TEXTE
26/2017

Monitoring the consequences of local climate change on the natural resources of the ice-free regions of Maxwell Bay (King George Island, Antarctic)

Final Report

Umwelt Bundesamt

TEXTE 26/2017

Environmental Research of the
Federal Ministry for the
Environment, Nature Conservation,
Building and Nuclear Safety

Project No. (FKZ) 3712 87 100
Report No. (UBA-FB) 002366/ENG

Monitoring the consequences of local climate change on the natural resources of the ice-free regions of Maxwell Bay (King George Island, Antarctic)

by

Christina Braun, Jan Esefeld, Dr. Hans-Ulrich Peter
Polar and Bird Ecology Group, Institute of Ecology,
Friedrich-Schiller-University Jena

On behalf of the German Environment Agency

Imprint

Publisher:
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
info@umweltbundesamt.de
Internet: www.umweltbundesamt.de

/umweltbundesamt.de
/umweltbundesamt

Study performed by:
Institute of Ecology, Friedrich-Schiller-University Jena
Friedrich Schiller-Universität Jena
Dornburger Straße 159
07743 Jena
Germany

Study completed in:
December 2017

Edited by:
Section II 2.8 Protection of the Arctic and Antarctic
Fritz Hertel

Publication as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4804

Dessau-Roßlau, March 2017

The Project underlying this report was supported with funding from the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear safety under project number FKZ 3712 87 100. The responsibility for the content of this publication lies with the author(s).

Abstract

The Fildes Region (King George Island, South Shetland Islands), consisting of the Fildes Peninsula, the neighbouring Ardley Island and all larger, nearby islands, is one of the largest ice-free regions in maritime Antarctica and has a relatively high level of biodiversity. This area also represents the logistical centre of the Antarctic Peninsula with its six permanent stations, numerous field huts and an airstrip which often leads to conflict of interests between the different use groups. Given the great importance of long-term monitoring programmes, especially in regions with natural resources at high risk and in areas of rapid climatic change, the survey of local breeding birds and seal communities started in the 1980s in the Fildes Region was continued in the summer months (December to February) of the 2012/13 to 2014/15 seasons. Besides, a monitoring of breeding birds in all large ice-free areas of Maxwell Bay, which borders the Fildes Region. These included the Barton, Weaver and Potter Peninsulas, Green Point (all on King George Island) and for the Stansbury Peninsula, Martin and Duthoit Points (all on Nelson Island). To analyse long-term trends in the bird and seal populations, extensive data from numerous, still unpublished expedition reports of German scientists from the 1980s and all available literature were added to recent observations. The results of both monitoring focus areas are presented in this research report. It could be shown, that regarding their breeding pair numbers most seabird species depend primarily on environmental factors, whereas others are more affected by anthropogenic impacts. Additionally, considerable glacial retreat in selected regions of the Maxwell Bay with reference to the regional climate changes were documented on the basis of aerial and satellite images.

Kurzbeschreibung

Die Fildes-Region (King George Island, South Shetland Islands), bestehend aus der Fildes Peninsula, der angrenzenden Ardley Island sowie allen größeren benachbarten Inseln, gehört zu den größten eisfreien Gebieten im Bereich der maritimen Antarktis und weist eine vergleichsweise hohe Biodiversität auf. Gleichzeitig repräsentiert diese Region mit sechs ansässigen Stationen, zahlreichen Feldhütten sowie einer Landebahn das logistische Zentrum im Bereich der Antarktischen Halbinsel, woraus häufig Interessenkonflikte zwischen den verschiedenen Nutzergruppen resultieren. Aufgrund der hohen Bedeutung langfristiger Monitoringprogramme, insbesondere in Gebieten rasanter klimatischer Veränderungen und mit einem hohen Gefährdungsrisiko für die Schutzgüter der Region, wurde die in den 1980er Jahren begonnene Bestandsaufnahme der lokalen Brutvogel- und Robbengemeinschaft in der Fildes-Region während der Sommermonate (Dezember bis Februar) der Saisons 2012/13 bis 2014/15 fortgesetzt. Daneben erfolgte eine Brutvogelerfassung in allen größeren eisfreien Bereichen der an die Fildes-Region angrenzenden Maxwell Bay. Diese umfassten die Gebiete Barton, Weaver und Potter Peninsula, am Green Point (alle King George Island) sowie für Stansbury Peninsula, Martin und Duthoit Point (alle Nelson Island). Für die Analyse von Langzeittrends der Vogel- sowie der Robbenbestände wurden zusätzlich zu eigenen Erfassungen umfangreiche Daten aus zahlreichen, bislang unveröffentlichten Expeditionsberichten deutscher Wissenschaftler aus den 1980er Jahren sowie sämtlicher verfügbarer Literatur herangezogen. Die Ergebnisse dieser beiden Monitoringschwerpunkte werden in dem vorliegenden Forschungsbericht präsentiert. Deutlich wird hierbei, dass die Mehrzahl der Seevogelarten hinsichtlich ihrer Brutpaarzahlen vornehmlich von natürlichen Umweltfaktoren abhängen, andere dagegen stärker auf anthropogene Einflüsse reagieren. Zusätzlich wurden anhand von Luft- und Satellitenaufnahmen teilweise erhebliche

Gletscherrückzugsgebiete ausgewählter Bereiche der Maxwell Bay in Bezug auf die regionale klimatische Entwicklung dokumentiert.

Table of Contents

Table of Figures

List of Tables

List of Abbreviations

AARI	Arctic & Antarctic Research Institute, Russia
ASMA	Antarctic Specially Managed Area
ASPA	Antarctic Specially Protected Area
ATCM	Antarctic Treaty Consultative Meeting
ATS	Antarctic Treaty Secretariat
BP	Breeding pair
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CCAS	Convention for the Conservation of Antarctic Seals
CEMP	CCAMLR Ecosystem Monitoring Program
COMNAP	Council of Managers of National Antarctic Programmes
ENSO	El Nino Southern Oscillation
GIS	Geographic Information System
GPS	Global Positioning System
IAA	Instituto Antártico Argentino, Argenntinien
IBA	Important Bird Area
INACH	Instituto Antártico Chileno, Chile
IUCN	International Union for Conservation of Nature
KGIS	SCAR King George Island GIS Project
NADC	National Antarctic Data Center, St. Petersburg, Russia
NASA	National Aeronautics and Space Administration
NGII	National Geographic Information Institute, South Korea
READER	Reference Antarctic Data for Environmental Research
SCAR	Scientific Committee on Antarctic Research
SCAR-BBS	Scientific Committee on Antarctic Research Bird Biology Sub-Committee
SSSI	Site of Special Scientific Interest
UAV	Unmanned Aerial Vehicles
UBA	Federal Environment Agency, Dessau, Germany (Umweltbundesamt, Dessau - Roßlau)
USGS	United States Geological Survey
WAP	Western Antarctic Peninsula

Summary

Introduction

The Fildes Region (King George Island, South Shetland Islands), consisting of the Fildes Peninsula, the neighbouring Ardley Island and all larger, nearby islands, is one of the largest ice-free regions in maritime Antarctic and has a relatively high level of biodiversity. The Fildes Region lies in an area of rapid climatic change. This area also represents the logistical centre of the Antarctic Peninsula with its six permanent stations, numerous field huts and an airstrip. Given the resulting multitude of human activities in the region, including research, logistics and tourism, there are often spatial and temporal overlaps of the various interests.

Monitoring the breeding birds and seals in the Fildes Region

Given the great importance of long-term monitoring programmes, especially in regions with natural resources at high risk, the survey of local breeding birds and seal communities started in the 1980s in the Fildes Region was continued in the summer months (December to February) of the 2012/13 to 2014/15 seasons. This produced a GPS/GIS-supported recording of breeding places and breeding pairs of all seabirds, except for storm petrels, as well as the breeding success of certain bird species throughout the entire Fildes Region. To count the giant petrel young in certain regions, a drone (UAV – Unmanned Aerial Vehicle) was employed for the first time. To analyse long-term trends in the bird and seal populations, extensive data from numerous, still unpublished expedition reports of German scientists from the 1980s were added to recent observations. The results of this monitoring are presented in this research report. A particular point of interest in the breeding bird monitoring in the Fildes Region is the counts of penguins on Ardley Island, which extend back to the 1979/80 season. The local colony is one of the few places in Antarctica where the three penguin species (Adélie, chinstrap and gentoo penguins) breed sympatrically. It has been labelled an Important Bird Area due to the relatively large number of breeding gentoo penguins. The database collected over 35 years reveals detailed conclusions about the development of local populations of the three penguin species. For example, the results of breeding pair recordings from the 2012/13 to 2014/15 seasons confirm the long-term population trends of this mixed colony for all three species. According to this, the number of breeding pairs of the chinstrap penguin has shrunk by over 90% since the start of data collection in 1979/80. After an evident drop in the 1980s and 1990s, the number of breeding pairs has remained stable since the 2004/05 season, although at a very low level. It even recently showed an upturn from its minimum of 8 breeding pairs in the 2007/08 and 2008/09 seasons to 16 breeding pairs in the 2014/15 season. A similar development was seen in the population of Adélie penguins on Ardley Island, whose numbers declined by over 30 % in the past 35 years. The 1980s and 1990s were characterised by strong annual fluctuations, reaching a peak of 1953 breeding pairs in the 1987/88 season, but then decreasingly strongly from the beginning of the 2000s. Since the 2003/04 season, the number of Adélie penguins has also stabilised, and 512 breeding pairs were counted in the 2014/15 season. The latest declines were associated with unfavourable weather conditions like snowy springs with a late snowmelt (2007/08, 2009/10 and 2013/14 seasons) and severe precipitation at the beginning of the breeding period (2014/15 season). In contrast to gentoo penguins, which demonstrate greater flexibility in their breeding phenology, Adélie penguins appear to find it difficult to evade adverse conditions in spatial or temporal terms. On the other hand, while the number of gentoo penguins showed steep drops in the early 1980s and in the second half of the 1990s, the total population increased by over 80 % and reached its highest level since continuous monitoring started with 6,475 breeding pairs in the 2014/15 season. Correspondingly, there was a clear negative correlation between the number of breeding pairs of Adélie penguins and

that of the gentoo penguins, which stresses the strong divergence in the population development of these two species. Nevertheless, there was no statistical connection in the annual rate of change in the number of breeding pairs of both species, calculated according to Carlini et al. (2009), i.e. the populations of both species changed each year neither simultaniously nor inversely. This suggests that the Adélie and gentoo penguins of this colony respond differently to the natural environmental factors like the availability of food or local snow and weather conditions or to human disturbance. The documented development of the number of breeding pairs of the three penguin species matches the frequently published long-term trends of the western Antarctic Peninsula. The causes of this are suspected to lie in complex ecological processes due to the progressing global warming and the concomitant regional decrease in the winter sea ice extent.

In addition to recording breeding pairs, an annual GPS-based mapping of the nesting groups of the three penguin species on Ardley Island was done in the last three breeding seasons, to determine potential spatial changes within the colony. The comparison of results from what is now 8 years of collection shows clearly that the spatial expansion of the nesting groups barely changed over that time period. The appreciable increase of over 50% in the total number of penguins breeding in the colony since the start of spatial recordings of nesting groups in the 1985/86 season is hardly reflected in recognisable changes in the distribution or surface area of the occupied nesting groups. Aside from limited fluctuations in the occupation of nesting groups in lower-lying areas, which were hardly or not at all occupied at the beginning of the breeding season if there was deep snow cover, there was no relevant expansion of the colony. A recently observed new colonisation of previously unoccupied areas in the extreme southwest of the colony by a few gentoo penguin breeding pairs is contrasted by the abandonment of a few small nesting groups in the northwest of the colony. On Ardley Island all of the optimally suitable areas for penguins appear to be colonised already, as the observed increase in the number of breeding pairs is reflected only in a maximisation of the nest density within the individual nesting groups and/or small spatial extensions of nesting groups. It is worthwhile noting that gentoo penguins in general space their nests further apart than Adélie or chinstrap penguins. Together with the observed population trends of the three penguin species, changes in the composition of nesting groups towards greater homogeneity are evident. For example, between 1994/95 and 2014/15 the number of mixed nesting groups clearly decreased, in which different penguin species nested sympatrically. The number of nesting groups with Adélie penguins sank from 20 to the current 12. Nesting groups consisting exclusively of Adélie penguins have not been seen since the 2008/09 season. Recolonisation of previously abandoned nesting groups by Adélie penguins has not been observed. Analysis of the data from 18 sympatric nesting groups between 1994/95 and 2014/15 revealed that the number of gentoo penguin breeding pairs in the entire colony in that period increased much more slowly than in the sympatric nesting groups. In addition, the total number of penguins nesting in the sympatric nesting groups remained largely constant, while the proportion of penguin species shifted in favour of the gentoo penguins. An active displacement of Adélie penguins by gentoo penguins seems unlikely as the annual rate of change in the number of breeding pairs of both penguin species does not appear to be associated with the increase or decrease of penguins per year. In contrast to other colonies, apparently almost all of the Adélie breeding places abandoned on Ardley Island due to the decrease in population were taken over by gentoo penguins within just a few years. The most likely cause of this is a strict limitation of the number of suitable nesting sites on Ardley Island for topographical reasons. Gentoo penguins also evidence greater plasticity in their breeding phenology and less breeding-site fidelity than Adélie penguins and can therefore probably respond better to adverse environmental conditions.

The breeding success (number of chicks per breeding pair) of the three penguin species nesting on Ardley Island showed distinct variations. The breeding success of the few chinstrap penguin breeding pairs still resident in these colonies remained consistently above the long-term average of 1.18 chicks per breeding pair in the past 8 years, but given the substantial fluctuations, especially in the 1990s, and a total loss of young in the 2003/04 season, no statistically significant trend is evident.

Adélie penguins on Ardley Island have a long-term average of 1.16 chicks per breeding pair, but the breeding success has fluctuated wildly and decreased significantly between the 1981/82 and 2014/15 seasons. As the breeding success level of Adélie penguins on Ardley Island is comparable or even higher than that of other colonies, the decline of Adélie penguins on Ardley Island does not seem to be due to a persistently low breeding success. We can assume that other factors contribute significantly to the observed general decline in Adélie penguins, such as high winter mortality, especially among the offspring, and low recruitment rates. The breeding success of gentoo penguins on Ardley Island demonstrates clearly fewer fluctuations over the years compared to the other two penguin species nesting there and was much higher than their breeding success with a long-term average of 1.30 chicks per breeding pair. This value is also high in comparison with other gentoo penguin colonies. Examined over the entire study period, however, the breeding success of gentoo penguins on Ardley Island decreased significantly. The proven inverse development of an evident population growth among gentoo penguins on Ardley Island with concurrent decline in their breeding success suggests that the number of surviving and recruited young birds returning to the colonies is apparently sufficient together with any immigrating individuals to ensure persistent population growth. Sharp declines in the breeding success of both Adélie penguins and gentoo penguins on Ardley Island were recorded predominantly in seasons with a snowy spring and late start of the snowmelt (2007/08, 2009/10 and 2012/13 seasons) and in association with heavy snowfalls during the breeding phase (2014/15 season). Chinstrap penguins were not or less obviously affected, as the few breeding pairs of this species nest on small, rocky heights, where snow does not readily accumulate.

The southern giant petrel is a highly susceptible species and thus carries a high risk for negative effects due to the concentration of human activities in the Fildes Region. In the 2011/12 and 2012/13 seasons, a total of 266 or 290 occupied southern giant petrels nests or breeding pairs, respectively, was recorded in the Fildes Region. In contrast, the recorded number of breeding pairs of 425 for the 2014/15 season clearly exceeded the long-term average of 303 breeding pairs and represents the highest value since the beginning of measurements. In long-term comparisons, the population of southern giant petrel in the Fildes Region has been stable for years despite large interannual fluctuations. When focussing on individual parts of the colony, very different developments can be noticed. While steady growth was seen in the northernmost colony in the Fildes Region, which is visited less often by scientists and rarely by station personnel in their leisure time due to its relatively great distance from the stations, the number of breeding pairs in a southern colony declined at the same time. A possible cause of this discrepancy could be the repeated disturbance caused by visitorsof the field hut located there. A decrease in the number of breeding pairs was also observed in the southernmost colony on Dart Island. This island is frequently visited by station staff who regularly goes fishing. The observed changes in the number of breeding pairs in different regions are likely not due to natural environmental factors, as neighbouring colonies subject to the same natural conditions (e.g. availability of food, predation, snow levels) demonstrate a different population development. Anthropogenic disturbance appears to have such a effect that a decline in the number of breeding pairs is only observed in colonies that are often visited by station staff in the summer months. Neighbouring colonies that are rarely or not at all visited have either a stable number of breeding pairs or show a population increase. The latter aspect suggests that repeated shifting of the nesting sites is due to anthropogenic influences. It is difficult to estimate how much areas bordering the Fildes Region (Barton & Potter Peninsula, Duthoit Point and Stansbury Peninsula on Nelson Island, Nelson Island) are similarly affected by the nesting site shifting as there are not enough data available yet. Another interesting point is the increasing number of nesting attempts in numerous abandoned breeding sites in the Fildes Region over the past ten years, which are partially affected by a high level of human activities. This suggests a possible habituation to regular and predictable disturbance. In the recolonised regions, however, hardly any young have been successfully raised to maturity. As the breeding success of southern giant petrels can be considered a suitable indicator of human disturbance, great attention is again being paid to recording this parameter. In the 2012/13 to 2014/15 seasons the breeding success was below the long-term average of 0.36 chicks per breeding pair. The adverse environmental conditions probably played a large role in this as all colonies in the Fildes Region were equally affected. The relatively low breeding success of the southern giant petrel in the Fildes Region compared to other breeding regions continued to decline. The breeding success of the southern giant petrel in the Fildes Region was already relatively low compared to other breeding regions and continued to decline during the study period. The individual colonies mostly show no significant differences in their average breeding success. Only two colonies with a low level of human disturbance demonstrated a clearly higher average breeding success than the other regions. In contrast to most other colonies over the study period, neither colony showed a decreasing trend. On the other hand, the breeding success in the frequently visited colonies was usually lower than that season's average breeding success. In summary, the results presented suggest an anthropogenic influence on the number of breeding pairs and the breeding success of southern giant petrel in the Fildes Region.

Another find of a dead southern giant petrel and a light-mantled sooty albatross after collision with an antenna or signalmast stresses the danger of this equipment for sea birds in the Fildes Region. For this reason, measures should be taken to make antennae and signal masts and their guy wires more visible to minimise the risk of bird strikes.

The number of breeding pairs of the cape petrel sank continuously over the study period and was only 10% of the average population in the 1980s with 39 breeding pairs in the 2014/15 season. There is no obvious cause as direct anthropogenic disturbance affects only a couple of breeding sites with relatively few breeding pairs.

After the successful first breeding record of light-mantled sooty albatross on Flat Top cliffs in the 2008/09 season and its confirmation in the 2011/12 season, there was again evidence of two breeding pairs in the 2013/14 season. No chicks were observed, however, in this breeding site located so far from the original range of the species. In addition, few breeding pairs of the snowy sheathbill were again registered in the 2012/13 to 2014/15 seasons.

The results of the continued recording of populations of brown skua and south polar skuas and of mixed pairs showed a strong rise in the number of breeding pairs of south polar skuas in the 2000s, followed by a dramatic decline in the past three seasons. In contrast, the population of brown skuas and the mixed pairs have remained stable in the past decades. There has been a significant increase in the number of territories colonised by skuas returning from their overwintering regions (data analysed for 2007/08 to 2014/15). Whether these pairs start breeding depends on the prevailing environmental conditions. In the past three seasons 174, 178 and 188 territories, respectively, were colonised by south polar skuas. On the other hand, there were 12 pairs in the 2012/13 and 2013/14 seasons and 30 pairs in the 2014/15 season that actually started breeding. The number of brown skuas occupying a territory in the same time period but not breeding was much smaller. This suggests that the two species respond differently to local environmental factors. This is supported by the fact that south polar skuas raised young successfully only in six of the past eight seasons, while the breeding success of brown skuas generally remained stable despite a negative tendency. It is likely that the limited number of breeding pairs and the lack of breeding success of south polar skuas in the recent past are primarily due to the poor availability of food in the marine-pelagic region as both skua species breed sympatrically there and are distinguished by their feeding ecology. In addition, predation by skuas, both inter- and intraspecific, has apparently contributed significantly to the reduction in breeding success. This applies especially to regions with a high density of skuas, as in the Fildes Region. The predation risk rises further with extended search flights for food due to a lack of food. Furthermore, feeding of birds which is practiced in the area could cause negative effects, articularly in case of skuas as an opportunistic foraging species the possible introduction of diseases cannot be excluded.

The number of nesting kelp gull fluctuated strongly and laid above the long-term average with 139 breeding pairs in the 2012/13 season and clearly below it in subsequent years (2013/14 and 2014/15 seasons: 91 and 49 breeding pairs, respectively). In long-term comparisons a significant decline in the number of breeding pairs of the kelp gull has become evident, most likely caused by deep snow cover in the spring due to a late snowmelt, which resulted recently in frequent failures to breed. The comprehensive survey of the Antarctic tern revealed 222 (2012/13), 284 (2013/14) and 296 (2014/15) breeding pairs. In long-term comparisons, this species displays a stable population – despite large interannual fluctuations – with a concurrent decrease in colony size and a high frequency of solitary breeding pairs.

As part of the assessment of all potential breeding birds, migrants and accidental migrants, species like emperor, king and macaroni penguins are being recorded again. In addition, individual snow petrels, southern fulmars, black-browed Albatrosses, cattle egrets and white-rumped sandpipers have been seen. As in previous years, Arctic terns that spend the austral summer there and fly occasionally in large flocks, were again recorded.

In addition to collecting data on the breeding birds, regular seal counts were conducted in the Fildes Region. The highest count of the southern elephant seals was recorded in January, and that of Antarctic fur seals in February, on the sandy bays of the west coast of Fildes Peninsula. Spatial changes in the location of hauled out elephant seals have not been recorded. In long-term comparisons, the number of both elephant and Weddell seals has decreased since the 1980s, despite stabilisation during recent decades. It remains an open question to what extent this is just a local change in these species or an actual regional population decline. In contrast, the number of Antarctic fur seals has been increasing since the 1980s. This development corresponds to results from other regions, in which this species experienced a rapid population growth after severe decimation by intensive seal hunting. During the study period, seal births were documented in the Fildes Region for the following species: southern elephant seal, Weddell seal, Antarctic fur seal and leopard seal. The spatial expansion of the fur seal pupping places continues.

The greatest danger at the moment for the populations of sea birds and seals in Antarctica concerns changed environmental conditions as a result of climate change, e.g. in the form of changes in food webs, habitat loss or shift. Direct anthropogenic effects, such as interactions with fishing activities or shipping (e.g. competition for food, injuries), could negatively affect the local populations of sea birds and seals. The Fildes Region is specifically affected by anthropogenic disturbances in the breeding and resting areas of birds and seals, especially by visitors from the resident stations. Highly sensitive species like the southern giant petrel are hit harder, as repeatedly shown by the steep decline in the number of breeding pairs and the low and continuously decreasing breeding success.

Breeding bird monitoring in the ice-free regions of Maxwell Bay

Another main focus involves recording the breeding birds in all large ice-free areas of Maxwell Bay, which border the Fildes Region. The data are supplemented by available information from the literature. For Barton, Weaver and Potter Peninsulas, Green Point (all on King George Island) and for Stansbury Peninsula, Martin and Duthoit Points (all on Nelson Island), an overview of the breeding bird populations could be prepared. Resilient long-term data series could nevertheless only be compiled for Fildes, Barton and Potter Peninsulas. Based on these data, some of which have been collected over a long period, which is unusual for any place in Antarctica, the development of the breeding bird populations in these regions in the past decades could be charted. This reveals that population trends, typical in the Western Antarctic Peninsula, are mostly reflected in all breeding bird colonies of Maxwell Bay. For example, the number of breeding pairs of gentoo penguins in the colonies on Ardley Island, Barton and Potter Peninsulas has continuously increased since the counts began in the 1960s. In contrast, the number of breeding pairs of Adélie penguins declined drastically on both Ardley Island and the Potter Peninsula after an increase in the 1980s, but it has recently stabilised. Chinstrap penguins are showing a less consistent picture than the other two penguin species. Current data from Maxwell Bay are only available for Barton Peninsula and Ardley Island. While the colony on Ardley Island has now stabilised at a very low level after a rapid decline in the 1980s and 1990s, the population in the Barton Peninsula colony has proven to be stable since the start of counting. In the penguin colony on the Potter Peninsula, sinking numbers of breeding pairs were observed in the 1980s (but no counting data are available after that time period). In the meantime, the chinstrap penguin has disappeared entirely from this colony. The number of breeding pairs of southern giant petrels on the Barton and Potter Peninsulas showed a decreasing tendency compared to data from the 1980s, while the population on the Stansbury Peninsula has increased slightly. At both occurrences of the blue-eyed shag near Maxwell Bay at Duthoit Point and on Low Rock near the Potter Peninsula, a decline of this species was evident compared with the populations in the 1990s. Current counts at Duthoit Point suggest a stabilisation of the number of breeding pairs of the blue-eyed shag. The relatively long data series collected for skua breeding pair numbers near Maxwell Bay reveals a stable population during the past decades. The recent sharp decline in the number of breeding pairs of both skua species was observed both in the Fildes Region and on the Barton and Potter Peninsulas. The counting data of kelp gull do suggest a stable population, which cannot be conclusively confirmed given the relatively small amount of data available. The database for all other breeding bird species around Maxwell Bay (outside the Fildes Peninsula) is fragmentary and does not enable any estimation of guaranteed population trends.

Documentation of glacial retreat in selected regions of Maxwell Bay with reference to the regional climate changes

King George Island and Nelson Island are almost completely glaciated, like all large islands of the South Shetland Islands, with an ice cover exceeding 90 %. In particular, the ice cap on King George Island is considered extremely sensitive to climate change based on its particular characteristics and the prevailing maritime climate. This applies particularly to an exposed glacier tongue like the Bellingshausen Dome at the northern end of the Fildes Peninsula. Given its major ecological significance for local ecosystems, glacial retreat has been documented in selected regions of Maxwell Bay along with the regional climate developments in the past decades, to supplement breeding bird and seal monitoring. This study has found that the climate in the examined region as part of the South Shetland Islands is characterised by the influence of the southern hemisphere polar front and the position of the islands in the ocean. The prevailing climate is characterised by relatively mild temperatures, high humidity, large amounts of precipitation spread evenly throughout the year and strong winds, primarily from the west. Rapid changes of weather are typical, determined by a strong cyclone activity. The average monthly temperature is generally above freezing in the summer months. The highest temperature ever measured in the Bellingshausen Station exceeded 8°C, the lowest winter temperature reached -30°C. Based on meteorological data from the Bellingshausen Station, the climate development of the past decades in the Fildes Region has been examined. For example, the average annual temperature between 1969 and 2013 rose slightly. The verifiable evident increase in the average air temperature in the summer (December – February) up to the year 2000 was relativised by a series of cool summers recently. While the autumn temperature (March – May) rose continuously, an increase in the winter temperature (June – August) noted in other areas of the WAP region could not be confirmed for the Bellingshausen Station. Although the measured precipitation over the course of the past 46 years has barely changed, the average monthly height of snow showed a significant increase for January and December, which could essentially be associated with a series of cool summers recently, which considerably delayed the melting of snow that fell in the winter or spring. An annual increase in the quantity of snow, as demonstrated for the WAP region, could not be ascertained for the Fildes Region, based on the analysis of amounts of precipitation. The documentation of glacial retreat around Maxwell Bay was then done for all large ice-free regions, which had not been previously documented. These regions include the north of the Fildes Peninsula, the north of Nelson Island (including Stansbury Peninsula and Martin Point), Duthoit Point/Nelson Island, and the Weaver and Barton Peninsulas. The analysis of numerous aerial and satellite images involved manual image interpretation with delineation of the horizontal glacier extent using GIS. As the usefulness of optical satellite data depends strongly on the seasonal timepoint of taking the image and the weather conditions, the number of evaluable images for some regions was limited. The results of evaluating the changes in glacier extent confirmed the findings of earlier studies of an evident retreat of the glacier fronts on King George Island. The clearest evidence came from the glacier front of the Bellingshausen-Dom, which retreated over 600 m in its central area between 1956 and 2012. The melting process of the neighbouring glacier became especially visible in the form of retreating glacier fronts or melting dead ice, which often appears in the moraine upstream of the glacier tongue. In addition, there are indications of a glacial retreat in the regions of the Barton and Weaver Peninsulas, for which we have no earlier data for comparison. A clear shift of the glacier front of up to 400 m over the course of the last six decades is likewise recognisable at Green Point. In contrast, the glacier development in the north of Nelson Island is much less uniform. There were evident areas of retreat as well as a slight advance of the glacier, possibly determined by more rapid draining of the glacier. Given the severe limitation of ice-free terrestrial areas in Antarctica, the new ice-free regions created by the glacial retreat are very important for local terrestrial ecosystems, by offering space for colonising by expanding or migrant or introduced microorganisms, arthropods, algae, mosses, lichens and flowering plants as well as resting and reproduction possibilities for native sea birds and seals.

