Effects of Human Activities on Southern Giant Petrels and Skuas in the Antarctic

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1 INTRODUCTION

Areas of true, undisturbed wilderness are rapidly decreasing in the world, and organisms have to adapt to a human-influenced environment with many additional sources of unpredictable events. How animals cope with these changes is a key issue of conservation biology to provide basic data for recommendations towards a more effective management of wildlife in multi-used landscapes.

Even the world's most remote continent - Antarctic - with special habitats for polar flora and fauna, encounters increasing and diversifying human activities. Early exploration by man started in 1772, exploitation of whales and seals followed, and nearly 50 years ago, the era of science began. Until now already 73 research stations have been built by 26 countries (http://www.comnap.aq/comnap/comnap.nsf/P/Stations/), several aerial and marine transport routes for the seasonal supply have been established, and tourism developed.

Sites without permanent ice and snow cover (2 % of the total area) are essential for breeding and resting wildlife, and parallel used and visited by humans. With the establishment of stations and scientific field sites, spatial conflicts occurred. Although mainly on a local scale, population dynamics, habitat structure, food chains and distribution of organisms have been affected over many years (e.g. Culik and Wilson 1995, Giese 1996, Harris 1991b, Naveen 1997, Naveen 2003, Wilson et al. 1990, Wilson et al. 1991, Woehler et al. 1994, Woehler et al. 2001).

Human-influenced changes on the population level are difficult to assess in long-living animals, as the variety of natural factors can not be fully measured to evaluate the relative impact of anthropogenic activities. But a combination of behavioural and physiological investigations on the individual level and a survey of population parameters can yield information about direct responses of animals to changes in their environment, and consequences at a larger scale.

The environment around an individual changes frequently, but only some events will be perceived as threat. The term ‘stress’ is widely used in this context, but there is no generally accepted definition (Møller et al. 1998). Cannon (1929) studied the reaction of animals to critical situations in their environment and found a mosaic of changes in their body functions (referred to as 'Fight or Flight Syndrome'). Selye (1950) introduced the term ‘stress’ as a non-specific response of the organism to any strong and potentially damaging *stimulus* (*stressor*) and described the 'General Adaptation Syndrome' (Selye 1936, Selye 1952). Thereafter, an organism reacts in the same pattern of physiological responses for the purpose of adaptation to a new situation (three stages: 1. alarm reaction, 2. stage of resistance, and 3. stage of exhaustion).

Environmental stressors are divided in natural and anthropogenic. *Natural stressors* include physical and chemical characteristics of the environment (e.g. temperature, water/drought, storms), factors occurring within a species (population density, predation, breeding) and between species (resource availability, pathogens, predation). *Anthropogenic stressors* include for example pollution, noise, visits, handling, captivity, transportation, translocation and global warming (Toates 1995).

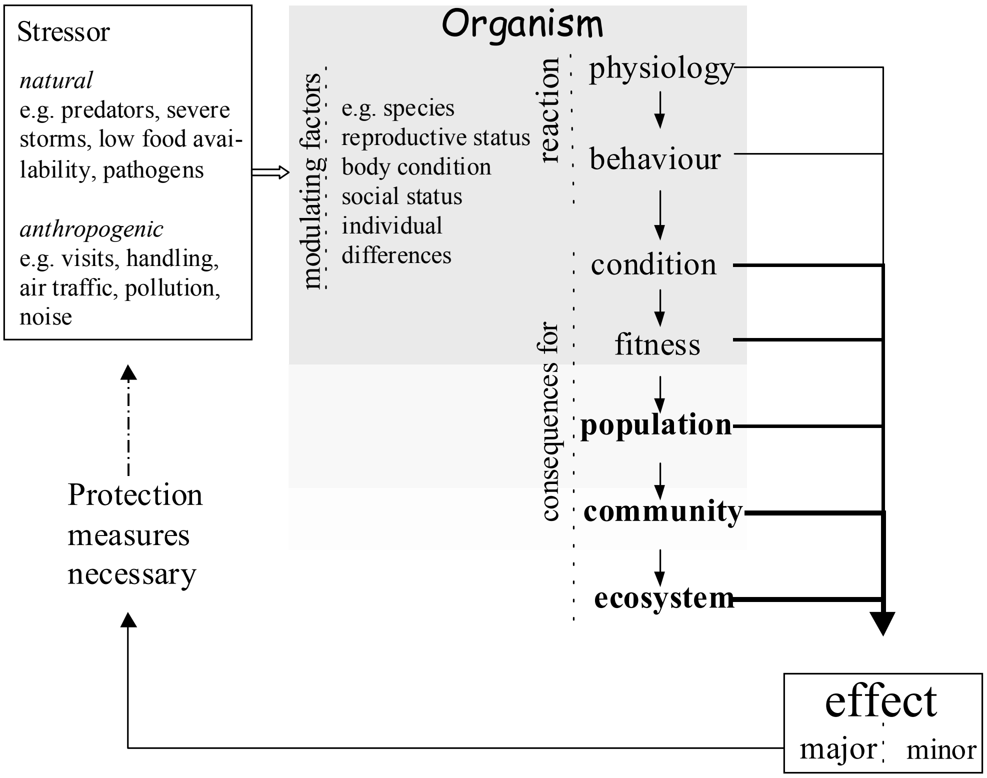

Figure 1.1. Schematic diagram of individual responses to environmental stressors and the consequences within the ecosystem. In cases of major adverse effects on wildlife, management approaches aim for the reduction of stressors (modified after Stock et al. 1994).

It exists a variety of stress concepts which use different criteria. A system view discussed in Toates (1995) is able to link environmental stimulus, organismal state, and organismal response in the context of stress (Fig. 1.1). The organism perceives changes in the environment as a potential threat to the internal homeostasis. It follows an evaluation of the success of potential internal and external actions to restore homeostasis. The individual response is modified by species and state-dependent factors and can, if without compensating result, lead to negative consequences for the organism. Nest desertion, abandonment of the colony site, reduction in hatching or breeding success, deaths of individual adults or reduction of local, regional or total populations are visible changes that can be interpreted in relation to certain stressors. Management activities to reduce (potential) stressors and/or their effects will only be initiated, when impacts on populations and communities occur or are expected to occur (precaution principle).

A problem of field studies lies in the identification of pre-pathological states such as physiological (heart rate or hormone increase) or behavioural changes (leave of the nest and return after a stimulus has ended). These direct responses to human activities, which are not inherently important, need to be considered in terms their relative importance (Nimon and Stonehouse 1995).

In this study, I compare the magnitude of bird reactions to human stimuli relative to responses to natural stimuli. An anthopogenic stressor would be considered equivalent to a natural stressor, if an organism's response to the two was similar or identical (Hofer and East 1998).

Conservation biologists and wildlife managers have used repeatedly the predation theory (Lima 1998, Ydenberg and Dill 1986) to study the effects of human activities on wildlife (Fox and Madsen 1997, Fernández-Juricic and Telleria 2000, Gill et al. 1996). Because closely approaching predators are life-threatening to adults and/or offspring, they are a natural stressor. If wildlife reacts to approaching humans in a similar way, the behaviour can be used to understand and predict the responses of individuals and populations to human stressors (Knight and Gutzwiller 1995). In this line, alert and fleeing distances (the distance between animal and approaching person, when it first becomes vigilant or leaves the site) found their application in the establishment of buffer zones and minimum distances in protected areas (e.g. Bélanger and Bédard 1990, Burger 1998, Fernández-Juricic et al. 2001, Rodgers and Smith 1995).

As physiological parameter, the heart rate has been often used for the registration of acute stress situations (e.g. Culik et al. 1990, Gebauer et al. 1989, Salwicka and Stonehouse 2000, Weimerskirch et al. 2002). Furthermore, glucocorticoids ('stress hormones') are increasingly secreted under a potentially threatening event. They are, therefore, considered as another useful indicator for a physiological response of animal to changes in its environment (e.g. Buchanan 2000, Silverin 1998, Wingfield et al. 1998).

One coping strategy to minimise the effect of a stressor is to habituate (Scott et al. 1996). *Habituation* is the gradual decline in the behavioural response as a result of repeated stimulation which is not followed by any kind of reinforcement (e.g. Hinde 1970).

1.1 Study Objectives

Detailed behavioural and physiological studies in the Antarctic concerning human activities have been concentrated on penguins (e.g. in respect to scientific work: Wilson et al. 1989, to visits: e.g. Giese 1998, Nimon et al. 1995, and to air traffic: e.g. Culik et al. 1990, Giese et al. 1999). The results found their implementation in widely used visitor and air traffic guidelines. However, minimum distances to other species have been only based on observations and anecdotal evidence. The rise in scientific and tourist activities in the Antarctic paired with an ongoing concern about the sufficiency of existing management programmes requires more species and site-specific studies and the revision of the effectiveness of existing guidelines (e.g. ATCM 2003, ATCM 2004b, Davis 1998).

Southern giant petrels *Macronectes giganteus* have been characterised as a highly sensitive species in terms of human disturbance, as nest site shifts and populations declines have been observed near stations (Chupin 1997, Naveen 2003, Peter et al. 1991). In contrast, brown skuas *Catharacta antarctica lonnbergi* and south polar skuas *C. maccormicki* breed closer to human infrastructure, partly use station food waste, and show stable or increasing population trends. They are, therefore, considered less sensitive to human activities. However, no detailed studies on the individual level have been carried out so far to document the extent of human impact and to show local habituation effects or sensitive breeding areas.

This thesis aims for a comprehensive assessment of physiological and behavioural response spectra of southern giant petrels and skuas to various anthropogenic stressors. Birds with different experience of human activities on the Fildes Peninsula (King George Island, South Shetlands, Antarctic) and surrounding islands have been compared particularly in terms of their response to visits and air traffic.

In a quantitative and experimental field work approach, non-invasive methods have been applied to minimise the investigator effect. Behavioural changes of the birds provided the basis for the assessment of effects of natural and human stimuli. Approach experiments (measuring alert and fly-off distance, aggression etc.) were combined with video recordings without presence of the investigator. Physiological measurements of heart rate and corticosterone-metabolites in the faeces of birds complemented the study to show responses that may or may not resulted in behavioural changes.

Following stimuli were tested:

- investigator visits at distances ranging between 0 and 100 m
- visit types: stand, walk near the nest, sit with obvious movements, and sit calmly
- repeated visits
- air traffic (regular and irregular flight routes)
- visits and air traffic occurring simultaneously (cumulative effect)
- simulation of a helicopter flight by playing helicopter sound (range 55 to 85 dB(A))
- simulation of helicopter and talking of a person (cumulative effect)
- road traffic
- natural stimuli (interaction with conspecifics or predators) for the comparison with human activities

To identify a human stimulus as a stressor, I compare the response strength of the birds to human and natural stimuli. All human stimuli that cause physiological and/or behavioural responses of studied animals similar to or higher than the responses to natural stimuli will be interpreted as current stressors. Under consideration of the relative importance of responses (on the individual or population level), the results will be the basis for management guidelines.

Main Questions and Hypotheses

- Are long-term habituation effects visible in behaviour and physiology?

Behavioural and physiological responses of southern giant petrels will vary with the amount of human experience. Birds that breed in areas of low human activity will react stronger to any presented human stimuli than birds used to more frequent exposure. In skuas, this effect is expected to be less pronounced, because their sensitivity to human activities is lower.

- What are current human stressors for southern giant petrels and skuas on the Fildes Peninsula and the surrounding islands?

Visits to the nest are expected to cause stronger physiological and behavioural reactions of the animals than air traffic due to a closer distance between source and receiver and less predictability.

- Do both skua forms behave differently towards human stimuli?

Brown skuas seem to be more associated with stations. Therefore, weaker behavioural and physiological responses are hypothesised for visits in areas of high human activity compared to south polar skuas.

- Do repeated tests of stimuli on the study birds result in short-term habituation?

Repeated visits and simulations will result in lower responses over time in both southern giant petrels and skuas. Particularly birds in areas of high human activity should habituate fast to repeated stimuli.

- What minimum distances should be established for southern giant petrels and skuas concerning visits and air traffic?

The closer the visit and air traffic, the stronger the behavioural and physiological responses of southern giant petrels and skuas will be. Threshold-distances at which the bird's response to human stimuli exceed reactions to natural stimuli will be assessed.

- Which breeding sites are adversely affected by human activities and what management is necessary?

A comprehensive assessment of the temporal and spatial extent of human activities and their impact on breeding birds in terms of physiology, behaviour, and breeding parameters will result in species and site-specific management recommendations.

Chapter 2 introduces the study sites, their spectrum and intensity of human activities, and the study species. Chapter 3 and 4 deal with behavioural and heart-rate responses of southern giant petrels and skuas to station, scientific and tourist activities. Chapter 5 presents the results of the faecal hormone analyses of the species studied. Data to breeding pair numbers, nest distribution, and breeding success are discussed in chapter 6. The next chapter presents the risk assessment and management recommendations for southern giant petrels and skuas on the Fildes Peninsula and surrounding islands based on the study results, and outlines broader use throughout the Antarctic. Chapter 8 reports of a short study on the tourist site Penguin Island. Behaviour and heart-rate measurements on southern giant petrels and skuas have been used as indicators in the assessment of tourism effects. The final discussion and outlook are given in chapter 9.

2 STUDY AREA AND SPECIES

2.1 Study Area

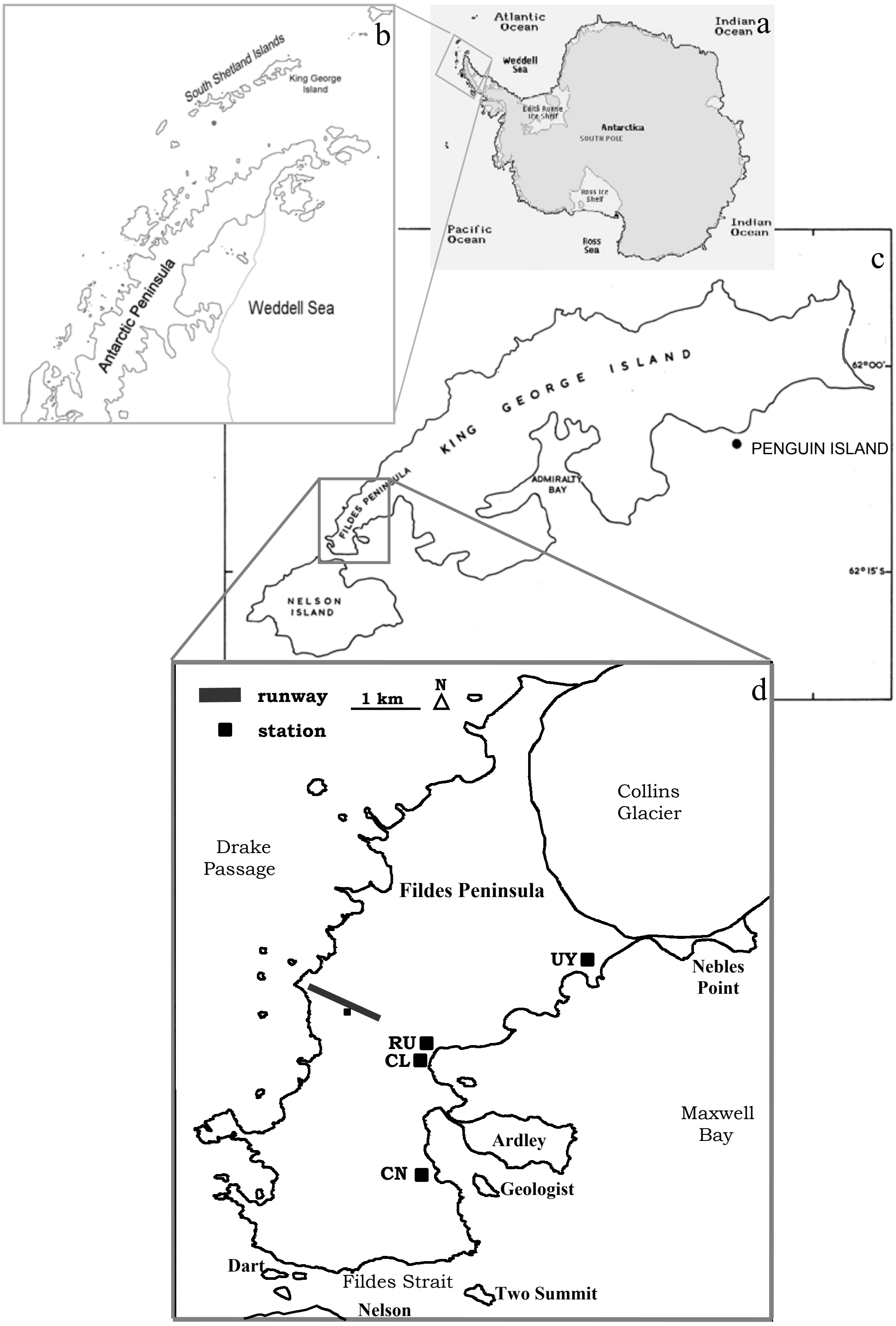

Figure 2.1. Map of a) Antarctica, b) the Antarctic Peninsula and c) King George Island as part of the South Shetland Archipelago in the maritime Antarctic. On Fildes Peninsula (d) are situated the Chilean (CL), Chinese (CN), Russian (RU), and Uruguayan (UY) stations.

I carried out my main field work on the Fildes Peninsula of King George Island (62°12' S, 58°58' W) and on the surrounding islands Ardley, Dart, Geologist, Nelson and Two Summit (Fig. 2.1d). My investigations took place from 20 Dec 2000 to 27 Jan 2001, 16 Dec 2001 to 16 Feb 2002, and 19 Nov 2002 to 27 Feb 2003. I also made short visits of 7-10 days to Penguin Island (Fig. 2.1c) in January and December 2000. Throughout the thesis, I represent a season by the second year (e.g. 2000 to 2001 written as 2001).

2.1.1 Human Activities

National Program Members

Since the 1960s, human activity in terrestrial Antarctic ecosystems has increased considerably because of the expansion of research stations. The concentration of energy and waste production, transport, air traffic, scientific and leisure activities around these stations has led to local environmental problems (e.g. Emslie et al. 1998, Harris 1991a,b, Harris 2000, Green and Nichols 1995). Especially in recent years, these problems have stimulated the implementation of intensive management of research and historic sites, the expansion of the protected area system, establishment and monitoring of clean-up programs, recycling, and impact studies (e.g. ATCM 1999, Cohen 2002, SCAR 1993).

Six nations have built stations and field huts on the Fildes Peninsula and Ardley Island since 1968 (Tab. 2.1).

Table 2.1. List of existing stations and *field huts* on the Fildes Peninsula and their capacity (data from Council of Managers of National Antarctic Programs COMNAP : http://www.comnap.aq).

operating nation	name of station or field hut	opened in	population		used during study period
			summer	winter	
Argentina	*Ballve*	1954	4	-	no
Brazil	*Padre Rambo*	1986	6	-	no
Chile	Professor Julio Escudero	1994	20	-	yes
	Presidente Eduardo Frei	1969	150	80	yes
	Julio Ripamonti	1982	4	-	yes
	Refugio Ripamonti	1981	3	-	yes
China	Great Wall	1985	40	14	yes
Russia	Bellingshausen	1968	38	25	yes
	Priroda	1987	2	-	yes
Uruguay	Artigas	1984	60	9	yes

Of a maximum 327 summer station members, 5 to 15 are scientists frequently working with birds and mammals near the stations and huts. International co-operation and separation of study objectives reduces overlapping field work activities on the same populations, but cumulative impacts exist because the area is very small.

All station members are permitted to walk freely over the Fildes Peninsula in their leisure time, and are only asked to give notice for safety reasons. They are supposed to receive a briefing from their national authority on recommended behaviour near wildlife. I have repeatedly observed violations of these recommendations. Breeding sites close to stations are frequently visited (weekly to daily) whereas remote sites of southern giant petrels and skuas are only infrequently visited by scientists and station personnel (at most ten times per season).

Ardley Island is designated as an 'Antarctic Specially Protected Area' (ASPA Nr. 150, before Site of Special Scientific Interest 33) because of its high species diversity and scientific value. The management plan limits access to scientists with permission from their own national authorities or visitors who give prior notice to Chilean scientists working at the site. Of especial scientific interest and also favourite visitor destinations are the large breeding sites of Adélie, chinstrap and gentoo penguins on Ardley Island. Therefore, a tourist zone was established on the northern site of Ardley Island next to the penguin long-term monitoring sites. This subdivision reduced cumulative visitor effects on wildlife and the interference of leisure activities with scientific work. Station personnel visited the penguin colonies one to five times per week during the chick rearing period (less before) and the majority followed the access regulations. Between 2000 and 2003, scientists worked for several months in the northeastern penguin colonies, the southeastern breeding groups of the island were only visited a few times per season. Southern giant petrels and skuas breeding near paths experienced nearly daily visits, whereas remoter breeding sites on Ardley were visited once per week.

Access to the ice-free islands Dart, Geologist, and Two Summit is permitted but during the study period scientific work took place only during favourable weather conditions (up to eight times per season). Additionally, a few station members fished near these islands. The northern part of Nelson Island is separated from the rest of the island by a glacier and was treated as a single separate study site. One small field station of the Czech Republic is used by up to five people every summer, who occasionally visited the study site but the exact number of visits is unknown. There, scientific work took place up to five times per season.

Tourism

An increasing number of tourists visit the Antarctic for its unique nature and for the experience of true wilderness (IAATO 2004). Areas like the Fildes Peninsula are in this aspect not particularly attractive, as their scenic value is spoiled by station infrastructure, waste sites and concentrated human activities. Nevertheless, Antarctic voyages include the presentation of scientific work and historical sites, so that suitable stations receive frequent visits by tourist groups. The Fildes Peninsula is primarily approached by tourist vessels in cases of emergency in order to fly out ill passengers or to transport scientists to their study sites. Therefore, visitor numbers have fluctuated over the past 14 years (official counts Fig. 2.2). Nevertheless, my experience during the three seasons, I spent in the region, suggests that the real number was higher. One reason is that air-based tourism was not recorded before 2004, and at least one ship was landing tourists in the 2001 season.

AEROVIAS DAP (Chile) was flying small tourist groups into Fildes Peninsula during the study period. These groups stayed in the airport hotel or stations for one to seven days and went out daily to view wildlife, make films, or practised climbing, glacier walking, and hot-air balloon flying. In respect to impact on wildlife, the activity type, spatial and temporal site use are more important than the tourist numbers as such. However, this information is rarely obtainable.

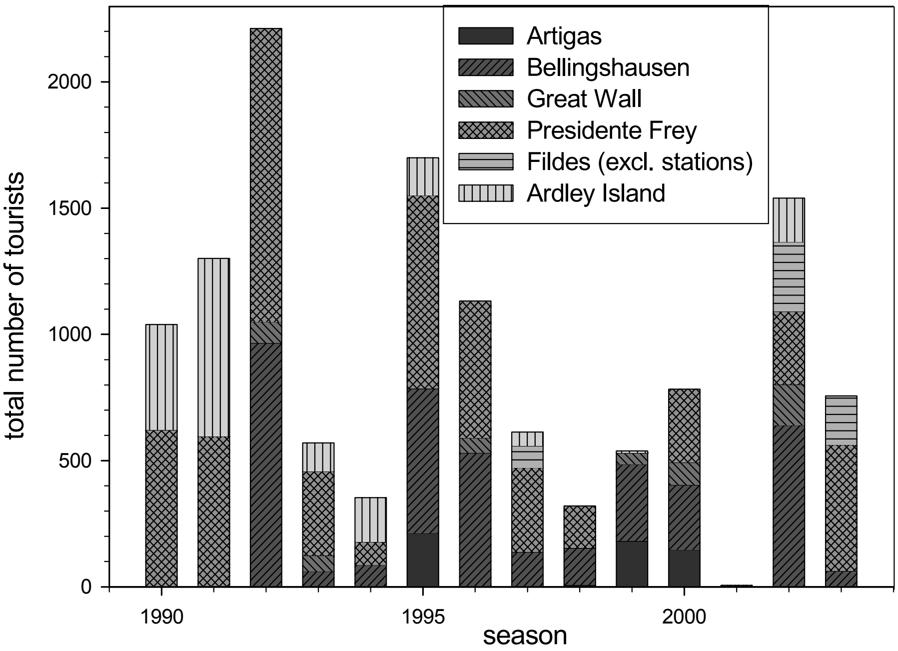

Figure 2.2. Documented number of tourists visiting sites on Fildes Peninsula (with separate records for stations) and Ardley Island. Compiled by the Association of Antarctic Tour Operators and National Science Foundation, US). Season: 1990 means summer months 1989/90.

In addition, I have noticed that there has been an increase in the number of governmental visits to stations with short wildlife tours, helicopter sightseeing or transfer to ships in recent years. However, the number of these visits has not been recorded.

Air Traffic

Presently, nine nations use the airport on the Fildes Peninsula (built in 1980) for transportation of people and cargo to and from the Antarctic, and their distribution to the ships and stations (Tab.2.2). Because there exists no accessible comprehensive monitoring of flight activities, I recorded all my sightings throughout the study and estimated the flight routes (missing a few remoter flight activities due to the large area). The number of flights of the aeroplane type Hercules C-130 was similar during the three seasons. Helicopter flights increased four times over two years which is especially relevant to local breeding sites (e.g. on Ardley Island, Fig. 2.3). The number of small planes (e.g. Twin Otter, Beechcraft KingAir, Dash-7) transferring people and cargo to the Antarctic Peninsula or tourists to Fildes Peninsula increased slightly. Tourist over-flights (type 'Boeing') are not numerous, and due to their altitude, of minor concern for wildlife disturbance. Beside the use of standard flight routes, Hercules and helicopters were observed repeatedly near Ardley, Dart, Geologist, and Nelson Island at low altitudes close to breeding sites (Fig 2.3). Published data of passenger numbers on Hercules and small planes range between 558 and 1537 passengers per year (statistics between 1997 and 2003, source: Dirección General de Aeronáutica Civil, www.dgac.cl/). Airport flight lists add up to higher numbers, than these published ones. The reasons for this inaccuracy are unknown.

Table 2.2. Summary of flight activities around Fildes Peninsula. Presented data between 20 December and 20 January 2000 to 2003.

	2001	2002	2003
total flights Hercules C-130	27	23	30
helicopter	27	61	131
small planes	21	27	29
number of flight days per period (%)	65.6	62.5	71.8
number of tourist flight days per period (%)	26.3	9.1	27.5

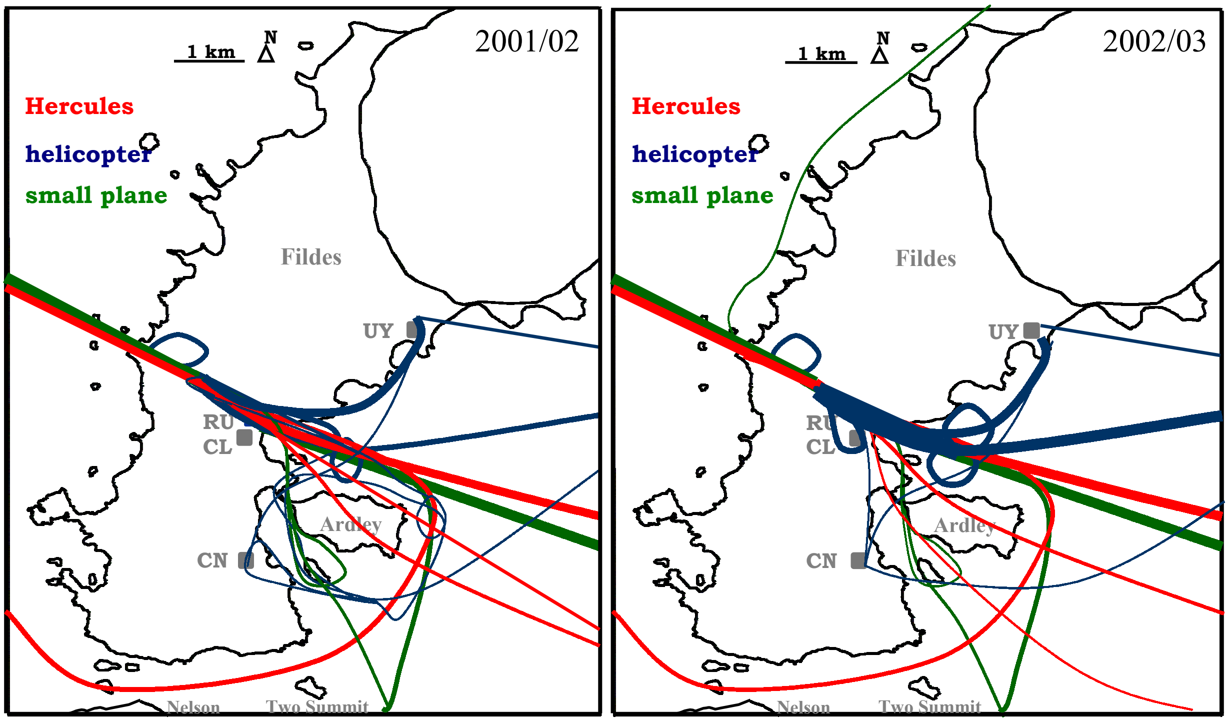

Figure 2.3. Map of flight activities of large aeroplanes (type Hercules C-130), helicopters, and small planes around the Fildes Peninsula in seasons 2002 and 2003. Thickness of lines represents flight frequency along routes. The presented routes are drawn from observations not from measurements.

Marine Traffic

A major part of station logistics and of tourism in the Antarctic is ship-based, so that Maxwell Bay is an anchorage point for supply, scientific, tourist and military vessels. I recorded up to eight supply and research vessels each season. Each of these spent one to four days in the bay, transferring cargo between airport and ship using helicopters and small boats. Throughout the study, I observed four military ships repeatedly anchoring in the bay. Up to ten tourist vessels and five yachts landed passengers and scientists, usually leaving the area within one day. Overall, at least one ship was in the bay on 8 to 19 days/month, and zodiac traffic occurred on 12 to 21 days/month.

Sound Levels

Air traffic and visits are not only visually perceived by the breeding birds but also acoustically. The *ambient noise* (background noise arising from wind, organisms, or sounds of engines in stations that is not of direct interest during a measurement or observation) can be very high (30-100 dB(A)) especially inside breeding colonies or on windy days. I measured short-term sound levels from aircraft, land vehicles, boats and people near nesting sites (sound meter Voltcraft 322). Human sources were up to 40 dB higher than ambient noise, that could have an adverse effect on wildlife (Richardson and al. 1995, Tab. 2.3).

Table 2.3. List of received maximum sound levels of objects measured in bird breeding sites on Fildes Peninsula and Ardley Island. Presented data were measured with sound meter (Voltcraft 322).

object	distance to birds in m	n	sound level in dB(A)		
			mean ± S.D.	max	min
Hercules	< 1000	32	73.2 ± 7.14	98.4	60.1
helicopter	< 1000	41	76.9 ± 8.91	90.2	57.0
small planes	< 1000	5	58.9 ± 6.15	62.7	48.1
track vehicle	< 100	1		77.4	
zodiacs	< 100	2	81.4 ± 9.90	88.4	74.4
researcher	< 50	3	61.4 ± 4.41	66.0	57.2
bird calls	< 50	10	65.4 ± 14.56	102.0	50.0

Definition of Areas within this Study

For the thesis, I distinguished broad area types in terms of the birds' experience with human activities before the actual start of my studies. If breeding birds have been and are exposed to frequent visits (including scientists, station members in free time and tourists) and/or breed closely to main aircraft flight routes (≤ 500 m), then the area was defined as an *area of high human activity* (A_{high}, Fig 2.4). In contrast, in *areas of low human activity* (A_{low}) birds receive only scientific visits (0-10 visits per season) during the season and infrequent air traffic. A_{medium} represents a southern giant petrel breeding site on Ardley Island that receives few visits but is close to the main flight route.

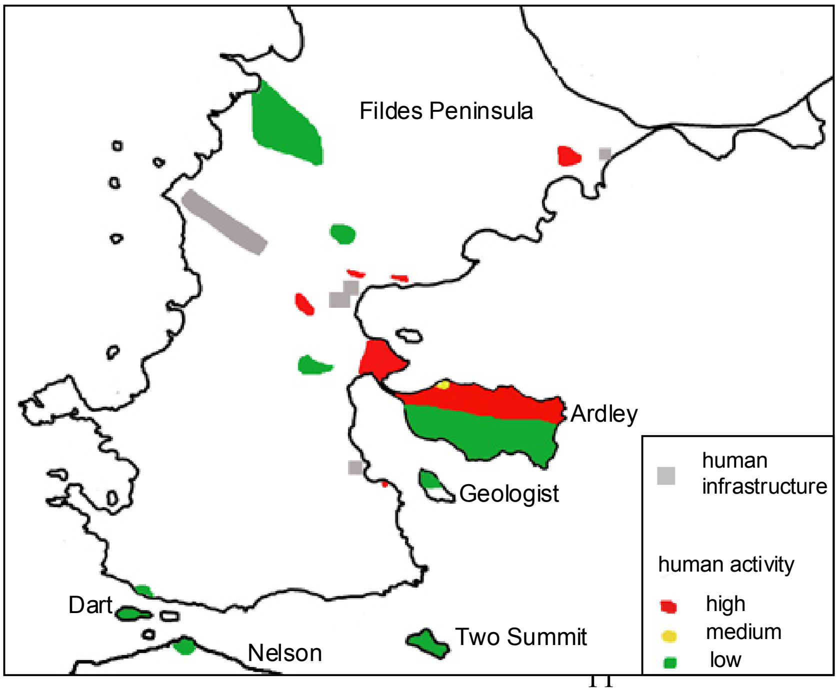

Figure 2.4. Map with study areas on the Fildes Peninsula and surrounding islands. Classification of study areas of low (green), medium (yellow) and high (red) human activity. Definition by the frequency of received visits and air traffic within 500 m.

2.1.2 Relative Importance of Stressors

For effective long-term management of a site, management objectives must be defined, and variations in sensitivity and vulnerability need to be recognised. I developed a conceptual model of human activities on Fildes Peninsula (Fig. 2.5). It shows potential stressors that occur as a result of actual human activities and their likely ecological effects on the assessment parameters.

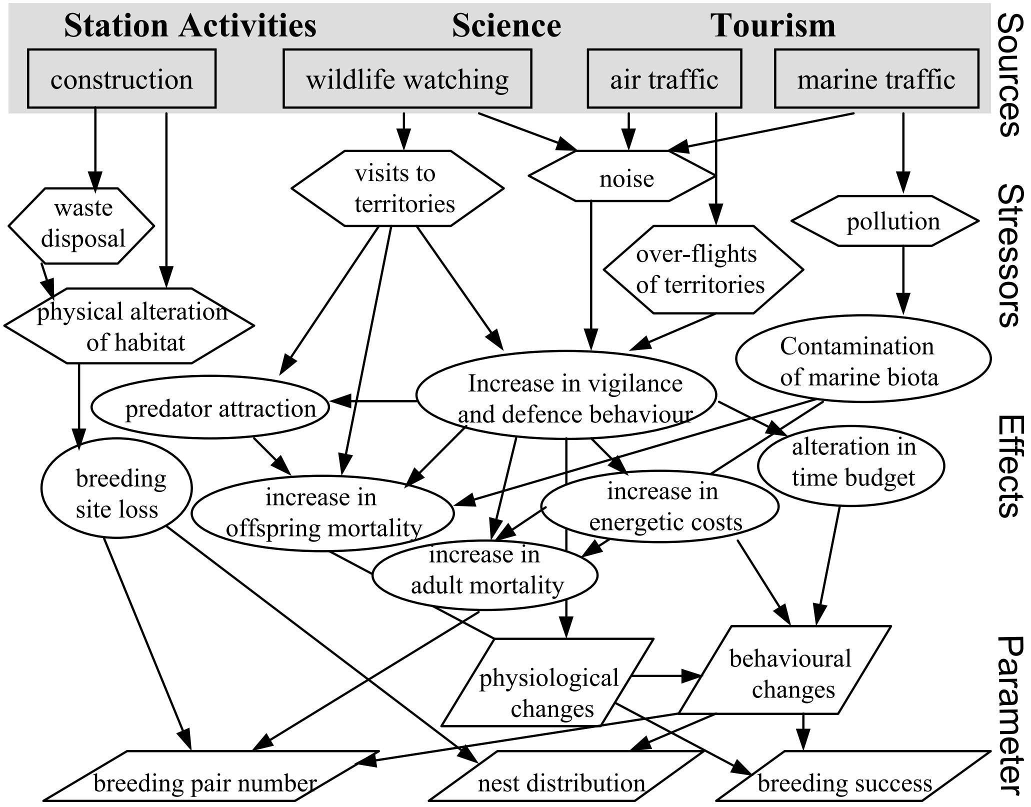

Figure 2.5. Conceptual model used for the risk assessment. Bold items are human activities. Rectangles represent sources of stressors, hexagons are potential stressors, ellipses represent effects of those stressors, and trapezoids indicate parameters that are affected (modified after Serveiss et al. 2004).

To evaluate the urgency of certain management tasks, the stressors had to be ranked in terms of their potential risk to wildlife (Tab. 2.4). I made scores ranging from minimal (1) to severe effects (3), based on best knowledge before the study. The scores were summed across the parameters to develop a cumulative ranking for each stressor. In chapter 7, the assumptions are discussed according to the study results.

Table 2.4. Assumptions about characteristics of stressors and their effect on different parameters on the Fildes Peninsula and surrounding islands (modified after Serveiss et al. 2004, 1 = minor, 2 = medium, 3 = severe, e.g. 1-3 means that it can range depending on stressor characteristics).

stressors	waste disposal	alteration of habitat	visits to territory	noise	over-flights of territory	pollution
stressor characteristic						
intensity	1	1	1-3	1-3	1-2	1
extensiveness	1	1	2	1-2	1-2	1
likely increase over time	1	1	2	1	1	1
sum	3	3	5-7	3-6	3-5	3
parameter						
physiological change	1-3	1-3	3	2	3	1
behavioural change	1	1-2	1-3	2	2	1
nest distribution	1	1-2	1-2	1-2	1-2	1
breeding pair number	1	1-2	1-2	1-2	1-2	1-2
breeding success	1	1-2	1-2	1	1	1
sum	5-7	5-11	7-12	7-9	8-10	5-6

2.2 Southern Giant Petrels

Giant petrels (Procellariiformes, Procellariidae) are large long-lived species (body length 87 cm) which exhibit high levels of philopatry (Gales 1998, Marchant and Higgins 1990, Warham 1990). Two sibling species with a circumpolar distribution in the Southern Ocean can be distinguished. Northern giant petrels *Macronectes halli* are primarily found in warmer water on sub-Antarctic islands, whereas the later-breeding southern giant petrels *M. giganteus* are more abundant in higher latitudes (Bourne and Warham 1966, Hunter 1984, Warham 1996).

The basic biology and life cycle of southern giant petrels (throughout the study referred to as SGP, Fig. 2.6) have been described in detail by Bretagnolle (1988), Bretagnolle (1989), Hunter (1984), Voisin (1978) and Warham (1962). They are scavengers of the Southern Ocean, capturing cephalopods, fish and crustaceans, but also prey terrestrially at seal pupping grounds and penguin rookeries (e.g. Emslie et al. 1995, Hunter 1985).

The estimated world population of SGP is 31,000 to 35,000 pairs (Group 1999, Patterson et al. 2000), showing a decrease of 15 % relative to Hunter (1985). The species is listed as “Vulnerable” by the IUCN (Birdlife International 2004) and as ‘Specially Protected Species’ under Annex II of the Madrid Protocol (SCAR 2000). Feeding and breeding habitat preferences, human disturbance and changes in pelagic foraging patterns are considered potential factors for local variability (Patterson et al. 2000). Long-line fishing is thought to play a role in decreased survival of dispersing juvenile giant petrels (Jouventin and Weimerskirch 1991, Patterson and Hunter 2000, Techow and O'Ryan 2004).

2.3 Skuas

Skuas (Charadriiformes, Stercorariidae), closely related to gulls, are also long-lived, and meet their partners yearly in the same breeding territory (Furness 1987, Wood 1971). The genus *Catharacta* can be found in both hemispheres, but five of the six distinguished forms live in southern latitudes (Furness 1996). The sub-Antarctic brown skua (BS) *Catharacta antarctica lonnbergi* and the south polar skuas (SPS, Fig. 2.6) *C. maccormicki* are closely related forms (Blechschmidt et al. 1993, Cohen et al. 1997) and breed both in the study area. They show differences in morphology, behaviour, and diet (Higgins and Davies 1996, Peter et al. 1990a, Pietz 1986, Pietz 1987, Reinhardt et al. 2000) but hybridisation occurs (Parmelee et al. 1977, Hahn et al. 2003). Both forms are not globally threatened, having c. 7000 breeding pairs each (Furness 1996).

Unlike giant petrels, skuas are considered less sensitive to human activities near their breeding sites. In the study region, BS feed mainly in penguin rookeries, and to a lesser extent, prey on other birds and marine organisms, whereas SPS feed mainly at sea (Peter et al. 1988, Reinhardt et al. 2000). An additional food source during the breeding season is station food waste (although since 1994 open sources have been prohibited due to the occurrence of chicken cholera Hemmings 1990, Hoberg 1984), so that animals are partly habituated to station activities (Wang et al. 1996, Wang and Peter 2002, Young 1990).

Figure 2.6. Adult southern giant petrel (upper photo). Adult south polar skua (lower photo).

3 EFFECTS OF HUMAN ACTIVITIES ON BEHAVIOUR AND HEART RATE OF SOUTHERN GIANT PETRELS

3.1 Introduction

Albatrosses and petrels dominate the vastness of the Southern Ocean, but 29 % of Procellariiformes species are threatened as a result of direct and indirect human activities in their natural foraging and breeding habitats (Birdlife International 2000, 2004). Southern giant petrels (SGP) are categorised as "Vulnerable" in the IUCN Red List (Birdlife International 2004). The main causes are ongoing accidental mortality (bycatch), pollution and human disturbance. Reduced breeding success, abandonment and shifts of breeding site are documented near research stations and support the idea that human activity is detrimental to this species (e.g. Chupin 1997, Croxall et al. 1984, Jouventin et al. 1984, Peter et al. 1991, Woehler et al. 1990). The assessment of long-term data on population dynamics revealed a diverse picture of local increases and decreases that suggest the influence of several factors (Woehler and Croxall 1997). However, the evaluation of the relative significance of human disturbance on population dynamics is complicated due to the variability of natural factors (e.g. food availability, weather conditions) that strongly influence organism's abundance and distribution especially in the Southern Ocean (Micol and Jouventin 2001).

Intensive research work on SGP in the late 1970s and 1980s was reduced, after population declines became evident at several sites throughout the Antarctic and sub-Antarctic islands. In the following years, some breeding areas were protected and recommendations of the minimum distance to which birds could be approached ranged between 5 to 100 m in the western and eastern Antarctic. However, these measures were not based on scientific studies as has been done for penguins (Giese 1998, Nimon et al. 1995).

Several SGP colonies on King George Island have been exposed to intensive station activities, research, and tourism. This area is therefore suitable for investigations of behavioural and physiological responses of SGP to varying human activities. The assessment of current anthropogenic stresses at several breeding sites produces a strong body of data on which to base site-specific management plans.

The aim of this part of the study is the detailed observation of behaviour and heart rate of SGP in response to visits and air traffic. Breeding areas with different experience to human activity were used to evaluate the habituation ability of this species and to identify a necessary minimum distance for visitors. Stimuli were applied repeatedly to study short-term habituation of SGP.

3.2 Methods

My studies on the behaviour and heart rate of SGP on the Fildes Peninsula and surrounding islands were carried out between 2000 and 2003. It these areas, SGP breed in small groups on ridges along the coast line. As all members of a breeding group were exposed similarly to human activities, I categorised the groups according to their prior visitor and air-traffic experience. One breeding group on Ardley Island (referred to as A_{high}) is situated near the path along the northern coast and encounters the highest number of visitors and frequent air traffic. A second group on the north-western side (A_{medium}) is less frequently visited (about 10 times/season) but has the same distance to the main air-traffic route as A_{high}. All other nesting sites on Ardley, Geologist, Two Summit, Dart and Nelson Island (A_{low}, map 2.5) received fewer visits (< 5 times/season) and fewer air traffic. All the data presented come from studies in groups of 7 to 12 breeding pairs. Because of this narrow range, group-size effects are likely to be negligible and can be neglected. On remote islands, colonies include up to 120 pairs, but they are subdivided through topography. Beside nesting birds a number of free-sitting individuals (partners and non-breeders) were present at all sites. There were no evident habitat differences apart from the distance to human infrastructure and the frequency of human activities. As the marine foraging grounds of SGP can lie within several hundred kilometres of their breeding sites, and some terrestrial feeding occurs in penguin rookeries and on seal carcasses (González-Solís et al. 2002, Obst 1985), it seems also unlikely that groups differ in food availability.

3.2.1 Behaviour

The behaviour of SGP in the study site was observed directly or recorded on video (Sony CCT–TR 415–E) and later analysed with the OBSERVER Programme 4.1 (Noldus Information Technology; behavioural categories used in Tab 3.1).

SGP show a large behavioural repertoire at the breeding sites interacting with partners, conspecifics, predators and in response to human activities (Bretagnolle 1988).

Table 3.1. Behavioural categories used for southern giant petrels and skuas to analyse video records in the OBSERVER Programme 4.1. Adult behaviour recorded during incubation and early chick rearing.

behavioural classes	action	description
call	alarm call	vocal response to natural or anthropogenic stimuli
movement	fly-off	bird leaves the nesting site
	walk	skua walks around in its territory
nest activities	sleep	bird rests with the head under one wing
	observe	bird is awake, watches surroundings without extending neck
	being alert	vigilance behaviour (neck extended, more abrupt head movements)
	defend	bird defends brood (SGP pecks or spits stomach contents, skua shows ground and aerial defence) against conspecifics or (potential) predators
	material picking	SGP pulls little stones, skua pulls plants
	preen	bird arranges/cleans feathers
	partner interaction	includes all ways of communication between partners
	feed	adult feeds chick

A frequently displayed feature is the low intensity attitude in which the birds raise the neck, turn the head down towards the disturbance source, ruffle the nape feathers, and sometimes swing the head and neck from side to side. Increased alertness is evident when the bird raises its head and silently watches the source of concern, often without lifting feathers but in response to close encounters with erecting its hackles. This posture is contagious, signalling alarm to neighbours (Voisin 1978). Like all Procellariiformes, SGP can spit stomach oil in defence or peck the intruder (Brooke 2004). Under strong threat they run away upwind, beating their wings until these grip the air, and then fly large circles leaving their nest alone for up to 25 minutes (pers. obs).

Behavioural Activity Patterns without Human Stimuli

I observed the attendance pattern of SGP only in A_{high}, because this was the only group that I could approach close enough to distinguish between sexes without causing fly-off. I present the results of 2003, because it was the longest field season. I recorded the basic behaviour of eight incubating SGP on Ardley and Geologist Island each season in December (a two-hour record without human stimuli between 10:00 and 14:00). Instantaneous scan sampling (Altmann 1974) was used, whereby the behaviour of the study bird was recorded every full minute. The A_{high} group was observed additionally for 8-h periods with a camera system (Masello et al. 2001).

Behavioural Response to Human Stimuli

I analysed the videos in terms of behaviour changes (vigilance) from ‘observe’ to ‘being alert’ during various human stimuli. I tested different stimuli in each area type on several birds during the whole study period. I compared fly-off and defence behaviour during the first visit in each season on Ardley and Geologist Island. During the direct approach of the nesting group (one pace/sec) to within 15 m, I counted the number of birds that flew off. While I walked closer to birds that remained, I classified the defence of each (spit and/or peck).

3.2.2 Heart Rate

I measured the heart rate (HR) with a stethoscope-microphone-unit that I installed in the nest of the study bird (detailed description in Hüppop and Hagen 1990, modified in the Institute of Solid State Physics, FSU Jena). In 94 % of all installations, SGP remained sitting, while I placed the equipment near the egg. When I could not hear a clear heart beat, I removed the equipment after some testing time. The time of a single record (i.e. a continuous installation in a certain nest) varied therefore, but lasted no longer than 3 hours for each bird. The heart beat was recorded during day-light hours. To reduce the investigator disturbance, I used two stethoscope-microphone-units in each nest, and switched between them to find the better transmission of the heart beat, when the bird changed its position in the nest. Although there is more advanced technology for HR recordings like artificial eggs, I decided in this study site against it after seeing the disadvantages during field work on Penguin Island (chapter 8).

