

RESEARCH/REVIEW ARTICLE

Environmental monitoring and management proposals for the Fildes Region, King George Island, Antarctica

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human impact; Antarctic; Fildes Region; environmental management; Antarctic Specially Managed Area; protected area.

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Abstract

The Antarctic terrestrial environment is under increasing pressure from human activities. The Fildes Region is characterized by high biodiversity, but is also a major logistic centre for the northern Antarctic Peninsula. Different interests, from scientific research, nature conservation, protection of geological and historical values, station operations, transport logistics and tourism, regularly overlap in space and time. This has led to increasing conflict among the multiple uses of the region and breaches of the legal requirements for environmental protection that apply in the area. The aim of this study was to assess the impacts of human activities in the Fildes Region by monitoring the distribution of bird and seal breeding sites and recording human activities and their associated environmental impacts. Data from an initial monitoring period 2003–06 were compared with data from 2008–10. We observed similar or increased levels of air, land and ship traffic, but fewer violations of overflight limits near Antarctic Specially Protected Area No. 150 Ardley Island. Open waste dumping and oil contamination are still major environmental impacts. Scientific and outdoor leisure activities undertaken by station personnel are more frequent than tourist activities and are likely to have a commensurate level of environmental impact. Despite the initial success of some existing management measures, it is essential that scientific and environmental values continue to be safeguarded, otherwise environmental impacts will increase and the habitat will be further degraded. We argue that the Fildes Region should be considered for designation as an Antarctic Specially Managed Area, a measure that has proven effective for environmental management of vulnerable areas of the Antarctic.

The Fildes Region (62°08′–62°14′S, 59°02′–58°51′W), consisting of the Fildes Peninsula, Ardley Island and adjacent islands within 0.5 km off the coast, is located at the south-western part of King George Island, South Shetland Islands, and represents one of the largest ice-free areas in the maritime Antarctic. This region is characterized by high biodiversity and hosts two Antarctic Specially Protected Areas (ASPAs): ASPA No. 125 Fildes Peninsula and No. 150 Ardley Island, Maxwell Bay, King George Island (SAT 2010). The area contains six permanent Antarctic stations, built between 1968 and 1994 (Fig. 1). Construction of the airport, by Chile,

turned the area into a major logistical hub for the Antarctic Peninsula. Scientific, logistic and tourist activities are concentrated here and frequently overlap in space and time. This can lead to conflicts of interests between the different forms of human activity in the region as well as breaches of the requirements of environmental protection that are detailed in the Protocol on Environmental Protection to the Antarctic Treaty, also known as the Madrid Protocol, which came into force in 1998.

The area is visited by inspections under Article 7 of the Antarctic Treaty and Article 14 of the Madrid Protocol at

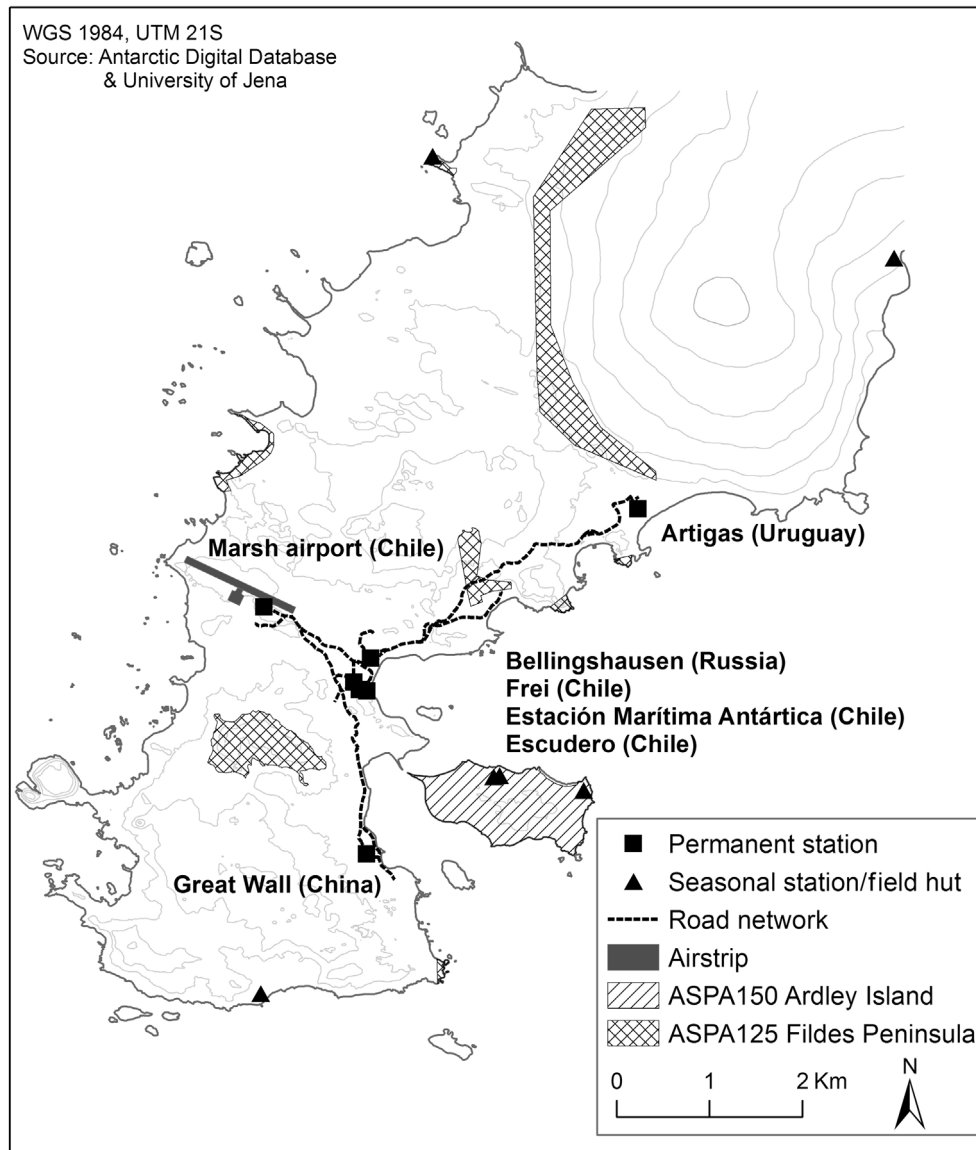


Fig. 1 Overview of the study area on the Fildes Peninsula.

irregular intervals. Inspection reports (United Kingdom & Germany 1999; United States 2001; Australia et al. 2005; United States 2007), together with non-governmental environmental reports (Tin & Roura 2004), have repeatedly described a variety of shortcomings in station operations and have pointed out frequent duplication of scientific projects. These reports have included recommendations regarding fuel transfer and storage, energy efficiency, use of renewable energy, waste management and sewage treatment, but at best the recommendations have been only partially implemented.

The unique situation and characteristics of the Fildes Peninsula and concerns about the environmental impacts

of human activity there have led to discussions about possible management measures that could supplement the existing ASPAs. A research project was commissioned in 2003 by the German Federal Environment Agency to provide a substantial body of data that would permit a thorough evaluation of environmental hazards for this area (Germany 2004). A risk analysis was carried out focusing on the often divergent practical requirement of nature conservation and environmental protection on the one hand, versus science, logistics and tourism activities. The final report of this study represented the first comprehensive assessment of the environmental situation for the whole Fildes Region (Germany 2008;

Peter et al. 2008). Peter et al. (2008) stated that an appropriate solution for coordination and reducing the conflict of interests would be the designation of the Fildes Region as an Antarctic Specially Managed Area (ASMA)—the only option that is legally binding for all Antarctic Treaty Parties. A draft ASMA management plan was prepared (Germany 2008).

