63 Human disturbance and long-term changes in Adélie penguin populations: a natural experiment at Palmer Station, Antarctic Peninsula

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ABSTRACT

Human activities (tourism and research) near Palmer Station, Anvers Island, Antarctic Peninsula, has increased significantly since 1975. Although these activities were focused on the large, easily accessible populations of Adélie penguins on Litchfield and Torgersen islands, Litchfield Island became a Specially Protected Area (SPA) in 1978. This ended tourism on the island and reduced research-related activity to negligible levels. Despite SPA status, the total breeding population of Adélie penguins on Litchfield Island decreased by 43% between 1975 and 1992. In contrast, on Torgersen Island, where tourism and research-related activities continued to increase over the same time period, the decrease in these populations was only 19%. There is increasing concern that tourism and other human activities may adversely impact Antarctic wildlife populations. Although this concern may be justified for some types of human activity, our data suggest that the potentially adverse effects of tourism and research may be negligible relative to the effects imposed by long-term changes in other environmental variables.

Key words: Antarctica, Adélie penguin, tourism, research, human activities, disturbance, population trends.

INTRODUCTION

Human disturbance due to tourism or research has been implicated in the decline of Adélie penguin (*Pygoscelis adeliae*) populations at many localities in Antarctica (Thompson 1977, Muller-Schwartze 1984, Wilson *et al.* 1990, Young 1990, Acero & Aguirre 1994, Woehler *et al.* 1994). Close inspection of some of the long-term demographic data that underpin these implications, however, reveals certain patterns that are inconsistent with the view that human disturbance is the only factor linked to changes in these Adélie penguin populations. These patterns include sharp increases in Adélie penguin populations following the construction of research stations (Young 1990, Acero & Aguirre 1994); asynchrony in the chronology of population change relative to the inception, expansion and abandonment of research stations (Wilson *et al.* 1990); and, most notably, increases and decreases in populations disturbed by humans coinciding with similar changes in undisturbed populations over broad geographic areas and spanning several decades (Stonehouse 1965, Taylor *et al.* 1990, Wilson *et al.* 1990).

Although these patterns do not completely rule out human disturbance as a possible reason for the decline of some Adélie penguin populations (see Wilson *et al.* 1990, Woehler *et al.* 1994), they agree with hypotheses presented by Blackburn *et al.* (1991), Fraser *et al.* (1992) and Taylor & Wilson (1990) that suggest that more complex environmental factors ultimately force changes in Antarctic penguin populations. In this study, we examine long-term population data on Adélie penguins breeding in the vicinity of Palmer Station, Antarctic Peninsula, relative to both exposure to human activity and the implications

