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UNUSUAL BREEDING BY SEABIRDS AT MARION ISLAND DURING 1997/98

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In 1997/98, breeding at subantarctic Marion Island was exceptionally good for five species of seabirds capable of foraging over wide areas and for a tern. The number of king penguin *Aptenodytes patagonicus* chicks surviving to the start of spring in 1997 was considerably more than previously recorded. Greater numbers of wandering *Diomedea exulans* and grey-headed *Thalassarche chrysostoma* albatrosses, northern giant petrels *Macronectes halli* and Kerguelen terns *Sterna virgata* bred than previously recorded, and more southern giant petrels *M. giganteus* did so than in any other year since 1994. For southern giant petrels, reproductive success was higher than in any other year, as was survival of chicks of northern giant petrels. Conversely, for two seabirds that feed close to the island, gentoo penguin *Pygoscelis papua* and Crozet shag *Phalacrocorax [atriceps] melanogenis*, 1997/98 was a particularly poor breeding season. Gentoo penguins initiated breeding later than usual and fledged few chicks. The number of Crozet shags that bred decreased; probably about 25% of the adult population did not breed. For two species with an intermediate foraging range that eat mainly crustaceans, macaroni *Eudyptes chrysolophus* and eastern rockhopper *E. chrysocome filholi* penguins, breeding was not noticeably different from normal except that chicks of rockhopper penguins fledged with a slightly heavier mass than in other years. However, for both these penguins, the mass of adults on arrival at colonies decreased substantially in the following (1998/99) breeding season. The unusual breeding by most of the seabirds coincided with the *El Niño* Southern Oscillation (ENSO) event of 1997/98. This synchrony contrasts with lagged responses to ENSO events of seabirds that breed farther south in the Southern Ocean. Continued monitoring of seabirds over well-separated sites in the Southern Ocean may elucidate how climatic perturbations operating at a global scale impact seabirds in the region.

Key words: albatrosses, breeding, Crozet shag, *El Niño*, giant petrels, Kerguelen tern, Marion Island, penguins, Subantarctic

Synchrony in the life-history parameters of different seabirds breeding at a particular locality has sometimes been observed. For example, at Adélie Land, Antarctica, in the 1976/77 breeding season, there was low breeding success followed by high mortality of adults for emperor *Aptenodytes forsteri* and Adélie *Pygoscelis adeliae* penguins, snow petrels *Pagodroma nivea* and southern or Antarctic fulmars *Fulmarus glacialoides* (Chastel *et al*. 1993, Croxall 1992). At Prydz Bay, Antarctica, there were similar trends in breeding success for Adélie penguins, Antarctic petrels *Thalassoica antarctica* and southern fulmars during the seasons 1983/84 –1987/88 (Whitehead *et al*. 1990). Concordant fluctuations in the abundance of seabirds has also been noted, e.g. off central and southern California between 1986 and 1994 (Ainley *et al*. 1995).

Aspects of the biology of several species of seabirds have been monitored at subantarctic Marion Island in the southern Indian Ocean for varying periods of time (Cooper *et al*. 1997, 2001, Nel *et al*. 2002). For most monitored species, there was an unusual aspect to breeding during 1997/98 in that parameters measured were either abnormally high or low, suggesting that the environment influenced breeding. This paper collates information on breeding in that season to demonstrate its unusual nature and notes its association with the *El Niño* Southern Oscillation (ENSO) event of the same period.

MATERIAL AND METHODS

Information on breeding by 10 seabirds at Marion Island (290 km^2; 46°52´S, 37°51´E) was collated from the literature as follows: king penguin *A. patagonicus* 1987–2002 (van Heezik *et al*. 1995, Crawford *et al*. 2003c); gentoo penguin *Pygoscelis papua* 1994/95–2002/03 (Crawford *et al*. 2003d); macaroni penguin *Eudyptes chrysolophus* 1979/80–2002/03 (Cooper *et al*. 1997, Crawford *et al*. 2003a), eastern rockhopper penguin *E. chrysocome filholi* 1983/84–2002/03 (Cooper *et al*. 1997, Crawford *et al*. 2003b); wandering albatross *Diomedea exulans* 1981/82–2002/03, grey-headed albatross *Thalassarche chrysostoma* 1984/85–2002/03 (Nel *et al*. 2002, Crawford *et al*. 2003c),