At present the application of substantial and broad-scale management measures in the Fildes Region is being discussed at an international level through the Antarctic Treaty Consultative Meeting's Committee for Environmental Protection. During this protracted process ongoing research is required to keep the scientific database up to date and relevant for the discussion.

Earlier monitoring was repeated between 2008 and 2010 to provide an updated standardized assessment of fauna and flora of the Fildes Region, with focus on changes in human activities compared to the results of the previous monitoring in 2003–06 (Germany 2009). On the basis of this body of data, the prognosis for future developments in the Fildes Region supports the need for effective management measures to reduce negative

impacts of human activities in the region, e.g., through its designation as an ASMA.

Methods

For a scientific description—based on global positioning and geographic information systems—of some of the biotic and abiotic parameters found within the Fildes Region, the terrestrial environmental situation was studied during the summer seasons (December to March) in 2008/09 and 2009/10. We applied the methods of Peter et al. (2008; Table 1).

Besides the regular monitoring of the distribution of bird and seal breeding sites, and recording human activities and their associated environmental impacts, attention was also paid to any obvious infringements of the regulations contained in the ASPA management plan as well as the occurrence of non-native species. In addition to our own data we used information provided by personnel from the stations in the region. All data gathered within station boundaries were collected with the permission of the person or persons responsible for the station concerned.

Table 1 Overview of monitoring methods employed during the study. For further details see Peter et al. (2008).

Study object	Method
Seabird breeding pair numbers and distribution	Standardized seabird census with repeated counts and mapping (GPS- and GIS ^a -based)
Numbers and distribution of resting and moulting seals	Monthly seal counts
Seal pupping sites	Monitoring, reports of station members during winter months
Air traffic	Record of all flight activities per aircraft, classification by operator and type Registration of flights below the defined vertical (610 m) and horizontal (460 m) distance near concentrations of birds (SAT 2004, 2009c) Reference period from 10 December–26 February =79 days
Ship traffic	Record of all ships present in the Maxwell Bay, classification by operator and type Reference period from 10 December–26 February =79 days
Land traffic	Mapping of vehicle tracks beyond the existing road network (GPS- and GIS-based)
Status of current and historical waste deposits	Monitoring, mapping (GPS- and GIS-based)
Recent entry of waste in the environment	Mapping of waste items (except marine debris) brought in after 2006 (GPS- and GIS-based), identification by type, age, origin
Current station's waste management, including sewage treatment	Monitoring, reports of station members
Oil contamination: visible staining of soil and oily sheens on water bodies	Mapping (GPS- and GIS-based)
Impact of construction activities	Monitoring, mapping (GPS- and GIS-based)
Land consumption by stations	Mapping (GPS- and GIS-based), use of data set in Vogt et al. (2004)
Use of field huts	Monitoring, examination of hut register
Impact of scientific and leisure activities of station members and tourism	Monitoring
Tourism	Documentation of the marathon event in March 2009 Analysis of tourism statistics published by International Association of Antarctica Tour Operators

^aGlobal positioning system and geographic information system.

Results

Monitoring of fauna

The Fildes Region is a breeding area for 13 seabird species and reproduction site for four seal species (Figs. 2, 3,

Table 2). Skuas (*Catharacta antarctica lonnbergi*, *C. macrorhynchos*), Antarctic terns (*Sterna vittata*) and storm petrels (*Oceanites oceanicus*, *Fregetta tropica*) also breed in the vicinity of the stations and the airstrip. The highest breeding pair density was found on Ardley Island (ASPA No. 150).

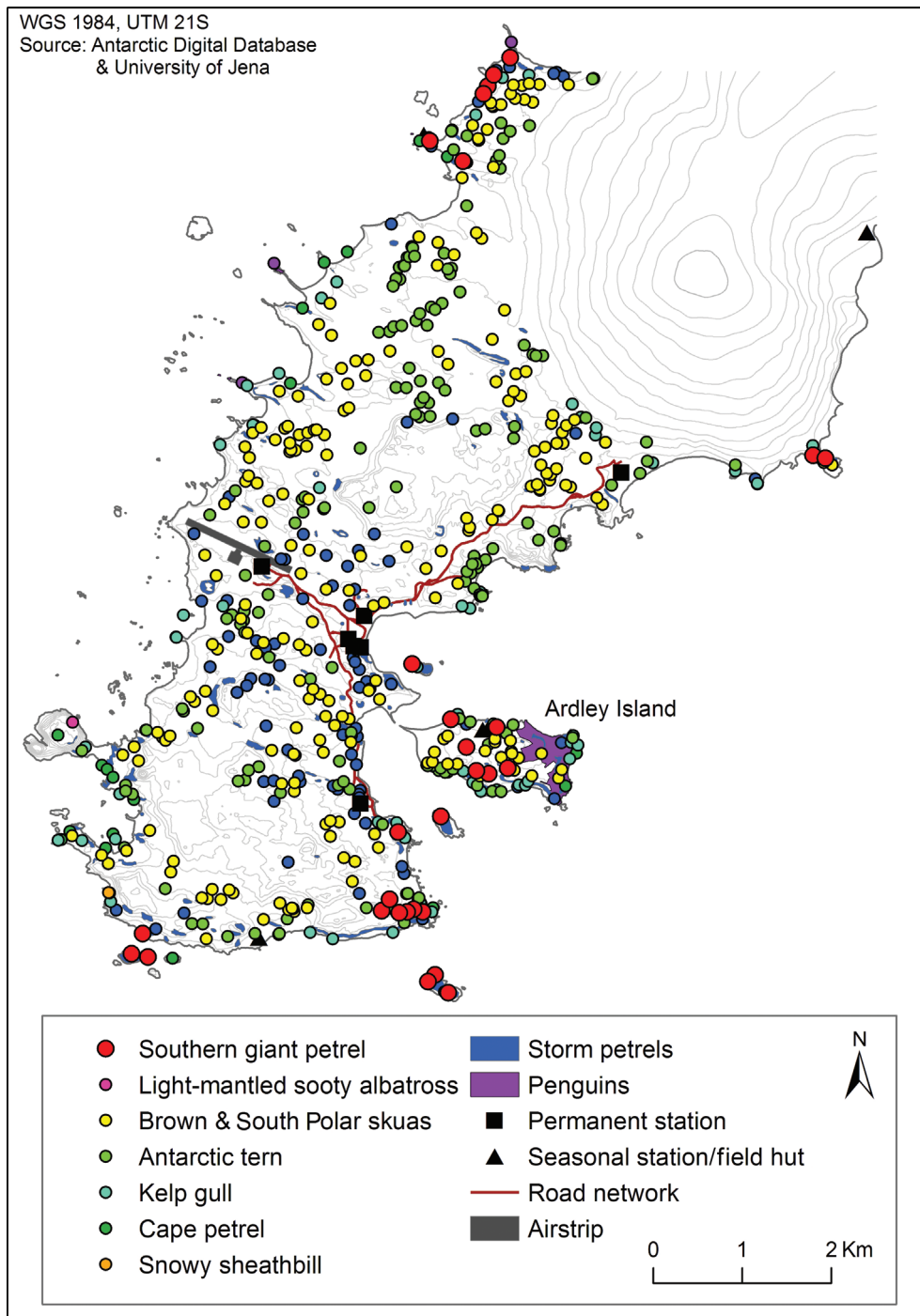


Fig. 2 The distribution of seabird breeding sites in the Fildes Region during the 2008/09 season.