Maxwell Bay, including the Fildes Region, lies in an area of rapid climatic change, which could have serious consequences for the animal and plant kingdoms that are almost impossible to estimate given their complexity. In addition, the high concentration of anthropogenic influences contributes to changes in the local ecosystem. As an evaluation of changes in sea bird and seal populations and their reproduction rates due to global, regional and/or local environmental changes can only be done on the basis of long-term data sets, continuation of the monitoring programmes in both the Fildes Region and other areas of Maxwell Bay is recommended.

Zusammenfassung

Einleitung

Die Fildes-Region (King George Island, South Shetland Islands), bestehend aus der Fildes Peninsula, der angrenzenden Ardley Island sowie allen größeren benachbarten Inseln, gehört zu den größten eisfreien Gebieten im Bereich der maritimen Antarktis und weist eine vergleichsweise hohe Biodiversität auf. Die Fildes-Region liegt in einem Gebiet rasanter klimatischer Veränderungen. Gleichzeitig repräsentiert diese Region mit sechs ansässigen Stationen, zahlreichen Feldhütten sowie einer Landebahn das logistische Zentrum im Bereich der Antarktischen Halbinsel. Infolge der daraus resultierenden Vielzahl menschlicher Aktivitäten auf den Gebieten, Forschung, Logistik und Tourismus kommt es häufig zu räumlichen und zeitlichen Überschneidungen der verschiedenen Interessen.

Monitoring der Brutvögel und Robben in der Fildes-Region

Aufgrund der hohen Bedeutung langfristiger Monitoringprogramme, insbesondere in Gebieten mit einem hohen Risiko für die Schutzgüter der Region, wurde die in den 1980er Jahren begonnene Bestandsaufnahme der lokalen Brutvogel- und Robbengemeinschaft in der Fildes-Region während der Sommermonate (Dezember bis Februar) der Saisons 2012/13 bis 2014/15 fortgesetzt. Hierfür erfolgten in der gesamten Fildes-Region eine GPS/GIS-gestützte Erfassungen der Brutplätze sowie der Brutpaarzahl sämtlicher Seevögel, mit Ausnahme von Sturmschwalben, sowie des Bruterfolgs ausgewählter Vogelarten. Erstmals wurde für die Zählung der Riesensturmjungvögel in einigen Gebieten eine Drohne (UAV – Unmanned Aerial Vehicle) eingesetzt. Für die Analyse von Langzeittrends der Vogel- sowie der Robbenbestände wurden zusätzlich zu eigenen Erfassungen umfangreiche Daten aus zahlreichen, bislang unveröffentlichten Expeditionsberichten deutscher Wissenschaftler aus den 1980er Jahren herangezogen. Die Ergebnisse dieses Monitoring werden in dem vorliegenden Forschungsbericht präsentiert. Einen Schwerpunkt des Brutvogelmonitorings in der Fildes-Region bildeten die Pinguinzählungen auf Ardley Island, die bis auf die Saison 1979/80 zurückgehen. Die dortige Kolonie ist einer der wenigen Orte in der Antarktis, an dem die drei Pinguinarten Adélie-, Zügel- und Eselspinguin sympatrisch brüten. Die Pinguinkolonie auf Ardley Island wird aufgrund der verhältnismäßig großen Zahl hier brütender Eselspinguine als Important Bird Area eingestuft. Anhand des inzwischen 35 Jahre umfassenden Datensatzes lassen sich detaillierte Aussagen über die Beurteilung der lokalen Bestandentwicklung der drei Pinguinarten treffen. So bestätigen die Ergebnisse der Brutpaarerfassungen in den Saisons 2012/13 bis 2014/15 für alle drei Arten die langjährigen Bestandstrends dieser gemischten Kolonie. Demnach schrumpfte die Brutpaarzahl der Zügelpinguine seit Beginn der Erfassung 1979/80 insgesamt um mehr als 90 %. Die Brutpaarzahl blieb jedoch nach einer deutlichen Abnahme in den 1980er und 1990er Jahren seit der Saison 2004/05 stabil, wenn auch auf sehr niedrigem Niveau. Sie zeigte jüngst sogar einen Zuwachs von minimal 8 Brutpaaren in Saisons 2007/08 und 2008/09 auf 16 Brutpaare in der Saison 2014/15. Eine ähnliche Entwicklung zeigte der Bestand der Adéliepinguine auf Ardley Island, deren Zahl in den vergangenen 35 Jahren insgesamt um mehr als 30 % sank. In den 1980er und 1990er Jahren zeigte diese Art starke jährliche Fluktuationen und erreichte in der Saison 1987/88 ein Maximum von 1953 Brutpaaren, nahm jedoch seit Beginn der 2000er Jahre stark ab. Seit der Saison 2003/04 hat sich die Zahl der Adéliepinguine jedoch ebenfalls stabilisiert, und in der Saison 2014/15 wurden 512 Brutpaare erfasst. Jüngste Einbrüche stehen im Zusammenhang mit ungünstigen Umweltbedingungen in Form schneereicher Frühjahre mit spät einsetzender Schneeschmelze (Saisons 2007/08, 2009/10 und 2013/14) sowie starken Niederschlägen zu Beginn der Brutsaison (Saison 2014/15). Im Gegensatz zu Eselspinguinen, welche eine höhere Flexibilität in ihrer

Brutphänologie aufweisen, scheinen Adéliepinguine kaum in der Lage zu sein, bestimmten widrigen Bedingungen räumlich oder zeitlich auszuweichen. Dagegen zeigte die Zahl der Eselspinguine starke Einbrüche zu Beginn der 1980er Jahre sowie in der zweiten Hälfte der 1990er Jahre. Insgesamt nahm der Bestand jedoch um mehr als 80 % zu und erreichte in der Saison 2014/15 mit 6475 Brutpaaren den höchsten Wert seit Beginn der kontinuierlichen Zählungen. Dementsprechend war eine deutliche negative Korrelation zwischen den Brutpaarzahlen der Adéliepinguine sowie denen der Eselspinguine nachweisbar, was die starke Divergenz in der Bestandsentwicklung der beiden Arten unterstreicht.

Dennoch fand sich kein statistischer Zusammenhang in der jährlichen Änderungsrate der Brutpaarzahlen beider Arten, berechnet nach Carlini et al. (2009), d. h. der Bestand beider Arten verändert sich jährlich weder überwiegend simultan noch gegenläufig. Dies weist auf eine unterschiedliche Reaktion der Adélie- bzw. der Eselspinguine dieser Kolonie auf natürliche Umweltfaktoren hin, wie z. B. Nahrungsverfügbarkeit oder lokale Schnee- und Witterungsverhältnisse oder aber auf Störungen durch Menschen. Die dargestellte Entwicklung der Brutpaarzahlen der drei Pinguinarten stimmt mit vielfach veröffentlichten Langzeittrends an der Westlichen Antarktischen Halbinsel überein. Die Ursachen hierfür werden in komplexen ökologischen Prozessen infolge der fortschreitenden klimatischen Erwärmung und der damit einhergehenden regionalen Abnahme der winterlichen Meereisausdehnung vermutet.

Ergänzend zur Brutpaarerfassung erfolgte in den vergangenen drei Brutsaisons eine jährliche GPS-gestützte Kartierung der Nestgruppen der drei Pinguinarten auf Ardley Island, um etwaige räumliche Veränderungen innerhalb der Kolonie festzustellen. Der Vergleich der Ergebnisse aus inzwischen acht Jahren macht deutlich, dass sich die räumliche Ausdehnung der Nestgruppen über den untersuchten Zeitraum hinweg nur geringfügig geändert hat. Die beträchtliche Zunahme der Gesamtzahl der in der Kolonie brütenden Pinguine seit Beginn der räumlichen Erfassung der Nestgruppen in der Saison 1985/86 um mehr als 50 % spiegelt sich kaum in erkennbaren Veränderungen der Verteilung oder der Fläche der besetzten Nestgruppen wider. Abgesehen von geringfügigen Schwankungen hinsichtlich der Besetzung von Nestgruppen in tiefer gelegenen Bereichen, die bei hoher Schneebedeckung zu Beginn der Brutzeit weniger oder gar nicht besetzt wurden, fand keine relevante Ausdehnung der Kolonie statt. Einer jüngst beobachteten Neubesiedlung bislang nicht besetzter Bereiche im äußersten Südwesten der Kolonie durch einige wenige Eselspinguinbrutpaare steht die Aufgabe einiger kleinerer Nestgruppen im Nordwesten der Kolonie gegenüber. Auf Ardley Islands scheinen bereits sämtliche optimal geeigneten Bereiche von Pinguinen besiedelt zu sein, da sich die beobachtete Erhöhung der Brutpaarzahl nur in einer Maximierung der Nestdichte innerhalb der einzelnen Nestgruppen und/oder geringfügigen räumlichen Ausweitung der Nestgruppen widerspiegelt. Dabei ist zu beachten, dass Eselspinguine im Allgemeinen weniger dicht brüten als Adélie- oder Zügelpinguine. Im Zusammenhang mit den beobachteten Bestandstrends der drei Pinguinarten sind Veränderungen in der Zusammensetzung der Nestgruppen in Richtung einer Homogenisierung erkennbar. So nahm zwischen 1994/95 und 2014/15 die Zahl der gemischten Nestgruppen, in denen verschiedene Pinguinarten sympatrisch brüten, deutlich ab. Die Anzahl von Nestgruppen mit Adéliepinguinen sank von 20 auf nunmehr 12. Nestgruppen, in denen ausschließlich Adéliepinguine brüteten, wurden seit der Saison 2008/09 nicht mehr registriert. Eine Wiederbesiedlung vormals verlassener Nestgruppen durch Adéliepinguine wurde nicht beobachtet. Eine Auswertung von Daten aus 18 sympatrischen Nestgruppen zwischen 1994/95 und 2014/15 zeigte, dass sich die Zahl der Eselspinguinbrutpaare im selben Zeitraum in der gesamten Kolonie deutlich langsamer erhöhte als in den sympatrischen Nestgruppen. Dabei blieb die Zahl der in den sympatrischen Nestgruppen brütenden Pinguine weitgehend konstant, während sich die Anteile der Pinguinarten zugunsten der Eselspinguine deutlich verschoben. Eine aktive Verdrängung von Adélie- durch Eselspinguine erscheint unwahrscheinlich, da die jährlichen Änderungsraten der Brutpaarzahlen beider Pinguinarten keinen Zusammenhang hinsichtlich der Zu- oder Abnahme der Pinguine pro Jahr aufweisen. Im Gegensatz zu anderen Kolonien wurden auf Ardley Island innerhalb weniger Jahre offenbar beinahe sämtliche aufgrund des Bestandrückgangs frei gewordene Adélie-Brutplätze unmittelbar von Eselspinguinen besetzt. Möglicherweise liegt die Ursache hierfür in einer starken Limitierung der Zahl geeigneter Brutplätze auf Ardley Island aufgrund topgraphischer Gegebenheiten. Zudem weisen Eselspinguine eine größere Plastizität in ihrer Brutphänologie auf und sind weniger brutortstreu als Adéliepinguine und können daher wahrscheinlich besser auf widrige Umweltbedingungen reagieren.

Der Bruterfolg (Anzahl der Jungvögel pro Brutpaar) der drei auf Ardley Island brütenden Pinguinarten weist deutliche Unterschiede auf. So lag der Bruterfolg der wenigen noch in dieser Kolonien vorkommenden Zügelpinguinbrutpaare in den vergangenen acht Jahren durchweg über dem langjährigen Mittel von 1,18 Jungvögeln pro Brutpaar, zeigt jedoch aufgrund erheblicher Schwankungen, vor allem in den 1990er Jahren, sowie eines totalen Brutverlusts in der Saison 2003/04 keinen statistisch signifikanten Trend.

Adéliepinguine auf Ardley Island zogen im langjährigen Mittel 1,16 Jungvögel pro Brutpaar auf, wobei der Bruterfolg stark schwankte und zwischen den Saisons 1981/82 und 2014/15 signifikant abnahm. Da die Bruterfolgswerte der Adéliepinguine auf Ardley Island dennoch vergleichbar oder höher als Werte anderer Kolonien sind, scheint der Rückgang der Adéliepinguine auf Ardley Island nicht in einem dauerhaft niedrigen Bruterfolg begründet zu sein. Vielmehr ist davon auszugehen, dass weitere Faktoren wie z. B. hohe Wintermortalität, insbesondere bei Jungtieren, und geringe Rekruitmentraten zur allgemein beobachteten Abnahme der Adéliepinguine erheblich beitragen. Der Bruterfolg der Eselspinguine auf Ardley Island weist über die Jahre hinweg deutlich weniger Schwankungen auf als der der beiden anderen Pinguinarten und war mit einem langjährigen Mittel von 1,30 Jungvögel pro Brutpaar deutlich höher als der Bruterfolg dort ebenfalls brütender Zügel- und Adéliepinguine. Auch im Vergleich mit anderen Eselspinguinkolonien erweist sich dieser Wert als hoch. Über den gesamten Untersuchungszeitraum hinweg nahm der Bruterfolg der Eselspinguine auf Ardley Island jedoch signifikant ab. Die nachgewiesene gegenläufige Entwicklung eines deutlichen Bestandswachstums der Eselspinguine auf Ardley Island bei gleichzeitigem Rückgang des Bruterfolgs weist darauf hin, dass die Anzahl der überlebenden und rekrutierten, in die Kolonien zurückkehrenden Jungtiere vermutlich ausreicht, um zusammen mit möglicherweise zugewanderten Individuen einen andauernden Bestandszuwachs zu gewährleisten. Einbrüche beim Bruterfolg sowohl von Adéliepinguinen als auch von Eselspinguinen auf Ardley Island wurden vor allem in Saisons mit einem schneereichem Frühjahr und sehr spät einsetzender Schneeschmelze (Saisons 2007/08, 2009/10 und 2012/13) und im Zusammenhang mit starken Schneefällen während der Brutphase (Saison 2014/15) registriert. Zügelpinguine waren davon nicht bzw. deutlich weniger betroffen, da die wenigen Brutpaare dieser Art auf kleinen felsigen Anhöhen brüten, wo keine hohe Schneeakkumulation auftritt.

Der Südliche Riesensturmvogel als sehr störanfällige Art unterliegt aufgrund der Konzentration menschlicher Aktivitäten in der Fildes-Region einem hohen Risiko für negative Auswirkungen, verursacht durch anthropogene Störungen. In den Saisons 2011/12 und 2012/13 wurden in der Fildes-Region insgesamt 266 bzw. 290 besetzte Riesensturmvogelnester bzw. Brutpaare erfasst. Die ermittelte Brutpaarzahl für die Saison 2014/15 lag mit 425 Brutpaaren dagegen deutlich über dem langjährigen Mittel von 303 Brutpaaren und stellt den höchsten Wert seit Beginn der Zählungen dar. Im Langzeitvergleich ist der Bestand des Südlichen Riesensturmvogels in der Fildes-Region seit Jahren trotz erheblicher interannueller Schwankungen stabil. Bei der Betrachtung einzelner Kolonien zeigten sich jedoch stark voneinander abweichende

Entwicklungen. Während die nördlichste Kolonie der Fildes-Region, die aufgrund der relativ großen Entfernung zu den Stationen seltener von Wissenschaftlern und kaum von Stationsmitgliedern in ihrer Freizeit aufgesucht wird, einen stetigen Zuwachs verzeichnete, sank gleichzeitig die Brutpaarzahl in der etwas südlicher gelegenen Kolonie. Mögliche Ursache hierfür sind wiederholte Störungen durch Besucher, die die dortige Feldhütte aufsuchen. Eine Abnahme der Brutpaarzahlen konnte auch in der südlichsten Kolonie auf Dart Island beobachtet werden. Diese Insel wird zeitweise von Stationsmitgliedern zum Angeln aufgesucht. Die beobachteten Änderungen der Brutpaarzahlen in verschiedenen Gebieten sind höchstwahrscheinlich nicht durch natürliche Umweltfaktoren verursacht, da benachbarte Kolonien, die denselben natürlichen Bedingungen (z. B. Nahrungsverfügbarkeit, Prädation, Schneeverhältnisse) unterliegen, eine unterschiedliche Bestandsentwicklung aufweisen. Anthropogene Störungen scheinen dagegen Auswirkungen zu haben, da ein Rückgang der Brutpaarzahlen nur in Kolonien beobachtet wurde, die während der Sommermonate häufig von Stationsmitgliedern besucht wurden. Benachbarte, wenig oder nicht-besuchte Kolonien zeigten entweder stabile Brutpaarzahlen oder aber eine Bestandszunahme. Letzteres weist auf eine erneut stattfindende Verlagerung von Brutplätzen infolge anthropogener Einflüsse hin. Inwieweit weitere, an die Fildes-Region angrenzende Gebiete (Barton & Potter Peninsula, Duthoit Point und Stansbury Peninsula auf Nelson Island, Nelson Island) ebenfalls von den hier beschriebenen Brutplatzverschiebungen betroffen sind, ist schwer einzuschätzen, da dafür derzeit keine ausreichenden Datenreihen zur Verfügung stehen. Bemerkenswert ist ferner die seit etwa zehn Jahren zunehmende Zahl von Brutversuchen an zahlreichen vormals verlassenen Brutplätzen in der Fildes-Region, die teilweise von einem hohen Niveau menschlicher Aktivitäten geprägt sind. Dies deutet auf eine mögliche Habituierung gegenüber regelmäßigen und vorhersehbaren Störungen hin. In den wiederbesiedelten Gebieten wurde jedoch bislang kaum erfolgreich Nachwuchs aufgezogen. Da der Bruterfolg von Riesensturmvögeln als geeigneter Indikator für menschliche Störungen betrachtet wird, wurde auf die Erfassung dieses Parameters erneut großen Wert gelegt. Der Bruterfolg des Südlichen Riesensturmvogels lag in den Saisons 2012/13 bis 2014/15 unterhalb des langjährigen Mittels von 0,36 Jungvögel pro Brutpaar. Eine wesentliche Rolle spielten dabei wahrscheinlich ungünstige Umweltbedingungen, da alle Kolonien der Fildes-Region gleichermaßen betroffen waren. Im Langzeitvergleich setzte sich in der Fildes-Region der Rückgang des ohnehin im Vergleich zu anderen Brutgebieten sehr geringen Bruterfolgs des Südlichen Riesensturmvogels fort. Die einzelnen Kolonien zeigten größtenteils keine signifikanten Unterschiede hinsichtlich ihres jeweiligen mittleren Bruterfolgs. Lediglich zwei Kolonien mit einem niedrigen Niveau menschlicher Störung zeigten einen deutlich höheren mittleren Bruterfolg als die übrigen Gebiete. Beide Kolonien zeigten im Gegensatz zu den meisten anderen Kolonien über die untersuchten Jahre hinweg keinen abnehmenden Trend. Dagegen lag der Bruterfolg in den häufiger besuchten Kolonien meist unterhalb des mittleren Bruterfolgs der jeweiligen Saison. Zusammenfassend weisen die dargestellten Ergebnisse auf einen anthropogenen Einfluss auf die Brutpaarzahl und den Bruterfolg des Südlichen Riesensturmvogels in der Fildes-Region hin.

Der erneute Fund eines frischtoten Riesensturmvogels sowie eines Rußalbatrosses an einer Antenne bzw. Signalmast unterstreicht die Gefährdung durch diese Anlagen für Seevögel in der Fildes-Region. Aus diesem Grund sollten Maßnahmen zur besseren Sichtbarmachung von Antennen und Signalmasten sowie deren Abspanndrähten ergriffen werden, um das Risiko von Vogelschlag zu minimieren.

Die Brutpaarzahl der Kapsturmvögel sank während des Untersuchungszeitraums kontinuierlich ab und betrug in der Saison 2014/15 mit 39 Brutpaaren nur noch etwa 10 % des mittleren Bestands in den 1980er Jahren. Die Ursache hierfür ist unklar, da direkte anthropogene Störung nur an wenigen Brutplätzen mit verhältnismäßig wenigen Brutpaaren infrage kommt.

Nach dem erfolgreichen Erstnachweis einer Brut von Rußalbatrossen am Flat Top-Felsen in der Saison 2008/09 und deren Bestätigung für die Saison 2011/12 gelang in der Saison 2013/14 erneut der Nachweis zweier Brutpaare. Jungvögel konnten an diesem weit außerhalb des ursprünglichen Verbreitungsgebiets dieser Art gelegenem Brutplatz jedoch nicht beobachtet werden. Daneben wurden in den Saisons 2012/13 bis 2014/15 erneut Bruten einiger weniger Paare Weißgesichtsscheidenschnäbel registriert.

Der Ergebnisse aus der Fortsetzung der Erfassung des Bestandes der Braunen Skua und der Südpolarskua sowie deren Mischpaare zeigen einen starken Zuwachs der Brutpaarzahl von Südpolarskuas in den 2000er Jahren, gefolgt von einem dramatischen Rückgang in den vergangenen drei Saisons. Dagegen blieb der Bestand der Braunen Skuas sowie der Mischpaare in den vergangenen Jahrzehnten stabil. Im Gegensatz dazu zeigte sich eine signifikante Zunahme der Zahl der Territorien, die nach der Rückkehr aus den Überwinterungsgebieten von den Skuas besetzt wurden (Daten für 2007/08 bis 2014/15 ausgewertet). Ob diese Paare jedoch mit der Brut beginnen, hängt mit den jeweils herrschenden Umweltbedingungen zusammen. In den vergangenen drei Saisons wurden jeweils 174, 178 bzw. 188 Territorien durch Südpolarskuas besetzt. Demgegenüber stehen jeweils 12 Brutpaare in den Saisons 2012/13 und 2013/14 bzw. 30 Paare in der Saison 2014/15, die tatsächlich mit der Brut begannen. Der Anteil an Braunen Skuas, die im selben Zeitraum zwar ein Territorium besetzten, jedoch nicht brüteten, war um ein Vielfaches geringer. Somit scheinen unterschiedliche Reaktionen beider Arten auf lokale Umweltfaktoren eine wesentliche Rolle zu spielen. Dafür spricht auch die Tatsache, dass Südpolarskuas nur in sechs der vergangenen acht Saisons überhaupt erfolgreich Junge aufzogen, während der Bruterfolg der Braunen Skuas trotz einer negativen Tendenz im Wesentlichen stabil blieb. Wahrscheinlich sind die geringe Brutpaarzahl und der ausbleibende Bruterfolg der Südpolarskuas in jüngster Vergangenheit hauptsächlich in mangelnder Nahrungsverfügbarkeit im marin-pelagischen Bereich begründet, da beide Skuaarten sympatrisch im Gebiet brüten und sich hinsichtlich ihrer Nahrungsökologie unterscheiden. Daneben scheint Prädation durch Skuas, sowohl inter- als auch intraspezifisch, wesentlich zur Reduzierung des Bruterfolgs beizutragen. Dies gilt insbesondere in Gebieten mit einer derart hohen Skuadichte wie in der Fildes-Region. Dabei steigt das Prädationsrisiko bei verlängerten Nahrungssuchflügen aufgrund von Nahrungsmangel noch weiter an. Das im Gebiet praktizierte Füttern von Vögeln durch Stationsmitglieder kann sich negativ auswirken, insbesondere bei Skuas als opportunistisch nahrungssuchende Arten kann eine mögliche Einschleppung von Krankheiten nicht ausgeschlossen werden.

Die Zahl der brütenden Dominikanermöwen schwankte sehr stark und lag mit 139 Brutpaaren in der Saison 2012/13 über dem langjährigen Mittel und in den Folgejahren deutlich darunter (Saisons 2013/14 und 2014/15: 91 bzw. 49 Brutpaare). Im Langzeitvergleich wird eine signifikante Abnahme der Brutpaarzahlen der Dominikanermöwe deutlich, vermutlich größtenteils bedingt durch eine hohe Schneebedeckung im Frühjahr wegen einer spät einsetzenden Schneeschmelze, in deren Folge es jüngst zu häufigen Brutausfällen kam. Die flächendeckende Erfassung der Antarktisseeschwalbe ergab insgesamt 222 (2012/13), 284 (2013/14) sowie 296 (2014/15) Brutpaare. Im Langzeitvergleich zeigt diese Art einen – trotz erheblicher interannueller Schwankungen – stabilen Bestand bei gleichzeitiger Abnahme der Koloniegrößen und einer großen Häufigkeit von Einzelbrütern.

Im Rahmen der Erfassung aller potentiellen Brutvögel, Durchzügler und Irrgäste wurden erneut Arten wie Kaiser-, Königs- oder Goldschopfpinguin registriert. Daneben wurden einzelne Exemplare von Schneesturmvogel, Silbersturmvogel, Schwarzbrauenalbatros, Kuhreiher und Weißbürzelstrandläufer beobachtet. Wie bereits in den Vorjahren wurden übersommernde Küstenseeschwalben, die häufig in größeren Trupps, auftraten, registriert.

Neben der Brutvogelerfassung wurden in der Fildes-Region regelmäßig Robbenzählungen durchgeführt. Die höchste Zahl an Südlichen Seeelefanten und Antarktischen Seebären wurde jeweils im Januar bzw. Februar an den sandigen Buchten der Westküste der Fildes Peninsula verzeichnet. Räumliche Veränderungen der Liegegruppen von Seeelefanten wurden nicht festgestellt. Im Langzeitvergleich nahm sowohl die Zahl der Seeelefanten als auch die der Weddellrobben seit den 1980er Jahren ab, trotz einer Stabilisierung während des letzten Jahrzehnts. Inwieweit es sich dabei lediglich um eine lokal veränderte Verbreitung dieser Arten oder um tatsächliche regionale Bestandsrückgänge handelt, bleibt offen. Dagegen stieg die Zahl der Antarktischen Seebären seit den 1980er Jahren deutlich an. Diese Entwicklung entspricht Ergebnissen aus anderen Gebieten, in denen diese Art nach der starken Dezimierung durch intensive Robbenjagd ein schnelles Populationswachstum zeigt. Während des Untersuchungszeitraums wurden in der Fildes-Region Robbengeburten für die Arten Südlicher Seeelefant, Weddellrobbe, Antarktischer Seebär und Seeleopard dokumentiert. Zudem setzte sich die räumliche Ausbreitung der Seebärenwurfplätze fort.

Die derzeit größte Gefährdung für die Populationen von Seevögeln und Robben in der Antarktis stellen veränderte Umweltbedingungen infolge von Klimaveränderungen dar, wie z. B. in Form von Veränderungen im Nahrungsnetz, Habitatverlust oder -verschiebung. Daneben können direkte anthropogene Einflüsse, wie beispielsweise Interaktionen mit Fischereiaktivitäten oder Schiffsverkehr (z. B. Konkurrenz um Nahrung, Verletzungen) sich negativ auf lokale Bestände von Seevögeln und Robben auswirken. Spezifisch für die Fildes-Region sind anthropogene Störungen, insbesondere durch Besucher der ansässigen Stationen in Brut- und Ruhegebieten von Vögeln und Robben. Davon sind insbesondere sensitive Arten wie der Südliche Riesensturmvogel betroffen, welcher wiederholt starke Rückgange der Brutpaarzahl sowie einen geringen und weiter abnehmenden Bruterfolg zeigt.

Brutvogelmonitoring in den eisfreien Gebieten der Maxwell Bay

Einen weiteren Schwerpunkt bildete die Brutvogelerfassung in allen größeren eisfreien Bereichen der an die Fildes-Region angrenzenden Maxwell Bay. Dabei wurden eigene Zählungen durch verfügbare Literaturdaten ergänzt. So konnte für die Gebiete Barton, Weaver und Potter Peninsula, am Green Point (alle King George Island) sowie für Stansbury Peninsula, Martin und Duthoit Point (alle Nelson Island) eine Übersicht über die Brutvogelbestände erstellt werden. Belastbare Langzeitdatenreihen konnten dennoch nur für Fildes, Barton und Potter Peninsula zusammengetragen werden. Anhand dieser Daten, die teilweise über einen langen Zeitraum erhoben wurden, wie sie kaum andernorts in der Antarktis zu finden sind, ließ sich die Entwicklung der Brutvogelbestände in diesen Gebieten in den vergangenen Jahrzehnten darstellen. Daraus wird deutlich, dass sich für die westliche Antarktische Halbinsel typische Bestandstrends meist in allen Brutvogelkolonien der Maxwell Bay widerspiegeln. So nahmen die Brutpaarzahlen von Eselspinguinen in den Kolonien auf Ardley Island, Barton und Potter Peninsula seit Zählbeginn in den 1960er Jahren kontinuierlich zu. Im Gegensatz dazu sanken die Brutpaarzahlen von Adéliepinguinen sowohl auf Ardley Island wie auch auf Potter Peninsula nach einer Zunahme in den 1980er Jahren drastisch, stabilisierten sich jedoch in jüngster Vergangenheit. Zügelpinguine zeigen ein weniger einheitliches Bild als die beiden anderen Pinguinarten. Aktuelle Daten aus der Maxwell Bay liegen nur von Barton Peninsula und Ardley Island vor. Während sich die Kolonie auf Ardley Island nach einem rapiden Rückgang in den 1980er und 1990er Jahren nun auf sehr niedrigem Niveau stabilisiert hat, erweist sich der Bestand in der Barton-Peninsula-Kolonie seit Zählbeginn als stabil. In der Pinguinkolonie auf Potter Peninsula wurden in den 1980er Jahren ebenfalls sinkende Brutpaarzahlen beobachtet (für den Zeitraum danach liegen jedoch keine Zähldaten vor). Inzwischen ist der Zügelpinguin aus dieser Kolonie allerdings ganz verschwunden. Die

Brutpaarzahlen des Südlichen Riesensturmvogels sowohl auf Barton als auch auf Potter Peninsula zeigten im Vergleich zu Daten der 1980er Jahre eine Tendenz zur Abnahme, während der Bestand auf Stansbury Peninsula leicht zugenommen hat. Bei beiden Vorkommen der Blauaugenscharbe im Bereich der Maxwell Bay am Duthoit Point und auf Low Rock nahe Potter Peninsula fand verglichen mit den Beständen der 1990er Jahre ein Rückgang dieser Art statt. Aktuelle Zählungen am Duthoit Point deuten eine Stabilisierung der Brutpaarzahl der Blauaugenscharbe an. Die verhältnismäßig langen Datenreihen über Skuabrutpaarzahlen im Bereich der Maxwell Bay weisen auf einen während der vergangenen Jahrzehnte stabilen Bestand hin. Der starke Einbruch der Brutpaarzahlen beider Skuaarten in jüngster Vergangenheit wurde sowohl auf in der Fildes-Region als auch auf Barton und Potter Peninsula beobachtet. Die Zähldaten der Dominikanermöwen deuten zwar auf einen stabilen Bestand hin, was sich aufgrund der verhältnismäßig geringen Datenbasis nicht abschließend bestätigen lässt. Die Datengrundlage bei allen übrigen Brutvogelarten im Bereich der Maxwell Bay (außerhalb Fildes Peninsula) ist lückenhaft und erlaubt keine Ableitung von gesicherten Bestandstrends.