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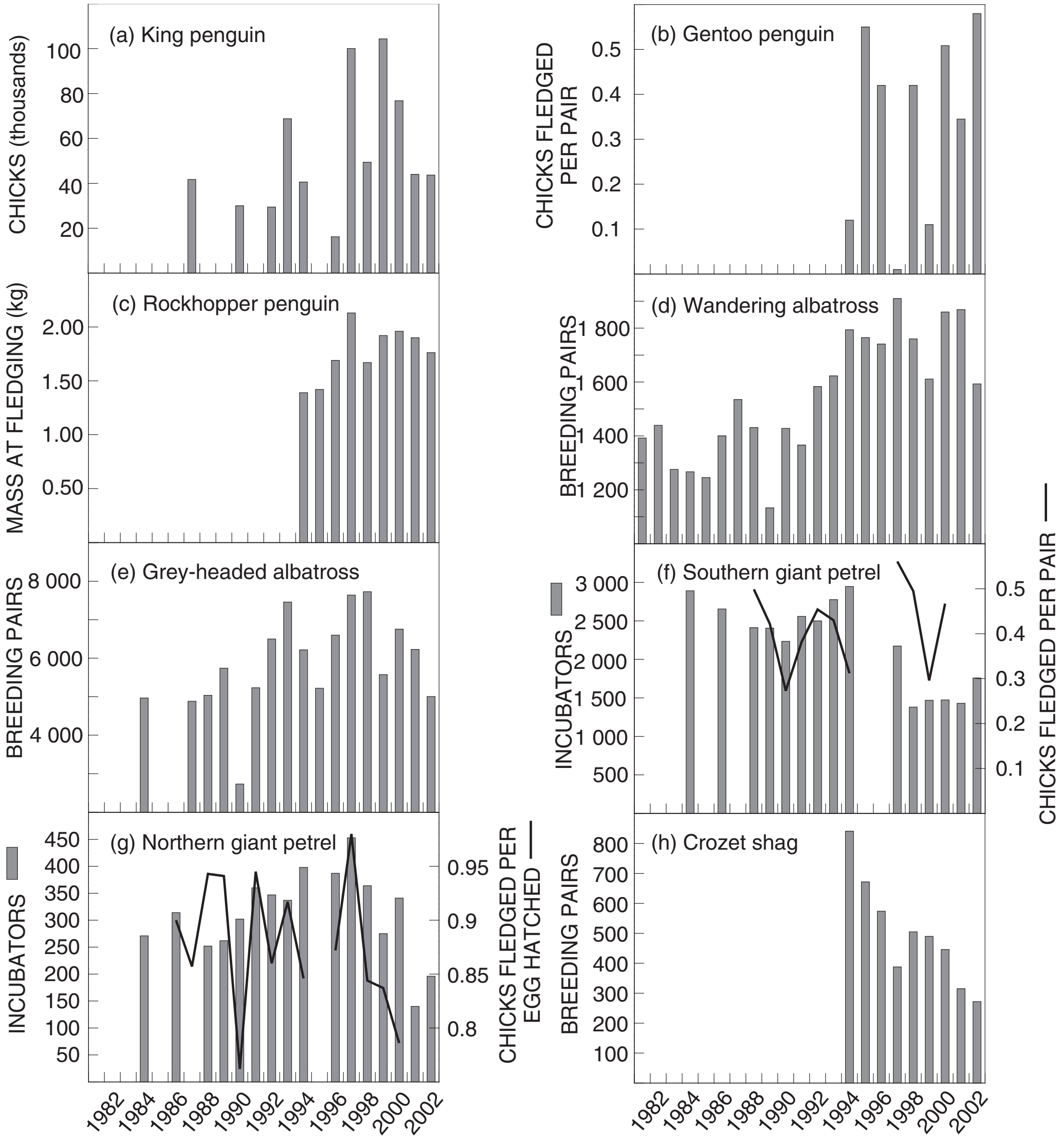