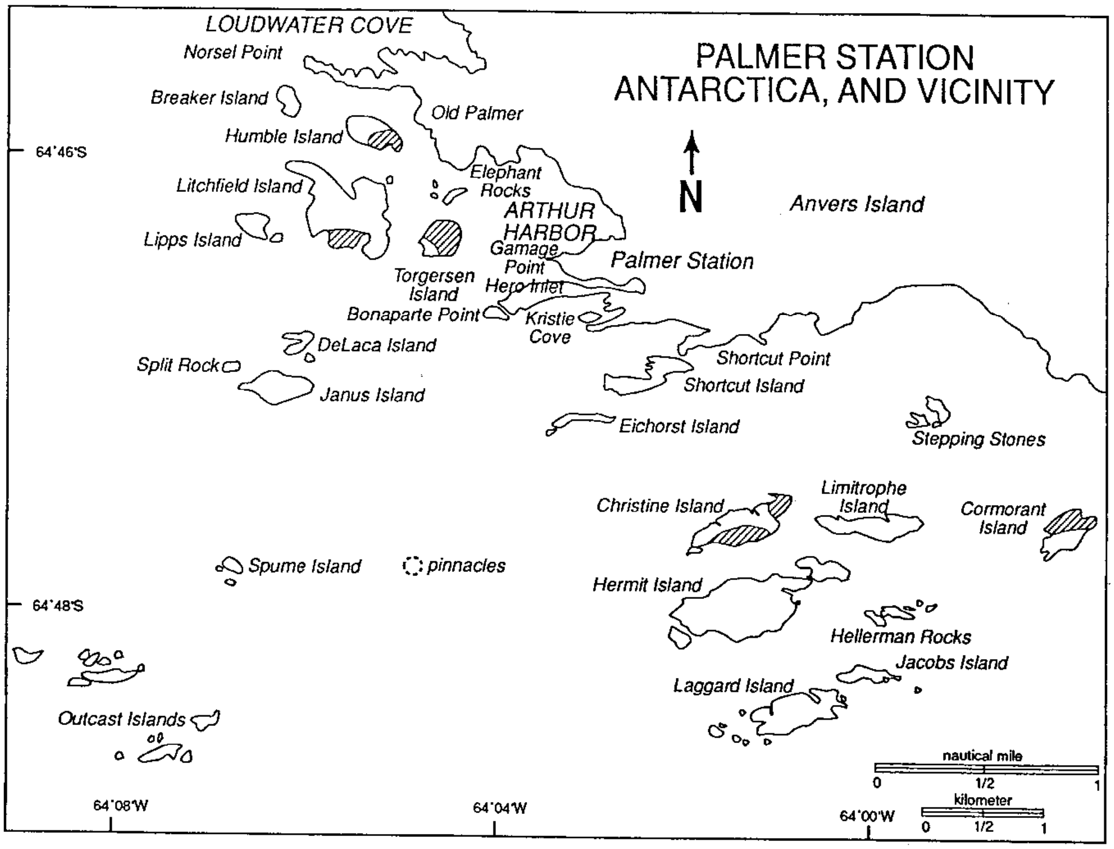

Fig. 63.1. Palmer Station, Antarctica, and vicinity. Adélie penguin colony sites on each island are identified by shading.

inherent in these hypotheses. Three factors make Palmer Station an ideal site for examining the issue of human disturbance. First, Adélie penguin populations near Palmer Station have been exposed to concurrent tourist and research-related activities for more than 20 years. Second, because all colonies occur on islands away from the station, construction activities never altered the availability of breeding habitat. Third, the designation of Litchfield Island (Fig. 63.1) as a Specially Protected Area (SPA No. 17) in 1978, combined with tourist management policies initiated by the US National Science Foundation (NSF) in 1986 and 1990, greatly reduced human access to penguin colonies, thus setting up a natural experiment in which the effects of human activity on penguin populations could be monitored at visited (experimental) and non-visited (control) colonies.

METHODS

Human activity

Data on the number of shipborne tourists visiting the Palmer Station area were obtained from unpublished field records (WRF, 1975–1977) and from information maintained by the US National Science Foundation (1980–1992). Data on the number of support and science personnel at Palmer Station were obtained from unpublished journal notes (WRF, 1975–1977, 1987–1992) and from science and logistics summaries published in the *Antarctic Journal of the United States*, 1975–1992. Additional information on the frequency of landings on the various islands by Palmer Station personnel was obtained from logs maintained at the station for October 1991 – March 1993 on behalf of the NSF when Multiple Use Planning Area (MPA) guidelines were implemented in 1990 (see Results, below).

Adélie Penguin censuses

Data were obtained from published censuses in Parmelee & Parmelee (1987), Heimark & Heimark (1988), Ainley & Sanders (1988), Fraser (1992) and Fraser *et al.* (1993): data for 1975 are based on unpublished records (WRF). In selecting census data, the following criteria were applied: (1) only N_1 counts were considered. These counts denote active (egg or chick present) nest counts with an accuracy of ±5% (see Croxall & Kirkwood 1979). Exceptions were made (1) for large colonies (>1100 pairs) on Torgersen and Humble islands where accuracy was estimated at ±10%; (2) where more than one census was done in a season, the census closest to the 7–25 November period (see item 4 below) was used; (3) no censuses were considered if they