Dokumentation von Gletscherrückzugsgebiete ausgewählter Bereiche der Maxwell Bay in Bezug auf die regionale klimatische Entwicklung

King George Island sowie Nelson Island sind wie alle größeren Inseln der South Shetland Islands mit einer Eisbedeckung von über 90 % fast vollständig vergletschert. Vor allem die Eiskappe King George Islands wird aufgrund ihrer Eigenschaften und des vorherrschenden maritimen Klimas als höchst sensitiv gegenüber Klimaveränderungen eingeschätzt. Dies gilt insbesondere für einen derart exponierten Gletscherausläufer wie dem Bellingshausen-Dom im Norden der Fildes Peninsula. Angesichts der großen ökologischen Bedeutung für lokale Ökosysteme wurde ergänzend zum Brutvogel- und Robbenmonitoring eine Dokumentation von Gletscherrückzugsgebieten ausgewählter Bereiche der Maxwell Bay erstellt sowie die regionale klimatische Entwicklung in den vergangenen Jahrzehnten dargelegt. Demnach ist das Klima im Untersuchungsgebiet als Teil der South Shetland Islands geprägt durch den Einfluss der südhemisphärischen Polarfront und der Lage der Inseln im Ozean. Dadurch zeichnet sich das vorherrschende Klima durch verhältnismäßig milde Temperaturen, eine hohe Luftfeuchtigkeit, große, ganzjährig gleichmäßige Niederschlagsmengen und starke Winde aus, vorwiegend aus westlicher Richtung. Ferner sind schnelle Wetterveränderungen typisch, bedingt durch eine starke Zyklonaktivität. Das monatliche Temperaturmittel liegt in den Sommermonaten gewöhnlich über dem Gefrierpunkt. Die höchste in der Station Bellingshausen jemals gemessene Temperatur liegt bei über 8°C, winterliche Tiefsttemperaturen erreichen bis zu -30°C. Mit Hilfe meteorologischer Daten der Station Bellingshausen wurde die Klimaentwicklung der vergangenen Jahrzehnte in der Fildes-Region untersucht. So zeigte sich, dass die Jahresmitteltemperatur zwischen 1969 und 2013 schwach anstieg. Die bis zum Jahr 2000 nachweisbare deutliche Erhöhung der mittleren Lufttemperatur im Sommer (Dezember – Februar) wurde durch eine Reihe kühler Sommer in jüngster Vergangenheit relativiert. Während die Herbsttemperatur (März – Mai) kontinuierlich zunahm, konnte eine Erhöhung der Wintertemperatur (Juni – August), wie sie für andere Gebiete der WAP-Region nachgewiesen wurden, für die Station Bellingshausen nicht bestätigt werden. Obwohl sich die gemessenen Niederschläge im Verlauf der vergangenen 46 Jahre nur minimal veränderten, zeigte die Schneehöhe im monatlichen Mittel für Januar und Dezember eine signifikante Zunahme, die im Wesentlichen im Zusammenhang mit der Reihe an kühlen Sommern in der jüngsten Vergangenheit stehen, welche ein Abschmelzen der im Winter oder Frühjahr gefallenen Schneemenge erheblich verzögerten. Eine jährliche Zunahme der Schneefallmenge, wie für die WAP-Region nachgewiesen, war hingegen für die Fildes-Region, basierend auf der Auswertung der Niederschlagsmenge, nicht feststellbar. Die Dokumentation von

Gletscherrückzugsgebieten im Bereich der Maxwell Bay erfolgte für alle größeren eisfreien Gebiete, für die eine entsprechende Erfassung bislang nicht vorlag. Diese Gebiete umfassten den Norden der Fildes Peninsula, den Norden von Nelson Island (einschließlich Stansbury Peninsula und Martin Point), Duthoit Point/Nelson Island als auch die Halbinseln Weaver und Barton. Die Auswertung zahlreicher Luft- und Satellitenaufnahmen erfolgte durch manuelle Bildinterpretation mittels Delineation der horizontalen Gletscherausdehnung mit Hilfe von GIS. Da die Verwendbarkeit optischer Satellitendaten stark vom saisonalen Zeitpunkt der Aufnahmen sowie von den Wetterbedingungen abhängt, war die Anzahl auswertbarer Aufnahmen für einige Gebiete eingeschränkt. Die Ergebnisse der Auswertung der Veränderungen der Gletscherausdehnung bestätigten Befunde früherer Studien über einen deutlichen Rückzug von Gletscherfronten auf King George Island. Am deutlichsten zeigte sich dies an der Gletscherfront des Bellingshausen-Doms, welche sich im zentralen Bereich zwischen 1956 und 2012 um über 600 m zurückgezogen hat. Hier werden die Abschmelzprozesse des angrenzenden Gletschers vor Ort in Form von sichtbar zurückweichenden Gletscherfronten oder ausschmelzendem Toteis besonders deutlich, das häufig aus der der Gletscherzunge vorgelagerten Moräne zum Vorschein kommt. Daneben gibt es Hinweise auf einen Gletscherrückzug in den Bereichen Barton und Weaver Peninsula, wobei ältere Vergleichsdaten fehlten. Ein deutliches Verlagern der Gletscherfront im Laufe der letzten sechs Jahrzehnte um bis zu 400 m ist ebenfalls am Green Point zu erkennen. Dagegen gestaltet sich die Gletscherentwicklung im Norden von Nelson Island weniger einheitlich. Hier waren Bereiche eines Rückzugs als auch ein geringfügiges Vordringen des Gletschers erkennbar, möglicherweise bedingt durch schnelleres Abfließen des Gletschers. Aufgrund der starken Limitation eisfreier terrestrischer Areal in der Antarktis sind die durch den Gletscherrückzug neu entstandenen eisfreien Gebiete von großer Bedeutung für lokale terrestrische Ökosysteme, indem sie z. B. Besiedlungsräume für sich ausbreitende oder neu einwandernde oder eingeschleppte Mikroorganismen, Arthropoden, Algen, Moose, Flechten und Blütenpflanzen sowie Ruhe- und Reproduktionsstätten für heimische Seevögel und Robben bieten.

Die Maxwell Bay, einschließlich der Fildes-Region, liegt in einem Gebiet rasanter klimatischer Veränderungen, die gravierende Folgen für die Tier- und Pflanzenwelt mit sich ziehen können und in ihrer Komplexität kaum abzuschätzen sind. Zusätzlich trägt die hohe Konzentration anthropogener Einflüsse zu Veränderungen im lokalen Ökosystem bei. Da die eine Beurteilung von Veränderungen in Seevogel- und Robbenbeständen und deren Reproduktionsraten infolge von globalen, regionalen und/oder lokalen Umweltveränderungen nur anhand von Langzeitdatensätzen erfolgen kann, ist eine Fortsetzung des Monitoringprogramms sowohl in der Fildes-Region als auch im weiteren Bereichen der Maxwell Bay zu empfehlen.

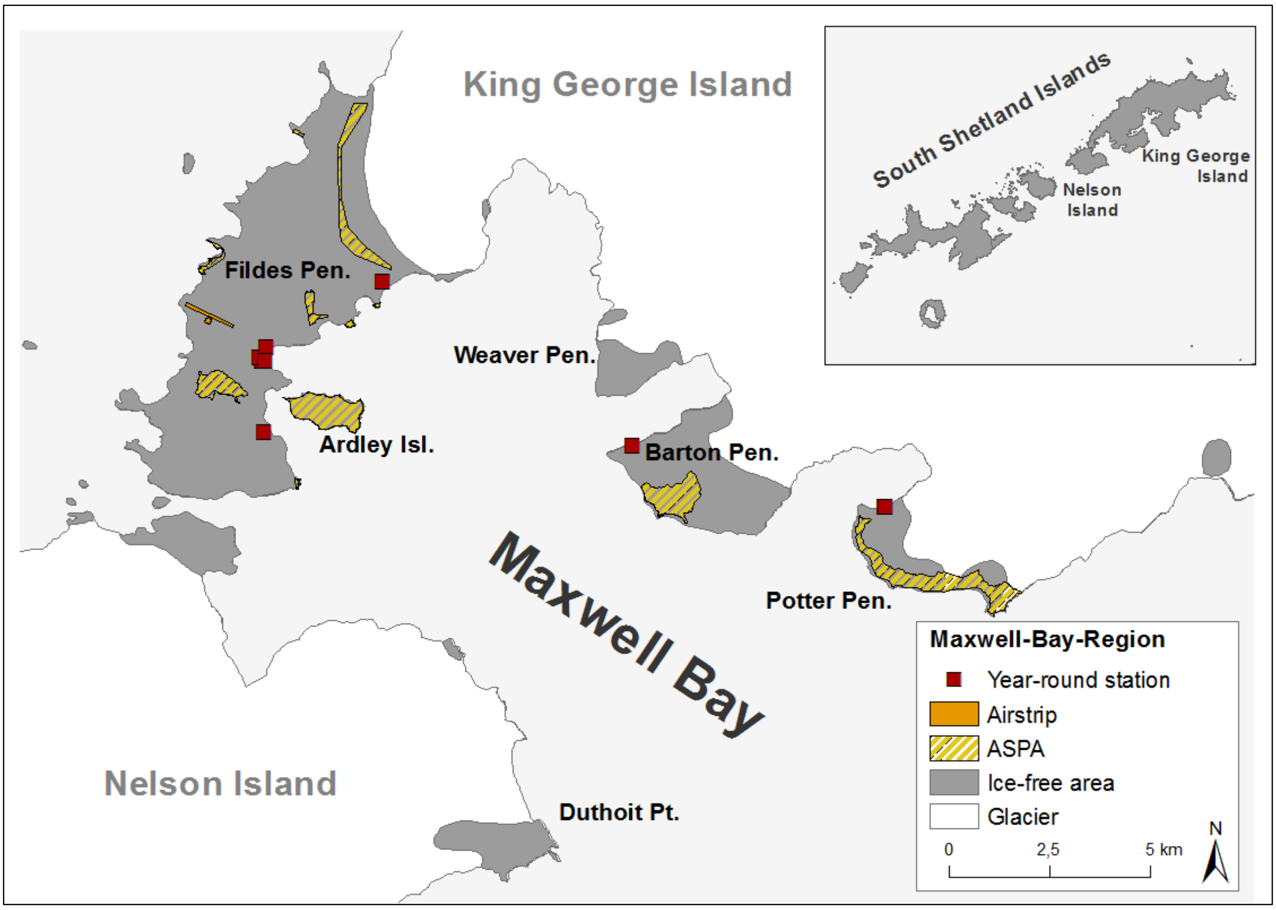
1 Introduction

The Antarctic is a region scarcely influenced by people. It has unique biological, geological and hydrological characteristics that are of global importance. This region, between 60° und 90° degrees of southerly latitude, was given a special role for science with the signing of the Antarctic Treaty in 1959. The Environmental Protection Protocol of the Antarctic Treaty (hereafter Madrid Protocol, in force from 1998) stipulates protection for the Antarctic flora, fauna, and landscapes. Nevertheless, the species and the ecosystems of the Antarctic are subject to increasing anthropogenic pressures. As well as the consequences of regional activities such as tourism, fishery and research (e.g. Tin et al. 2009; Braun et al. 2012; Ainley et al. 2014) there are more and more intense traces of global warming (e.g. Schofield et al. 2010; Turner et al. 2014). This is particularly applicable to the West Antarctic Peninsula (WAP) (Meredith et al. 2005; Ducklow et al. 2007; Trivelpiece et al. 2011) to which the South Shetland Islands belong. This island group possesses relatively large ice-free areas characterized by comparative high floral and faunal biodiversity. As an example, 15 species of birds are recorded as breeding on the largest island, King George Island, as well as a rich cryptogamic flora. In addition, five of the Antarctic's six seal species breed on the island's coasts. To protect this biodiversity, important fossil beds and geological phenomena, and to preserve future research possibilities, five Antarctic Specially Protected Areas (ASPA) and an Antarctic Specially Managed Area (ASMA) have been designated on King George Island (ATS 2009b, c, 2013a, b, 2014; see also Antarctic Treaty Protected Areas Database: http://www.ats.aq/devPH/apa/ep_protected.aspx?lang=e, accessed: 30.05.2016).

In contrast, King George Island has the highest density of research stations in the whole Antarctic. In Maxwell Bay alone, in the southwest of the island, there are currently eight permanent stations. In addition, there are at least 11 field huts and a landing strip. The landing strip has a key role in the logistics of transport between South American and the Antarctic Peninsula (Figure 1). There is a particular concentration of multiple human activities around the Fildes Peninsula, Ardley Island and the neighbouring islands (henceforth 'Fildes Region'). These include, in a small area, logistics, research, tourism (Peter et al. 2008; Peter et al. 2013). As these activities frequently overlap in space or time, they produce conflicts of interest between the different groups of users and to contraventions of the legally agreed environmental protection requirements. The particularity of this situation is reflected in considerable local anthropogenic effects. These effects include, for example, habitat destruction, disturbance of breeding birds and of seals during breeding or resting on land, damage to vegetation and the contamination of the soil, water and air (Peter et al. 2008; Braun et al. 2012; Peter et al. 2013; Amaro et al. 2015).

Because of local antropogenic effects, there was a need for the efficient management of these activities. A research project was therefore initiated in 2003 to investigate the environmental situation in this region. Within this project, a comprehensive scientific, GPS and GIS based, framework of biotic and abiotic parameters of the Region was created. Likewise, the multiplicity of human activities and their environmental effects in the Fildes Region were quantified (Peter et al. 2008). Using this knowledge, a risk analysis was carried out together with the formulation of need for action and specific management suggestions as the basis for discussions aimed at solving the environmental problems. Further investigations followed in order to fulfil the need for updated basic data. These investigations revealed improvements but also shortfalls (Peter et al. 2013). The discussions on formulating an international management plan are currently on hold.

Figure 1: Overview of the Maxwell Bay with the locations of the Antarctic Specially Protected Areas (ASPAs); South Shetland Islands displayed without Clarence, Elephant and Gibbs Island



The need for carrying out substantial and meaningful long term monitoring programmes has been repeatedly raised at the international level (e.g. ATCM, SCAR) (Lewis Smith 1990; ATS 2005; COMNAP 2005, 2006; Hughes 2010). Monitoring programmes are particulary useful in areas with concentrated and multiple activities and a high biodiversity, like this is particularly valid for the Fildes Region. In this respect, long term monitoring of indicator species such as breeding birds that are sensitive to disturbance, can play an important role because their population levels and reproductive rates can reflect both natural and anthropogenic environmental influences.

The aim of the project reported here was to continue the standardized and GPS/GIS supported recording of seals, breeding and transient birds in the Fildes Region and the expansion of that survey over selected parts of Maxwell Bay. A further aspect was to document glacier retreat in selected areas of Maxwell Bay in connection with regional climatic changes.

The project was based to a considerable degree on previous research by German scientists who investigated aspects of the ecology of birds, seals, arthropods and of the vegetation in the Fildes Region between 1979 and 1990 (Table 1). Thereafter, several aspects of this work were continued by scientists from the Polar and Bird Ecology Group (Institute of Ecology, Friedrich Schiller University, Jena). Particular emphasis was given to the ecology of skua species and of the southern giant petrel. As part of the project mentioned above, in 2003, systematic monitoring was restarted of all the breeding bird and seal species in the study area. Monitoring continued with scarcely a break during all successive southern summers. Further data was provided by several scientific studies and two student expeditions (2000/01 and 2007/08) (Table 1).

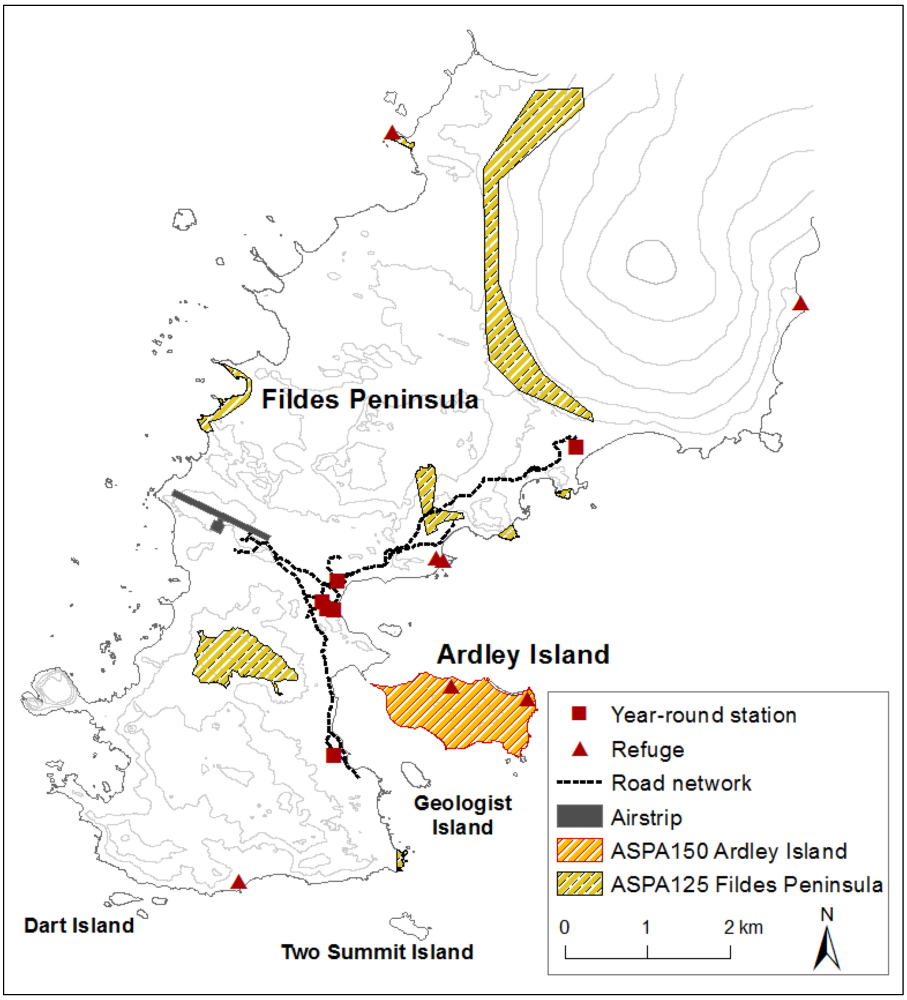
The project could only have been carried out in this way with the collaboration of J. Krietsch, M.-C. Rümmler, M. Senf, and M. Stelter as well as in in close cooperation with scientists from other countries (e.g. South Korea, Russia, China, Chile, Argentina). These scientists supported our fieldwork and/or provided data. Particularly important was the logistic support provided by the Russian Institute of Polar Research (AARI), the Russian Antarctic Expedition, the Chilean Antarctic Institute (INACH), the Chilean Airforce (FACH) and Aerovías DAP, Chile. Several counts, some of them using drones, were carried out in close cooperation with staff of the company ThINK (Thüringer Institut für Nachhaltigkeit und Klimaschutz GmbH [Thuringian Institute for Sustainability and Climate Protection plc]). We thank the leaders and the members of the stations on the Fildes Peninsula for their collaboration in the Antarctic. Part of the monitoring in Maxwell Bay was only possible with the logistic support of A. Contreras Staeding. We owe considerable thanks to F. Hertel and H. Herata (Umweltbundesamt [German Environment Agency]) for their exceptional liaison work. The Alfred Wegener Institute in Bremerhaven supported the project by providing polar clothing and for organizing part of the transport logistics. Last but not least, we thank all our colleagues who supported the project by helping in the field or by providing data.

2 Monitoring the breeding birds and seals of the Fildes Region

2.1 Methods

The Fildes Region covers the Fildes Peninsula, Ardley Island and neighbouring islands up to a maximum distance of 500 m (Figure 2). Monitoring of breeding birds in the Region was carried out in December and January in the seasons 2012/13, 2013/14 and 2014/15. The methodology followed was that described in Peter et al. (2008, Sec. 3.4.1). Based on these surveys, the changes in the populations of breeding birds is presented in detail. Not included in these surveys were the species of storm petrel breeding in the region, Wilson's storm petrel (*Oceanites oceanicus*) und black-bellied storm petrel (*Fregetta tropica*) because, compared to Peter et al. (2008; 2013) no new bird registration took place.

Figure 2: Overview of the Fildes Region study area



The number of breeding pairs represents the number of active nesting birds. Breeding success is defined as the number of fledged young per breeding pair and season. It should be noted, however, that the precision of counting breeding birds can vary for logistical or methodological reasons. Among these are differences in the time of counting, or the breeding grounds of some species being unreachable or difficult to observe. Older count data were included in the analyses where there were indications that they were sufficiently precise (e.g. known counting times, methodological descriptions being available). Since 2003/04 breeding pairs have been counted according to a standardized method (Peter et al. 2008). And since

2010/11 detailed maps of all known breeding places have been used in order to check these systematically.

In the 2013/14 and 2014/15, during recording penguin colonies on Ardley island, a drone (Unmanned Aerial Vehicle - UAV) was used for the first time (Mustafa et al. 2014). The drone was a remote controlled octocopter MK ARF Okto XL (HiSystems). The vehicle was equipped with GPS, Inertial Measurement Unit (IMU), as well as with a steerable digital camera (Canon Powershot G15, Sony Alpha 6000) (Rümmler et al. 2015). The drone was able to remain airborne for about 15 min. The operating altitude depended on the target and the local relief. On Ardley Island it was 100 m in 2013/14 and 50 m above ground level in 2014/15. On Diomedea, Geologist & Two Summit Island the altitude was 50 m a.s.l. and on Nelson Island 50 m above ground level. After the survey, a mosaic was made of the air photos taken and geoferenced. Several different people then independently counted the number of breeding pairs of penguins manually. These counts were ground truthed against counts made by observers on the ground. The differences between the ground and air counts were between -1 % and +9 % (pers. Mitteilg. O. Mustafa). The counts made by ground observers were used in the subsequent analyses to retain comparability with existing data on breeding pair counts.

In addition, counts of young southern giant petrel were supplemented by drone use in some areas during the 2014/15 season. Experience on the ground as well as during data analysis indicated that drones are well suited to counting young southern giant petrels. An experiment was made of the disturbance caused by drones. The drone was repeatedly flown over a southern giant petrel colony and the reaction of the birds watched through telescopes and also filmed. Both adult and young birds showed much weaker behavioural changes in response to the drone than to field workers carrying out counts on the ground (pers. comm. M.-C. Rümmler). Furthermore, the local topography sometimes necessitates very close approaches to the birds. This greatly raises the danger of disturbance. To reduce the error when counting southern giant petrel young using drones, the counts from the aerial photos were carried out independently by two co-workers. Their results were then compared. The young birds can be easily distinguished because of their light plumage and the topography of the southern giant petrel colonies of the region. The precision of this method thus seems sufficiently high (Figure 3) for future application to be recommended. Future recording by drones also appears suitable for minimising the inevitable considerable disturbance caused by direct ground counts of southern giant petrels.

To complement the breeding bird survey, all the vagrant and transient birds observed in the study area were recorded in the seasons 2012/13 to 2014/15. No bird species were observed in the Fildes Region other than those given in the overview of Peter et al. (2008, Kap. 3.1.1, Tab. 1).

Furthermore, a complete survey was made of seal populations in each of the summer months (December, January, February) in the seasons 2012/13 to 2014/15. The survey covered each and every bay along the coast of the Fildes Peninsula and Ardley Islands using the method described by Peter et al. (2008, Kap. 3.4.2). Data collection for the project ended in February 2015.

Data in addition to our own records was obtained in order to investigate possible long-term changes in sea bird and seal populations. Large amounts of data came from numerous, previously unpublished, reports by German researchers of expeditions made during the 1980s (Table 1). Where there were two counts per month we used the data from the second half of the month. Further data was provided by researchers working on site (Table 1).

All sources of count data from the Fildes Region used in the analyses are listed (Table 1). From the 2003/04 season onwards this data is primarily derived from records made on site by project colleagues.

Figure 3: Example of an aerial photograph captured by drone use (detail of Diomedea Island), flight altitude 50 m above sea level; the juvenile southern giant petrel is clearly visible due to surrounding faeces and bright plumage colour (photo: ThINK, 19.02.2015).

Table 1: Sources of the used monitoring data from the Fildes Region

Season	source	monitored species
1979/80	Bannasch et al. 1981	all breeding birds
1980/81	Bannasch et al. 1983; Jablonski 1984	all breeding birds, seal census
1981/82	Bannasch et al. 1983	all breeding birds
1982/83	Lorenz 1984; Peter et al. 1988	all breeding birds, seal census
1983/84	Lorenz 1984; Peter et al. 1988	all breeding birds, seal census
1984/85	Rauschert et al. 1987; Peter et al. 1988; Peter et al. 1989	all breeding birds, seal census
1985/86	Rauschert et al. 1987; Zippel 1987; Mönke et al. 1988	all breeding birds, seal census
1986/87	Mönke et al. 1988	all breeding birds, seal census
1987/88	Lange et al. 1989; Nadler et al. 1989	all breeding birds, seal census
1988/89	Lange et al. 1989	all breeding birds, seal census
1989/90	Erfurt et al. 1990; pers. comm. H. Grimm	all breeding birds, seal census
1990/91	pers. comm. J. Valencia & M. J. Roselló	penguins Ardley Island
1991/92	pers. comm. J. Valencia & M. J. Roselló	penguins Ardley Island

Season	source	monitored species
1992/93	pers. comm. J. Valencia & M. J. Roselló	penguins Ardley Island
1993/94	pers. comm. J. Valencia & M. J. Roselló	penguins Ardley Island
1994/95	pers. comm. J. Valencia & M. J. Roselló, Valencia et al. 1996	penguins Ardley Island
1995/96	pers. comm. J. Valencia & M. J. Roselló Soave et al. 2000	penguins Ardley Island skuas, snowy sheathbill
1996/97	pers. comm. J. Valencia & M. J. Roselló Chupin 1997	penguins Ardley Island southern giant petrel
1997/98	pers. comm. J. Valencia & M. J. Roselló	penguins Ardley Island
1998/99	pers. comm. J. Valencia & M. J. Roselló pers. comm. H.-U. Peter & J. Welcker Welcker 2001	penguins Ardley Island southern giant petrel kelp gull
1999/2000	pers. comm. J. Valencia & M. J. Roselló Welcker 2001	penguins Ardley Island kelp gull
2000/01	pers. comm. J. Valencia & M. J. Roselló Braun 2001	penguins Ardley Island all breeding birds, seal census
2001/02	pers. comm. J. Valencia & M. J. Roselló	penguins Ardley Island
2002/03	pers. comm. J. Valencia & M. J. Roselló pers. comm. I. Chupin & S. Pfeiffer pers. comm. A. Petrov	penguins Ardley Island southern giant petrel seal pupping sites
2003/04	pers. comm. M. Ritz	skuas
2004/05	pers. comm. M. Ritz pers. comm. I. Chupin	skuas kelp gull, seals
2005/06	pers. comm. M. Ritz	skuas
2006/07	Fröhlich 2007 pers. comm. M. Kopp	penguins Ardley Island, southern giant petrel, seal breeding sites & census skuas
2007/08	pers. comm. M. Kopp Braun 2008	skuas all breeding birds, besides skuas, seal census
2008/09	pers. comm. S. Lisovksi & M. Kopp	skuas, seal breeding sites
2009/10	pers. comm. M. Kopp pers. comm. V. Sjomin	skuas seal breeding sites
2010/11	pers. comm. A. Soloviev & B. Zatsepin	seal breeding sites
2011/12	pers. comm. A. Contreras Staeding & R. Eliseev	seal breeding sites
2012/13	pers. comm. O. Sakharov	seal breeding sites
2013/14	pers. comm. M. Xing	seal breeding sites

During the project period, monitoring of breeding birds was extended to all large ice-free areas of Maxwell Bay. Our recording effort covered the areas of Green and Duthoit Point and Stansbury Peninsula in the north of Nelson Island as well as over part of the Barton Peninsula. These data were supplemented with data from other sources, particularly for areas that it was not possible to visit (the Weaver and Potter Peninsulas, parts of the Barton Peninsula and Martin Point). We used all currently available data from the literature, data from numerous unpublished reports from expeditions by German researchers in the 1980s, and data provided by South Korean (Barton and Weaver Peninsulas) or German (Potter Peninsula) scientists. Figures are only given where there is sufficient source data. All the other data is presented in tables along with the data sources.