In the field season 2001, I tested the equipment in six SGP nests. Then I installed the equipment in 33 nests in 2002 and 48 in 2003 (245 recording hours in total). To minimise possible stress responses during the study, I handled the birds as little as possible. Therefore, I determined the sexes only in a small number of pairs by measuring the bill length (males > 95 mm, females < 90 mm, Obst and Nagy 1992, Peter et al. 1988).

I standardised visits by walking at 1 pace/sec toward the nest, stopped for 1 min at a defined distance and then walked away at the same speed. Graphics will present bars for visits that show the time spent in a certain distance from the birds (not the time spent coming and going). To test for cumulative effects, visits and air traffic were combined as one stimulus. For the helicopter-sound simulations, I placed a loudspeaker 20 m from the nest and a sound meter (type Voltcraft 322) 5 m from the nest. Because the ambient noise varies (see chapter 2), I adjusted the volume so that the nesting bird would experience noise 15-25 dB louder than the ambient. As a result, the simulated helicopter sound lay between 55 and 85 dB. To test cumulative effects, simulation and a person talking loud were combined as one stimulus.

To test short-term habituation effects, I used seven repeated applications of the same stimulus (visit or simulation) to the same study bird (10 birds of each species and in each area type). I standardised visits by walking with one pace/sec toward the nest, stopped for 1 min in a defined distance and then walked away. Repeated visits were conducted with a 25 m distance.

During the records of heart beats, the temperature inside and outside the nest was measured with datalogger in five second-intervals (Hobo H 8 Pro Series from Synotech Sensor und Messtechnik GmbH in Linnich, Germany).

Other weather data were taken from the recording station of the Russian base Bellingshausen. I defined, throughout the study, a wind speed > 10 m/s (equals 6- 12 Beaufort scale strong wind to storm) as windy, and < 10 m/s as calm.

I transferred the heart-beat records to OBSERVER, counted, summed over 15 seconds, and multiplied by four to produce beats/minute (= HR). For a measure of variability of the basic HR, I used the threshold of a double standard deviation from the HR as tolerance spectrum (after Neebe and Hüppop 1994). Any HR higher than this level was seen as excitation caused by a stimulus. The excitation ended, when the HR runs for at least 30 seconds within the tolerance spectrum. In some cases, it was not possible to get an end-value through this method. I then calculated it from the lowest value during the whole experimental run. To assess a response to a certain stimulus, I took the average HR over one minute before the stimulus as reference for the calculation of the relative HR increase during the stimulus. For comparison, I used the maximum HR increase, i.e. the difference between maximum HR during the stimulus and the average HR one minute before the event.

Data Analysis

I used the statistical package of SPSS 11.0, and produced the graphics in Sigma Plot 8.02. All data were tested for normality and if not normal were suitably transformed. If transformation did not produce normality, non-parametric tests were applied. All tests were two-tailed unless stated otherwise. Binary logistic regression (Wald) was applied in cases where dependent variables contained 0 and 1. The influence of factors (e.g. area, year, stimuli type) on parameters (e.g. fly-off distance, HR change) were tested with general linear models (GLM, univariate or multivariate ANOVA). Short-term habituation was tested with GLM for repeated measurement (RM). As non-parametric tests, the Kolmogorov-Smirnov, Mann-Whitney U and Kruskal-Wallis were used. The significance level is $p < 0.05$.

3.3 Results

3.3.1 Behaviour

Behavioural Activity Patterns without Human Stimuli

The attendance study in A_{high} in 2003 showed that in 86 % of the observed cases only one of the pair was present (Fig. 3.1, females with 44 % less frequent than males with 56 %, Wald = 7.60, p = 0.006). Both parents went foraging when chicks were able to defend themselves. Two out of three breeding pairs remained in the group after having lost eggs or chicks.

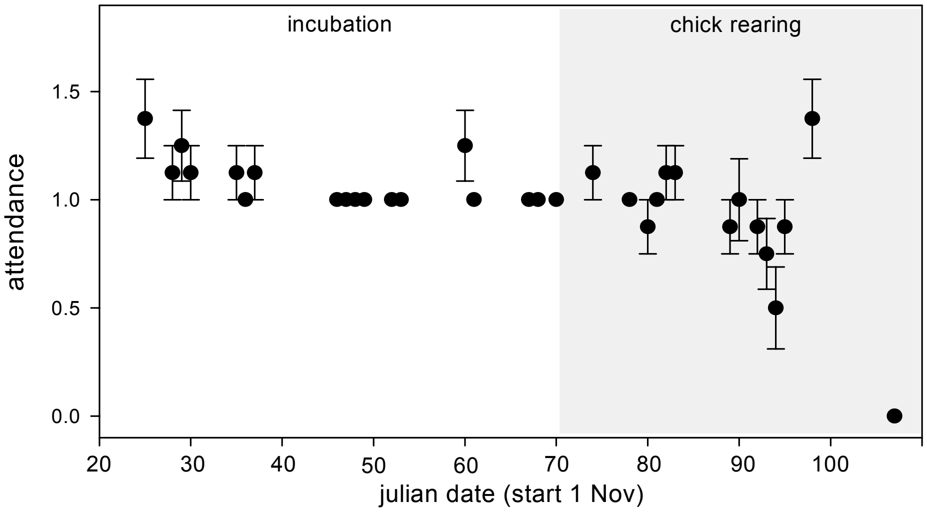

Figure 3.1. Attendance of southern giant petrel breeding pairs (n=8) in area of high human activity on Ardley Island during the incubation and chick rearing period in 2003 (mean ± S.E.).

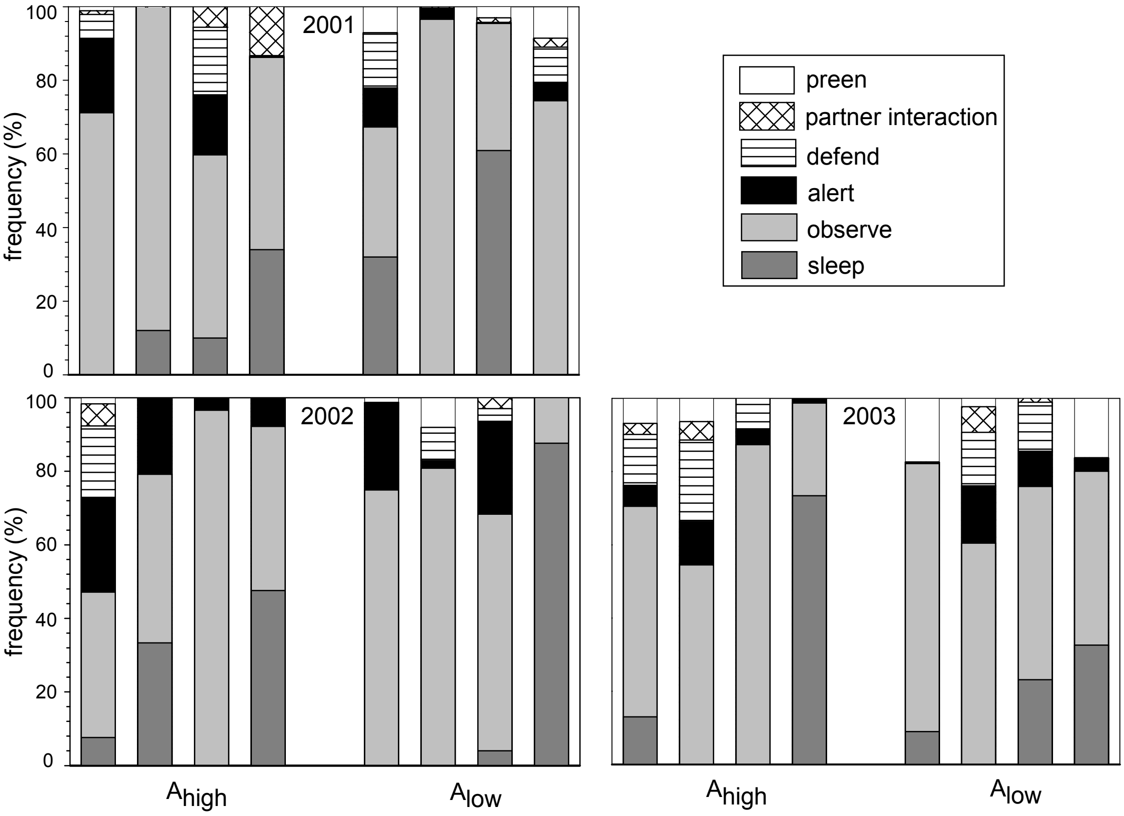

Figure 3.2. Basic behaviour of incubating southern giant petrels in areas of high and low human activity (average of two-hour video records of four individuals per area and year without human stimuli, records taken between 10:00 and 14:00).

SGP showed a large activity spectrum at their nesting sites (Fig. 3.2 and 3.3). The basic behaviour of incubating SGP varied considerably, and consisted 45 to 100 % of sleeping and observing independent of year and area type (Fig. 3.3, GLM ANOVA factor year: $F_{2,23} = 0.20$, $p = 0.82$; area: $F_{1,23} = 0.003$, $p = 0.96$). Up to 26 % of an hour were spent in alertness in response to natural stimuli (i.e. over-flights of conspecifics and skuas, interaction with neighbours; year: $F_{2,23} = 2.92$, $p = 0.08$; area: $F_{1,23} = 0.24$, $p = 0.81$). Defence behaviour was displayed on the nests including short stand-ups, but no fly-off occurred in response to natural stimuli. Partner exchanges lasted on average 96.5 seconds ± 32.8 ($n = 10$). When both partners were present at the nesting site, displays took place frequently.

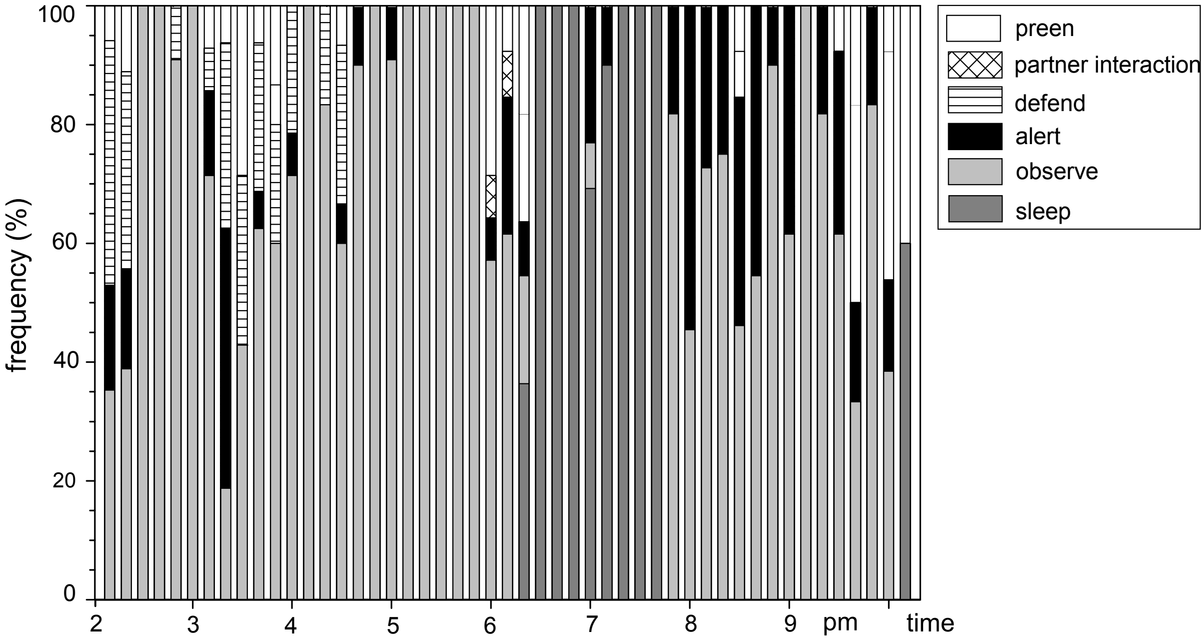

Figure 3.3. Example of the activity pattern of an incubating southern giant petrel in the area of high human activity on Ardley Island on 25 December 2002. Alertness was caused by movements of birds in the group, by near over-flights and calls of skuas and terns.

Behavioural Response to Human Activity

Vigilance behaviour (e.g. behavioural change from 'observe' to 'alert') was shown by 75 to 80 % of all SGP studied in response to natural stimuli (Tab. 3.2). In A_{high}, only visits and air traffic at the same time caused a higher proportion of birds to respond with behavioural change. In comparison, SGP breeding in A_{medium} were more vigilant under visits and visits simultaneously with air traffic. Birds in A_{low} showed more behavioural changes compared to natural stimuli in all tested human stimuli, except air traffic. Simulations, in particular, caused increased alertness in this area. The response to air traffic was significantly lower than to natural stimuli in all three area types (Tab. 3.2).

Vigilance and defence were more evident in areas of low human activity compared to A_{high} and A_{medium}, when visits, simulations or air traffic occurred (Fig. 3.4). Even after the stimuli had ended, the birds in the A_{low} group were still alert or defended their nests from returning conspecifics.

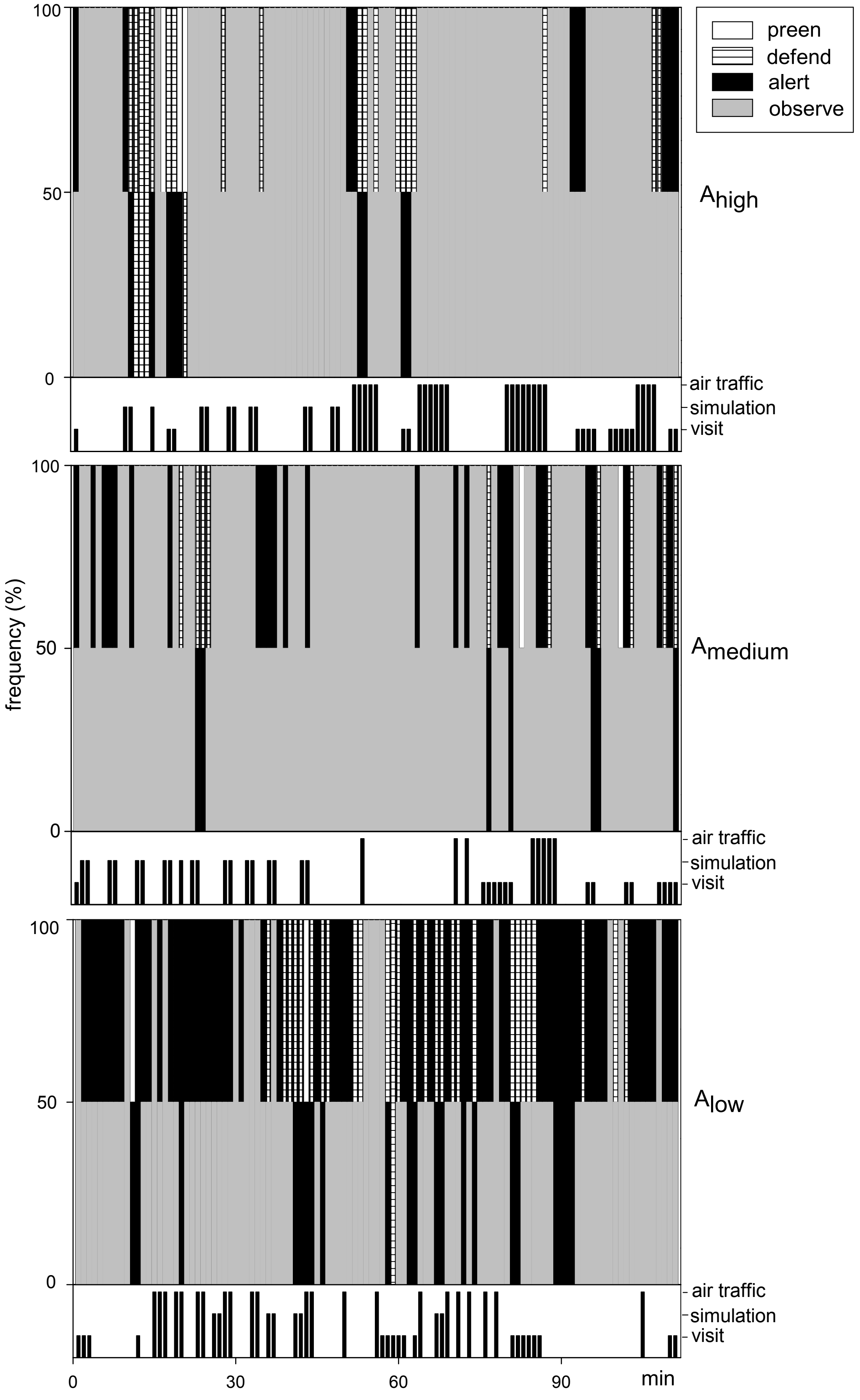

Figure 3.4. Behaviour of one southern giant petrel in each area type (high, medium, and low human activity; behaviour recorded in scan sampling every 30 sec) observed for two hours under different human activities (black bars in lower part of plots with human stimuli type on the right y-axis). Record time mid January 2003 (chick rearing period).

Table 3.2. Percent of incubating southern giant petrels with behavioural change from ‘observe’ to ‘alert’ at first occurrence of a stimulus. Number of individuals tested in brackets. Binary logistic regression for area comparison. Binomial tests applied for comparison between human and natural stimulus within each area type (* if significantly different).

stimulus	A_{high}	A_{medium}	A_{low}	Wald-Statistic, p-value
natural	75 (16)	80 (12)	75 (32)	0.95
visit at 25 m	67 (15)	91 (11)	84 (32)	0.25
regular air traffic	30 * (10)	43 * (7)	50 * (5)	0.80
simulation	57 (14)	55 (11)	86 (29)	0.06
visit + air traffic	88 (8)	100 (6)		0.93
simulation + talk	60 (10)	78 (9)	87 (15)	0.33

Of non-incubating and non-brooding birds, 98 % left the nesting sites, when the investigator approached to 5 m. The percentage of birds that had flown off in response to a 15 m approach, differed significantly between areas but not years (Tab. 3.3, area: Wald = 10.15, $p = 0.006$; year: Wald = 1.83, $p = 0.40$; area*year: Wald = 1.70, $p = 0.79$). 8 to 29 % of all birds in A_{high} left the site. Up to 20 % of the A_{high}-group spit and more than half hit in defence. In A_{medium}, more than 80 % of all birds left the site, when visited, and the remaining animals defended in part. In A_{low}, 30 to 41 % of all present giant petrels left the site, and the remaining ones tried to hit more than they spit. A_{low} had a higher proportions of birds flying off (Wald = 3.85, $p = 0.050$) and spitting than A_{high} (Wald = 4.50, $p = 0.03$), but pecking was similar (Wald = 0.07, $p = 0.80$).

Table 3.3. Behavioural responses of southern giant petrels on Ardley (A_{high}, A_{medium}) and Geologist Island (A_{low}) during first visit each season. Percentage of birds that showed particular behaviour during human and natural stimuli as average over years (total number of birds in brackets). Kolmogorov-Smirnov-test for the difference between human and natural stimuli (pooled over all years).

behaviour	area	response to natural stimuli	response to human stimuli (% of birds)			K-S p-value
			2001	2002	2003	
fly-off	A_{high}	0 (12)	17 (12)	29 (14)	8 (13)	0.17
	A_{medium}	0 (12)	83 (12)	83 (12)	90 (10)	< 0.001
	A_{low}	0 (22)	30 (23)	41 (22)	38 (24)	< 0.001
spit stomach content	A_{high}	17 (12)	10 (10)	20 (10)	17 (12)	1.00
	A_{medium}	33 (12)	0 (2)	50 (2)	0 (1)	1.00
	A_{low}	23 (22)	38 (16)	46 (13)	33 (15)	0.27
peck	A_{high}	58 (12)	60 (10)	50 (10)	58 (12)	0.50
	A_{medium}	42 (12)	50 (2)	50 (2)	0 (1)	1.00
	A_{low}	41 (22)	56 (16)	54 (13)	53 (15)	0.43

The fly-off distance was significantly lower in A_{high} than A_{low} (Fig. 3.5, $F_{2,47} = 6.92$, $p = 0.002$; A_{medium} $p = 0.052$), and increased slightly on windy days (wind speed > 10 m/s, t-test:

$t_{18} = 1.24$, $p = 0.23$). SGP in A_{high} also returned earlier to the nest than birds in A_{low} ($F_{2,38} = 3.75$, $p = 0.03$; A_{medium} $p = 0.061$).

When SGP left the nest in response to a visit, they stayed away on average 491.1 seconds ± 206.8 before continuing offspring care. The temperature decline in the nest after fly-off was on average 3.6 °C/min ± 2.13 (outside temperature 3.4 °C ± 2.33, n = 37).

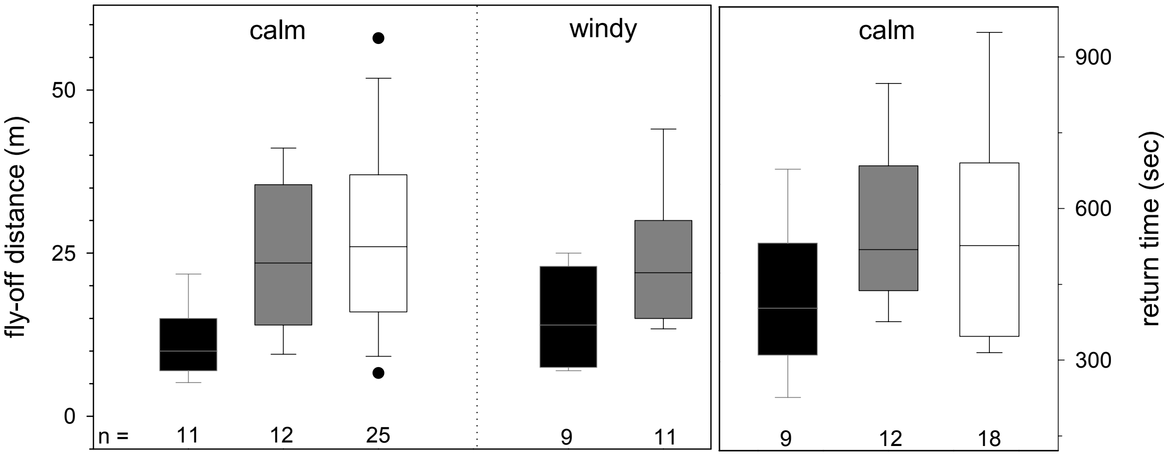

Figure 3.5. Fly-off distances and return time of southern giant petrels in areas of high (black), medium (grey) and low (white) human activity on calm and windy days in 2003. Boxplots for each category show 10th, 25th, median, 75th, and 90th (5th and 95th as dots) percentiles. (Windy means > 10 m/s, wind speed data records from Bellingshausen station).

3.3.2 Heart Rate

The basic HR of SGP were not different between year, sex and area type (GLM ANOVA year: $F_{2,57} = 4.07$, $p = 0.29$; sex: $F_{1,57} = 0.18$, $p = 0.74$; area type: $F_{2,57} = 5.33$, $p = 0.15$). The basic HR increased over the season ($r^2 = 0.19$, $p = 0.03$), but there was no seasonal change in the relative HR increase in response to stimuli ($r^2 = 0.001$, $p = 0.91$).

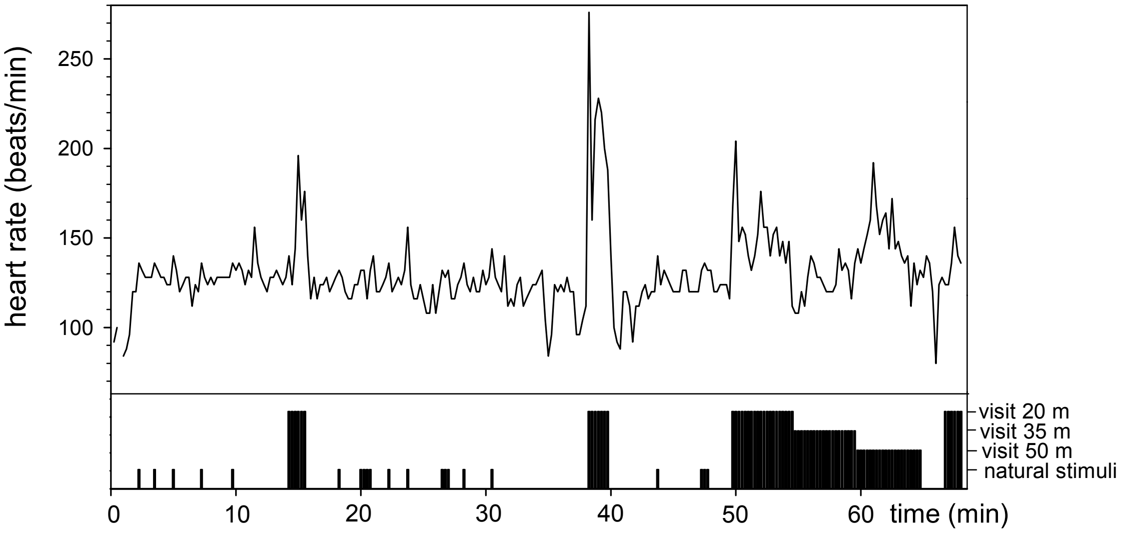

Figure 3.6. Heart-rate example (line) of a southern giant petrel breeding on Geologist Island (area of

low human activity) exposed to visits and natural stimuli (bars) on 7 January 2002.

Visits to SGP breeding sites caused HR increases of different strength depending on the visitor distance (Fig. 3.6) and visit type. In A_{high}, birds could be approached up to 10 m, before the relative HR increase exceeded that during natural stimuli (Fig. 3.7, Kruskal-Wallis $H_8 = 33.7$, $p < 0.001$). In A_{medium} the threshold was 20 m ($H_8 = 41.2$, $p < 0.001$) and in A_{low} 40 m ($H_8 = 47.5$, $p < 0.001$). If the threshold of the 10 % response to natural stimuli (Fig. 3.7 dashed line) is applied, then at a distance < 40 m birds in A_{high} show higher responses, < 70 m in A_{medium}, and < 40 m in A_{low}. Birds in all area types responded strong to a person walking around in front of the nest. In A_{low} a person arriving, standing for one minute and then going away also caused higher HR than did natural stimuli (A_{high}: $H_4 = 8.3$, $p = 0.08$; A_{medium}: $H_4 = 16.8$, $p = 0.002$; A_{low}: $H_4 = 45.7$, $p < 0.001$).

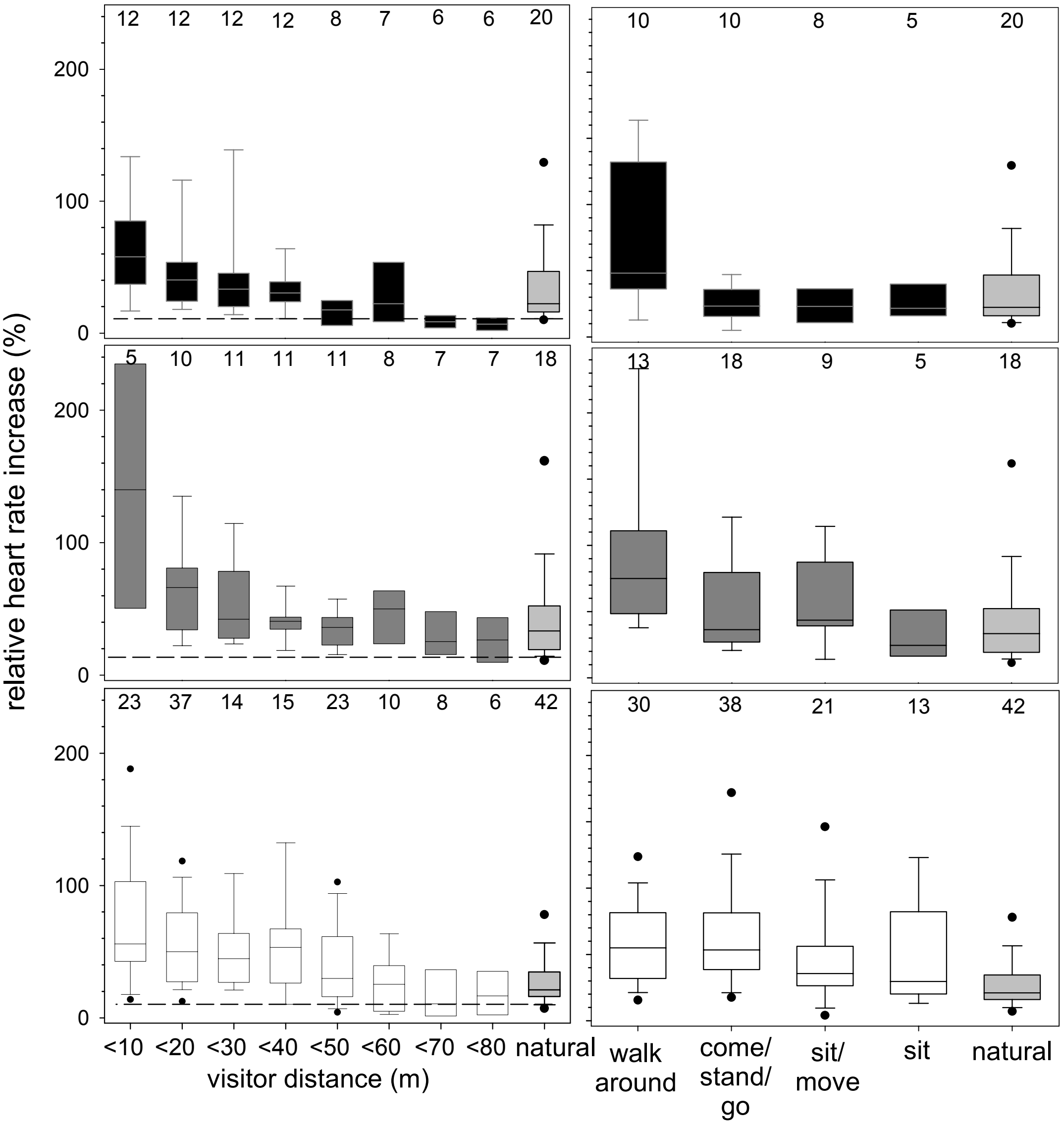

Figure 3.7. Comparison of heart rate increases of southern giant petrels to various visitor distances and visit types in areas of high (black), medium (grey), and low (white) human activity. Sample size above boxplots. Dashed lines represent value of 10th percentile of natural stimuli boxplots. Threshold used for assessment of minimum distance.

The responses of SGP to air traffic varied between area, aircraft type and flight route (Fig. 3.8).

In A_{high}, irregular helicopter flights, i.e. off normal flight routes, caused the strongest reactions, but similar to natural stimuli (Mann Whitney $U_{22} = 61.0$, $p = 0.42$).
In A_{medium}, birds reacted strongest to irregular Hercules over-flights with similar HR increases measured under natural stimuli ($U_{20} = 52.0$, $p = 0.64$). In A_{low}, birds had higher HR increases during regular Hercules, irregular helicopter and small plane over-flights than under natural stimuli, but no significant differences could be shown (regular Hercules to natural stimuli: $U_{47} = 194.5$, $p = 0.59$).

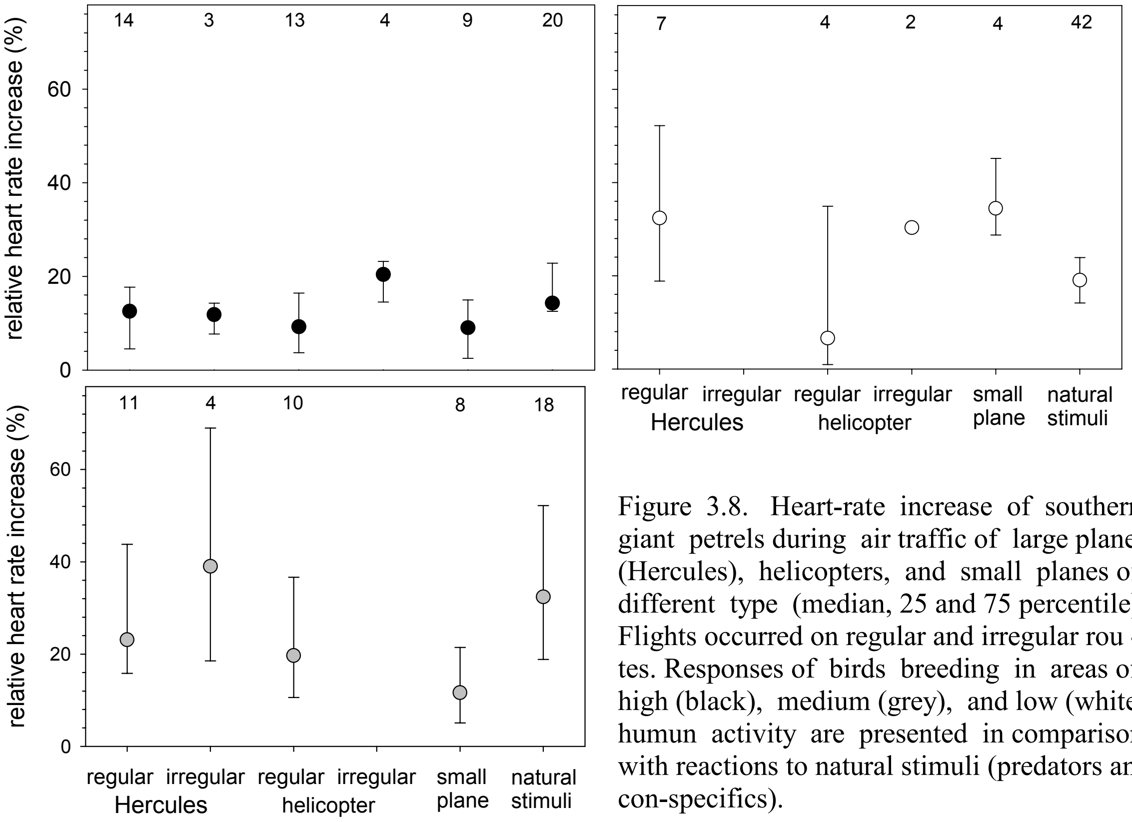

Figure 3.8. Heart-rate increase of southern giant petrels during air traffic of large planes (Hercules), helicopters, and small planes of different type (median, 25 and 75 percentile). Flights occurred on regular and irregular routes. Responses of birds breeding in areas of high (black), medium (grey), and low (white) humun activity are presented in comparison with reactions to natural stimuli (predators and con-specifics).

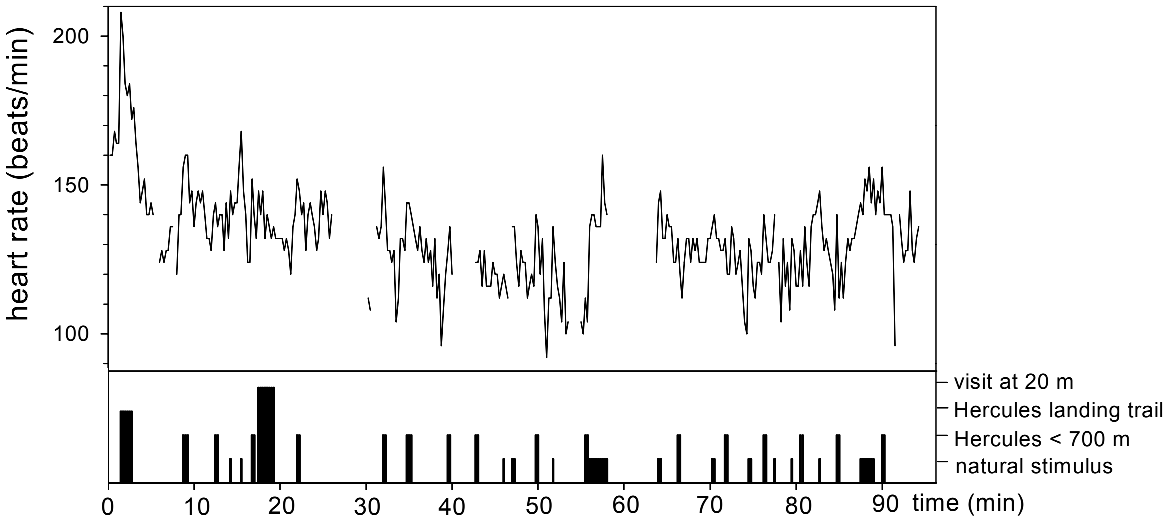

Figure 3.9. HR example (line) of a southern giant petrel breeding in the area of high human activity on Ardley Island, recorded on 17 January 2002. At the beginning, a plane (type Hercules C-130) tried to land (bar), but was unsuccessful due to heavy fog. The plane circled around Ardley Island every 4 to 10 minutes waiting for a landing possibility.

Especially aircraft involved in starting and landing procedures caused stronger HR responses in the birds than when passing in a constant height (Hercules example Fig. 3.9).

The simulation experiments with helicopter-flight sounds resulted in HR increases in all area types, which was slightly intensified by parallel talking of humans (human not seen by bird, Fig. 3.10 and 3.11). Statistical testing showed no significant difference from natural stimuli (A_{high}: Kruskal-Wallis H = 2.48, p = 0.29; A_{medium}: ANOVA F = 1.64, p = 0.21; A_{low}: Kruskal-Wallis H = 5.28, p = 0.07).

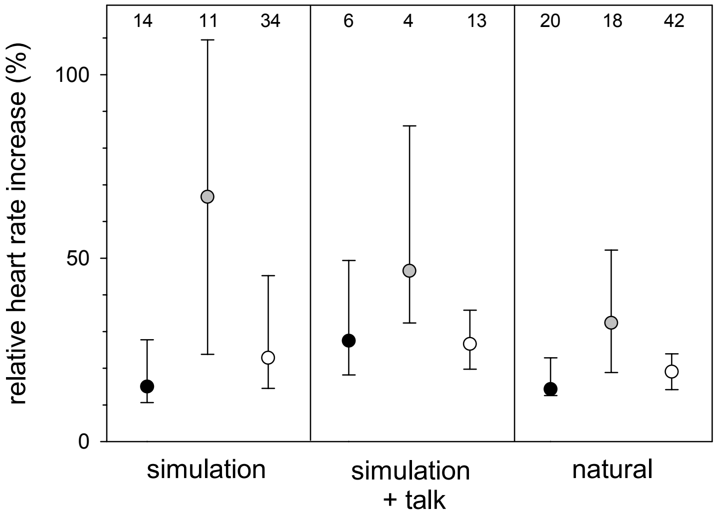

Figure 3.10. HR increase of southern giant petrels in response to helicopter-sound simulations, simulations and human talking as cumulative stimuli and natural stimuli for comparison. Data of all area types (high human activity – black, medium – grey, low – white) are presented as median, 25 and 75 percentile.

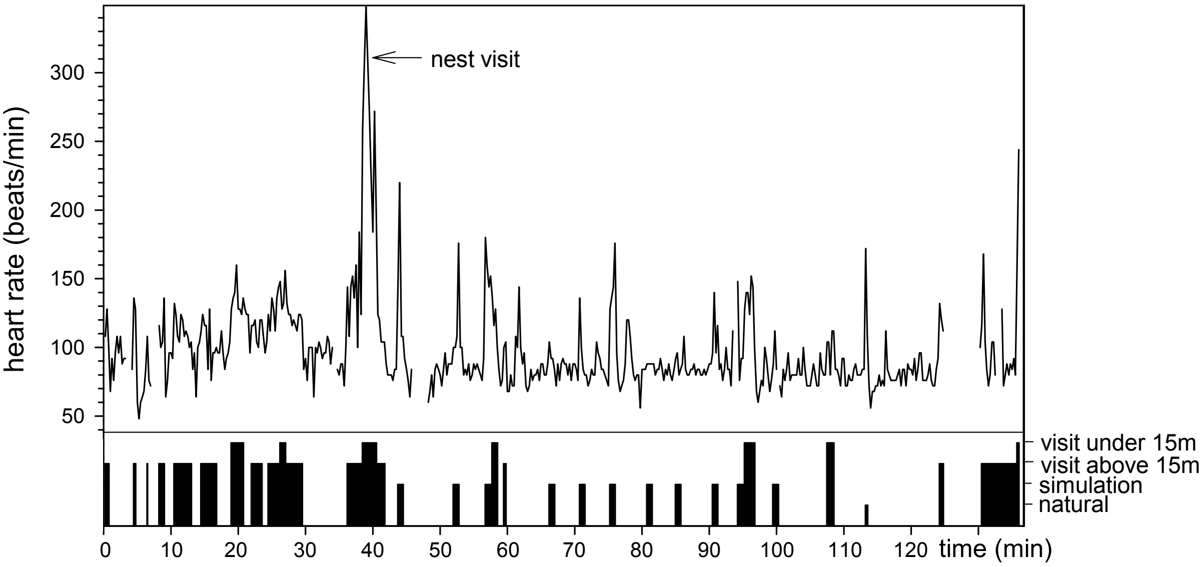

Figure 3.11. HR example (line) of a southern giant petrel breeding in the area of medium human activity on Ardley Island, recorded on 9 January 2002. Human and natural stimuli that occurred during observation are presented by bars of different height. The closest visit to the nest and the first simulation caused the highest heart-rate increases.

Repeated visits to SGP resulted in all area types in lower HR increases over time (Fig. 3.12, RM GLM within-subject effects A_{high}: $F_3 = 7.62$, p = 0.001; A_{medium}: $F_3 = 3.30$, p = 0.04; A_{low}:

$F_6 = 2.73$, $p = 0.02$). Responses to repeated simulations declined in areas of medium and low human activity but not in A_{high} (Fig. 3.12, RM GLM A_{high}: $F_6 = 1.16$, $p = 0.34$; A_{medium}: $F_6 = 6.45$, $p < 0.001$; A_{low}: $F_6 = 2.96$, $p = 0.01$).

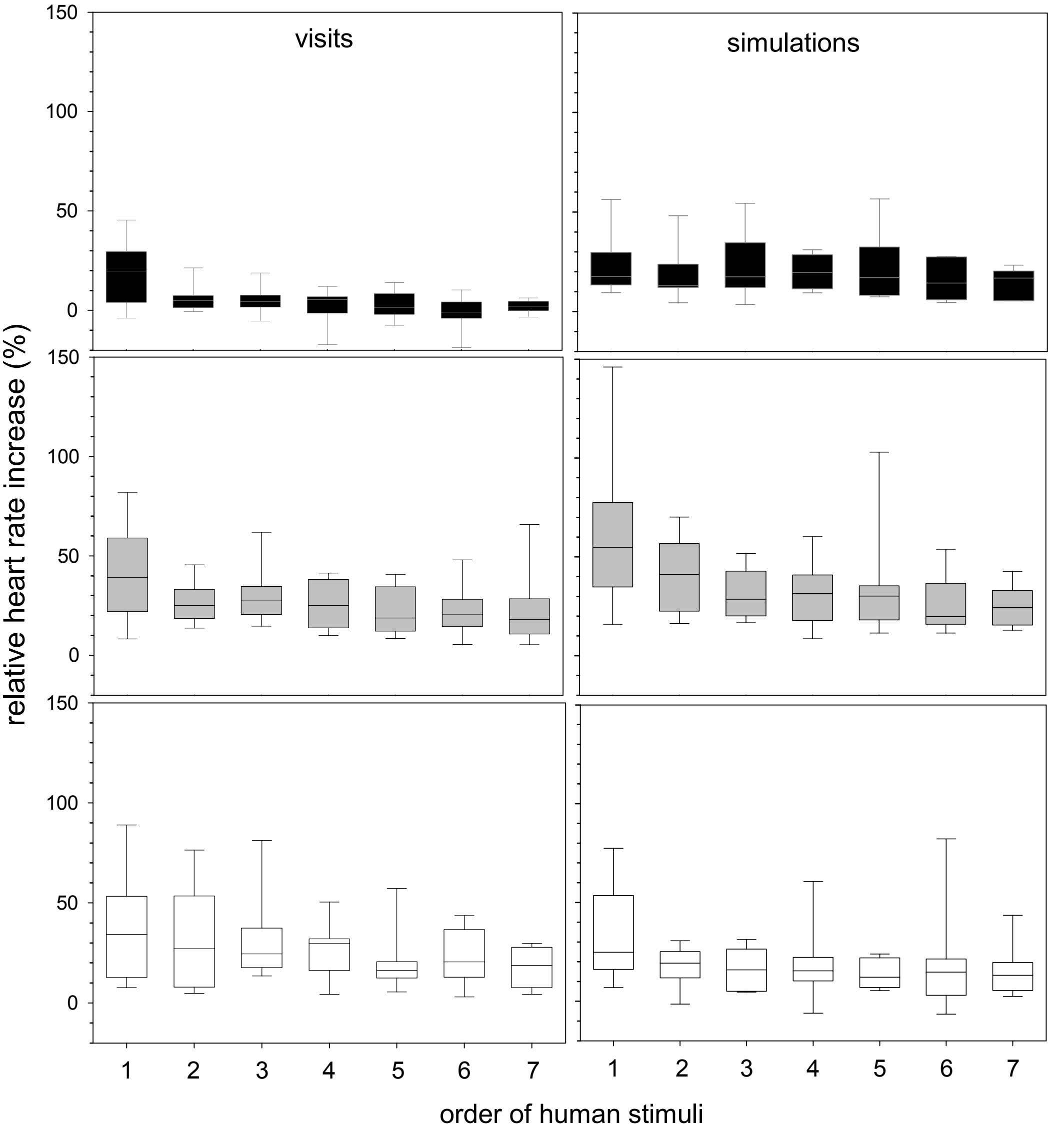

Figure 3.12. Comparison of the HR responses of 10 SGP in each area type (high – black, medium – grey, low – white) to repeated human stimuli. Presented are relative HR increases during exposure to a 1-min stimulus with a 5-min interval to the next stimulus.

3.4 Discussion

This is the first comprehensive attempt to study behavioural and physiological responses of SGP to various human stimuli at their breeding sites. In the past, visits and air traffic have been seen as reasons for lower breeding success and nest-site shifts in the study area and other breeding sites (see chapter 7). The focus of this chapter is whether this sensitivity to human activities is still evident after more than 15 years of logistic operations, science and tourism, or whether habituation resulted in reduced individual stress responses.

The main challenges breeding SGP have to cope with on land are harsh weather, a short breeding season and predation. At least one bird needs to attend the nest, until the chick is large enough to defend itself by spitting stomach oil and sustain the weather (Hunter 1984). In order to show anti-predator behaviour, birds need to perceive the presence of a predator and assess their own vulnerability. Most birds became alert, when skuas approached, gulls and terns called, or conspecifics moved into the breeding group. This was often followed by nest defence against predators or other giant petrels.

Visits

The vigilance of birds in response to visitor approach (to a distance of 25 m) was similarly high, so that a human seems to be a potential threat. Both responses to a predator and to human stimuli divert time and energy from other fitness-enhancing activities such as feeding, parental care, or mating displays (Frid and Dill 2002). Animals optimise the trade-offs by changing antipredator behaviour to the perceived predation risk (e.g. squirrels reduce fleeing initiation distance when closer to refuge, Dill and Houtman 1989, Lima 1998).

During natural stimuli, ground defence of breeders and non-breeders was observed. In contrast, visits caused flight or fight responses in SGP. Non-breeders assess only their own vulnerability and flee most frequently. Partners of birds on nests have no incubation pressure, but need to decide about brood defence. Most partners left the nest site, when closely visited (< 10 % attacked the visitor). The clumsy movement of SGP on land caused defence behaviour in the remaining nesting birds, as eggs or chicks could be stepped on. Because of their smaller size, skuas can only prey on eggs and small chicks. Ground defence of adult SGP reduces, thereby, the predation risk considerably. In contrast, an approaching person can cause a higher potential threat to the adult. To which extent seal and whale hunters used SGP or their eggs as food in the 19th and early 20th century is unknown. Scientists (and station personnel), however, handled a large proportion of adults and chicks in the Fildes Peninsula area especially in the 1980s, and eggs were taken as souvenirs and food (ringing programmes and pers. comm. Z. Wang).