Table 63.1. *Years during which islands in the Palmer Station area occupied by Adélie penguins were open to various human visitors*

Island	Use		
	Tourism	Research	Recreation by station personnel
Litchfield	1975–1978	1975–1992	1975–1978
Humble[1]	1975–1989	1975–1992	1975–1989
Christine[1]	1975–1989	1975–1992	1975–1989
Cormorant[1]	1975–1989	1975–1992	1975–1989
Torgersen	1975–1992	1975–1992	1975–1992

Note:

[1] Islands where tourism was restricted by agreement between the National Science Foundation and tour operators after the Litchfield Island SPA was established in 1978. All tourism and recreation by station personnel ended on these islands in 1989.

occurred after 5 January to avoid the possibility that the creche period had begun; (4) published censuses were used without correcting the data to account for variations in census date and the progressive loss of nests that occurs during the breeding season. Calculating such corrections requires concominant data on annual variability in breeding chronology and mortality, which are not yet well developed for the Palmer Station area, as is true for most of the Antarctic. However, based on the data that are available (censuses and reports by WRF and others in 1975, 1991 and 1992), peak egg laying occurs between 12–21 November and peak hatching between 13–22 December. By peak hatching, 14–16% of the nests in the Palmer area have, on average, been lost. Virtually every census conducted in the area, aside from those by WRF, fall between peak egg laying and peak hatching based on the WRF 1975, 1991 and 1992 data. This would suggest that true breeding populations based on censuses conducted after peak egg laying are underestimated by 14–16%. Censuses in 1991 and 1992 by WRF and others were made during the peak egg laying period and require no corrections, meaning overall estimates of population decrease through 1992 are conservative relative to censuses done in prior years.

RESULTS

Patterns of human activity

Human access to islands populated by Adélie penguins (Fig. 63.1) has been progressively curtailed since 1975, Torgersen Island being the only exception (Table 63.1). Three factors were involved. First, the Litchfield Island SPA was established in 1978, which officially ended most human activity on the island. Second, an unofficial agreement between tour operators and the NSF to protect research sites was reached coincident with implementation of the SPA in 1978. This effectively ended nearly all tourist access to Humble, Cormorant and Christine islands at about the same time. Third, in 1990, guidelines were implemented in accordance with Multiple-Use Planning Area (MPA) management objectives that restricted personnel without permits from landing on islands with large seabird populations during the nesting season (1 October – 1 March).

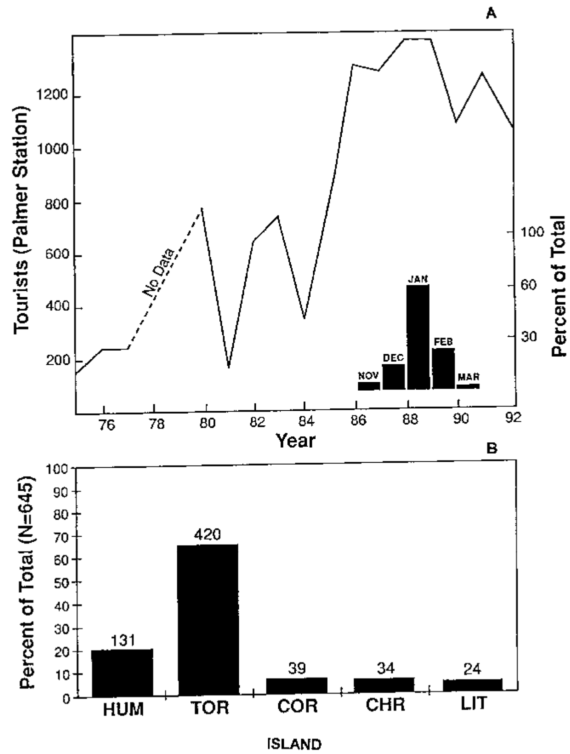

Fig. 63.2. (A) Trends in shipborne tourist landings on Torgersen Island, Palmer Station. Landings by month are shown as a percentage of the total for all years. (B) Landings by island for science and non-science Palmer Station personnel based on data obtained between October 1991 and March 1993. Island codes are HUM (Humble), TOR (Torgersen), COR (Cormorant), CHR (Christine) and LIT (Litchfield).