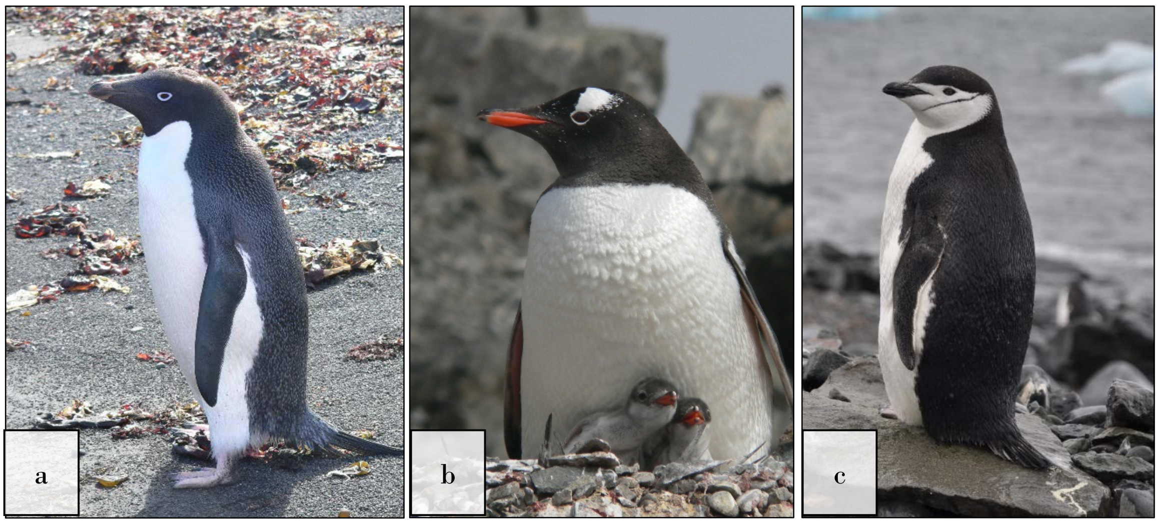
The statistical investigation of the data for temporal trends was carried out using linear regression (Sigma Plot© Vers. 13.0) unless otherwise stated. The significance for all statistical analyses was set at 5 %. Only significant trends were presented graphically. Where means are given they are always accompanied by their standard deviations.

In the figures data indicated as for a single year always refers to the second half of the austral summer. Thus, for example, the indication ‘2015’ refers to the austral summer, i.e. the season, 2014/15. Years for which there were no records are not specifically indicated.

2.2 Penguins (*Pygoscelis* spec.)

In the Fildes Region three penguin species breed on Ardley Island and along the west coast of the Fildes Peninsula. One of these is the Adélie (*Pygoscelis adeliae*, Figure 4 a) which is currently identified as ‘near threatened’ according to the IUCN criteria (BirdLife International 2015b). The species is associated with ice and greatly dependent on krill and is the species most severely affected by the climate warming currently observed (e.g. Taylor et al. 1990; McClintock et al. 2008; Schofield et al. 2010). At the moment the population is assessed at over 2 million breeding pairs (BP) (BirdLife International 2015b). However, a major decline is expected if climate warming continues (Ainley et al. 2010). The prognosis that all Adélie colonies north of 67-68°S will disappear if the temperature rises to 2°C above pre industrial levels (Ainley et al. 2010) is counteracted to some degree by the expectation that newly ice-free areas might be colonized.

Figure 4 a - c: *Pygoscelis* penguin species breeding in the Fildes Region: Adélie, gentoo and chinstrap penguin (photos: C. Braun)



The gentoo penguin (*P. papua*, Figure 4 b) is another penguin species breeding in the region that is currently classified as ‘near threatened’ (BirdLife International 2015b). This classification is because the number of breeding pairs in some of the colonies in the Subantarctic that are important for the total population have experienced major declines (e.g. Bingham 1998). More recent surveys indicate that breeding pair numbers have stabilized or have begun to grow again in particular on the Antarctic Peninsula and thus at the most southerly border of its distribution (e.g. Clausen et al. 2003; Lynch et al. 2008; Crawford et al. 2009; Forcada et al. 2009). The current estimate of the total gentoo penguin population stands at 387,000 breeding pairs (Lynch 2012).

The third penguin species that breeds in the Fildes Region is the chinstrap penguin (*P. antarctica*, Figure 4 c). This species is very widely distributed and its population is estimated at 8 million individuals. It therefore lies outside the agreed criteria for being threatened and is classified as of 'least concern' (BirdLife International 2015b). Although the number of chinstrap penguins increased in some areas (Woehler et al. 2001), considerable reductions have been recorded in numerous other colonies including in the South Shetland Islands area (Woehler et al. 2001; Sander et al. 2007a; Sander et al. 2007b; Trivelpiece et al. 2011; Barbosa et al. 2012; Naveen et al. 2012).

Other penguin species have been recorded occasionally in the Fildes Region as vagrants or visitors such as, for example, emperor penguin (*Aptenodytes forsteri*), macaroni penguin (*Eudyptes chrysolophus*) and rockhopper penguin (*Eudyptes chrysocome*) (Sec. 2.10; Peter et al. 2008; Peter et al. 2013). Occasional breeding by the king penguin (*Aptenodytes patagonicus*), a species previously seen as a vagrant, has been documented on King George Island (Sec. 3.5; Juáres et al. 2014).

2.2.1 Ardley Island

Ardley Island is one of the few areas in the Antarctic where the three penguin species breed sympatrically, i.e. together in one colony. In addition, the colony has particular importance for the gentoo penguin because a large number (>1 % of the world population) breed there. In consequence, it is classified as 'Important Bird Area' (IBA) No. 48 (until 2011 IBA No. 53) (BirdLife International 2015a; Harris et al. 2015). These categories were introduced by BirdLife International, the non-governmental umbrella group for bird protection organisations worldwide. The categories designate, on a global scale, areas that are particularly important for the protection of birds (Peter et al. 2008) and are based on agreed criteria. These special bird protection areas have no legally binding status, nevertheless they are able to contribute to the long-term protection of threatened species because they raise the profile of areas particularly worthy of protection. They should also attract greater consideration for the development of environmental impact assessments and designations and ASPAs (ATS 2015). The selection of Ardley Island as an IBA was supported by the collation of relevant data by the SCAR-BBS committee (Harris et al. 2015).

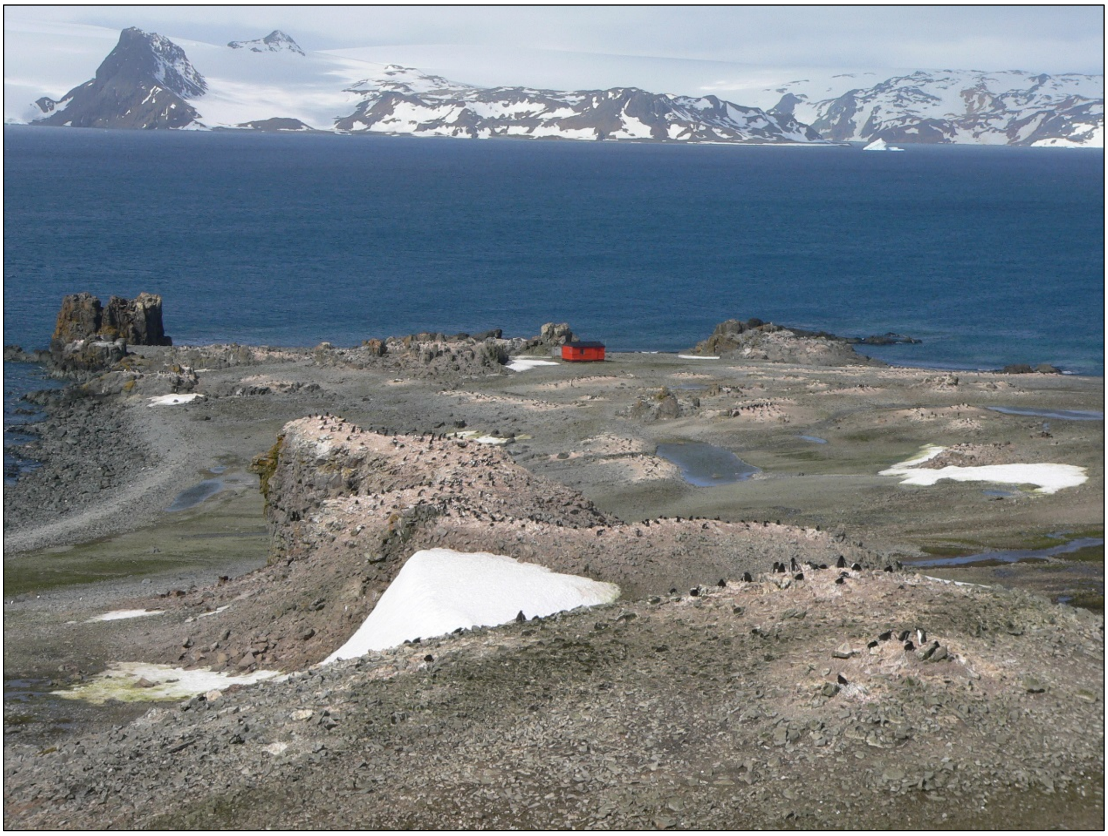
The penguin colony on Ardley Island is marked by a clear topographical structure (Figure 5). The penguins in this colony breed mostly on small rocky outcrops, slopes and the upper levels of the site because these become snow-free earlier than those lower down.

There have been repeated reports of negative effects of anthropogenic disturbance on the reproduction and physiology of penguins (e.g. Giese 1996; Fowler 1999; Holmes et al. 2006; Bricher et al. 2008; Trathan et al. 2008; Lynch et al. 2010b), even though penguins do show habituation to some specific and regularly occurring stressors (e.g. Culik et al. 1995; Cobley et al. 1999; Otley 2005; Walker et al. 2006; Viblanc et al. 2012).

The risk of negative human influences from research, logistics and tourism is particularly high on Ardley Island because of its proximity to the Fildes Peninsula with its high density of human activities. The high activity of shipping (including zodiac traffic) in the northerly Ardley Cove presents a high risk for penguins that are foraging near the coast or returning to the colony (Peter et al. 2008; Lynch et al. 2010a; Braun et al. 2012; Peter et al. 2013). The main air route for the Chilean airport Tte. March runs immediately north of Ardley Island. Because of the predominant observance of the minimum distances (vertical 610 m, horizontal 460 m; ATS 2009c) during the most recent 10 years specified in the management plan for ASPA No. 150 the possible threat from low flying aeroplanes and helicopters to sea birds breeding on Ardley has been measurably reduced (Peter et al. 2008; Braun et al. 2012; Peter et al. 2013).

However, there is a risk of anthropogenic influences from visits to the penguin colony by personnel from the neighbouring stations (Peter et al. 2008; Braun et al. 2012; Peter et al. 2013). Visits by tourists in the real sense play a far lesser role on Ardley Island as tourists are usually restricted to groups of 20 or fewer, are led by experts, and restrict themselves to the zones specified for visitors (ATS 2011).

Figure 5: Relief in the area of the penguin colony on Ardley Island (photo: C. Braun)

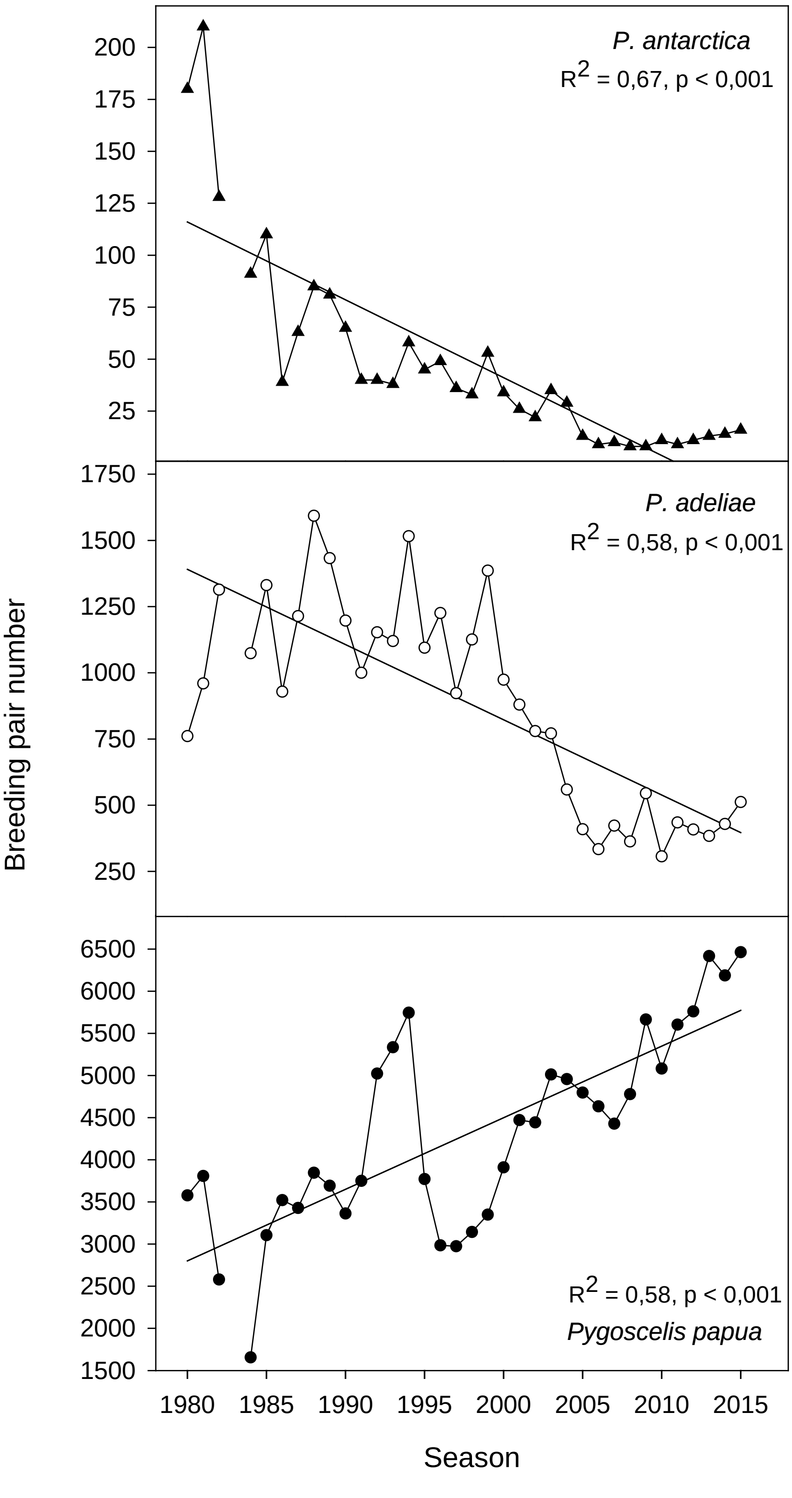


2.2.1.1 Breeding pair numbers

A strong point of breeding bird monitoring on the Fildes Region is the counting of penguins on Ardley Island. This started in the 1979/80 season and was carried out predominantly by German and Chilean researchers. There were only two previous estimates of colony size (Müller-Schwarze et al. 1975). The continuous series provides 35 years of comprehensive local data, which is of the greatest importance in determining the changes in the populations of Adélie, chinstrap and gentoo penguins on the west Antarctic Peninsula. It is of particular relevance given the alterations that have been observed in the populations of these three species.

Taken together the results of the breeding pair surveys for 2012/13 to 2014/15 (Figure 6) confirm the long-term population trends for all three species in this colony (Peter et al. 2008; Peter et al. 2013; Braun et al. 2014). The numbers of breeding pairs of chinstrap penguins have fallen by more than 90 % since counts began in 1979/80 and those of Adélie penguins by more than 30 % (Figure 6). In contrast, numbers of gentoo penguins increased over the same period by more than 80 % and, in 2014/15 had reached 6,475 BP, the highest value recorded since continuous counts began (Figure 6).

Figure 6: **Breeding pair numbers of gentoo, Adélie and chinstrap penguins on Ardley Island between the 1979/80 and 2014/15 seasons with presentation of significant trends by means of linear regression; if there are no values, no data were available for the particular season.**



Looking at the details, the population of chinstrap penguins has now remained stable for more than 11 years after a clear decline during the 1980s and 1990s. However, the population is at a very low level although over this period it has grown slightly from 8 to 16 BP (Figure 6). This situation is similar for the Adélie penguins on Ardley Island. Their population fluctuated strongly annually during the 1980s and 1990s and declined precipitously from 2000. The numbers of Adélie penguins appear to have been generally stable for the last 12 years (Figure 6). More recent declines were observed however, as also for data from the Stranger Point colony (Juáres et al. 2015), in springs with heavy snow and late snow melt (seasons 2007/08, 2009/10 and 2013/14) and when there was heavy precipitation at the start of the breeding season (2014/15, Figure 11, Table 11). In contrast to the gentoo penguin, whose breeding phenology is more flexible, Adélie penguins appear unable to avoid particularly adverse conditions either in time or spatially (Boersma 2008; Juáres et al. 2013; Juáres et al. 2015).

The possible relationship between the numbers of breeding pairs of the chinstrap penguin and those of the other two Ardley Island species were not investigated because of the very limited numbers of chinstrap penguins. There was, however, a clear negative relationship between BP numbers of Adélie and gentoo penguins (Pearson $r = 0.59$, $p < 0.001$). This relationship further emphasizes the strong divergence in the population changes of these two species (Figure 6). Nevertheless, there was no statistical relationship between the annual rate of change in the BP numbers of the two species (calculated as in Carlini et al. 2009: Pearson $r = 0.22$, $p = 0.22$). This means that the populations of these species show neither parallel nor inverse annual changes. The two species in the same colony must therefore react differently to natural environmental factors such as food availability or local snow and weather conditions or, indeed, to people disturbing them. In contrast, Carlini et al. (2009) described a positive relationship between the annual changes in Adélie and gentoo penguins in the Stranger Point colony on the neighbouring Potter Peninsula. In this case, the BP numbers of the two species changed inversely as well (gentoo penguins increased and Adélie penguins decreased), however, the data analysed spanned a much shorter time (Carlini et al. 2009).

These patterns in the BP numbers of the three penguin species agree with many published long term trends including, for example, those from the nearby Barton (Zhu et al. 2005; Ahn 2011) and Potter (Carlini et al. 2009; Juáres 2013) Peninsulas, those from the Lions Rump colony (Korczak-Abshire et al. 2013), from Admiralty Bay (Sander et al. 2007b; Chwedorzewska et al. 2010; Korczak-Abshire 2010) and Penguin Island (Sander et al. 2007a). An overview of the percentage decline of the chinstrap penguin in various South Shetland Island colonies appears in Barbosa et al. (2012). Similar results have also been documented from other regions of the Antarctic Peninsula (e.g. Ducklow et al. 2007; Hinke et al. 2007; Sander et al. 2007a; Sander et al. 2007b; Lynch et al. 2008; McClintock et al. 2008; Lynch et al. 2010b; Trivelpiece et al. 2011; Barbosa et al. 2012; Lynch et al. 2012b; Fraser et al. 2013; Gil-Delgado et al. 2013a). The causes for these changes have often been ascribed to complex ecological processes resulting from the continuing warming of the climate and decline associated with it in the extent of winter sea ice (e.g. Smith et al. 2003; Ducklow et al. 2007; Ainley et al. 2010). This 'sea ice hypothesis' claims that a reduction in winter sea ice leads directly to a reduction in ice dependent species such as Adélie penguins as a consequence of habitat loss whereas numbers of ice independent species such as the chinstrap and the gentoo increase (e.g. Fraser et al. 1992). Long term studies demonstrate, however, significant declines in Adélie as well as chinstrap penguins in the whole WAP region and in the Scotia Sea (Forcada et al. 2006; Trivelpiece et al. 2011).

An alternative hypothesis ascribes both increases and decreases in penguin populations to the abundance of krill, the main food of both Adélie and chinstrap penguins (Lynnes et al. 2004; Ratcliffe et al. 2011; Trivelpiece et al. 2011). This hypothesis holds that these two species benefit from the increased biomass of krill resulting from the occasional decimation of the seal and baleen whale populations that compete for this food source ('Krill surplus hypothesis', e.g. Trathan et al. 2012; Emslie et al. 2013) but that they are currently negatively affected by the decline in krill occurring as a consequence of the climate change induced decline in winter sea ice (Loeb et al. 1997; Trivelpiece et al. 2011; Clucas et al. 2014). Chinstrap penguins would be particularly threatened by this mechanism because they show more rapid population declines and occur only in the WAP region and Scotia Sea. Declines in local Adélie penguin populations, in contrast, might be buffered by the large and stable populations elsewhere, e.g. in the Ross Sea (Trivelpiece et al. 2011), where glacier retreat provides more and more new breeding areas (Taylor et al. 1990; LaRue et al. 2013). The gentoo penguin, in comparison, counts as the 'winner' under current climate warming conditions because it forages predominantly in open water (Lynch et al. 2012b). Furthermore, as a rule it eats lots of fish and squid and are thus clearly less dependent on krill (Ratcliffe et al. 2011), even though the diet of gentoo penguins from Barton Pensinsula consistend mainly of Krill in recent years (Kokubun et al. 2015). This species thus reacts with more flexibility to the current changes in climate and is increasingly extending its range southwards (e.g. Lynch et al. 2012b; Clucas et al. 2014).

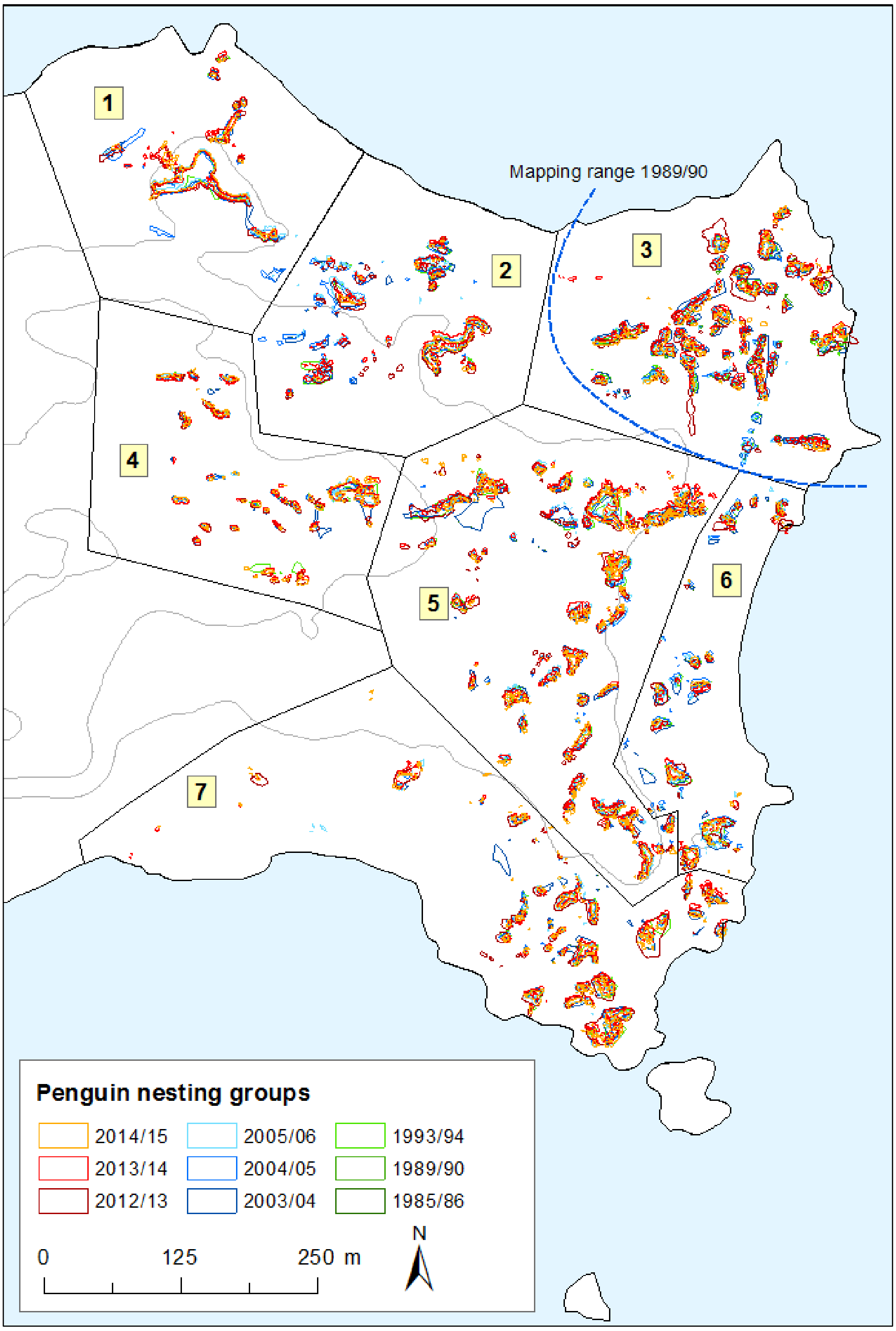
2.2.1.2 Structure and spatial distribution of nesting groups

To complement the breeding pair survey, groups of nests of the three penguin species on Ardley Island were mapped anew during the most recent three breeding seasons. The mapping was carried out in order to detect any changes in the spatial arrangement of nests within the colony. There is available, in fact, complete maps of the nest groups for 8 years although they used different methods (Figure 7). The two oldest data sets are based on aerial photography (1985/86) and hand drawn sketches by German (1985/86) and Chilean (1993/94) researchers (Peter et al. 2008). The data for 2003/04 – 2005/06 and 2012/13 – 2014/15 was obtain using differential GPS (Novatel smart antenna™, Peter et al. 2008). The separation of the colony by Chilean researchers into definable groups (zones, nest groups) was continued. Groups of penguin nests (breeding groups) were individually surveyed when they lay more than one meter from the next nearest nest. The number of occupied nests (= number of breeding pairs) in breeding groups were then determined by walking past the nests at about 0.5 m from nest edges whilst taking the greatest possible care to avoid disturbing the birds.

The spatial distribution of breeding groups in recent years is given in Figure 7. Quantitative comparison of these distributions is only possible to a limited degree because of methodological differences in the mapping (e.g. the precise apportioning of individual pairs to breeding groups in the field, and individual differences in the accuracy of those carrying out the mapping) (cf also the size and form of the polygons drawn for the same breeding groups - Figure 8). However, it can be seen from Figure 7 that there has been only limited change in the spatial extent of breeding groups during the period of the investigation. The considerable increase in the numbers of breeding penguins, more than 50 % since spatial patterns started to be recorded in the 1985/86 season, is hardly reflected at all in the distribution or the size of occupied breeding groups. There was no meaningful extension of the colony apart from the limited fluctuations in the occupation of low lying areas which were unoccupied when there was high snow cover at the beginning of the breeding period.

Because the increase in BP numbers observed have merely maximized the density of nests within breeding groups or produced only minor increases in their spatial extent, it appears that penguins already occupy all optimally suitable areas of Ardley Island. However, it is necessary to take account of gentoo penguins breeding at lower densities than Adélie and chinstrap penguins. This is because gentoo penguins are bigger than the other two species (Volkman et al. 1981). However, both competition within a species (intraspecific) and between species (interspecific) would tend to oppose any increase in the density of breeding pairs within nesting groups. The methodological problems mentioned above prevent, however, any quantitative analysis of breeding group size and breeding pair density.

Figure 7: Spatial distribution of breeding groups within the penguin colony on Ardley Island. The two oldest data sets are based on aerial photographs (only 1985/86) and sketches from ground survey of German (1985/86) and Chilean (1993/94) scientists. The collection of data for 2003/04 – 2005/06 and 2012/13 – 2014/15 was carried out using Differential GPS. The subdivision of the colony into seven zones serves for better orientation.