The total breeding pair number of southern giant petrels in the Fildes Region increased during recent years (Peter et al. 2008), up to 407 pairs in 2008/09, but in the following season it decreased to 225 pairs. While southern giant petrels raised on average 0.42 ± 0.1 chicks per breeding pair between 2003/04 and 2005/06 (Peter et al. 2008), the breeding success between 2007/08 (unpubl. data) and 2009/10 decreased to 0.12 ± 0.13 chicks per breeding pair. The decline of breeding pair numbers and breeding success was much more striking in some colonies of southern giant petrel whereas others in adjacent colonies either showed no change or a slight increase in breeding pairs.

Monitoring of air traffic

The registration of local aircraft operations revealed a constant high level of air traffic in terms of days with flight activity. On average we observed aircraft flights on 69% of days during the study period. There was no significant change over the five studied seasons in numbers of flight days ($R^2 = 0.06, p = 0.68$; Fig. 4). Except for the 2008/09 season the main flight activity was caused by smaller aircraft (e.g., KingAir, BAE-146, Twin Otter), which were mainly operated for tourism purposes by Aerovías DAP, a private tour company offering flights from Chile to the Antarctic. The flight activity of aircraft operated by this company exceeded logistics flights by Hercules C-130 airplanes by up to 48%.

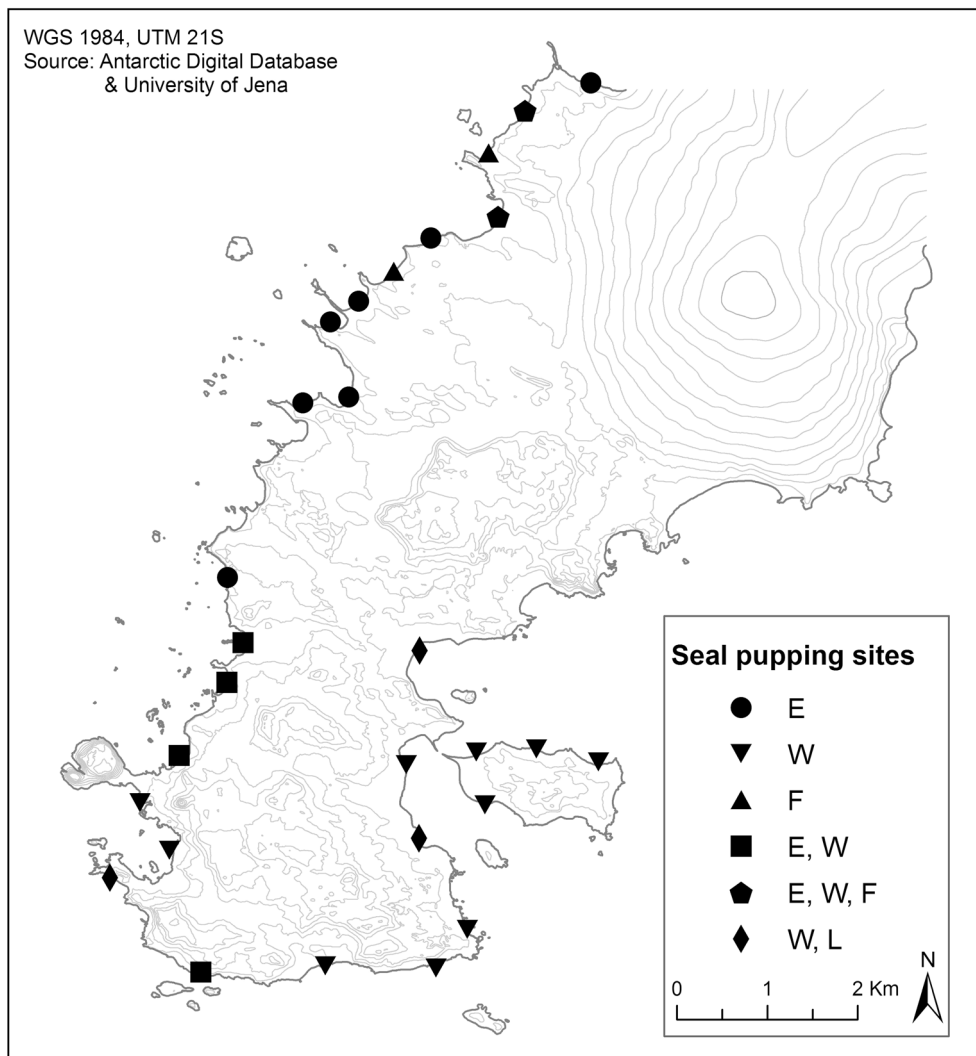


Fig. 3 The location of pupping sites for elephant seals (*Mirounga leonina*; E), Weddell seals (*Leptonychotes weddelli*; W), fur seals (*Arctocephalus gazella*; F) and leopard seals (*Hydrurga leptonyx*; L). Data from 2003/04 to 2009/10 are included.

Table 2 Breeding pair numbers in the Fildes Region during the 2008/09 and 2009/10 seasons.

Species	Breeding pair numbers
Chinstrap penguin (<i>Pygoscelis antarctica</i>)	8–11 (Ardley Island) (ca. 70 at western coast)
Gentoo penguin (<i>Pygoscelis papua</i>)	5083–5665
Adélie penguin (<i>Pygoscelis adeliae</i>)	307–545
Southern giant petrel (<i>Macronectes giganteus</i>)	297–350
Light-mantled sooty albatross (<i>Phoebastria palpebrata</i>)	0–5
Cape petrel (<i>Daption capense</i>)	>300
Wilson’s storm petrel (<i>Oceanites oceanicus</i>)	ca. 3500–5000
Black-bellied storm petrel (<i>Fregatta tropica</i>)	ca. 500–1000
Brown skua (<i>Catharacta antarctica lonnbergi</i>)	27–59
South Polar skua (<i>Catharacta maccormicki</i>)	146–178
Mixed skua pairs (<i>C. a. lonnbergi</i> x <i>C. maccormicki</i>)	11–16
Kelp gull (<i>Larus dominicanus</i>)	50–109
Antarctic tern (<i>Sterna vittata</i>)	<100–700
Snowy sheathbill (<i>Chionis alba</i>)	1–2

Station-based helicopters were used more often than ship-based helicopters (Fig. 4). Although a slight decrease of total helicopter flight days was observed over the five studied seasons, this does not indicate a generally reduced use of this aircraft type, but rather a higher concentration on certain days on account of weather conditions. Helicopters are intensively used during logistics operations, usually carrying out many flights per operation to transport cargo and persons between stations, ships and the airstrip.

After a steady decrease in aircraft passenger numbers during five seasons (IAATO 2004, 2005, 2006, 2007, 2008), tourism-motivated overflights by passenger jets (Boeing 737-200, Airbus 319) were not offered in 2008/09 and 2009/10 (Fig. 4; IAATO 2009, 2010a).

