	3 095	3 520	2 693	1 772	1 205	2 302
King Penguin Bay						14 839	8 723	17 000	8 650	7 600	37 000	11 830	5 534	44 774	24 830	59 341	46 148	13 100	16 571
Sea Elephant Bay						2 492		3 050	1 110	1 900	4 050	1 493	1 219	6 242	2 809	2 970	2 121	1 757	2 817
Blue Petrel Bay						1 907	582	1 310	560	620	1 170	481	544	997	863	920	871	672	915
Sealer's Beach	1 855	1 493	957		1 818	2 450	705	2 546	1 300	1 220	1 569	1 175	803	2 321	1 234	1 930	1 561	1 321	1 426
Total						41 717			30 015	29 455	68 785	40 593	16 220	100 059	49 423	104 353	76 797	43 987	43 680

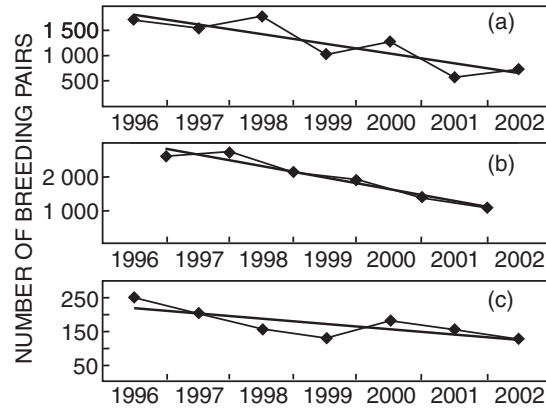


Fig. 4. Trends at Marion Island of (a) number of pairs breeding in any year and (b) estimated overall breeding population for dark-mantled sooty albatrosses, and (c) number of pairs of light-mantled sooty albatrosses breeding around the coast, 1996/97–2002/03. The linear trends are shown

Marion Island decreased from 1 541–1 775 pairs in 1996/97–1998/99 to 564–721 pairs in 2001/02 and 2002/03 (Table II). The distribution of nests in 1997 is shown in Figure 2a. The decrease over time was significant ($n = 7$, $r = -0.873$, $p < 0.02$, Fig. 4a). The estimated overall population at Marion Island decreased from about 2 600–2 700 pairs between 1996/97 and 1998/99 to about 1 100 pairs in 2001/02–2002/03 (Fig. 4b).

Counts of light-mantled sooty albatrosses at Marion Island were 334 pairs in 1997/98 but fewer than 200 pairs in both 2001/02 and 2002/03 (Table II). The distribution of nests in 1997/98 is shown in Figure 2b. The estimated overall population at the island in 2001/02 and 2002/03 was 192 pairs. Numbers breeding around the coastline decreased from 1996/97 to 1999/00, increased in 2000/01 and then decreased again in 2001/02 and 2002/03 (Fig. 4c). The decrease over time was significant ($n = 7$, $r = -0.778$, $p < 0.05$).

Subantarctic skua

For Subantarctic skuas, 749 breeding pairs were counted in 1997/98 and 546 pairs in 2001/02.

Kelp gull

Numbers of kelp gulls at Marion Island, estimated

Table II: Number of breeding pairs of different seabirds counted at or estimated for Marion Island, 1980s and 1994/95–2002/03. Estimates for the 1980s are from Cooper and Brown (1990). For other seasons, sources of information not derived in this paper are: gentoo penguin – Crawford *et al.* (2003c); macaroni penguin – Crawford *et al.* (2003a); rockhopper penguin – Crawford *et al.* (2003b); wandering albatross, grey-headed albatross – Nel *et al.* (2002a); northern and southern giant petrels (Cooper *et al.* 2001, Nel *et al.* 2002a), Crozet shag – Crawford *et al.* (2003d). Gaps indicate an absence of information