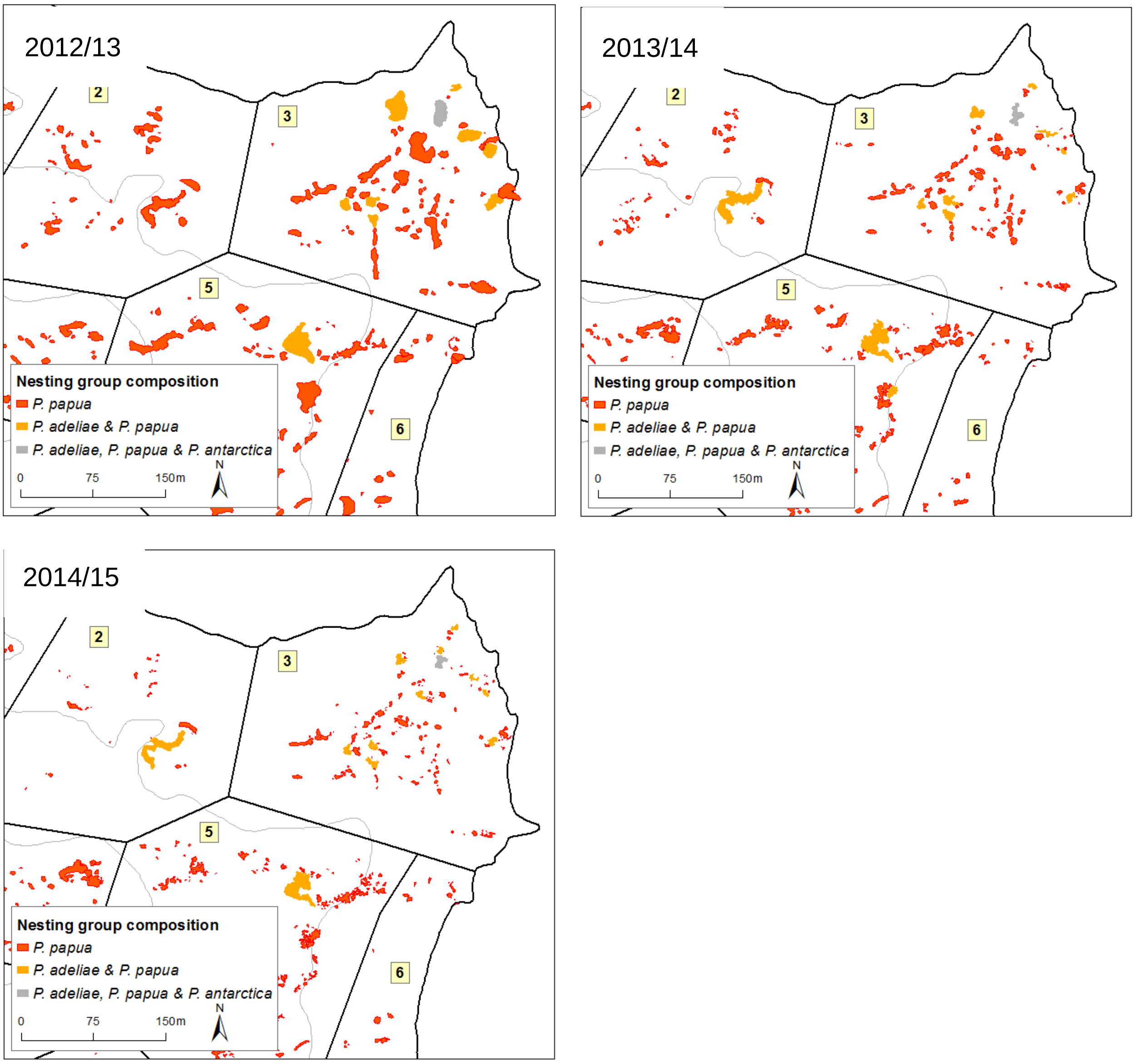


It is not clear how many additional areas of Ardley Island the penguins might colonize if there were to be a continued major increase in their population. These areas were demonstrably occupied some thousands of years ago (Sun et al. 2000; Wang et al. 2007). An indication of the possible process is that, for some years, there has been increasing new settlement of previously unoccupied areas in the far south west of the colony (zone 7) by a few breeding pairs of gentoo penguins (season 2005/06: 5 BP, 2012/13: 4 BP, 2013/14: 22 BP, 2014/15: 13 BP, Figure 7). Some small breeding groups in the north west have, in contrast, disappeared (zones 1 & 2, Figure 7). It remains to be seen whether the new settlements will last or, where it is possible, will grow further. Gentoo penguins appear to be less selective about their breeding sites than Adélie and chinstrap penguins. Furthermore, our observations indicate that gentoo penguins also use higher areas, contrary to earlier observations in a mixed colony in Admiralty Bay (Volkman et al. 1981). As they also show less disposition to form colonies than do the other two species, they may be able to colonize new areas more easily, starting with just a few breeding pairs.

A further aspect that has clearly changed over the most recent 30 years in the penguin colony on Ardley Island is the species composition of the breeding groups. The decline in the numbers of breeding pairs of Adélie and chinstrap penguins and considerable increase in gentoo penguins has, of course, resulted in an increasing decline in the number of mixed breeding groups (Figure 8 a - c). This homogenisation is clearly seen in a detailed analysis of numerical data, including Chilean data (Figure 8 a - c). Thus, though in the 1994/95 season there were still six different types of breeding group based on their species composition (no figure, source: personal communication J. Valencia & M. J. Roselló) there were only three types in the seasons 2012/13 to 2014/15 (Figure 8 a - c). The number of breeding groups containing Adélie penguins declined from 20 to 12 between 1994/95 and 2014/15 (Figure 8 a - c). No breeding groups in which only Adélie penguins were breeding have been recorded since the 2008/09 season.

Similar trends have been demonstrated for other penguin colonies on King George Island. For example, the number of Adélie penguin breeding groups in the Stranger Point colony on the Potter Peninsula has declined from 50 in 1995/96 (Carlini et al. 2009) to 20 in the 2011/12 season (Juáres 2013; Juáres et al. 2015). At the Lions Rump colony the corresponding decline was from 11 in the 1995/96 season to 6 in 2010/11 (Korczak-Abshire et al. 2013). There is no observation of a permanent resettlement by Adélie penguins, in consequence of the stabilization of their BP numbers, of sympatric breeding groups that they had previously abandoned in either Ardley Island or in the Stranger Point colony (Juáres et al. 2015). There is therefore no discernible recovery in the number of mixed breeding groups.

Figure 8 a - c: Composition of breeding groups of gentoo, Adélie and chinstrap penguins within the penguin colony on Ardley Island in the seasons 2012/13 to 2014/15 (see also Peter et al. 2008)

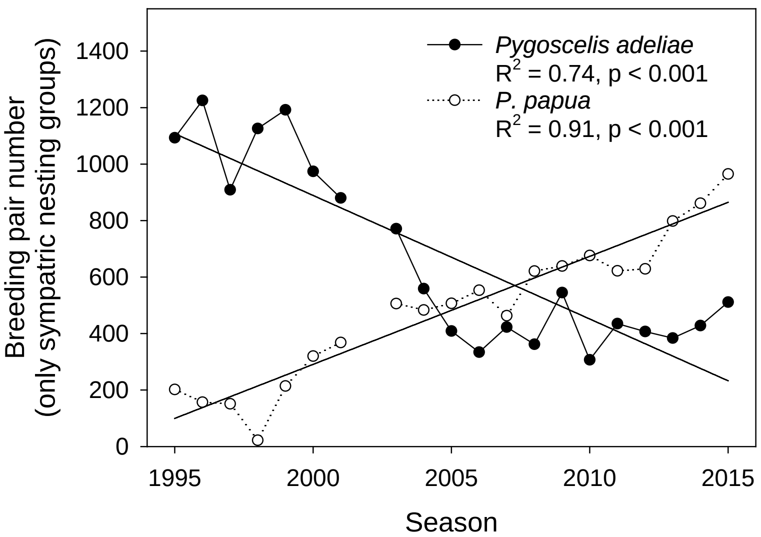


In order to investigate to what degree interspecific competition can be detected between penguin species, we analysed data for 21 years (1994/95 – 2014/15) from 18 mixed breeding groups. Each of these had more than one breeding pair of Adélie or gentoo penguins. (Chinstrap penguins were not considered because of the small number of samples.) As for the complete colony, this data shows a significant decrease, by more than half, in Adélie penguins (R^2 = 0.74, $p < 0.001$) concurrently with a more than threefold increase in gentoo penguins (R^2 = 0.91, $p < 0.001$, Figure 9). It is noticeable, however, that the population of gentoo penguins in the whole colony rose with an increase of more than 70 % substantially more slowly, over the same time, than in mixed breeding groups.

Furthermore, it can be clearly seen in Figure 9, that there has been almost no change in the total number of nests in the mixed groups over the last 20 years (R2 = 0.04, p = 0.41, average BPs 1,152 ± 179) during which time the proportions of species have changed in favour of the gentoo penguin (Figure 9, Pearson correlation: r = -0.83, $p < 0.001$).

Gentoo penguins have more plasticity in breeding phenology and are less stably attached to their breeding places than are Adélie penguins and might therefore be better able to react appropriately to environmental conditions (e.g. Lescroel et al. 2009; Lynch et al. 2009; Ainley et al. 2010; Hinke et al. 2012; Lynch et al. 2012a; Chambers et al. 2013; Juáres 2013; Juáres et al. 2013). Nevertheless, it seems improbable that gentoo penguins actively displace Adélie penguins, especially as the annual rate of change in BP numbers of the two species in sympatric groups are uncorrelated (Pearson correlation: r = -0.32, p = 0.22). Thus, there is no detectable relationship between increases and decreases in the penguins in a single year. In contrast to the Stranger Point colony on the Potter Peninsula (Carlini et al. 2009), on Ardley Island practically all the breeding places that become free because of the decline in Adélie penguins are taken up by gentoo penguins within a few years. This is perhaps caused by there being a strict limit on the total number of suitable breeding places on Ardley Island because of topographic factors.

Figure 9: Breeding pair numbers of Adélie and gentoo penguins on Ardley Island between 1994/95 and 2014/15 with presentation of significant trends by means of linear regression; if there are no values, no data were available for the particular season.

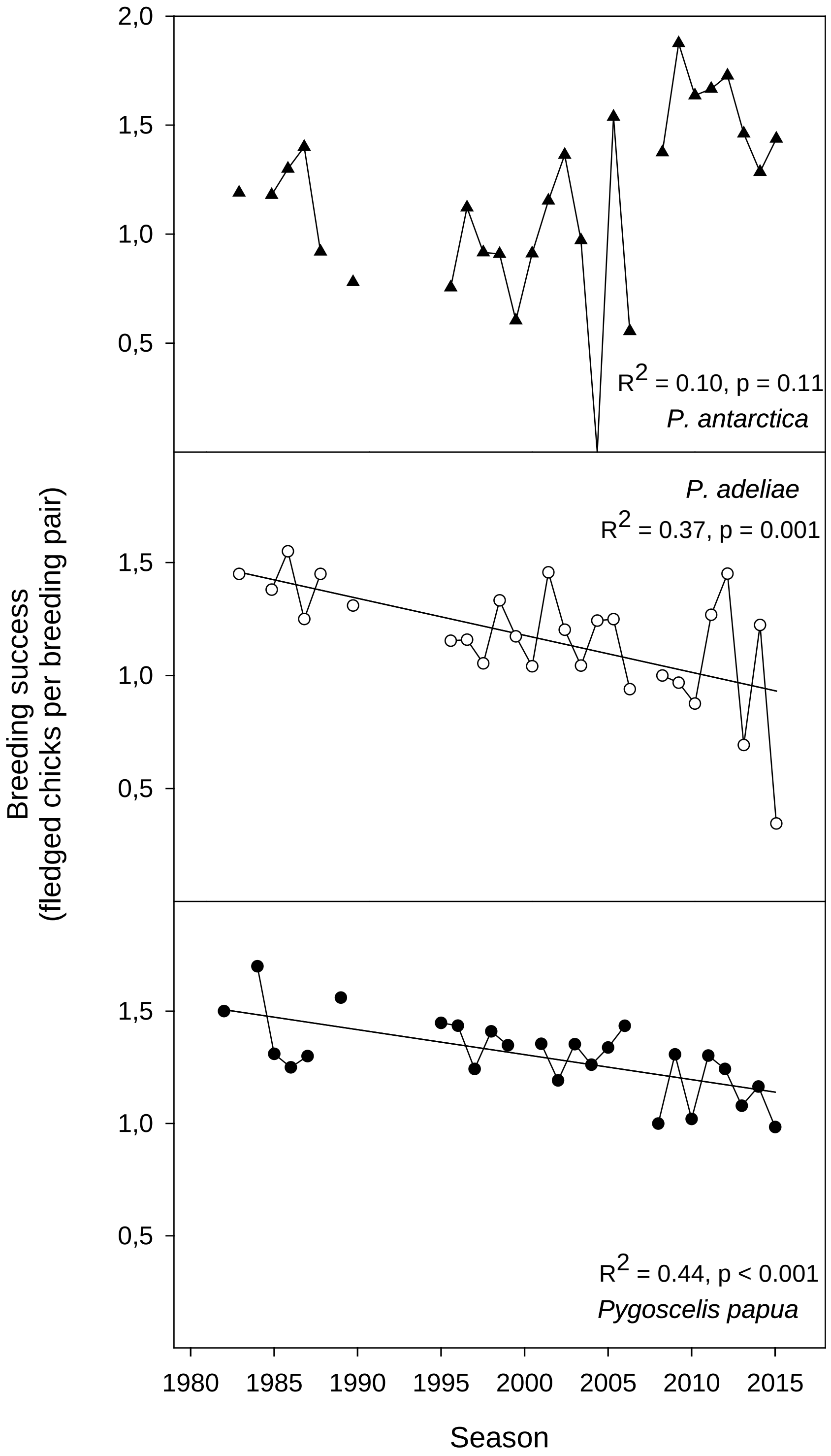


2.2.1.3 Breeding success

Recording the breeding success is of major importance breeding success in order to estimate the state of a population. For the penguin colony on Ardley Island there is now data going back 26 years, beginning in the 1981/82 season. The results show clear differences between the three penguin species as regards breeding success (Figure 10). In the last eight years, the breeding success of the small number of chinstrap penguins still present on Ardley Island has been consistently above the long-term average of 1.16 ± 0.42 chicks per breeding pair. However, due to substantial fluctuations, particularly in the 1990s, as well as a total lack of breeding success in the 2003/04 season, no statistically significant trend can be discerned (R^2 = 0.10, p = 0.11, Figure 10). Barbosa et al. (2012) was also unable to identify any such tendency relating to breeding success for a chinstrap penguin colony studied on Deception Island, South Shetland Islands. Similarly high values for breeding success as on Ardley Island in recent years have also been documented for neighbouring Barton Peninsula (Republic of Korea 2014) and for further colonies on Deception Island, for example (Barbosa et al. 2012). This is noteworthy insofar as penguin breeding success appears to be greater in larger nesting groups (> 400 BP) than in smaller groups (< 50 BP) (Barbosa et al. 1997). On Ardley Island there is now only a limited number of chinstrap penguins (2014/15: 16 BP) breeding in a spatially very divided nesting group (2014/15: total 112 BP) together with gentoo and Adélie penguins.

The breeding success of the Adélie penguins on Ardley Island is also subject to sometimes considerable annual fluctuations (Figure 10). Over the long term, Adélie penguins on Ardley Island successfully raise an average of 1.16 ± 0.26 chicks per breeding pair. Over the research period there was a clear decline in the breeding success of Adélie penguins (Figure 10), a trend that was also shown on Potter Peninsula (Carlini et al. 2009; Juáres et al. 2015). Possible causes for this recent decline in breeding success are suspected to be a reduction in the availability of food, together with heavy falls of snow at the start of the breeding season (see below, Juáres et al. 2015). Nevertheless, the figures for breeding success from Ardley Island are comparable with – or even higher than – values from numerous other Adélie penguin colonies (e.g. Carlini et al. 2007; Carlini et al. 2009; Lynch et al. 2010b; Juáres et al. 2015). Thus, the decline in Adélie penguins on Ardley Island does not seem to be based on low breeding success over a long period. It is much more likely that other factors such as high winter mortality, especially in young birds, and low recruitment rates contribute substantially to the generally observed decline in Adélie penguins (Croxall et al. 2002; Hinke et al. 2007; Lynch et al. 2010b).

Figure 10: Breeding success of the three *Pygoscelis* species of the Ardley Island penguin colony with presentation of significant trends by means of linear regression; if there are no values, no data were available for the particular season.



The breeding success of gentoo penguins on Ardley Island has fluctuated considerably less over the years than that of the other two *Pygoscelis* species (Figure 10). In addition to the larger sample, this could be linked to the high interannual variability of several breeding parameters (Bost et al. 1990; Lynch et al. 2009; Hinke et al. 2012; Juáres et al. 2013). With a long-term average of 1.30 ± 0.17 chicks per breeding pair, the breeding success of gentoo penguins is as high as, or higher than, that of other colonies (e.g. Cobley et al. 1999; Holmes et al. 2006;

Carlini et al. 2009; Forcada et al. 2009; Lynch et al. 2010b). However, over the entire research period the breeding success of gentoo penguins on Ardley Island declined significantly (Figure 10). In contrast, gentoo penguin breeding success increased in other colonies (Hinke et al. 2007; Carlini et al. 2009) or showed no trend (Lynch et al. 2010b). The contrast between the clear increase in the population of gentoo penguins on Ardley Island and, at the same time, a decline in breeding success, indicates that the number of survivors and recruits, i.e. young birds returning to the colony, is probably sufficient to guarantee continuing population growth. Additionally, there are possibly a certain number of individuals which, despite a relatively high degree of breeding site loyalty (philopatry), come from other areas (Bost et al. 1990). As the gentoo penguin population on Ardley Island is continuing to grow, the capacity of this colony does not appear to be exhausted as regards suitable breeding places.

The lowest breeding success of both Adélie penguins and gentoo penguins on Ardley Island since records began, was recorded in the 2014/15 season (Figure 10) with 0.35 Adélie penguin chicks and 0.98 gentoo penguin chicks per breeding pair. The reason for this was heavy snow during the breeding phase at the end of November 2014, as a result of which a large proportion of Adélie penguins and some gentoo penguins abandoned their nests (Figure 11). In contrast, the chinstrap penguins on Ardley Island were not affected by these weather conditions, as the small number of breeding pairs of this species breed on small, rocky elevations, where no such accumulations of snow were observed.

Figure 11: Abandoned Adélie penguin nests on Ardley Island as a result of heavy snow fall during spring (photo: M.-C. Rümmler, 30.11.2014)

In addition, the breeding success of Adélie and gentoo penguins was also significantly reduced in seasons with a lot of snow in spring and a very late start to the snowmelt (2007/08, 2009/10, 2012/13). This indicates that it is not only large-scale influences such as regional weather phenomena (e.g. Trathan et al. 1996; Forcada et al. 2006; Ducklow et al. 2007; Hinke et al. 2007) which have a significant effect on breeding success, but also small-scale environmental factors (e.g. Cobley et al. 1999; Trathan et al. 2008; Lynch et al. 2010b; Juáres et al. 2015). These factors can also represent effects of climate change, in particular with increasing amounts of precipitation resulting from the temperature changes observed on the Antarctic Peninsula (Turner et al. 2005b; Boersma 2008) having an increasingly negative impact on the breeding birds of the peninsula (Lynch et al. 2010b).

Anthropogenic disturbance of penguins should also be taken into account as an additional important factor affecting long-term population developments (Woehler et al. 1994; Bricher et al. 2008; Chwedorzewska et al. 2010). Although disturbances by low-altitude flights or visits have been observed on Ardley Island (Peter et al. 2008; Peter et al. 2013), no negative influence on populations has so far been proven. Such negative effects from anthropogenic disturbance have possibly concealed by the general population trends. Studies on this subject from other areas are frequently inconsistent (Lynch et al. 2010b) and obtain differing results (e.g. Giese 1996; Cobley et al. 1999; Holmes et al. 2006; Carlini et al. 2007; Trathan et al. 2008). Neither was it possible, on the basis of the available data, to derive effects on bird population resulting from the contamination of Ardley Cove with diesel fuel in the 2009/10 and 2014/15 seasons (Braun et al. 2012; Peter et al. 2013, as well as unpublished data), like a reduced breeding success or an immediate increase in mortality. However, physiological effects resulting in long-term damage cannot be excluded (e.g. Culik et al. 1991; Briggs et al. 1996; Briggs et al. 1997).

2.2.2 Penguin colonies on the west coast of Fildes Peninsula

The breeding population of four small chinstrap penguin colonies on the west coast of the Fildes Peninsula can only be partially estimated due to the inaccessible location of the cliffs on which they breed. The number of breeding pairs was therefore recorded from a distance using binoculars, combined with an inspection of the accessible colonies. Therefore, only limited statements can be made on population developments in these colonies.

In the last three seasons between 148 and 202 pairs of chinstrap penguins bred on the west coast of the Fildes Peninsula with increasing tendency. Therefore, their numbers were somewhat larger than previously estimated (Peter et al. 2013). As similar breeding pair numbers were recorded towards the end of the 1980s (Lange et al. 1989; Erfurt et al. 1990), the chinstrap penguin population in these small colonies is considered to be stable, in spite of natural fluctuations. Despite methodological imprecision, the breeding success of this colony, with on average 0.76 chicks per BP (data from 2008/09 - 2014/15), seems to be significantly below the breeding success rate of 1.58 per BP observed on Ardley Island in the same period, although this figure is based on only a few dozen breeding pairs. It is possible that the pressure of predation by skuas is significantly greater on the west coast of the Fildes Peninsula. Some skua pairs that breed in the vicinity demonstrably specialise in predating on penguins. It is not known, however, whether there is food-related territoriality among skuas here as there is on Ardley Island.

A smaller chinstrap penguin colony at Exotic Point in the extreme south-west of the Fildes Peninsula is still considered to have died out as no new broods have been recorded there since the 2000/01 season (Peter et al. 2008; Peter et al. 2013). The next large chinstrap penguin colony, with more than 10,000 BP, is 5.8 km south-west of the Fildes Peninsula, on Withem Island (Mustafa et al. 2014).

2.3 Southern giant petrel (*Macronectes giganteus*)

The southern giant petrel (*Macronectes giganteus*, Figure 12) is considered to be a species that is very sensitive to human disturbance (e.g. Chupin 1997; Micol et al. 2001; Pfeiffer et al. 2004). In addition, plastic material found in the digestive tract of birds shows that this species – as many other seabird species – is negatively affected by waste floating in the sea (Copello et al. 2003). Due to its considerable interactions with diverse fishing techniques (longline and trawler fishing) and the corresponding risks (e.g. Kock 2001; Sullivan et al. 2006), the southern giant petrel is a subject of the Agreement on the Conservation of Albatrosses and Petrels (ACAP), which came into force in 2004. With the help of this agreement, efforts are made to minimise threats to populations of albatrosses and petrels by reducing fishing-related mortality. The southern giant petrel breeding colony on Ardley Island is listed as Breeding Site No. 67 within the framework of the ACAP (ACAP 2014).

Figure 12: Juvenile and adult southern giant petrel (*Macronectes giganteus*), white morph (photo: C. Braun)

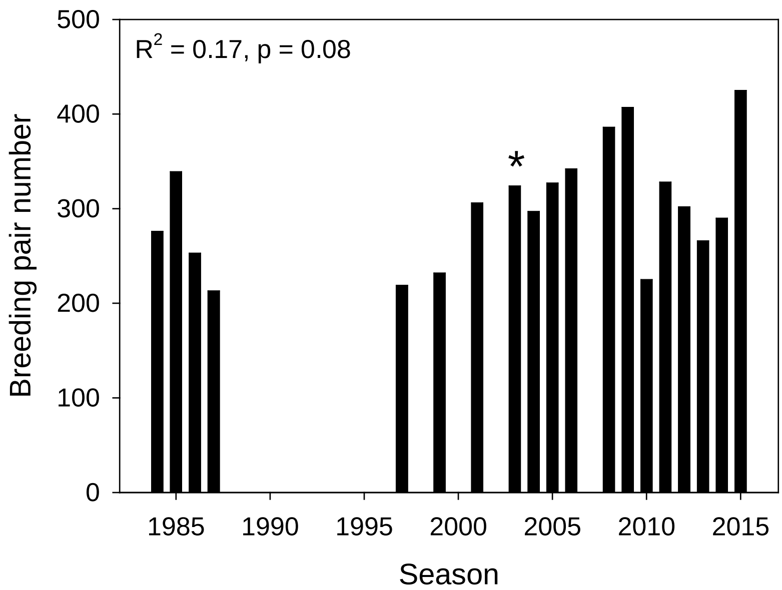
Older estimates of the total world population of the circumpolar southern giant petrel (Figure 12) assume a decline of approx. 20 % over the last few decades to 38,000 BP in 2000 (Patterson et al. 2008). A more up-to-date analysis gives a worldwide breeding pair population of 54,000 (BirdLife International 2015b), of which 20 % are in the Antarctic (ACAP 2010). Of those, approx. 5,400 pairs breed in the South Shetland Islands area (Patterson et al. 2008). The breeding pair population on King George Island, following a decline in the last few decades (Patterson et al. 2008), was stable between 2001 and 2007, and currently totals approx. 2000 pairs (ACAP 2015). As the global southern giant petrel population is on the increase, this species is currently categorised as not being endangered (IUCN status 'least concern', BirdLife International 2015b).

Due to the great concentration of human activities in the areas of research, logistics and tourism in the Fildes Region, continuous monitoring of the southern giant petrel is of major importance, because the substantial local anthropogenic influences can have a direct impact on the population of this species in the region. Records of the number of breeding southern giant petrels and their offspring began in the 1979/80 season and there are now complete data sets for 19 years. In addition, there are partial counts for some areas, so that for various colonies data from up to 25 years can be analysed. This enables researchers to make reliable statements regarding population developments, despite frequent 'sabbatical years', as they are known. In such years, a significant part of the population suspends reproduction in the year following a brood, while the majority breed once again. On average, the sabbatical period lasts 1.4 years (Voisin 1988; ACAP 2010).

Heidelberg and Middle Islands in the Fildes Strait are regularly populated by up to 10 BP. However, as the bulk of data is based on estimates made from a distance, because of the islands' relative inaccessibility, these areas will not be considered below.

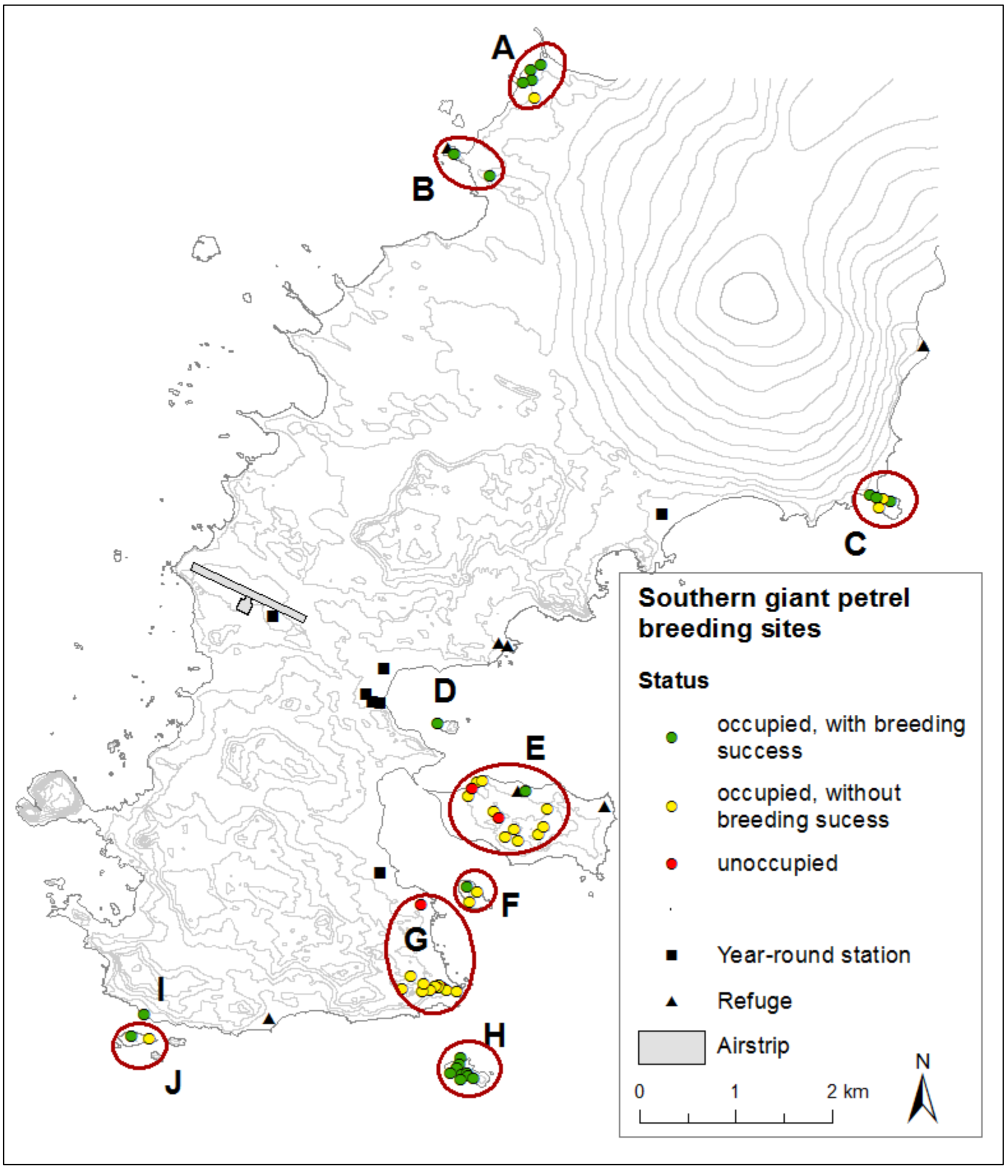
In the Fildes Region a total of 266 occupied southern giant petrel nests or breeding pairs were recorded in the 2011/12 and 290 occupied nests or breeding pairs were recorded in 2012/13. The total of 425 BP recorded for the 2014/15 season was, however, significantly higher than the long-term average of 303 ± 62 BP and represented the highest value since counting began (Figure 13).