Trends in the number of shipborne tourists to the area are shown in Fig. 63.2A. During 1975–1977, Litchfield and Torgersen islands were each visited with equal frequency by the same number of tourists (WRF unpublished data). Tourist landings doubled after 1985, and by 1989 only Torgersen Island still remained accessible due to restrictions placed on other sites (Table 63.1). In 1986, the NSF began to limit the number of tourists permitted to visit the area to no more than 1300 annually due to the demands placed on station resources and personnel. A summary of tourist landings by month during 1975–1992 is shown in Fig. 63.2A. In all years, landings occurred primarily during the December–February period, with 60% taking place in January. This period coincides precisely with the peak hatching, growth and fledging stages of Adélie penguins (Fraser *et al.* 1993). Ships typically carried 80–120 passengers, landing groups of 20–40 on Torgersen Island for up to 1 h per group. Visitation frequency increased from one ship every 9–14 days before 1985 to one every 4–6 days beginning in 1986.

There is no historical record comparable to the one presented above for tourist activity that details the frequency with which Palmer Station personnel visited the islands with Adélie penguin populations during the October–March breeding season. In the case of Litchfield Island, however, where access was regulated by permit beginning in 1978 (Table 63.1), it appears that fewer than 35 people entered the site between 1978–1992 (unpublished data based on logistics reviews and the NSF permit offices). Moreover, there is no evidence that any science project working with Adélie penguins on Litchfield Island ever engaged in anything more than population censuses during 1975–1992, suggesting the island was probably visited no more than one to three times a season (see Parmelee & Parmelee 1987, Fraser *et al.* 1993). Use patterns for the island before 1978 cannot be ascertained. However, Palmer Station is small, able to house no more than 43 people. Before 1987, the number of science and support personnel present at the station during the October–February Adélie penguin breeding season rarely exceeded 22 people. Thus, their use of Litchfield Island during 1975–1977 may have been inconsequential relative to the activities of tourists (Fig. 63.2A).

Torgersen Island is currently the most frequently visited of the islands by personnel from Palmer Station (Fig. 63.2B). This pattern was obviously affected by implementation of the MPA guidelines in 1990 (Table 63.1); however, there is reason to believe that such a use pattern would have existed prior to enforcement of the MPA because it reflects two key factors that have not changed since 1975. The first is that the island is close to the station (Fig. 63.1) and holds the area's largest penguin colonies (*c.* 8000 pairs; Fraser *et al.* 1993): what draws tourists to the island also draws station personnel. The second, and perhaps most pertinent factor relative to this study, is that during nearly 18 years between 1975–1992, one to three projects involving two to ten researchers per season have used the Adélie penguin colonies for a variety of studies investigating physiology, behaviour, foraging ecology, demography, chick development and reproductive biology (unpublished NSF records). Because virtually every study has involved serial sampling, the island has been the most intensively used by researchers in the area. In contrast to Torgersen Island, Cormorant and Christine islands are remote and accessible only during good weather, making them poor choices for research sites and of limited use for recreation by personnel in general; the use patterns shown in Fig. 63.2B reflect these qualities and probably also apply to the pre-1975 period. The use pattern shown for Humble Island (Fig. 63.2B) reflects its status as a long-term Adélie penguin monitoring site since 1987 (Fraser & Ainley 1988). Historical use patterns for this island are unknown, but prior to implementation of the MPA it probably received more visits from station personnel in general than it does at present.