The number of observed flights below the defined vertical (610 m; 2000 ft) and horizontal (460 m; 1500 ft) distance (SAT 2004, 2009c) near ASPA No. 150 Ardley Island decreased significantly ($R^2 = 0.76$, $p = 0.05$; Fig. 5) as well as the number of days with such overflights ($R^2 = 0.81$, $p = 0.03$, Fig. 5). The overflights were operated almost exclusively by national Antarctic programmes.

Monitoring of ship traffic

The number of ship arrivals in Maxwell Bay increased significantly over the five studied seasons ($R^2 = 0.80$, $p = 0.04$; Fig. 6), mainly caused by supply, research and patrol vessels. In contrast, the strong increase in days

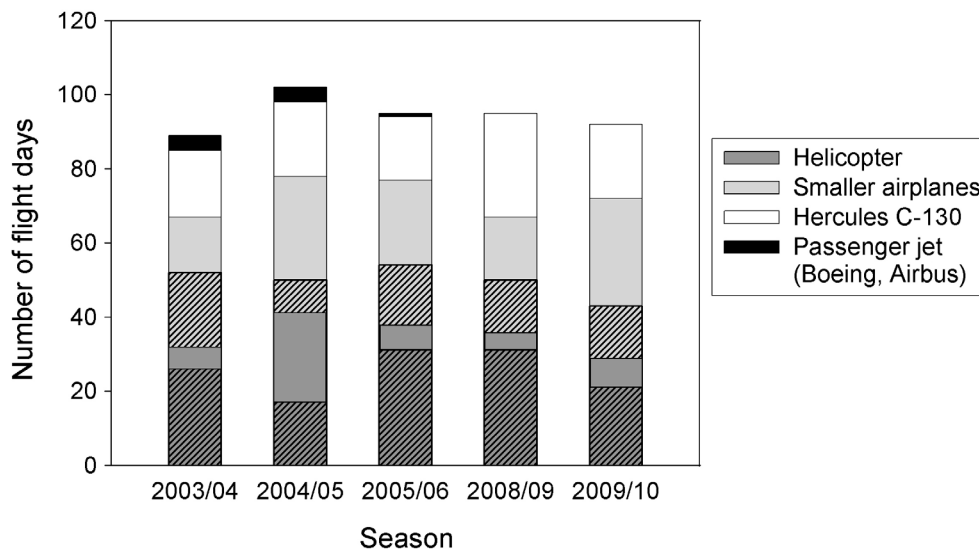


Fig. 4 Number of days with flight activity in the Fildes Region by aircraft type, between 10 December and 26 February each season. Shading indicates the proportion of station-based aircrafts.

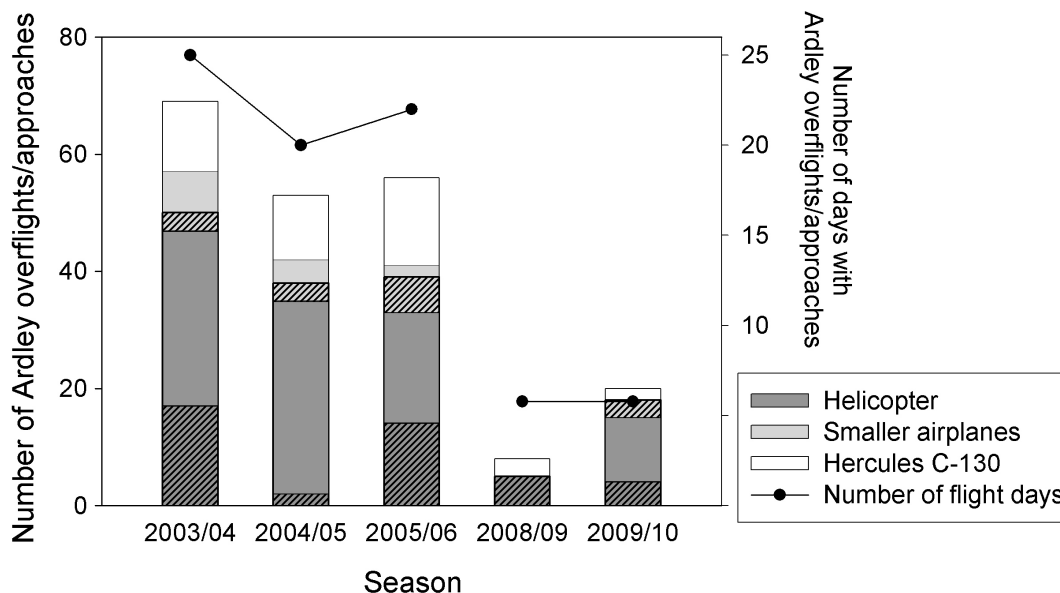


Fig. 5 Observed incidences of flights within the overflight exclusion zone, i.e., below the altitude (610 m) or within the horizontal distance (460 m) set out for Ardley Island in Resolution 2 (SAT 2004).

with ship traffic seen between 2003 and 2006 (Peter et al. 2008) did not continue ($R^2=0.60$, $p=0.12$; Fig. 6). Both findings indicate a growing accumulation of ships, with up to seven ships in Maxwell Bay at the same time (Peter et al. 2008). These peaks of ship activity are often connected with peaks in aircraft use and other activities, for example, station visits by ship crews or tourists or cargo transport with inflatable boats and heavy vehicles.

Monitoring of land traffic

Compared to previous data (Peter et al. 2008), an increasing amount of vehicle tracks beyond the existing road network was recorded (unpubl. data). Many of these tracks are carved deeply into the permafrost soil and are very often associated with visible damage of vegetation (Fig. 7a). These tracks are linked to scientific and leisure activities and mainly were caused by the

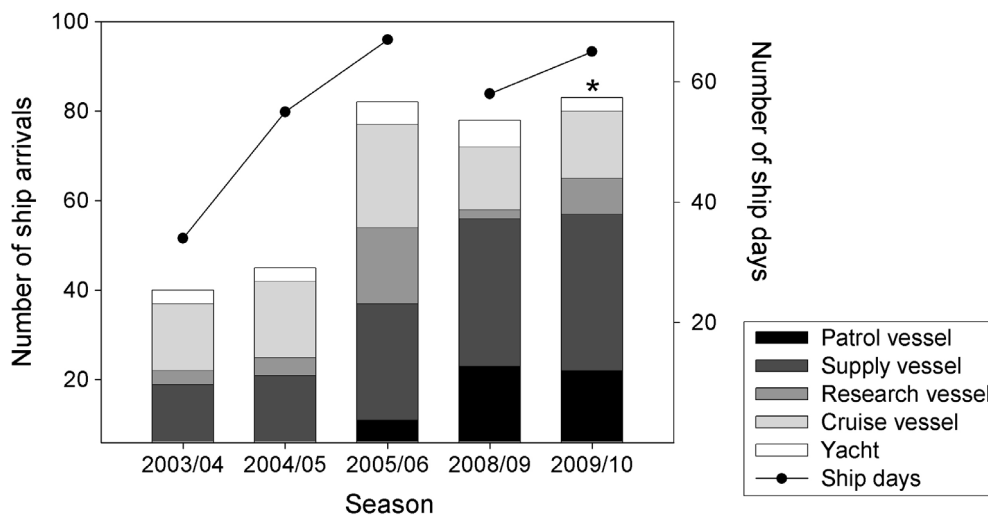


Fig. 6 Number of ship arrivals in Maxwell Bay by type of ship (left axis) and number of ship days (right axis, not summable). The asterisk represents one additional unknown freight ship, not included in the other categories.