The fly-off reaction during visits was most evident in A_{medium}, where also the majority of breeders left the nests. Situated behind a hill, the group is visibly separated from the main path on Ardley Island. Because visits occurred irregular but several times per season and from different directions, habituation is less likely than in a group nesting close to human infrastructure. A_{high} showed the lowest fly-off percentage, when visitors approached. SGP in A_{low} flew away less often than in A_{medium} and in only slightly higher numbers than in A_{high}. An explanation for the high fly-off in A_{medium} could be that birds are less experienced breeders (i.e. more nervous which is supported by generally higher HR increases during human and natural stimuli). Secondly, the 'snowball effect' in A_{low} is perhaps smaller than in A_{medium}, because fly-off occurs seldom in the remote groups. In other words, a larger proportion of birds activated frequently used natural defence strategies instead of following the rarely used decision of fleeing. Breeding birds in A_{low} showed more alert and defence behaviour during and after human stimuli (see Fig. 3.4). Another reason for the relatively low fly-off could also be a higher predation pressure. After leaving the nest, the egg or young chick is without any protection for several minutes until one adult returns. In the study period, one or two skua pairs bred close to each SGP nesting site and approached the groups regularly, not suggesting large differences in pressure. Nevertheless, the three cases, when I directly observed predation after fly-off, were in A_{low} groups. Therefore, in terms of predation but also thermoregulation, nest leaving should be avoided or be of short duration. Both fly-off distance and return time were smallest in A_{high} and similar in A_{medium} and A_{low}, indicating an adjustment to frequent visits.

The drawback of behavioural studies is the fact that the strength of behavioural changes does not necessarily represent the stress level experienced by the animal, because internal and external factors could influence the individual decision (e.g. Beale and Monaghan 2004, Gill et al. 2001, Neebe and Hüppop 1994). This drawback can be circumvented by measuring physiological parameters. HR changes in animals are more sensitive indicators of the perception of a potential stressor in the environment (Hüppop 1995). The HR of SGP increased during relevant human and natural stimuli. I observed in most cases a two-phase reaction whereby a HR increase was followed by a decrease below the pre-stimulus HR, before it returned to the previous level. These increases lasted not long after stimuli had finished suggesting no chronic stress. I was unable to control the HR levels for body size or oxygen consumption because these measurements would have produced considerable disturbance to the adults potentially changing their behaviour. The large individual variation in each group resulted, however, in an overall similarity in basic HR.

In order to find an appropriate minimum distance for visitors of SGP breeding sites, I applied two methods. First, I looked at significantly higher HR increases in response to a certain visitor distance compared to natural stimuli. SGP in A_{high} could be approached up to 10 m, SGP in remoter places up to 40 m. These distances would cause similar or stronger threat to the birds than encounters with predators. However, if the aim lies in a similar or lower threat level to minimise birds being affected during visits, birds that responded least to natural stimuli could draw the reference lines (10th percentile in boxplot, Fig. 3.6). In this case, distances causing higher HR changes were < 40 m in A_{high} and < 70 m in A_{medium} and A_{low}. Both methods joined, breeding group A_{high} should be visited no closer than 10 - 40 m, A_{medium} 20 - 70 m, and A_{low} groups no less than 40 - 70 m.

Minimum distances to wildlife in the Antarctic are only recommendations for tourists and station members in their free time, and activity areas are still expanding. The decision about a suitable spatial limit should, therefore, not be based on the response of the most tolerant birds, but instead represent a wide-ranging species reactivity. Therefore, I suggest a minimum distance of 50 m to SGP. Because the A_{high} group on Ardley Island is more tolerant, the shorter distance of people walking on the path will not harm them. This tolerance of frequently visited animals near paths and roads has been described in many studies of birds and mammals (e.g. Boyle and Samson 1985, Carney and Sydeman 2000, Cobley and Shears 1999, Fowler 1999, Hüppop and Hagen 1990, Recarte et al. 1998, Scott et al. 1996, but see also Blühdorn 1998). Any 'off-road' visits should not be approach closer than 50 m.

Also, the visit type influenced SGP differently, whereby unexpected, fast movements caused the highest physiological response (similarly Burger and Gochfeld 1999, Giese 1998, Lord et al. 2001). Repeated visits to the same study birds resulted in all area types in the reduction of HR changes of time also demonstrating short-term habituation abilities of SGP.

In conclusion, behavioural and physiological responses of SGP varied depending on experience. Birds exposed to relatively frequent and predictable approaches of visitors (scientists, station personal and tourists) showed the lowest flight and defence response as expected by the habituation hypothesis. The results support observations about habituation effects made during a carefully planned long-term research project on this species near Palmer Station, Antarctica (pers. comm. D. Patterson), and in frequently visited tourist sites (e.g. Hannah Point on Livingston Island, Pfeiffer and Peter 2003).

Air Traffic

Because the breeding sites of SGP in the study area are relatively close to a airstrip, I assessed air traffic as a second potential stressor to this species. Flight activities began on the Fildes Peninsula in 1980 and increases parallel to the construction of stations (see chapter 2). In 1985, the Chinese station was built using helicopters and planes to transport material from ship to land, and SGP were observed to be affected in terms of behavioural changes and lower breeding success (pers. comm. H.-U. Peter). Between 2000 and 2003, I recorded air traffic on over 60 % of the observed days (details chapter 2). Daily activities ranged from single arrival, or departure, of large and small planes to more than 50 helicopter flights during unloading operations between ship and station. Weather conditions modified the schedules considerably so that especially large planes (Hercules) were repeatedly observed circling above Ardley Island and central Fildes for up to an hour waiting for a landing possibility.

SGP showed no fly-off reaction in response to air traffic during my observations, but anecdotal reports of fly-off during low over-flights exist (pers. comm. H.-U. Peter). The vigilance behaviour of breeders was significantly lower than under natural stimuli in all area types. However, HR increases occurred to varying degree depending on aircraft type, distances and route. SGP in A_{medium} and A_{high} on Ardley Island breed within 600 m of the main flight route. All aircraft passing on this route caused smaller reactions of SGP in comparison to other human stimuli. But starting and landing as well as off-route flights increased the HR considerably in any of the sites. All areas of low human activity lie in greater distance to the main route, but occasionally aircraft pass at low altitude (< 300 m) or even over-fly breeding groups (e.g. Dart Island). In particular, helicopter and Hercules pilots regularly train their flight skills by passing low over land and along the coast line. Since the establishment of the area protection for Ardley Island, these activities have been reduced but not prohibited. Habituation is therefore only evident, when main flight routes are used.

In the Antarctic and sub-Antarctic, only a few other anecdotal reports and experimental studies of the effects of air traffic on wildlife exist and show a broad response range (Harris 2001). Taylor and Wilson (1990) observed no behavioural changes on Adélie penguins *Pygoscelis adeliae* during over-flights of Hercules at 300 m, whereas Adélie penguin adults and chicks flee helicopters passing at 300 m Culik et al. 1990). In emperor penguin

Aptenodytes forsteri chicks and adults behavioural responses to helicopters were also small (Stone et al. 2003), but the body temperature was increased after aircraft over-flights, which caused energetic costs (Regel and Pütz 1995). Giese and Riddle (1999) observed behavioural changes in emperor penguin chicks during helicopter flights and suggested an increase of distance from 1000 to 1500 m.

Air traffic should not have the same threatening character for Antarctic animals as for Arctic ones where e.g. caribou were hunted from aircraft (references in Andersen et al. 1996). The aircraft movement may triggers antipredator behaviour as the main predators in the Antarctic approach partly in flight. If so direct aircraft approaches as seen during off-route flights around Ardley Island or over Dart Island would be expected to cause the strongest response in birds.

Other studies have shown that adverse effects of air traffic on birds include energetic constrains (Bélanger and Bédard 1990), breeding site shifts (Stock 1992), egg and chick mortality (Thomson 1977, Zonfrillo 1993). Especially colonial breeders and large feeding flocks react stronger to air traffic (Bourne 1991, Bunnell et al. 1981, Culik et al. 1990, Dierschke 1998, Olsson and Gabrielsen 1990, Zonfrillo 1993, but see Dunnet 1977).

If aircraft movement suggests an aerial predator approach, responses should be stronger than to sound alone. The study results showed the opposite, i.e. helicopter-sound simulations caused more physiological and behavioural responses in birds independent of area type. This suggests that not specifically the simulation of the helicopter sound, but also the new stimulus as such caused the response in birds. Air traffic exists already for more than two decades, whereas simulations were applied for the first time from unexpected positions. However, none of the simulations during this study caused fly-off in SGP, although the distance of the stimulus was similar to visits. In A_{medium} and A_{low}, birds showed short-term habituation the repeated simulations. SGP in A_{high} reacted least to the simulations, but showed no significant reduction in HR changes over the first stimuli repeats. Breeding close to human infrastructure, these birds were more exposed to human noise sources and may also associate such sounds with threatening incidents.

Conclusion

SGP showed similar or more strong physiological and behavioural responses to visits than to natural stimuli (Tab. 3.4). Visits are therefore current stressors for the birds, independent of area type. Nevertheless, birds in A_{high} showed several signs of habituation (lower fly-off, shorter fly-off distances, less defence behaviour). Birds in A_{medium} reacted to visits with frequent fly-off resulting in the highest predation risk for eggs and young chicks. Birds in nesting and resting areas of low human activity showed the strongest HR increases and ground defence against a visitor. In contrast, air traffic caused similar HR changes as under natural stimuli but lower behavioural responses. Stressful for breeding birds are only aircraft approaches in low altitude from unpredictable directions. The exposure to helicopter-sound simulations increased HR similar to natural stimuli in all area types, but repeated applications showed short-term habituation abilities of birds breeding in A_{medium} and A_{low}.

Table 3.4. Summary of physiological and behavioural responses of southern giant petrel breeding in areas of high, medium and low human activity. Response strength to human stimuli categorised in relation to significant differences to natural stimuli as 1 - lower, 2 - similar, 3 – higher. In brackets categories supposed from few observations (sample sizes too small for statistical confirmation).
↓ represent short-term habituation effects, = similar values over all repeated stimuli

stimulus	A_{high}	A_{medium}	A_{low}
visits at 25 m			
behavioural change	2	2	2
relative HR increase	2	2	3
first visit to nest			
fly-off	3	3	3
spit stomach content	2	(2)	3
hit with bill	2	(2)	2
air traffic regular			
behavioural change	1	1	1
relative HR increase	2	2	2
air traffic irregular			
behavioural change	(2)	(2)	(2)
relative HR increase	2	2	2
helicopter-sound simulation			
behavioural change	2	2	2
relative HR increase	2	2	2
repeated visits at 25 m			
relative HR increase	↓	↓	↓
repeated simulations			
relative HR increase	=	↓	↓

4 EFFECTS OF HUMAN ACTIVITIES ON BEHAVIOUR AND HEART RATE OF SKUAS

4.1 Introduction

According to life-history theory there will often be a conflict between investment in current versus future reproduction (Roff 1992, Stearns 1992). The bird decides about the allocation of time to actual offspring care (effort of incubation, brooding, and feeding, defence strength) versus own survival (feeding, resting, preening, defence strength) and future reproduction. Parents that defend the nest more vigorously suffer lower nest predation (e.g. Andersson et al. 1980, Byrkjedal 1987, Wiklund 1990). But these birds are likely to spend energy and risk injury or even death (e.g. Montgomerie and Weatherhead 1988, Viñuela et al. 1995).

Pietz 1986) studied daily activity patterns of brown (BS) and south polar skuas (SPS), revealing form differences in distribution and length of resting and foraging periods related to diet-specific foraging strategies. Nevertheless, the importance of nest attendance is shown in both forms in a shared, well co-ordinated pattern during incubation, brooding, and chick guarding. Skuas in the northern and southern hemisphere are known to defend their breeding territories vigorously against any natural and human intruders (Furness 1987). In addition, individuals of various skua species hold feeding territories with the benefit of higher offspring survival (Hahn and Peter 2003, Votier et al. 2004a, Young 1994).

Unpredictable events in the environment can affect the time budget negatively leading to additional energetic costs that have to be paid for. Changes in sea ice extent and food availability as well as severe weather conditions have been recognised as major natural factors influencing breeding and survival of seabirds in the Antarctic (Büßer et al. 2004, Micol and Jouventin 2001, Woehler and Croxall 1997).

Hemmings 1990) reviewed human impacts on skuas around scientific stations in the Antarctic and found records of killing, egg collection, and habitat destruction. The former activities have been banned, but the latter is still of concern (ASOC 2004, ATCM 2003). The lack of waste management in the early station history of the Antarctic resulted in an exploration of human food waste by skuas, whereby chicken cholera was spread (Hemmings 1990). Most open dump sites have been capped in recent years, but almost every station has a few 'pet' BS being fed by station personnel (Reinhardt et al. 2000). A diet study on BS on the Fildes Peninsula in 2001 revealed that about 9 % of food remains in territories have been of human origin. The amount of human food and the nest distance from the stations were negatively correlated (Peter et al. 2001). BS breeding closer to stations could, therefore, show signs of habituation towards humans. Alert and fly-off distance, and aggression should be reduced in comparison to birds breeding in areas of low human activity. In contrast, SPS that feed at sea are expected to be less habituated.

This study aims to assess the behavioural and physiological responses of breeding BS and SPS to various human activities. Actual human stressors and the coping ability of individuals will be identified in the study site.

4.2 Methods

4.2.1 Behaviour

Behavioural Activity Patterns without Human Stimuli

I recorded territorial attendance of skuas at the first visit each season. Equivalent to SGP, the behaviour of incubating skuas was recorded on video and analysed using the described behavioural categories in the programme OBSERVER 4.1 (chapter 3, Tab. 3.1). I compared the basic behaviour of four BS and four SPS in areas of high (A_{high}) and low (A_{low}) human activity.

Behavioural Response to Human Stimuli

Alert distance, fly-off distance, and aggression were used to compare individual responses to human visits at the beginning of each season. I approached the territory (1 pace/sec) and walked directly towards the nest. The alarm call is usually the first response of skuas to an approaching object and was used for the assessment of the alert distance (measured only in 2003). The fly-off distance is the distance between intruder and bird at the time it leaves the nest in response to the visit. Both partners defend the nest, and the strength of each was categorised applying following modified aggression score after Furness 1987): 0 - bird stays on the nest when approached, 1 - adult leaves territory, 2 - bird circles above territory, 3 - adult swoops at person but does not hit, 4 - bird swoops and hits person occasionally, and 5 - bird swoops and hits most times. The aggression strength of a single bird is less than if the partner is also defending (Hamer and Furness 1993). Aggression was included in the analysis, when both parents were present. Attacks generally intensify in the progress of laying and incubation, and are greatest shortly after chick hatching (Furness 1987). The aggression was therefore measured within a few days in both area types.

To compared vigilance behaviour, I analysed the behavioural change from 'observe' to 'being alert'. For the comparison of different stimuli, the first response of each bird was included in the analysis to exclude possible short-term habituation effects.

4.2.2 Heart Rate

The stethoscope-microphone-units were used in the nests of skuas as described for SGP (see chapter 3). The equipment was installed after the bird had flown off the nest. Skuas are curious and the microphones and cables had to be fixed and hidden. The installation lasted under three minutes, and most skuas returned within 2 min after I had left the territory. The heart rate (HR) could only be measured while one bird was incubating the eggs or brooding newly hatched chicks. Due to the differing starting dates of the field work periods (section 2.1), I studied the majority of birds in the last field season. In 2001, I tested the HR equipment in 5 BS and 5 SPS nests. In 2002 and 2003, I installed it in 6 BS and 10 SPS nests, and 15 BS and 14 SPS nests respectively (total of 181 recording hours).

The experiments of repeated visits and simulations and the data analysis were conducted in the same ways as for SGP (chapter 3).

4.3 Results

4.3.1 Behaviour

Behavioural Activity Patterns without Human Activity

Territorial attendance of both partners of BS and SPS during the incubation period varied, but was not significantly different over the years (binary logistic regression - Wald = 0.38, df = 1, p = 0.54), between skua forms (Wald = 0.32, p = 0.57) or area types (Wald = 0.06, p = 0.81, mean attendance values in Tab. 4.1.).

Table 4.1. Territorial attendance means ± S.E. of brown and south polar skua breeding pairs during the first visit of each field season (nest number in brackets). Skua forms and areas of high and low human activity showed no significant differences.

season	BS		SPS	
	A_{high}	A_{low}	A_{high}	A_{low}
2001	1.45 ± 0.16 (11)	1.42 ± 0.15 (12)	1.81 ± 0.09 (21)	1.80 ± 0.11 (15)
2002	1.89 ± 0.72 (19)	1.63 ± 0.13 (16)	1.89 ± 0.11 (9)	1.69 ± 0.08 (36)
2003	1.67 ± 0.08 (33)	1.67 ± 0.10 (24)	1.50 ± 0.10 (28)	1.65 ± 0.10 (33)

Independent of year, skua form, and area type, the basic behaviour of incubating skuas consists in 78 to 99 % of observing the surrounding (Fig. 4.1, GLM ANOVA factor year: $F_{2,48} = 0.38$, p = 0.69; forms: $F_{1,48} = 0.04$, p = 0.84; area: $F_{1,48} = 1.69$, p = 0.20). Up to 15 % of an hour were spent in vigilance as response to natural stimuli near the bird, independent of year (Kruskal-Wallis $H_2 = 1.70$, p = 0.43), form (Mann-Whitney U = 561.0, p = 0.89), and area type (U = 638.5, p = 0.30). Some birds left the nests for defence, territorial display or other unknown reasons and returned directly or after a few minutes of walking in the territory. Preening and sleeping lasted maximum 5 min per observed hour. Egg turning occurred in the studied cases only during resettling after fly-off and some partner interactions. It was included according under these categories.

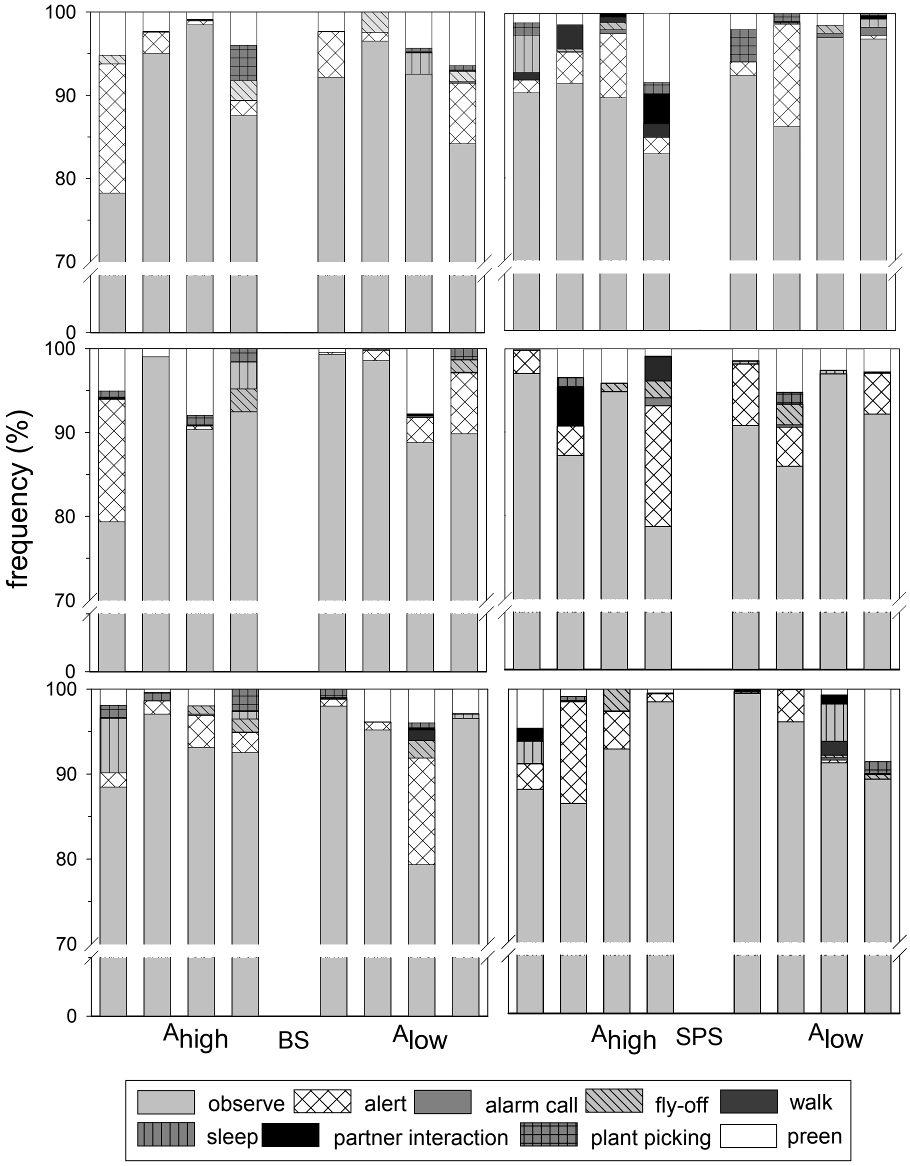

Figure 4.1. Basic behaviour of incubating skuas (four brown and four south polar skuas in areas of high and low human activity). Upper plots season 2001, middle 2002, and lower 2003. Average of a two-hour video record taken between 10:00 and 14:00. No human stimuli occurred while recording. More than ¾ of an hour were spend observing. Activity patterns were not significantly different ($p > 0.05$).

Behavioural Response to Human Activity

Skuas became alert in 55 to 77 %, when other skuas flew over the territories (Table 4.2). All tested human stimuli, except air traffic, resulted in similar respond ranges. In A_{low}, both skua forms reacted stronger to visits up to 15 m, whereas simulations caused contradictory responses. All other human stimuli caused a similar number of birds to respond with increased vigilance.

Changes in behaviour ‘observe’ to ‘alert’ of BS and SPS did neither decrease during repeated visits (Nested Mixed Model: $F_{1,59} = 0.68$, $p = 0.93$), nor during repeated simulations ($F_{1,59} = 0.64$, $p = 0.96$).

Alert and fly-off distance strongly correlated (Pearson $r = 0.70$, $n = 101$, $p < 0.001$) ranging between 0 to 100 m. Nesting birds of both skua forms in A_{high} responded to visits significantly later with an alarm call than animals in A_{low} (GLM area: $F_{1,100} = 13.83$, $p < 0.001$, forms: $F_{1,100} = 0.48$, $p = 0.49$). The distance between alarm sign and fly-off was larger in areas of high human activity (A_{high}: mean 8.7 m ± 4.8 (S.D.), A_{low}: 6.8 m ± 4.2; $F_{1,100} = 4.58$, $p = 0.03$; forms, $F_{1,100} = 1.14$, $p = 0.29$). Skuas breeding in A_{high} flew off the nest significantly later than birds in A_{low} (Fig, 4.2, GLM $F_{1,318} = 20.84$, $p < 0.001$). There was neither a significant difference between years ($F_{2,318} = 0.54$, $p = 0.59$) nor skua forms ($F_{1,318} = 0.02$, $p = 0.89$).

Table 4.2. Percent of brown and south polar skuas with behavioural change from 'observe' to 'alert' at first occurrence of different stimuli. [1] conspecifics over-fly territory. Number of individuals tested in brackets. Binary logistic regression was used for comparison of areas with high and low human activity. Binomial tests applied for comparison between human and natural stimuli within each area type (* if significantly different $p < 0.05$).

stimulus	BS		Wald-Statistic	SPS		Wald-Statistic
	A_{high}	A_{low}	p	A_{high}	A_{low}	p
natural [1]	77 (26)	73 (26)	0.75	58 (26)	65 (26)	0.14
visit at 15 m	69 (26)	77 (26)	0.001	69 (26)	73 (26)	0.002
air traffic	41* (17)	40* (5)	0.30	50 (16)	50 (6)	0.67
simulation	62 (21)	74 (19)	0.04	65 (20)	62 (21)	0.04
visit + air traffic	66 (9)			60 (10)		
simulation + talk	71 (7)	75 (8)	0.08	67 (6)	63 (8)	0.29

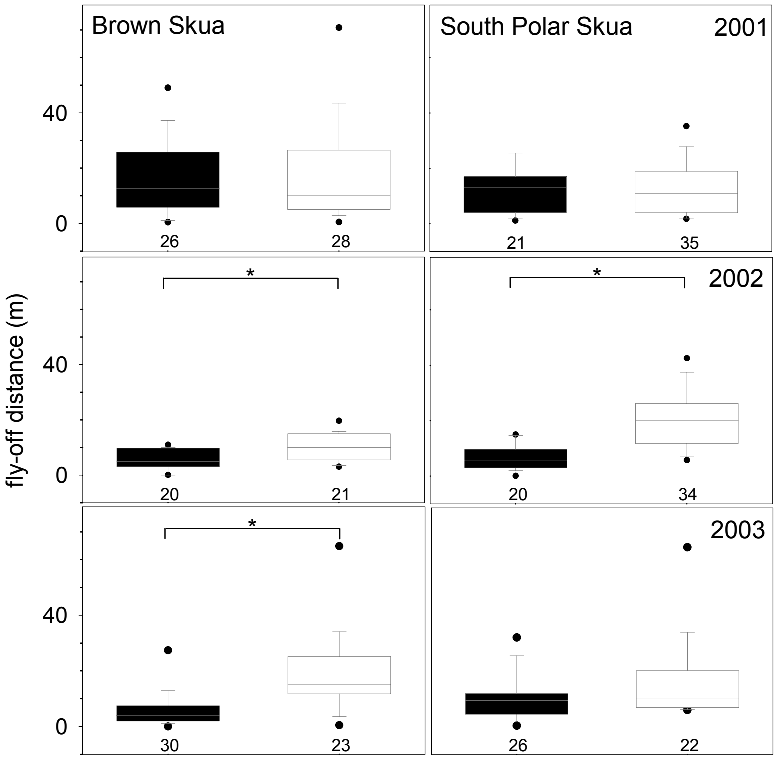

Figure 4.2. Fly-off distance of skuas in areas of high (black) and low (white) human activity presented as boxplots (median 5, 10, 25, 75, 90, 95 percentile) with sample size below plot. Territories were approached by visitor during the incubation period of three seasons. * represent t-test results ($p < 0.05$).

Air traffic on frequently used routes and helicopter-noise simulations did not result in fly-off of BS and SPS during any of the studied seasons.

The aggression of SPS was higher than of BS and differed significantly between years (Fig. 4.3, Likelihood ratio for forms: $\chi^2 = 57.58$, $p < 0.001$; for years $\chi^2 = 147.56$, $p < 0.001$). Aggression scores of SPS were in two of three years significantly higher in areas of low human activity (Tab. 4.3). BS showed the same tendency.

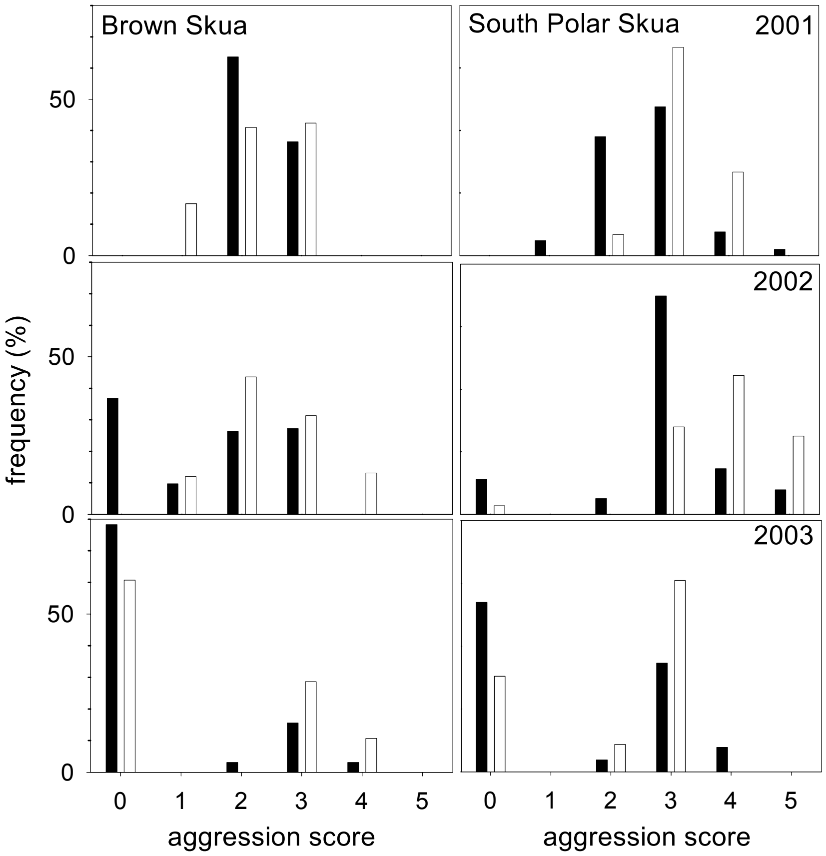

Figure 4.3. Aggression of skuas against visitor in areas of high (black bars) and low human activity (white). Territories were approached by visitor during the incubation period of three seasons. Aggression of birds was higher in areas of low human activity. Score after Furness 1987, see method.

Table 4.3. Likelihood ratio chi-square tests for area-type differences in brown and south polar skua aggression against visitor. Measured during incubation period and separated for forms and year.

season	BS		n	SPS		n
	χ^2	p		χ^2	p	
2001	4.45	0.22	54	9.89	0.04	56
2002	9.58	0.48	41	12.73	0.005	54
2003	4.55	0.21	53	5.64	0.13	48

4.3.2 Heart Rate

Basic HR differed significantly between years (Fig. 4.4; GLM $F_{1,82} = 10.26$, $p = 0.002$) and areas ($F_{1,82} = 10.34$, $p = 0.002$; year*area $F_{1,82} = 4.08$, $p = 0.047$), but not between forms ($F_{1,82} = 1.86$, $p = 0.18$).

The relative HR increases in BS and SPS were similar in both years, so that data were pooled for the analyses of different stimuli in the different areas (ANOVA for forms: $F_{1,295} = 0.05$, $p = 0.83$; for year: $F_{1,295} = 0.65$, $p = 0.42$).

Visits between 10 to 30 m distance to a BS resulted in considerable HR increases (Fig. 4.5). The bird responded stronger to long visits with visitor movement near the nest, than to shorter repeated visits.

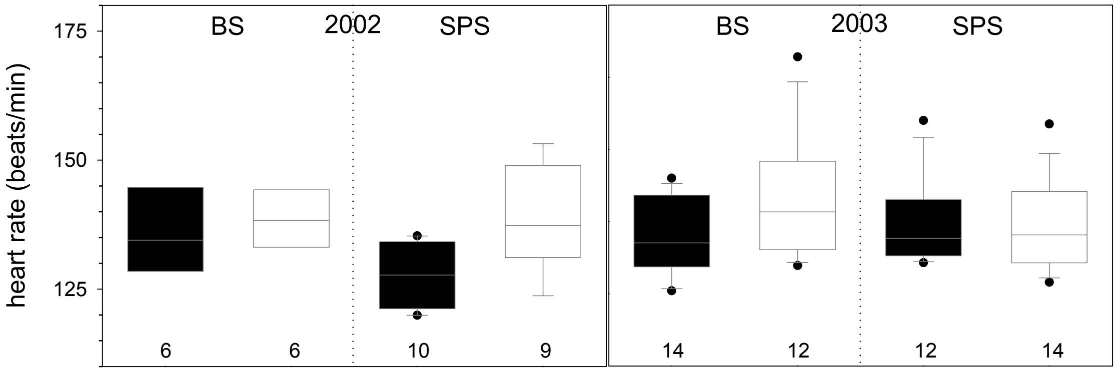

Figure 4.4. Basic heart rates of incubating brown and south polar skuas in areas of high (black) and low (white) human activity (sample size below plot). Comparison of field season 2002 and 2003 on the Fildes Peninsula and Ardley Island.

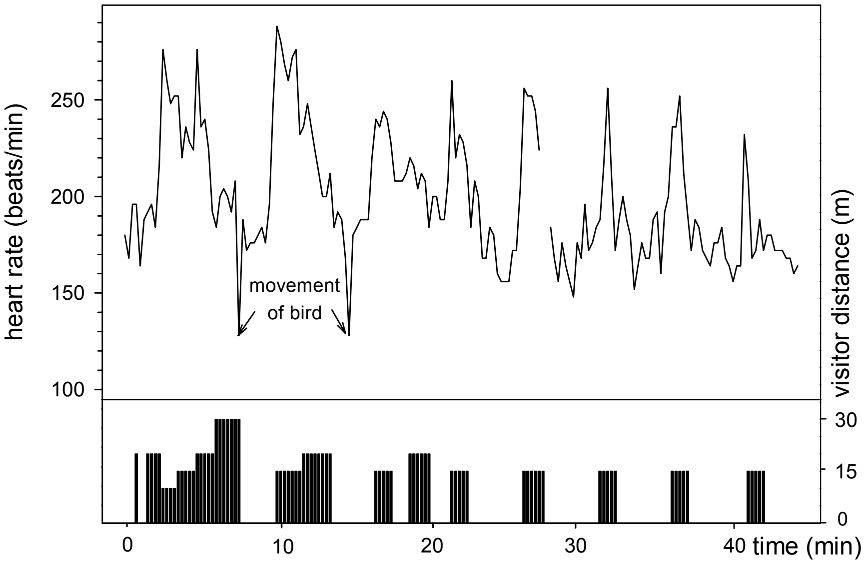

Figure 4.5. Example of heart rate record (upper line) of a brown skua breeding in A_{high} on 6 January 2003. Visits at different distances (continues scale in the lower part of the graph) increased the heart rate significantly, but bird responded less strong to repeated approaches.

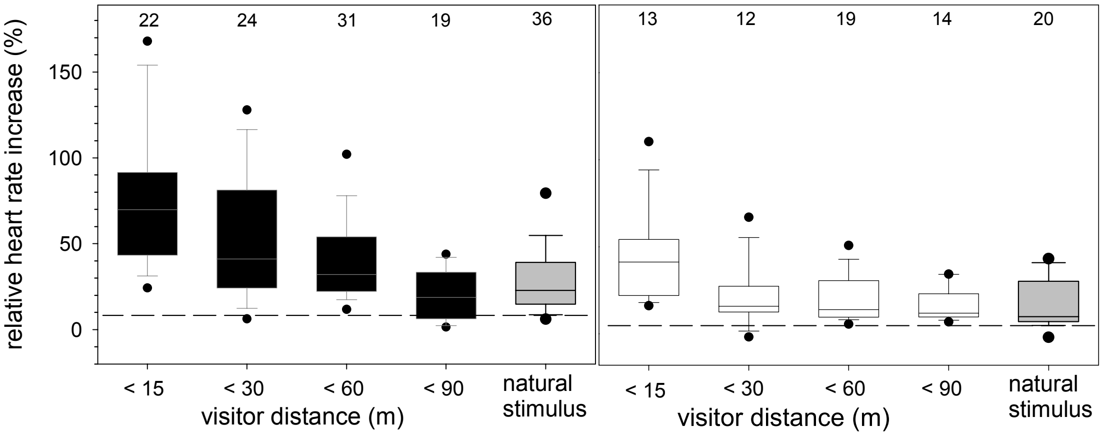

Figure 4.6. Comparison of relative heart-rate increases during visits at different distances to both skua forms in areas of high (black) and low (white) human activity. Data presented in relation to responses of the same study birds to natural stimuli in the same observation period (incubating or brooding). Dashed lines represent value of 10^{th} percentile of natural stimuli boxplots.

Visits closer than 30 m to skuas in A_{high} resulted in a significantly larger HR change than under observed natural stimuli (Fig. 4.6, Kruskal-Wallis $H_4 = 47.10$, $p < 0.001$, *post hoc* Dunn against natural: 0 - 30 m $p < 0.05$). Relative HR increases of skuas in A_{low} were significantly smaller compared to birds in A_{high} (t-tests of areas for each stimulus $p < 0.006$, except 60 - 90 m with $p = 0.49$). In A_{low}, only visits < 15 m produced higher HR increases than natural stimuli (Kruskal-Wallis $H_4 = 16.84$, $p = 0.002$, *post hoc* Dunn against natural $p < 0.05$).

Also the type of visit affected the response of skuas (Fig. 4.7). In both area types walking caused significant higher HR increases than natural stimuli (ANOVA A_{high} $F_{4,152} = 6.50$, $p < 0.001$, A_{low} $F_{4,112} = 4.42$, $p = 0.009$, in both cases: *post hoc* Dunnett against natural, walking and come/stand/go: $p < 0.05$).

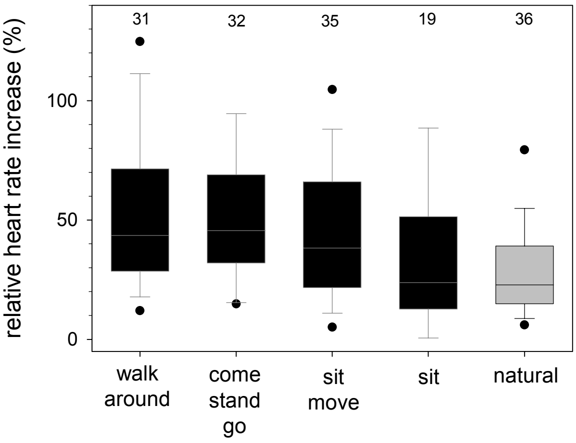

Figure 4.7. Heart-rate changes of brown and south polar skuas exposed to different visit types in area of high human activity. All but sitting caused significantly higher HR increases than natural stimuli (sample size above plot).

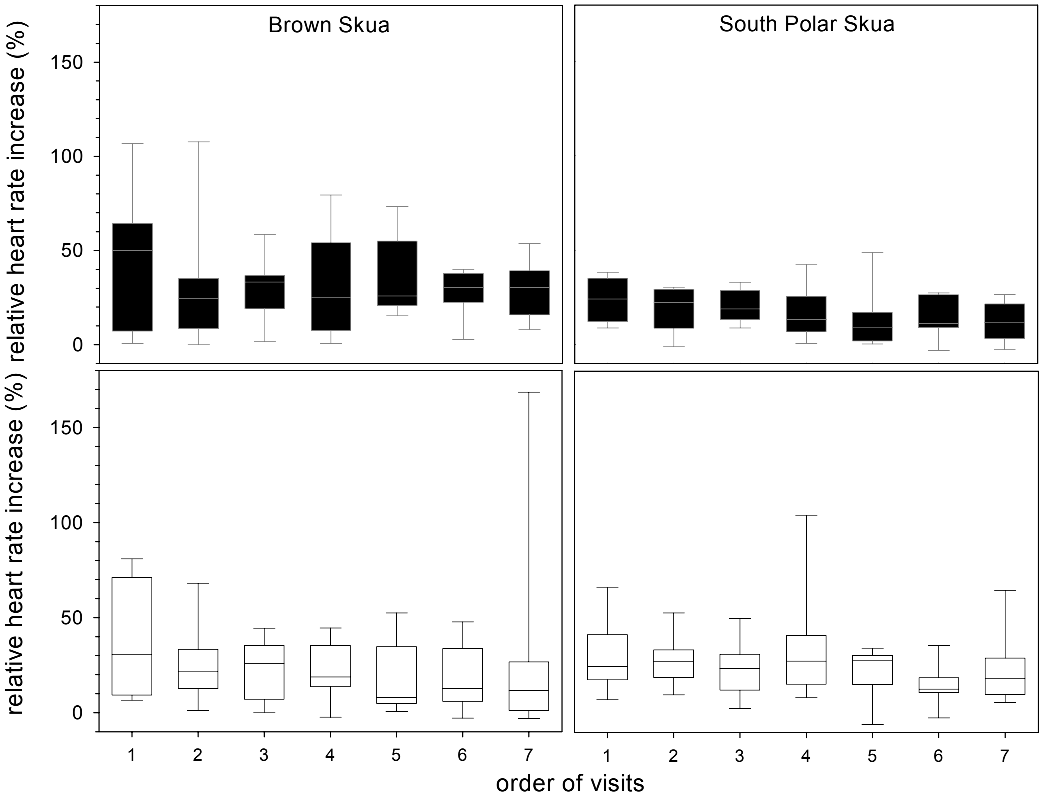

Figure 4.8. Comparison of heart–rate changes to repeated visits of 10 BS and 10 SPS in each area type (high human activity – black, low – white) are presented. Stimuli were repeated every 5 minutes. Boxplots represent median, 10, 25, 75 and 90 percentiles.

Repeated visits to the same individuals showed a greater variance in BS than in SPS (Fig. 4.8). Only SPS in A_{high} showed reduced heart-rate changes over time (RM ANOVA within-subject effects for BS A_{high}: $F_3 = 0.82$, $p = 0.50$, A_{low}: $F_6 = 0.97$, $p = 0.45$; for SPS A_{high}: $F_3 = 3.02$, $p = 0.04$, A_{low}: $F_6 = 1.82$, $p = 0.11$).

The physiological response of skuas to visits was overall stronger than to air traffic (Fig. 4.9 BS and SPS exposed to the same stimuli).

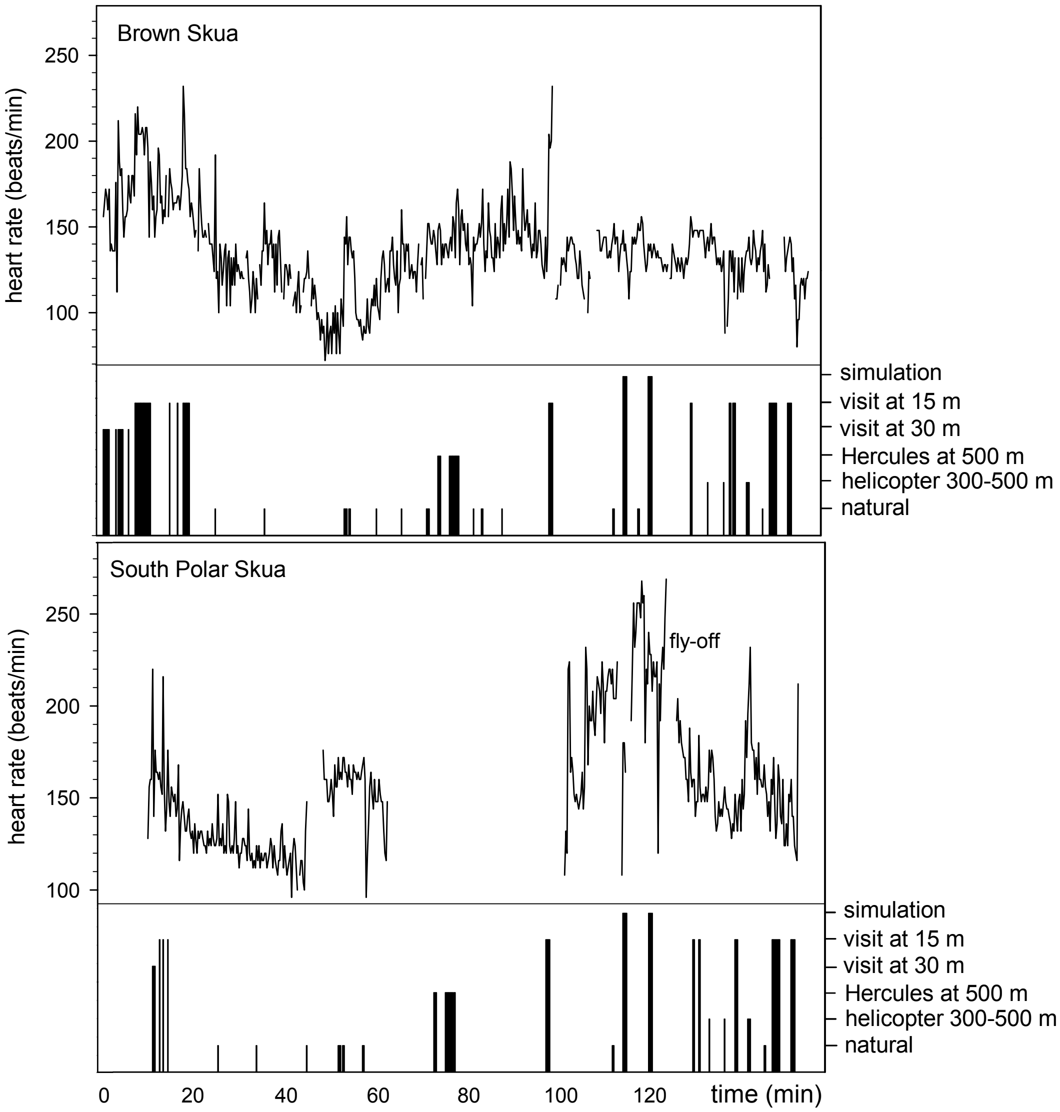

Figure 4.9. Heart-rate example (lines) of one BS and one SPS, nesting 60 m apart from each other. Both were exposed to the similar stimuli (bars) at the same time on 18 December 2002. Gaps caused by movement of bird inside the nest or displacement of stethoscope-microphone.

Especially BS breeding inside station areas showed relatively small HR increases when overflown by Hercules C-130 in very low altitude compared to visits (Fig. 4.10).

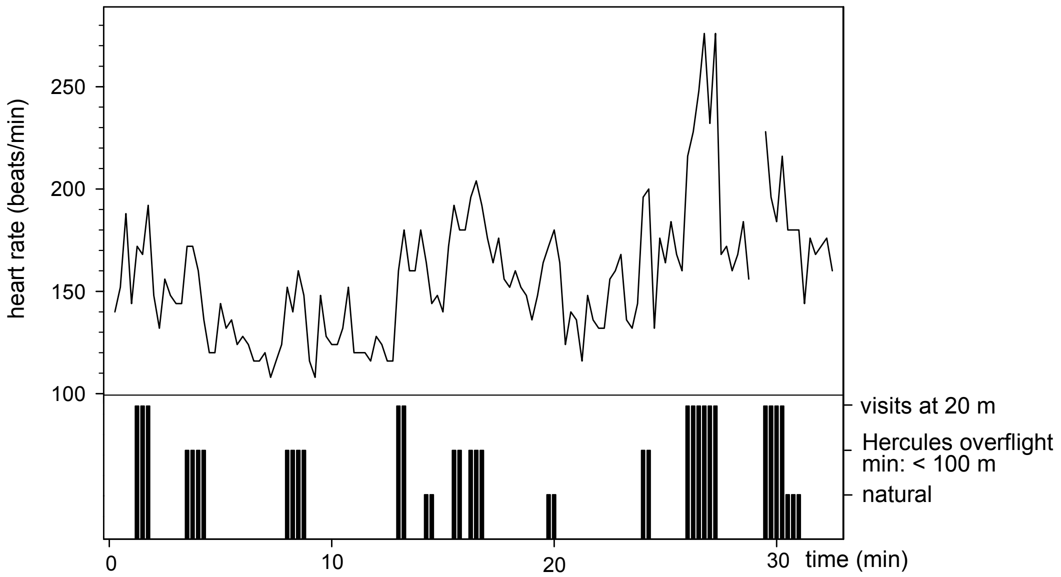

Figure 4.10. HR example (line) of a brown skua nesting 50 m apart from station buildings of Bellingshausen, recorded on 7 January 2003. Human and natural stimuli that occurred during observation are presented by bars of different height. Repeated over-flights of aeroplane type Hercules lead to less elevation of heart rates than visits.