Long-term changes in Adélie Penguin populations

As shown in Fig. 63.3, Adélie penguin populations near Palmer Station were at an 18-year high in 1975, and have been decreasing steadily since that time, a pattern noted in other sectors of the Antarctic Peninsula as well (Poncet & Poncet 1987). The large decrease in 1987 corresponds with the disruption of food webs in many parts of the world as a result of altered climate patterns (Croxall *et al.* 1988, Ainley & Boekelheide 1990); it is not yet clear if the large decreases evident in 1992 can be similarly explained. It is notable that despite closure of Litchfield Island in 1978 to virtually all human activity (Table 63.1), penguin populations continued to decrease. By 1992, this decrease represented 388 breeding pairs, or approximately 43% of the pairs present in 1975. On Torgersen Island, in contrast, where the volume of human activity increased dramatically over the same time period (Fig. 63.2A), annual decreases in penguin populations were, on average, of smaller magnitude than the changes for the area as a whole, and quite different than the trends exhibited on Litchfield Island.

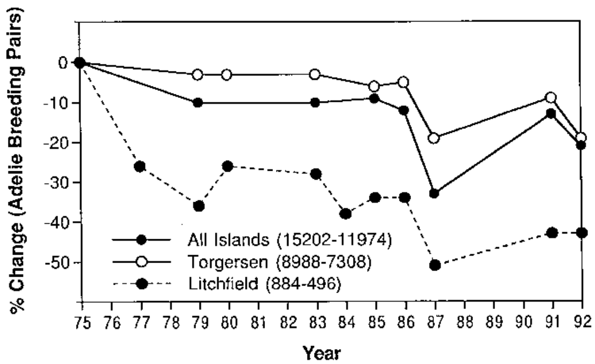

Fig. 63.3. Long-term change in Adélie penguin populations on Torgersen and Litchfield islands, compared with data from all islands, 1975–1992. Numbers in parentheses represent the number of breeding pairs present at the beginning (1975) and end (1992) of the census period. Change is shown relative to the number of breeding pairs present in 1975.

Factors associated with long-term change in Adélie Penguin populations

During 1975–1992, the percentage decrease in Adélie penguins on Litchfield Island was greater than on any of the other islands in the area. Litchfield Island also has the largest number of extinct colonies in the area (Fig. 63.4A), indicating not only that higher numbers of penguins previously bred on the island (Ainley & Sanders 1988), but also suggesting that the decrease in populations started earlier than 1975. Extinct colonies occur on each of the islands currently occupied by Adélie penguins except Humble Island. The most obvious factor characterizing these extinct colonies when compared with currently active colonies is that 86% of them (18 out of 21 total) are located on the southwest side of topographic features >5 m in height (Fig. 63.4B). In contrast, only 17% of active colonies exhibit this aspect. For the Palmer Station area, where the predominant wind direction during storms is from the northeast (Fraser *et al.* 1993), this means that most extinct colonies are situated downwind from, and in the lee side of, high topographic features. On Litchfield Island, the entire penguin rookery (active and extinct colonies) is