Fig. 1: Trends in selected reproductive parameters measured for some seabirds at Marion Island, 1981–2002. For summer-breeding species, the year indicated refers to the year in which the austral summer began: (a) estimated number of king penguin chicks at the commencement of spring; (b) reproductive success of gentoo penguin; (c) mass at fledging of rockhopper penguin chicks; (d) number of pairs of wandering albatross breeding; (e) number of pairs of grey-headed albatross breeding; (f) number of pairs breeding and number of chicks fledged per pair for southern giant petrel; (g) number of pairs breeding and number of chicks fledged per egg that hatched for northern giant petrel; (h) number of pairs of Crozet shags breeding. Gaps indicate an absence of data. Information for (a) from van Heezik *et al.* (1995) and Crawford *et al.* (2003c); (b) from Crawford *et al.* (2003d); (c) Crawford *et al.* (2003b); (d) and (e) Nel *et al.* (2002) and Crawford *et al.* (2003c); (f) and (g) Cooper *et al.* (2001) and Crawford *et al.* (2003c); (h) Crawford *et al.* (2003e)

southern giant petrel *Macronectes giganteus* 1984/85–2002/03, northern giant petrel *M. halli* 1984/85–2002/03 (Cooper *et al*. 2001, Crawford *et al*. 2003c), Crozet shag *Phalacrocorax [atriceps] melanogenis* 1994/95–2002/03 (Crawford *et al*. 2003e) and Kerguelen tern *Sterna virgata* 1996/97–2002/03 (Crawford *et al*. 2003c).

In order to investigate the state of the environment at Marion Island, monthly average maximum and minimum air temperatures for each year from 1994 to 2001 taken from the meteorological station at Transvaal Cove were obtained from the South African Weather Service. The values for the months June–October were compared with long-term climatic means for the period 1961–1990 to provide a deviation from the means. Sea surface temperature (SST) anomalies for the south-west Indian Ocean were reviewed for the period April–October 1997. These images were obtained from the NOAA/NESDIS website (http://www.osdpd.noaa.gov/PSB/EPS/SST/al_climo.html) and represent anomalies from satellite-derived information at 36-km resolution. There have been long-term increases in both the annual mean surface air and sea temperatures at Marion Island (Smith 2002, Mélice *et al*. in press b).

RESULTS

Breeding of seabirds

In 1997, an estimated 100 000 king penguin chicks survived the winter at Marion Island, more than in any other year for which there is information for all colonies, except 1999 (104 000, Fig. 1a). The mean for 12 years with complete information for all colonies (1987, 1990, 1992–1994, 1996–2002) was 50 000 (SD 31 000, Crawford *et al*. 2003c).

In 1997, the first egg of gentoo penguins was laid on 20 July, 95% of nests had eggs by 3 August and the last egg was laid on 13 August. For other years from 1994 to 2001, these dates ranged from 1 June–11 July, 14 June–25 July and 18 June–1 August respectively. Therefore, laying was at least nine days later in 1997/98 than in any other season for which information exists for Marion Island. Breeding pairs fledged an average of just 0.01 chicks from first clutches laid in 1997/98, compared with 0.11–0.58 during other seasons (Fig. 1b). In 1997/98, Subantarctic skuas *Catharacta antarctica* returned to Marion Island at the end of August and inflicted substantial mortality on the eggs and small chicks of gentoo penguins (Crawford *et al*. 2003d).

For macaroni penguins, no parameter investigated was noticeably different from normal. For rockhopper penguins there were no obvious differences in the number of birds breeding or in breeding success at monitored colonies during 1997/98 (Crawford *et al*. 2003b). However, the mass of chicks at fledging was slightly higher in that season than in any other during the period when measurements were made (Fig. 1c).

Numbers of wandering albatrosses breeding at Marion Island peaked in 1997/98 (Fig. 1d). Numbers of grey-headed albatrosses breeding attained their highest values in 1997/98 and 1998/99 (Fig. 1e, Nel *et al*. 2002).