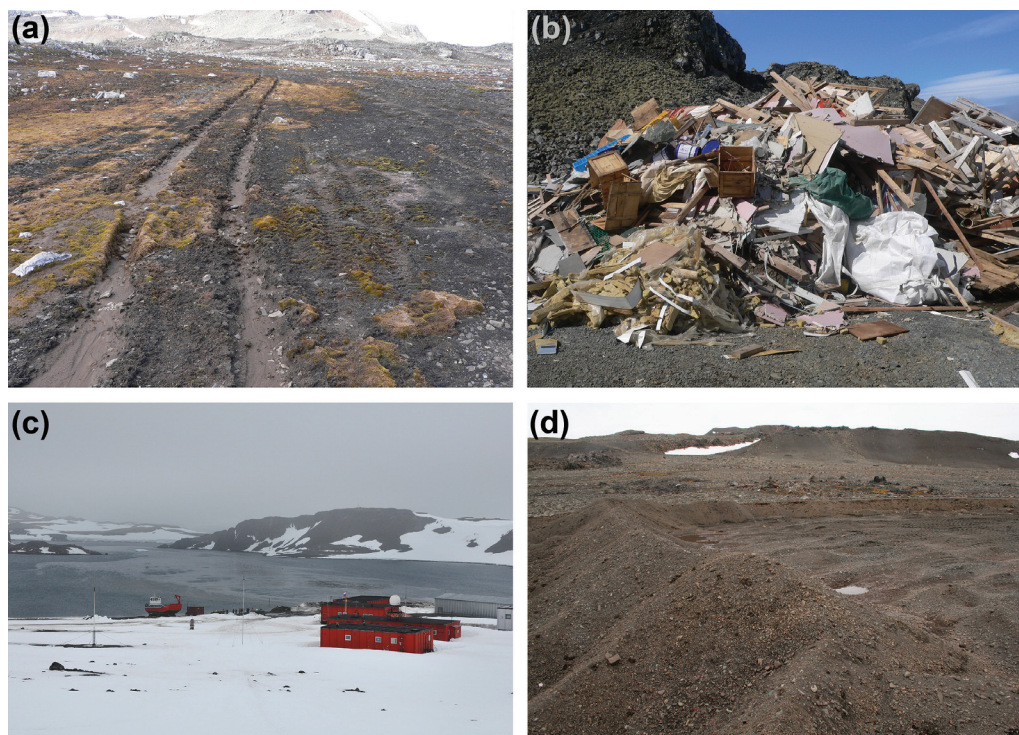


Fig. 7 Examples of environmental impacts in the Fildes Region: (a) vegetation damage caused by land traffic; (b) open waste deposit; (c) diesel plume in Maxwell Bay (visible as the sheen on the ocean in the centre of the image); and (d) beach ridge, damaged by quarrying.

increasing use of four-wheel motorcycles, which allow access to regions not previously affected by vehicle traffic.

Monitoring of waste management

We observed several efforts to improve waste management in the stations compared with the first monitoring period. For example, the remains of some destroyed or collapsed buildings were removed from the Fildes Region. However, several decayed field huts still remain. As in the first monitoring period, we observed the remains of open waste burning and open waste dumps, which included hazardous items. A major incident was the open storage of a wide variety of unsorted material (construction waste, insulation material, cardboard, paint buckets, batteries, fire extinguishers) inappropriately stored outside during the 2008/09 season for at least four months without any measures to prevent distribution by wind drift (Fig. 7b). Large amounts of lighter weight waste materials were spread over the southern part of Fildes Peninsula and into Maxwell Bay (Fig. 8). Due to the predominantly westerly main wind direction, ASPA No. 150 Ardley Island was heavily affected. Levels

of waste distribution in the northern part of Fildes Peninsula were lower.

In recent years, the main sources for skuas and gulls to gain access to anthropogenic organic material has been eliminated by the storage of human food remains in closed rooms or in locked containers (Peter et al. 2008). Nevertheless, the banned practice (see Annexes II and III of the Madrid Protocol) of actively feeding skuas and gulls with human food and food remains, including poultry products, was observed at all stations on Fildes Peninsula.

Since the 2008/09 season all stations on Fildes Peninsula have installed and operate sewage treatment plants of different levels of sophistication. Before then, one station discharged waste water without treatment despite the fact that the number of resident summer station personnel exceeded the recommended maximum of 30 people (see Annex II of the Madrid Protocol). Treated effluent is directly discharged into the sea with one exception, where the treated water is drained into a stream approximately 1 km from the coast. At some sewage outfalls discharged water had a pungent smell and high turbidity, probably indicating poor or ineffective sewage treatment.

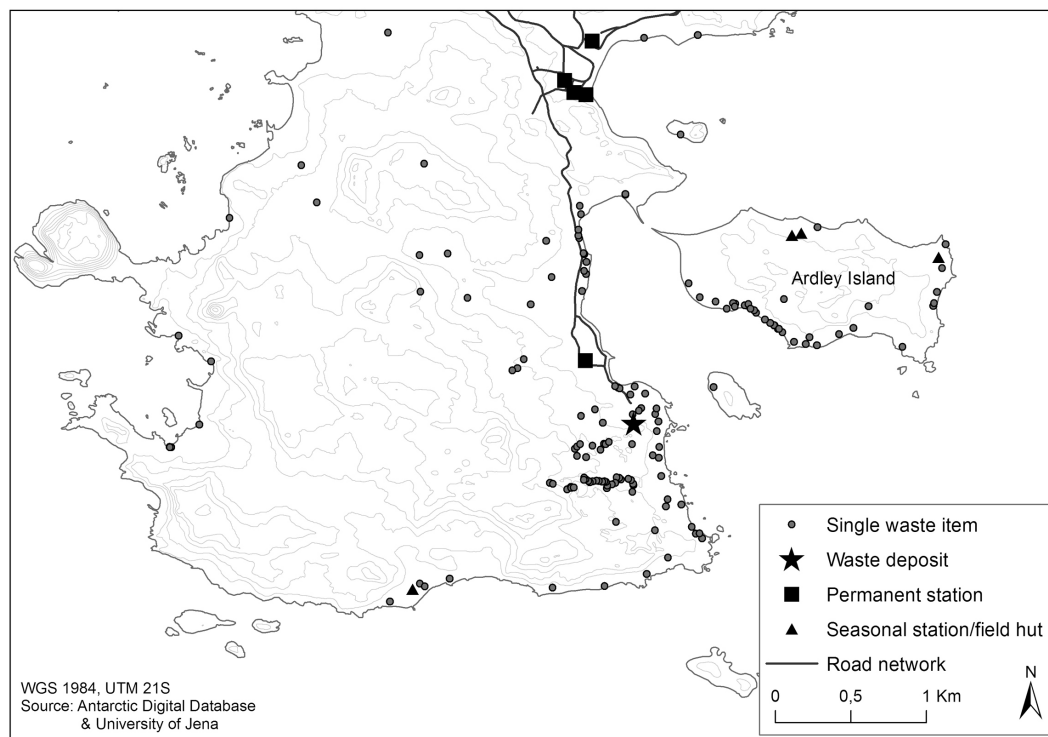


Fig. 8 Waste distribution in the southern part of the Fildes Region; only items recorded after 2006 are presented.