Figure 13: **Total breeding pair numbers of southern giant petrel (*Macronectes giganteus*) in the Fildes region (* data incomplete, since no data for colony A – North were available, season not included in the calculation of the long-term trend by means of linear regression; if there are no values, no data were available for the particular season.**



In a long-term comparison the number of southern giant petrel breeding pairs in the Fildes Region shows considerable interannual fluctuations, but no statistically significant trend (R^2 = 0.17, p = 0.08, Figure 13). The southern giant petrel population in the Fildes Region has thus been stable for years and, as a result of the very large number of breeding pairs in the 2014/15 season, it even shows a slight upward tendency. This agrees with various studies that also report stable or growing populations of southern giant petrels in some areas, while major population declines can be observed in other colonies (see below).

Figure 14: Location of the breeding sites of southern giant petrels (*Macronectes giganteus*) in the Fildes region, indicating the status of all breeding sites known since 2003/04 (not occupied, occupied – no breeding success, occupied – with breeding success, indication refers to the seasons 2012/13 to 2014/15)



In the past there have been clear indications in the Fildes Region of southern giant petrels moving their breeding sites due to anthropogenic influences. In the wake of the construction of the Artigas and Great Wall research stations, the colonies there disappeared, whereas the numbers of breeding pairs increased in colonies in areas that were undisturbed or less affected (Peter et al. 1991; Chupin 1997; Woehler et al. 2001; Pfeiffer 2005). Peter et al. (2013) again describe repeated breeding site relocations due to disturbance by visitors to the surrounding stations, although to a more limited extent than in earlier periods. In order to observe this development in a detailed fashion, breeding pair numbers are no longer put together in zones (Peter et al. 2008; Peter et al. 2013), but instead all the data from the individual colonies is considered (Figure 14). This makes it clear that for the period investigated (from the 1980s to the 2014/15 season), statistically significant trends can be shown in six of the 10 colonies (Figure 15 & Figure 16). A noticeable development is above all a current increase in breeding southern giant petrels in the northernmost colony of the Fildes Region (colony A, Figure 14 & Figure 15). As it is relatively far from the stations, it is less frequently visited by scientists and hardly ever by station staff in their leisure time. In this colony, the number of breeding pairs, which was a maximum of 8 BP in the 1980s, has risen continuously since the 2008/09 season to 71 BP currently. The biggest rise in percentage terms was in the 2010/11 season (Figure 15). At the same time, the number of breeding pairs in the slightly more southerly Priroda colony (colony B, Figure 14 & Figure 15) fell substantially following a period of growth. A possible cause is suspected to be repeated disturbance by station staff and tourists who visit the Priroda field huts. A decline in breeding pair numbers was also observed in the southernmost colony on Dart Island (colony J, Figure 14 & Figure 16). In certain periods, this island is visited by station staff from time to time in order to go fishing (Peter et al. 2013) and was overflown by aircraft (Peter et al. 2008).

The conflicting changes in breeding pair numbers observed in various areas have very probably not been caused by natural environmental factors, as neighbouring colonies that are subject to the same natural conditions (e.g. food availability, predation, amounts of snow) show a different population development (Braun et al. 2014). Instead, anthropogenic disturbance appears to have considerable effects (Peter et al. 2008; Braun et al. 2012; Peter et al. 2013), as a decline in numbers of breeding pairs is only observed in colonies that are frequently visited by station staff in the summer months. Neighbouring colonies that are rarely or never visited either have stable numbers of breeding pairs or show a population increase (Braun et al. 2014). The latter points to renewed relocations of breeding sites.

It is difficult to assess to what extent other areas adjacent to the Fildes Region (Barton & Potter Peninsula, Duthoit Point & Stansbury Peninsula on Nelson Island, northern coast of Nelson Island) are also affected by the breeding site relocations described, because for these areas there are as yet insufficient data series available (Sec. 3).

A further noteworthy fact is that for around 10 years there have been increasing numbers of attempts to breed at previously abandoned breeding sites of the eastern colonies of the Fildes Region. Thus, following a significant decline in the number of breeding pairs in the late 1980s and the 1990s, the number of breeding pairs of southern giant petrel on Ardley Island (colony B) rose once again. The number of breeding sites in the north and north-west of the island remained more or less the same, while old nests in the centre and the south of the island were regularly reoccupied in recent times, although they were quickly abandoned early in the breeding season. Renewed attempts to breed at previously abandoned breeding sites were also recorded on Diomedea Island (colony G), Nebles Point (colony D) or in the extreme south-west of the Fildes Peninsula (G – Halfthree Point, incl. surroundings of Great Wall Station, Figure 14 - Figure 16). In these areas breeding pair numbers have stabilised since the 2000s, but to date hardly any chicks have been successfully raised (Figure 15 & Figure 16).

Both Ardley and Diomedea Island are marked by a high degree of human activity. Diomedea Island is only 1.7 km east of the Chilean runway and therefore immediately under the approach path. For its part, Ardley Island is often visited by scientists and station staff working in the Fildes Region (Peter et al. 2008; Peter et al. 2013). In spite of this, southern giant petrel breed at these sites or reoccupy previously abandoned nests. This indicates a habituation effect, which is defined as a gradual decrease in a behavioural response as a result of a repeated stimulus without subsequent reinforcement (Hinde 1970). It has been repeatedly shown that birds can exhibit reduced behavioural responses to permanent or frequently occurring stressors such as visitors or noise (e.g. Young 1990; Scott et al. 1996; Fraser et al. 1997; Nimon 1997; Cobley et al. 1999; Holmes et al. 2006; Walker et al. 2006; De Villiers 2008). On Ardley Island and in other southern giant petrel colonies in the Fildes Region, it has been possible to substantiate experimentally both short-term and long-term habituation effects, provided that the human disturbance was regular and predictable (Pfeiffer 2005). However, if visits are made to less frequently visited areas at irregular intervals, several times during the breeding season and from different directions, it is less likely that the birds will become habituated than at breeding sites near to human infrastructure (Pfeiffer 2005). In qualification, it should be noted that at previously abandoned breeding sites that have been reoccupied, birds have so far had very little success in raising chicks (see below).

The breeding success of southern giant petrels is considered to be an appropriate indicator for human disturbance, as a flight response by the parent birds greatly increases the risk of predation of the eggs and chicks by skuas (Peter et al. 2008; Peter et al. 2013). However, natural factors such as climatic conditions, diseases or food availability are also of great importance for the successful rearing of chicks.

In the seasons 2012/13 to 2014/15 the breeding success of the southern giant petrel was below the long-term average of 0.36 ± 0.19 chicks per breeding pair. In the 2012/13 season in particular, in all colonies of the Fildes Region, a very low number of chicks were successfully raised, with a breeding success rate of 0.15 chicks per breeding pair (Figure 15 & Figure 16), which indicates unfavourable environmental conditions as the cause. Similarly low values were also recorded in the 2007/08 and 2009/10 seasons, which had comparably large amounts of snow (0.08 and 0.12 chicks per BP). In a long-term comparison, the decline in breeding success of the southern giant petrel in the Fildes Region continued (Peter et al. 2013; Figure 17).

When the average breeding success in the various colonies of the Fildes Region is considered (Figure 15 & Figure 16), hardly any significant differences can be recognised between the individual breeding sites. Only the breeding success of the colony on Two Summit Island, with 0.51 ± 0.21 chicks per breeding pair, was significantly higher than that of the other colonies (One-Way-ANOVA Tukey-Test, $p = 0.04$). The colony on the shore of the Fildes Strait is the only one with a similarly high average breeding success of 0.5 ± 0.31 chicks per breeding pair. The level of human disturbance is estimated as being low in these areas. Both colonies showed no downward trend during the years studied, in contrast to most other colonies (Two Summit Island: $R^2 = 0.17$, $p = 0.13$, Fildes Strait: $R^2 = 0.005$, $p = 0.81$) (Figure 15 & Figure 16). Limited average breeding success was documented in the Priroda, Ardley Island and Dart Island colonies. In these colonies the number of chicks raised successfully since the beginning of the 2000s has usually been below the average breeding success of the season in question in the Fildes Region. An additional factor on Dart Island was that in some seasons a pair of brown skuas (*Catharacta antarctica lonnbergi*, Sec. 2.7) nested in the centre of the colony. In such a situation, predation pressure in the event of disturbance by visitors is particularly high and this in turn can be reflected in low breeding success.

It was additionally apparent that while a few eastern colonies (Nebles Point, Diomedea Island, area around Great Wall/Halfthree Point) were once again used regularly as breeding sites after having been abandoned for many years, the conditions there did not appear to be sufficiently good for successfully raising chicks, with the exception of Diomedea Island (Figure 15 & Figure 16).

Figure 15: Breeding pair numbers and breeding success of southern giant petrels (*Macronectes giganteus*) in the colonies A – E of the Fildes region with presentation of significant trends by means of linear regression; note the different scales of the Y-axes. If there are no values, no data were available for the particular season.

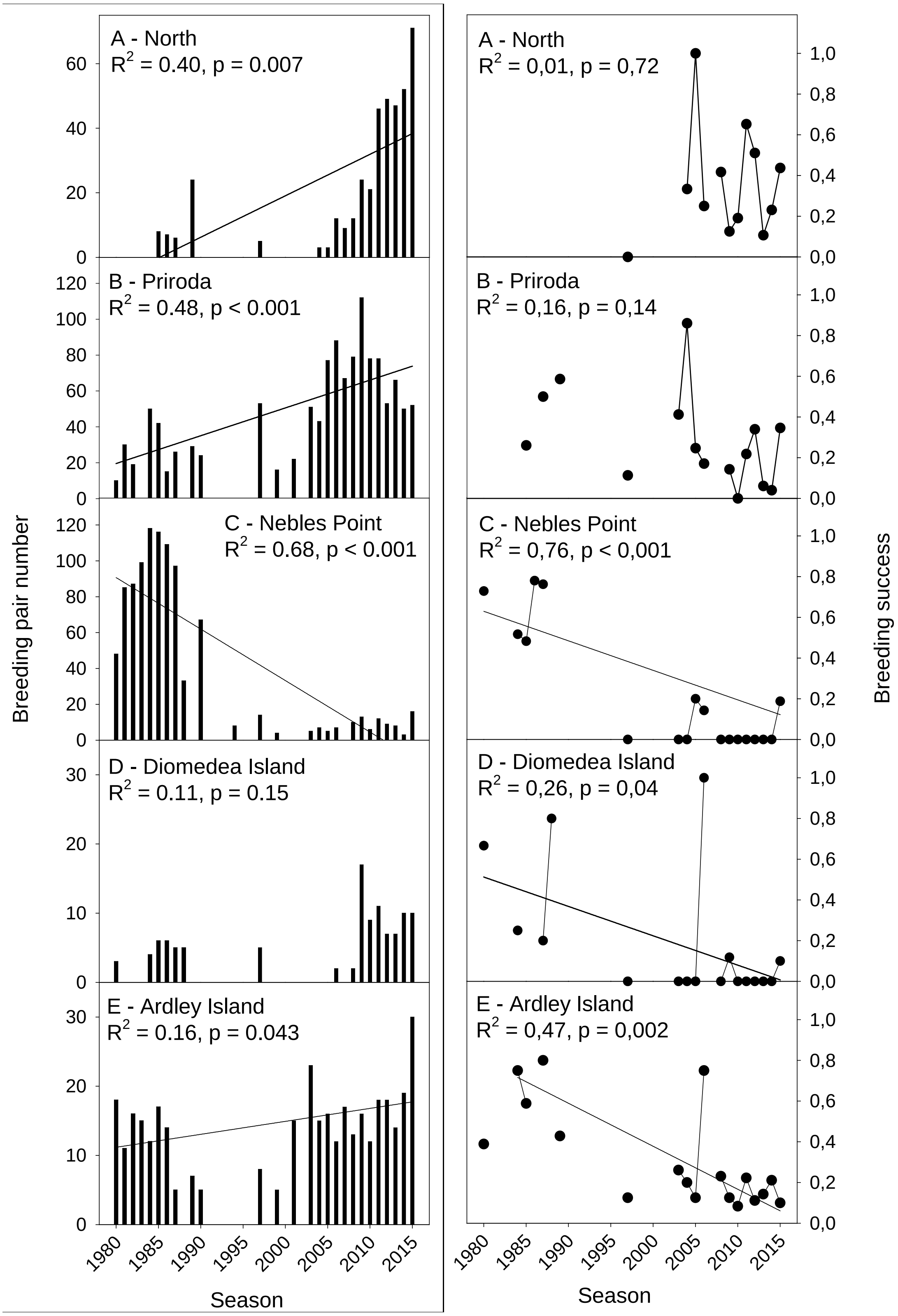


Figure 16: Breeding pair numbers and breeding success of southern giant petrels (*Macronectes giganteus*) in the colonies F – I of the Fildes region with presentation of significant trends by means of linear regression; note the different scales of the Y-axes. If there are no values, no data were available for the particular season.

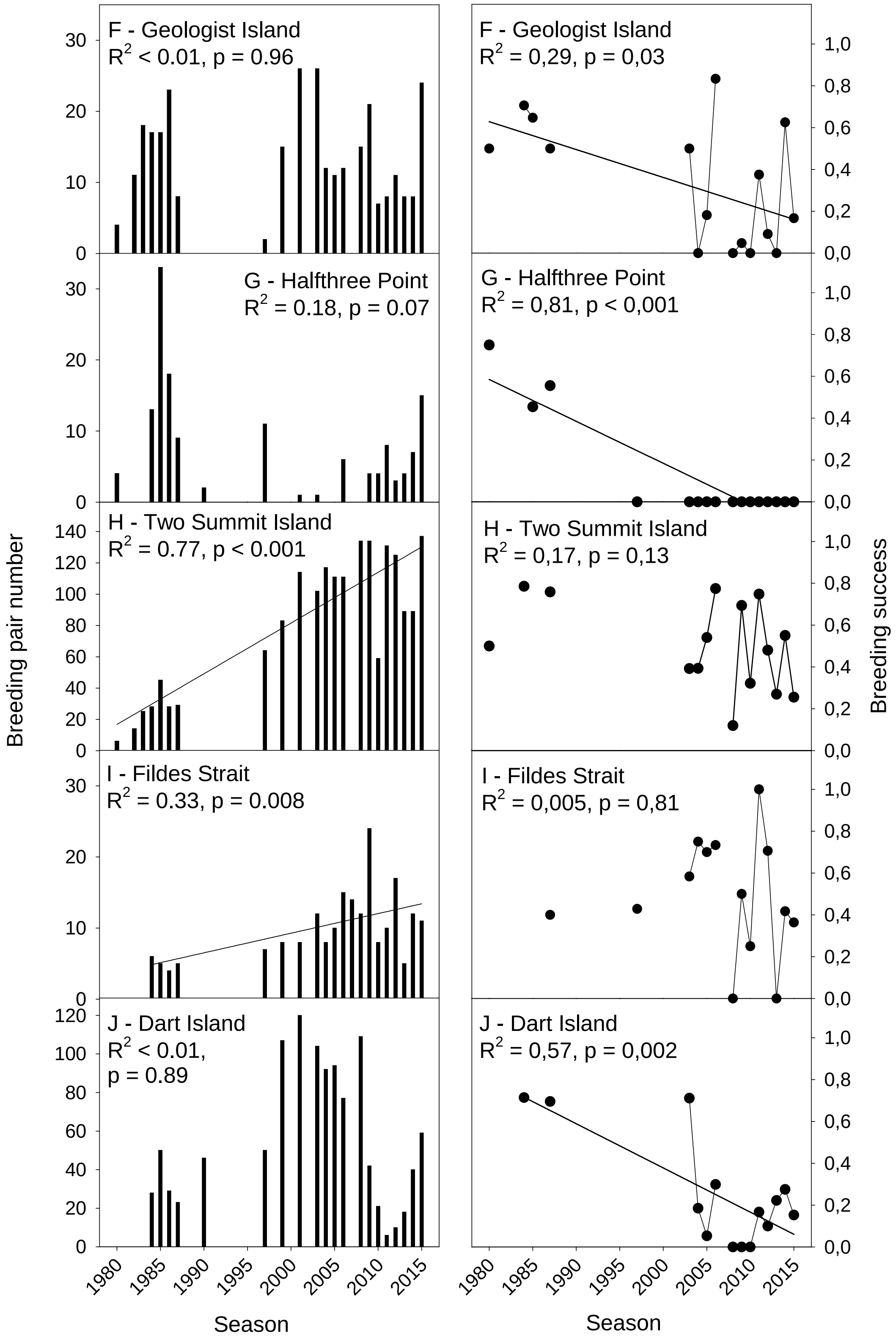
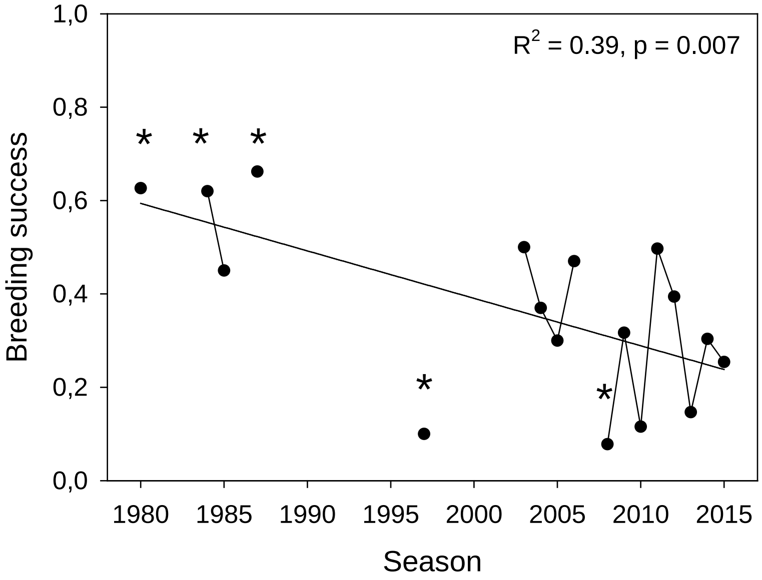


Figure 17: Total breeding success of southern giant petrels (*Macronectes giganteus*) in the Fildes region with presentation of significant trends by means of linear regression (* data incomplete, no breeding success assessed for the colonies F, H & J, seasons not included in the calculation of the long-term trend; if there are no values, no data were available for the particular season.)



The breeding success of the southern giant petrel in the Fildes Region is very limited when set against comparable published data (Marchant et al. 1990; ACAP 2010). Breeding success on neighbouring Potter Peninsula was over 0.7 chicks per breeding pair in the period 1994 to 2007 and therefore significantly above the long-term average of the Fildes Region.

In summary, the results presented indicate an anthropogenic influence on breeding pair numbers and breeding success of southern giant petrel in the Fildes Region. Natural environmental conditions such as food availability, predation or climatic factors should have similar effects in colonies adjacent to each other. Because, for the most part, neighbouring colonies have very different population trends and major differences in breeding success, and also differ from one another in the intensity of visits, it would appear that anthropogenic influences are more important than natural factors (Braun et al. 2012; Braun et al. 2014).

Population declines in southern giant petrels as a result of anthropogenic disturbance are well documented (e.g. Peter et al. 1991; Sierakowski 1991; Chupin 1997; Micol et al. 2001). When there are breeding site relocations due to disturbance (Braun et al. 2012) there is the danger that not all breeding birds that are forced out will find sufficient space (Micol et al. 2001) or suitable breeding conditions, so that breeding success might be reduced due to suboptimal conditions. This factor should not be underestimated in some colonies (Sierakowski 1991), as reduced breeding success, even with breeding pair numbers that are stable over the medium term, as documented in the Fildes Region, can contribute to a general decline in the total population (Woehler et al. 2003; Patterson et al. 2008).

In spite of the substantial anthropogenic influences, the stable BP numbers in the Fildes Region in a long-term comparison substantiate findings from other studies, which report local southern giant petrel colonies that are either stable or growing (e.g. Woehler et al. 1997; Gonzalez-Solís et al. 2000; Woehler et al. 2001; Creuwels et al. 2005; Reid et al. 2005; Quintana et al. 2006; Lynch et al. 2008; Patterson et al. 2008; Reid et al. 2008; ACAP 2010; Gil-Delgado et al. 2013a). In contrast, a decline in the number of breeding pairs was shown for other colonies (e.g. Woehler et al. 2001; Patterson et al. 2008; Reid et al. 2008). A significant decline in the number of breeding pairs is also reported for the colony on Nelson Island between 2001 and 2005 (ACAP 2015) and for Potter Peninsula between 1994 and 2007 (ACAP 2010). This makes it even more important to have regular monitoring of the breeding pair population and of breeding success, as well as to minimise disturbance of breeding sites of this seabird species.

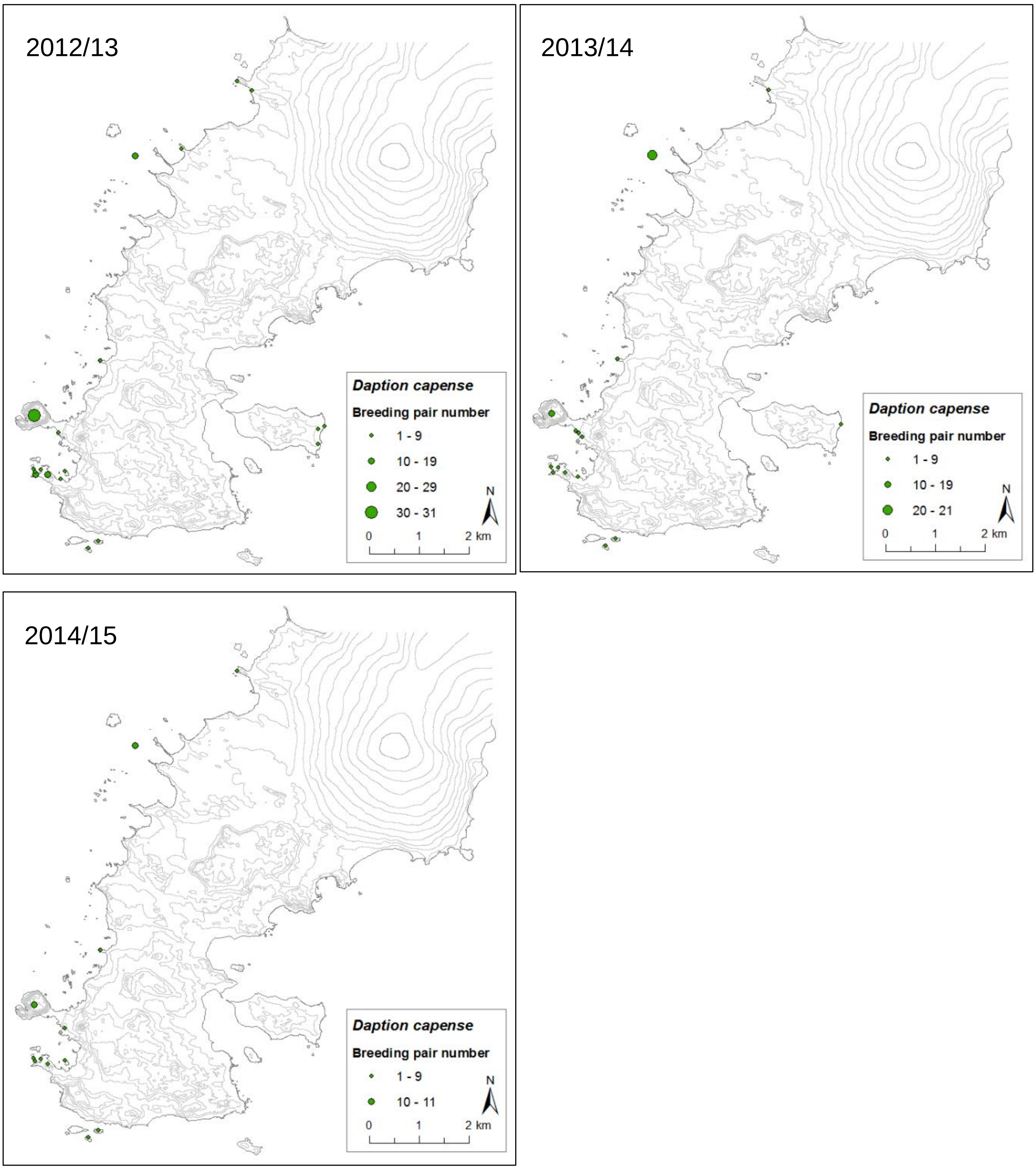
It should be noted that in December 2012 a recently dead southern giant petrel was discovered at an aerial or signal mast of the airport. There was also a report of a dead light-mantled sooty albatross, which was found in winter next to an antenna (personal communication Russian station staff). As there have been a number of finds of this kind (Peter et al. 2013), it would seem advisable to take measures to improve the visibility of antennas and signal masts, and also of their guy wires, in order to minimise the risk of bird strike (Peter et al. 2013).

2.4 Cape petrel (*Daption capense*)

The population of cape petrel (*Daption capense*, Figure 18) was 109 BP in the 2012/13 season, 67 BP in 2013/14 and only 39 in 2014/15 (Figure 19 a - c & Figure 20, average value 1984/85 - 2014/15: 270 ± 133). This means that the number of breeding birds was most recently only around 10 % of the average population of the 1980s. It was noticeable in this regard that some well-known and easily visible breeding places had for a number of years not been occupied at all or only by significantly fewer breeding pairs (Figure 19 a - c & Figure 20, Peter et al. 2013).

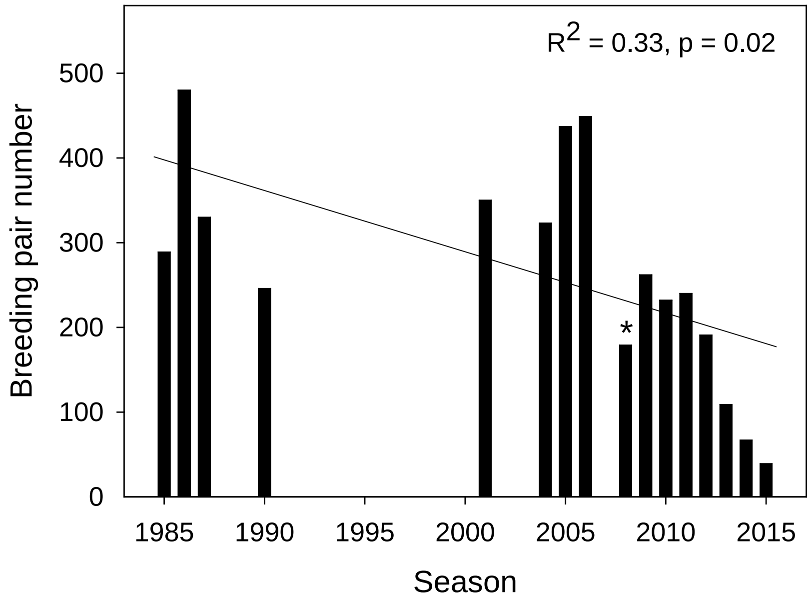
Figure 18: Cape petrel (*Daption capense*, photo: C. Braun)

Figure 19 a - c: Location and size of cape petrel (*Daption capense*) breeding colonies in the seasons 2012/13 to 2014/15



There is now data going back 15 years on the cape petrel population in the Fildes Region (Figure 20). The very high figure of 1,081 BP for the Fildes Region given in Soave et al. (2000) appears to be based on a different methodology, as numerous breeding sites were recorded by boat from the sea. For this reason, this number is disregarded below. Assuming that all other count data is sufficiently precise, including data from the 1980s, it is possible to draw conclusions regarding the population development of this species in the study area. Fairly substantial population fluctuations were already observed for the period between 1984/85 and 2005/06 (Figure 20). However, after this period the population started to decline significantly. In particular due to the extraordinary low numbers of breeding pairs of the last three seasons, a significant trend in the cape petrel population in the study area can be discerned (Figure 20) and it is possible to confirm the negative development of the population of this species (Peter et al. 2013). The cause of this development is not known. Direct anthropogenic disturbance is only a factor at a few breeding sites with relatively few breeding pairs, for example at Halfthree Point in the south-east and at Punta Torres in the north-west of the Fildes Peninsula – both of which are areas frequently visited by station staff. Therefore, more likely causes of the sharp population decline are suspected to be environmental conditions, possibly in the form of a lack of food and/or bad weather conditions. Local wind patterns in particular appear to affect the presence of adult birds at a breeding site (Weidinger 1996a). To what extent the population decline observed here is refelcted in other areas is unclear due to a lack of comparable records. For example, the cape petrel population in the north of Nelson Island (Stansbury Peninsula, see Sec. 3.7), as well as in neighbouring parts of the Fildes Peninsula, was still estimated at 2,000-3,000 BP in the 1991/92 season (Weidinger 1996b), but there are no later count figures. There is also insufficient information about the worldwide population trend of this circumpolar breeding species, the total population of which, at more than 2 million individuals, is assessed as being stable (IUCN status 'least concern', Brooke 2004; BirdLife International 2015b).