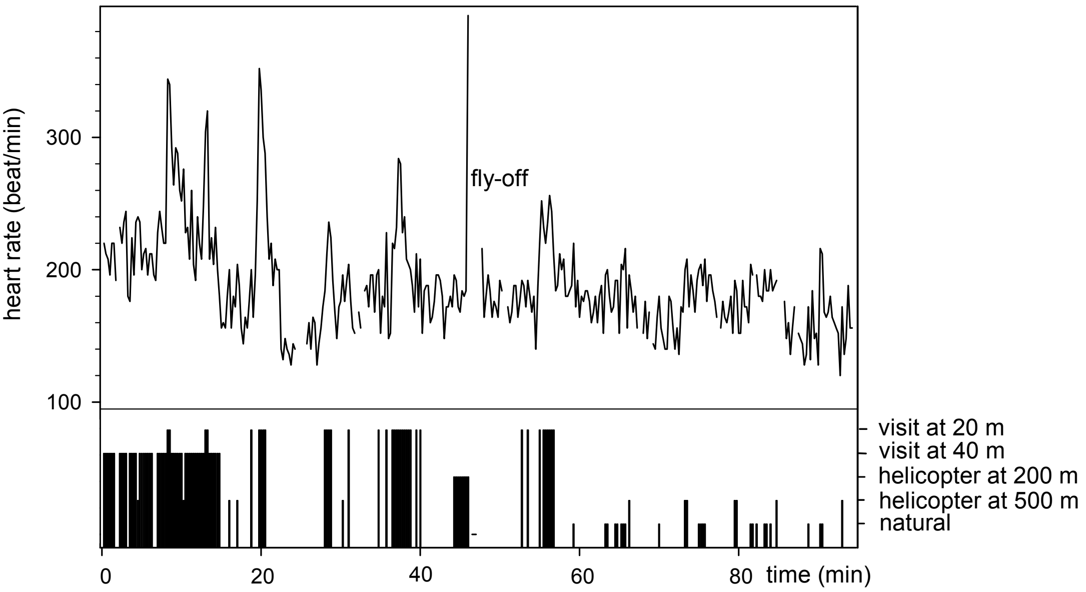

Figure 4.11. HR example (line) of a south polar skua nesting on Ardley Island on 16 December 2003. Human and natural stimuli that occurred during observation are presented by bars of different height. A strong behavioural response was cased by a helicopter flight outside the regular route (resulted in fly-off) and closer visits of one person.

However, flights outside the normal routes resulted in higher HR-increases (Fig. 4.11 and 4.12). Irregular air traffic < 500 m caused in 11 % of the observed cases fly-off responses (27 cases).

The responses of skuas to several air-traffic types were not significantly different from natural stimuli (Fig. 4.12, ANOVA $F_{5,71} = 1.94$, $p = 0.10$).

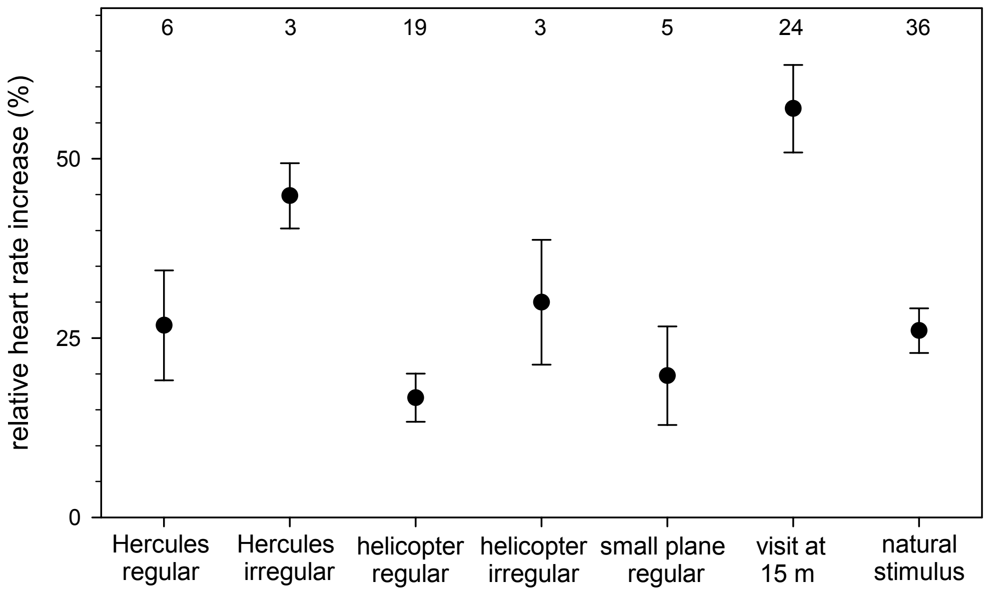

Figure 4.12. HR increases of brown and south polar skuas in response to air traffic, visits and natural stimuli (mean ± S.E.). The physiological response of birds to large aeroplanes (type Hercules C-130), helicopters and small planes (e.g. Twin Otter) was compared for frequently and rarely used routes and set in relation to encounters with humans and other birds.

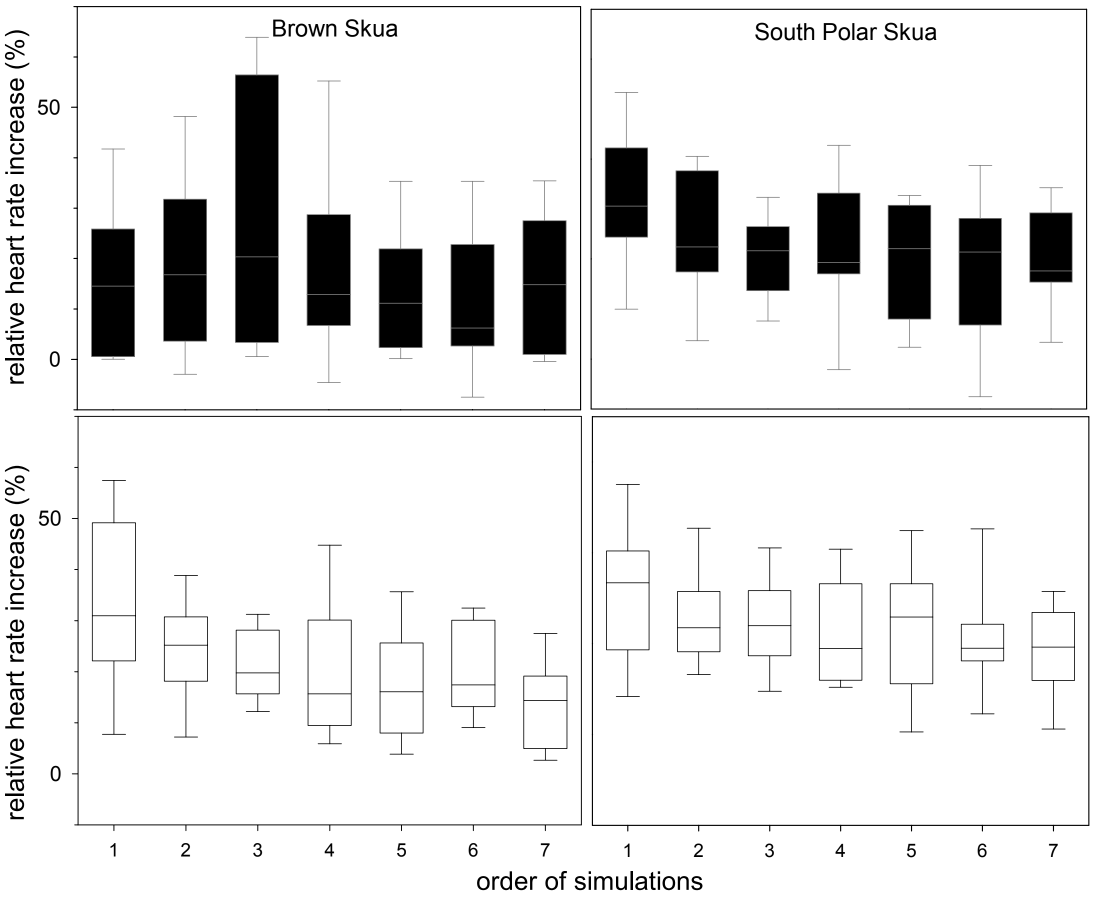

Figure 4.13. Comparison of the heart-rate changes of 10 BS and 10 SPS to repeated simulations in each area type (area of high – black – and low – white – human activity). Stimuli were repeated every 5 minutes. Boxplots represent median, 10, 25, 75 and 90 percentiles.

The helicopter-sound simulations in both area types showed similar HR increase and no differences in simulation type (ANOVA area: $F_{1,38} = 3.46$, $p = 0.07$; type: $F_{1,38} = 0.94$, $p = 0.34$). Repeated simulations to individuals showed the greatest variance in BS of A_{high} (Fig. 4.13). All except BS in A_{high} reduced their HR during repeated simulations (RM ANOVA within-subject effect BS A_{high}: $F_4 = 1.17$, $p = 0.34$; A_{low}: $F_4 = 5.78$, $p = 0.002$; SPS A_{high}: $F_4 = 6.30$, $p = 0.001$; A_{low}: $F_3 = 2.88$, $p = 0.04$).

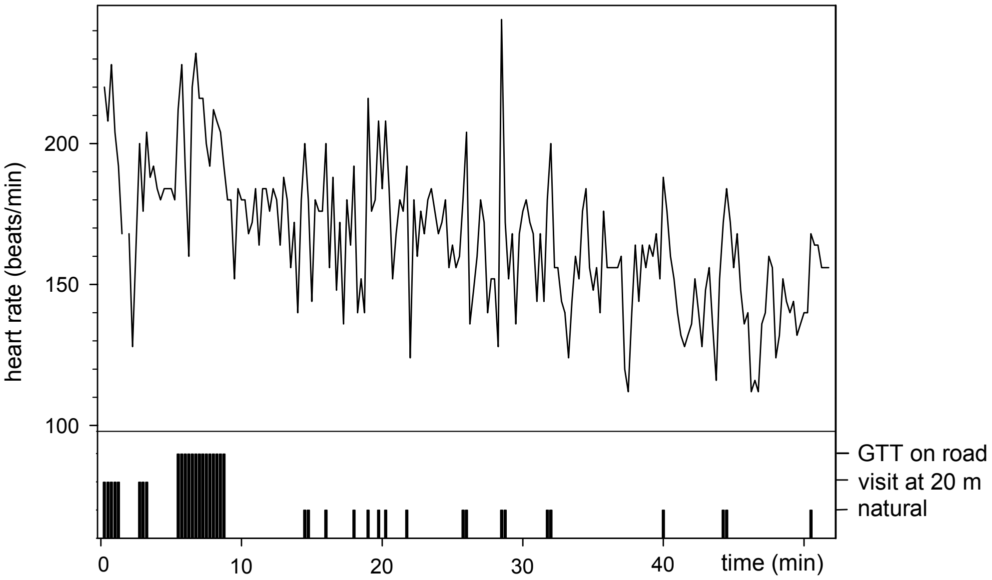

Figure 4.14. Heart-rate record (line) of brown skua nesting on a hill 60 m from the road on 15 December 2002. Close visits and the noise of a track vehicle (GTT) caused a high heart rate, but also calls of other skuas resulted in short increases.

Track vehicles (GTT) are used relatively seldom on roads (mean speed 11 km/h, perceived noise for the bird breeding on a hill beside the road: around 50 dB(A) at 100 m distance). Therefore, HR increased considerably in a BS nesting near the road (Fig. 4.14).

The comparison of different human stimuli in areas of high human activity showed significantly higher HR increases for visits but not for air traffic, simulations and land traffic (Fig 4.15, Kruskal-Wallis $H_4 = 60.09$, $p < 0.001$, *post hoc* Dunn against natural $p < 0.05$).

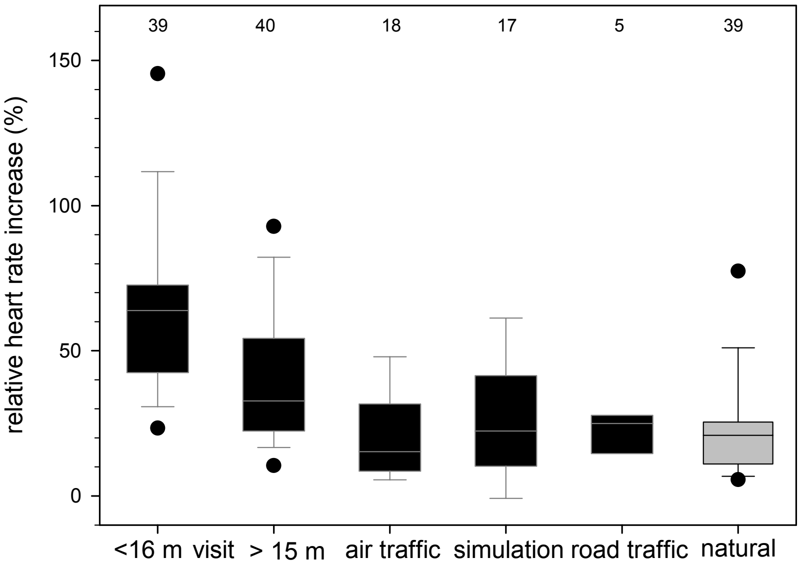

Figure 4.15. Heart-rate responses of brown and south polar skuas in A_{high} to different human and natural stimuli. Boxplots present median, 5, 10, 25, 75, 90, 95 percentiles.

4.4 Discussion

Brown and south polar skuas are top predators in the Antarctic ecosystems that feed in seabird colonies on land and at sea. Their diet and foraging strategies vary between (Reinhardt et al. 2000) and within skua forms (i.e. territorial and non-territorial feeders in BS, Hahn and Peter 2003). They can, therefore, live sympatricly in some regions including the study site. Skuas show also cannibalism by preying on skua eggs and chicks (Furness 1984). This predation has been identified as main reason for egg and chick mortality in BS and SPS (e.g. Reinhardt 1995, Williams 1980, Young 1994). Low over-flights of conspecifics can, therefore, be seen as potential natural stressors to breeding skuas.

In response to the predation risk, pair partners co-ordinate territorial attendance and actively defend it by aerial attacks against intruders. At least one bird of a pair is usually in the territory. If both partners are present, the nesting bird can remain longer near eggs or small chicks, while the other initiates the defence. The longer the nest is unattended, the more the brood is exposed to predators and weather. For the adult birds, it is therefore advantageous to remain on the nest until the birds themselves are under risk (Kruuk 1964). In addition, fly-off is more energetically expensive than basal metabolism (Carlson and Moreno 1992), and birds should therefore minimise these costs.

Around Antarctic research stations and at tourist sites, skuas are exposed to various human activities ranging from station noise, aircraft over-flights, tourist visits to capture and handling by scientists. To which extent these activities are seen by the birds as stressors was tested in this study.

Experience with Humans

On the Fildes Peninsula and Ardley Island, skua territories are widely distributed. Some breed within station areas, whereas others are as far as 6.3 km from any infrastructure. In addition, BS are partly associated with stations, when their diet includes human food waste. The relative amount depends on the specialisation of each bird. A diet study in 2001 showed that BS use station food as additional source even if they breed in up to 2.4 km distance (Peter et al. 2001). Although most open human waste sites have been removed over the last 10 years, several BS are actively fed by station members (pers. obs.).

The majority of birds became alert, when other skuas flew over the territories. Active territorial defence against conspecifics occurred, however, only in a minority of cases and took a few minutes independent of area type. In contrast, the standardised visits to the nests caused different reactions depending clearly on experience with human activity. Both, BS and SPS, in A_{high} flew off the nests much later compared to A_{low}. This confirms the hypothesis, that skuas habituated to frequent human activities. Fly-off distance is influenced by body condition, habitat structure, group size, seasonal and daily as well as the behaviour of visitors (e.g. Beale and Monaghan 2004, Borkowski 2001, Burger and Gochfeld 1983, Gander and Ingold 1997, Gill et al. 2001, Scott et al. 1996). Alert and fly-off distance of skuas were highly correlated, which has also been found in gulls (Burger and Gochfeld 1983).

The aggression strength against a visitor depends on the skua form, breeding stage, nest density and individual characteristics (Furness 1987). I recorded a higher aggression of SPS than of BS, which confirms studies by Reinhardt (1995). SPS in A_{high} showed lower aggression suggesting that birds learned that the intrusion is not life threatening or that a lower aggression strength is sufficient to defend eggs and chicks. An increase in nest defence related to offspring age has been observed in skuas (Hamer and Furness 1991) and other bird species (e.g. Andersson and Götmark 1980, Blühdorn 1998, Ferrer et al. 1990). The annual variation in aggression, found in this study, suggests a state-dependent behavioural adjustment. In years of favourable breeding conditions, offspring defence is stronger and therefore parental investment higher than in years of unfavourable environmental conditions.

Effects of Visitor Type and Visitor Distance

Human activities should be only threatening in cases where the result of a visit cannot be judged by the bird. Frequent visits without negative consequences for the nesting bird lead usually to a reduction in fly-off distance and defence (Becker 1996, Burger and Gochfeld 1983, Lemmetyinen 1971, Lord et al. 2001). Siebolts (1998) recorded in a frequently visited colony of common terns *Sterna hirundo* lower fly-off distance but higher aggression. The latter could be explained by conditioning, i.e. because eggs and chicks were not harmed during visits, terns were successful in their defence and therefore motivated to increase aggression with time. Repeated visits of scientists that sometimes handle adults and chicks can also result in increased fly-off distance and aggression (pers. comm. S. Hahn and M. Ritz for skuas, Warham 1990 for petrels). This sensitisation to scientists could subsequently result in stronger responses to station personnel or tourists (shown in mallards: Balát 1969).

I found HR increases in all measured distances (up to 90 m), but visits closer than 15 m caused in both area types higher levels than observed under natural stimuli. Over-flights of conspecifics increased HR up to 80 %, visits under 15 m up to 170 %. Surprisingly, skuas in A_{high} had also significantly higher HR increases < 30 m and reacted therefore more sensitive to visits than A_{low} skuas. Birds may differed in their decision making depending on the frequency of visits. There exist only a few paths that are frequently used by station members, tourists and scientists, and all can leave them at any time. Therefore, predicting visitor directions should be difficult for the birds. When skuas in A_{low} receive a visit, they decide earlier about fly-off (greater fly-off distance than A_{high} birds). Birds that remain on their nest may judge the visit as non-threatening, and HR increases are less pronounced. In contrast, skuas breeding in A_{high} are more often visited and probably have experienced more threatening events (higher probability of being banded, frequent visits from different directions). So they reduced their fly-off distance or aggression, but are physiologically ‘alert’ to be able to react fast to any stressful stimulus.

As expected, all skuas reacted stronger to a person walking, especially when coming and going from different directions, than to a person sitting. The size reduction of approaching objects leads generally to reduced stress responses (Giese 1998).

Repeated visits did not result in lower HR increases over time except in SPS breeding in A_{high}. Variation between skuas breeding within the same area type was relatively high suggesting strong individual differences in stimuli perception and response strategies. Frequent, but unpredictable scientific visits could be stressful and therefore prevent short-term habituation in most skuas.

Because fly-off distances varied considerably between individuals, a recommendation for a defined minimum approach distance to skuas cannot be given. The HR studies showed significant differences to natural stimuli below 30 m, whereas the lower natural boundary method suggests about 60 m. Skuas show, however, clear behavioural signs when disturbed (alarm call and fly-off with frequent aerial attacks) that visitors can easily recognise. Visitors should, therefore, be advised to leave the site as soon as these behavioural changes occur. Birds which do not show any alertness, should still not be visited closer than 15 m because HR increases are significant.

Air Traffic

As seen in SGP, also skuas show less behavioural and physiological stress responses to passing aircraft compared to visits of the territory. In particular BS seem to have habituated to air traffic. Pairs which breed inside stations or near the airport showed HR increases during over-flights < 100 m, but they disrupted their current behaviour only shortly. This has been described in others studies where birds bred close to airports or in areas with regular air traffic (review in Kempf and Hüppop 1998). The important difference in the response strength of the birds was the predictability of air traffic. Flights outside the frequently routes resulted in stronger HR responses.

Repeated simulations showed short-term habituation effects in BS and SPS except for BS in A_{high}. These birds had the highest variation in their HR measurements suggesting some very sensitive birds reacting strongly to novel stimuli. Brown (1990) found during his aircraft-simulation studies on crested terns *Sterna bergii* no habituation effects within one day or over successive days. He clearly showed in a controlled experiment that the behavioural responses of birds depended on the sound level of simulated aircraft noise. They prepared to fly or few off when the sound level exceeded 85 dB(A). I played helicopter sound ranging 55-85 dB(A) and had no fly-off of any bird. As the measured sound levels for helicopters < 1000 m reached in breeding groups a maximum of 90.2 dB (Tab. 2.3), fly-off of some skuas in my study is not surprising, especially when helicopters are additionally seen by the bird.

Conclusion

BS and SPS differ in their behavioural responses to natural and human stimuli. Although fly-off distances are of similar range, BS show clearer signs of habituation with reduced distances in A_{high}. SPS are generally more aggressive than BS, but I found lower defence strength in A_{high}. Both, BS and SPS, became alert when stimuli occurred from unexpected directions (natural, visits, irregular air traffic and simulations, Tab. 4.4). Close visits resulted thereby in the strongest physiological and behavioural changes and can be seen as current stressor. Air traffic on normal flight routes is not threatening but off-route flights caused fly-off of sensible birds. Short-term habituation during repeated visits and simulations was only partly seen in heart-rate measurements and not in vigilance. Alarm calls and fly-off from the territory are clear signs of disturbance and should prompt visitors to leave the territories. Concerning sensitivity to human stimuli, no specific breeding groups could be identified for special protection.

Table 4.4. Summary of physiological and behavioural responses of skuas breeding in areas of high and low human activity. Response strength to human stimuli categorised in relation to significant differences to natural stimuli as 1 - lower, 2 - similar, 3 - higher. In brackets categories supposed from few observations (sample sizes too small for statistical confirmation). ↓ represent short-term habituation effects, = similar values over all repeated stimuli.

	brown skua		south polar skua	
stimulus	A_{high}	A_{low}	A_{high}	A_{low}
first visit to nest				
fly-off distance	2	3	2	3
aggression	2	2	2	3
visits at 15 m				
behavioural change	2	2	2	2
relative HR increase	3	3	3	3
air traffic regular				
behavioural change	1	1	2	2
relative HR increase	2	2	2	2
air traffic irregular				
behavioural change	(2)	(2)	(2)	(2)
relative HR increase	(3)	(3)	(3)	(3)
helicopter-sound simulation				
behavioural change	2	2	2	2
relative HR increase	2	2	2	2
repeated visits at 25 m				
relative HR increase	=	=	↓	=
repeated simulations				
relative HR increase	=	↓	↓	↓

5 EFFECTS OF HUMAN ACTIVITIES ON HORMONE LEVELS OF SOUTHERN GIANT PETRELS AND SKUAS

5.1 Introduction

Birds time life-history events such as reproduction and moulting by natural stimuli including day length, temperature and food availability (Wingfield and Kenagy 1991). These cues provide predictable information about forthcoming events, such as the onset of the breeding season. However, severe storms or low food availability can cause individuals to modify their physiology and behaviour towards their own survival (e.g. increase in foraging, spatial shifts) and away from reproduction. Human activities can also elicited these responses (Clemmons and Buchholz 1997).

Most vertebrates have a general response pattern to stress exposure (Axelrod and Reisine 1984, Moberg and Mench 2000, Møller et al. 1998, Wingfield and Ramenofsky 1999). First, catecholamines are released resulting in heart-rate increase and glucose mobilisation. Second, the hypothalamo-pituitary-adrenal axis is activated leading to the secretion of glucocorticoids (GC, triggering the gluconeogenesis). At the same time cytokines secretion is initiated to activate the immune system. However, despite the benefits of acute hormone secretion during emergency situations, chronically high levels of GC can have negative consequences. They can suppress territorial and/or reproductive behaviour (Silverin 1986, Wingfield and Silverin 1986), compromise the immune system (Briggs et al. 1997), and deplete protein reserves through promotion of gluconeogenesis (Wingfield 1994). The measurement of hormones like cortisol and corticosterone (the avian GC) can, therefore, indicate potential and actual environmental stress (Wasser et al. 2000).

GC has been often quantified in blood (Blanchard et al. 1998, Cockrem and Silverin 2002b, Hood et al. 1998, Pereyra and Wingfield 2003, Scheuerlein et al. 2001). However, using blood is inappropriate for many species because animals have to be captured and this, in itself, causes stress. In consequence, non-invasive, easily applicable methods are an attractive alternative (Foley et al. 2001, Goymann et al. 1999, Millspaugh et al. 2001). One such method, used for stress studies in several species, is to measure the metabolites of steroid hormones excreted in the faeces (Cockrem and Rounce 1994, Hiebert et al. 2000, Nakagawa et al. 2003, Touma et al. 2004, Wasser et al. 1997). These metabolites represent an accumulated fraction of plasma GC and may provide, therefore, a more accurate assessment of long-term GC levels (Goymann et al. 1999). Allowance has to be made, however, for hormone variation due to metabolic breakdown after collection (Millspaugh and Washburn 2004).

This is the first study in which corticosterone metabolites have been measured in the faeces of southern giant petrels (SGP), brown (BS) and south polar skuas (SPS). In order to evaluate the method as one easily applicable in these species, I evaluated the influence of some methodological parameters. Furthermore, I analysed the influence of natural (breeding status and weather) and anthropogenic factors (experience of humans, and whether the birds were experiencing visits or air traffic when they produced the faeces). Hormone levels were analysed by SGP colonies to indicated possible chronic stress. Beside the effect of visits to breeding sites, the influence of handling of skua chicks was analysed.

5.2 Methods

I collected SGP samples opportunistically, when I found relatively fresh faeces or, in rare cases, when a bird was seen defecating. Totals of 87 faecal samples in 2002 and 117 samples in 2003 were obtained from adult SGP on Ardley, Geologist, Two Summit, Dart and Nelson Island. I collected samples in the breeding groups (areas of high, medium and low human activity as defined in chapter 3) and in the resting sites of non-breeders and non-nesting adults.

In 2003, I obtained 305 faecal samples of BS adults, 93 of BS chicks, and 106 of SPS adults on the Fildes Peninsula and Ardley Island. I took these samples from the ground immediately after the birds had defecated. In order to test for handling effects, chicks were captured and held for several seconds, until defecation occurred. The sample size was small because only a few older chicks defecated repeatedly.

The breeding success of SPS was very low in 2003. Therefore, breeding adults could not be repeatedly sampled throughout the season, and hatched chicks died within a few days. All faecal samples were taken in daylight between 0700 and 2100 hours, and were stored and transported to Europe at –15°C.

To calibrate the faecal samples with plasma GC, blood samples were taken from five BS and six SPS adults about 10 min after capture (including approaching time). These birds' body condition was determined by measurement (Phillips and Furness 1997). The skuas showed similar plasma GC levels independent of form or body condition (GLM ANOVA skua form: $F_{1,11} = 1.36$, $p = 0.28$; body condition: $F_{1,11} = 2.21$, $p = 0.18$). Plasma GC levels and faecal samples of these birds correlated weakly (Pearson of correlation $r_{11} = 0.23$, $p = 0.499$). Temperature and wind speed data (recorded at 00:00, 6:00, 12:00, 18:00) were provided by the weather station at the Russian base Bellingshausen. According to the sampling time, I used the mean value of the last 24 hours for analysis in SGP and the closest measure for skuas.

Laboratory Analysis

The amount of hormone in faecal samples were analysed in the Institute of Biochemistry, Veterinary University of Vienna. In both years, there was 36 weeks between first sample collection and analysis. Between 0.1 g and 0.3 g of each sample were extracted for the enzyme immunoassays (EIA). A special EIA for tetrahydrocorticosterone (5β–pregnane-3α,11β,21-triol-20-one; from Steraloids, Wilton, N.H., USA) had been developed for faecal samples of wilson's storm petrels *Oceanites oceanicus* and I used the same assay for SGP and skuas (detailed description in Quillfeldt and Möstl 2003, for Adélie penguins *Pygoscelis adeliae* by Nakagawa et al. 2003).

Data Analysis

Because the exact defecation times of SGP samples were unknown, I divided samples into two groups. These were those from birds exposed to human stimuli (i.e. visits and air traffic) within 24 hours before collection and those from birds not so exposed. Skuas were compared according to the length of visits before sampling and whether air traffic had occurred within 24 hours. All data were tested for normality and if not normal were suitably transformed. If transformation did not produce normality, non-parametric tests were applied. To avoid pseudo-replication, only the first sample of a bird was included in the analysis of factor effects. Repeated samples from the same bird were treated as independent if they were more than four days apart (Furness 1983). The effect of natural and human stimuli were tested with ANOVA or under repeated sampling with RM ANOVA.

5.3 Results

5.3.1 Southern Giant Petrels

GC levels in faeces of SGP showed a great variation (median = 163.7 ng/g, range 10.2 - 1735.9, n = 199). Samples of urea had significantly lower GC titres than faeces or a mix of both (Tab. 5.1, Bonferroni *post hoc* $p < 0.01$), and were therefore excluded from analyses. Although samples of different season and age (old or fresh) were similar, there was a significant interaction between the two parameters (Tab. 5.1). Sampling date during the season had no influence on GC levels of SGP (quadrate regression: $r^2 = 0.006$, $p = 0.55$). Nor did breeding status affect hormone levels (Fig. 5.1a). Samples collected after windy days (wind speed $\geq$ 10 m/s) did not differ from samples collected after calmer days (t - test: $t_{110} = 1.23$, $p = 0.22$).

Table 5.1. GC levels in urine and faeces (ng/g) of southern giant petrels sampled in 2002 and 2003. Statistic: GLM (ANOVA) with log10-transformed data to test several biological and methodological parameters.

parameter	groups	n	median	25 %	75 %	min	max	F	p
season	2002	76	135.4	56.8	291.2	10.2	1245.0	0.058	0.810
	2003	115	176.8	74.1	422.6	24.4	1735.9		
status	non-breeder	21	126.5	52.6	302.5	22.9	716.7	1.82	0.166
	breeder	93	173.1	79.8	392.4	13.8	1735.9		
	unknown	76	136.8	61.1	362.8	10.2	1292.9		
sample state	urine	36	79.5	36.5	196.8	13.1	807.2	5.72	0.004
	faeces	102	218.7	84.1	429.5	10.2	1735.9		
	mix	53	133.7	60.3	426.8	22.9	1680.3		
sample age	fresh	134	153.4	71.6	365.5	10.2	1735.9	2.00	0.160
	old	57	161.6	57.8	400.3	13.1	1245.0		
season * state								2.34	0.100
season * age								4.03	0.047
state * age								0.41	0.661

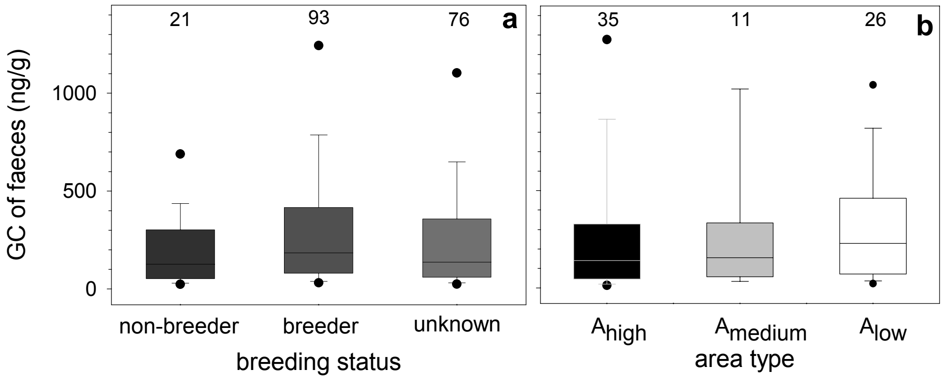

Figure 5.1. Glucocorticoid levels in faeces of adult southern giant petrels around Fildes Peninsula in 2002 and 2003. (a) status comparison, and (b) area comparison of bird samples not exposed to human activities in the last 24 hours. Boxplots represent the median and the 5, 10, 25, 75, 90, and 95 percentiles.

There were similar GC levels in all areas, irrespective of how much human influence they had experienced (Fig. 5.1b, ANOVA $F_{2,72} = 0.70$, $p = 0.50$).

Influence of Visits and Air Traffic

Samples collected after human activities in the breeding areas did not show significantly elevated hormone titres (Tab. 5.2).

Table 5.2. Glucocorticoid (ng/g) measured in faeces of southern giant petrels breeding on different islands around the Fildes Peninsula 2002 and 2003. Comparison of samples collected after human stimuli (+) or without human activity (-). Statistics from log-transformed titres.

area type	island	stimuli	n	median	range	t-test / K-S	p
A_{high}	Ardley	-	19	206.8	1234.8	0.47	0.64
		+	31	167.3	1712.1		
A_{medium}	Ardley	-	9	239.1	1064.5	0.70	0.71
		+	12	226.7	1218.5		
A_{low}	Geologist	-	2	734.4	824.0		
		+	15	203.0	1655.9		
	Two Summit	-	8	228.1	624.2	0.49	0.63
		+	18	194.6	810.8		
	Nelson	-	10	245.9	813.5	0.86	0.40
		+	33	113.1	1265		

There were no significant differences in hormone titres between different area types (Fig. 5.2, ANOVA A_{high}: $F_{3,54} = 0.12$, $p = 0.95$; A_{medium}: $F_{2,20} = 0.68$, $p = 0.52$; A_{low}: $F_{3,83} = 0.26$, $p = 0.86$).

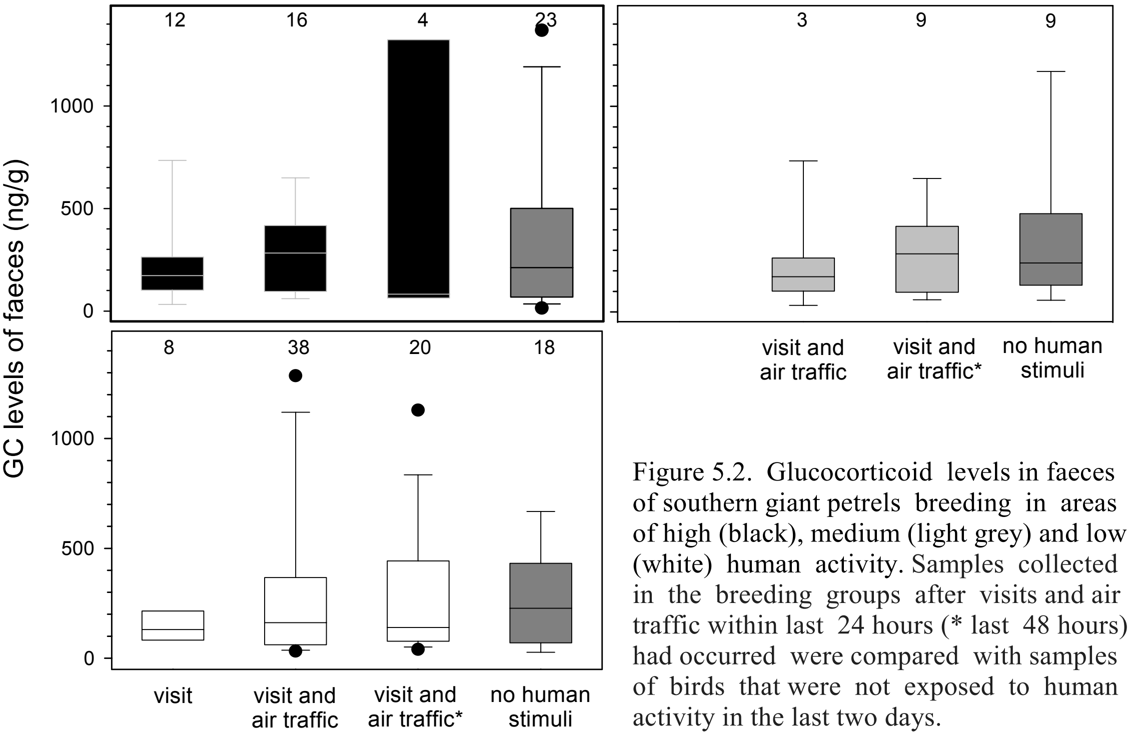

Figure 5.2. Glucocorticoid levels in faeces of southern giant petrels breeding in areas of high (black), medium (light grey) and low (white) human activity. Samples collected in the breeding groups after visits and air traffic within last 24 hours (* last 48 hours) had occurred were compared with samples of birds that were not exposed to human activity in the last two days.

Adult SGP of a frequently visited resting site on Ardley Island had higher GC titres than adults on a less visited resting site on Nelson Island (Ardley: GC-mean: 523.8 ± 138.9, n = 7; Nelson: 252.2 ± 58.2, n = 12; t-test: t = 2.1, p = 0.050).

5.3.2 Skuas

The median GC levels of faeces of adult skuas was 47.6 ng/g (range 7.8 - 567.3, n = 411), and the median of chicks was 50.7 (range 10.7 - 986.6, n = 93). All birds had defecated just before collection and the samples consisted mostly of faeces with a small urea fraction (no separation possible).

BS and SPS different significantly in their hormone levels (BS median = 56.5, SPS median = 29.2; Mann-Whitney U = 9720, p < 0.001). The breeding status of BS affected the GC levels (Table 5.3).

Table 5.3. GC levels in faeces (ng/g) of brown and south polar skuas sampled immediately after first-time approach of non-breeders (NB), breeders (B) and birds that lost the brood (L).

form	status	n	median	25 %	75 %	min	max	Kruskal-Wallis
BS	NB	40	26.9	19.0	46.5	10.1	90.4	$\chi^2 = 27.45$
	B	51	86.8	39.3	139.3	11.5	492.0	$p < 0.001$
	L	11	73.8	43.3	155.8	32.0	255.5	
SPS	NB	49	27.5	19.0	39.0	9.7	164.3	$\chi^2 = 2.87$
	B	29	37.3	20.5	85.0	8.0	215.5	$p = 0.24$
	L	12	30.8	15.2	92.9	7.8	121.5	

In contrast, SPS showed similar hormone titres in non-breeders, breeders and birds that had lost their brood. Comparing each status of both skua forms, non-breeders did not differ (t-test $t_{87} = 0.28$, $p = 0.78$). Breeding BS had significantly higher GC titres than breeding SPS ($t_{78} = 2.95$, $p = 0.004$). Also the GC levels of birds that had lost their brood were different between the forms ($t_{21} = 2.20$, $p = 0.04$).

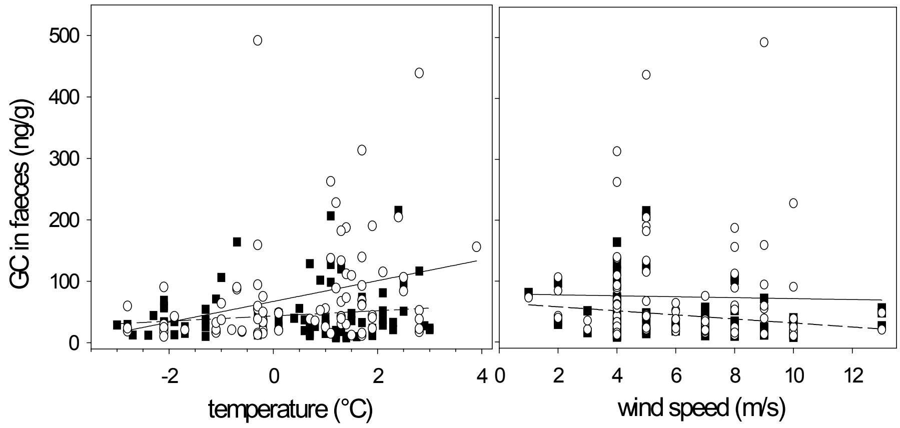

Figure 5.3. Glucocorticoid levels of brown skuas (white) and south polar skuas (black) are not influenced by temperature or wind speed. Samples collected immediately after first time approach in 2003. Regressions for BS (lines) and SPS (dashed lines).

Weather conditions had no influence except for a weak positive relationship between temperature and BS GC levels (Fig. 5.3, linear regression: temp - BS: $r^2 = 0.095$, $F_{1,85} = 8.84$, $p = 0.004$; SPS $r^2 = 0.03$, $p = 0.11$; wind speed - BS: $r^2 < 0.001$, $p = 0.83$; SPS: $r^2 = 0.02$, $p = 0.21$).

Influence of Area Type

Although there was a high variation among breeding BS within areas of high and low human activity, the area difference was still pronounced (Fig. 5.4, ANOVA individual BS nested within area: $F_{19,102} = 8.56$, $p < 0.001$). In contrast, samples of breeding SPS show a higher variation in GC within an area than between ($F_{1,28} = 0.59$, $p = 0.45$).

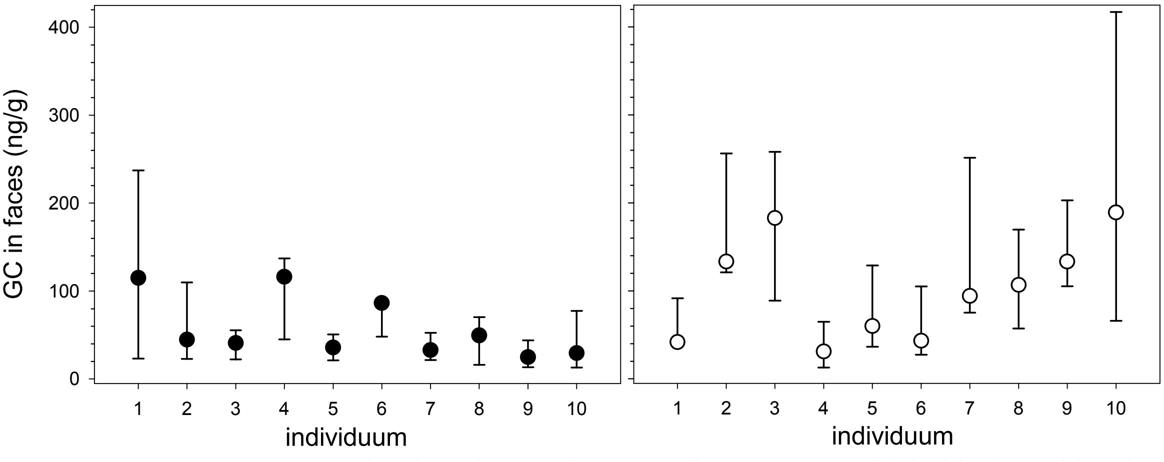

Figure 5.4. Comparison of GC levels of brown skuas breeding in areas of high (black) and low human activity (white). Each individuals defecated several times immediately after visits in 2003 (median, 25 and 75 percentiles). The area difference is significant ($p < 0.001$).

In both area types increased the GC level during the breeding season (Fig. 5.5, BS: $r^2 = 0.15$, $F_{1,85} = 15.15$, $p < 0.001$; SPS: $r^2 = 0.07$, $F_{1,87} = 6.18$, $p = 0.02$). The sample time during the day showed no strong influence on GC values (BS: $r^2 = 0.07$, $F_{1,85} = 6.09$, $p = 0.02$; SPS: $r^2 = 0.02$, $p = 0.21$).

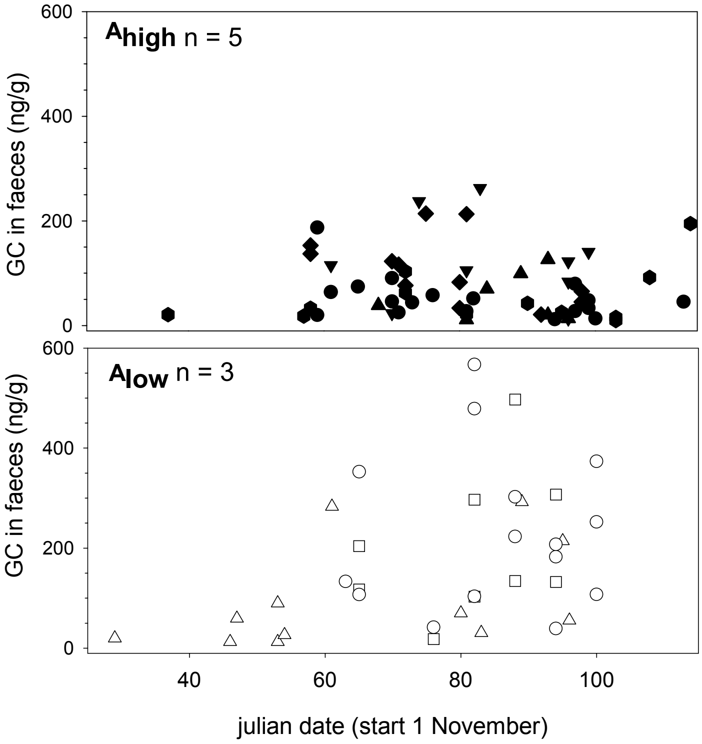

Figure 5.5. Glucocorticoid levels of breeding brown skuas in areas of high and low human activity. Samples collected immediately after visit to territories. Each symbol type represents one individual bird sampled repeatedly over the season.

Influence of Visits

GC levels of breeding BS did not increase significantly with the length of visits (Fig. 5.6, $F_{4,201} = 1.19$, $p = 0.23$).

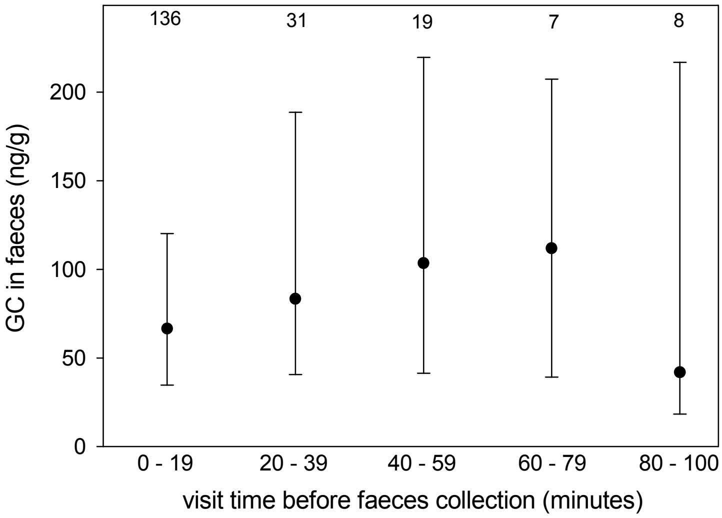

Figure 5.6. Glucocorticoid titres in faeces of breeding brown skuas collected after visits of varying length in the territory. Median with 25 and 75 percentiles presented.

In a second test, I excluded samples that showed elevated GC levels prior visits. For this I used the 75th percentile of the data set of non visited BS breeder (see Tab. 5.3, > 139.3 ng/g) as threshold, and removed all samples with a prior visit length < 3 min and higher values from the analysis. GC titres showed then some increase with visit length (GLM with factor visit length and covariate date: $F_{47,191} = 0.40$, $p = 0.071$).

Because non-breeding and breeding SPS had similar GC levels without human activity, I analysed the effect of visits by pooling data. I excluded all samples higher than the 75th percentile (NB > 39 ng/g, B > 85 ng/g) with a visit length < 3 min. The analysis showed that GC titres of SPS did not increase with the length of visits (linear regression $r^2 = 0.04$, $F_{1,93} = 3.90$, $p = 0.051$).

Hormone Levels of BS Chicks

GC levels were independent from age (Pearson correlation for age $r_{63} = -0.16$, $p = 0.22$) and hatching date of the chicks (part. corr. hatching date, controlled for age: $r_{60} = -0.13$, $p = 0.31$). The highest GC titres were measured in a sample of an injured chick with 779.5 ng/g, and a visited chick with 986.6 ng/g (excluded from analyses). Regarding human experience, GC levels differed marginally between areas of low and high human activity (Tab. 5.4).

Table 5.4. GC levels in faeces (ng/g) of brown skua chicks growing up in areas of low and high human activity. Samples from chicks taken immediately after first visit.

area type	n	median	25%	75%	min	max	t-test
A_{low}	25	88.8	46.6	123.4	18.1	236.8	$t_{56} = 1.90$
A_{high}	34	43.1	31.4	93.9	10.7	267.1	$p = 0.06$

Hormone levels varied not only within a few hours of the same day but also showed partly strong declines from one day to the next (Fig. 5.7).

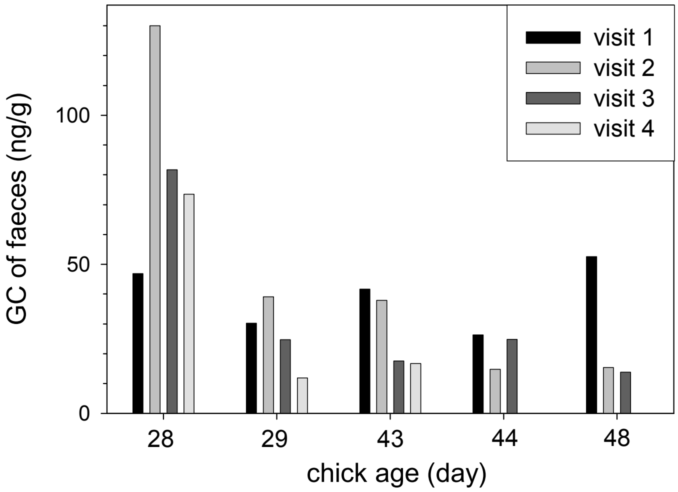

Figure 5.7. Glucocorticoid levels of a brown skua chick in A_{high} after repeated visits on five days. There was a 30 min interval between visits within one day. After a strong reaction on the first day, titres remained low.