The count of incubating southern giant petrels in 1997 (2 173) was 48% higher than in any other year between 1996 and 2002. There was no count in 1995, but counts for all years between 1984 and 1994 were higher than in 1997. Overall breeding success was higher in 1997/98 than in any other split year in which it was measured (Fig. 1f, Cooper *et al*. 2001). The count of incubating northern giant petrels was higher in 1997 than in any other year. The overall breeding success was not measured in 1997/98, but survival of chicks in a long-term study was higher in 1997/98 than in any other split year (Fig. 1g, Cooper *et al*. 2001).

In 1997, 388 pairs of Crozet shags bred at Marion Island. This was the lowest number recorded until 2001 (Fig. 1h). It was 100–150 pairs fewer than the number breeding in 1996 and 1998, suggesting that about 25% of the adult population may not have bred in 1997 (Crawford *et al*. 2003e).

In 1997/98, 56 pairs of Kerguelen terns were reported breeding at Marion Island, more than double the maximum for other seasons between 1996/97 and 2002/03 and more than any previous estimate of numbers breeding at the island (Crawford *et al*. 2003c).

Environmental conditions

The mean maximum air temperature at Marion Island during the months June–October 1997 was 1.2°C above the average for the years 1961–1990. In the same period the minimum temperature was about 1°C above average. Temperatures during the months June–October were similarly high in 1996 and 1999, whereas 1998 was only 0.5°C above the 30-year average (Fig. 2).

The satellite-derived SST showed positive anomalies around Marion Island from April to September 1997. SST anomalies for June are shown in Figure 3a. Warm water west of tropical America showed well-developed *El Niño* conditions. By October 1997, anomalously warm water in the south-western Indian Ocean was restricted to the region north of Marion Island (Fig. 3b). At the island the SST was close to the long-term average. South of the island, it was considerably colder than the climatology. *El Niño* conditions in the western Pacific had intensified.