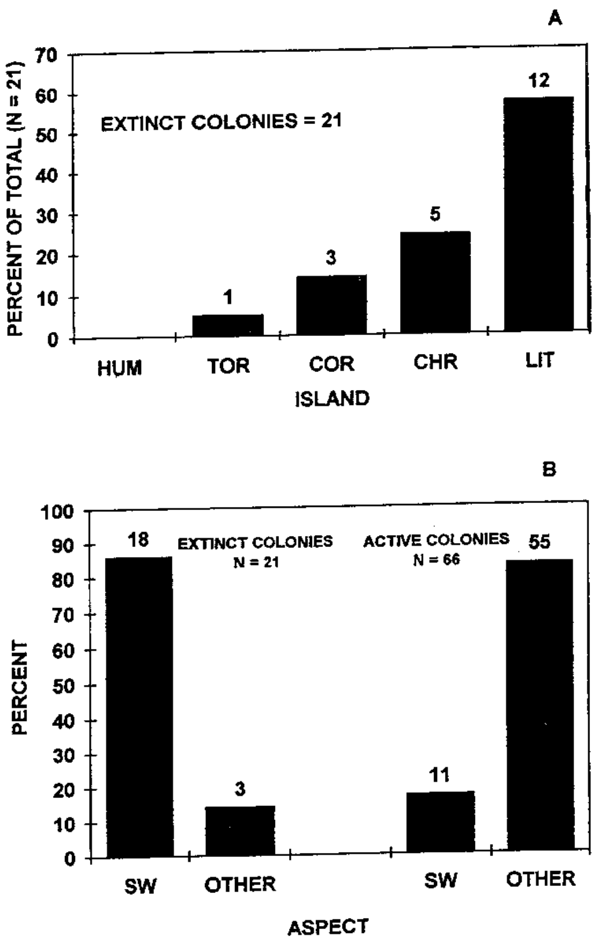

Fig. 63.4. (A) Extinct colonies by island in the Palmer Station area. (B) Aspect (SW=southwest) relative to colony status (active or extinct). Numbers above each bar in both figures are the actual number of colonies present for each category.

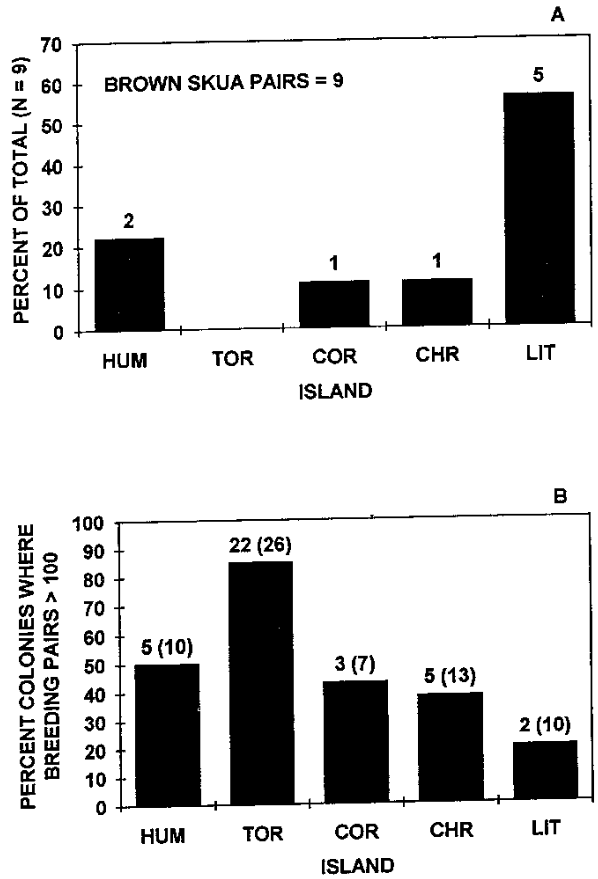

Fig. 63.5. (A) Breeding brown skua pairs by island in the Palmer Station area. Numbers above each bar represent the actual number of breeding pairs. (B) Large colonies (>100 breeding pairs) of Adélie penguins by island in the Palmer Station area. Percentages are calculated for each island. The number before the parentheses is the actual number of large colonies; the number in parentheses is the total number of active colonies on each island.

located on the southwest side of a series of high (60–70 m) rock outcrops. Indeed, nine of the 11 active colonies with a southwest aspect occurring in the Palmer Station area (Fig. 63.4B) are also part of the Litchfield Island rookery. Torgersen Island, in contrast, has no similar topographic features, and colonies are directly exposed to the predominant wind direction. This is also true of most of the other active colonies on the islands (Fig. 63.4B).