Monitoring of oil contamination

Hydrocarbon contamination, observed as visible staining of soil and oily sheens on water bodies, was noted along the existing road network and within the boundaries of almost all stations. Oil pollution was mainly caused by spills that occurred during fuel transfer or came from damaged vehicles, as a result of leaking station pipelines and tanks and when contaminated soils were remobilized with heavy precipitation (Peter et al. 2008). In spring 2009 a major oil spill, originating from a tank that started leaking some time during the previous winter, was recorded. This led to the release of an unknown amount of diesel fuel into the snow and, with the onset of snowmelt, into a stream that crossed the station and discharged into Maxwell Bay (Fig. 7c). The pollution continued throughout the following summer. Applied mitigation measures included the removal and burning of contaminated snow, the application of absorbent oil booms in the stream and the use of inflatable boats in Maxwell Bay to increase the fuel evaporation. The measures were largely inadequate and failed to prevent chronic and widespread pollution of the local marine environment (Fig. 7c). The spilled oil was in close proximity to the penguin colony on Ardley Island (ASPA No. 150), and penguins were observed regularly diving through the dense plume of diesel.

Construction activities

The activity with potentially the most impact on Fildes Peninsula is the ongoing construction activity at and around stations. In order to fulfil current and future demand, new buildings have been erected and existing facilities extended or renewed at five out of six stations since 2006. In one case, this included the replacement of severely corroded single-walled fuel tanks by double-walled, but not bunded, tanks. The significant expansion of one station caused clear environmental impacts ranging from an increased level of oil pollution by leaking vehicles, major waste entry into the environment and the local extraction of construction material. The local extraction and removal of sand and gravel for building purposes led in some instances to heavy disturbance or even a complete destruction of seabird breeding sites (skuas, gulls, terns, storm petrels), damage of areas with dense vegetation and a permanent change of the landscape. Despite their high scientific value for regional and global palaeoclimate research, a number of beach ridges were quarried for construction material (Fig. 7d). The total affected area covered more than 40 000 m². According to our information (anonymous station leader, pers. comm.), an environmental impact assessment (EIA) was not undertaken in advance of the quarrying.

Monitoring of scientific, leisure and tourism activities

Science. The environmental impact of scientific field work is generally hard to assess as access to information is sometimes limited. All national Antarctic programmes emphasize the increase in scientific research in the Fildes Region. Therefore, associated environmental impacts are likely to increase proportionately, especially if methods are selected without carrying out appropriate EIAs and putting mitigation steps in place. During our study we observed broken installations of long-term experiments left in place after one or two seasons and unnecessary vehicle use beyond the road network, which often led to extensive damage of vegetation, disturbance of birds and seals or residues left in the field.

Station personnel recreational activities. The leisure activities of station members make a substantial and growing contribution to human disturbance of fauna and flora in the region. In particular, we recorded frequent excursions into sensitive and/or protected areas, for the purposes of taking photographs or fishing, for example. Leisure visits to protected areas were not in compliance with the ASPA management plans (SAT 2009b,c). We also observed local station personnel occasionally collecting fossils and minerals and touching or catching animals to take their photographs (C. Braun, A. Nordt, pers. obs.).

Tourism industry. Tourism, which IAATO classifies as sea-borne, air-borne and combined air- sea-borne, represents another important aspect of human activity in the Fildes Region. The number of landings of cruise ship passengers (sea-borne tourism) did not show an increase during the study period (IAATO 2010b). Although exact data are difficult to obtain, the increased number of flights operated by the Chilean air company (see above), which offers one- or two-day tours, indicates an increase in air-borne tourism. The relatively new combined air-cruise package permits the transfer of passengers between cruise vessels and the Fildes-Punta Arenas air-link. Sparing tourists the potentially rough crossing of the Drake Passage by ship, air transport has shown steady growth in recent years. The numbers of transported passengers between 2003/04 to 2009/10 rose almost 10-fold (IAATO 2004, 2010a). Nevertheless, no direct negative impacts have been associated to date with these types of tourism.

The marathon in March 2009 was carried out in line with accepted IAATO guidelines (SAT 2009a). The track

was marked by guides after consultation with scientists. The runners (189 in total) were landed from two ships at two separate landing sites. The track mainly followed the existing road network. Within a distance of about 30 m the runners crossed an area with sparse moss vegetation (coverage ca. 10%) that was affected negatively. Apart from using a station's garage to house vehicles imported for use during the marathon, no station facilities were used. All materials were taken back to the ships and no noteworthy litter was left after the event. In March 2010 a reduced number of 97 runners participated in the event.

Tourism associated with national Antarctic programmes. Another category of tourism is passengers travelling on national Antarctic programme ships. In contrast to IAATO-regulated tourism, passengers travelling with national Antarctic programmes were usually not guided during landings. On several occasions such passengers were observed without guides approaching close to penguins and seals. When queried, the passengers had no knowledge of the existing IAATO and Antarctic Treaty System visitor guidelines (Government of Japan 1994).

Official delegations, media and educational visits. The spectrum of other visitors frequently arriving in the area includes official (inter)national delegations, media teams and educational programmes. Even though exact data are not available, the number of educational programmes seems to be increasing in the Fildes Region, with almost all stations involved to some extent in such programmes. Some shortcomings were noted regarding the preparation and execution of these programmes, including entry into an ASPA for scientific sampling without an appropriate permit.

Discussion

The manifold human activities in the Fildes Region led to extensive environmental impacts at a local scale.

Fauna

Our seabird monitoring showed that the highest breeding pair density was on Ardley Island, which was one of the main reasons for its designation as ASPA No. 150. During breeding, skuas, terns, gulls and storm petrels did not appear to avoid areas of concentrated human activity, such as around stations. This suggests that these birds are

habituated to people and are not highly sensitive to continuous or frequent stressors like noise and visitors. Generally, habituation occurs if disturbance is regular and predictable (de Villiers 2008), as has been shown for Antarctic seabirds in various studies (e.g., Young 1990; Nimon et al. 1995; Fraser & Patterson 1997; Cobley & Shears 1999). On the other hand, southern giant petrels have been characterized as a highly sensitive species in terms of human disturbance (González-Solís et al. 2000; Micol & Jouventin 2001; Pfeiffer & Peter 2004) and their breeding success can be considered as a sensitive indicator of human disturbance (Peter et al. 2008). Declines in bird population near stations and relocation of nest sites away from areas of human impact have been observed in the Fildes Region (Peter et al. 1991; Chupin 1997; Pfeiffer 2005; Peter et al. 2008). The current rapid decrease in southern giant petrel breeding pair numbers and breeding success at some breeding sites is unlikely to be attributable solely to environmental conditions (e.g., food availability, climatic conditions, predation) as adjacent colonies which should be subject to the same natural factors were unequally affected. Human disturbance seems to be the immediate reason for these observed changes since only areas which are frequently visited during summer by station members in their leisure time showed greater declines. The slight increase in some adjacent colonies suggests a nest site shift.

The presence of pupping sites for four seal species in the Fildes Region represents another vulnerable aspect prone to human disturbance, especially in areas close to the station or field huts.

Air traffic

As a logistics hub the Fildes Region is characterized by a great deal of flight activity involving different types of aircraft. The regular flight route crosses the central part of the Fildes Peninsula in a west-east/east-west direction. Pfeiffer (2005) found evidence of habituation effects in skuas and southern giant petrels if the recommended main flight route and altitude are followed. In contrast, other flight patterns, including low overflights, may have caused physiological and behavioural reactions, e.g., heart rate increase, fly-off behaviour or nest site shift (Pfeiffer 2005).