Handling had a significant effect on GC titres of chicks in A_{high} (Fig. 5.8, RM ANOVA $F_{2,14} = 4.56$, $p = 0.048$). Chicks in A_{low} already had elevated titres when visited (paired t-test $t_5 = 2.17$, $p = 0.08$).

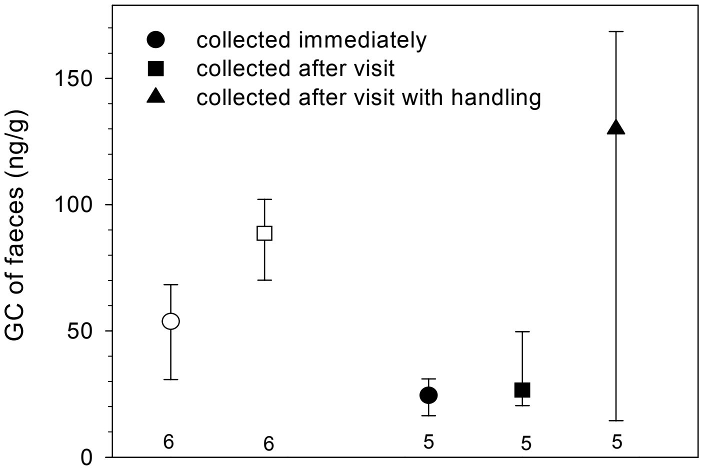

Figure 5.8. Glucocorticoid levels of brown skua chicks compared in low (white) and high human activity areas (black) in response to visits. Median with 25 and 75 percentile presented.

Influence of Air Traffic

Non-breeders had no elevated GC titres after aircraft over-flights compared with samples collected at times without flight activity ($t_{62} = 0.19$, $p = 0.85$). Also breeding birds within 1000 m of flight routes had similar GC on days with and without air traffic (BS $t_{81} = 0.09$, $p = 0.93$; SPS $t_6 = 1.44$, $p = 0.20$). Air traffic in A_{high} did also not result in GC-level rise of BS chicks ($t_{21} = 1.20$, $p = 0.25$).

5.4 Discussion

I found a great variation in corticosterone-metabolite measures of SGP within each breeding group and small differences between area types. This could represent interpretable study results. But since several confounding factors have been encountered in other studies, I will first discuss their possible influences on the present study. Due to my non-invasive study design, I was also unable to control for some social and natural factors influencing the hormone titres. I will, however, discuss the results in the light of human experience, visitor and air traffic effects.

Confounding Factors

The analyses of faecal glucocorticoid metabolites is increasingly being used to examine stress in wildlife. The advantage of this method is the more rapid sampling compared to other physiological or behavioural studies that require weeks of field work for similar information. However, a review of Millspaugh and Washburn (2004) lists a number of factors that make the interpretation of study results problematic. GC levels could be effected by the sample type (Millspaugh et al. 2003), sample age and mass (Washburn and Millspaugh 2002), time of day (Touma et al. 2003), or storage techniques (Khan et al. 2002).

I measured GC titres in faeces of SGP and skuas for the first time and partly encountered interpretation difficulties that question the suitability of this method. SGP defecated infrequently so that the exact time was unknown. This is less important if the general stage of a breeding population or sub-group is of interest. Then overall hormone differences between groups could suggest variations in susceptibility to stress from active stimuli. However, the older the samples the larger the risk that GC levels are biased due to ongoing bacterial metabolism (Washburn and Millspaugh 2002). In my study, old and fresh looking samples of SGP produced similar results. Antarctic conditions will preserve faeces because metabolic processes are generally slower. However, both sample groups showed high variation and uncertainty remains concerning sample bias in SGP. In contrast, all skua samples were freshly obtained.

Giant petrels and skuas are opportunistic marine and terrestrial feeders (chapter 2, estimated gut passage times of seabirds: 5 to 20 hours, Hilton et al. 1998, Laugksch and Duffy 1988). There is a rapid increase in faecal GC of northern spotted owls two hours after injection with ATCH (adrenal corticotropic hormone) peaking after 12 hours (Wasser et al. 1997). In a Adélie penguin study the peak was 13 hours after injection (Nakagawa et al. 2003). Therefore, faecal samples provide a record proportional to plasma GC of minutes to hours before defaecation.

There is also a distinct daily rhythm of basal GC levels (e.g. Breuner et al. 1999, Romero and Remage-Healey 2000) that could also be relevant for faecal sampling. In this study, neither SGP nor skuas showed clear changes in GC with time of day. However, I did not test this specific question and diurnal rhythms may exist in these species.

Additional variation is caused by the material sampled (Millspaugh and Washburn 2003). I collected faeces, urea and mixed samples in SGP, and the analysis revealed lower GC levels in urea. Similar variations were found in other studies (Ludders et al. 2001, Quillfeldt and Möstl 2003, Washburn et al. 2003). Skua samples were also variable depending on the food content, but a clear separation in urea and faecal samples were seldom possible. I mixed each sample before taking a set amount of 0.3 g for analysis and used only lower amounts when samples had been very small. Nevertheless, the samples were still larger than published masses that could cause biased GC titres (< 0.02 g, Millspaugh and Washburn 2004).

Furthermore, storage and transportation until analysis have been considered critical, although this seemed not to be a problem in this study. I followed the recommendation of freezing the samples as soon as possible without any chemical treatment (pers. com. E. Möstl, Millspaugh and Washburn 2004). There was no difference in GC levels of SGP over time, although storing time ranged between 24 and 36 weeks, and similar times were used for skuas. In this case, I found a seasonal increase in GC levels, which I did not consider as a confounding effect.

Bird Status and Environmental Factors

Because the seasonal increase in GC levels in BS (less in SPS) was highest around hatching and chick rearing, I consider the higher parental investment as the main explanation. Territorial defence causes high energetic costs in skuas, and higher hormone titres would be expected. This is supported by generally higher GC levels of breeding BS compared to non-breeders as is true for other species (e.g. Astheimer et al. 1992, Kitaysky et al. 1999, Romero et al. 1998). In addition to these annual variations, unpredictable environmental events activate the hormone secretion.

High predator density, low food availability or poor body condition are potential stressors leading to elevated GC levels (Hayward and Wingfield 2004, Kitaysky et al. 2001b, McQueen et al. 1999, Silverin 1986, Smith et al. 1994, Wingfield et al. 1999). However, long-lived birds breeding in harsh environments with short breeding seasons could show a reduced sensitivity to these stresses to assure own survival (O'Reilly and Wingfield 2001). To maximise lifetime reproductive success, adults should maintain their own body condition under unfavourable breeding conditions despite having to pay the cost of reducing current parental effort (see in Quillfeldt and Möstl 2003). This occurred to SPS in 2003 due to long-lasting snow cover and low food availability. Their territorial defence was relatively low (see Fig. 4.3), a large number of nest were deserted, and all chicks died within the first week after hatching. This reduced reproductive effort could explain the lower GC levels compared to BS breeders that found sufficient food in nearby penguin rookeries.

Short-term changes in weather conditions could also influence GC secretion. SGP fly easy in strong winds but have difficulties in take-off and landing on calm days. Foraging at sea is partly based on visual clues (looking for bird aggregations or fishing boats) so fog could lower feeding success. Severe storms reduce foraging for all species. However, whereas harsh weather can cause lower survival and breeding success in some species (e.g. Büßer et al. 2004, Romero et al. 2000), skuas and giant petrels show strong resistance. In this study, weather parameters had no effect on GC levels.

Predation is often considered as a stress (Hofer and East 1998, Scheuerlein et al. 2001), but animals do not necessarily respond to predator presence with elevated GC levels (Cockrem and Silverin 2002a, Silverin 1998). Depending on individual state, one animal will perceive a predator as threat, another will not. The physiological responses will vary accordingly. In SGP breeding groups, interactions with predators and conspecifics occur frequently. As with the behavioural variation (chapter 3), the large range of GC levels could represent these different sensitivities. The hormone levels showed differences between the areas of A_{low} (Geologist, Two Summit and Nelson Island). SGP on Geologists had more variable GC titres than found at the other two sites. This could suggest a greater exposure to natural stresses for some of the birds on Geologist Island. On one hand, this site holds breeders and non-breeders densely within a small area. Any predator approach or movement of conspecifics is seen by all members of the group. On the other hand, the number of gulls and terns breeding on this island is higher than in other tested areas of low human activity. Skuas frequently prey on gulls and terns eggs and chicks and their defence involves alarm calls and aerial attacks. This could potentially stress SGP breeding close by.

Experience with Humans

The typical hormone response is activated in response to human activity in the wild and faecal GC titres are higher in sites with higher human activity where comparisons have been made (e.g. Creel et al. 2002, Wasser et al. 1997). However, habituation occurs in some sites, for example in tourist sites (Fowler 1999, Romero and Wikelski 2002).

In this study, SGP differed neither significantly between area type nor islands. Due to the low frequency of human activities, I would not expect chronic stress responses in A_{low} SGP colonies. In contrast, A_{medium} and A_{high} are more frequently exposed to visits and air traffic. A_{medium} differed significantly from A_{high} and A_{low} in behaviour and heart-rate studies (chapter 3), but showed similar GC levels. This suggests that breeding groups of SGP on Ardley Island are also not chronically stressed by human activities. A_{high} and A_{medium} had, however, more variable hormone levels than A_{low}. This suggests that human activities affect some birds more than others. As faecal samples integrate over time, more frequently exposed birds could show stronger hormone elevations. Maybe only measurements of plasma GC are able to separate such short time-scale events. However, a small group of SGP resting beside the main landing to Ardley Island had higher GC levels than samples taken in a remote non-nesting group on Nelson Island. The former group was exposed to all Ardley Island visitors and all flew off together when approached closer than 50 m. Non-breeders may be less habituated to human stimuli, as they are not tied to parental care as breeders. If nests are left for a short time, it does not harm the offspring. But corticosterone levels need to decline that breeding can be resumed immediately after the pertubation has passed (Wingfield et al. 1997). In non-nesting birds this is not relevant and hormone titres are perhaps regulated differently.

In response to human experience in the long-term, breeding BS showed significantly higher GC levels in A_{low} compared to A_{high}. This can be interpreted as reduced sensitivity of birds regularly exposed to human stimuli. Alternatively, it could suggest stronger exposure to natural stressors (e.g. higher predation risk), but the breeding success was not different between area types (chapter 6).

Visits

The presence of humans near the nest of a bird that has not been subject to a history of frequent visits should elicit the typical vertebrate adrenocortical response to stress (Siegel 1980). However, I did not find any direct visitor effect in SGP, probably due to the above mentioned methodological problems. The hormone variation in the samples could suggest individual differences in the response to human stimuli, but they can not be separated from natural stimuli.

In contrast, I found small visitor effects in breeding BS and SPS (after excluding samples that were already high before visits and controlling for seasonal changes). If faecal GC levels peak at several hours after stimulus occurrence, a higher sample size for long-lasting visits would have resulted in stronger effects.

BS chicks reared in A_{low} reacted more strongly to visits than chicks in A_{high}. The response therefore depends from an early age on the activity spectrum within the breeding site. A concentration of human activities to certain areas would enhance habituation in multi-used areas but also allow remote colonies to maintain natural behaviour.

Stress-protocols measuring plasma GC levels are based on the fact that handling stresses animals that then show elevated hormone levels after a few minutes (e.g. Cockrem and Silverin 2002b, Harper and Austad 2001, Hunt et al. 2004, Wingfield et al. 1997). How fast

GC increases after capture depends on individual state (Hood et al. 1998). The short handling of BS chicks in this study showed higher GC levels compared to samples when the chicks were only visited. Increased levels of corticosterone in seabird chicks were measured under food shortage resulting in more frequent begging and increased aggressiveness (Kitaysky et al. 2001a, Kitaysky et al. 2003). These behavioural modifications are beneficial to chicks as they facilitate feeding by parents and may trigger brood reduction. However, elevated levels of GC are also costly as they lead to lower growth efficiency and cognitive abilities later in life (Frigerio et al. 2001, Kitaysky et al. 2003).

Air Traffic

Chapter 3 and 4 showed that behavioural and heart-rate changed relatively little during air traffic. The GC analysis was in line with these finding since neither SGP nor skuas responded with elevated hormone levels to air traffic. Non-breeders of both skua forms have been repeatedly observed to fly off when helicopters passed low over their resting sites. Nevertheless, nearby air traffic caused no hormone increases.

Conclusion

The study of faecal glucocorticoids of SGP and skuas had advantages in terms of collection time and minimal scientific impact. The interpretation of the results was, however, difficult due to a number of additional influences (Tab.5.5). I therefore, find this method less suitable for assessing stress responses of breeding groups or even individual differences of SGP. SGP defecated too seldom at the nesting sites to collect fresh samples. This led to uncertainty about the sample age and the characteristics of the individual that had defaecated. Overall, I found no significant differences between colonies. The number of factors that potentially influenced GC levels was too large to sufficiently interpret the data in terms of human activities.

In skuas, this method was applied more successfully. Fresh samples allowed exact timing and individual assignment. GC titres varied naturally with skua form, status, season, and weather. Visits and handling elevated hormone levels slightly but more studies are needed to confirm these first results (Tab. 5.5).

Table 5.5. Summary of hormone responses of southern giant petrels, brown and south polar skuas breeding in areas of high, medium and low human activity on the Fildes Peninsula and surrounding islands 2002 and 2003. Faecal glucocorticoid levels tested against area type, actual visits and air traffic. No hormone elevations or no area differences represented by '=', GC increases by '↗'. List of factors that caused data interpretation problems.

	area type	visit	air traffic	confounding factors
SGP	$A_{high} = A_{medium} = A_{low}$	=	=	sample type (urine or faeces) sampled individuals unknown
BS	$A_{high} < A_{low}$	↗	=	varying mixture of urine and faeces
BS chicks	$A_{high} \leq A_{low}$	↗	=	
SPS	$A_{high} = A_{low}$	↗	=	

6 EFFECTS OF HUMAN ACTIVITIES ON REPRODUCTIVE PARAMETERS

6.1 Introduction

Previous chapters were concerned with behavioural and physiological responses of individual giant petrels and skuas to anthropogenic stress. However, species conservation focuses on populations and communities. Many populations of seabirds show high inter-annual variation in breeding success, and most dramatic fluctuations are often the result of stochastic phenomena such as adverse weather conditions or changes in food supplies (e.g. Monaghan et al. 1989, Weimerskirch 1992). In addition, reproductive success can be affected by interactions with other breeding birds. Both inter- and intraspecific interactions can have a direct effect through predation or indirectly through competition (e.g. Emslie et al. 1995, Finney et al. 2003, Votier et al. 2004a). Nevertheless, the population growth of long-lived seabird species is less influenced by annual variations in breeding parameters than by recruitment and adult survival (Cuthbert et al. 2001).

Human activities mainly add to the variation in breeding parameters (Micol and Jouventin 2001). Air traffic, and scientific or recreational visits, often reduce reproductive success (e.g. Blackmer et al. 2004, Cairns 1980, Giese 1996, Rodway et al. 1996), although the effects are negligible in other cases (e.g. Nisbet 2000, Willis 1973). This difference is produced by local environmental conditions, species, and time in the breeding cycle. Therefore, neither blanket rules on the part of managers nor universal research protocols on the part of investigators seem appropriate to minimise adverse effects for wildlife populations.

Antarctic exploration and exploitation started in 1819 on the islands in front of the Antarctic Peninsula. At first, the effects fell most heavily on seals, and later on whales. However, at the same time, other local breeding populations have been also influenced by people. On the Fildes Peninsula, continues anthropogenic activities began in the 1960s with the construction of research stations (chapter 2). As SGP and skuas show a high breeding site fidelity, individuals experienced the development year after year. Intensive scientific programmes on penguins, skuas, giant petrels and terns were run by several nations on site. Therefore, some of the chicks grew up exposed to human activities and, when mature, probably returned to their native breeding grounds. Although individual life-history data have not been analysed, human activities certainly influenced chick and adult behaviour leading to habituation or sensitisation depending on internal and external factors. To some extent, consequences on the population level seem inevitable. Therefore, I present data regarding population size, nest distribution, and reproductive success of SGP and skuas. I compare these data with available long-term data sets from the Fildes Peninsula and surrounding islands.

6.2 Methods

Monitoring of the SGP population in the study area has been infrequent and inconsistent over the last 25 years. Censuses were neither standardised in time nor method, and area descriptions for the counts are partly unknown. Because egg laying starts in October, later counts do not represent the initial number of breeding pairs (BP), and non-breeders cannot be separated from birds that lost their brood early in the season. Therefore, existing population records are only estimates, so that long-term population trends should be regarded with caution.

Skua nests were mapped annually. For the description of the nest-distribution patterns of skuas, I used point-pattern analysis by Wiegand and Molony (2004), *Programita* software, Fig. 6.3). In this method, concentric rings with a radius h and a width δh are constructed around each point (i.e. nest, station centre, penguin colony) in the study area. Then, the number of points within these rings is counted. The average across all rings of the same radius is then taken and compared to the number of points expected at scale h assuming a random process (Wiegand and Moloney 2004). Upper and lower confidence envelopes were generated from 19 simulations resulting in a confidence level of $p = 0.05$. Values outside the confidence envelopes represent significant differences from the random pattern whereby upper values showed nest aggregation and lower values avoidance.

In 2003, I randomly choose BS and SPS territories in A_{high} and A_{low} to follow some breeding parameters. Clutch size was compared using Kolmogorov-Smirnov (K-S) test. Egg length and width were measured to the nearest 0.1 mm and egg volume was calculated using the formula $V = 0.00048 * \text{length} * \text{width}^2$ (Coulson 1963). Hatching and breeding success were compared with general linear integrated model (GLIM) 3.77 for analysis of non-normally distributed data with non-normal error structure.

6.3 Southern Giant Petrels - Results and Discussion

On the Fildes Peninsula and surrounding islands several SGP groups exist. These groups are distributed as solitary birds or dense colonies. The main breeding colonies are on Two Summit, Dart Island, and in the North of the Fildes Peninsula (Fig. 7.1, for locations see map 2.1). Geologist, the northern part of Nelson Island and South Fildes have smaller colonies. All of them received less visits and air traffic than Ardley and Albatros Island, where SGP breed in areas with medium to high human activity.

Obvious declines occurred in frequently visited areas like Nebles Point and South Fildes (Fig. 6.1). Nebles Point has been a research site between 1980 and 1988 and scientific work and intensive helicopter traffic contributed to reduction in BP numbers and breeding success (Chupin 1997, Peter et al. 1990b, Peter et al. 1991). Banding programmes have shown negative effects on the population numbers of SGP in other Antarctic regions (ATCM 2003, Micol and Jouventin 2001). SGP breeding sites near the Chinese station (built in 1985 on South Fildes) were visited by station personnel and scientists and eggs were taken as souvenirs and for food (pers. com. Z. Wang). It seems likely that several breeding pairs from Nebles Point and South Fildes moved to the nearby islands of Geologist, Two Summit, Dart and Nelson (Bannasch and Odening 1981, Bannasch et al. 1983, Peter et al. 1988, Peter et al. 1991). The most isolated islands had the highest increase in BP numbers after years of intense construction work in the 1980s. At that time, scientist over-wintered and were present during the whole reproductive period of SGP and worked more intensively.

Helicopter flights low over breeding groups occurred more frequently (pers. com. H.-U. Peter). Nest-site shifts were, therefore, much more likely as natural and anthropogenic factors acted together to influence the birds' decisions. Since intense scientific work on SGP has ended, birds can lay eggs, before the main station and research period starts. Therefore, many birds decide to breed assessing on natural conditions alone. Anthropogenic activities influence only breeding success, if they have influence at all. Because the reproductive outcome naturally fluctuates considerably, birds should return to the same sites year after year. I would, therefore, not expect significant nest-site shifts under the current level of human activity.

There is only anecdotal documentation of the temporal and spatial extent of visits to wildlife (by station members and tourists) and air traffic, so that historical changes in the study area cannot be analysed in detail. Overall, the growing interest in and pressure for nature conservation in the 1990s resulted in less intrusive visitor behaviour and more regulated flight activities. Even with the trend toward more tourism and station extension, anthropogenic population decline seems avoidable by applying a few guidelines (see below). Estimation of the total population size of SGP in the study area exist only for a few years. In 1980, a minimum of 116 BP was recorded, but this increased to 289 in 1986. Thereafter, the population declined and reached again about 219 BP in 1997. In 2001, 339 BP were estimated and in 2003, 289 pairs altogether.

The analysis of long-term data of other SGP breeding populations in the sub-Antarctic and Antarctic revealed increases in some locations and declines in others (Woehler et al. 2001). Decreases are thought to be caused by introduced predators, fishery, human visits, but also reduction in prey species (e.g. Croxall et al. 1984, Jouventin et al. 1984, Jouventin and Weimerskirch 1991, Rounsevell and Brothers 1984, Woehler et al. 1990, Woehler 1991).

Breeding success of SGP on the Fildes Peninsula and surrounding islands have been infrequently recorded (Tab. 6.1). For Ardley Island, the direct effects on SGP breeding activities were reported during intensive construction work in the early 1980s (Bannasch et al. 1984). At this time, dogs were still allowed in stations and one was seen killing a SGP juvenile (pers. com. H.-U. Peter). Since 1991, dogs have been prohibited by the Environmental Protocol Annex II, Art. 4. I observed predation by skuas, a factor that was the main reason for reduced hatching success in other sites (e.g. Hunter 1984, Warham 1996). In addition, clutches were lost through broken and addled eggs. Chicks died through unsuccessful hatching, predation, being stepped on by adults or fledglings crushed at their first flights (Peter et al. 1988). In 2003, the large colonies on remoter islands showed the greatest breeding success. On Ardley Island, the breeding group A_{high} had a greater success (2002: 38 %, 2003: 71 %) than A_{medium} (2002: 25 %, 2003: 17 %). This could partly be a result of behavioural adaptations to regular human activities (chapter 3). In 1986, Roby et al. (1986) encountered no successful breeders at either site, suggesting that, at that time, human activities were more severe (construction work, science and unregulated visits).

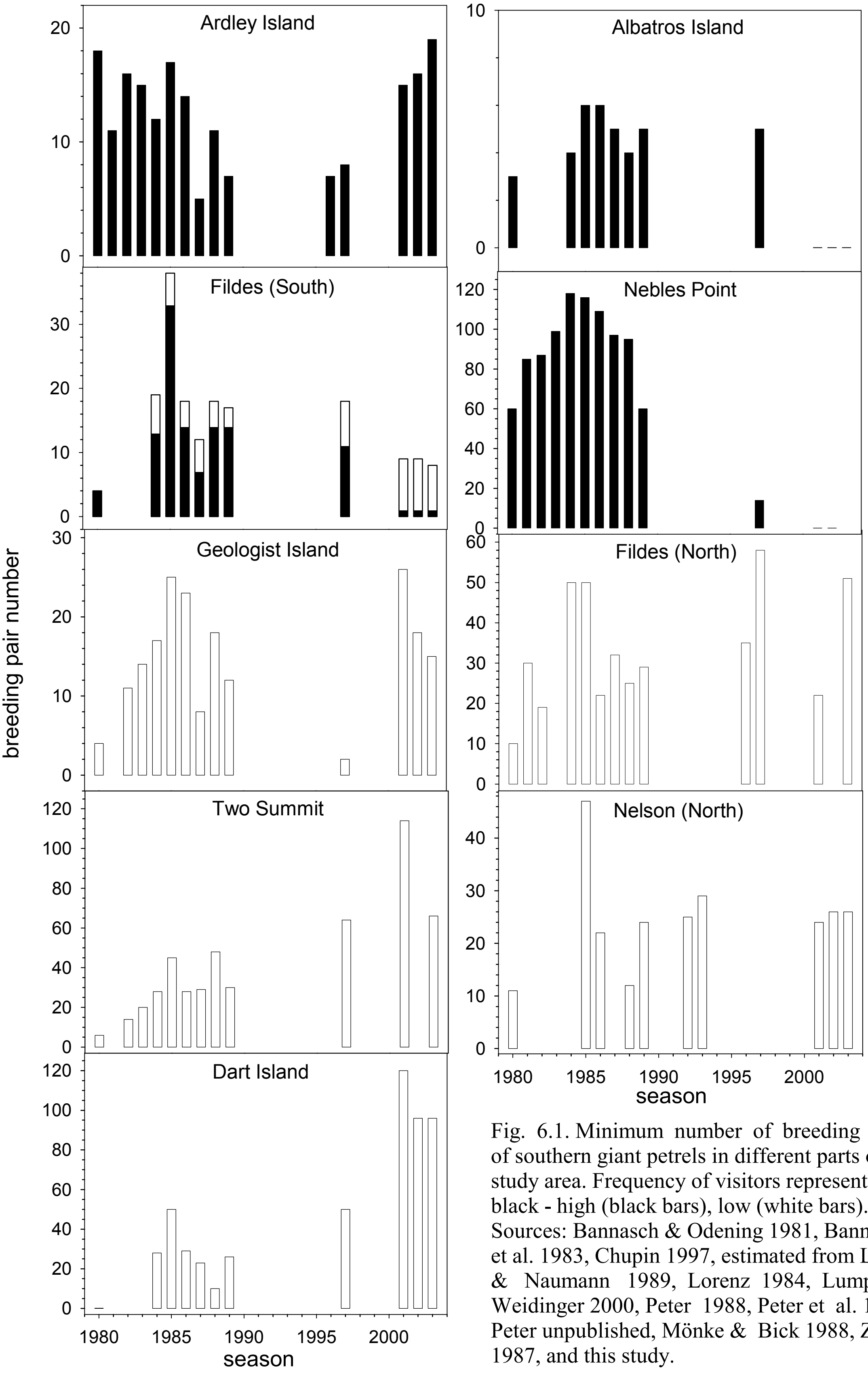

Fig. 6.1. Minimum number of breeding pairs of southern giant petrels in different parts of the study area. Frequency of visitors represented: black - high (black bars), low (white bars). Sources: Bannasch & Odening 1981, Bannasch et al. 1983, Chupin 1997, estimated from Lange & Naumann 1989, Lorenz 1984, Lumpe & Weidinger 2000, Peter 1988, Peter et al. 1986, Peter unpublished, Mönke & Bick 1988, Zippel 1987, and this study.

Based on my observations, I assume that the breeding groups of SGP on Ardley Island loose a larger proportion of eggs and chicks due to predation enhanced by human activity than other islands. However, Ardley Island holds only 5 % of the total BP number in the study area.

Geologist, Two Summit and Dart are islands with larger and more scattered breeding groups, so that only parts are disturbed when visited (except during census). My visits caused three successful predations during a total of 16 visits to remote islands over all study years, and I saw 16 fly-offs from occupied nests. In contrast, during a total of 92 visits in A_{high} and A_{medium}, no brood was seen being lost, and 12 fly-offs from occupied nests occurred. Ardley Island has a higher number of skuas that could prey in SGP breeding groups, but on the remote islands, skuas were more strongly attracted by visits and were perhaps more specialised on this prey. Overall, the breeding success of SGP is highly variable across sites and between years in my study area as elsewhere (e.g. Conroy 1972, Hunter 1984).

Table 6.1. Maximum breeding success (%) of southern giant petrel (1980 = summer season 1979/80, Fildes South represents here only the frequently visit part. Source: Bannasch & Odening 1981, Chupin 1997, Peter et al. 1988, unpubl. data of I. Chupin and this study).

season	Ardley Island	Albatros Island	Fildes South	Nebles Point	Geologist Island	Fildes North	Two Summit Island	Nelson North	Dart Island
1980	39	66	75	73	50				
1984	75	25		52	71		79		74
1985	61	75	45	48	76	26			
1986				77	74	64	82		
1987	80	20	57	76	50	41	62		
1989	43					59		38	
1991								66	
1992								55	
1997	13	0		0		11			
2001			0		33				
2002				0	25	78			
2003		41	0	0	32	87	61	77	

6.4 Skuas - Results and Discussion

Compared to SGP, the population size (Fig. 6.2) and nest distribution of skuas (Fig. 6.3) seem less affected by human activity. While BS population size retained stable, SPS increased, especially in the early 1980s and late 1990s. The beginning of the 2003 season was characterised by a long-lasting snow cover that prevented several SPS from laying eggs. In contrast, BS nesting numbers did not change. Breeding parameters like egg size, hatching success and chick growth of SPS are more strongly influenced by abiotic factors (e.g. sea ice cover, wind speed) than is the case in BS (Hahn et al. 2004).

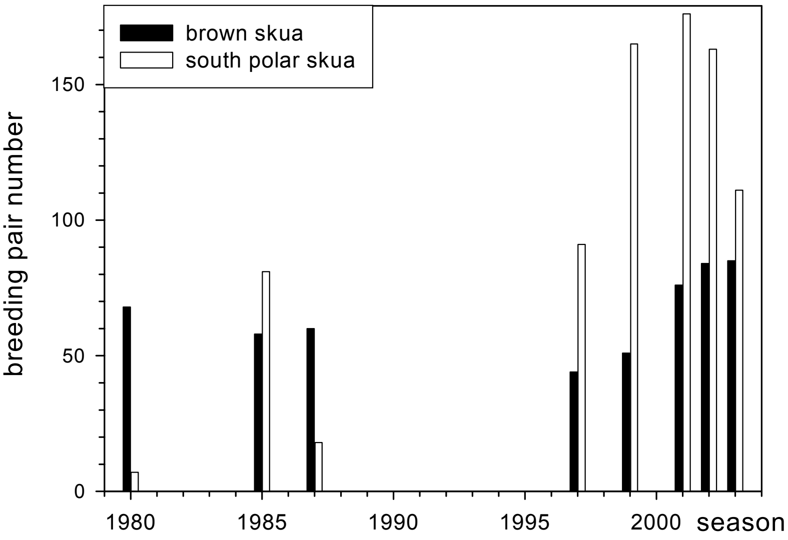

Figure 6.2. Brown and south polar skua breeding pair number on the Fildes Peninsula and Ardley Island from 1980 to 2003 (source: Hahn et al. 2003, mixed pairs have been excluded in this graphic, data added from this study in co-work with H.-U. Peter, D. Stremke, and J. Welcker).

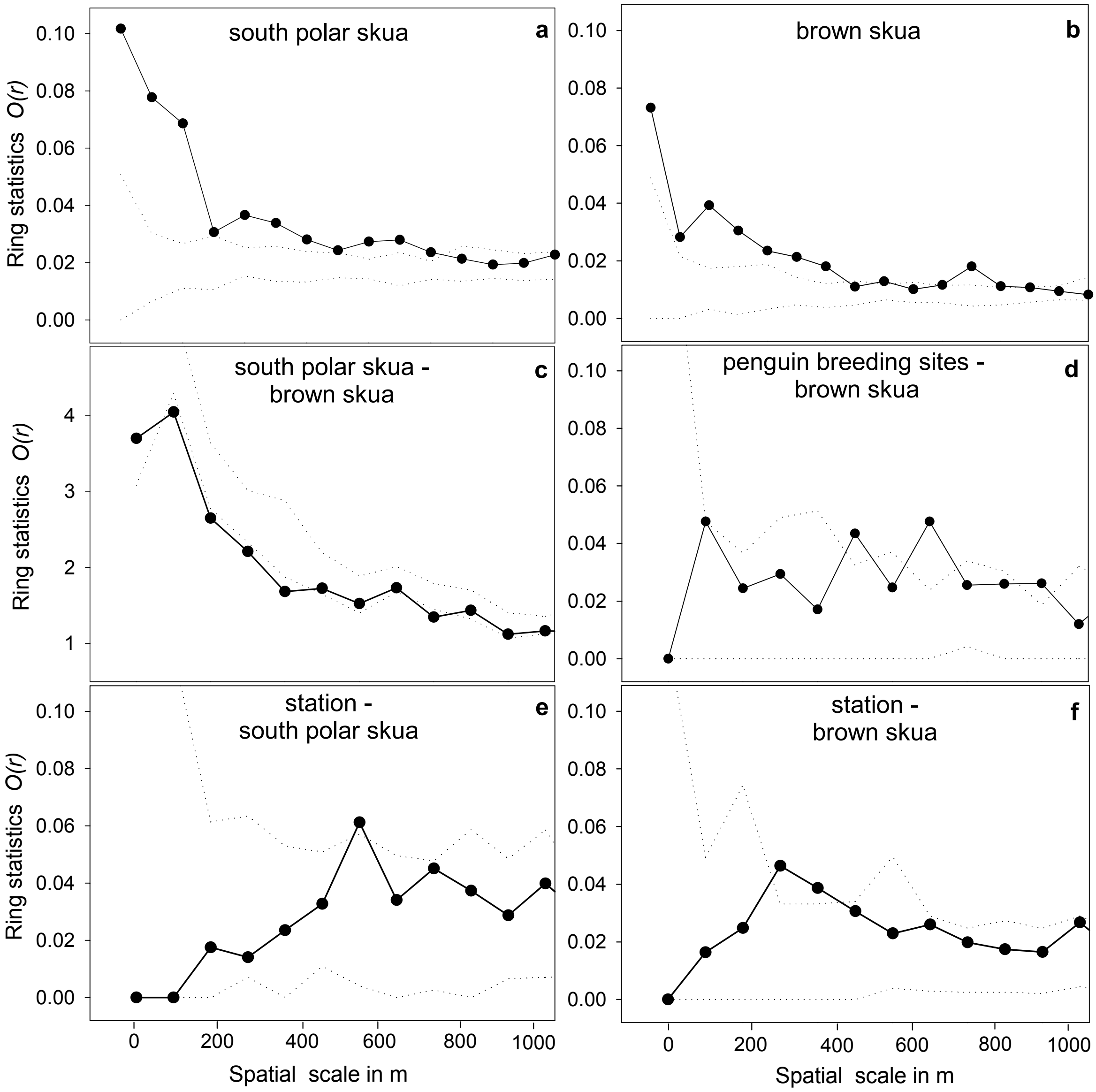

Figure 6.3. Nest-distribution pattern of brown and south polar skuas from 2003 compared within species (a, b), between (c), in relation to penguin colonies (d) and stations (e, f). Method: point-pattern analysis of Wiegand & Molony (2004). Significant deviations from random distribution of both patterns when black line outside confidence envelopes (dashed lines); above - attraction, below - avoidance.

BS and SPS are not randomly distributed in the study area but individuals of the same species are attracted towards each other (6.3 a und b, univariate Wiegand-Molony's *O*-ring statistic). Although it seems that both species breed in mixed groups at some sites, the random labelling analysis demonstrated weak avoidance behaviour (6.3 c). Nevertheless, in the last two decades the number of mixed pairs increased on Fildes Peninsula (27 % BS, 63 % SPS and 10 % mixed pairs in 2000/01, Hahn et al. 2003). Skuas choose territories with several viewpoints (small hills), vegetation cover, and in good distance to food sources. BS prey mainly on penguins in the study area (Peter et al. 1988), and their breeding territories are partly associated with penguin colonies (Fig. 6.3 d, toroidal shift analysis). BS are also frequently seen feeding on food waste in the stations (Peter et al. 2001, Reinhardt et al. 2000). The spatial analysis shows that significantly more BS nests are found 250 to 400 m from the station centres than would be expected if nest distribution were random (Fig. 6.3 f, toroidal shift analysis), whereas SPS breed in greater distance to stations (Fig.6.3 e).

Non-breeders gather in 'clubs', where they look for future breeding partners and a free territory nearby. A comparison of club sites reveals a change from one large club in 1985 to several small clubs in stations (Russian and Chinese station) and remoter areas (Northwest of the airport) in 2003. The locations of these clubs suggest that the birds are attracted to human food sources in combination with freshwater access. This seems especially so for BS.
Younger, inexperienced skuas lay one egg, whereas older birds have a nest with two (Furness 1987). A low percentage is also able to relay after loosing eggs (pers. com. M. Ritz). In 2003, clutch size was similar between areas and for skua forms (percentage of 2-egg clutches: BS A_{high} 94.1 mm^3, n = 17, A_{low} 88.2 mm^3 for n = 51, K-S test: p = 0.67 ; SPS A_{high} 94.1 mm^3 for n = 17, A_{low} 87.1 mm^3 for n = 62, K-S test: p = 0.67).
The comparison of egg volume showed no significant differences (BS in A_{high}: 99.3 ± 1.33 mm^3, n = 21; BS in A_{low}: 101.9 ± 1.97 mm^3, n = 10, t-test $t_{29} = 1.1$, p = 0.29; SPS in A_{high}: 81.3 ± 2.60 mm^3, n = 23; SPS in A_{low}: 86.6 ± 1.76 mm^3, n = 14, t-test $t_{35} = 1.5$, p = 0.15).
Hatching dates of the 2003 season were similar for both species and area types (Tab. 6.2). However, compared to the previous season, the long snow cover delayed egg laying by more than one week (first week Dec 2002 compared to last week Nov 2001). In the seasons 1984 and 1985, SPS had laid eggs significantly earlier (mid Nov) than BS (end of Nov) (Peter et al. 1990a). SPS respond more strongly to weather conditions and lay as soon as the territories are snow-free.

Table 6.2. Hatching dates of first chicks from brown and south polar skuas in the 2003 season on the Fildes Peninsula and Ardley Island

	area	Mean hatching date of first chick ± S.E.	n	t-test	
BS	A_{high}	4 January ± 1.3	39		
	A_{low}	6 January ± 0.9	12	$t_{49} = 1.59$	p = 0.12
SPS	A_{high}	4 January ± 1.0	15	$t_{19} = 0.83$	p = 0.42
	A_{low}	3 January ± 0.8	6		

The numbers of BS hatchlings were not significant different in areas of low and high human disturbance in 2003 (A_{low}: 1.27 ± 0.75, A_{high}: 1.12 ± 0.70, GLIM $\chi^2_{66} = 42.13$, $p > 0.05$). Penguins, their main food source, were available in 2003, but BS and SPS non-breeders and adults that had given up breeding searched the surroundings for food and frequently attacked neighbouring skuas. Thus, BS lost most broods through predation. BS breeding in A_{high} produced fewer chicks per nest than birds in A_{low}, but the difference was not statistically significant (A_{low}: 0.51 ± 0.73, A_{high}: 0.35 ± 0.70, GLIM $\chi^2_{66} = 72.49$, $p > 0.05$). Human visits could have had some impact on chick survival by causing additional energetic cost during territorial defence.

In contrast, SPS had slightly higher numbers of hatchlings in areas of high human activity (A_{low}: 0.34 ± 0.60, A_{high}: 0.59 ± 0.71, GLIM $\chi^2_{77} = 72.72$, $p > 0.05$), but the number of fledglings was reduced to nearly zero in both area types (A_{low}: 0.01 ± 0.13, A_{high}: 0.00, GLIM $\chi^2_{77} = 8.26$, $p > 0.05$). Egg desertion, chick starvation and predation caused breeding failure in SPS in 2003 suggesting low food availability besides long snow cover on the nesting grounds (Tab. 6.3, see also Peter et al. 1990a). It can not be said to what extent human activities influenced breeding parameters of SPS, but it seems less important than in BS.

Compared with the 1985 season, 2003 provided less favourable breeding conditions for BS and SPS populations on the Fildes Peninsula and Ardley Island (Peter et al. 1990a: about 50 % breeding success for both skua forms). Overall, the results are in line with other studies showing generally a higher breeding success of BS compared to SPS (BS range between 27 and 85 %, SPS 0 – 78 % in Reinhardt 1997).

Table 6.3. Reproductive success of brown and south polar skuas in the 2003 season breeding in areas of low or high human activity. (mean ± S.E.)

	BS		SPS	
	A_{low}	A_{high}	A_{low}	A_{high}
number of nests	51	17	62	17
clutch size	1.88 ± 0.04	1.94 ± 0.06	1.87 ± 0.04	1.94 ± 0.05
hatching success	67.7 %	57.6 %	18.1 %	30.3 %
breeding success	27.1 %	18.2 %	0.9 %	0 %

If human activities have significant adverse effects on skua populations, it should be more easily detectable in seasons where natural stressors occur to a greater extent (low food availability, high predation pressure). The birds of A_{high} and A_{low} showed no significant differences in breeding parameters. Therefore, natural factors drive all relevant variation in reproductive success of skuas on the Fildes Peninsula and Ardley Island.

7 RISK ASSESSMENT AND SPECIES PROTECTION MEASURES

7.1 Introduction

A major aim of this dissertation is to provide a scientific basis for management recommendations for the species studied. The behavioural and physiological changes measured, and their consequences for reproductive outcome have been discussed in the previous chapters. A risk assessment (the process of obtaining quantitative or qualitative measures of a risk level, Suter 1993) can also be used to describe in probabilistic language the effect on populations (Burgman et al. 1993). With this it is possible to compare human impacts against the other background risks that a population faces. This should ideally lead to calculations and models that incorporate degrees of uncertainty (like phenotypic variation, demographic variation, environmental variation, spatial variation). But a lack of understanding of the complex interactions between natural and human stimuli limits the factors being included in the risk assessment (mostly the use of indicators).

From the assessment, management objectives can be derived that specifically aim to protect the species or to minimise anthropogenic stress in general. Widely used direct management of visits to wildlife include (1) limiting visitor numbers, (2) dispersing visitors, (3) zoning, (4) using viewing points, and (5) setting guidelines for minimum approach distances. Indirect strategies are those that aim to modify the behaviour of visitors i.e. educating them about potential disturbances. Air traffic has been mainly regulated by zoning and minimum distances (Carney and Sydeman 1999, Roe et al. 1997, Yorio et al. 2001).

All these strategies have been used by tourist companies (e.g. IAATO 2003) and national programmes in the Antarctic (e.g. ATCM 2002). But because existing recommendations and guidelines vary in their implementation, discussions continue (ATCM 2002, ATCM 2003, Davis 1995, IAATO 2003). Other important management tools in the Antarctic are the environmental impact assessment, a permissions system and a system of protected areas (Cohen 2002). These measures have also been repeatedly revised (ATCM 1999, SCAR 2001).

In this chapter, human activities and their impact on SGP and skuas on the Fildes Peninsula and surrounding islands (results from previous chapters) will be incorporated in a verbal risk assessment. Possible future development will be discussed within it. In addition to existing protection measures, I will give management recommendations more specific to species and sites.

7.2 Risk Assessment

7.2.1 Human Activities

The spatial and temporal extent of station, scientific, and tourist activities was presented in chapter 2 and 6. It is difficult to quantify how these activities affect wildlife because of their diversity in range and type. The nature of any disturbance caused by construction work, visits or air traffic will depend upon their predictability, frequency and magnitude.

Butler (1980) introduced the 'life cycle concept' that summarised the outcome of tourism development (Fig. 7.1). He states that unless areas are managed, they will become over-used by tourism and, consequently, resources (i.e. desired values like wilderness) will decline. I use this concept to demonstrate the current development of station construction and tourism on the Fildes Peninsula (grey boxes in Fig. 7.1).

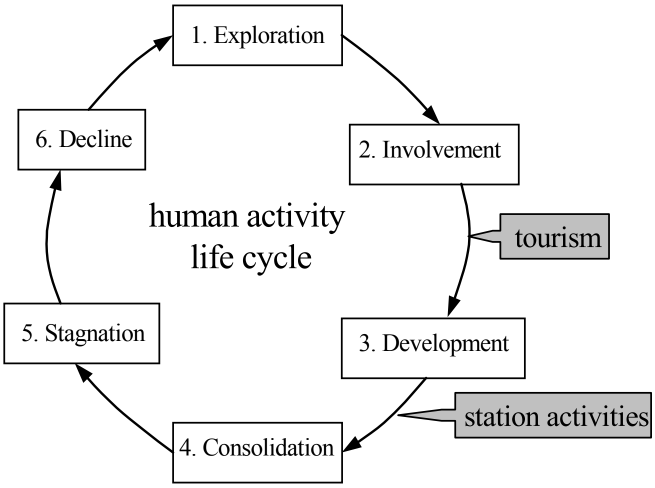

Figure 7.1. Life cycle concept (after Butler 1980), of tourism development modified to classify current tourist and station activities on the Fildes Peninsula (grey boxes). The concept consists of six stages that show how human activities may evolve without regulation.
1. few activities, poor facilities, environment unchanged; 2. increasing activities, local initiatives; 3. many activities, locals lose control, deterioration of environment; 4. activity exceeds others; 5. environmental problems, activity peaks; 6. activity decline.

Station construction started in 1968 (chapter 2, exploration stage), and with the building of the airport in 1980, more countries were attracted to the Fildes Peninsula (involvement). Human waste was openly damped at that time, and wildlife was effected by several station activities (chapter 6, development stage). Several stations are currently still expanding. In most stations the existing environmental management and monitoring is carried out at the lowest agreed level (agreed on by the Treaty Parties). Some nations, like Uruguay, conduct more comprehensive programmes, most effectively minimising adverse effects on the environment (http://www.iau.gub.uy/). In other stations on the Fildes Peninsula, the development approaches stage 4 (see 7.2.3), and protection measures need to be activated to prevent adverse effects.

In contrast, tourism has not so far developed to a degree at which major impacts are evident. However, activities will reach stage 3 soon with the construction of tourist attractions (e.g. Russian church built in the season 2004), a planned airport extension and new tourist programmes. And, in the case of tourism, no adequate management is currently in place.

Science is not included in the life-cycle concept, because all development in relation to scientific infrastructure is directly linked to station expansions. Otherwise, science as such aims to use non-invasive techniques to minimise stress on wildlife. On the Fildes Peninsula and Ardley Island, activities involve a number of cumulative effects, making it difficult to distinguish impacts arising from the different individual activities (scientific, logistic, tourist). Environmental change also occurs naturally, making human-induced changes hard to quantify (seen particularly on the population level).

In the following, I will present the anthropogenic stresses identified for SGP and skuas on the Fildes Peninsula and surrounding islands, and also discuss the relative risk for the species in respect to human activities planned in the near future.

7.2.2 Relative Importance of Stressors

Current stresses have been identified, and individual physiological and behavioural responses of the study birds have been interpreted accordingly (chapter 3 - 6). I summarised the potential risk of visits, air traffic and cumulative effects of both, on SGP and skuas (Tab. 7.1, Fig. 7.2) and specified stressor characteristics and their effects accordingly (Tab. 7.2). It is clearly necessary to consider the contribution to the reduction of local, regional or total populations, of the increasing severity of physiological effects, leaving and returning to the nest, deserting the nest, abandoning the colony site, reducing hatching and breeding success and adult mortality (Nisbet 2000).

Scientific visits resulted in the greatest physiological and behavioural responses of the species studied. These effects are unpredictable in space and time and threat value because the activities range from close nest approaches during census to handling of adults and young. SGP and skuas are no target species for wildlife viewers in the same way as penguins and seals. They are nevertheless exposed to visits at their breeding and resting sites. I observed station personnel and tourists off-path, although their greatest use of space was concentrated in areas of high human activity. Tourists were mostly accompanied by guides or scientists who are able to minimise strong behavioural responses of the birds. In contrast, station personnel on their own was also seen to approach wildlife, causing strong behavioural responses of individual birds. Such lack of knowledge and self-control by staff caused fly-off and defence behaviour of adults. Some handling of offspring can also be assumed even though it is prohibited. The species I studied habituated to some extent in areas of high human activity, however.

Air traffic on regular routes caused insignificant behavioural responses, and birds reacted at most with heart-rate increases. When planes and helicopters flew lower than normal or on less frequently used routes, birds responded more strongly, showing behavioural changes that potentially lower breeding success (e.g. when SGP fly off the nests).

If several human activities occur at the same time, a higher percentage of SGP responded with behavioural changes. Skuas, on the other hand, reacted to the most threatening activity independently of other surrounding events. Because scientific and tourist visits to breeding groups in A_{low} are short, the probability that air traffic occurs at the same time is very low.