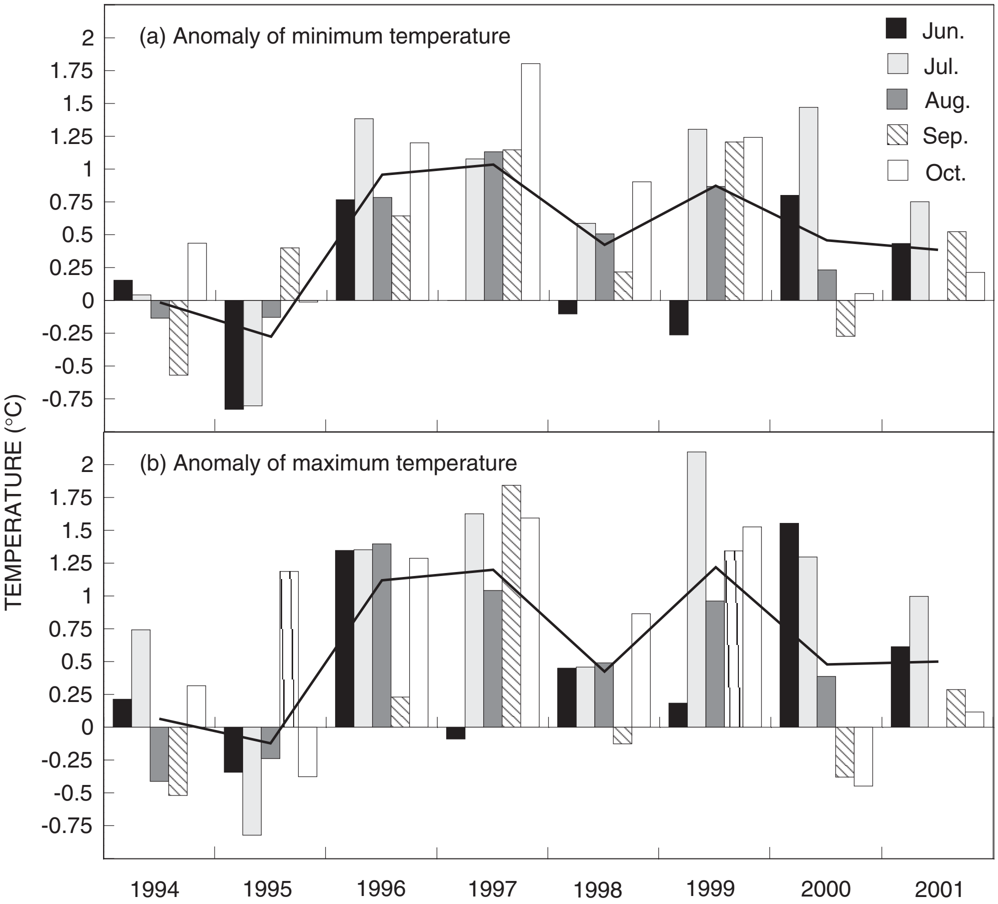

Fig. 2: The anomaly for (a) minimum and (b) maximum surface air temperatures at Marion Island for June–October for each year during the period 1994–2001. The climatic monthly mean temperature used is for the period 1961–1990. The line shows the average anomaly for the months June–October. Information was provided by the Weather Office at Marion Island

DISCUSSION

Information presented in this paper is only that which suggests that some aspect of breeding at Marion Island by the seabirds concerned was unusual in 1997/98. Not all parameters measured for the 10 species considered were necessarily unusual and none was for the macaroni penguin.

For some species, breeding in 1997/98 appears to have been exceptionally good. The number of king penguin chicks surviving to the start of spring in 1997 was considerably more than previously recorded. Greater numbers of wandering and grey-headed albatrosses, northern giant petrels and Kerguelen terns bred in 1997/98 than previously, and more southern giant petrels did so than in any other year since 1994. For southern giant petrels, reproductive success was higher in 1997/98 than in any other year, as was survival of chicks of northern giant petrels. Chicks of rockhopper penguins fledged with a slightly heavier mass than in other years. Conversely, for gentoo penguins and Crozet shags, 1997/98 was a particularly poor breeding season. Gentoo penguins initiated breeding later than usual (Williams 1980b) and fledged few chicks. The number of Crozet shags that bred decreased; probably