Figure 20: **Development of breeding pair numbers of cape petrels (*Daption capense*) in the Fildes region since the 1980s with presentation of significant trends by means of linear regression (* data incomplete, season not included in the calculation of the long-term trend; if there are no values, no data were available for the particular season.)**



2.5 Light-mantled sooty albatross (*Phoebetria palpebrata*)

After the first successful sighting of a brood of light-mantled sooty albatrosses (*Phoebetria palpebrata*) on Flat Top cliff in the 2008/09 season (5 BP, Lisovski et al. 2009; Peter et al. 2013; Figure 21 a & b) and renewed confirmation of a brood for the 2011/12 season (1 BP, Peter et al. 2013), two breeding pairs were again recorded in the 2013/14 season (Figure 22). While chicks were observed in 2008/09, such observations were not possible in subsequent years. However, on several occasions in January 2013 and in December 2014 light-mantled sooty albatrosses were observed in flight at Flat Top cliff (Figure 22), including pairs in simultaneous flight, which is typical courtship or pair-bonding behaviour. This Fildes Region record is the southernmost breeding site of this endangered species (IUCN status 'endangered', BirdLife International 2015b). Its distribution extendsto the Subantarctic islands between 46° and 53° S near the Antarctic Convergence (Lisovski et al. 2009).

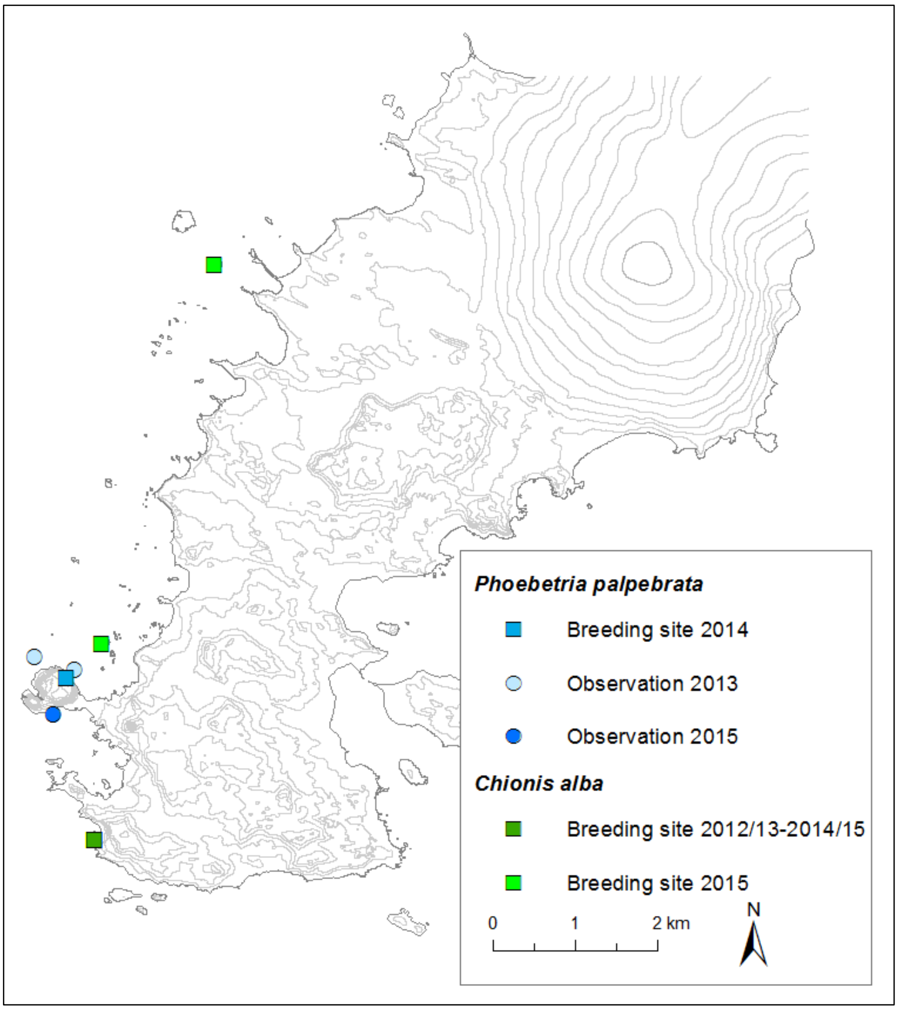
Figure 21 a & b: Light-mantled sooty albatross (*Phoebetria palpebrata*) and breeding site situated in the Fildes Region at Flat Top rock (photos: C. Braun)

2.6 Snowy sheatbill (*Chionis alba*)

There is data going back to the 1980s on the snowy sheathbill (*Chionis alba*), which breeds in the Fildes Region. Between 1979/80 and 1989/90 up to five breeding pairs bred each year in the study area, mostly in the extreme south-west of the Fildes Peninsula and along the Fildes Strait (Bannasch et al. 1981; Lorenz 1984; Rauschert et al. 1987; Zippel 1987; Mönke et al. 1988; Peter et al. 1988; Lange et al. 1989; personal communication H. Grimm). Soave et al. (2000) report four breeding pairs along the Fildes Strait in the 1995/96 season.

In each of the 2012/13, 2013/14 and 2014/15 seasons, one breeding pair of snowy sheathbills was recorded in the extreme south-west of the Fildes Peninsula in spring (Peter et al. 2008; Peter et al. 2013; Figure 22). In addition, suspected broods were confirmed for a few of the smaller islands off the west coast (Peter et al. 2008; Figure 22). Both in the area north of the Flat Top Peninsula and north-west of the Fildes Peninsula a snowy sheathbill breeding pair was recorded. A brood was last recorded here in the 1985/86 season (Rauschert et al. 1987). Possible sources of food for the sheathbills on the west coast of the Fildes Peninsula could be nearby cape petrel and penguin colonies or a large penguin colony on Withem Island more than 5 km away.

Figure 22: Sightings and breeding sites of light-mantled albatross (*Phoebetria palpebrata*) and snowy sheathbill (*Chionis alba*) in the seasons 2012/13 to 2014/15



2.7 Skuas (*Catharacta* spec,)

Two skua species – the brown skua (*Catharacta antarctica lonnbergi*) and the south polar skua (*C. maccormicki*) – are present in the study area and they regularly hybridise in zones where their distribution areas intersect (Parmelee 1988; Ritz et al. 2006). The worldwide population of brown skuas, which are mainly distributed on the Subantarctic islands, is given as 13,000-14,000 BP (del Hoyo et al. 1996; BirdLife International 2015b). The number of south polar skuas breeding in the ice-free coastal areas of the Antarctic is estimated at 10,000 - 20,000 individuals (BirdLife International 2015b). As the populations of both species are stable and no major risks are known, both brown skuas and south polar skuas are currently categorised as not endangered (IUCN status 'least concern', del Hoyo et al. 1996; BirdLife International 2015b).

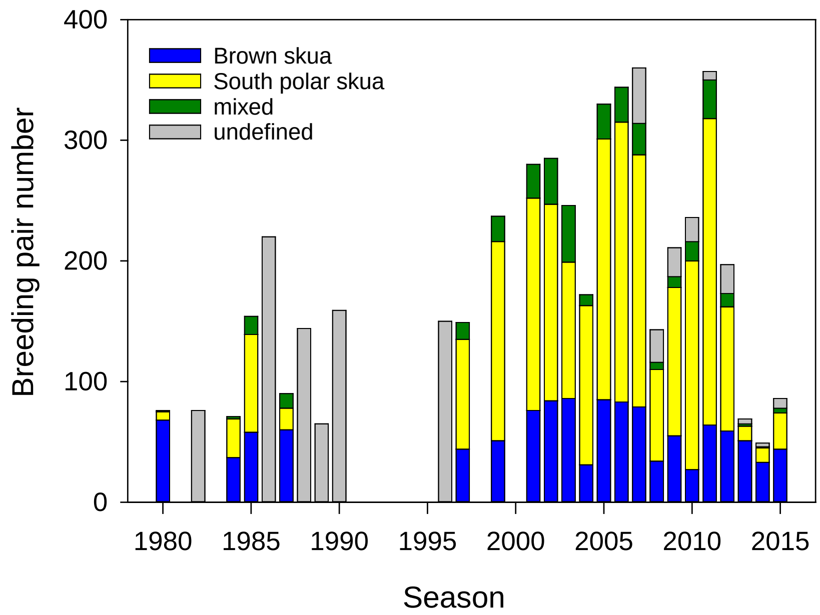
Records of the numbers of brown skuas and south polar skuas in the Fildes Region began in the 1979/80 season and there are now 26 data sets from a 36-year period. The pair type is determined on the basis of the partner of a breeding pair for which the species has been identified (brown skuas, south polar skuas, hybrids & mixed pairs). Skua pairs are classified as 'undefined' in cases where there was generally no identification (particularly in the 1980s and 1990s) or where the species of a partner is not known. A detailed analysis of the skua population in the Fildes Region and on Potter Peninsula can be found in Krietsch et al. (2016; however, classification of the pair type diverges in the case of an unknown partner!). The current distribution of skua nests in the study area in the seasons 2012/13 to 2014/15 is presented in Figure 24 a - c.

In a long-term comparison, an increase in the total number of skuas can be recognised, in particular due to strong growth in the 2000s, although the level of significance for the entire study area was not quite achieved (Figure 23, $R^2 = 0.14$, $p = 0.06$). The development is more differentiated when the two skua species, and also the mixed pairs or breeding hybrids, are considered separately.

As a result, the number of breeding pairs of brown skuas showed no significant changes between the 1979/80 season and that of 2014/15 (Figure 23, $R^2 = 0.01$, $p = 0.64$). On average 58 ± 19 pairs of brown skuas breed in the Fildes Region. In contrast, up to the 2011/12 season, south polar skuas showed a significant increase in the number of breeding pairs ($R^2 = 0.52$, $p < 0.001$, maximum 2010/11 season: 254 BP), which, however, was followed by dramatic declines in the last three seasons (Figure 23), so that no linear trend was achieved over the research period as a whole ($R^2 = 0.09$, $p = 0.18$). For its part, the number of mixed breeding pairs made up of both skua species or pairs with at least one identifiable hybrid remained stable during the research period ($R^2 = 0.01$, $p = 0.65$) and was on average 17 ± 13 BP.

The sharp rise in numbers of south polar skuas observed in the Fildes Region in the past is in accordance with results from other breeding areas of King George Island such as Admiralty Bay (Carneiro et al. 2010; Pereira de Albuquerque et al. 2012) or Potter Peninsula (Krietsch et al. 2016), but also on Pointe Géologie, eastern Antarctic (Micol et al. 2001; Woehler et al. 2001).

Figure 23: Breeding pair numbers of skuas (*Catharacta* spec.) in the Fildes region. Skua pairs were classified as 'undetermined' if the pair type was not determined or if the species of one partner was not known. If there are no values, no data were available for the particular season.



An examination of the number of territories in the Fildes Region which are occupied after birds return from overwintering areas (data for 2007/08 to 2014/15 analysed) makes it clear that from this point of view both species show a significant increase (brown skua: $R^2 = 0.52$, $p = 0.04$, south polar skua: $R^2 = 0.85$, $p = 0.001$, Krietsch et al. 2016). However, whether or not these pairs begin to breed depends on the prevailing environmental conditions at the time. In the seasons 2012/13, 2013/14 and 2014/15 there were 174, 178 and 188 territories occupied by south polar skuas. In comparison, there were 12 BP in the 2012/13 and 2013/14 seasons, and 30 BP in the 2014/15 season, which actually began to breed. The proportion of brown skuas that occupied a territory during the same period, but failed to breed, was many times smaller.

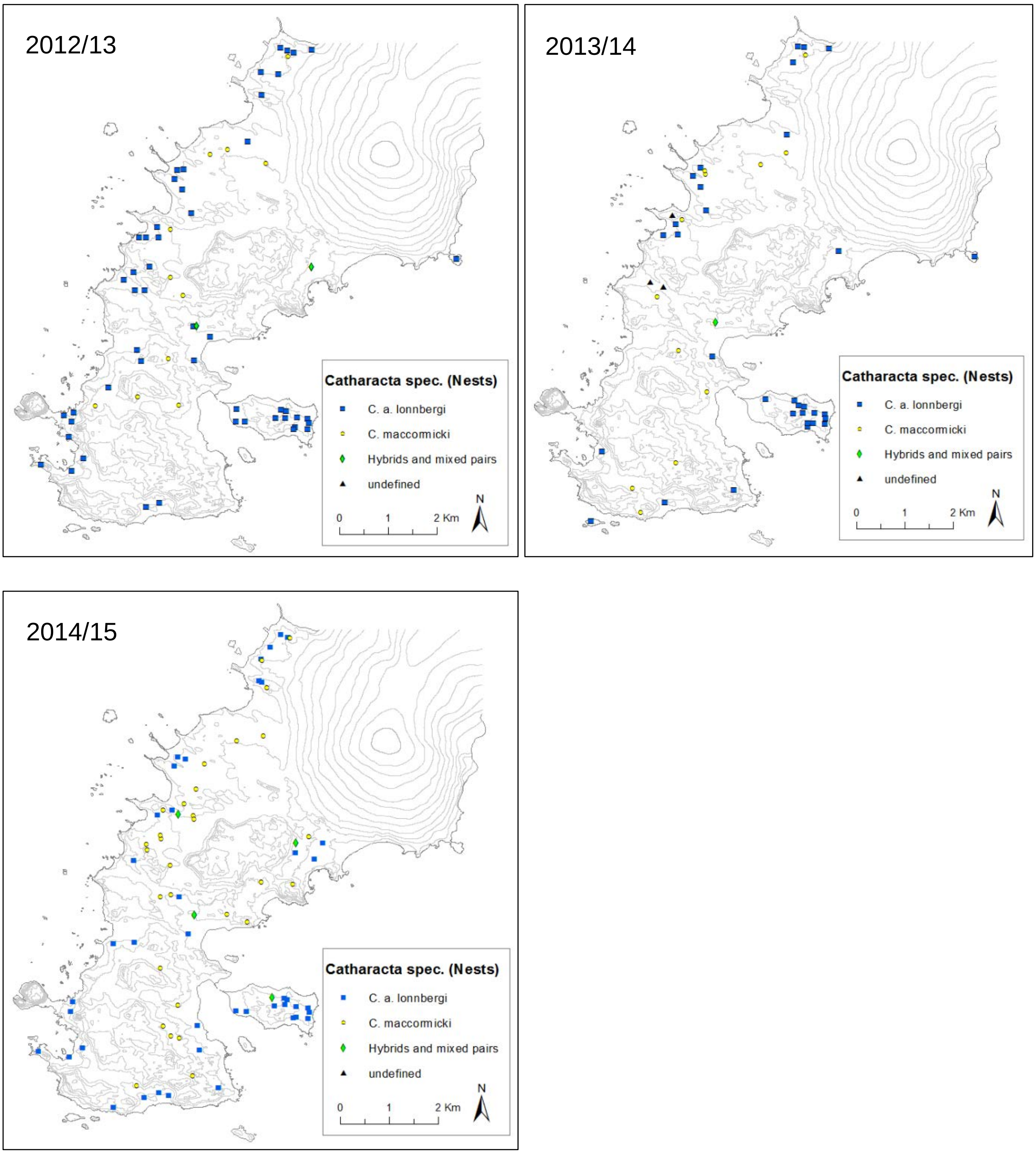
As seabirds can skip breeding in years with unfavourable conditions (Ainley et al. 1990), differing reactions of the two species to local environmental factors appear to be decisive in this regard. This is also supported by the fact that south polar skuas only successfully raised chicks at all in six of the last eight seasons, whereas the breeding success of brown skuas remained fundamentally stable, despite a negative tendency ($R^2 = 0.43$, $p = 0.08$) (Table 2). Similar observations were made on neighbouring Potter Peninsula (Graña Grilli 2014; see Sec. 3.5).

Table 2: Breeding pair numbers and breeding success of skuas in the Fildes region in the seasons 2007/08 to 2014/15 (* value is based on only one breeding pair)

Season	Brown skua	South polar skua	Hybrids and mixed pairs	Undefined pairtype
2007/08	0,47	0	0	0
2008/09	0,36	0	0	0
2009/10	0,37	0,46	0,19	0,05
2010/11	0,43	0,32	0,56	0,14
2011/12	0,32	0	0,09	0
2012/13	0,31	0	0	0
2013/14	0,42	0	1,00 *	0
2014/15	0,16	0	0	0

In areas in which they breed sympatrically, brown skuas and south polar skuas differ in their feeding ecology (Pietz 1987; Reinhardt et al. 2000; Hahn et al. 2008a; Hahn et al. 2008b) and in their sensitivity to environmental conditions (Hahn et al. 2007). A proportion of brown skuas regularly occupy feeding territories in neighbouring seabird colonies, especially penguin colonies (Hahn et al. 2003), or stay near stations and in this way benefit from stable sources of food (Hahn et al. 2008a; Krietsch et al. 2016). In contrast, brown skuas without feeding territories, and also those raising chicks, depend to a greater extent on fish as their main source of food, just as south polar skuas do (Reinhardt 1997; Reinhardt et al. 2000; Hahn et al. 2007; Hahn et al. 2008b; Montalti et al. 2009; Carneiro et al. 2015). It is therefore to be suspected that the small number of south polar skua breeding pairs and their lack of breeding success in the recent past in the Fildes Region is principally a consequence of a lack of food availability in the marine pelagic area (Hamer et al. 1991; Phillips et al. 1996; Reinhardt 1997). In addition, interspecific and intraspecific predation of eggs and chicks by skuas can significantly reduce breeding success (Hamer et al. 1991; Reinhardt et al. 2000), especially in regions with such a high skua density as in the Fildes Region. Because declining food availability forces many seabirds, including skuas, to spend longer searching for food, the risk of predation rises for the chicks that are left unguarded during that time (Krietsch et al. 2016). Aside from extreme weather events, which can lead to total brood loss, it appears that local climatic conditions play a subsidiary role in relation to reproduction (Hahn et al. 2007).

Figure 24 a - c: Distribution of skua nests (*Catharacta lonnbergi*, *C. maccormicki*, hybrids and mixed pairs) in the Fildes region in the seasons 2012/13 to 2014/15



In the seasons 2012/13 to 2014/15 it was again possible to document the active feeding of skuas by staff of all the stations located on the Fildes Peninsula. Therefore, this practice, which has been described repeatedly (Peter et al. 2008; Braun et al. 2012; Peter et al. 2013) and which is completely in conflict with the provisions of the Madrid Protocol (Annex II and III), is still common. Evidently, skuas continue to have access to human food waste (or introduced animal species). The most striking current example was the finding of fresh remains of a turtle in a brown skua nest in very close proximity to the Chinese station Great Wall (Figure 25).

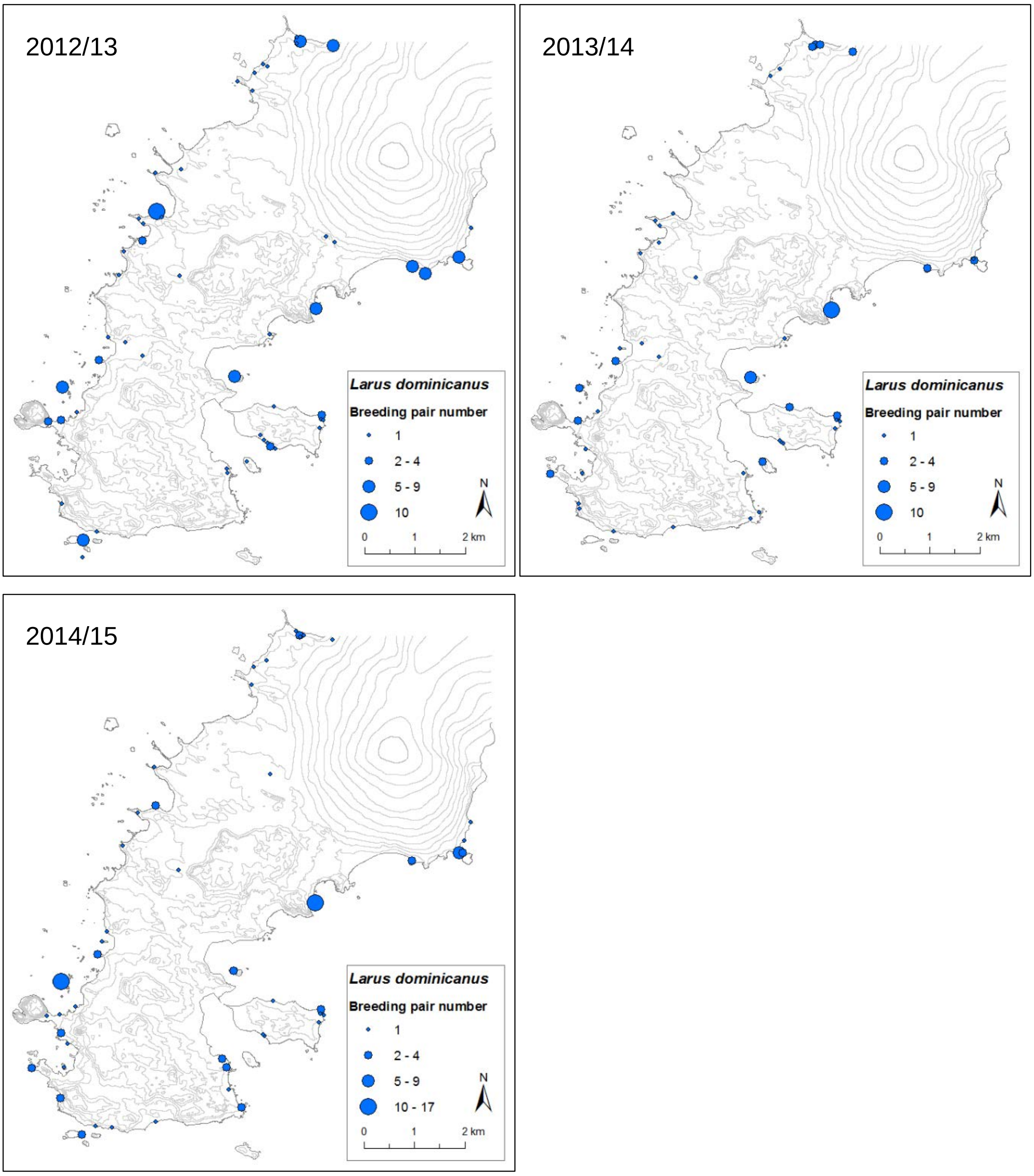
Figure 25: Remains of a turtle found at a Brown skua's nest situated close to a station (photo: M.-C. Rümmler, 28.01.2015)

2.8 Kelp gull (*Larus dominicanus*)

Since 2003/04, as part of previous projects in the Fildes Region, a total of 140 breeding sites of kelp gulls (*Larus dominicanus*, Figure 26) have been recorded. Of those, between 45 and 54 sites were occupied during the last three seasons (Figure 27 a - c). Fairly large breeding colonies exist at Norma Cove, north of the Neftebasa large fuel tank, as well as on Diomedea Island and Dart Island, with a regular population of more than 10 breeding pairs of kelp gulls. It was possible once again to confirm the existence of broods at various different locations inland (Peter et al. 1988; Peter et al. 2008; Peter et al. 2013).

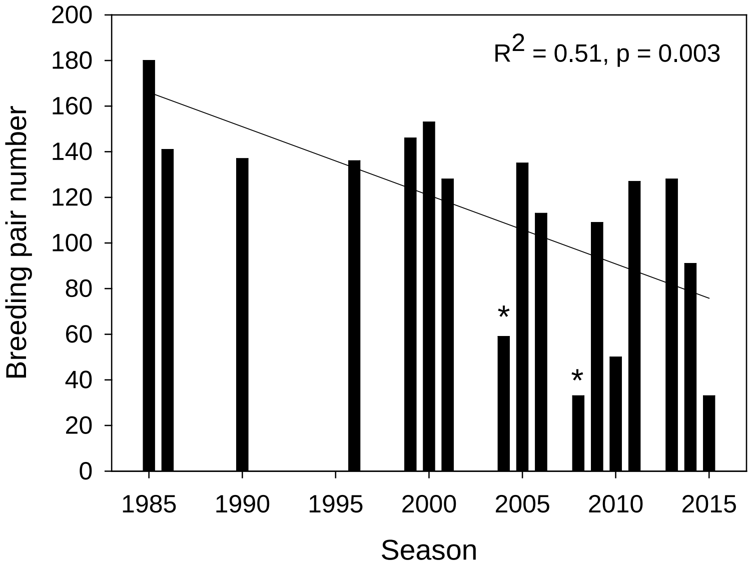
Figure 26: Kelp gull (*Larus dominicanus*, photo: C. Braun)

Figure 27 a - c: Location and size of kelp gull (*Larus dominicanus*) breeding colonies in the seasons 2012/13 to 2014/15



There is detailed information about kelp gull breeding pair numbers in the Fildes Region going back to the 1979/80 season. However, there has only been comprehensive data since the 1984/85 season (Figure 28). Based on this mostly unpublished data from a total of 15 years, it is possible to determine an average value (1984/85 – 2014/15) for this species in the Fildes Region of 122 ± 36 BP, which breed annually in the study area. In the 2012/13 season the number of breeding pairs of 139 that was recorded was above the long-term average, while the totals for the 2013/14 season (91 BP) and the 2014/15 season (49 BP) were significantly lower due to unfavourable environmental conditions (Figure 28). With regard to population development in the Fildes Region during the last three decades, a significant downward statistical trend can be determined (Figure 28). Thus, statements found in reports of earlier studies that talk of a stable breeding population can no longer be confirmed (Peter et al. 2008; Peter et al. 2013). In contrast, in other parts of the South Shetland Islands stable or growing populations have been documented, for example in Admiralty Bay, King George Island (Sander et al. 2006; Branco et al. 2009) and on Byers Peninsula, Livingston Island (Gil-Delgado et al. 2013a), although there was considerably less data from these areas or there were large time gaps in the data series. The reasons for the decline in kelp gulls in the Fildes Region are not sufficiently understood. However, the frequent occurrence of Antarctic summers in which late snow melt has been observed (see above) could well play a significant role in this, as a large number of gulls breed in the more level areas along the coasts. In such areas deep snow cover in spring can, in some cases, make breeding impossible.

Figure 28: Breeding pair numbers of kelp gulls (*Larus dominicanus*) in the Fildes region since the 1980s with presentation of significant trends by means of linear regression (* data incomplete, season not included in the calculation of the long-term trend; if there are no values, no data were available for the particular season.)

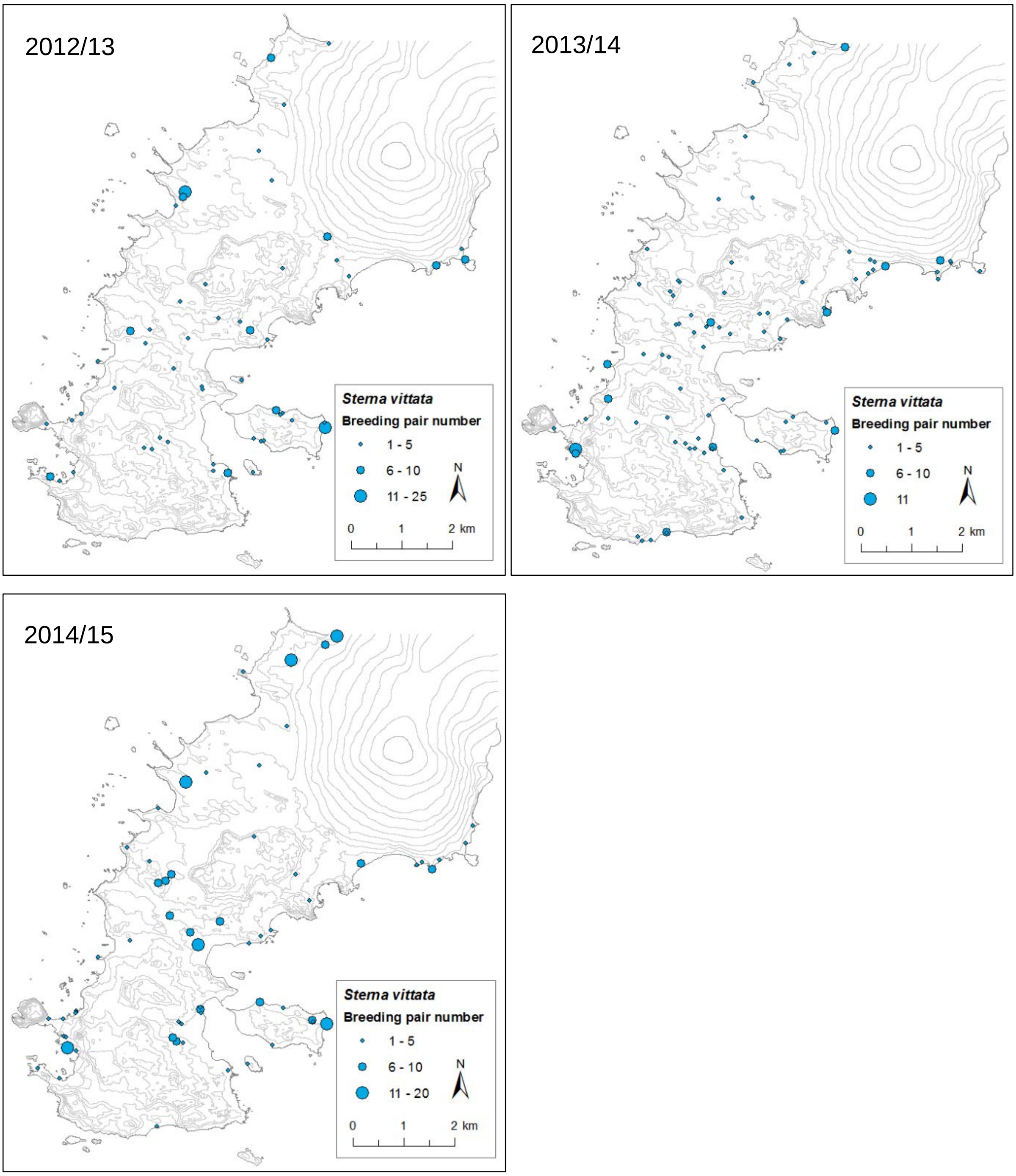


Due to the lack of suitable population counts no statements can be made regarding the total population of kelp gulls in the Antarctic. Globally, the estimated population of 3.3 to 4.3 million individuals of this species, found over wide areas of the southern hemisphere, appears to be growing (category 'least concern', BirdLife International 2015b).