By adding all classified effects along the different scales (physiology, behaviour, and breeding parameters), strong physiological responses are evident during most human activities, whereas behavioural changes occurred mainly in unpredictable situations. Direct effects of visits on breeding parameters were only observed in SGP, but the potential exists also for skuas when territorial defence is repeatedly activated. The local population size of SGP and skuas seems unaffected by current human activities.

All species studied seem to still have some unused suitable breeding habitat in the study area. Although, large numbers of SGP already inhabit remote islands, there are in other coastal parts with suitable habitat characteristics. SPS have expanded in recent years, probably due to increased marine food sources in response to changes in sea ice extent (Atkinson et al. 2004). In contrast, BS depend mainly on the fluctuations of local penguin populations (Ciaputa and Sierakowski 1999, Woehler et al. 2001).

Table 7.1. Summary of the effects of (potential) stressors on physiology, behaviour and breeding parameters of southern giant petrels and skuas (brown and south polar skua together) on the Fildes Peninsula and surrounding islands. Classification: 1 = minor, 2 = medium, 3 = severe effects compared to natural stressors (predator and conspecific interactions). Responses of birds breeding in areas of high (A_{high}) and low (A_{low}) human activity presented. Where experiments/observations could not be obtained with large sample sizes, I stated assumptions, based on the data, in brackets.

(potential) stressor	scientific visits	station personnel and tourist visits	air traffic regular	air traffic irregular	visits + air traffic	sum
SGP ($A_{high+medium}$)						
physiology	3	2	1	2	(3)	11
behaviour	3	2	1	2	3	11
breeding parameter	1	1	1	1	1	5
SGP (A_{low})						
physiology	3	3	2	2	(3)	13
behaviour	3	2	1	(2)	(3)	11
breeding parameter	2	(2)	1	(2)	(2)	9
skuas (A_{high})						
physiology	3	3	3	2	(3)	14
behaviour	2	1	1	2	1	7
breeding parameter	1	1	1	1	(1)	5
skuas (A_{low})						
physiology	3	3	3	2	(3)	14
behaviour	3	2	1	(2)	(2)	10
breeding parameter	1	1	1	1	(1)	5

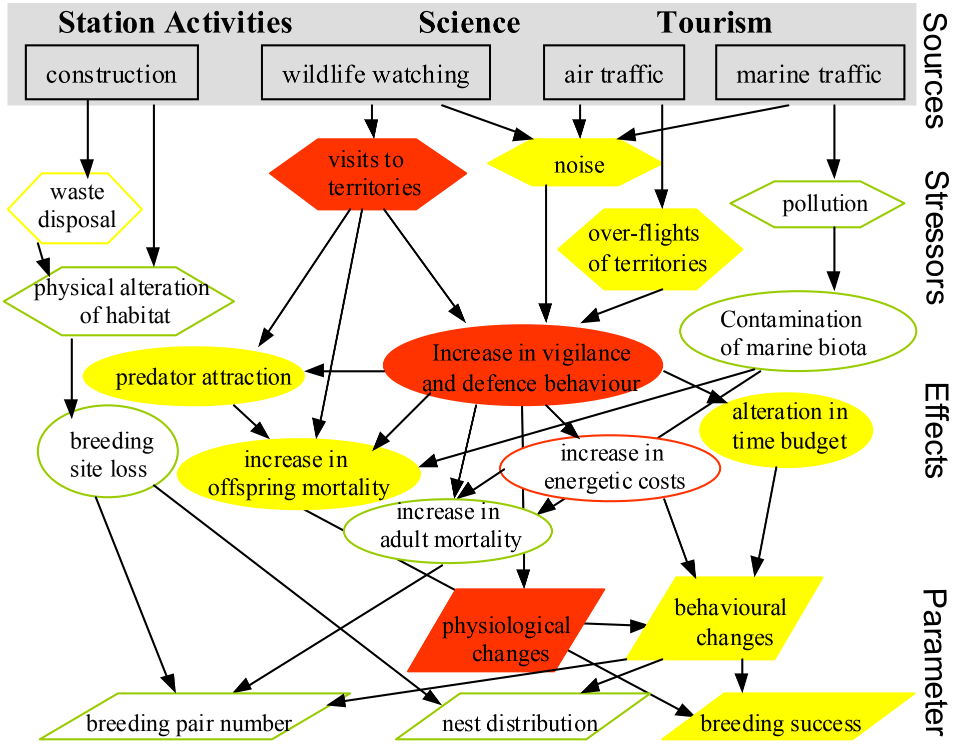

Figure 7.2. Relative importance of human activities on breeding birds in areas of high human activity on the Fildes Peninsula and Ardley Island during this study (modified figure 2.5 in chapter 2). Observed (filled with colour) and expected (framed with colour) effects are categorised by colours - red: severe, yellow: medium, green: minor effect.

Table 7.2. Study results about characteristics of stressors and their effect on different parameters on areas of high human activity on the Fildes Peninsula and Ardley Island (modified after Serveiss et al. 2004, 1 = minor, 2 = medium, 3 = severe, in brackets assumed effects).

stressors	waste disposal	alteration of habitat	visits to territory	noise	over-flights of territory	pollution
stressor characteristic						
intensity	1	1	2	2	1	1
extensiveness	1	1	2	1	1	1
likely increase over time	1	2	2	1	2	1
sum	3	4	6	3	4	3
parameter						
physiological change	(1)	(2)	3	3	3	1
behavioural change	(1)	(2)	2	2	2	1
nest distribution	(1)	(1)	1	1	1	1
breeding pair number	(1)	(1)	1	1	1	1
breeding success	(1)	(1)	2	1	1	1
sum	5	7	9	8	8	5

7.2.3 Planned Human Activities and Their Possible Consequences

There are four permanently occupied research stations on the Fildes Peninsula and Ardley Island and several frequently-used field huts. Because of this concentration, there are continues renovations and expansions in the area. These activities are now increasing in run-up to the International Polar Year 2007. The Chinese will enlarge the facility area of their Great Wall station from 3000 m^2 to 5000 m^2 in the next years (plans presented at XVI COMNAP meeting 2004). Furthermore, the Chilean airport will be extended by a new parking space for aircraft allowing more frequent traffic of national-programme and tourist company traffic (http://www.e-seia.cl/portal/busquedas/antarticos.php). Due to financial constrains, the Uruguayan station plans to offer tourist stays (article in La República, October 2004). As the number of tourists staying overnight on Fildes Peninsula is increasing, visits of surrounding will inevitably also increase. In the 2004 season, the tourist company DAP enlarged their programme with helicopter sightseeing flights and longer walks to the northern part of the Fildes Peninsula. And from 2004 onwards, a new company (Antártica XXI) will fly passengers from Chile to Fildes who will then spend several days on the ship in the Antarctic before returning by plane. This avoids crossing of the Drake passage, thus a new attractive development for tourist companies. These increased activities in the Maxwell Bay could result in more visits to the surrounding islands which have so far not been tourist destinations.

7.3 Existing Protection Measures

SGP are listed as threatened species under the IUCN category ‘Vulnerable’ (BirdLife International 2004) and ‘Specially Protected Species’ under Annex II of the Madrid Protocol (SCAR 2000). This species is therefore of special conservation interest. Adverse effects of scientific work have been observed in the past prompting an end to banding and less frequent census work (chapter 6, Micol and Jouventin 2001).

Antarctic visitor guidelines have been adopted by all Antarctic Treaty members (ATCM Recommendation XVIII-1) and specified by IAATO (http://www.iaato.org) and national programmes (e.g. http://www.aad.gov.au/default.asp?casid=1344, Code of Conduct for Australian Field Activities). The majority of tourists, station personnel and scientists receive introductions to guidelines concerning wildlife and environmental protection in the Antarctic.

In 1991, Ardley Island was classified as ‘Site of Special Scientific Interest’ due to the species richness of its flora and fauna (SSSI 33, ATCM Recommendation XVI-2, changed to 'Antarctic Specially Protected Area', ASPA 150 in 1998, Annex V of the Madrid Protocol). The management plan includes the regulation of visitors and air traffic. Pedestrians should keep away to breeding sites and vegetation except when research studies have been approved. Tourists and non-scientific station and ship personnel should only visit the tourist zone in the northern part of the island (see Fig. 7.2). Vehicle use is prohibited, and aircraft should not land on, or over-fly, the island below 300 m. However, I observed repeated violations of all these restrictions because control mechanisms are limited and violations have no consequences for station personnel and pilots.

7.4 Recommended Minimum Distances

7.4.1 Recommendations for Visits

Before this study, the minimum approach distance was 15 m for SGP and skuas. This applied to tourists, station personnel and scientists not involved in research. Whether this was enough for SGP has been repeatedly discussed (e.g. Carstens et al. 1999), but only the Australian government has implemented a minimum distance of 100 m for this species. And, of course, this ruling applies only to the Australian sector. A minimum of 100 m is inapplicable in the Antarctic Peninsula region because their is a greater density of infrastructure and visitor paths and consequently shorter distances to breeding sites.

Fly-off distances have been used as a measure of bird tolerance (Burger and Gochfeld 1991), and to determine minimum visitor approach distances (e.g. Knight and Knight 1984, Rodgers and Smith 1995). However, the distance can be affected by several factors like habitat characteristics and availability (Gill et al. 2001), weather (Chapter 3), or the birds’ body condition (Beale and Monaghan 2004). Therefore, a set distance for visitors will probably minimise stress only for some birds. The maximum distance causing birds to become alert depends on the same internal and external factors but is a more conservative measurement (Fernández-Juricic et al. 2001, Gutzwiller et al. 1998, Rodgers and Smith 1997, Skagen et al. 1991). In species like SGP, where alert distance is not easily recognised, heart-rate measurements can be an early indicator of a threatening stimuli, and have also been used to determine minimum distances for visitors (Giese 1998). The behavioural and physiological responses of SGP that I record (chapter 3 and 8) show that a 50 m visitor distance is most appropriate.

Immediately after this distance was first proposed (Pfeiffer and Peter 2003), it was added to the visitor guidelines set by the German Federal Environmental Agency (http://www.umweltdaten.de/antarktis/antarktis.pdf). Also IAATO set the minimum distance for tourists to SGP to 25-50 m (http://www.iaato.org/docs/wildlife_guide_03.pdf). One could argue that the study shows differences in bird responses depending on prior human activity levels and, therefore, the minimum distances should be more site-specific. However, practise shows that the implementation of minimum distances is difficult and diverse recommendations would complicate this even more. The recommended 50 m is a precaution measure providing an easily understood guide to visitors.

The experimental work on skuas in this thesis showed that the fly-off distance is highly variable between individuals and skua form. A strict implementation of a minimum distance seems therefore inappropriate. Visitors should leave the site as soon as a bird calls or, at the latest, if it flies off from the breeding territory. Birds that remain on the nest should not be approached more closely than 15 m.

My studies also showed that visitor behaviour influences the response of SGP and skuas. Fast, direct movements towards and around nests are most alerting, whereas calm approaches and sitting during the observation result in least negative effects. Using only the main visitor paths (and avoiding of less frequently used walking routes) and set scientific routine routes can promote habituation. This is particularly relevant in multi-used areas. I therefore suggest providing site maps showing the recommended routes.

7.4.2 Recommendations for Air Traffic

Aircraft operations will continue for logistic and tourist purposes in proximity to bird concentrations around the Fildes Peninsula. To minimise impacts on bird populations, it is necessary to provide consistent and practical guidelines to pilots. A variety of minimum distances to wildlife have been suggested and partly applied within the Antarctic. The first recommendations were adopted by the Antarctic Treaty Parties in 1964, prohibiting landing close to bird concentrations and any flights by helicopter or other aircraft that would unnecessarily disturb them (Heap 1990). Currently a inconsistent mix of recommendations and guidelines exists. Besides general recommendations, specific minimum distances are included in the management plans for several specially protected sites. According to these, Ardley Island should not be over-flown below 300 m by helicopters, and aircraft landing at or taking off from the airport should not over-fly the island. The Antarctic Flight Information Manual (AFIM 2004) for the airport on Fildes gives clear instructions for landing and starting. However, in relation to wildlife, the manual states only that the tower personnel have responsibility of informing pilots. Flight activities observed on-site suggest insufficient information transfer. So far, local maps showing sensitive breeding and resting sites have not been provided to the authorities. This is planned within the next two years. New comprehensive air-traffic guidelines for the Antarctic were introduce in 2004. These recommend that flights should maintain a minimum distance of 460 m from all coasts and a minimum altitude of 610 m over wildlife concentrations (ATCM 2004).

7.5 Recommendations for Zoning

Because the minimum distances are only partly applied in practice, zoning can additionally support wildlife protection. Zoning can either totally isolate breeding sites from human activities or concentrate certain activities in certain areas to enhance habituation. Isolating breeding sites is relevant for SGP because visits caused lower breeding success (chapter 6). Concentrating activities relates to both, SGP and skuas because they can habituate to frequent activities (chapter 3 and 4).

Besides the existing ASPA 150 of Ardley Island with its tourist zone, I suggest the application of three further zone types (classified by Harris 1994, Fig. 7.3) on the Fildes Peninsula and surrounding islands. The identification of zones in which activities are prohibited, restricted or managed, can be applied for ASPAs and ASMAs (Antarctic Specially Managed Areas, Art. 5 Annex V, Environmental Protocol, SCAR 2001).

Two Summit and Dart Island should be taken under complete protection in defining them as ‘Restricted Zones’, where only scientific and management activities can be carried out. These islands have the highest number of breeding pairs and a high breeding success of SGP. Visits to the islands caused egg and chick predation due to fly-off of nesting birds. Hercules C-130 directly over-fly Dart Island below 300 m and pass close to Two Summit Island. If tourism increases (see 7.2.3) these island could be considered as landing sites. The example of Nebles Point, 20 years ago, showed that also air traffic can lead to decline in numbers of breeding pairs. Planned helicopter sight seeing is therefore a potential threat and zoning can considerably minimise these effects.

Medium-sized breeding groups of SGP in North and South Fildes, Geologist and the northern part of Nelson Island (referred to as A_{low}), as well as the north-western group on Ardley Island (referred to as A_{medium}) should be classified as 'Sensitive Zone'. These would assure that people are aware of the existence of vulnerable species in these areas. Entry permission would be required if these sites were within an ASPA or an ASMA, but not otherwise.

All stations, the airport, and other infrastructure, fall within facility zones, thus confining them inside predefined areas. In these zones, special management guidelines concerning environmental and human safety should be applied.

At present, there is little evidence that tourists significantly impact SGP nesting sites. Disturbances occur mainly during visits of scientists and station personnel. The latter group is not well informed about local wildlife and potential stresses so education should be the primary management aim. If tourism increases as expected over the next years, a larger number of tourist zones could be established depending on the requirements.

BS and SPS have nests distributed over the Fildes Peninsula and surrounding islands. Zoning, therefore, is not a suitable method for their protection. However, habituation will be facilitated by zoning for SGP.

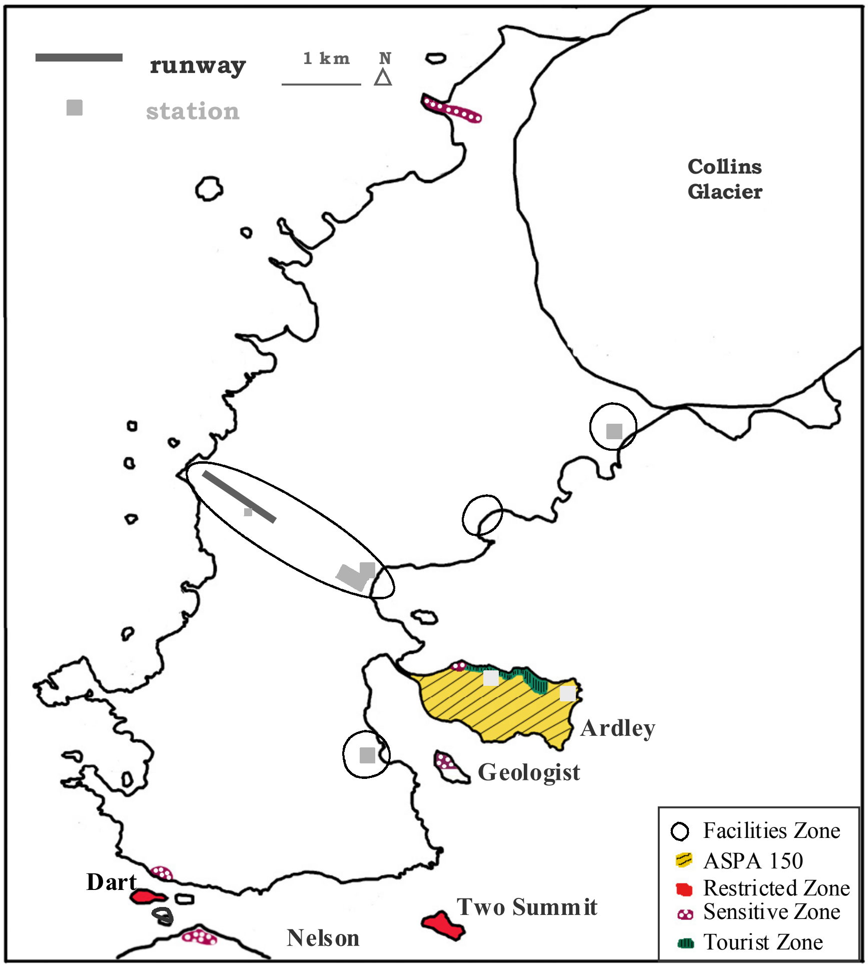

Figure 7.3. Recommendation of the protection of southern giant petrel breeding sites in the study area. Scenario for the designation of Antarctic Specially Protected Area 150 and a number of zones within the Antarctic Specially Managed Area 'Fildes Peninsula and Ardley Island'.

7.6 Scientific and Management Activities

Although many field biologists are careful to investigate the effects of their activities and are successful in minimising them, others appear insufficiently aware of the potential for harm, so that there is still a need for guidelines and better training. Mineau and Weseloh (1981) outlined a general system of nest-checking for colonial birds that minimises investigator disturbance while maximising data collection. Safina and Burger (1983) recommended the use of telescopes to observe colonies and sensitive areas rather than entering them. Because some habituation to researcher visits is possible (Parsons and Burger 1982, pers. obs.), consistency in timing and intensity of visits may alleviate some problems. Selection of a study population already habituated to human activity sometimes may eliminate unwanted side effects of scientific research. Multinational activities in the Antarctic still employ different methodologies, ranging from very invasive to non-invasive studies. Some countries, like Germany, have strict permission procedures, asking scientists to state planned research activities and impacts expected. Because other countries are less restrictive, only international co-operation with training and publication restrictions can raise the standard.

Management activities can also be stressful to wildlife. Regular counts cause short-term disturbance in the breeding groups (Hofer and East 1998, this study). Therefore, a sufficiently low frequency of census should be stated in the management plan.

8 ECOLOGICAL STUDIES TOWARD THE MANAGEMENT OF AN ANTARCTIC TOURIST LANDING SITE (PENGUIN ISLAND, SOUTH SHETLAND ISLANDS)

8.1 Introduction

Tourist activities in the Antarctic more than doubled during the last 10 years (season 2003: 13,571 tourists, http://www.iaato.org/tour_stats.html), and the upwards trend is expected to continue due to an increasing number of ships, the use of large vessels, and a wide activity spectrum.

It is assumed that tourism has a much lower impact than constructing and operating stations or undertaking scientific work. However, tourism has opened new landing sites in close proximity to wildlife and work areas, where governmental and non-governmental activities overlap. Therefore, its own impact and cumulative effects should be monitored (De Poorter and Dalziell 1996, NSF et al. 2000). Although the Antarctic Treaty introduced protection measures to reduce negative effects on wildlife (see Environmental Protocol Art. 3 (2) and Art. 8 as well as its Annexes I, II (Art. 3, 4) and V; ATCM 1994), tourism impact and management of human activities are still under discussion (ASOC 1999, ASOC 2001, ASOC 2002, ATCM 2003). Guidelines for visitors from the International Association of Antarctica Tour Operators (IAATO) and the Antarctic Treaty Consultative Parties (ATCPs) are quite general, to make them easier to implement, but do not account for site-specific differences (http://www.iaato.org/visitor_guide.html, ATCM 1994). As tourist visits at landing sites range from one per season to four times per day, and sites vary in their characteristics, wildlife responses will differ as well. Since 1994, many tourist sites have been surveyed by OCEANITES Inc. (Naveen 1997, 2002, 2003, Naveen et al. 2001). At the same time, Project Antarctic Conservation was initiated at the Scott Polar Research Institute, Cambridge, studying tourism impact more closely at different sites (e.g. Davis 1995, Minbashian 1997, Nimon et al. 1995, Stonehouse 1995). Furthermore, monitoring of tourism has been carried out near research stations (e.g. Acero and Aguirre 1994, Fraser and Patterson 1997, Harris 1991a).

In 1999, commissioned by the Federal Environmental Agency of Germany, a research project was initiated to establish a theoretical site-evaluation system being tested at two frequently used landing sites, Hannah Point and Penguin Island (Pfeiffer and Peter 2003). Several indicator variables were used for studying environmental impact of tourism, and site-specific management measures were suggested. The main results of the avian studies on Penguin Island are presented here.

In the inventory of OCEANITES Inc., Penguin Island is categorised as having a high species diversity, but also being highly sensitive to potential disturbances by visitors (e.g. Naveen 1997, 2003). Tourist companies allow passengers to climb the caldera during a longer walk, but since the path is situated close to breeding southern giant petrels (SGP) and skuas, the animals could be negatively affected.

I investigated behavioural and heart-rate changes of SGP and skuas in more detail to have a scientific base for the revision of minimum distances to these species. In combination with the monitoring of breeding pair numbers and visitor use, these results were the basis for site-specific recommendations for the use and management of this tourist site.

8.2 Methods

Study Site

Penguin Island (62°06'S, 57°54'W, area 1.7 km^2, Fig. 8.1) is situated on the southeastern side of King George Island, South Shetland Islands, Antarctic (chapter 2: Fig. 2.1). It lies within a belt of active (Deception Island), inactive (Penguin Island), and extinct (Melville Peak on King George Island) volcanoes that developed in the Bransfield Strait (Birkenmajer 1982). At the southern end of the island the volcanic cone of Deacon Peak rises up to 180 m above sea level, and on the eastern side a second crater is filled with brackish water.

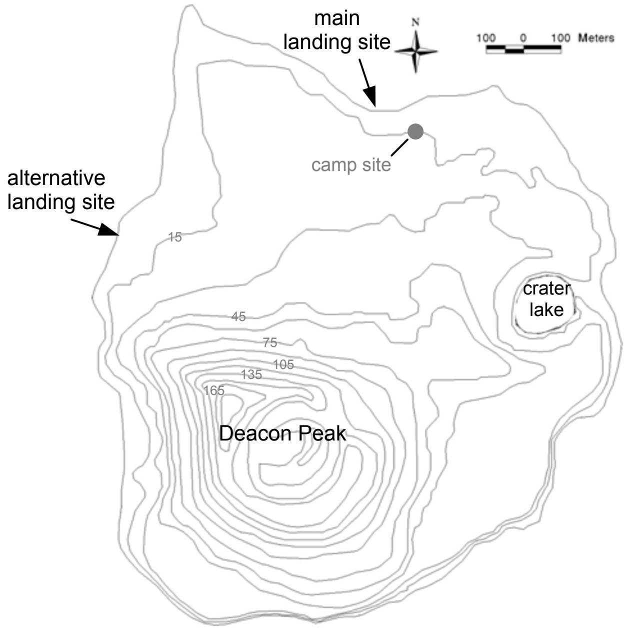

Figure 8.1. Map of Penguin Island with its landing sites and our campsite during the study in 2000 and 2001.

The tourist numbers on Penguin Island have fluctuated in recent years, with 10 - 24 landings allowing some 1200 visitors per season. During the work on the island, two groups landed in January 2000 but no tourist visit took place in December 2000 due to bad weather. Most groups land at the north side of Penguin Island to see whaling remains (bones and harpoon piece), visit the penguin and seal groups to the east, and pass the SGP colonies to climb the volcanic caldera of Deacon Peak (pers. comm. with expedition leaders). The main path leads from the north beach over a barrier in a southerly direction to the base of the hill. In most areas along the path, vegetation is scarce and erosion seems insignificant. Several groups visited the penguin colonies on the eastern coast and the crater lake, but the dense vegetation cover of some parts limits the access. When the wind prohibited landings at the north side, the west coast was used to allow tourists to walk to Deacon Peak.

Bird Number

We worked on Penguin Island from 4 to 12 January 2000 and 16 to 21 December 2000. In January, three people conducted counts of penguins with a high accuracy (± 5 %) in the large colonies, whereas in December counts by two people resulted in lower accuracy (± 10 %). The populations of storm petrels were estimated by nocturnal calls of the birds. Our data are comparable with counts at similar dates in previous years (e.g. Jablonski 1980, 1984, Naveen et al. 2000), but since census results can vary considerably, it is difficult to describe trends (Woehler et al. 2001).

Behaviour

We used fly-off distance and aggression of brown (BS) and south polar skuas (SPS) breeding on Penguin Island as indicators for the assessment of visitor effects (same methodology as described in chapter 4). During nest counts, we also observed the behaviour of SGP in terms of relevant distances to tourists. Birds of frequently visited areas (in the northern and central part of the island, referred to as A_{high}) were compared with birds breeding in rarely visited parts of the island (western and eastern side, referred to as A_{low}).

Heart Rate

The heart rate (HR) of SGP was measured as a physiological response to human activities. We used a non-invasive method by recording the HR with an artificial egg in the nests of incubating birds (detailed descriptions in Nimon et al. 1996). During the HR measurement, the bird's egg was replaced by the artificial egg and incubated by another breeding bird nearby. Four SGP pairs in A_{high} were compared with four in A_{low}. We recorded also the nest and outside temperature using dataloggers (Hobo H 8 Pro Series from Synotech Sensor und Messtechnik GmbH in Linnich, Germany) to study the egg cooling effect when incubating birds left the nest.

For the assessment of a minimum distance to breeding SGP, study birds in A_{high} were approached (seven repeats of the experiment for each bird) and behaviour and HR were simultaneously observed. We used following standardised procedure: starting at 210 m distance from the incubating bird, one person walked 50 m towards the nest, then stood for 1 min visible for the bird. Then the person hid for 5 min, thereafter walked another 50 m towards the bird, and stood again for 1 min. This procedure was continued, until the person was close to the nest. The recorded heart rates during visits were compared with the HR during natural disturbance (including encounters with conspecifics and predators). Human activities should not cause higher HR than under natural disturbance to avoid additional metabolic costs for the breeding bird. We used, therefore, the lower natural disturbance boundary (10th percentile) as a reference for identifying the recommended minimum distance to SGP.

8.3 Results

Bird Number

Eleven bird species breed on Penguin Island (census data in Tab. 8.1). The December count resulted in lower breeding pairs than in January, but colonies and territories were re-occupied without visible shifts (Fig. 8.5). An exception was one larger group of Antarctic terns *Sterna vittata* breeding on the western coast in January 2000, which moved eastwards in December 2000. We found one cave with a nest of sheathbills *Chionis alba* on the north-eastern side, and several birds fed in the penguin colonies on the island. Cape petrels breed on one rock in the rarely visited south of the island. In January 2000, non-breeding gentoo penguins *Pygoscelis papua*, macaroni penguin *Eudyptes chrysolophus*, and black-necked swans *Cygnus melanocorypha* were seen on the island.

Table 8.1. Breeding bird census data on Penguin Island in January and December 2000. Breeding pair numbers were counted or estimated.

Species	Scientific name	January	December
Adélie penguin	*Pygoscelis adeliae*	2,390 [1]	792 [2]
Chinstrap penguin	*P. antarctica*	3,774 [2]	3,296 [2]
Southern giant petrel	*Macronectes giganteus*	698	456
Cape Petrel	*Daption capensis*	35	< 50
Wilson's storm petrel [3]	*Oceanites oceanicus*	> 100	> 100
Black-bellied storm petrel [3]	*Fregetta tropica*	< 50	< 50
Sheathbill	*Chionis alba*	> 2	> 2
South polar skua	*Catharacta maccormicki*	15	13
Brown skua	*C. antarctica lonnbergi*	32	29
Kelp gull	*Larus dominicanus*	> 22	> 15
Antarctic tern	*Sterna vittata*	> 42	> 35

[1] chicks during crèching, [2] nests with chicks, [3] nocturnal calling was used as population estimate

Behaviour

The fly-off distance of BS and SPS on Penguin Island varied considerably between individuals (range 0 – 50 m). The comparison of A_{high} and A_{low} showed no significant difference (Fig. 8.2, GLM (ANOVA): skua forms: $F_{1,69} = 2.69$, $p = 0.11$; area: $F_{1,69} = 0.03$, $p = 0.87$; species * area: $F_{1,69} = 2.90$, $p = 0.09$). The aggression of BS was similar to an approaching person in A_{high} and A_{low} of Penguin Island (Fig. 8.2, Likelihood ratio chi-square test for area type BS: $\chi^2 = 5.26$, $p = 0.15$). SPS showed a lower aggression in A_{high} ($\chi^2 = 11.36$, $p = 0.01$).

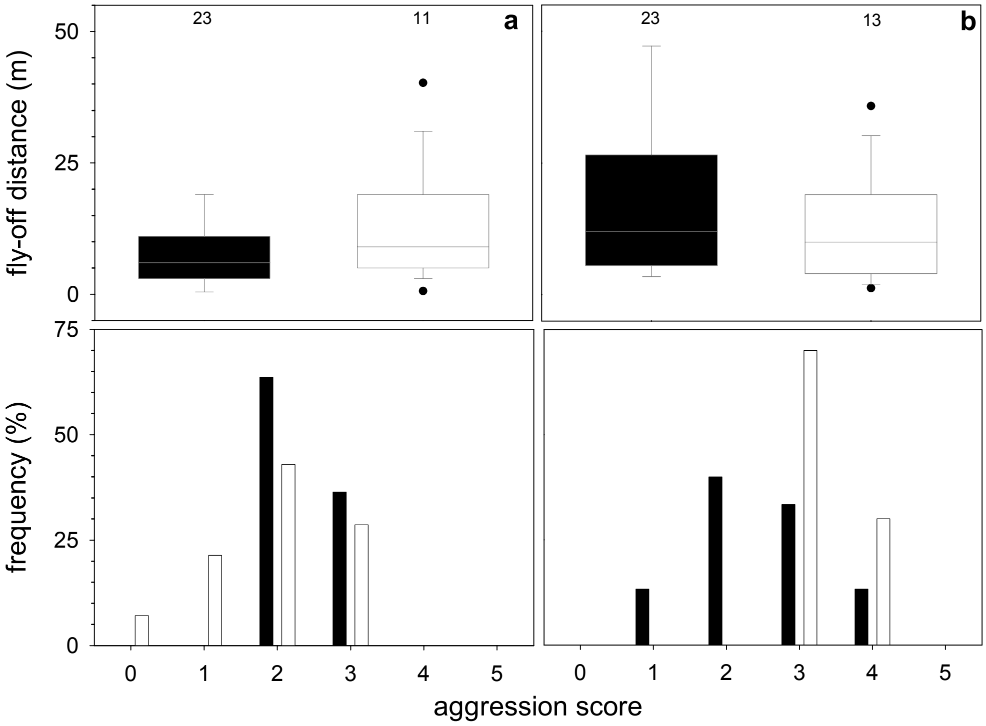

Figure 8.2. Comparison of (a) brown skua and (b) south polar skua fly-off distance and aggression score (after Furness 1987) in area of high (black) and low (white) human activity on Penguin Island in January 2000. Boxplots for each category show 5, 10, 25, median, 75, 90, and 95 percentiles. Number of birds above boxplots.

In A_{high}, fly-off responses were not evident, when incubating SGP were visited up to 15 m, but non-incubating partners and non-breeders, that were within 50 m, walked or flew away. Two incubating and several non-incubating giant petrels flew off in A_{low}, when approached within 50 m. After more than five minutes of flying large cycles above the colony, the incubating birds returned. Temperature datalogger in the nests registered a fast temperature decline (mean decline: 2.3 °C per minute ± 0.5 under a mean outside temperature of 6 °C ± 1.9 during behavioural and physiological observations) around the eggs, when the birds had left the nests. In cases where the investigator could approach incubating birds closer without causing fly-off, they reacted in both areas with alarm and defence behaviour (ruffled nape feathers and repeated attempts to spit out stomach contents). After retreat from the nest, the birds seemed to relax in a few minutes.

Heart Rate

The basal HR of studied breeding SGP ranged between 59 and 116 beats min^{-1} with no significant differences between A_{high} and A_{low} on Penguin Island ($t_6 = 0.71$, $p = 0.87$). The HR was on average 63 % higher than the basal HR (max. 116 %) when visitors approached up to 20 m. Approaches of 100 m to the nest already caused HR increase but compared with responses to natural disturbance, the difference to the basal values was lower (Fig. 8.3). Visits closer than 40 m resulted in HR increases larger than under natural disturbance situations. If a visitor stood for 15 min in 20 m distance to an incubating SGP, the HR decreased slightly over time (regression: y = -0.4 – 143.9, $r^2 = 0.32$, $p < 0.001$). The longer the period between two approaches of visitors, the higher is the HR of the incubating bird (Fig. 8.4).

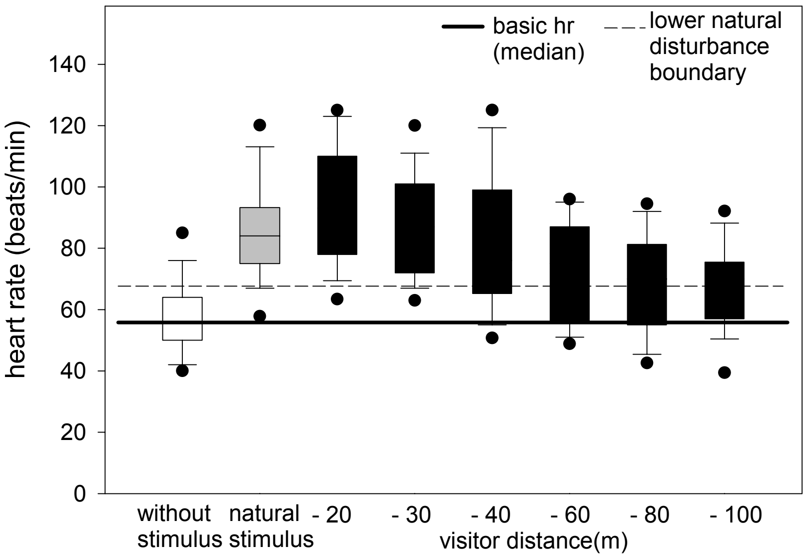

Figure 8.3. Heart-rate response of a breeding southern giant petrel on Penguin Island to different stimuli in increasing distance to the nest. Boxplots for each category show 5, 25, median, 75, 90, and 95 percentiles. 10 percentile is threshold for minimum distance method. Visitor distance is categorised in meters where ‘-20’ equals ’10 to 20’, ‘-30’ equals ’21 to 30’ etc.

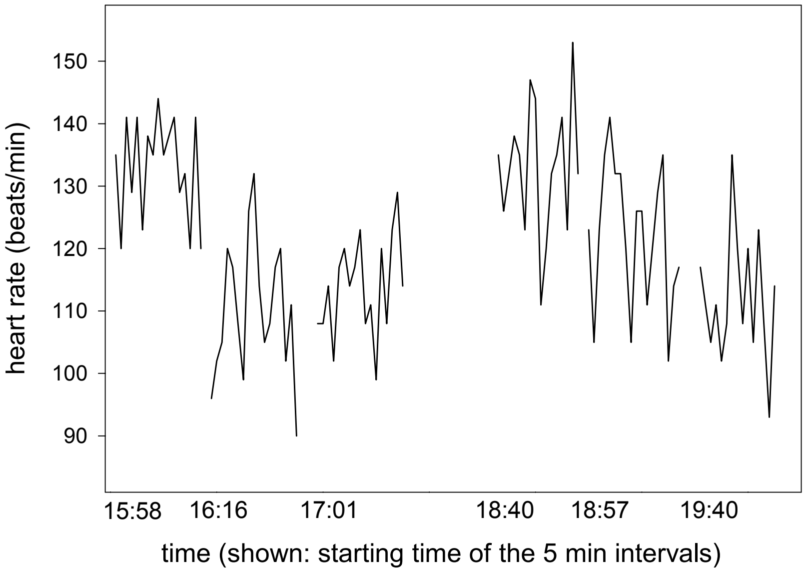

Figure 8.4. Heart-rate record of repeated 5 min-visits to a breeding southern giant petrel on Penguin Island in 2000.

8.4 Discussion

Bird Number

Scientists from the British Antarctic Survey, Polish expeditions, OCEANITES and the Scott Polar Research Institute have carried out bird counts on Penguin Island (Croxall and Kirkwood 1979, Jablonski 1980, 1984, Naveen 2003, Naveen et al. 2000, Stonehouse 1995). Adélie and Chinstrap Penguin breeding pair numbers declined in the 1980s as described in other breeding sites on King George Island (e.g. Peter et al. 2001). The numbers showed annual variation due to changing environmental parameters independent of human activity.

The comparison of SGP data from Jabłoński (1980) and this study also shows a decrease of nest numbers and a change in distribution on the northern and eastern sites of Penguin Island. SGP moved their breeding sites to the western part of the island, which could have been caused by increased visits. Nest site changes and population decreases of this species also occurred in the 1980s in parts of King George Island, where they were partly influenced by human activities (Chupin 1997, Peter et al. 1991, Woehler et al. 2001). Station construction and frequent visits by scientists and station personnel caused reductions in breeding success on Fildes Peninsula and shifts of nesting sites to small islands close-by.

Interpretations of breeding pair numbers of other species are difficult due to small numbers or little changes over time. Antarctic terns are known for their regular change of nest sites influenced by natural and human disturbance (Gebauer et al. 1989, Peter et al. 1988), and this was observed on Penguin Island. Although gulls and skuas can be disturbed by visitors, there is no obvious negative effect on breeding pair numbers, and breeding success has not been monitored. Storm petrels and Cape petrels are not directly influenced by tourism as their breeding sites are more sheltered.

Behaviour

Both skua forms often react to visitors that approach the territory too close with alarm calls or aerial attacks. I found a large individual variation in the fly-off distance of birds in A_{high} and A_{low} of Penguin Island which masked possible differences in area and skua forms. Eggs and chicks were only shortly unprotected leading to slight temperature declines, but predation by other skuas would still be possible although it was not observed. The reduced aggressiveness of SPS in A_{high} can be interpreted as a sign of habituation. Young (1990) observed SPS in a long-term study site on Ross Island where they maintained their tolerance to approaching people that had been developed in the first years of scientific work. It has also been shown in other studies, that regular visits can result in reduced stress responses in birds (Burger et al. 1995, Conomy et al. 1998, Fitzpatrick and Bouchez 1998, Scott et al. 1996). In the second most visited site in the Antarctic Peninsula region, Port Lockroy, visitors can approach breeding gentoo penguins very close without causing any discernible impact upon their breeding success (Cobley and Shears 1999). Fowler (1999) recorded fewer stress reactions of Magellanic penguins *Spheniscus magellanicus* to regular tourist visits, not only in behavioural but also hormonal studies, suggesting that individuals are able to learn that visitors frequently walking along a certain path do not cause a threat. On the other hand, less sensitive birds could breed in frequently visited areas whereas anxious individuals prefer less disturbed sites.

Although SGP on Penguin Island breed in relatively large groups, the number of interactions with conspecifics and potential predators were still relatively low (observed natural encounters max. 6 min/hour). If tourist groups visited the island, they walked near SGP for up to 20 minutes. Visits to breeding groups caused several breeders and non-breeders to stand up or fly off for longer periods. The uncovered white eggs or chicks are easy prey for skuas (Hunter 1984, Peter et al. 1991), and even if not, the egg or body temperature will drop considerably, by the time the birds return, resulting in the expenditure of re-warming.

Heart Rate

On Penguin Island, we measured for the first time the HR of SGP as it is a more sensitive indicator for stress responses than behavioural changes (similar results for penguins in Giese 1998 and Nimon et al. 1996). The study animals registered a change in their environment when visitors where 100 m away, and the HR increases were within 15 m higher than under natural interactions with conspecifics and partners. If people observed breeding groups quietly for several minutes, HR decreased. But any sudden movements of visitors resulted in new arousal of the birds. We could also observe that a visitor moving below a nesting SGP caused less threat than an approaching visitor at the same height as the bird (compare Giese 1998).

Management Considerations

All visitors receive general information on protection values and how to avoid harassing wildlife before landing on any Antarctic site. However, in recent years, site-specific differences have increasingly led to more specific management recommendations (e.g. ATCM 2003 a, Naveen 2003). Expedition leaders and guides play a key role in adjusting new protection measures at tourist sites in the Antarctic.

The 15 m distance of visitors to skuas, gulls and terns complies with the average fly-off distances we recorded on Penguin Island. However, due to the individual variation, visitors should leave the area at any distance if the birds react with alarm calls or fly-off. We also recommend the use of the path (Fig. 8.5) to allow further habituation to tourist activities on the island.

The large breeding groups of SGP are particularly important. Visits of the colonies on Penguin Island have an impact on the behaviour and physiology as shown in this study, and perhaps have altered nest number and distribution in the last 20 years. Based on the physiological study results, we recommend a minimum distance of 50 m to SGP on Penguin Island. This conservative measure will assure that HR increases will on average less than in interactions with conspecifics or predators. Some Antarctic tourist sites are of relatively small size, so that regularly used paths are in close vicinity to breeding groups. In these cases, the adjustment of the minimum distance should be considered to allow access if no alternative route exists.

On Penguin Island, landings should not be made on the western shore, in order to avoid disturbance at the close breeding sites of SGP. The western and southern sites should serve as control areas for monitoring non-visited bird colonies (in agreement with ATCM 2003a). The behavioural studies on this species in the northeastern part of Penguin Island resulted in the consideration of a new path to the Deacon Peak. A more westwardly start on the beach should be preferred to achieve the minimum distance of 50 m to the breeding birds (Fig. 8.5). Marking of the recommended tourist path, especially at the entrance point, could assure a consistency in appliance. In order to visit of penguins and seals on the northeastern side of Penguin Island, breeding SGP should be passed in the greatest possible distance by walking close to the water edge. Tourist activities show a large variety in spatial use of landing sites, from free exploration over several hours to guided walks in one large group. Furthermore, I would suggest a concentration of tourists when visiting SGP breeding sites to reduce repeated HR increases and possible behavioural changes.

These management recommendations will further minimise impacts on Penguin Island without losing its attractiveness as a tourist site. A large part of the island can be visited without any disturbance to breeding birds, only the close nesting sites along the path should be accessed with caution. There seems to be no need for further restrictions of tourist numbers, as they have not risen considerably in recent years.

Generally, tourism in the Antarctic has been conducted in a considered way, and increasing numbers can be managed by Recommendation XVIII-1 (ATCP 1994) and by site-specific guidelines to account for special requirements of the wildlife at the landing sites. Monitoring of indicator species and visitor use of tourist sites should be repeated regularly to assure the protection of Antarctic wildlife from increasing pressure by tourist activities.

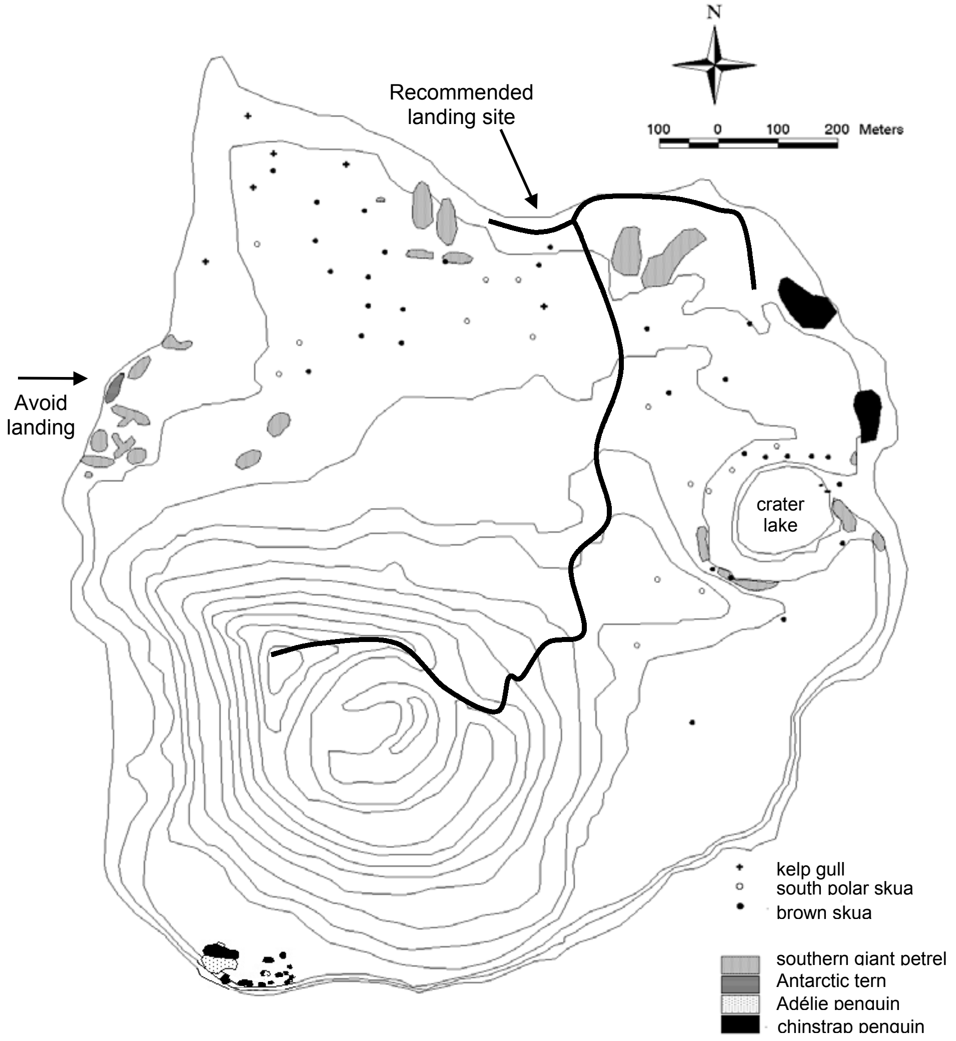

Figure 8.5. Recommended tourist path (black line) on Penguin Island to observe wildlife along the north-eastern beach and climb the caldera of Deacon Peak. All breeding sites of the listed bird species are presented (modified after Pfeiffer and Peter 2003).

9 FINAL DISCUSSION AND OUTLOOK

9.1 Final Discussion

This is the first study on the effects of current anthropogenic stresses on southern giant petrels and skuas in their Antarctic breeding sites. I found a wide variation in the physiological and behavioural responses confirming the complexity of influencing factors that have been described in the literature. Depending on the animals perception (visual and through sound or smell), habitat characteristics (plateau, hill side, rocky outlets), and weather conditions (wind from certain direction, fog), a natural or human stimulus will cause different responses. In bird colonies, many individuals will follow when the shyest one flies off (van der Zande 1984). In this study, SGP breeding in A_{medium} had the highest proportion of fly-off and the longest fly-off distance compared to A_{high} and A_{low}. This was caused by one or two non-breeders, and other birds followed immediately. Results also varied depending on breeding status and season.

The experience with human shaped behavioural and physiological responses particularly. I recorded lower proportions of fly-off, shorter fly-off distance and reduced aggression of birds in areas of high human activity. SGP and skuas show therefore the ability to habituate to frequent human stimuli.

I identified two current anthropogenic stressors. Both, SGP and skuas, responded to close visits and irregular air traffic with increased heart rate, alertness, fly-off and partly defence. For SGP, classified as highly sensitive to human activities, I found reductions in breeding success due to increased predation during visits. In contrast, I did not observe predation of eggs or chicks in response to visits or air traffic in skuas. However, adult survival and population size seem not be directly affected by anthropogenic stresses. The given management recommendations can reduce exposure to potential stresses and maximise the ability of individuals to cope with stressful situations.