We observed flights below the recommended vertical and horizontal distance near concentrations of birds (SAT 2004, 2009c), although much less than reported by Peter et al. (2008). This could be explained by the increased acceptance and implementation of the guidelines.

Up to now, all flight activities in the Fildes Region have relied on suitable weather conditions and visibility for

landing and take-off. The adverse and rapidly changing maritime climate causes delays and cancellations of many flights. The installation of a transponder landing system (TLS) in the 2009/10 season, to allow flight operations even under conditions of low visibility, will presumably further increase the number of flights in the Fildes Region. The greatest increase is expected to be in tourist flights. Previously, bad weather caused delays in essential logistic flights while many tourism flights were cancelled altogether. Together with the construction of a parking zone for large aircraft beside the runway in 2004/05 (Peter et al. 2008), the TLS may allow more flights and extend the regional importance of the airport.

Ship traffic

The proportion of cruise vessels in the increased ship traffic was relatively low during the study period, even though the levels of passenger exchange via air-cruise tour packages have grown. As the Fildes Region is not a preferred destination during Antarctic cruises (Lynch et al. 2010), a number of cruise vessel visits was linked exclusively to the transport of scientists or the medical evacuation of passengers.

It is expected that the observed peaks in human activity during cargo operations of ships have led to some cumulative environmental effects, at least at the stations and their vicinities. This includes increased noise emission as well as disturbance of resting seabirds and seals by supply vessel crews.

We expect levels of future ship traffic in the Fildes Region to remain high or increase further. Although a number of ships will be affected by the International Maritime Organization's ban on heavy fuel in the Antarctic, which entered into force in August 2011 (IMO 2010), the ban may not lead to a long-term reduction in ship traffic in the Fildes Region. IAATO does not expect any significant effect on the number of cruise vessels carrying fewer than 200 passengers (IAATO 2010a), which is the most common type of cruise vessel visiting the Fildes Region. It is hard to estimate the extent to which supply and research vessels will be affected by the heavy fuel ban. However, in combination with the airstrip, the planned construction of docking facilities at two stations in the next few years (CAA 2007; Anonymous 2010) will facilitate easier passenger landings and cargo operations.

Land traffic

Stations on the Fildes Peninsula are connected to one another by a gravel road network and each national

programme has a variety of vehicles to transport people and/or cargo. While the regular land traffic moves along the roads, off-road vehicle use beyond the existing road network is occasionally linked with scientific purposes but mainly with leisure activities (C. Braun, A. Nordt, pers. obs.). Due to the high vegetation coverage (Peter et al. 2008), off-road vehicle movement leads often to physical destruction of vegetation. Our experience shows that the botanical knowledge of station personnel is limited; for example, many do not consider lichens as vegetation. Only a few publications have dealt with the effect of physical human disturbance on Antarctic flora (e.g., Bargagli 2005), reflecting a lack of scientific study (Tin et al. 2009). Nevertheless, it is known that vehicle tracks can be visible for decades, with mosses likely to be more vulnerable than lichens (Peter et al. 2008).

Off-road traffic may cause negative effects on seabirds and in some cases on seals. Because gulls and southern giant petrels usually nest at elevated sites along the coastline on Fildes Peninsula, the breeding sites of these birds are hard to access by vehicles. In contrast, skuas and terns breeding in more open areas are more vulnerable to direct disturbance by off-road driving and the associated noise. The degree of impact may depend on the species concerned, the timing of the disturbance relative to the breeding season of the species and the distance between the vehicle and the wildlife. Behavioural and physiological responses may result in increased energy costs of breeding birds, especially during the reproduction period (de Villiers 2008). Abandonment of the nest may lead to brood failure by cooling of the clutch or predation of eggs and chicks by predators (de Villiers 2008).

Waste management

The findings of this study reveal several shortcomings regarding current waste management practice in some stations. The existence of open waste dumps and the practice of open waste burning are contradictory to the guidelines of the Madrid Protocol (Annex III). Furthermore, some waste items brought into the environment may cause injury to resting seals or may impact breeding birds, e.g., by covering nest burrows of storm petrels.

There is a high risk that bird interactions with anthropogenic organic material may lead to the introduction and spread of diseases in Antarctic animals (e.g., Parmelee et al. 1979; Hemmings 1990; Gardner et al. 1997; Australia 2001; Bonnedahl et al. 2005). However, repeated requests over a period of years from scientists specializing in birds and marine mammals did not prevent station personnel from actively feeding skuas.

Sewage treatment plants are in operation at all stations on Fildes Peninsula. Recent installations of modern sewage treatment plants demonstrate growing efforts by national Antarctic programmes to fulfil the guidelines of the Madrid Protocol. Nevertheless, a constant monitoring regime should be implemented to guarantee the efficiency of the treatment processes and to minimize the risk of introducing nutrients, pollutants and alien micro-organisms (Smith 2000; Hughes 2003; Conlan 2004, 2010; ASOC 2009; Grondahl et al. 2009; Smith & Riddle 2009). Several studies have shown that discharging even low volumes of sewage may have a significant effect on the environment (ASOC 2009; Tin et al. 2009). Marine biologists reported that the sea floor off the coast of the central part for the Fildes Peninsula is covered with a layer of organic material of anthropogenic origin and shows a very low biodiversity of marine organisms (ASOC 2007).

Oil contamination

Oil contamination in the Antarctic is one of the most widespread environmental impacts of human activity. The consequences of an oil spill in the Antarctic are especially pronounced because oil degrades so slowly in cold climates (e.g., Filler 2008; Tin et al. 2009). Much of the infrastructure on Fildes Peninsula connected with fuel storage and transfer is in need of upgrading and improvement (Australia et al. 2005; United States 2007). Due to poor fuel handling and maintenance of vehicles, minor and local oil spills frequently occur within station areas and along the road network. Following the recommendations of the Council of Managers of National Antarctic Programs (COMNAP 2008), efforts are being made to replace old single-walled fuel tanks and improve fuel handling protocols. However, contingency plans and resources needed to contain an oil spill are not available at all stations. Therefore, the containment and remediation measures applied during the major oil spill in 2009 were limited in their extent and effectiveness. Although neither direct nor indirect negative effects (e.g., reduced survival rate or breeding success) were recorded in penguins breeding on Ardley Island, they cannot be ruled out. Possible indirect impacts on wildlife of sub-lethal exposure to oil include increased susceptibility to disease, increased energy costs or perturbation of parental behaviour (Eppley 1992).

To avoid the continuation of the chronic fuel spillage all recommendations made by Council of Managers of National Antarctic Programs (COMNAP 2008) should strictly be followed.

Construction activities

The extensive environmental impacts of recent construction activities in the Fildes Region that we observed illustrate the problems that occur during the planning and execution of such projects. Pursuant to the Madrid Protocol, projects that are likely to exceed “minor or transitory” impacts should be subject to the highest level of EIA, known as a comprehensive environmental evaluation (CEE). However, on the Fildes Peninsula, the level of EIA has not always been appropriate for the likely level of impact. For example, an initial environmental evaluation (IEE), which implicates “minor or transitory” impacts, was prepared for the expansion of a station, but the impact caused by the local extraction of material resulted in the destruction of beach ridges. This long-lasting environmental damage could have been predicted—and thereby avoided—had a CEE been carried out. We are not aware if any monitoring or other procedure has been put in place to assess and verify the impact of the construction process, as called for in Annex I of the Madrid Protocol.