Species	Number of breeding pairs									
	1980s	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03
King penguin	215 230									
Gentoo penguin	888	1 352	1 355	1 119	956	990	846	801	844	806
Macaroni penguin	405 084	434 000	395 000	395 000	405 000	361 000	388 000	407 000	363 000	356 000
Rockhopper penguin	137 652	173 000		150 000					67 000	
Wandering albatross	1 533	1 794	1 765	1 741	1 910	1 760	1 611	1 860	1 869	1 593
Grey-headed albatross	5 037	6 217	5 219	6 600	7 641	7 728	5 573	6 757	6 229	5 005
Dark-mantled sooty albatross	2 055			1 701	1 541	1 775	1 012	1 269	564	721
Light-mantled sooty albatross	201				334				179	127
Northern giant petrel	314	411		387	453	364	275	341	295	196
Southern giant petrel	2 891	2 947		1 198	2 173	1 381	1 468	1 473	1 430	1 759
Crozet shag	589	841	672	537	388	505	490	443	344	272
Subantarctic skua	900				749				546	
Kelp gull	200				65	88	81	109	24	25
Antarctic tern	<25			0	9	2	8	8	2	10
Kerguelen tern	10			13–18	56	20	27	26	16	12

from counts of active nests, fluctuated between 65 and 109 pairs from 1997/98 to 2000/01. About 25 pairs were estimated as present in both 2001/02 and 2002/03 (Table II).

Terns

Between 1997/98 and 2001/02, Antarctic terns were recorded breeding at five localities at Marion Island and Kerguelen terns at six (Fig. 1). The number of Antarctic terns reported breeding in any season fluctuated between none in 1996/97 and 10 pairs in 2002/03 ($n = 7$, mean = 6 pairs, $SD = 4$ pairs).

The number of Kerguelen tern pairs reported breeding was 13–18 in 1996/97, 16 in 2001/02 and 56 in 1997/98 (Table III). If 1997/98 is excluded, the mean number reported was 19 pairs ($n = 6$, $SD = 6$ pairs).

Other species

Estimates of the breeding populations of wandering albatross, grey-headed albatross, northern giant petrel and southern giant petrel for 2001/02 and 2002/03 are given in Table II. The count of incubating wandering albatrosses in 2001/02 was similar to that for 2000/01, but the numbers of incubating birds decreased in 2002/03. The numbers of incubating grey-headed albatrosses decreased from 6 757 in 2000/01 to 5 005 in 2002/03, when none was found at Crawford Bay

(where there were 37 incubating adults in November 2001).

For the northern giant petrel, there were 67 active nests between Skua Ridge and Hansen Point in September and October 2001. For the remainder of the island, 137 active nests were counted from 18 to 23 December 2001, which after accounting for an assumed breeding failure of 40% (Cooper *et al.* 2001) represented 228 pairs. This gave an overall estimate of 295 pairs for 2001/02 (Table II). In September 2002, only 196 active nests of northern giant petrels were counted. There were about 1 450 breeding pairs of southern giant petrels in each year from 1999/00 to 2001/02 (Table III). This increased to 1 759 for 2002/03.

DISCUSSION

Comparison of numbers of seabirds presented in this paper with earlier estimates of abundance is made difficult by sometimes poor documentation of the methods used in previous surveys. Information on the timing of former surveys and their extent is often lacking, and it is sometimes unclear whether any adjustments were made to account for failed breeding prior to the surveys (Ryan *et al.* 2003). More recently, these aspects of surveys have been standardized to a large extent, providing for greater confidence in trends observed since the early 1990s.

Table III: Estimates of the number of Kerguelen and Antarctic terns (pairs) breeding at different localities at Marion Island, 1996/97–2002/03

Colony	Number of breeding pairs													
	1996/97		1997/98		1998/99		1999/00		2000/01		2001/02		2002/03	
	K	A	K	A	K	A	K	A	K	A	K	A	K	A
Tom, Dick and Harry	10–15	0	29	6	11	2	7	2	6	2	6	0	9	4
Watertunnel Stream	0	0	0	0	0	1	0	0	0	1	0	1	0	0
Kampkoppie	0	0	0	0	0	0	9	0	9	0	0	0	0	0
Cape Davis Beach	3	0	5	1	2	0	2	3	2	3	2	1	0	3
Lou-se-Kop	0	0	4	0	4	0	5	0	5	0	1	1	0	0
Long Ridge	0	0	18	2	3	0	2	3	2	3	4	0	3	3
Ship's Cove	0	0	0	0	0	0	2	0	2	0	3	0	0	0
Total	13–18	0	56	9	20	3	27	8	26	9	16	3	12	10

K = Kerguelen
A = Antarctic

King penguin

In 1951/52, Rand (1955) estimated an adult population of 52 410 birds at 16 mapped localities, of which only seven were named as breeding sites (Rand 1954). Van Zinderen Bakker (1971) gives a figure of two million birds for both Marion and Prince Edward Islands for 1965/66. This figure may be regarded as little more than a guess.