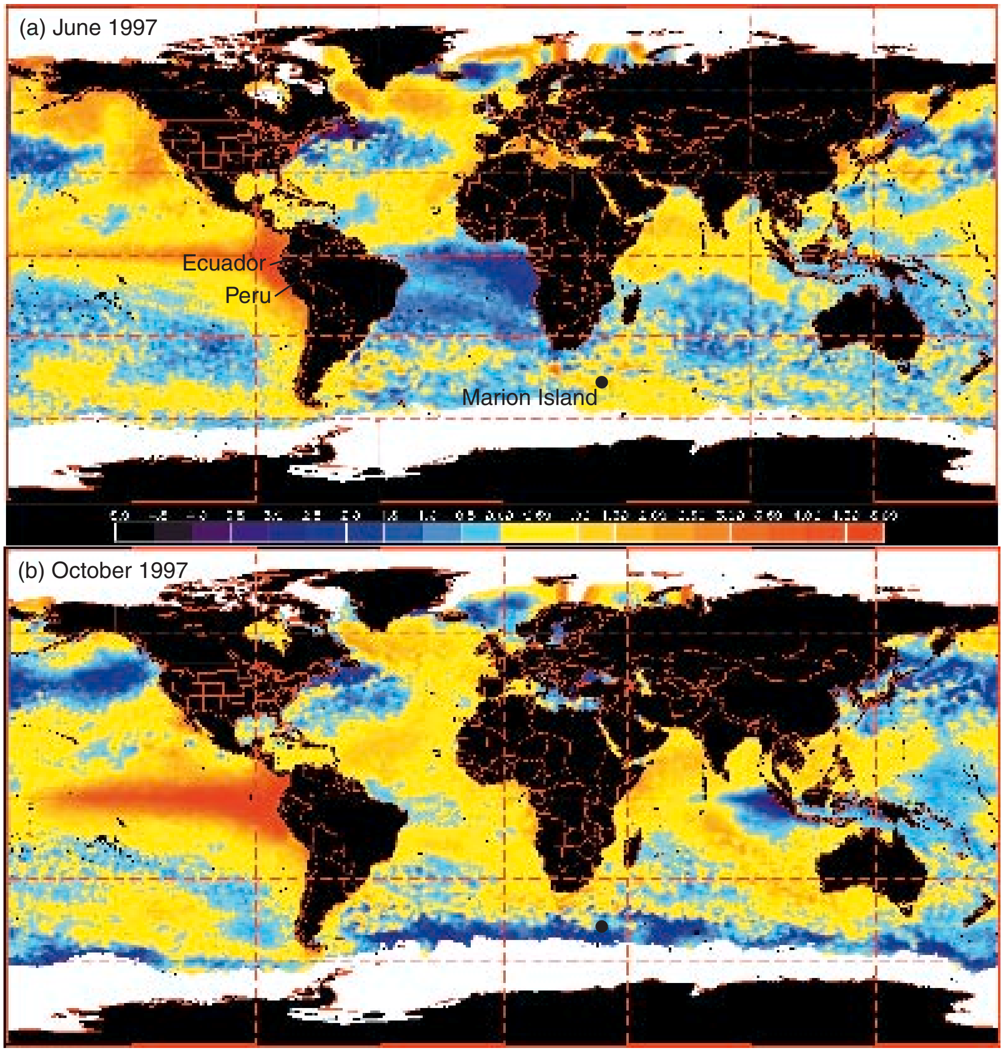

Fig. 3: SST anomalies in the world's oceans in (a) June and (b) October 1997 indicating the location of Marion Island. In June 1997, anomalously warm SST was clearly apparent off the coasts of Peru and Ecuador (*El Niño* conditions). Less marked warm anomalies were also apparent in the south-west Indian Ocean in the vicinity of Marion Island. In October 1997, the *El Niño* conditions had intensified, but the warm anomaly around Marion Island had moderated. The area south of the islands showed anomalously cold conditions. Source: http://www.osdpd.noaa.gov/PSB/EPS/SST/al_climo.html

about 25% of the adult population did not breed.

In 1997, the period July–October was characterized by warmer ambient temperatures than in most other recent years (Fig. 2), perhaps as a result of the anomalously warm SST around the island (Fig. 3a). Similarly in 1999, the period July–October had higher maximum ambient temperatures than other recent years (Fig. 2). The milder climates in 1997 and 1999 may have increased survival of king penguin chicks in the later part of winter. It is estimated that more than 100 000 chicks survived to the start of spring in both these years (Fig. 1a). However, the number of chicks surviving until spring reflects not only survival through winter but survival of eggs and chicks during the early portion of the breeding season as well as the number of pairs breeding in a particular season. At Marion Island, king penguins commence laying from mid November (Cooper and Brown 1990) and there is marked interannual variation in the number of breeding birds (van Heezik *et al*. 1995).

Similar to 1997/98, gentoo penguins also bred relatively late (95% of nests had eggs by 24 July) and had a low breeding success in 1999/00 (Fig. 1b, Crawford *et al*. 2003d). It is uncertain how the warmer climate in these years may have influenced the later than usual start to breeding, if it did. It is possible that the availability of prey organisms around Marion Island was affected. Gentoo penguins feed near the island when breeding. In 1984, the mean foraging range from colonies was 14 km and the maximum 103 km (Adams and Wilson 1987). Inshore fish, especially nototheniids, form a large proportion of their diet during the breeding season (La Cock *et al*. 1984, Adams and Klages 1989). A late start to breeding by gentoo penguins renders their eggs and small chicks susceptible to heavy predation by Subantarctic skuas, most of which return to the island in late August and September (Williams 1980a).

The other seabird with a low breeding effort at Marion Island in 1997/98, the Crozet shag, is also a diving seabird that forages inshore (Cooper 1985). At Marion Island, where it feeds largely on nototheniid fish, there is considerable overlap between its diet and that of the gentoo penguin (Espitalier-Noel *et al*. 1988).

SST anomalies at Marion Island at the close of 1997 and the start of 1998 were higher than any previously recorded (Mélice *et al*. in press a), and may have influenced the unusual nature of breeding by most of the seabirds in the 1997/98 season.