A second factor associated with Adélie penguin population decrease on Litchfield Island is the presence of brown skuas (*Catharacta lonnbergi*), which during the breeding season prey exclusively on penguin eggs and chicks (Neilson 1983). As shown in Fig. 63.5A, 56% of the nine brown skua pairs that occur in the area are found on Litchfield Island, a ratio that has persisted since at least 1974 (Neilson 1983), and probably longer. Since 1987, two penguin colonies have become extinct on Litchfield Island (Fraser & Ainley1988). These were small colonies (<30 pairs) within brown skua feeding territories where skuas took every egg and/or chick every season (Fraser *et al.* 1993). Litchfield Island has the smallest percentage (two out of nine total) of large (>100 pairs) penguin colonies of any of the islands (Fig. 63.5B) and the remaining 7 colonies average only 37 pairs (n=7–83 pairs). According to Trivelpiece *et al.* (1980), brown skua feeding territories encompass 90–2011 ($\bar{x}$=1028) breeding pairs of Adélie penguins, suggesting that predation pressure from brown skuas on the Litchfield Island colonies was potentially high even as early as 1975 (884 breeding pairs of penguins, Fig. 63.3).

DISCUSSION

Questions related to the real and potential consequences of tourism and the activities of researchers on Adélie penguin populations are not new to Antarctica (Thompson 1977, Muller-Schwartze 1984). However, the rapid proliferation of these activities since 1970, particularly on the Antarctic Peninsula (Harris 1991, Enzenbacher 1992), has not only forced an extension of these questions to wildlife populations in general, but also coloured them with a sense of urgency and controversy that has polarized the opinions of private industry, scientists, government organizations and environmental groups (Tangley 1988).

In Adélie penguins, the clearest relationships between human activity and potential disturbance have been demonstrated in seasonal short-term studies that have correlated exposure to different types of human activity with changes in physiological, behavioural and reproductive parameters of individual birds (Wilson *et al.* 1989, 1991, Culik *et* al. 1990, Fraser & Trivelpiece 1994). The results of these studies have in general concluded that human activity has potentially negative consequences to Adélie penguins (see Fraser & Trivelpiece 1994). However, support for these conclusions based on data in which human activity has been examined relative to long-term demographic changes has, with rare exception (see Woehler *et al.* 1994), not been forthcoming. In these studies, environmental variability rather than human disturbance has been implicated as being the key factor forcing change in penguin populations (Taylor & Wilson 1990, Blackburn *et al.* 1991).

Different scales of measurement thus appear to offer different conclusions regarding the relative effects of human disturbance on Adélie penguin populations. What may seem obvious over the short-term based on the responses of individual birds does not necessarily correspond with what is observed over the long-term at the colony and population levels. The results presented in this study add further support to this observation. The data shown in Fig. 63.3 suggest a lack of correspondence between island-specific human activity patterns and long-term change in Adélie penguin populations. Despite a six-fold increase in tourist-related activities alone, and the continued long-term use of Torgersen Island colonies for research purposes and recreation (Fig. 63.2A), trends in the Adélie penguin population remained characteristic of changes exhibited by the area as a whole. This was not the case for Litchfield Island, which by 1992 had lost 43% of its penguin population despite a 15-year absence of human activity. Resolving the apparent contradictions in conclusions between short-term and long-term studies may rest on the idea that in order for human disturbance to affect colonies and populations, disturbance must first become pathological (i.e. lead to death or long-term reproductive failure) to the individuals that ultimately constitute these demographic groups. These were the joint observations of a recent workshop that noted and addressed this issue (see Fraser & Trivelpiece 1994, p. 10). Pathological responses of the type that would lead to population declines have not been documented in short-term studies. This suggests that the changes in parameters being measured in response to 'disturbance' may fall within the adaptive range of an individual's ability to deal with environmental stress in general, and not specifically with human activity. For Torgersen Island, this would imply that the types of human activity associated with tourism, research and recreation have not been incompatible with the long-term fitness of Adélie penguins.