Siegfried *et al.* (1978) estimated the Marion Island annual population in the period 1974–1977 as 215 234 breeding pairs in eight colonies, based on aerial photographs taken in March. By the mid 1980s, 10 colonies existed, with new ones reported as being established south of Bullard Beach (“Bullard River”) and at Goodhope Bay (Watkins 1987). In 1951/52 the latter locality was used for roosting only (Rand 1955). However, Siegfried *et al.* (1978) report the presence of 21 045 breeding pairs at Goodhope Bay during the period 1974–1977, so uncertainty exists as to when breeding commenced. They did not report a breeding colony at Bullard River in the 1970s, which was first reported to contain 50 chicks in 1981 (van Heezik *et al.* 1995).

Because about 20% of king penguins at Marion Island do not breed in each season (van Heezik *et al.* 1994), the overall population in 1974–1977 would have been about 270 000 pairs. The estimate of 215 230 pairs breeding annually was retained by Cooper and Brown (1990) as being applicable to the 1980s.

Based on numbers of adults counted at colonies between February and March and assumptions concerning absenteeism of mates at sea, failed breeding at the time of the counts and the proportion of birds not breeding in a season, van Heezik *et al.* (1995) estimated the overall population of king penguins at Marion Island in 1990/91 to be of the order of 760 000

adults, equivalent to 380 000 breeding pairs.

At the Crozet Islands, the proportion of chicks of king penguins surviving to the end of the winter fasting period in October during 1986/87–1988/89 was variable, but over three seasons averaged 0.41 (Weimerskirch *et al.* 1992). Applying this rate to the mean post-winter count of chicks obtained at Marion Island during the period 1987–2002 (54 000), the average number of pairs breeding in any season would be 132 000. Assuming 20% of pairs did not breed each season (van Heezik *et al.* 1995), the breeding population at the island would be about 165 000 pairs. This estimate is lower than those of both Williams *et al.* (1979) and van Heezik *et al.* (1995) and highlights the influence of the different assumptions used to estimate the overall population. The assumptions that no failed breeders, absentee breeders or mates were at colonies makes the estimate of van Heezik *et al.* (1995) an upper limit. However, the long period between initiation of breeding and September or October means that the use of post-winter counts of chicks to estimate the number of breeders has a potentially large error. There must have been c. 100 000 breeding pairs in 1997 and 1999 because equivalent numbers of chicks survived the winter fast. The estimate of 165 000 pairs is probably a lower limit. Although the extrapolation from incubation to post-winter chicks precludes accuracy, on average the numbers of chicks surviving to the end of winter have not decreased since the 1980s and may have increased (Fig. 3). Therefore, the population may be regarded as stable to increasing.

Populations of king penguins have increased at Possession Island (Crozet Islands), Kerguelen Islands and Heard Island since the 1960s or early 1970s, with the larger colonies possibly stabilizing during the 1990s (Jouventin and Weimerskirch 1990, Woehler

et al. 2001). At Macquarie Island, South Georgia and Falkland Islands, less frequent or incomplete data also suggest increases in numbers of king penguins. The increases have in instances been recoveries from earlier exploitation to low levels of abundance and may also have resulted from an enhanced availability of myctophid fish, the main prey of king penguins at all breeding localities, including Marion Island (Adams and Klages 1987, Jouventin and Weimerskirch 1990, Marchant and Higgins 1990, Ridoux 1994, Guinet *et al.* 1995, Woehler and Croxall 1997, Ellis *et al.* 1998, Woehler *et al.* 2001). King penguins were exploited at Marion Island's King Penguin Bay in the 1800s (Cooper and Avery 1986).