Rockhopper penguins forage 4–157 km (mean 33 km) from Marion Island when breeding, macaroni penguins 59–303 km (mean 178 km, Brown 1987). Both species prey extensively on crustaceans, there being incomplete dietary segregation (Brown and Klages 1987). Breeding by these penguins was normal in 1997/98, except that fledging rockhopper penguins were slightly heavier than usual (Fig. 1c). However, masses of both macaroni and rockhopper penguins on arrival at colonies showed a marked decrease in 1998/99, suggesting a reduced availability of food for these species in winter and early spring 1998. Also, breeding success of rockhopper penguins decreased substantially in 1998/99 (Crawford *et al*. 2003a, b). Macaroni and rockhopper penguins return to Marion Island to breed in late spring between 3 October and 20 November (Crawford *et al*. 2003a, b).

Five of the seabirds that experienced good breeding at Marion Island in 1997/98 (king penguin, both albatrosses, both giant petrels) all have wide foraging ranges (Marchant and Higgins 1990, Weimerskirsch *et al*. 1997). The giant petrels are also predators and scavengers at Marion Island (Hunter and Brooke 1992). When breeding, king penguins at Marion Island have a mean foraging range of 300 km (maximum 900 km, Adams 1987). Grey-headed albatrosses have a mean range of 2 182 km (maximum 4 060 km) when incubating and 722 km (maximum 1 812 km) during early chick-rearing (Nel *et al*. 2000). Their foraging is associated with oceanographic features, including eddies, north of Marion Island when incubating and southwest of the island when feeding chicks. The distance of these features from Marion Island may change with time (Nel *et al*. 2001).

The sixth seabird to experience good breeding at Marion Island in 1997/98, the Kerguelen tern, feeds mainly within 200 m of the island in surface waters and to a limited extent near lakes on the island (Ryan 1987).

All seabirds are not necessarily affected by environmental conditions in the same way but, if food availability influences breeding, species with similar feeding regimes are most likely to be influenced similarly. For example, at South Georgia in years of low availability of Antarctic krill *Euphausia superba*, the reproductive performance of birds that feed on krill (gentoo penguin, macaroni penguin, black-browed albatross *Thalassarche melanophrys*) was reduced, whereas that of birds feeding on fish and squid (wandering albatross, grey-headed albatross) was unaffected (Croxall *et al*. 1988). By contrast, for two penguin species at King George Island, South Shetland Islands, with different winter foraging grounds, the trends in the number of birds breeding were inversely related (Trivelpiece *et al*. 1990).

Of 15 correlations between breeding success and indices of weather for five seabirds at Marion Island, only one was significant at the 5% level (similar to the one in 20 at this level, for which significance might be expected by chance), leading to the conclusion that breeding success was probably more influenced by food availability than meteorological conditions (Cooper and Lutjeharms 1992). In 1997/98, inshore feeders experienced poor breeding, whereas species that were able to forage far from the island bred in large numbers and, when measured, breeding was successful.

There was a strong and unusual ENSO event during 1997/98 that began in April 1997 and attained its first peak in July/August of that year (Wolter and Timlin 1998). Although there were positive SST anomalies in the eastern central Pacific and around Marion Island from April to September 1997 (http://www.osdpd.noaa.gov/PSB/EPS/SST/al_climo.html), this does not necessarily indicate that the warm sea and air temperatures at Marion Island in winter and spring 1997 resulted from the ENSO event. However, anomalous oceanographic events in well-separated parts of the world's oceans are often synchronous (e.g. Crawford *et al.* 1995), as are regimes of fish populations (e.g. Schwartzlose *et al.* 1999). Similarly, ENSO events have a wide-scale influence on seabirds. Their impact on seabirds off western South America has been well documented. Numbers of one or more of Humboldt penguin *Spheniscus humboldti*, guanay cormorant *Phalacrocorax bougainvillii*, Peruvian booby *Sula variegata* and Peruvian pelican *Pelecanus thagus* decreased as a result of mortality and reduced breeding following ENSO events in 1953, 1957/58, 1965, 1972 and 1982/83 (Jordán 1964, Jordán and Fuentes 1966, Tovar 1983, Hays 1986, Tovar *et al.* 1987, Ainley *et al.* 1988, Crawford and Jahncke 1999). The foraging behaviour of penguins (Culik *et al.* 2000) and boobies *Sula* spp. (Jahncke and Goya 2000) was altered.