From a conservation perspective, human disturbance is only relevant if it affects survival or fecundity and causes populations to decline. However, because long-lived species are exposed to a range of environmental factors that influence reproductive and mortality rates, direct effects from anthropogenic activities are difficult to show. As stressors affect on individual's endocrinology, immunology, and behaviour, studies can be conducted on the individual level. If physiology and behaviour change in response to anthropogenic stimuli, energetic costs can be calculated accordingly and potential effects on fitness and survival can be estimated.

In this final chapter, I discuss (1) the variety of indicators that have been used to measure stress in animals, (2) some theoretical aspects about stress studies, (3) possible calculations of energetic costs to link individual and population studies, (4) the relative importance of anthropogenic and natural stresses in the Antarctic, and (5) how management recommendations can be implemented in the Antarctic. I will close with an outlook for further field work and analysing methods of existing data sets.

Choosing Indicators for Stress

When choosing key indicators for a stress study, consequences on the mortality rate and population size are often considered the ultimate criteria for identifying negative human impacts (Culik and Wilson 1991). However, decreases in population number reflect only extreme stresses, and the variety of stimuli causing sublethal physiological or behavioural responses would not be adequately studied (Nimon and Stonehouse 1995). Therefore, obvious behavioural changes, heart rate and hormone increases have been used which may reduce fitness and therefore have ultimately consequences on the population level. The extensive literature on human disturbance especially on birds and mammals represents the wide spectrum of impacts ranging from minor heart-rate increases to population shifts and declines (Burger 1981b, Carney and Sydeman 1999, Götmark 1992, Knight and Gutzwiller 1995, Nisbet 2000, Robert and Ralph 1975).

In the field, the magnitude of behavioural changes to e.g. human presence is frequently used to measure the relative sensitivity of a species to human disturbance (Carney and Sydeman 1999, Burger 1981a). Species which show strong avoidance of humans are considered to be in greater need of protection than those reacting less. If, however, the behavioural response is state-dependent (the internal condition of the individual within a certain environment McNamara and Houston 1996), it is maybe misleading as an index for fitness consequences (Gill et al. 2001). Beale and Monaghan (2004) observed that better fet waders in their wintering ground showed larger behavioural changes than conspecifics in poorer body condition. Whether the same is true for breeding birds has still to be shown as their interest lies not only in maximising food intake for their own survival, but also maximising life time reproductive success. In trying to assure offspring survival by feeding and defending efficiently, a behavioural change towards an approaching person could, therefore, be less influenced by body condition.

Because feeding grounds of southern giant petrels lie in a radius of several 100 km (González-Solís et al. 2002, Obst and Nagy 1992), bird conditions should not differ significantly between area types within my study site. In contract, brown skua distribution and condition could be correlated stronger. Female birds with feeding territories in penguin rookeries are of larger size and show a higher reproductive performance (Hahn and Peter 2003). South polar skuas, however, feed at sea and their nest distribution on land should not group them by body condition. SPS expanded on the Fildes Peninsula, and over time the remaining free breeding habitats were of lower quality compared to earlier occupied territories. In this case, new coming birds would not only be younger and less experienced, but would have also a disadvantage in habitat quality.

Although a behavioural approach may have these limitations when predicting long-term population trends (Gill et al. 2001), it has proved quite useful in assessing the local impacts of different recreational activities, and the management strategies that may promote coexistence between research, logistics, tourism and wildlife in areas of conservation interest (reviews in Knight and Gutzwiller 1995).

Non-invasive measures of stress have a wide scope of applications for conservation biology, wildlife management and behavioural ecology. Especially in the Antarctic, researchers use these methods because working permissions are given after assessment of minimal impact strategies. Behavioural observations from hides and installations of video systems are nowadays standards and assure a unbiased study of behavioural changes associated with environmental events outside the observers influence. Equipment for HR studies developed quickly over recent years from body-dataloggers (Culik and Wilson 1991) to nest installations that accurately assess stress without the bias of capture-induced or disturbance-induced increases in physiological parameters (e.g. Giese et al. 1999, Hüppop and Hagen 1990, Ingold et al. 1992, Neebe and Hüppop 1994, Nimon et al. 1995). However, if carried out with a sufficiently large sample size, HR measurements are very time-consuming. Scientists used therefore often less than 10 birds to show individual responses to human stimuli (e.g. Helb and Hüppop 1991, Neebe and Hüppop 1994, Nimon et al. 1995).

Comparing the study results from the Fildes Peninsula region and Penguin Island, it could be discussed whether a three-year study on behaviour and physiology is necessary to assess potential human stresses. The heart-rate experiments showed similar results and behaviour varied according to experience with humans in both study sites. Investigations on a larger number of birds allow statistical analyses and testing of various biotic and abiotic factors. But for short-term studies in remote breeding sites, a design with a few, easily applicable indicators (e.g. proportion of fly-off, fly-off distance, aggression) seems adequate.

An alternative are the non-invasive faecal glucocorticoid analysis for assessing stress associated with environmental disturbance (natural and human) in wildlife (Wasser et al. 2000, Wingfield 1994). Although the inter-specific variation in excreted glucocorticoid metabolites requires careful analytic methodology (Millspaugh and Washburn 2004), sampling in the field is fast and easy.

The rise in human activities in the Antarctic, not only in number but also in spectrum (tourism diversified from nature walks to currently practised climbing, kayaking, diving, marathon running etc.), should be monitored in terms of environmental impact. Necessary assessments should be fast and inexpensive. Key indicators could therefore include certain behavioural and physiological responses of seabirds to particular human activities.

Theoretical Background of Stress Studies

Scientific studies on stress in free living animals have no strong theoretical background partly due to the difficulty of an objective assessment, but use different concepts of behavioural studies and life-history (Hofer and East 1998).

Archer (1976) presented one of the first theoretical models concerning ‘flight or fight’ reactions of vertebrates. The animal perceives a change (stimulus) in its environment, takes some time to assess it by comparing with previous stimuli (experience). If it is not threatened, no further action will occur. However, if the stimulus is either unknown or seen as dangerous, the next decision process will determine whether the individual will attack or flee. In most cases, any response will reduce the stressor effect. However, if the stimuli is unknown to the animal (new human activity, young inexperienced animal) its reaction could be inappropriate and may lead to injury or death. Depending on the stimuli strength, the individual will respond differently (with HR increase, alertness or fleeing). Brown (1990) showed for example in crested terns *Sterna bergii* a series of gradual increases in responses (from scanning to fly-off) with increasing loudness of aircraft noise. If the stimuli is over, the animal can return to its previous behaviour or if more severe will take longer to recover from the stressor exposure.

Recent behavioural studies showed that the response of animals to predators (antipredator behaviour) arrives from a complex system (Curio 1993). A simplification of a stimulus to a few characteristics like size or shape of an approaching object can therefore not sufficiently explain animals' responses (Kempf and Hüppop 1998).

There is a well-developed body of theory that predicts how environmental and social factors (resource availability, population density, pathogens, and predators) mold life-history tactics, behaviour, survival, and reproductive success of wildlife (Krebs and Davies 1997, Roff 1992, Stearns 1992). State-dependent models of life history can predict how individuals should respond to stress as a function of their body condition, and the amount of parental work they do (McNamara and Houston 1996).

Because there are natural equivalents for most anthropogenic factors, there may be evolved abilities of coping with anthropogenic factors (Hofer and East 1998). If stress is an evolutionary force, then the organism's evaluation of an environmental stimulus and its response may be an evolved trait, variation in evaluation and response may thus not be random but adaptive (Hofer and East 1998). Adaptation is generally used to mean within-species evolutionary response to a particular, often new environment with the implication that natural selection has favoured alleles that gave their carriers an advantage in the specified environment. The response would then be predictable in at least those cases, where a particular type of stimulus occurred sufficiently frequently during the evolutionary history of a population. One could also ague that the behaviour is a product of selection for tolerance over several generations, but in the study area frequent human activities began just three decades ago and life expectancy of giant petrels and skuas is about 20 to 35 years. However, some of the SGP and skua offspring returned after 4-9 years (Furness 1996, Hunter 1984) to the native site to breed having experienced human activities during growth. An evolutionary approach to stress showing the consequences for reproductive success and persistence of populations could therefore certainly be discussed.

Calculation of Additional Energetic Costs

Exposure to natural and human stressors will not only change the physiology and behaviour of an individual, they can have considerable influence on the energy budget of animals. Additional energetic costs (due to fly-off, heart-increase, body temperature rise etc.) can be estimated in respect to the frequency, duration and type of stimulus. Studies on birds showed thereby reduced feeding rates (e.g. Bélanger and Bédard 1990), changing activity patterns (Stock 1992), and reduced energy storage (Madsen 1995). Also heart-rate increases result in energetic costs. (Hubert and Hüppop 1993) showed that the doubling of HR resulted in a three-folded energy consumption in kittiwakes *Rissa tridactyla*.

The basic energetic requirements of SGP and skuas can be estimated using calculations of closely related northern-hemisphere skuas, gulls and other Procellariformes (sources: Hunter

1984, Obst and Nagy 1992, Phillips et al. 1999, Pietz 1986, Prince and Ricketts 1981, Ricklefs and Matthew 1983, Spellerberg 1969, Warham 1990, Weimerskirch et al. 2000 Weimerskirch et al. 2002).

Gremillet et al. (1995) could estimate that a human approaching a cormorant *Phalacrocorax carbo* colony caused an increase of 82 KJ/bird to a daily energy budget of about 950 KJ/bird. These calculations were based on daily activity patterns, metabolic measurements and knowledge of frequency and duration of human activities. Such a data basis is not available for my study birds, but some calculations of oxygen consumption (according to my heart rate measurements) for different activities could be made to quantify additional costs for breeding birds exposed to human activities.

Complexity of the Antarctic Ecosystem

The complexity of factors influencing Antarctic ecosystems is so evident that even after more than 45 years of intense scientific programmes, the relative importance of natural and human factors can only be speculated (Micol and Jouventin 2001). Seabirds are long-lived (15-70 years) top predators that can integrate environmental variability over large spatial and temporal scales (Ainley and Boekelheide 1990, Furness and Greenwood 1993, Votier et al. 2004). Changes in their abundance and distribution can therefore indicate environmental changes. The majority of Antarctic seabird species showed stable populations over many years when habitats were not exposed to strong environmental variability or human activities. Significant decreases in populations occurred in species that are caught by long-lining like SGP, albatrosses and *Procellaria* spp. (Woehler et al. 2001).

In most species, numbers fluctuated in reproductive and mortality rates depending on local food and nest site availability, weather conditions and human activities (e.g. Croxall and Rothery 1991, Micol and Jouventin 2001, Woehler and Croxall 1997). In the Antarctic, penguins have been counted in long-term monitoring programmes and the combination with paleoecological censuses revealed significant population changes. Contrasts in habitat preferences, for examples of sea-ice obligated Adélie penguins and sea-ice intolerant chinstrap penguins, were used to assess ecological consequences of climate warming along the Antarctic Peninsula (Smith et al. 1999, Taylor and Wilson 1990).

Only a few long-term studies on the impact of research stations on Antarctic wildlife exist (Fraser and Patterson 1997, Taylor and Wilson 1990, Woehler et al. 1994) which resulted in distribution and abundance changes. Short-term studies documented parallel physiological and behavioural changes that influenced also reproductive parameters (Culik et al. 1990, Giese 1996, Nimon 1997, Woehler et al. 1994). Overall, there is no apparent general trend among different seabird species (Woehler et al. 2001). The multi-factorial influence and difficulty in minimising impacts is particularly visible in seabirds, because land and marine threats occur parallel. Human impacts decreased populations up to 35 % which appears still relatively small in relation to observed long-term population trends (Micol and Jouventin 2001).

The population growth of southern giant petrels on and around the Fildes Peninsula is currently little influenced by direct human activity. Visits and air traffic contribute to annual variations in breeding parameters, but adult survival is not threatened by the current activity spectrum and intensity. Whether recruitment is limited by fishery (accidental mortality) or low breeding habitat availability and quality (may affected by human activity), can only be speculated. In contrast, brown and south polar skua populations are stable or increasing and less influenced by current human activities.

Antarctic Legislation

The Antarctic offers unique opportunities to study biological processes under special environmental conditions, climate change, magnetism, glaciology, geology etc. Science has been therefore the driving force of ongoing international activities on this continent, although political interests reached further, and tourism developed quickly. Public and scientific interests in preserving Antarctica's wilderness supported the progress of area and species protection since the establishment of the Antarctic Treaty System (Cohen 2002). However, only in 1991, the Antarctic Treaty Consultative Parties adopted the Environmental Protocol to the Antarctic Treaty (ATCM 1991). The necessary ratification in the national laws took several years more. The most important obligations the Protocol imposes are (1) Antarctica is designated as 'natural reserve devoted to peace and science', (2) mineral activities are prohibited for at least 50 years except for scientific purposes, and (3) all activities are to be conducted so as to limit adverse environmental impacts.

The unique political situation of the Antarctic results however in several difficulties in the implementation of species protection measures. Decision-making in the Antarctic is based on consensus and once this is reached, there are no direct means of enforcing the decisions. Self-restraint and diplomatic persuasion are practised rather than compulsive action (Hall and Johnston 1995). This results in very slow and weak decision-making processes due to wide-ranging views of necessary management steps. Additionally, the ambiguous wording of the international guidelines allows broad interpretation (ATCM 1999, Harris 1991b).

Multi-national projects can strengthen environmental management by encouraging nations to share responsibilities for larger areas. King George Island is particularly suitable for these joint research and monitoring projects due to the concentration of stations and field huts. A first major co-operation was established as King George Island - GIS project in 1998 (http://www.geographie.uni-freiburg.de/ipg/forschung/ap3/kgis/Home.php). It produced an integrated geographic database (for international access) that is used for (1) planning and co-ordination of activities, (2) environmental impact assessments, (3) as a scientific database, and (4) for management plans.

In 2003, a comprehensive environmental impact assessment on the Fildes Peninsula and Ardley Island was initiated by Dr. Peter, Jena University (commissioned by the Federal Environmental Agency of Germany, CEP 2004). It will provide a substantial body of data (biological and environmental) necessary to fully evaluate management needs in the most densely habituated part of King George Island. Within an international co-ordination group, the study progress and management plan drafts will be discussed to assure regional acceptance. The results of my dissertation will be incorporated in the management package.

9.2 Outlook

Field Studies

A three-year field work allows only a limited number of observations, measurements and experiments, which leads inevitably to gaps in the study design. Further behavioural studies on predation pressure and time budget of SGP and skuas would answer open questions.

There are some evidence from this studies' observations that the breeding success of SGP is strongly influenced by skua predation. The study also showed that nest visits enhance predation risk. Longer video recordings in SGP breeding groups would allow calculations on predation rates. Furthermore, the specialisation of skuas in preying on SGP should be compared on islands with small and large SGP colonies using pellet analyses. Variations in predation risk could then be incorporated in management decisions.

A proportion of BS defend beside the breeding territory also a feeding territory in penguin rookeries. Increased energetic costs due to defence is paid by the benefit of a stable food supply and reduced foraging time (Hahn and Peter 2003). A comparison of daily activity patterns of BS with different feeding strategies in relation to human activities could show how individuals allocate their time in respect to reproduction and survival.

Energetic Analysis

For a quantitative risk assessment for SGP and skuas, the observed responses of birds to visits and air traffic could be translated into an energy currency. By combining literature data and study results, additional costs caused by human activities could be calculated beside the daily energetic requirements in the breeding season.

Multivariate Analysis

A current doctoral thesis on the Fildes Peninsula involves the capture of adult skuas, whereby body measurements and blood are obtained. These data and records of previous studies are currently entered in a skua database holding information on individual characteristics, breeding success, nest site change. Combining this data set with behavioural and physiological records of individual birds, collected in my study, would allow a multivariate analysis concerning individual parameters. By adding records of weather data, a Principle Component Analysis or multiple regressions could reveal the relative importance of natural and anthropogenic factors influencing reproductive success of local breeding populations.

Modelling

Policy makers and environmental managers frequently ask ecologists for advice them about the environmental consequences of human activities. However, ecological systems as in the present case are often complex, non-linear and strongly influenced by stochasticity (Harwood and Stokes 2003). In a spatial-temporal model, the effects of human activities on SGP and skuas on the Fildes Peninsula and surrounding islands could be built (Enggist-Düblin and Ingold 2003, Milsom et al. 2000). A comparison of different management strategies could identify the most suitable site-specific solutions.

SUMMARY

Birds are adapted in morphology, physiology, and behaviour, to extremes of their habitat, and to energetically demanding processes in their life cycle. In addition to predictable factors of the environment, they are also adapted to unpredictable events (e.g. severe weather, low food resources, high predator density) that can adversely affect reproduction, moult or even individual survival. To avoid stress, birds adjust to these events (=stimuli) by changing their behaviour temporarily. However, this can be very costly depending on the kind, frequency, duration and intensity of the stimulus. In long-lived species, the allocation of resources between reproduction and survival is of particular interest because only a small reduction in adult survival may have a large negative effect on population size.

In addition to natural factors, anthropogenic activities can also be stressors. The increase of such anthropogenic stressors in the Antarctic, through the continued construction of research stations and the rise in tourism, has led to ongoing concern about the sufficiency of existing management. Decision makers, conservationists and tourist companies therefore focus on species- and site-specific studies to guide the improvement of protection measures.

In this thesis, I conducted the first comprehensive assessment of current human-derived stresses in the breeding areas of seabird species. The southern giant petrel (SGP), *Macronectes giganteus*, has been characterised as a highly sensitive species in terms of human disturbance (categorised ‘vulnerable’ in the IUCN red species list). In contrast, the brown skua (BS), *Catharacta antarctica lonnbergi*, and the south polar skua (SPS), *C. maccormicki*, are partly associated with Antarctic stations and thus considered less sensitive. Between the years 2000 and 2003, I worked at breeding sites in the most inhabited part of the West Antarctic (Fildes Peninsula, King George Island with 6 stations, 4 field huts, and an airport, in about 30 km^2) and on Penguin Island, a frequently visited tourist site. Using non-invasive methods, I studied behavioural and physiological (heart-rate and glucocorticoid in faeces) responses of breeders, non-breeders and chicks. I compared individuals according to their experience of humans (areas of high, medium, and low human activity, A_{high}, A_{medium}, A_{low}). My results, and my analysis of the anthropogenic effects on reproduction, allowed me to construct a risk assessment for the birds and to make several specific recommendations for better management.

1. I found wide variation in behavioural and physiological parameters to different human and natural stimuli. Variation existed within and between species, between breeding sites, and between stimulus types (visits, air traffic, helicopter-sound simulations, road traffic, predators and conspecifics). Although faeces are easily collected in the field, the interpretation of glucocorticoid titres in terms of anthropogenic stress-induced elevations was difficult. I therefore, based species protection measures on the heart-rate and behavioural studies (of a total of 95 SGP and 124 skuas).
2. The responses of SGP varied with human experience. In $A_{high,}$, compared to A_{medium} and A_{low}, fewer birds flew off when approached closely during visits and they defended the nests less vigorously. Their heart-rate increases were also relatively small compared to birds visited in A_{medium} and A_{low}. This effect was also found in skuas, but was less pronounced. BS showed a clear reduction in fly-off distance in A_{high}, compared to other categories, whereas SPS were less

aggressive. Compared with natural stimuli, SGP and skuas reacted less to regular air traffic and, similarly, to aircraft approaching from unpredictable directions and helicopter-sound simulations. Therefore, SGP and skuas show clear signs of long-term habituation in the multi-used and tourism sites.

3. Close visits and irregular air traffic are current stresses for both SGP and skuas. Scientists cause the strongest physiological and behavioural reactions when specifically working on skuas or monitoring breeding success in SGP. But unguided station personnel, scientists in their free time and tourists also increase vigilance, fleeing or defence behaviour. Aircraft approaching at low altitude or from unpredictable directions changed the behaviour of sensitive individuals in both species.
4. Short-term habituation occurred in SGP in all area types as indicated by responding to repeated visits with decreases in heart rate. In contrast, only SPS in A_{high} showed a reduction over time. Repeated helicopter-sound simulations resulted in clearer short-term habituation effects in SPS and skuas.
5. SGP have already shifted their breeding sites to remoter islands in response to intensive human activity in recent decades. Currently, visits to SGP colonies increase predation by skuas and still have a negative effect on breeding success. However, visits affect many small breeding sites and have, therefore, no significant impact on the population size. In contrast, I found no detectable impact on reproductive performance of skuas, although individual responses to the presence of visitors and air traffic were evident. Overall, human activities add to the variation in breeding parameters of SGP and skuas on the Fildes Peninsula and surrounding islands, but changes in population size are mainly driven by local and regional natural conditions.
6. I derive the following management recommendations from the results of my studies.
   - The necessity of enlarging the existing minimum approach distance for SGP from 15 m to 50 m. Due to the individual variation in fly-off distance (0-100 m) and the aggression by skuas, strict implementation of a fixed minimum distance seems inappropriate. Visitors should leave the site as soon as birds call or fly off the territory. Calm, quiet, indirect approaches to breeding sites and the repeated use of fixed paths or routes can increase habituation to visits. Whereas scientists are experienced in minimising stresses to their study birds, station personnel need further information and training.
   - Existing air traffic recommendations for wildlife over-flights need to be more strongly enforced. Low and irregular flights of Hercules C-130 and helicopters should be prohibited at all breeding sites independent of whether the sites have protected area status. Educational material about sensitive breeding sites should be provided to pilots and airport staff responsible for flight activities.
   - Beside the existing protected areas, I suggest further zoning to enhance the protection of SGP. Areas with currently low human activity but containing large colonies should become ‘Restricted Zones’. Smaller, remote, breeding sites of SGP should receive the status of ‘Sensitive Zones’. All protected areas and zones should be incorporated in an ‘Antarctic Specially Managed Area’ to allow international designation.
   - Beside the census of breeding pairs, regular monitoring should also include short behavioural and hormone studies to assess sublethal and lethal impacts of human activities.

ZUSAMMENFASSUNG

Vögel sind in Morphologie, Physiologie und Verhalten an Extreme in ihrem Habitat und an energieaufwendige Prozesse in ihrem Lebenszyklus angepaßt. Zusätzlich zu den vorhersagbaren Faktoren in der Umgebung sind sie aber auch an unvorhersehbare Ereignisse (z.B. schlechtes Wetter, geringe Nahrungsressourcen, hohe Räuberdichte) angepaßt, die Reproduktion, Mauser oder Überleben negativ beeinflussen können. Um Stress zu vermeiden, verändern Vögel dabei vorübergehend ihr Verhalten. Dies kann je nach Art, Häufigkeit, Dauer und Intensität des Ereignisses hohe Kosten bewirken. Bei langlebigen Arten ist die Aufteilung von Ressourcen zwischen Reproduktion und Überleben von besonderem Interesse, weil bereits geringe Abnahmen im Überleben der Altvögel starke negative Auswirkungen auf die Populationsgröße haben können.

Zusätzlich zu natürlichen Faktoren können auch anthropogene Aktivitäten als Stressoren auftreten. In der Antarktis läßt deren Zunahme durch kontinuierlichen Stationsausbau und wachsenden Tourismus die Qualität bestehenden Managements bezweifeln. Entscheidungsträger, Naturschützer und Touristikunternehmen fordern daher art- und ortsspezifische Studien als Basis für verbesserte Schutzmaßnahmen.

In der vorliegenden Dissertation wurde die erste umfassende Bewertung aktueller anthropogener Stressoren in Brutgebieten von Seevogelarten vorgenommen. Der Südliche Riesensturmvogel (SRV), *Macronectes giganteus*, gilt als hoch sensible Art im Bezug auf menschliche Aktivitäten (eingestuft als ‘gefährdet’ in der Rote Liste der IUCN). Dagegen sind die Braune Skua (BS), *Catharacta antarctica lonnbergi*, und die Südpolarskua (SPS), *C. maccormicki*, teilweise mit Antarktischen Stationen assoziiert und werden daher als weniger sensibel angesehen. Im Zeitraum 2000 - 2003 arbeitete ich in den Brutgebieten im dichtest besiedelten Teil der West-Antarktis (Fildes Halbinsel auf der Insel King George mit 6 Stationen, 4 Feldhütten und einem Flugplatz auf einer Fläche von rund 30 km^2) und auf der Insel Penguin, einer häufig besuchten Touristenanlandestelle.

Unter Benutzung nicht-invasiver Methoden untersuchte ich ethologische und physiologische (Herzschlagrate und Glukokortikoide im Kot) Stressantworten von Brütern, Nichtbrütern und Küken. Ich verglich Individuen entsprechend ihrer Erfahrung mit Menschen (Gebiete mit hohen, mittleren und niedrigen menschlichen Aktivitäten, A_{hoch}, A_{mittel}, $A_{niedrig}$). Diese Ergebnisse und die Analyse anthropogener Effekte auf Reproduktionsparameter führten zu einer Abschätzung des Gefährdungsgrades der Vogelarten und zu spezifischen Managementvorschlägen in ihren Lebensräumen.

1. Ethologische und physiologische Parameter zeigten eine große Variation gegenüber verschiedenen menschlichen und natürlichen Ereignissen. Variationen existierten innerhalb und zwischen Arten, zwischen Brutgebieten und Ereignis-Typen (Besuch, Flugverkehr, Helikoptergeräusch-Simulationen, Straßenverkehr, Räubern und Artgenossen). Obwohl sich Tierkot einfach während der Feldarbeiten sammeln ließ, war die Interpretation der Glukokortikoidwerte in Bezug auf anthropogen ausgelöste Erhöhungen schwierig. Die Ableitung der artspezifischen Schutzmaßnahmen basiert daher auf Herzschlagrate-Messungen und Verhaltensparametern (von insgesamt 95 SRV und 124 Skuas).
2. Die Stressantworten von SRV variierten entsprechend der Erfahrung mit Menschen. In $A_{hoch,}$, verglichen zu A_{mittel} und $A_{niedrig}$, flogen weniger Vögel vom Nest auf, wenn sich ein Besucher näherte, und die Nester wurden weniger stark verteidigt. Auch Herzschlagrate-Erhöhungen fielen geringer als bei besuchten Vögeln in A_{mittel} und $A_{niedrig}$ aus. Der gleiche Zusammenhang fand sich bei Skuas, aber weniger

deutlich ausgeprägt. BS zeigten verkürzte Aufflugdistanzen in A_{hoch}, während SPS weniger aggressiv waren. Verglichen mit natürlichen Ereignissen, reagierten SRV und Skuas einerseits weniger auf regelmäßigen Flugverkehr. Andererseits waren die Reaktionen gegenüber Flugzeugen, die sich aus unvorhersehbarer Richtung näherten, und Helikoptergeräusch-Simulationen ähnlich stark. SRV und Skuas zeigten damit Zeichen von Langzeit-Gewöhnung auf der Fildes Halbinsel und der Insel Penguin.

3. Besuche und irregulärer Flugverkehr sind aktuelle Stressoren für brütende SRV und Skuas. Wissenschaftler verursachen die stärksten ethologischen und physiologischen Reaktionen durch Feldarbeiten an Skuas oder Monitoring von SRV. Aber auch nicht-geführte Stationsmitglieder, Wissenschaftler in der Freizeit und Touristen können die Aufmerksamkeit bzw. Flucht und Verteidigung von Tieren erhöhen. Tiefflüge oder Flüge aus unvorhersehbarer Richtung verändern das Verhalten von sensiblen Tieren der untersuchten Arten.
4. Kurzzeit-Gewöhnung trat bei SRV in allen Gebietstypen auf, wie verminderte Herzschlagraten bei wiederholten Besuchen zeigten. In Skuas war diese Abnahme nur bei SPS in A_{hoch} zu beobachten. Wiederholte Helikoptergeräusch-Simulationen resultierten in Gewöhnungseffekten in SRV und Skuas.
5. SRV hatten ihre Brutgebiete bereits in früheren Jahren aufgrund intensiver menschlicher Aktivitäten teilweise auf entlegenere Inseln verlagert. Aktuell verursachen Besuche in SRV-Kolonien erhöhte Prädation durch Skuas und haben damit immer noch negative Auswirkungen auf den Bruterfolg. Da Besuche vor allem in kleineren Brutgebieten stattfinden, haben sie keine signifikanten Auswirkungen auf die Populationsgröße. In Skuas konnte ich keine Einflüße anthropogener Stimuli auf die Reproduktion nachweisen, obwohl individuelle Stressantworten während Besuchen und durch Flugverkehr vorlagen. Insgesamt tragen menschliche Störungen zu Variationen in Brutparametern von SRV und Skuas auf der Fildes Halbinsel und umliegenden Inseln bei. Die Populationsgröße-Änderungen werden aber hauptsächlich von lokalen und regionalen natürlichen Bedingungen bestimmt.
6. Ausgehend von den Ergebnissen schlage ich folgende Managementmaßnahmen vor.
   - Der bisher verwendete Mindestabstand zu SRV sollte von 15 m auf 50 m erhöht werden. Durch die individuelle Variation in der Aufflugdistanz (0-100 m) und Aggression von Skuas erscheint die strikte Umsetzung eines Mindestabstandes für diese Art ungeeignet. Besucher sollten das Territorium verlassen, sobald eine Skua ruft oder auffliegt. Langsame, leise und indirekte Annäherungen an Brutgebiete und die Benutzung bestimmter Wege und Routen können die Gewöhnung an Besucher erhöhen. Während Wissenschaftler Methoden zur Minimierung von Störungen ihrer Untersuchungstiere kennen, sollten Stationsmitglieder besser eingewiesen werden.
   - Bestehende Flugverkehrsrichtlinien zu Überflügen von Brutgebieten bedürfen einer stärkeren Einhaltung. In allen Brutgebieten, unabhängig vom bestehenden Schutzstatus, sollten Tiefflüge und irreguläre Flüge von Hercules C-130 und Helikoptern verboten sein. Den Piloten und dem verantwortlichen Flughafenpersonal sollte Informationsmaterial über sensible Brutgebiete zur Verfügung gestellt werden.
   - Um den Schutz von SRV zu erhöhen, schlage ich eine weitere Zonierung neben bereits bestehenden Schutzgebieten vor. Gebiete, die momentan niedrigen Störungen ausgesetzt sind, aber große Kolonien aufweisen, sollten “Gesperrte Zone” werden. Kleinere, abgelegene Brutgebiete von SRV sollten den Status von “Sensiblen Zonen” erhalten. Für die internationale Anerkennung bedarf es einer Eingliederung der Schutzgebiete und Zonen in ein “Besonders Verwaltetes Gebiet”.
   - Das reguläre Monitoring sollte neben der Erhebung von Brutpaarzahlen auch kurze Verhaltens- und hormonelle Studien einschließen, um Einflüsse menschlicher Aktivitäten bewerten zu können.

REFERENCES

Acero, J.M. and C.A. Aguirre (1994) A Monitoring Research Plan For Tourism in Antarctica. Annals of Tourism Research 21(2): 295-302.

Ainley, D.G. and R.J.e. Boekelheide (1990) *Seabirds of the Farallon Islands: Ecology, Dynamics and Structure of an Upwelling-System Community*. Stanford (CA), Stanford University Press.

Alados, C.L., J.M. Escos and J.M. Emlen (1996) Fractal structure of sequential behaviour patterns: an indicator of stress. Animal Behaviour 51: 437-443.

Altmann, J. (1974) Observational study of behavior - sampling methods. Behaviour 49(3-4): 227-267.

Anderson, D.W. and J.O. Keith (1980) The Human Influence on Seabird Nesting Success: Conservation Implications. Biological Conservation 18: 65-80.

Andersson, M. and F. Götmark (1980) Social organization and foraging ecology in the arctic skua Stercorarius parasiticus: a test of the food defendability hypothesis. Oikos 35: 63-71.

Andersson, M., C.G. Wiklund and H. Rundgren (1980) Parental defence of offspring: A model and an example. Animal Behaviour 28: 536-542.

Andersen, R., J.D.C. Linnell and R. Langvatn (1996) Short term behavioural and physiological response of moose Alces alces to military disturbance in Norway. Biological Conservation 77(2-3): 169-176.

Antarctic Flight Information Manual (AFIM) 2003. published by COMNAP.

Archer, T. (1976) The organisation of aggression and fear in vertebrates. *Perspectives in Ethology*. P.P.G. Baleson and P. Klopter. New York, Plenum Press: 231-298.

ASOC (Antarctic and Southern Ocean Coalition) (1999) Large Scale Antarctic Tourism. Lima, Peru, XXIII ATCM.

ASOC (2001) Antarctic Tourism. St. Petersburg, ATCM.

ASOC (2002) Regulating Antarctic Tourism. Warshaw, XXV ATCM.

ASOC (2004) Are more Antarctic stations justified? Cape Town, South Africa, XXVII ATCM.

Astheimer, L.B., W.A. Buttemer and J.C. Wingfield (1992) Interactions of corticosterone with feeding, activity and metabolism in passerine birds. Ornis Scandinavica 23: 355-365.

ATCM (Antarctic Treaty Consultative Meeting) (1991) Protocol on Environmental Protection to the Antarctic Treaty (plus annexes and annex proposals). Madrid, Spain. XI ATCM.

ATCM (1994) Recommendation XVIII-1 Guidance for Visitors to the Antarctic and Guidance for those Organising and Conducting Tourism and Non-governmental Activities in the Antarctic. Kyoto, Japan, XVIII ATCM.

ATCM (1999) Appendix to Resolution XXIII-1: Guidelines for Environmental Impact Assessment in Antarctica. Lima, Peru. XXIII ATCM.

ATCM (2002) Proposed Guidelines for the operation of aircraft near concentrations of birds. Warsaw, Poland. XXV ATCM.

ATCM (2003a) Proposals to improve the Management and Regulation of Antarctic Tourism. Madrid, Spain. XXVI ATCM.

ATCM (2003b) Final Report from the Intersessional Contact Group on Cumulative Environmental Impacts. Madrid, Spain. XXVI ATCM.

ATCM (2004a) Resolutions. Cape Town, South Africa. XXVII ATCM.

ATCM (2004b) Working Paper on Guidelines for the Operation of Aircraft near Concentrations of Birds in Antarctica. Cape Town, South Africa. XXVII ATCM.

Atkinson, A., V. Siegel, E. Pakhomov and P. Rothery (2004) Long-term decline in krill stock and increase in salps within the Southern Ocean. Nature 432: 100-103.

Axelrod, J. and T.D. Reisine (1984) Stress hormones: their interaction and regulation. Science 224: 452-459.

Baillie, J. and B. Groombridge, Eds. (1996) *IUCN Red List of Threatened Animals*. Gland, Switzerland and Cambridge, UK, IUCN.

Balát, F. (1969) Influence of repeated disturbance on the breeding success in the mallard *Anas platyrhynchos* Linn. Zoologické Listy. 18: 247-252.

Bannasch, R., K. Feiler and M. Rauschert (1984) Fortsetzung der biologischen Untersuchungen im Gebiet der sowjetischen Antarktisstation Bellingshausen. Geodätische und geophysikalische Veröffentlichungen Reihe1 11: 1-63.

Bannasch, R. and K. Odening (1981) Zoologische Untersuchungen im Gebiet der sowjetischen Antarktisstation " Bellingshausen" [Zoological investigations in the area of the soviet Antarctic base " Bellingshausen"]. Geodätische und geophysikalische Veröffentlichungen Reihe1 8: 3-20.

Bannasch, R., M. Rauschert, K. Feiler and U. Lundberg (1983) Fachlicher Bericht über die Teilnahme der 2.Biologengruppe der DDR (erste Überwinterung) an der 26./27.Sowjetischen Antarktisexpedition (SAE), sowjetische Station Bellingshausen auf King George (Waterloo). Berlin, Potsdam: 77.

Beale, C.M. and P. Monaghan (2004) Behavioural responses to human disturbance: a matter of choice? Animal Behaviour 68(5): 1065-69.Bélanger, L. and J. Bédard (1990) Energetic cost of man-induced disturbance to staging snow geese. Journal of Wildlife Manage. 54(1): 36-41.

Becker, P.H. (1996) Flußseeschwalben (Sterna hirundo) in Wilhelmshaven. Oldenburger Jahrbuch: 263-296

Bignert, A., M. Olsson, W. Persson, S. Jensen, S. Zakrisson, K. Litzen, U. Eriksson, L. Häggberg and T. Alsberg (1998) Temporal trends of organochlorines in Northern Europe, 1967-1995. Relation to global fractionation, leakage from sediments and international measures. Environmental Pollution 99: 177-198.

BirdLife International (2000) *Threatened Birds of the World*. Barcelona, Spain and Cambridge, UK, Lynx Edicions and BirdLife International.

BirdLife International (2004) *Macronectes giganteus. IUCN Red List of Threatened Species*.

Birkenmajer, K. (1982) The Penguin Island Volcano, South Shetland Islands (Antarctica): its structure and succession. Studia Geologica Polonica LXXIV: 155-173.

Blackmer, A.L., J.T. Ackerman and G.A. Nevitt (2004) Effects of investigator disturbance on hatching success and nest-site fidelity in a long-lived seabird, Leach's storm-petrel. Biological Conservation 116(1): 141-148.

Blanchard, R.J., J.N. Nikulina, R.R. Sakai, C. McKittrick, B. McEwen and D.C. Blanchard (1998) Behavioral and Endocrine Change Following Chronic Predatory Stress. Physiology & Behaviour 63(4): 561-569.

Blechschmidt, K., H.-U. Peter, J. De Korte and u.a. (1993) Untersuchungen zur molekularen Systematik der Raubmowen (Stercorariidae). Zoologisches Jahrbuch Systematik 120: 379-387.

Blühdorn, I. (1998) Auswirkungen potentieller Störreize auf das Verhalten brütender und jungeführender Kiebitze *Vanellus vanellus*. Vogelwelt 119: 105-113.

Borkowski, J. (2001) Flight behaviour and observability in human-disturbed sika deer. ACTA THERIOL 46(2): 195-206.

Bourne, W.R.P. (1991) Gannets and aircraft at Troup Head. BTO-News 176: 19.

Bourne, W.R.P. and J. Warham (1966) Geographical variation in the Giant Petrels of the genus Macronectes. Ardea 54: 45-67.

Boyle, S.A. and F.B. Samson (1985) Effects of nonconsumptive recreation on wildlife: a review. Wildlife Society Bulletin 13: 110-116.

Braun, M.J. and R.T. Brumfield (1998) Enigmatic phylogeny of skuas: an alternative hypothesis. Proceedings of the Royal Society Biological Sciences Series B 265: 995-999.

Bretagnolle, V. (1988) Social behaviour of the Southern Giant Petrel. Ostrich 59: 116-125.

Bretagnolle, V. (1989) Temporal Progression of the Giant Petrel Courtship. Ethology 80: 245-254.

Breuner, C.W., J.C. Wingfield and L.M. Romero (1999) Diel rhythms of basal and stress-induced corticosterone in a wild, seasonal vertebrate, Gambel's white-crowned sparrow. Journal of Experimental Zoology 284(3): 334-342.

Briggs, K.T., M.E. Gershwin and D.W. Anderson (1997) Consequences of petrochemical ingestion and stress on the immune system of seabirds. ICES Journal of Marine Science 54(4): 718-725.

Brooke, M. (2004) *Albatrosses and Petrels across the World*. Oxford, University Press.

Brown, A.L. (1990) Measuring the effect of aircraft noise on sea birds. Environment International 16: 587-592.

Buchanan, K.L. (2000) Stress and the evolution of condition-dependent signals. Trends in Ecology and Evolution 15(4): 156-160.

Bunnell, F.L., D. Dunbar, L. Koza and G. Ryder (1981) Effects of disturbance on the productivity and numbers of White Pelicans in British Columbia - observations and models. Colonial Waterbirds 4: 2-11.

Burger, J. (1981a) The Effect of Human Activity on Birds at a Coastal Bay. Biological Conservation 21: 231-241.

Burger, J. (1981b) Effects of Human Disturbance on Colonial Species, Particularly Gulls. Symposium on Human Disturbance and Colonial Waterbirds, Colonial Waterbirds.

Burger, J. and M. Gochfeld (1983) Behavioural responses to human intruders of herring gulls (Larus argentatus) and great black-backed gulls (L. marinus) with varying exposure to human disturbance. Behavioural Processes 8: 327-344.

Burger, J. and M. Gochfeld (1991) Human Disturbance and Birds: Tolerance and Response Distances of Resident and Migrant Species in India. Environmental Conservation 18(2): 158-165.

Burger, J. (1998) Effects of motorboats and personal watercraft on flight behavior over a colony of Common Terns. The Condor 100(3): 528-534.

Burger, J., M. Gochfeld and L.J. Niles (1995) Ecotourism and Birds in Coastal New Jersey: Contrasting Responses of Birds, Tourists, and Managers. Environmental Conservation 22(1): 56-65.

Burger, J. and M. Gochfeld (1999) Role of human disturbance in response behavior of laysan albatrosses (Diomedea immutabilis). Bird Behavior 13(1): 23-30.

Burgman, M.A., S. Ferson and H.R. Akcakaya (1993) *Risk Assessment in Conservation Biology*. London, Chapman & Hall.

Büßer, C., A. Kahles and P. Quillfeldt (2004) Breeding success and chick provisioning in Wilson's storm-petrels Oceanites oceanicus over seven years: frequent failures due to food shortage and entombment. Polar Biol 27(10): 613-622.

Butler, R.W. (1980) The Concept of a Tourist-Area Cycle of Evolution and Implication for Management. The Canadian Geographer 24: 5-12.

Byrkjedal, I. (1987) Antipredator behaviour and breeding success in greater golden-plover and eurasian dotterel. The Condor 89: 40-47.

Cairns, D. (1980) Nesting Density, Habitat Structure and Human Disturbance as Factors in Black Guillemot Reproduction. Wilson Bulletin 92(3): 352-361.

Cannon, W.B. (1929) *Bodily Changes in Pain, Hunger, Fear and Rage.* Boston, Branford.

Carlson, A. and J. Moreno (1992) Cost of Short Flights in the Willow Tit Measured with Doubly-labeled Water. The Auk 109(2): 389-393.

Carney, K.M. and W.J. Sydeman (1999) A Review of Human Disturbance Effects on Nesting Colonial Waterbirds. Waterbirds 22(1): 68-79.

Carney, K.M. and W.J. Sydeman (2000) Response: disturbance, habituation and management of waterbirds. Waterbirds 22: 333-334.

Carstens, M., L. Süfke, B. Borkowitz, K. v. Juterzenka, H. Hanssen, C. Zimmermann, T. Böhmer and M. Spindler (1999) Nutzung der Erkenntnisse der marinen Ökosystemforschung für die Antarktis-Umweltschutzaufgaben nach dem AUG. Kiel, Institut für Polarökologie Christian-Albrechts-Universität Kiel: 559.

CEP (Committee for Environmental Protection) (2004) Research Project "Risk assessment for the Fildes Peninsula and Ardley Island and the development of management plans for designation as Antarctic Specially Protected or Managed Areas". Cape Town, South Africa. VII CEP.

Chupin, I. (1997) Human Impact and breeding success in Southern Giant Petrel *Macronectes giganteus* on King George Island (South Shetland Islands). Korean Journal of Polar Research 8(1,2): 113-116.

Ciaputa, P. and K. Sierakowski (1999) Long-term population changes in Adelie, Chinstrap, and Gentoo Penguins in the regions of SSSI No. 8 and SSSI No.34 , King George Island, Antarctica. Polish Polar Research 1: 365-373.

Clemmons, J.R. and R. Buchholz (1997) *Behavioural approaches to conservation in the wild*. Cambridge, University Press.

Cobley, N.D. and J.R. Shears (1999) Breeding performance of gentoo penguins (*Pygoscelis papua*) at a colony exposed to high levels of human disturbance. Polar Biology 21: 355-360.

Cockrem, J.F. and J.R. Rounce (1994) Fecal measurements of oestradiol and testosterone allow the non-invasive estimation of plasma steroid concentrations in the domestic fowl. British Poultry Science 35: 433-443.

Cockrem, J.F. and B. Silverin (2002a) Sight of a predator can stimulate a corticosterone response in the great tit (Parus major). General and Comparative Endocrinology 125(2): 248-255.

Cockrem, J.F. and B. Silverin (2002b) Variation within and between birds in corticosterone responses of great tits (Parus major). General and Comparative Endocrinology 125(2): 197-206.

Cohen, B.L., A.J. Baker, K. Blechschmidt, D.L. Dittmann, R.W. Furness, J.A. Gerwin, A.J. Helbig, J. De Korte, H.D. Marshall, R.L. Palma, H.U. Peter, R. Ramli, I. Siebold, M.S. Willcox, R.H. Wilson and R.M. Zink (1997) Enigmatic phylogeny of skuas (Aves: Stercorariidae). Proceedings of the Royal Society of London Series B Biological Sciences 264(1379): 181-190.

Cohen, H.K. (2002) *Antarctic Treaty Handbook*. Washington, United States of America Department of State. COMNAP, S.a. (1999) Monitoring of Environmental Impacts of Scientific Activities and Operations in Antarctica. Working Paper, ATCM XXIII.

Conomy, J.T., J.A. Dubovsky, J.A. Collazo and W.J. Fleming (1998) Do black ducks and wood ducks habituate to aircraft disturbance? Journal of Wildlife Management 62(3): 1135-1142.

Conroy, J.W.H. (1972) Ecological aspects of the biology of the Giant Petrel, *Macronectes giganteus* (Gmelin), in the maritime Antarctic. BAS, Scientific Report 75: 1-74 + bilder.

Coulson, J.C. (1963) Egg size and shape in the Kittiwake (Rissa tridactyla) and their use in estimating age composition of populations. Proceedings of zoological Society, London 140: 211-227.

Creel, S., J.E. Fox, A. Hardy, J. Sands, B. Garrott and R.O. Peterson (2002) Snowmobile activity and glucocorticoid stress responses in wolves and elk. Conservation Biology 16(3): 809-814.

Croxall, J.P. and E.D. Kirkwood (1979) The Distribution of Penguins on the Antarctic Peninsula and Islands of the Scotia Sea. Cambridge, British Antarctic Survey: 186 pp.

Croxall, J.P., P.A. Prince, I. Hunter, S.J. McInnes and P.G. Copestake (1984) The Seabirds of the Antarctic Penincula, Islands of the Scotia Sea, and Antarctic Continent between 80°W and 20°W: their Status and Conservation. *Status and conservation of the world's seabirds*. J.P. Croxall, P.G.H. Evans and R.W. Schreiber. Cambridge, International Council for Bird Preservation Technical Publication 2: 637-666.

Croxall, J.P. and P. Rothery (1991) Population regulation of seabirds: implications of their demography for conservation. *Bird Population Studies. Relevance to Conservation and Management*. C.M. Perrins, J.-D. Lebreton and G.J.M. Hirons. Oxford, Oxford University Press: 272-296.

Culik, B., D. Adelung and A.J. Woakes (1990) The effect of disturbance on the heart rate and behaviour of Adélie Penguins *(Pygoscelis adeliae)* during the breeding season. *Antarctic Ecosystems. Ecological Change and Conservation*. K.R. Kerry and G. Hempel. Berlin, Springer Verlag: 177-182.

Culik, B. and R.P. Wilson (1991) Penguins crowded out? Nature 351: 340.

Culik, B.M. and R.P. Wilson (1995) Penguins disturbed by tourists. Nature 376: 301-302.

Curio, E. (1993) Proximate and developmental aspects of antipredator behavior. Advances in the Study of Behavior 22: 135-238.

Cuthbert, R., D. Fletcher and L.S. Davis (2001) A sensitivity analysis of Hutton's shearwater: prioritizing conservation research and management. Biological Conservation 100(2): 163-172.

Davis, P.B. (1995) Antarctic visitor behaviour: are guidelines enough? Polar Record 31(178): 327-334.

Davis, P.B. (1998) Understanding visitor use in Antarctica: the need for site criteria. Polar Record 34(188): 45-52.

De Poorter, M. and J.C. Dalziell (1996) Cumulative Environmental Impacts in Antarctica Minimisation and Management. IUCN Workshop on Cumulative Impacts in Antarctica, Washington DC, USA.

Dierschke, V. (1998) Anthropogene und natürliche Störreize für Küstenvögel im Windwatt von Hiddensee. Seevögel 19(Sonderheft): 53-56.