The similar trends in numbers of chicks surviving to the end of winter at the two largest colonies at Marion Island, which together hold about 80% of the island's population, suggest that environmental conditions may affect either numbers breeding or breeding success. In both 1997 and 1999, when more than 100 000 chicks survived to the end of winter, there were higher than normal ambient temperatures from July–October (Crawford *et al.* 2003e). Goodhope Bay, where there was a long-term decrease in numbers of chicks, is the only colony not situated on the north and east coasts of the island. Human disturbance may cause reductions in king penguin colonies (Jouventin and Weimerskirch 1990), but the colony at Goodhope Bay is well removed from most human disturbance at Marion Island.

Sooty albatross species

Van Zinderen Bakker (1971) estimated the combined numbers of breeding pairs at Marion Island and Prince Edward Island in 1965/66, based on counts of nests, as 1 000 pairs of dark-mantled and 50 of light-mantled sooty albatrosses. Based on surveys undertaken from January 1974 to April 1975 and from April 1976 to May 1977, the annual breeding population of dark-mantled sooty albatrosses at Marion Island was estimated to be 2 032 pairs (Siegfried *et al.* 1978, Berruti 1979, Williams *et al.* 1979). In October and November 1986, there were 1 974 active nests (1 546 birds were incubating, 428 were standing at nests, JC unpublished data). In 1987/88, 2 055 pairs were counted from 8 to 14 October (Cooper and Brown 1990, JC unpublished data). This value decreased to 1 541–1 775 pairs in the mid 1990s and to fewer than 1 000 pairs in the early 2000s.

From 1974 to 1977, the annual breeding population of light-mantled sooty albatrosses at Marion Island was estimated to be 176 pairs (Siegfried *et al.* 1978, Williams *et al.* 1979), of which 97 bred around the coast (Berruti 1979). In October and November 1986, a

coastal count recorded 71 pairs breeding (JC unpublished data). In 1988/89, a count of all breeding localities from 23 November to 27 December indicated a population of 201 pairs, of which once again 97 bred around the coast (Cooper and Brown 1990, JC unpublished data). The overall number breeding was 334 pairs in 1997/98, but fewer than 200 pairs in the early 2000s. The number breeding around the coast decreased from 249 pairs in 1996/97 to 88 pairs in 2002/03 (Fig. 4b).

Numbers of both dark-mantled and light-mantled sooty albatrosses decreased at Possession Island (Crozet Islands) between 1980 and 1994, the former at a much higher rate than the latter. The decreases were caused by a low survival of adults and immature birds, which was attributed to mortality caused by longline fishing in the south-western Indian Ocean (Weimerskirch and Jouventin 1998). Similar mortality may have been responsible for the decreases in the two species of sooty albatross at Marion Island. Since 1994, the number of dark-mantled sooty albatrosses at Possession Island has remained low, whereas the number of light-mantled sooty albatrosses has increased (Woehler *et al.* 2001).

Subantarctic skua

Van Zinderen Bakker (1971) estimated the 1965/66 population as 4 000 birds for both Marion and Prince Edward islands. This figure is assumed to include non-breeding birds. From 1974–1977, there were an estimated 406 pairs of Subantarctic skuas at Marion Island (Siegfried *et al.* 1978, Williams *et al.* 1979). In 1987/88, 900 pairs bred at the island (Hunter 1990). The population decreased to 546 pairs by 2001/02 (Table II). At Marion Island the skuas are essentially terrestrial feeders during the breeding season, eating burrowing petrels, preying on eggs and chicks of penguins and scavenging from carcasses of seals and penguins. In 1987/88, the density of breeding birds was highest in the vicinity of large colonies of penguins, which were thought to be the skuas' main source of food (Hunter 1990). It is possible that their food supply was reduced by the decreases in some penguin species. Increases in skua populations have been shown in response to station garbage (Hemmings 1990), which is no longer made available at Marion Island (pers. obs.). Subantarctic skuas were killed in small numbers between 1996 and 2000 by the longline fishery that operated around the Prince Edward Islands (Nel *et al.* 2002b). In the period 1990/91 to 1992/93 a total of 92 skuas was killed in gin traps set for feral cats *Felis catus* (Bester *et al.* 2002). The estimated number of Subantarctic skuas breeding at Prince Edward Island has increased since the 1980s, but this is attributed to better coverage and more accurate mapping of nests (Ryan *et al.* 2003).