ENSO events have influenced seabirds in more tropical parts of the Pacific Ocean, for example the Galapagos penguin *Spheniscus mendiculus* (Boersma 1978, 1998), flightless cormorant *Nannopterum harrisi* (Harris 1979), dark-rumped petrel *Pterodroma phaeopygia* (Cruz and Cruz 1990), red-tailed tropic bird *Phaëthon rubricauda* (Schreiber 1994) and black-footed albatross *Phoebastria nigripes* (Ludwig *et al.* 2000). The 1982/83 event influenced seabirds throughout the western Pacific Basin as far north as Alaska (Graybill and Hodder 1985, Ainley *et al.* 1988, Massey *et al.* 1992).

Several studies of seabirds and seals in the Southern Ocean have suggested the possibility that ENSO events may affect their breeding success or survival. Poor breeding success of snow petrels in Adélie Land in 1966/67, 1976/77 and 1983/84 followed the ENSO events of 1965, 1976 and 1982/83 (Chastel *et al.* 1993). Two years of low availability of Antarctic krill to predators at South Georgia (1977/78, 1983/84) each occurred one year after a major ENSO event (Croxall *et al.* 1988). Large-scale oceanographic processes such as ENSO and the Antarctic Circumpolar Wave (ACW) may be responsible for periodic decreases in the availability of food to Weddell seals *Leptonychotes weddellii* and other top predators in the Southern Ocean (Hastings *et al.* 1999). Annual variability in numbers of wandering albatrosses and northern giant petrels breeding at Marion Island was positively correlated with the annual maximum ENSO index (Nel *et al.* 2002).

During the 1982/83 ENSO event, seabirds off California responded to an apparently altered foodweb well before the physical environment there had changed enough to be noted by oceanographers. Conversely, altered breeding success of the black-legged kittiwake *Rissa tridactyla* in Alaska lagged changes for seabirds farther south (that were influenced by the Pacific gyres) by about one year (Ainley *et al.* 1988). Synchronous biological responses to environmental change over well-separated geographical areas are likely to be mediated via the Earth's atmosphere, whereas lagged responses may be mediated through the oceans (Crawford *et al.* 1991).

The anomalous breeding by seabirds at Marion Island (47°S) in 1997/98 coincided with the ENSO event of that period. Warm SST south of the Kerguelen Islands (49°S) occur within a year of ENSO events (Guinet *et al.* 1998). Farther south, at South Georgia (54°S) and Adélie Land (66°S), responses by seabirds have lagged ENSO events by about one year (Croxall 1992, Chastel *et al.* 1993), although at King George Island breeding success of both Adélie and chinstrap penguins *Pygoscelis antarctica* was significantly reduced during the ENSO event of 1982/83 (Trivelpiece *et al.* 1990). To the north, indices of seabird abundance in the Benguela (25–35°S) and Humboldt systems (the latter directly impacted by ENSO events) two years later were significantly negatively related before the initiation of purse-seine fisheries that influenced the food supply for birds in both systems (Crawford and Jahncke 1999). There was an irruption of Southern Ocean seabirds along the South African coast in 1984, one year after the 1982/83 ENSO event (Ryan *et al.* 1989).

Monitoring of seabirds over widespread areas in the Southern Ocean under the auspices of the Ecosystem Monitoring Program of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) has the potential to elucidate further how climatic perturbations operating at a global scale may impact seabirds and seals in the region (Guinet *et al.* 1994). This should facilitate differentiation between changes in predator populations that are caused by the commercial exploitation of prey species, such as Antarctic krill, and those that result from environmental variability.

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In 1997/98 there was unusually good breeding at Marion Island by (clockwise from top) king penguins (photo B. M. Dyer), grey-headed albatrosses, northern giant petrels and southern giant petrels (photos R. J. M. Crawford)