The Adélie penguin population decrease on Litchfield Island between 1975 and 1992 (Fig. 63.3) in the absence of human activity suggests that other processes have been involved. Here we propose that the key agents forcing this decline are related to long-term change in the patterns of snow accumulation on the island, combined with the effects of predation by brown skuas. As shown in Fig. 63.4B, 18 of the 21 extinct colonies in the area have a southwest aspect. At Palmer Station, where the predominant wind direction during storms is from the northeast (Fraser *et al.* 1993), snow accumulates on the southwest side of all topographic features. Colony aspect and status (active or extinct) thus do not appear to be the result of random processes. This is further supported by the fact that 55 of the 66 active colonies in the area have aspects other than southwest (Fig. 63.4B). As shown in Fig. 63.1, the entire Litchfield Island rookery is located on the southwest side of the island. Its location is also directly below the island's highest topographic feature (see Results, above). The height of this feature obviously determines how much snow accumulates below it, and, in turn, combined with the effects of temperature, the rate at which the accumulation melts during the season.

Adélie penguins nest only where mounds or ridges provide ground where neither snow nor meltwater accumulate (Wilson *et al.* 1990). The high number of extinct colonies on Litchfield Island (Fig. 63.4A) thus suggests that at some time in the past the availability of these nesting areas coincided with the breeding chronology of the penguins. Fraser *et al.* (1992) have suggested that a warming trend on the Antarctic Peninsula in the last four decades has forced a decrease in the number of cold years with extensive winter sea-ice cover, a pattern recently confirmed by Stammerjohn (1993). Because sea ice blocks the exchange of water vapour with the atmosphere, colder winters with extensive sea ice cover would have potentially resulted in diminished snowfall during the past (Barry 1982, Foster 1989), conditions that would have promoted the availability and use of currently extinct colonies. We therefore suggest that an increase in the frequency of years with open water (Fraser *et al.* 1992) has resulted in a gradual increase in mean annual snowfall in the area, and because of the prevailing wind direction, accumulations are amplified at breeding sites with a southwest aspect. Although a corresponding increase in temperature has occurred, melt rates associated with these sites may simply be inadequate to accommodate the temporal requirements of Adélie penguin breeding chronology. An interesting analogue to the process herein proposed is described in Wilson *et al.* (1990). When the joint US–NZ base was built at Cape Hallett in 1956, snowdrifts that developed down-wind from the buildings covered several small Adélie Penguin colonies. These colonies, initially abandoned, were subsequently recolonized three decades later after the buildings were taken down and natural patterns of wind flow and snow deposition restored.

The decrease in the Litchfield Island Adélie penguin population since 1975 has been characterized by the extinction of small colonies and a reduction in the size of larger colonies (Fraser & Ainley 1988, Fraser *et al.*1993). The latter has involved the coincident processes of habitat loss around colony perimeters due to meltwater accumulation and/or the persistence of snow, and a decrease in the number of breeding pairs. The 'final step' in the extinction process, however, appears to be aided by predation from brown skuas, which are effectively able to remove every egg or chick from smaller colonies. Based on the two extinctions recorded on the island since 1987 (see Results, above), the vulnerable colony size is approximately 25–30 pairs. In both cases, the colonies became extinct (i.e. no adults returned to breed) after two consecutive seasons of complete egg and chick losses. This suggests there is some critical minimum density of breeding adults required to maintain colony viability in relation to predation from brown skuas, although habitat changes associated with other environmental factors ultimately mediate the consequences of predation by brown skuas on Adélie penguins.

ACKNOWLEDGEMENTS

This research was funded by grants from the National Science Foundation, Office of Polar Programs, and by the National Marine Fisheries Service. During 1975–1992, these grants were awarded to one or more of the following individuals: David F. Parmelee, University of Minnesota; David G. Ainley, Point Reyes Bird Observatory; William R. Fraser and Wayne Z. Trivelpiece, Old Dominion University and Montana State University. We thank D. Neilson and B. Showers for help in the acquisition of early data, and support personnel of the US Antarctic Program for logistical support. We are grateful to B. Houston for his commitment to the research during 1991 and 1992, and to E. Stephens and D. Keller for help in data acquisition. Comments by J. Croxall, G. Robertson and E. Woehler on earlier drafts of this paper greatly improved the final manuscript.

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