Populations of Subantarctic skuas at Palmer and Admiralty Bay, King George Island (South Shetland Islands) have been stable for 10–20 years, whereas there have been recent decreases at Potter Peninsula and Fildes Peninsula, King George Island (Woehler *et al.* 2001).

Kelp gull

Van Zinderen Bakker (1971) recorded that “not more than 500 gulls occur around the islands” [Marion Island and Prince Edward Island] in 1965/66. From 1974 to 1977, there were an estimated 200 pairs of kelp gulls at Marion Island (Siegfried *et al.* 1978, Williams *et al.* 1979); the same value was assumed for the 1980s (Cooper and Brown 1990). The population in the 1990s was less than half this amount, whereas estimates for Prince Edward Island remained roughly constant (Ryan *et al.* 2003).

Terns

Van Zinderen Bakker (1971) recorded that “not more than 150 [Kerguelen terns] are thought to occur on the islands” in 1965/66. He did not observe Antarctic terns breeding at the Prince Edward Islands. From 1974 to 1977, the population of Antarctic terns at Marion Island was estimated to be fewer than 50 pairs (Williams *et al.* 1979). It was thought to be fewer than 20 pairs in 1979 (Brooke 1984) and fewer than 25 pairs in the 1980s (Cooper and Brown 1990). Between 1996/97 and 2002/03, the highest estimate was 10 pairs, confirming the small size of the population.

Fewer than 50 pairs of Kerguelen terns were estimated for Marion Island during the period 1974–1977 (Williams *et al.* 1979). Less than 10 pairs bred at the island in 1979 (Brooke 1984). Between 28 August and 16 September 1984, 11 Kerguelen terns were counted at the island. They were seen between Kampkoppie and Goney Plain, and the population for Marion Island was estimated as five pairs (Ryan 1987). It was thought to be 10 pairs in the 1980s (Cooper and Brown 1990) but reached 56 pairs in 1997/98. However, this was more than double the next highest estimate for the period 1996/97–2002/03. Excluding 1997/98, the mean of 19 pairs for that period is similar to earlier estimates. The high number reported breeding in 1997/98 matched the unusually good or poor breeding by several other seabirds at Marion Island and may have been influenced by the ENSO (*El Niño* Southern Oscillation) event of 1997/98 (Crawford *et al.* 2003e).

In 1984, Kerguelen terns were not encountered along

the east coast between Ship’s Cove and Green Hill (Ryan 1987), where they have subsequently occupied suitable breeding habitat (Table III, Fig. 1). It was thought that their earlier absence from that area was related to disturbance from feral cats, which were finally eradicated from Marion Island in 1991 (Bester *et al.* 2000, 2002), or from the research station (Ryan 1987). Numbers of Kerguelen terns at Prince Edward Island, 21 km distant and with minimal human disturbance, have decreased since the mid 1980s (Ryan *et al.* 2003).

Other albatrosses and giant petrels

Nel *et al.* (2002a) reported that populations of five seabirds breeding at Marion Island, (wandering albatross, grey-headed albatross, northern giant petrel, southern giant petrel and white-chinned petrel *Procellaria aequinoctialis*) all showed similar trends in the 1980s and 1990s. All were stable or decreasing during the 1980s, followed by a slight recovery during the early to mid 1990s. In the late 1990s, they all stabilized or again decreased in numbers. The trends for wandering albatross were strongly correlated with the trends for other Indian Ocean populations of the same species and corresponded with changes in longline fishing effort for tunas *Thunnus* spp. in the southern Indian Ocean (Nel *et al.* 2002a). Fishing effort for tunas in the region increased greatly during the early 1980s, peaking during the mid 1980s, before decreasing to a low level in 1990 and then increasing again (Tuck and Polacheck 1997). As all five species of seabird were killed in significant numbers by tuna longline fishing vessels operating at the Subtropical Convergence or at other productive oceanographic features where seabirds concentrate (Ryan and Boix-Hinzen 1998), it was thought that by-catch mortality in the tuna fisheries had influenced the trends (Nel *et al.* 2002a, b).