Our observations support earlier reports that the level of EIA is not always commensurate with the likely level of environmental impact (ASOC 2007; Bastmeijer & Roura 2008). In particular, cumulative effects of the station expansion were not fully considered in the EIA process. Cumulative effects may include (1) direct impacts, such as the emission of noise or pollutants (e.g., cement dust) or physical damage to vegetation or bird breeding sites, while (2) indirect impacts may include increased fuel consumption or increased waste and waste-water production by the higher number of personnel supported by the expanded stations. The accommodation of more people in the area will also increase the potential risk of human disturbance of local flora and fauna (see below).

A positive consequence of the recent construction and modernization activities has been the implementation of recommendations made following earlier inspections (Australia et al. 2005; United States 2007) regarding the replacement of old single-wall fuel tanks and the installation of a permanent fuel pipeline that reduces the oil spill risk.

Scientific, leisure and tourism activities

Some scientific research is known to have considerable environmental impacts (e.g., Blackmer et al. 2004; de Villiers 2008), especially if it requires direct contact with flora and fauna, e.g., approaching or handling animals (ASOC 2007; Tin et al. 2009). Inadequate coordination and cooperation between researchers on King George

Island, and especially in the Fildes Region, is widely recognized and the Scientific Committee on Antarctic Research (SCAR) has expressed concern (SCAR 2001, 2009a). Lack of coordination may lead to duplication of research projects and greater cumulative environmental effects. Scientists working in the same area may also inadvertently impact upon one another’s research, which may have detrimental effects on the quality and usefulness of the results. For example, birds have been studied simultaneously by more than one research group, compromising the quality of the data collected (Peter et al. 2008). However, these factors are difficult to assess objectively. Researchers currently depend on personal communication with scientists from other national programmes working in similar disciplines in order to make known their plans for similar field research and to avoid potential conflicts.

In general, the area would benefit from more attention being paid to the methods being used, the preparation and execution of fieldwork and the removal of field equipment once the work is complete. SCAR recently published an environmental code of conduct for terrestrial scientific field research in Antarctica which could be usefully applied (SCAR 2009b).

While ongoing discussions on the impacts of human activities on the Antarctic environment concentrate mainly on the tourism aspect (Stewart et al. 2005), relatively little is known about the impact of participants of national programmes. The activities of station personnel have caused shifts in breeding areas and population declines in birds and seals (Chwedorzewska & Korczak 2010). Non-indigenous species introductions are a major threat to Antarctic ecosystems and there is strong evidence that national programme personnel throughout Antarctica carry a higher propagule load than tourists (SCAR 2010). The large number of station personnel in the Fildes Region and the extended period over which the area has been occupied means there is a high risk of negative impacts on fauna and flora (Headland 1994); extensive damage to the environment has already occurred.

Tourists in the Fildes Region undertake a wide spectrum of activities and the numbers arriving by cruise vessel or airplane far exceed the number of station personnel. Nevertheless, national programme personnel account for more person-days ashore, and the lack of care and awareness shown by some station workers means that personnel are more likely than tourists to be associated with the environmental damage observed in the area (Headland 1994; Haase 2005; Riddle 2010). Our experience shows that station personnel in the Fildes Region roam almost freely in the whole area. In personal

discussions a number of station personnel expressed the opinion that the Antarctic environment is not susceptible to damage and not worth protecting. One reason for this view may be that some station members, including scientists, arrive in the Antarctic without an appropriate environmental briefing (anonymous technical and scientific station personnel, pers. comm.). Not all station personnel were aware of the existence of formal management plans for the two ASPAs and copies of these documents were unavailable at some stations. In contrast, most tourists are strictly guided, limited to certain routes and are briefed about existing guidelines, such as those recommended by IAATO and by the Antarctic Treaty System. Therefore, the local environmental impact of tourism in the Fildes Region is considered to be lower than the impact of national programme personnel.

The impact of the yearly marathon event was also considered to be low, as it takes place at the very end or after the bird breeding season and is restricted to the existing road network. Adverse effects of the marathon on scientific projects (Chile 2009) are not known, mainly because at time of year most scientists have already left the Antarctic.

Invited or paying passengers transported to the region on supply or patrol vessels belonging to some national Antarctic programmes are also, in effect, tourists (Hall 1992; Riffenburgh 1998). They should receive an appropriate environmental briefing (Government of Japan 1994) and should be guided in order to avoid negative impacts on fauna and flora.

Educational programmes should be managed appropriately and, when indicated, coordinated with ongoing scientific projects.

Possible future management

The framework of the Madrid Protocol sets forth a multitude of management strategies aimed at protecting the Antarctic environment, such as the implementation of a zoning system, codes of conduct and site guidelines. The designation of the area as an ASMA offers an integrated strategy to (1) manage the conflicts of interests between nature conservation, science, logistics and tourism, (2) to rationalize scientific activities and (3) minimize the impact of diverse human activities. ASMA designation but requires consensus across all National Antarctic Programmes active in the region and, unlike alternative management measures, it represents the only management tool that is legally binding for all Treaty Parties. ASMAs are currently designated at seven locations, including Deception Island and Larsemann Hills (SAT 2005, 2007), which have a similar scale and which

experience similarly diverse human activities as the Fildes Region. Expertise gained through the management of the Deception Island and Larsemann Hill ASMAs could be applied usefully to the Fildes Region (SAT 2010; United States 2010). In our view, designating Fildes Region as an ASMA would be the best way to minimize the negative effects of human activities in the area.

According to the definition and objectives set out in the Madrid Protocol, the Fildes Region would be a suitable candidate for an ASMA. Designating the Fildes Region as an ASMA would allow for effective environmental management while taking into consideration the requirements of multiple stakeholders. To discuss management approaches for the Fildes Region, possibly aiming at drafting a management plan for an ASMA, Germany and Chile convened an international working group, involving government representatives of Parties with stations and/or huts in the area, Parties with an interest in the area and Observers to the Antarctic Treaty (Germany & Chile 2010). So far, two draft management plans have been presented for discussion by Germany at meetings of the Committee for Environmental Protection in 2007 and 2010, including a proposal for a zoning system, the establishment of a management group and codes of conduct for a facility zone, and for scientific research according to SCAR recommendations (Germany 2007, 2010). Ideally, a coordinated monitoring of environmental impacts should be undertaken by all national Antarctic programmes (Hughes 2010; Kennicutt et al. 2010).

Conclusions

The Fildes Region shows a variety of environmental impacts due to the concentration of stations and the wide range of human activities. Our analysis shows that the most significant environmental threats, and those that should receive highest priority, are (in no meaningful order) (1) habitat destruction by quarrying, (2) chronic hydrocarbon contamination, (3) human disturbance caused by station personnel, (4) inadequate waste management and (5) vegetation damage by vehicle use.

Since the implementation of the Madrid Protocol in 1998 (Annex V), some improvements have been made in the management of waste, oil or sewage by individual national Antarctic programmes acting individually (ASOC 2007). Nevertheless, insufficient cooperation between the diverse stakeholders present in the region has led to quantifiable cumulative impacts which require a more comprehensive and broad-scale management approach. If no additional management measures are generated and implemented, future levels

of environmental impacts, including ecosystem damage and disturbance of fauna and flora, will almost certainly be higher than at present.

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