Dill, L.M. and R. Houtman (1989) The influence of distance to refuge on flight initiation distance in the gray squirrel (*Sciurus carolinensis*). Canadian Journal of Zoology 67: 233-235.

Dunnet, G.M. (1977) Observations on the effects of low-flying aircraft at seabird colonies on the coast of Aberdeenshire, Scotland. Biological Conservation 12: 55-63.

Emslie, S.D., N. Karnovsky and W. Trivelpiece (1995) Avian predation at penguin colonies on King George Island, Antarctica. Wilson Bulletin 107(2): 317-327.

Emslie, S.D., W. Fraser, R.C. Smith and W. Walker (1998) Abandoned penguin colonies and environmental change in the Palmer Station area, Anvers Island, Antarctic Peninsula. Antarctic Science 10(3): 257-268.

Enggist-Düblin, P. and P. Ingold (2003) Modelling the impact of different forms of wildlife harassment, exemplified by a quantitative comparison of the effects of hikers and paragliders on feeding and space use of chamois Rupicapra rupicapra. Wildlife Biology 9: 37-45.

Fernández-Juricic, E. and J.L. Telleria (2000) Effects of human disturbance on spatial and temporal feeding patterns of Blackbird Turdus merula in urban parks in Madrid, Spain. Bird Study 47: 13-21.

Fernández-Juricic, E., M.D. Jimenez and E. Lucas (2001) Alert distance as an alternative measure of bird tolerance to human disturbance: Implications for park design. Environmental Conservation 28(3): 263-269.

Ferrer, M., L. Garcia and R. Cadenas (1990) Long-Term Changes in Nest Defense Intensity of the Spanish Imperial Eagle, Aquila-Adalberti. Ardea 78(3): 395-398.

Finney, S.K., M.P. Harris, L.F. Keller, D.A. Elston, P. Monaghan and S. Wanless (2003) Reducing the density of breeding gulls influences the pattern of recruitment of immature Atlantic puffins Fratercula arctica to a breeding colony. Journal of Applied Ecology 40(3): 545-552.

Fitzpatrick, S. and B. Bouchez (1998) Effects of recreational disturbance on the foraging behaviour of waders on a rocky beach. Bird Study 45: 157-171.

Foley, C.A.H., S. Papageorge and S.K. Wasser (2001) Noninvasive Stress and Reproductive Measures of Social and Ecological Pressures in Free-Ranging African Elephants. Conservation Biology 15(4): 1134-1142.

Fowler, G.S. (1999) Behavioural and hormonal responses of Magellanic penguins *(Spheniscus magellanicus)* to tourism and nest site visitation. Biological Conservation 90: 143-149.

Fox, A.D. and J. Madsen (1997) Behavioural and distributional effects of hunting disturbance on waterbirds in Europe: implications for refuge design. Journal of Applied Ecology 34: 1-13.

Fraser, W.R. and W.Z. Trivelpiece (1994) Workshop on researcher - seabird interactions. Monticello, Minnesota, USA, Polar Oceans Research Group, Department of Biology, Montana State University: 57.

Fraser, W.R. and D.L. Patterson (1997) Human disturbance and long-term changes in Adelie penguin populations: a natural experiment at Palmer Station, Antarctic Peninsula. *Antarctic Communities Species, Structure and Survival*. B. Battaglia. Cambridge, University Press: 445-452.

Frid, A. and L.M. Dill (2002) Human-caused disturbance stimuli as a form of predation risk. Conservation Ecology 6(1): 11.

Frigerio, D., E. Moestl and K. Kotrschal (2001) Excreted metabolites of gonadal steroid hormones and corticosterone in greylag geese (Anser anser) from hatching to fledging. General and Comparative Endocrinology 124(2): 246-255.

Furness, R.W. (1983) Variations in size and growth of Great skua Catharacta skua chicks in relation to adult age, hatching date, egg volume, brood size and hatching sequence. J. Zool., London 199: 101-116.

Furness, R.W. (1984) Influences of adult age and experience, nest location, clutch size and laying sequence on the breeding success of the great skua Catharacta skua. J. Zool., London 202: 565-576.

Furness, R.W. (1987) *The Skuas*. Calton, Staffordshire, A D Poyser.

Furness, R.W. and J.J.D.e. Greenwood (1993) *Birds as Monitors of Environmental Change*. London, Chapman & Hall.

Furness, R.W. (1996) Family Stercorariidae (Skuas). *Handbook of the Birds of the World*. J. del Hojo, A. Elliot and J. Sargatal. Barcelona, Lynx Editions. 3: 556-571.

Gales, R. (1998) Albatross populations: status and threats. *Albatross biology and conservation*. G. Robertson and R. Gales, Chipping Norton: Surrey beatty & Sons: 20-45.

Gander, H. and P. Ingold (1997) Reactions of male alpine chamois Rupicapra r rupicappa to hikers, joggers and mountainbikers. Biological Conservation 79(1): 107-109.

Gebauer, A., M. Kaiser and H.-U. Peter (1989) Der Einfluß der Vigilanz und verschiedener Erregungszustände auf die Herzrate brütender Antarktisseeschwalben. Der Falke 36: 331-137.

Giese, M. (1996) Effects of human activity on Adelie penguin *Pygoscelis adeliae* breeding success. Biological Conservation 75: 157-164.

Giese, M. (1998) Guidelines for people approaching breeding groups of Adelie penguins (*Pygoscelis adeliae*). Polar Record 34(191): 287-292.

Giese, M., R. Handsworth and R. Stephenson (1999) Measuring resting heart rates in penguins using an artificial egg. Journal of field ornithology 70(1): 49-54.

Giese, M. and M. Riddle (1999) Disturbance of emperor penguin *Aptenodytes forsteri* chicks by helicopters. Polar Biology 22: 366-371.

Gill, J.A., W.J. Sutherland and A.R. Watkinson (1996) A method to quantify the effects of human disturbance on animal populations. Journal of Applied Ecology 33(4): 786-792.

Gill, J.A., K. Norris and W.J. Sutherland (2001) Why behavioural responses may not reflect the population consequences of human disturbance. Biological Conservation 97: 265-268.

González-Solís, J., J.P. Croxall and D.R. Briggs (2002) Activity patterns of giant petrels, Macronectes spp., using different foraging strategies. Marine Biology 140(1): 197-204.

Götmark, F. (1992) The effects of investigator disturbance on nesting birds. *Current Ornithology*. D.M. Power. New York, Plenum Press. 9: 63-104.

Goymann, W., E. Mostl, T. Van't Hof, M.L. East and H. Hofer (1999) Noninvasive fecal monitoring of glucocorticoids in spotted hyenas, Crocuta crocuta. General and Comparative Endocrinology 114(3): 340-348.

Green, G. and P.D. Nichols (1995) Hydrocarbons and sterols in marine sediments and soils at Davis Station, Antarctica: a survey for human-derived contaminants. Antarctic Science 7(2): 137-144.

Gremillet, D., D. Schmid and B. Culik (1995) Energy requirements of breeding great cormorants Phalacrocorax carbo sinensis. Marine Ecology Progress Series 121(1-3): 1-9.

Group, W.M.S.B. (1999) Recovery Plan for Albatrosses and Giant Petrels.

Gutzwiller, K.J., H.A. Marcum, H.B. Harvey, J.D. Roth and S.H. Anderson (1998) Bird tolerance to human intrusion in Wyoming Montane Forests. The Condor 100(519-527).

Hahn, S. and H.-U. Peter (2003) Feeding territoriality and the reproductive consequences in brown skuas Catharacta antarctica lonnbergi. Polar Biology 26(8): 552-559.

Hahn, S., M.S. Ritz and H.-U. Peter (2003) Living in mixed pairs - Better for fitness? A study in Skuas. *Antarctic Biology in a Global Context*. A.H.L. Huiskes, W.W.C. Gieskes, J. Rozemaet al. Leiden, Backhuys Publishers: 229-233.

Hahn, S., K. Reinhardt, T. Janicke, M.S. Ritz and H.-U. Peter (2004) Influence of local weather conditions and sea ice extent on reproductive performance of Antarctic skuas. SCAR Open Science Conference, Bremen, Alfred-Wegener-Stiftung.

Hall, C.M. and M.E. Johnston (1995) *Polar Tourism:Tourism in the Arctic and Antarctic regions*. Chichester, John Wiley & Sons Ltd.

Hamer, K.C. and R.W. Furness (1991) Age-specific breeding performance and reproductive effort in great skuas Catharacta skua. Journal of Animal Ecology 60: 693-704.

Hamer, K.C. and R.W. Furness (1993) Parental investment and brood defence by male and female great skuas *Catharacta skua*: the influence of food supply, laying date, body size adn body condition. Journal of Zoology, London 230: 7-18.

Harper, J.M. and S.N. Austad (2001) Effect of capture and season on fecal glucocorticoid levels in deer mice (Peromyscus maniculatus) and red-backed voles (Clethrionomys gapperi). General and Comparative Endocrinology 123(3): 337-344.

Harris, C.M. (1991a) Environmental effects of human activities on King George Island, South Shetland Islands, Antarctica. Polar Record 27(162): 193-204.

Harris, C.M. (1991b) Environmental management on King George Island, South Shetland Islands, Antarctica. Polar Record 27(163): 313-324.

Harris, C.M. (1994) Standardisation of zones within specially protected and managed areas under the Antarctic Environmental Protocol. Polar Record 30(175): 283-86.

Harris, C.M. (2000) Guidelines for the operation of aircraft near concentrations of birds, specifically within Antarctic Specially Protected Areas. Discussion Paper for the Bird Biology Subgroup of SCAR 2000.

Harris, C.M. (2001) Review on Guidelines for the Operation of Aircraft near Concentrations of Birds in Antarctica. St. Petersburg, 24. ATCM: 1-9.

Harwood, J. and K. Stokes (2003) Coping with uncertainty in ecological advice: lessons from fisheries. Trends in Ecology and Evolution 18(12): 617-.

Hayward, L.S. and J.C. Wingfield (2004) Maternal corticosterone is transferred to avian yolk and may alter offspring growth and adult phenotype. General and Comparative Endocrinology 135: 365-371.

Heaney, V. and P. Monaghan (1996) Optimal allocation of effort between reproductive phases: the trade-off between incubation costs and subsequent brood rearing capacity. Proceedings of the Royal Society of London B 263: 1719-1724.

Heap, J. (1994) *Handbook of the Antarctic Treaty System, part 2: the Antarctic environment*. Cambridge, Polar Publications.

Helb, H.-W. and O. Hüppop (1991) Herzschlagraten als Maß zur Beurteilung des Einflusses von Störungen bei Vögeln. *Ornithologen-Kalender '92 Jahrbuch für Vogelkunde und Vogelschutz*. E. Bezzel. Wiesbaden, Aula-Verlag.

Hemmings, A.D. (1990) Human Impacts and Ecological Constraints on Skuas. *Antarctic Ecosystems - Ecological Change and Conservation*. K.R. Kerry and G. Hempel. Berlin, Springer Verlag: 224-230.

Hiebert, S.M., M. Ramenofsky, K. Salvante, J.C. Wingfield and C.L. Gass (2000) Noninvasive Methods for Measuring and Manipulating Corticosterone in Hummingbirds. General and Comparative Endocrinology 120: 235-247.

Higgins, P.J. and S.J.J.F. Davies (1996) *Handbook of Australia, New Zealand and Antarctic birds*. Melbourne, Oxford University Press.

Hilton, G.M., D.C. Houston and R.W. Furness (1998) Which components of diet quality affect retention time of digesta in seabirds? Functional Ecology 12: 929-939.

Hinde, R.A. (1970) Aggression in Animals. Proceedings of the Royal Society of Medicine London 63(2): 162-172.

Hoberg, E.P. (1984) Trematode parasites of marine birds in Antarctica: The distribution of *Gymnophallus deliciosus* (Olsson 1893). Antarctic Journal 19(5): 159-160.

Hofer, H. and M.L. East (1998) Biological conservation and stress. *Stress and Behavior*. A.P. Moller, M. Milinski and P.J.B.E. Slater. London, Academic Press. 27: 405-525.

Hood, L.C., P.D. Boersma and J.C. Wingfield (1998) The Adrenocortical Response to Stress in Incubating Magellanic Penguins *(Spheniscus magellanicus)*. The Auk 115(1): 76-84.

Hubert, B. and O. Hüppop (1993) The influence of excitement on heart rate and oxygen consumption of kittiwakes (*Rissa tridactyla*). *Proceedings of the international congress on applied ethology*. M. Nichelmann. Berlin.

Hunt, K.E., A.W. Trites and S.K. Wasser (2004) Validation of a fecal glucocorticoid assay for Steller sea lions (Eumetopias jubatus). Integrative and Comparative Biology 80(5): 595-601.

Hunter, S. (1984) Breeding biology and population dynamics of giant petrels *Macronectes* at South Georgia (Aves: Procellariiformes). J. Zool. 203: 441-460.

Hunter, S. (1985) The Role of Giant Petrels in the Southern Ocean Ecosystem. *Antarctic Nutrient Cycles and Food Webs*. W.R. Siegfried, P.R. Condy and R.M. Laws. Berlin, Springer Verlag.

Hüppop, O. and K. Hagen (1990) Der Einfluß von Störungen auf Wildtiere am Beispiel der Herzschlagrate brütender Austernfischer *(Haematopus ostralegus)*. Die Vogelwarte 35: 301-310.

Hüppop, O. (1995) Störungsbewertung anhand physiologischer Parameter. Der Ornithologische Beobachter 92: 257-268.

IAATO (International Association of Antarctica Tour Operators) (2003) IAATO Site Specific Guidelines 2003 in the Antarctic Peninsula Further Addressing Potential Cumulative Impacts, ATCM XXVI.

IAATO (2004) IAATO Overview of Antarctic Tourism 2003-2004 Antarctic Season. Cape Town, South Africa, ATCM XXVII.

Ingold, P., B. Huber, B. Mainini, H. Marbacher, P. Neuhaus, A. Rawyler, M. Roth, R. Schnidrig and R. Zeller (1992) Freizeitaktivität - ein gravierendes Problem für Tiere? Der Ornithologische Beobachter 89(4): 205-216.

Jablonski, B. (1980) Distribution and numbers of birds and pinnipedes on Penguin Island (South Shetland Islands) in January 1979. Polish Polar Research 1(1): 109-116.

Jablonski, B. (1984) Distribution and numbers of penguins in the region of King George Island (South Shetland Islands) in the breeding season 1980/1981. Polish Polar Research 5(1-2): 17-30.

Johnson, R.A. (1938) Predation of gulls in murre colonies. Wilson Bulletin 50: 161-172.

Jouventin, P., J.-C. Stahl, H. Weimerskirch and J.-L. Mougin (1984) The seabirds of the French sub-Antarctic islands and Adélie Land, their status and conservation. *Status and conservation of the world's seabirds*. J.P. Croxall, P.G.H. Evans and R.W. Schreiber, International Council for Bird Preservation Technical

Publication 2: 609-624.

Jouventin, P. and H. Weimerskirch (1991) Changes in the population size and demography of southern seabirds: management implications. *Bird population studies: their relevance to conservation and management*. C.M. Perrins, J.D. Lebreton and G.J.M. Hirons. Oxford, Oxford University Press: 297-314.

Kaiser, M., H.-U. Peter and A. Gebauer (1988) Zum Bruterfolg und einigen Gelegeparametern der Antarktisseeschwalbe, *Sterna vittata* (Gmelin, 1789) auf King George Island, Südshetlandinseln. Beiträge zur Vogelkunde 34: 317-340.

Kempf, N. and O. Hüppop (1998) Wie wirken Flugzeuge auf Vögel? Naturschutz und Landschaftsplanung 30(1): 17-28.

Khan, M.Z., J. Altmann, S.S. Isani and J. Yu (2002) A matter of time: evaluating the storage of fecal samples for steroid analysis. 128(1): 57-64.

Kitaysky, A.S., J.C. Wingfield and J.F. Piatt (1999) Dynamics of food availability, body condition and physiological stress response in breeding Black-legged Kittiwakes. Functional Ecology 13: 577-584.

Kitaysky, A.S., E.V. Kitaiskaia, J.C. Wingfield and J.F. Piatt (2001a) Dietary restriction causes chronic elevation of corticosterone and enhances stress response in red-legged kittiwake chicks. Journal of Comparative Physiology B 171(8): 701-709.

Kitaysky, A.S., J.C. Wingfield and J.F. Piatt (2001b) Corticosterone facilitates begging and affects resource allocation in the black-legged kittiwake. Behavioral Ecology 12(5): 619-625.

Kitaysky, A.S., E.V. Kitaiskaia, J.F. Piatt and J.C. Wingfield (2003) Benefits and costs of increased levels of corticosterone in seabird chicks. Hormones and Behavior 43: 140-149.

Knight, R.L. and S.N. Knight (1984) Responses of wintering bald eagles to boating activity. Journal of Wildlife Management 48: 999-1004.

Knight, R.L. and D.N. Cole (1995) Factors that influence wildlife responses to recreationists. *Wildlife and Recreationists: Coexistence Through Management and Research*. R.L. Knight and K.J. Gutzwiller. Washington, DC, USA, Island Press: 71-79.

Knight, R.L. and K.J. Gutzwiller (1995) *Wildlife and recreationists. Coexistence through management and research*. Washington, Covelo.

Kotrschal, K., K. Hirschenhauser and E. Möstl (1998) The relationship between social stress and dominance is seasonal in greylag geese. Animal Biology 55: 171-176.

Krebs and I. Davies (1997) *Behavioural ecology: an evolutionary approach*. London, Blackwell Scientific Publication.

Kruuk, H. (1964) Predators and anti-predator behaviour of the black-headed gull (*Larus ridibundus* L.). Behaviour Supplement 11.

Laugksch, R.C. and D.C. Duffy (1988) Food transit rates in cape gannets and jackass penguins. The Condor 88: 117-119.

Lemmetyinen, R. (1971) Nest defense behaviour of common and arctic terns and its effect on the success achieved by predators. Ornis Fennica 48: 13-24.

Liddle, M. (1997) *Recreation ecology - the ecological impact of outdoor recreation and ecotourism*. London, Chapman & Hall.

Lima, S.L. (1998) Stress and decision making under the risk of predation: recent developments for behavioral, reproductive, and ecological perspectives. Advances in the Study of Behavior 27: 215-290.

Lord, A., J.R. Waas, J. Innes and M. Whittingham, J. (2001) Effects of human approaches to nests of northern New Zealand dotterels. Biological Conservation 98(2): 233-240.

Ludders, J.W., J.A. Langenberg, N.M. Czekala and H.N. Erb (2001) Fecal corticosterone reflects serum corticosterone in Florida sandhill cranes. Journal of Wildlife Diseases 37(646-652).

Madsen, J. (1995) Impacts of disturbance on migratory waterfowl. Ibis 137: 67-74.

Manuwal, D.A. (1978) Effects of man on marine birds: a review. *Forestry Conference. Proceedings on Wildlife and People*. J.S. Wright, Purdue University Press: 140-160.

Marchant, S. and P.J. Higgins (1990) *Handbook of Australian, New Zealand & Antarctic birds*. Melbourne, Oxford University Press.

Masello, J.F., G.A. Pagnossin, G.E. Palleiro and P. Quillfeldt (2001) Use of miniature security cameras to record behaviour of burrow-nesting birds. Die Vogelwarte - Kurze Mitteilungen 41(2): 150-154.

McNamara, J.N. and D.C. Houston (1996) State-dependent life histories. Nature 380: 189-191.

McQueen, S.M., L.S. Davis and G. Young (1999) Sex Steroid and Corticosterone Levels of Adélie Penguins *(Pygoscelis adeliae)* during Courtship and Incubation. General and Comparative Endocrinology 114: 11-18.

Micol, T. and P. Jouventin (2001) Long-term population trends in seven Antarctic seabirds at Pointe Geologie (Terre Adelie). Human impact compared with environmental change. Polar Biology 24(3): 175-185.

Millspaugh, J.J., R.J. Woods, K.E. Hunt, K.J. Raedeke, G.C. Brundige, B.E. Washburn and S.K. Wasser (2001) Fecal glucocorticoid assays and the physiological stress response in elk. Wildlife Society Bulletin 29(3): 899-907.

Millspaugh, J.J., B.E. Washburn, M.A. Milanick, R. Slotow and G. van Dyk (2003) Effects of heat and chemical treatments on fecal glucocorticoid measurements: implications for sample transport. 31(2): 399-406.

Millspaugh, J.J. and B.E. Washburn (2003) Within-sample variation of fecal glucocorticoid measurements. 132(1): 21-26.

Millspaugh, J.J. and B.E. Washburn (2004) Use of fecal glucocorticold metabolite measures in conservation biology research: considerations for application and interpretation. 138(3): 189-199.

Milsom, T.P., S.D. Langton, W.K. Parkin, S. Peel, J.D. Bishop, J.D. Hart and N.P. Moore (2000) Habitat models of bird species' distribution: an aid to the management of coastal grazing marshes. Journal of Applied Ecology 37(5): 706-727.

Minbashian, Y. (1997) Biological integrity: an approach to monitoring human disturbance in the Antarctic Peninsula region. *Scott Polar Research Institute*. Cambridge, University of Cambridge: 107.

Mineau, P. and D.V.C. Weseloh (1981) Low-disturbance monitoring of herring gull reproductive success in the Great Lakes. Colonial Waterbirds 4: 138-142.

Moberg, G.P. and J.A. Mench (2000) *The Biology of Animal Stress - Basic Principles and Implications for Animal Welfare*. Oxon, CABI Publishing.

Møller, A.P., M. Milinski and P.J.B.E. Slater (1998) *Stress and Behavior*. London, Academic Press.

Montgomerie, R.D. and P.J. Weatherhead (1988) Risks and Rewards of Nest Defence by Parent Birds. The Quarterly Review of Biology 63(2): 167-187.

Monaghan, P., J.D. Uttley, M.D. Burns, C. Thaine and J. Blackwood (1989) The relationship between food supply, reproductive effort and breeding success in Arctic terns Sterna paradisaea. Journal of Animal Ecology 58: 261-274.

Monaghan, P. and R.G. Nager (1997) Why don't birds lay more eggs? Trends in Ecology and Evolution 12(7): 270-274.

Nakagawa, S., E. Möstl and J.R. Waas (2003) Validation of an enzyme immunoassay to measure faecal glucocorticoid metabolites from Adélie penguins (*Pygoscelis adeliae*): a non-invasive tool for estimating stress? Polar Biology - Short Note.

Naveen, R. (1997) *Compendium of Antarctic Peninsula Visitor Sites: A Report to the Governments of the United States and the United Kingdom*, US Department of State and UK Foreign and Commonwealth Office.

Naveen, R. (2002) Antarctic Site Inventory 1994-2002. Warsaw, ATCM XXV.

Naveen, R. (2003) Compendium of Antarctic Peninsula Visitor Sites. Chevy Chase, MD, Oceanites, Inc.

Naveen, R., S.C. Forrest, R.G. Dagit, L.K. Blight, W.Z. Trivelpiece and S.G. Trivelpiece (2000) Censuses of penguin, blue-eyed shag, and southern giant petrel populations in the Antarctic Peninsula region, 1994-2000. Polar Record 36: 323-334.

Naveen, R., S.C. Forrest, R.D. Dagit, L.K. Blight, W.Z. Trivelpiece and S.G. Trivelpiece (2001) Zodiac landings by tourist ships in the Antarctic Peninsula region, 1989-99. Polar Record 37(201): 121-132.

Neebe, B. and O. Hüppop (1994) Der Einfluß von Störreizen auf die Herzschlagrate brütender Küstenseeschwalben *(Sterna paradisaea)*. Artenschutzreport 4: 8-13.

Nimon, A.J., R.C. Schroter and B. Stonehouse (1995) Heart rate of disturbed penguins. Nature 374: 415.

Nimon, A.J. and B. Stonehouse (1995) Penguin responses to humans in Antarctica: some issues and problems in determining disturbance caused by visitors. *The Penguins*. P. Dann, I. Norman and P. Reilly. Chipping Norton, Surrey Beatty & Sons: 420-439.

Nimon, A.J., R.C. Schroter and R.K.C. Oxenham (1996) Artificial Eggs: Measuring Heart Rate and Effects of Disturbance in Nesting Penguins. Physiology & Behavior 60(4): 1019-1022.

Nimon, A.J. (1997) Gentoo penguin (*Pygoscelis papua*) responses to tourist and other disturbances in Antarctica. *Scott Polar Research Institute*. Cambridge, University of Cambridge: 189.

Nisbet, I.C.T. (2000) Disturbance, Habituation, and Management of Waterbird Colonies. Waterbirds 23(2): 312-332.

NSF (National Science Foundation US), US Environmental Agency and IAATO (2000) Assessment of the Possible Cumulative Environmental Impacts of Commercial Ship-Based Tourism in the Antarctic Peninsula Region, La Jolla, Califonia.

Obst, B.S. (1985) Densities of Antarctic seabirds at sea and the presence of the krill. The Auk 102(3): 540-549.

Obst, B.S. and K.A. Nagy (1992) Field energy expenditures of the Southern Giant Petrel. The Condor 94: 801-810.

Olsson, O. and G.W. Gabrielsen (1990) Effects of Helicopters on a large and remote colony of Brünnich's Guillemots *(Uria lomvia)* in Svalbard. Rapportserie 64: 36 pp.

O'Reilly, K.M. and J.C. Wingfield (2001) Ecological factors underlying the adrenocortical response to capture stress in arctic-breeding shorebirds. General and Comparative Endocrinology 124(1): 1-11.

Palme, R. and E. Möstl (1997) Measurement of cortisol metabolites in faeces of sheep as a parameter of cortisol concentration in blood. Berlin, Proceedings of the 1st International Symposium of Physiology and Ethology of Wild and Zoo Animals: 192-197.

Parmelee, D.F., W.R. Fraser and D.R. Neilson (1977) Birds of the Palmer Station area. Antarctic Journal of the United States 12: 14-21.

Parsons, K.C. and J. Burger (1982) Human disturbance and nestling behavior in black-crowned night herons. The Condor 84: 184-187.

Patterson, D.L. and S. Hunter (2000) Giant petrel Macronectes spp. band recovery analysis from the International Giant Petrel Banding Project, 1988/89. Marine Ornithology 28(1): 69-74.

Patterson, D.L., E.J. Woehler, J.P. Croxall, J. Cooper, S. Poncet and W.R. Fraser (2000) Breeding distribution and population status of the northern giant petrel *Macronectes halli* and the southern giant petrel *M. giganteus*. draft for Marine Ornithology.

Pereyra, M.E. and J.C. Wingfield (2003) Changes in plasma corticosterone and adrenocortical response to stress during the breeding cycle in high altitude flycatchers. General and Comparative Endocrinology 130(3): 222-231.

Peter, H.-U., M. Kaiser and A. Gebauer (1988) Untersuchungen an Vögeln und Robben auf King George Island (South Shetland Islands, Antarktis). Geodätische und geophysikalische Veröffentlichungen Reihe 1(14): 1-127.

Peter, H.-U., M. Kaiser and A. Gebauer (1990a) Ecological and morphological investigations on South Polar Skuas (*Catharacta maccormicki*) and Brown Skuas (*Catharacta skua lonnbergi*) on Fildes Peninsula, King George Island, South Shetland Islands. Zool. Jb. Syst. 117: 201-218.

Peter, H.-U., M. Kaiser and A. Gebauer (1990b) Ecological studies in the Southern Giant Petrel (Macronectes giganteus) on southwestern parts of King George Island. Geodätische und geophysikalische Veröffentlichungen 16: 387-399.

Peter, H.-U., M. Kaiser and A. Gebauer (1991) Breeding Ecology of the Southern Giant Petrels *Macronectes giganteus* on King George Island (South Shetland Islands, Antarctic). Zool. Jb. Syst. 118: 465-477.

Peter, H.-U., S. Braun, C. Büsser, U. Gerighausen, J. Gonzales, J. Gutsell, T. Kahl, O. Mustafa, S. Pfeiffer, J. Valencia and Z. Wang (2001) Human impacts on Fildes Peninsula, King George Island, South Shetland Islands. Amsterdam, VIII SCAR International Biology Symposium 27.8.-1.9.

Pfeiffer, S. and H.-U. Peter (2003) Umsetzung des Umweltschutzprotokoll-Ausführungsgesetzes (AUG), Teilvorhaben 3: Bestandsaufnahme und Managementpläne für zwei touristisch genutzte Gebiete der Antarktis. Berlin, Umweltbundesamt: pp 247.

Phillips, R.A. and R.W. Furness (1997) Sex-specific variation in the loss of mass by breeding Arctic Skuas. Journal of Avian Biology 28: 163-170.

Phillips, R.A., D.R. Thompson and K.C. Hamer (1999) The impact of great skua predation on seabird populations at St Kilda: a bioenergetics model. Journal of Applied Ecology 36: 218-232.

Pietz, P.J. (1986) Daily activity patterns of South Polar Skua and Brown Skua near Palmer Station, Antarctica. The Auk 103: 726-736.

Pietz, P.J. (1987) Feeding and nesting ecology of sympatric South Polar and Brown skuas. The Auk 104: 617-627.

Prince, P.A. and C. Ricketts (1981) Weight loss in incubating albatrosses and its implications for their energy. The Condor 83: 238-242.

Quillfeldt, P. and E. Möstl (2003) Resource allocation in Wilson's storm-petrels Oceanites oceanicus determined by measurement of glucocorticoid excretion. Acta Ethology 5: 115-122.

Recarte, J.M., J.P. Vincent and A.J.M. Hewison (1998) Flight responses of park fallow deer to the human observer. Behavioural Processes 44: 65-72.

Regel, J. and K. Pütz (1995) Effect of human disturbance on body temperature and energy expenditure in penguins. Polar Biology 18: 246-253.

Reinhardt, K. (1995) Nahrungs- und brutoekologische Untersuchungen an antarktischen Raubmoewen (Aves; Stercorariidae). *Institut für Ökologie*. Jena, Friedrich-Schiller Universität: 118.

Reinhardt, K. (1997) Breeding success of southern hemisphere skuas Catharacta spp.: the influence of latitude. Ardea 87(1): 73-82.

Reinhardt, K., S. Hahn, H.-U. Peter and H. Wemhoff (2000) A review of diets of southern hemisphere skuas. Marine Ornithology 28: 7-19.

Richardson, W.J. and e. al. (1995) *Marine mammals and noise*. London, Academic Press.

Robert, H.C. and C.J. Ralph (1975) Effects of human disturbance on breeding success in gulls. The Condor 77: 485-490.

Roby, D.D., M.A. Sallaberry and K.L. Brink (1986) Nota sobre nidificacíon de Petreles (Procellariiformes) en isla Ardley, Shetland del Sur. Serie Científica Instituto Antártica Chile 34: 67-72.

Rodgers, J.A.J. and H.T. Smith (1995) Set-back distances to protect nesting bird colonies from human disturbance in Florida. Conservation Biology 9(1): 89-99.

Rodgers, J.A. and H.T. Smith (1997) Buffer zone distances to protect foraging and leafing waterbirds from human disturbance in Florida. Wildlife Society Bulletin 25(1): 139-145.

Rodway, M.S., W.A. Montevecchi and J.W. Chardine (1996) Effects of investigator disturbance breeding success of Atlantic puffins Fratercula arctica. Biological Conservation 76: 311-319.

Roe, D., N. Leader-Williams and B. Dalal-Clayton (1997) *Take Only Photographs, Leave Only Footprints: The Environmental Impacts of Wildlife Tourism*. London, Environmental Planning Group.

Roff, D.A. (1992) *The Evolution of Life Histories*. New York, Chapman & Hall.

Romero, L.M., K.K. Soma, K.M. O'Reilly, R. Suydam and J.C. Wingfield (1998) Hormones and territorial behavior during breeding in snow buntings (Plectrophenax nivalis): An arctic-breeding songbird. Hormones and Behavior 33(1): 40-47.

Romero, L.M., J.M. Reed and J.C. Wingfield (2000) Effects of weather on corticosterone responses in wild free-living passerine birds. General and Comparative Endocrinology 118(1): 113-122.

Romero, L.M. and L. Remage-Healey (2000) Daily and seasonal variation in response to stress in captive starlings (Sturnus vulgaris): Corticosterone. General and Comparative Endocrinology 119(1): 52-59.

Romero, L.M. and M. Wikelski (2002) Exposure to tourism reduces stress-induced corticosterone levels in Galápagos marine iguanas. Biological Conservation 108(3): 371-374.

Rounsevell, D.E. and N.P. Brothers (1984) The status and conservation of seabirds at Macquarie Island. *Status and conservation of the world's seabirds.* J.P. Croxall, P.G.H. Evans and R.W. Schreiber, International Council for Bird Preservation Technical Publication 2: 587-592.

Safina, C. and J. Burger (1983) Effects of human disturbance on reproductive success in the black skimmer. The Condor 85: 164-171.

Salwicka, K. and B. Stonehouse (2000) Visual monitoring of heartbeat and respiration in Antarctic seals. Polish Polar Research 21(3-4): 189-197.

Sanson, L. (1994) An ecotourism case study in sub-Antarctic islands. Annals of Tourism Research 21(2): 344-354.

SCAR (Scientific Committee on Antarctic Research) (2000) Specially Protected Species. The Hague, CEP.

SCAR (2001) Resolution 1 (2000) Guidelines for Implementation of the Framework for Protected Areas set forth in Article 2, Annex V of the Environmental Protocol. SCAR Bulletin 140: 6-15.

SCAR (1993) The Protocol on Environmental Protection to the Antarctic Treaty, with Annexes, done at Madrid 4 October 1991, and an additional Annex done at Bonn 17 October 1991. SCAR Bulletin 110(170).

Scheuerlein, A., T.J.V.t. Hof and E. Gwinner (2001) Predators as stressors? Physiological and reproductive consequences of predation risk in tropical stonechats (Saxicola torquata axillaris). Proceedings of the Royal Society, London Series B 268(1476): 1575 - 1582.

Scott, G.W., A.R. Niggebrugge and B. Sweeney (1996) Avian habituation to recreational disturbance on the north Yorkshire coast. Naturalist 121: 11-15.

Selye, H. (1936) A syndrome produced by diverse nocuous agents. Nature 138: 32-34.

Selye, H. (1950) *Stress*. Montreal, Acta.

Selye, H. (1952) *The Story of the Adaptation Syndrome*. Montreal, Acta.

Serveiss, V.B., J.l. Bowen, D. Dow and I. Valiela (2004) Using Ecological Risk Assessment to Identify the Major Anthropogenic Stressor in the Waquoit Bay Watershed, Cape Cod, Massachusetts. Environmental Management 33(5): 730-740.

Siebolts, U. (1998) Reaktionen der Flußseeschwalbe *Sterna hirundo* gegenüber Menschen in verschiedenen Brutkolonien. Vogelwelt 119: 271-277.

Siegel, H.S. (1980) Physiological stress in birds. Bioscience 30: 529-534.

Silverin, B. (1986) Corticosterone-binding proteins and behavioural effects of high plasma levels of corticosterone during the breeding period. General and Comparative Endocrinology 64: 67-74.

Silverin, B. (1998) Behavioural and hormonal responses of the pied flycatcher to environmental stressors. Animal Behavior 55: 1411-1420.

Skagen, S.K., R.L. Knight and G.H. Orians (1991) Human disturbance of an avian scavenging guild. Ecology Appllications 1: 215-225.

Smith, G.T., J.C. Wingfield and R.R. Veit (1994) Adrenocortical Response to Stress in the Common Diving Petrel, *Pelecanoides urinatrix*. Physiological Zoology 67(2): 526-537.

Smith, R.C., D. Ainley, K. Baker, Domack-Eugene, Emslie-Steve, Fraser-Bill, Kennett-James, Leventer-Amy, Mosley-Thompson-Ellen, Stammerjohn-Sharon and Vernet-Maria (1999) Marine ecosystem sensitivity to climate change: Historical observations and paleoecological records reveal ecological transitions in the Antarctic Peninsula region. Bioscience 49(5): 393-404.

Spellerberg, I.F. (1969) Incubation temperatures and thermoregulation in the McCormick Skua. The Condor 71: 59-67.

Stearns, S.C. (1992) *The Evolution of Life Histories*. Oxford, Oxford University Press.

Stock, M. (1992) Effects of man-induced disturbances on staging Brent Geese. Netherlands Institute for Sea Research, Publication Series 20: 289-293.

Stock, M., H.-H. Bergmann, H.-W. Helb, V. Keller, R. Schnidrig-Petrig and H.-C. Zehnter (1994) Der Begriff Störung in naturschutzorientierter Forschung: ein Diskussionsbeitrag aus ornithologischer Sicht. Zeitschrift für Ökologie und Naturschutz 3: 49-57.

Stone, R., M. Ridout and J. Shears (2003) Unpublished data from observations on the effects of helicopter overflights on the behaviour of king penguins (Aptenodytes patagonicus) at South Georgia, South Atlantic. Cambridge, British Antarctic Survey.

Stonehouse, B. (1995) Management recommendations for visitor sites in the Antarctic region. Cambridge: PAC, Scott Polar Research Institute.

Suter, G.W. (1993) *Ecological Risk Assessment*. Boca Raton, Fla, Lewis Publishers.

Taylor, R.H. and P.R. Wilson (1990) Recent increase and southern expansion of Adélie penguin populations in the Ross sea, Antarctica, related to climate warming. New Zealand Journal of Ecology 14: 25-29.

Techow, N.M.S.M. and C. O'Ryan (2004) Characterization of microsatellite loci in White-chinned Petrel (Procellaria aequinoctialis) and cross-amplification in six other procellariiform species. Molecular Ecology Notes 4: 33-35.

Thomson, R.B. (1977) Effects of Human Disturbance on an Adélie Penguin Rookery and Measures of Control. *Adaptations within Antarctic Ecosystems*. G.A. Llano. Washington, Smithsonian Institution: 1177-1180.

Toates, F. (1995) *Stress: Conceptual and Biological Aspects*. New York, John Wiley and Sons.

Touma, C., N. Sachser, E. Mostl and R. Palme (2003) Effects of sex and time of day on metabolism and excretion of corticosterone in urine and feces of mice. General and Comparative Endocrinology 130(3): 267-278.

Touma, C., R. Palme and N. Sachser (2004) Analyzing corticosterone metabolites in fecal samples of mice: a noninvasive technique to monitor stress hormones. Hormones and Behavior 45: 10-22.

Viñuela, V., J.A. Amat and M. Ferrer (1995) Nest defence of Nesting Chinstrap Penguins (*Pygoscelis antarctica*) against Intruders. Ethology 99: 323-331.

Voisin, J.-F. (1978) Observations Sur Le Comportement Des Petrels Geants De L'archipel Crozet. Alauda 46(3): 209-234.

Votier, S.C., S. Bearhop, N. Ratcliff and R.W. Furness (2004a) Reproductive Consequences for Great Skuas Specializing as Seabird Predators. The Condor 106(2).

Votier, S.C., R.W. Furness, S. Bearhop, J.E. Crane, R.W.G. Caldow, P. Catry, K. Ensor, K.C. Hamer, A.V. Hudson, E. Kalmbach, N.I. Klomp, S. Pfeiffer, R.A. Phillips, I. Prieto and D.R. Thompson (2004b) Changes in fisheries discard rates and seabird communities. Nature 427(6976): 727-730.

Wang, Z., F.I. Norman, J.S. Burgess, S.J. Ward, A.P. Spate and C.J. Carson (1996) Human influences on breeding of south polar skuas in the eastern Larsemann Hills, Princess Elizabeth Land, East Antarctica. Polar Record 32(180): 43-50.

Wang, Z. and H.-U. Peter (2002) Comparison on ecology of skua populations at Great Wall Station and Zhonshan Station. Chinese Journal of Polar Research 14: 83-92.

Warham, J. (1962) The Biology of The Giant Petrel *Macronestes giganteus*. The Auk 79(2): 139-160.

Warham, J. (1990) *The Petrels- their Ecology and Breeding Systems*. London, Academnic Press.

Warham, J. (1996) *The Behaviour, Population Biology and Physiology of the Petrels*. London, Academic Press.

Washburn, B.E. and J.J. Millspaugh (2002) Effects of simulated environmental conditions on glucocorticoid metabolite measurements in white-tailed deer feces. The Condor 27(3): 217-222.

Washburn, B.E., J.J. Millspaugh, J.H. Schulz, S.B. Jones and T. Mong (2003) Using fecal glucocorticoids for stress assessment in mourning doves. 105(4): 696-706.

Wasser, S.K., K. Bevis, G. King and E. Hanson (1997) Noninvasive physiological measures of disturbance in the northern spotted owl. Conservation Biology 11: 1019-1022.

Wasser, S.K., K.E. Hunt, J.L. Brown, K. Cooper, C.M. Crockett, U. Bechert, J. Millspaugh, S. Larson and S.L. Monfort (2000) A Generalized Fecal Glucocorticoid Assay for Use in a Diverse Array of Nondomestic Mammalian and Avian Species. General and Comparative Endocrinology 120: 260-275.

Weimerskirch, H. (1992) Reproductive effort in long-lived birds: age-specific patterns of condition, reproduction and survival in the Wandering Albatross. Oikos 64: 464-473.

Weimerskirch, H. and T. Guionnet (2002) Comparative activity pattern during foraging of four albatross species. Ibis 144(1): 40-50.

Weimerskirch, H., T. Guionnet, J. Martin, S.A. Shaffer and D.P. Costa (2000) Fast and fuel efficient? Optimal use of wind by flying albatrosses. Proceedings of the Royal Society, London, Series B 267: 1869-1874.

Wiegand, T. and K.A. Molony (2004) Rings, circles, and null-models for point pattern analysis in ecology. Oikos 104: 209-229.

Wiklund, C.G. (1990) Offspring protection by merlin *Falco columbarius* females; the importance of brood size and expected offspring survival of defense of young. Behavior Ecology and Sociobiology 26: 217-223.

Williams, A.J. (1980) Variation in weight of eggs and its effect on the breeding biology of the great skua. Emu 80: 198-202.

Willis, E.O. (1973) Survival rate of visited and unvisited nests of bicolored antbirds. The Auk 90: 263-267.

Wilson, K.-J., R.H. Taylor and K.J. Barton (1990) The impact of man on Adélie Penguins at Cape Hallett, Antarctica. *Antarctic Ecosystems. Ecological Change and Conservation*. K.R. Kerry and G. Hempel. Berlin, Springer Verlag.

Wilson, R.P., N.R. Coria, H.J. Spairani, D. Adelung and B. Culik (1989) Human-induced behaviour in Adélie penguins *Pygoscelis adeliae*. Polar Biology 10: 77-80.

Wilson, R.P., B. Culik, R. Danfeld and D. Adelung (1991) People in Antarctica - how much do Adelie Penguins *Pygoscelis adeliae* care? Polar Biology 11: 363-370.

Wingfield, J.C. and B. Silverin (1986) Effects of corticosterone on territorial behavior of free-living male song sparrows, *Melospiza melodia*. Hormones and Behavior 20: 405-417.

Wingfield, J.C. and G.J. Kenagy (1991) *Natural regulation of reproductive cycles*. New York, Academic Press.

Wingfield, J.C. (1994) Modulation of the adrenocortical response to stress in birds. *Perspectives in Comparative Endocrinology*. K.G. Davey, R.E. Peter and S.S. Tobe. Ottawa, National Research Council, Canada: 520-528.

Wingfield, J.C., K. Hunt, C. Breuner, K. Dunlap, G.S. Fowler, L. Freed and J. Lepson (1997) Environmental stress, field endocrinology, and conservation biology. *Behavioral approaches to conservation in the wild*. J.R. Clemmons and R. Buchholz. Cambridge, University Press: 95-131.

Wingfield, J.C., D.L. Maney, C.W. Breuner, J.D. Jacobs, S. Lynn, M. Ramenofsky and R.D. Richardson (1998) Ecological bases of hormone-behavior interactions: The "emergency life history stage". American Zoologist 38(1): 191-206.

Wingfield, J.C. and W. Ramenofsky (1999) Hormones and the behavioral ecology of stress. *Stress Physiology in Animals*. P.H.M. Balm. Sheffield, Sheffield Academic: pp.1-51.

Wingfield, J.C., G. Ramos-Fernandez, A. Nunez-de- la Mora and H. Drummond (1999) The Effects of an "El Nino" Southern Oscillation Event on Reproduction in Male and Female Blue-Footed Boobies, *Sula nebouxii*. General and Comparative Endocrinology 114: 163-172.

Woehler, E.J., M.R. Martin and G.W. Johnstone (1990) The status of southern giant petrels, *Macronectes giganteus*, at the Frazier Islands, Wilkes Island, East Antarctica. Corella 14: 101-106.

Woehler, E.J. (1991) Status and conservation of the seabirds of Heard Island and the McDonalds Islands. *Seabird status and conservation: a supplement*. J.P. Croxall, International Council for Bird Preservation Technical Publication 11: 263-275.

Woehler, E.J., R.L. Penny, S.M. Creet and H.R. Burton (1994) Impacts of human visitors on breeding success and long-term population trends in Adélie Penguins at Casey, Antarctica. Polar Biology 14: 269-274.

Woehler, E.J. and J.P. Croxall (1997) The status and trends of Antarctic and Sub-antarctic seabirds. Marine Ornithology 25: 43-66.

Woehler, E.J., J. Cooper, J.P. Croxall, W.R. Fraser, G.L. Kooyman, G.D. Miller, D.C. Nel, D.L. Patterson, H.-U. Peter, C.A. Ribic, K. Salwicka, W.Z. Trivelpiece and H. Weimerskirch (2001) A statistical assessment of the status and trends of Antarctic and Subantarctic seabirds, SCAR BBS: 43.

Wood, R.C. (1971) Population dynamics of breeding South Polar Skuas of unknown age. The Auk 88: 805-814.

Ydenberg, R.C. and L.M. Dill (1986) The economics of fleeing from predators. Advances in the Study of Behavior 16: 229-249.

Yorio, P., E. Frere, P. Gandini and A. Schiavini (2001) Tourism and recreation at seabird breeding sites in Patagonia, Argentina: current concerns and future prospects. Bird Conservation International 11(4): 231-245.

Young, E.C. (1990) Long-Term Stability and Human Impact in Antarctic Skuas and Adelie Penguins. *Antarctic Ecosystems. Ecological Change and Conservation*. K.R. Kerry and G. Hempel. Heidelberg, Springer Verlag: 231-236.

Young, E. (1994) *Skua and Penguin: predator and prey*. Cambridge, University Press.

Zande, A.N. van der (1984) Outdoor recreation and birds: conflict or symbiosis? Leiden, Rijksuniversiteit.

Zonfrillo, B. (1993) Low-flying aircraft and seabirds on Ailsa Craig. Seabird Group Newsletters 64: 7-8.

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Pfeiffer, S. and H.-U. Peter. 2004. Ecological studies toward the management of an Antarctic tourist landing site (Penguin Island, South Shetland Islands). Polar Record 40: 345-353.

Votier, S. C., R. W. Furness, S. Bearhop, J. E. Crane, R. W. G. Caldow, P. Catry, K. Ensor, K. C. Hamer, A. V. Hudson, E. Kalmbach, N. I. Klomp, S. Pfeiffer, R. A. Phillips, I. Prieto and D. R. Thompson. 2004. Changes in fisheries discard rates and seabird communities. Nature 427(6976): 727-730.

Köhler, G. and S. Pfeiffer. 2004. Zur ökologischen Effizienz einer Entwaldungsmaßnahme auf einem Muschelkalksteilhang. Landschaftspflege und Naturschutz in Thüringen. 41 (1): 15-22.

Pfeiffer, S. and H.-U. Peter. 2003. Umsetzung des Umweltschutzprotokoll-Ausführungsgesetzes (AUG), Teilvorhaben 3: Bestandsaufnahme und Managementpläne für zwei touristisch genutzte Gebiete der Antarktis. Berlin, Umweltbundesamt: pp 247.

SELBSTÄNDIGKEITSERKLÄRUNG

Ich erkläre hiermit, daß ich die vorliegende Arbeit selbständig und nur unter Verwendung der angegebenen Hilfsmittel und Literatur angefertigt habe.

Jena, am 06. Dezember 2004

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Simone Pfeiffer