Numbers of wandering and grey-headed albatrosses breeding at Marion Island increased again in 2000/01 and 2001/02 but then decreased to low levels in 2002/03, indicating fluctuations, but no clear trend, in the most recent 10 seasons (Nel *et al.* 2002a, Table II). Numbers of northern giant petrels breeding at Marion Island increased in 2000/01 but were lower in 2002/03 than at any time since 1984/85 (Cooper *et al.* 2001, Table II), suggesting either a reduced population or substantial non-breeding in that season. Numbers of southern giant petrels breeding at the same island remained low in 2000/01 and 2001/02 but improved in 2002/03 (Table II). However, they remain considerably fewer than the 2 235–2 947 pairs recorded between 1984/85 and 1994/95 (Cooper *et al.* 2001).

Other penguins and Crozet shag

There have been substantial decreases in numbers of gentoo penguins, rockhopper penguins and Crozet shags breeding at Marion Island since the mid 1990s (Table II, Crawford *et al.* 2003b, c, d). At most monitored localities in the Antarctic Peninsula numbers of gentoo penguins increased after 1980. However, the colony at Admiralty Bay, King George Island, decreased in size, as did numbers at the subantarctic island of South Georgia (Woehler *et al.* 2001).

The decrease in numbers of rockhopper penguins at Marion Island matches decreases at several other localities in the south-western Atlantic and Indian oceans and south of New Zealand, where altered environmental conditions are thought to have reduced the availability of its prey (Cunningham and Moors 1994, Bingham 1998, Ellis *et al.* 1998, Guinard *et al.* 1998, Woehler *et al.* 2001).

There appears to have been a decrease in numbers of macaroni penguins breeding at Marion Island between 1994/95 and 2002/03 (Table II, Crawford *et al.* 2003a). Numbers of macaroni penguins also have decreased at Prince Edward Island (Ryan *et al.* 2003) and Bird Island, South Georgia, since the mid 1980s, and they may have decreased at the Kerguelen Islands (Woehler *et al.* 2001).

The decreases in populations of gentoo, rockhopper and macaroni penguins and Crozet shags at Marion Island are likely to have resulted from a reduced availability of food that may have resulted from altered environmental conditions (Crawford *et al.* 2003b, c, d). At Marion Island, annual mean surface air temperature has increased and annual precipitation has decreased since the 1960s (Smith 2002) and sea surface temperatures increased by about 1.5°C between 1949 and 1988 (Mélise *et al.* in press). Gentoo penguins and Crozet shags feed near the island, where there is considerable overlap in their diet (Cooper 1985, Adams and Wilson 1987, Espitalier-Noel *et al.* 1988, Adams and Klages 1989). It is likely that availability of prey to these two seabirds has changed since the mid 1980s (Crawford *et al.* 2003c, d).

Potential interactions with marine mammals

Interactions between fur seals and seabirds at the Prince Edward Islands (e.g. Ryan *et al.* 2003) can be expected to increase as populations of fur seals at the islands increase (e.g. Wilkinson and Bester 1990, Bester *et al.* 2003). Increased numbers of fur seals may have caused the reduced number of rockhopper penguins at Amsterdam Island (Guinard *et al.* 1998). In the Ben-

guela ecosystem off the west coast of southern Africa, increases in Cape fur seals *Arctocephalus pusillus* have adversely affected some populations of seabirds through predation and displacement of birds from breeding sites (Crawford *et al.* 1989, David *et al.* 2003). Fur seals and other marine mammals may compete with seabirds for food (e.g. Jouventin and Weimerskirch 1990).

ACKNOWLEDGEMENTS

We are grateful to all who helped with counts of seabirds at Marion Island, including C. J. Gilbert, B. Hanise, S. R. Henley, C. L. Holness, D. G. Keith, J. L. Nel, K. Spencer and A. C. Wolvaardt. We thank the Department of Environmental Affairs and Tourism for facilitating the survey of Marion Island in December 2001 and supporting the seabird research programme at Marion Island since 1994. We are grateful to Captain D. Hall and the officers and crew of the F.R.S. *Africana* for their hospitality and skill in landing the scientific team at Marion Island in December 2001.

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A view of Marion Island showing the main base in the foreground (photo B. M. Dyer)



Numbers of dark-mantled (top left, photo L. Upfold) and light-mantled (top right, photo R. J. M. Crawford) sooty albatrosses have decreased at Marion Island, whereas populations of Kerguelen tern (bottom left) and Antarctic tern (bottom right) remain small (photos B. M. Dyer)