2.9 Antarctic tern (*Sterna vittata*)

The comprehensive count of Antarctic terns (*Sterna vittata*) in the Fildes Region gave a total of 222 BP (2012/13), 284 BP (2013/14) and 296 BP (2014/15), and the distribution is shown in Figure 29 a - c. As this species is very sensitive to environmental influences and anthropogenic disturbance, and often reacts by relocating breeding sites, methodological errors such as multiple entries during mapping cannot be excluded. Taking this limitation into account, a comparison of all available long-term data indicates a stable Antarctic tern population − despite considerable interannual fluctuations (Figure 30). However, clear differences can be recognised regarding the size of the individual breeding colonies (Peter et al. 2008). Large colonies with up to 300 BP in a very restricted space, such as those observed at Nebles Point in the 1984/85 season (Kaiser et al. 1988b; Peter et al. 1988), now no longer exist. The colony sizes recorded between 2003/04 and 2014/15 (excluding single nests) was around 6 ± 5 BP on average. Colonies with more than 20 BP were relatively rarely recorded (approx. 4 % over all years). The largest breeding colony of recent years, with at least 50 BP, was recorded in the 2008/09 season north of the runway (Peter et al. 2013). As well as colony breeders, one can also often find individual breeding pairs in the Fildes Region, although to date this is known only for a few breeding sites in the Antarctic (Higgins et al. 1996).

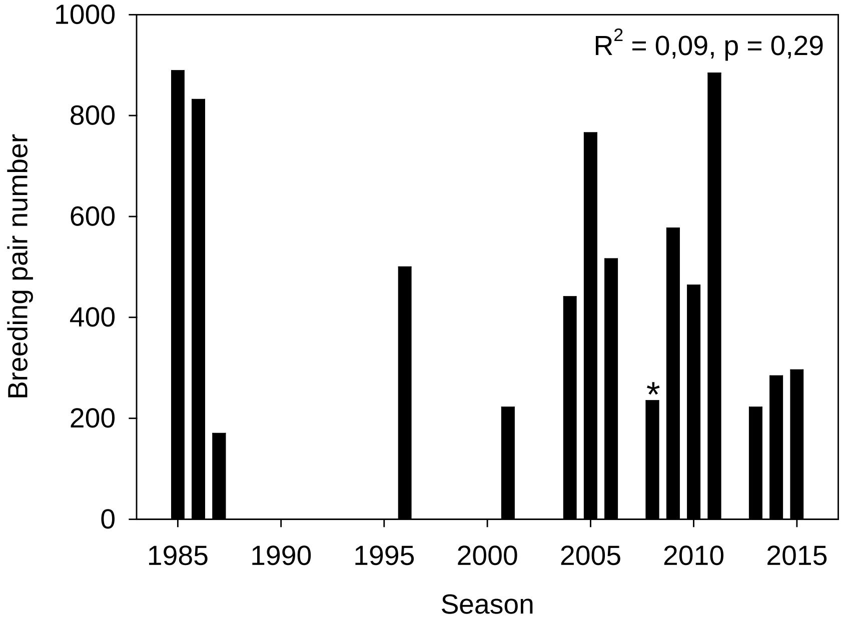
Figure 29: Location and size of Antarctic tern (*Sterna vittata*) breeding colonies in the seasons 2012/13 to 2014/15



Breeding pair density in the Fildes Region fluctuated between approx. 6 BP/km^2 in the 1986/87 season (Mönke et al. 1988) and approx. 31 BP/km^2 in the 1984/85 and 2010/11 seasons (Peter et al. 1988; Peter et al. 2013), with a total ice-free area of approx. 29 km^2, and is therefore lower than the values recorded for Admiralty Bay (34 - 96 BP/km^2 on 19 km^2, Jablonski 1995) but higher than the breeding pair density on James Ross Island (2.2 - 2.9 BP/km^2 on 117 km^2, Weidinger et al. 2013).

The total population of Antarctic terns in the 1990s was estimated at approx. 35,000 for the South Shetland Islands and at 1,500 individuals for the Antarctic Peninsula and adjacent islands (Higgins et al. 1996). The limited amount of long-term data available for breeding pair numbers of Antarctic terns in other areas does not allow any definite statements as to the development of the population of this species in the Antarctic (Woehler et al. 2001). For example, stable populations have been documented for Barton Peninsula (Sec. 3.2, Table 6) and Byers Peninsula, Livingston Island (Gil-Delgado et al. 2013a). In contrast, it appears that the number of breeding pairs in the Admiralty Bay area fell significantly between 1978/79 and 2004/05 (Sander et al. 2005).

Figure 30: Change of breeding pair numbers of Antarctic terns (*Sterna vittata*) in the Fildes region since the 1980s with presentation of significant trends by means of linear regression (* data incomplete, season not included in the calculation of the long-term trend; if there are no values, no data were available for the particular season.)

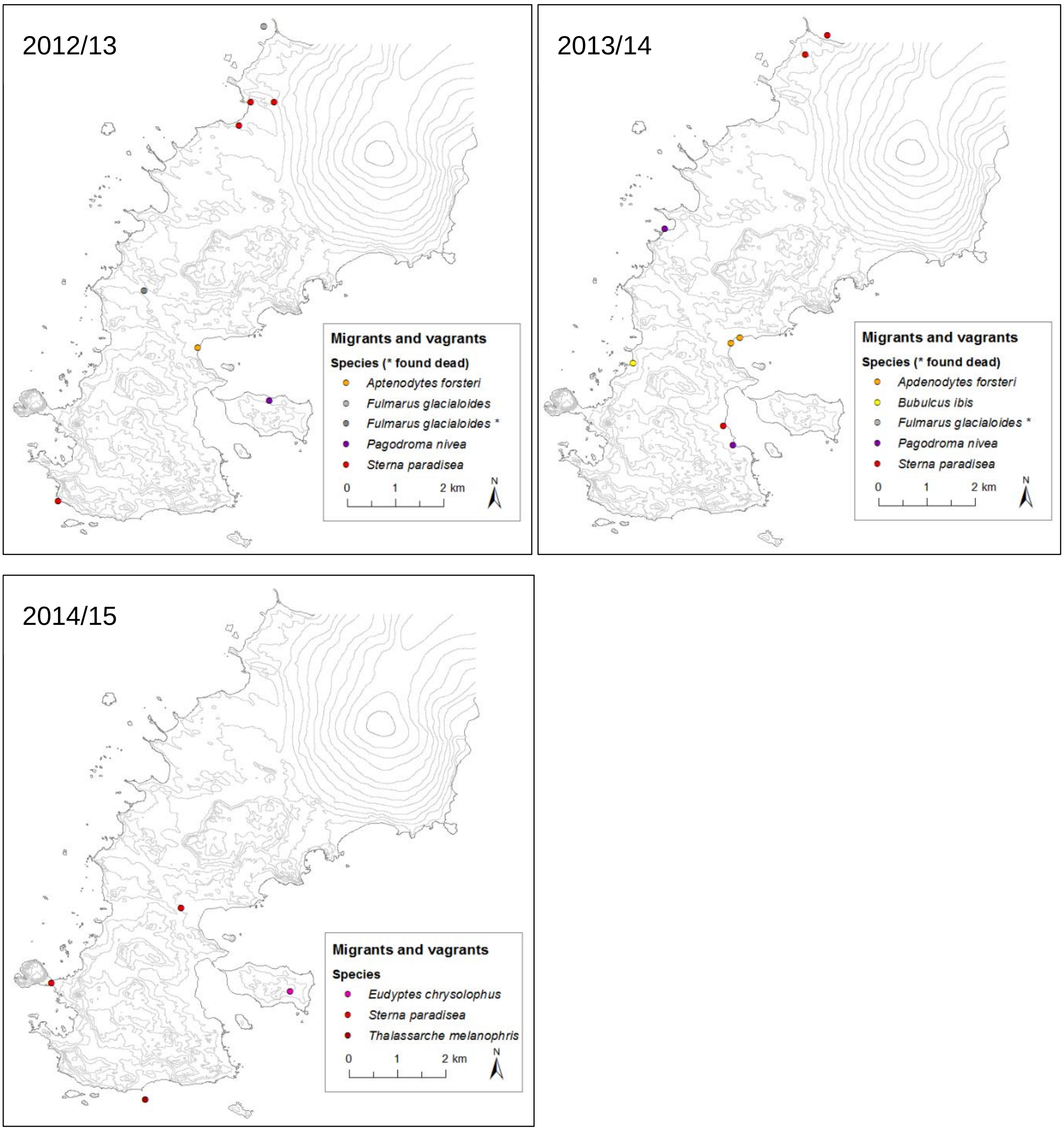


2.10 Potential breeding birds, migrants and vagrants

Some 25–50 blue-eyed shag (*Phalacrocorax atriceps*) have been noted in recent years regularly visiting all coastal stretches of the Fildes Region (Peter et al. 2008; Peter et al. 2013). For this reason, a separate recording of blue-eyed shag was not done as part of this study. Confirmed evidence of breeding in the Fildes Region for this species exists only from the years 1979/80 (Bannasch et al. 1981), 1983/84 (Peter et al. 1988) and 1986/87 (Mönke et al. 1988). Currently, there is no indication of renewed breeding, so this species is still considered a potential breeding bird here. In Maxwell Bay several breeding sites are known, some of them important, e.g. at Duthoit Point, Nelson Island (see Sec. 3.5 & 3.6).

During the three seasons examined, a total of 7 bird species were noted as vagrants or transients (Figure 31 a - c). Immature emperor penguins are regular guests in the Fildes Region (Peter et al. 2013) and are again being documented in the region, such as single individuals near the Russian Bellingshausen station on 10 June 2012 (pers. comm. O. Sakharov), 08 January 2013, 26 November 2013 (pers. comm. M. Villegas) and 18 December 2013.

Figure 31 a - c: Observations and finds of dead birds of vagrants and migrants in the Fildes region in the seasons 2012/13 to 2014/15



In the Fildes Region in the austral summers of 2012/13 to 2014/15, no king penguins were registered, in contrast to previous years (Peter et al. 2008; Peter et al. 2013). It is interesting that breeding attempts of this species were documented on the neighbouring Potter Peninsula (see also Sec. 3.5) by one breeding pair in two seasons (2011/12 and 2012/13) and two breeding pairs on Elephant Island, South Shetland Islands (Petry et al. 2013). It is still not clear whether these observations suggest individual behaviour (artefact) or a possible expansion of this species southwards (Petry et al. 2013; Juáres et al. 2014). Similarly, the macaroni penguin, another Subantarctic species, has been noted as a breeding bird on Livingston Island, South Shetland Islands, since the 1950s (Croxall et al. 1979; Woehler 1993; Naveen et al. 2000; Pfeiffer et al. 2004) and has been registered increasingly further south of its original range, including breeding attempts in the WAP region close to Anvers Island (Gorman et al. 2010). Since the 1980s individual macaroni penguins have been sighted on the coasts of the Fildes Region, mostly in the penguin colony on Ardley Island (e.g. Mönke et al. 1988; Peter et al. 1988; Lange et al. 1989; Erfurt et al. 1990) and extending over the period from 2003 to 2012 (Peter et al. 2008; Peter et al. 2013). On 02 February 2015 one macaroni penguin was observed in the penguin colony on Ardley Island.

Members of the tubenoses (order: Procellariformes) have been spotted as transients in the Fildes Region again (Peter et al. 2008; Peter et al. 2013), including snow petrel (*Pagodroma nivea*), southern fulmar (*Fulmarus glacialoides*) and black-browed albatross (*Thalassarche melanophris*). Table 3 lists all known observations of individuals of these species during the survey period.

Table 3: Observations of members of the order Tubenoses (Procellariformes) in the Fildes region in the seasons 2012/13 to 2014/15

Species	Date of observation	No. of indivuals	Source (if not assessed by project staff)
Pagodroma nivea	12.12.2012	1	
	01.08.2013	1	pers. comm. M. Xing
	01.01.2014	1	pers. comm. Z. Zhang
Fulmarus glacialoides	08.12.2012	> 20	
	20.12.2012	1 (found dead)	
	17.01.2014	1 (found dead)	
Thalassarche melanophris	26.12.2014	1	

Sightings of cattle egrets (*Bulbucus ibis*), a species originating from Africa and Asia and now also established in South America, in the study area extend back to the 1970s and 1980s (e.g. Torres et al. 1986; Kaiser et al. 1988a; Peter et al. 1988; Mönke et al. 1990). In the Fildes Region numerous findings of dead Cattle Egrets were documented between 2003 and 2012 (Peter et al. 2008; Peter et al. 2013). This species has a low chance of survival due to the lack of food available for it here. There were several findings of dead birds on Potter Peninsula (Silva et al. 1995). On 22 March 2013 a living individual was sighted in the Valle Grande in the centre of the Fildes Peninsula (pers. comm. M. Xing).

Oversummering Arctic terns (*Sterna paradisea*) have been regularly observed in the Fildes Region in the past few years (Peter et al. 2008; Peter et al. 2013). During the survey period repeated sightings of resting or foraging individuals of this species were noted (Table 4). They were mostly observed in large flocks.

Table 4: Observations of Arctic terns (*Sterna paradisea*) in the Fildes region in the seasons 2012/13 to 2014/15

Date of observation	No. of indivuals	Source (if not recorded by project staff)
27.12.2012	3	
15.01.2013	14	
03.02.2013	13	
11.02.2013	21	
29.01.2014	3	pers. comm. Z. Zhang
10.20.2014	6	
16.02.2014	2	
13.12.2014	1	

Date of observation	No. of indivuals	Source (if not recorded by project staff)
03.02.2015	3	

White-rumped sandpipers (*Calidris fuscicollis*) are common guests around the South Shetland Islands (Silva et al. 1995; Peter et al. 2008; Korczak-Abshire et al. 2011; Peter et al. 2013). In the past three seasons, however, none were spotted in the Fildes Region.

2.11 Seals

In the Antarctic the seal hunt in the 19th century and into the 20th century played a significant role in the drastic decline of several seal species and brought a few species to the edge of extinction. Regulations imposed by the Antarctic Treaty System and the Convention for the Conservation of Antarctic Seals (CCAS), which took effect in 1978, protected all Antarctic seal species from commercial exploitation. In ranges north of 60°S, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and various national protective measures partly apply. The evident increase in the severely decimated seal populations is ascribed as a success of these protective measures (e.g. Laws 1994; Jabour 2008). Nowadays the greatest dangers for Antarctic seals involve changes in their food web due to industrial fishing practices and changes in the sea ice situation resulting from climate change (Siniff et al. 2008).

Five of the six Antarctic seal species live in the Fildes Region and raise their young there – with the exception of the crabeater seals (Lobodon carcinophagus). Leopard seals (Hydrurga leptonyx) and crabeater seals rarely entered the survey area during the austral summer. Therefore, observations of these species were generally sporadic and are not considered here further. The results of the monthly seal counts in each specific cove during the 2012/13 to 2014/15 seasons are given in Table 23 - Table 27 in Appendix 1.

As in previous years the largest seal concentrations were found on the west coast of the Fildes Peninsula (Peter et al. 2008; Peter et al. 2013). The southern elephant seal (*Mirounga leonina*), which concentrate at particular resting places (Figure 33), and Antarctic fur seals (*Arctocephalus gazella*) in particular visit the sandy coves to moult and rest. In contrast, resting Weddell seals (*Leptonychotes weddelli*), which are generally observed much less often in the summer, are regularly recorded on the east coast and especially near the Ardley isthmus. The fluctuations in the annual presence and distribution patterns among the different seal species are determined by differences in arrival date, duration of stay, habitat preferences, behaviour and the number of individuals (Salwicka et al. 2002).

The results of the monthly counts of seal populations on the coasts of the Fildes Peninsula and Ardley Island were documented and interpreted. In contrast to the 1980s, counts were only conducted in the summer months in the past 13 years. That is why the presentation of seal data given below is restricted to the months of December, January and February. In addition, the current state of knowledge on seal pupping areas in the Fildes Region is given.

2.11.1 Southern elephant seal (*Mirounga leonina*)

The southern elephant seal is the largest seal species in the world, with a circumpolar range and a concentration on the Subantarctic islands (South Georgia, Macquarie Island, Heard Island, Crozet and Kerguelen Islands). Other colonies exist in the Antarctic and in the temperate southwest Atlantic (Península Valdés). This seal species was intensively hunted commercially in the 19th and beginning of the 20th century and was severely decimated. The total population was estimated in the 1990s at over 660,000 individuals, with more than 60 %

living on South Georgia and Península Valdés (Laws 1994). As the species is currently not exposed to any great risks and the majority of the more sizeable populations are stable, they are no longer considered endangered (IUCN status 'least concern') (Campagna 2008).

The southern elephant seal comes to the Fildes Region for reproduction (spring) and moulting (summer and autumn). The distribution of groups by gender and age differs clearly over the course of the year due to the different moulting times (Laws 1984; Kirkman et al. 2003); in the austral summer primarily moulting females and young males are seen in the survey area (Peter et al. 1988). The seals depart the Fildes Region in a northerly direction before winter except for a few individuals, which were still observed in June and July (Peter et al. 1988; Fröhlich 2007).

In agreement with observations from Admiralty Bay (Salwicka et al. 2002), the number of elephant seals increases markedly on the coast of the Fildes Region after the reproduction phase (Peter et al. 1988; Fröhlich 2007) and reaches its peak in the austral summer. On Heard Island and the Península Valdés, in contrast, the number of elephant seals sank after reproduction (Slip et al. 1999; Lewis et al. 2004). The deviating pattern seen on King George Island is likely due to the immigration of younger animals and those who are not reproducing that season; they probably come from South Georgia (Salwicka et al. 2002).

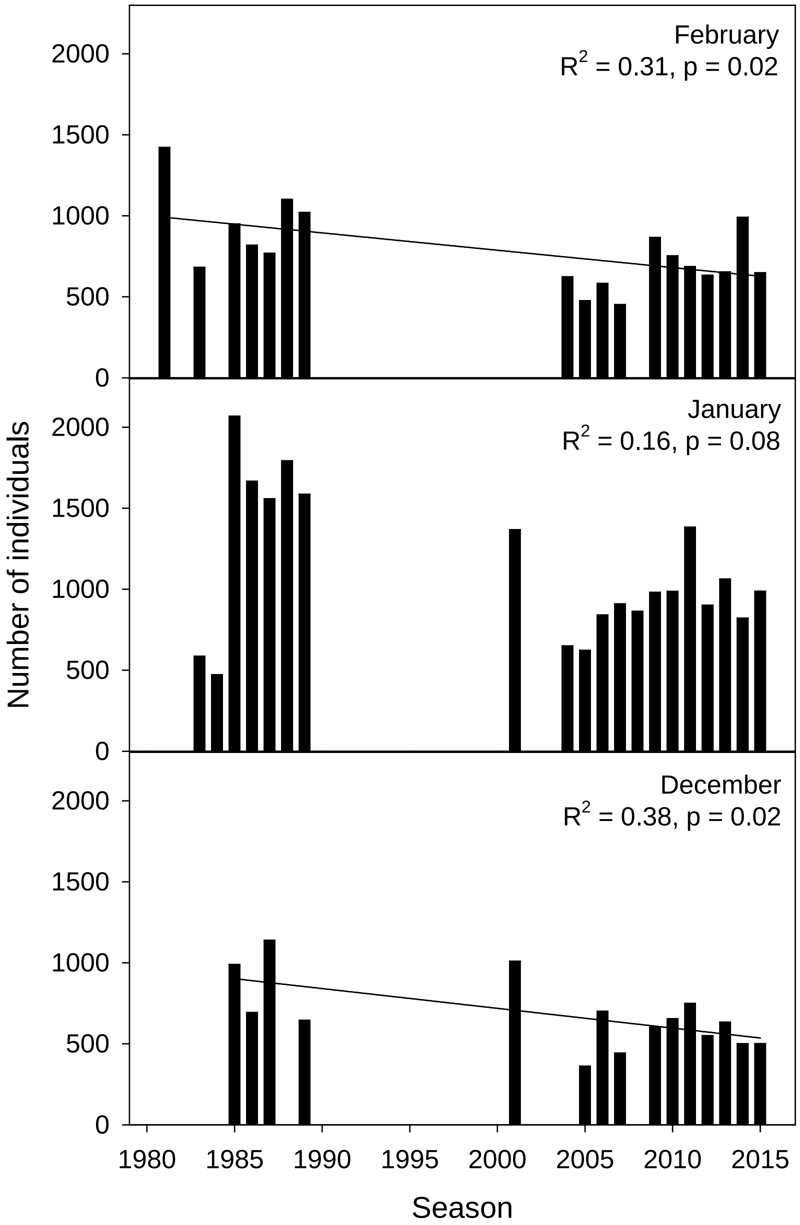
The number of elephant seals observed in the Fildes Region in the austral summers during the survey period from 1980/81 to 2014/15 is subject to evident fluctuations (Figure 32). The highest number of elephant seals was recorded in January, respectively, with a long-term average is 1,105 ± 444 individuals. The peak value so far being 2,068 individuals was registered during the count in January 1985 (Peter et al. 1988).

In contrast, the counts of individuals in the other summer months, with an average of 678 ± 219 individuals in December and 794 ± 246 individuals in February, clearly lie below the January counts (Figure 32).

The estimate made by Laws (1994) of 2,300 animals in the region of the South Shetland Islands seems too low. Considering the proportionate surface area of the Fildes Peninsula and the large number of elephant seals observed, the actual population must be much higher.

In Figure 32 it is evident that the number of elephant seals counted in December and February since the 1980s has decreased significantly. For the month of January a decrease is also looming, which lies just under the level of significance ($R^2 = 0.16$, $p = 0.08$, Figure 32). The cause of the decline in the long-term comparison of moulting elephant seals in the Fildes Region is unknown. In the past 11 years, however, the number of elephant seals counted in the summer months appears to have stabilised and shows either no trend (December: $R^2 = 0.02$, $p = 0.67$) or even an increasing tendency (January: $R^2 = 0.30$, $p = 0.06$; February: $R^2 = 0.28$, $p = 0.09$, Figure 32).

Figure 32: Numbers of southern elephant seals (*Mirounga leonina*) recorded during the monthly seal counts on Fildes Peninsula and Ardley Island during the austral summer with presentation of significant trends by means of linear regression; if there are no values, no data were available for the particular season.)

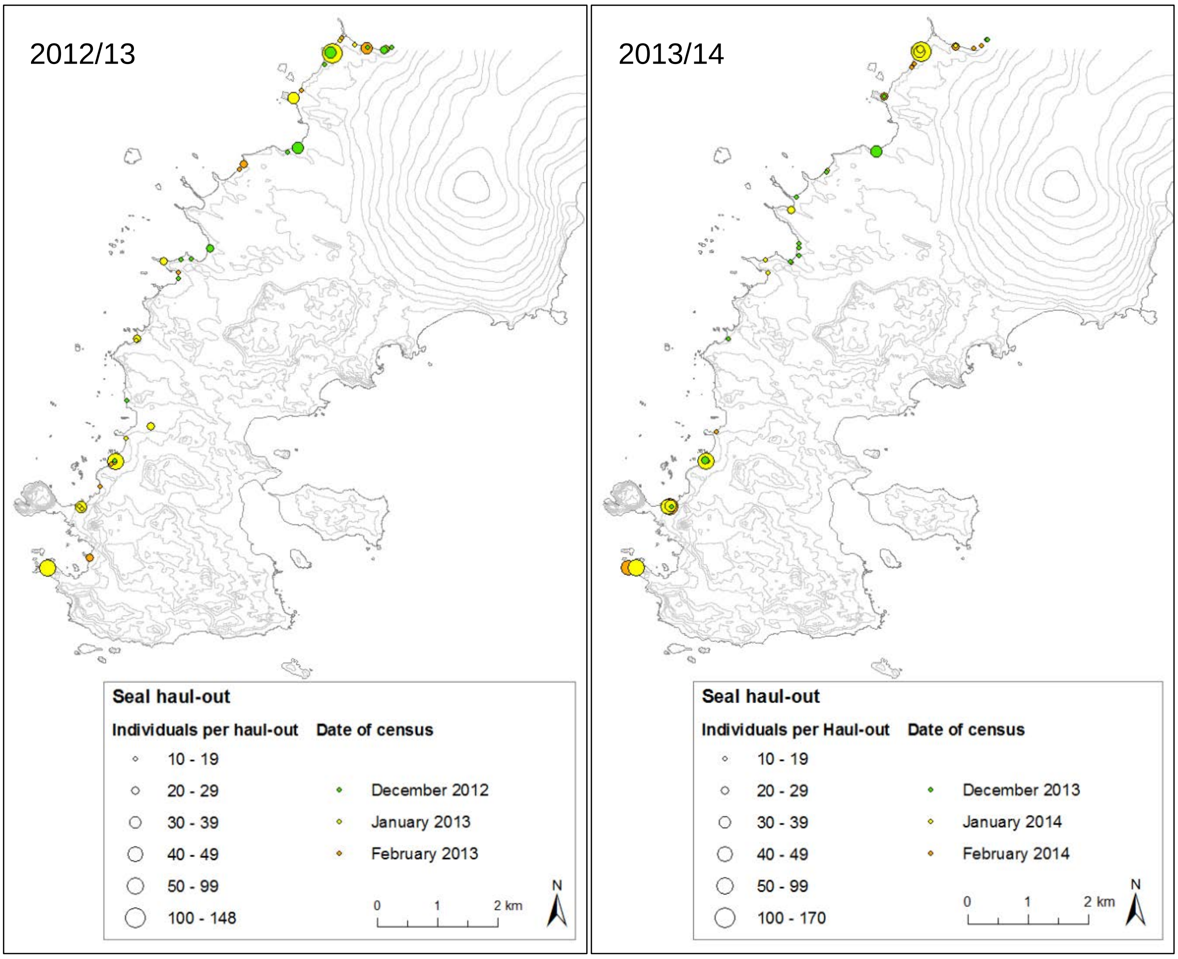


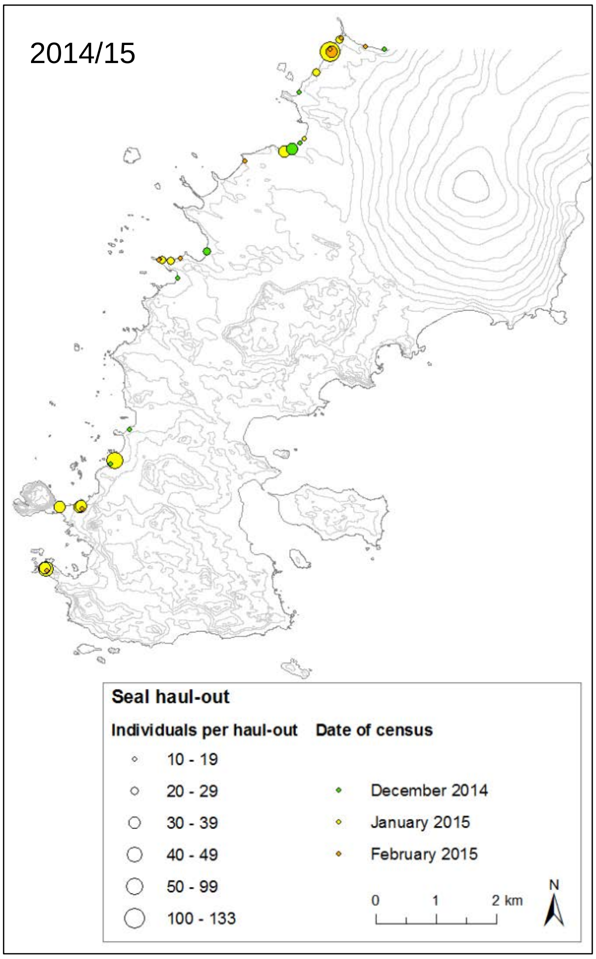
It is suspected that elephant seals profit from regional climate change on the one hand, as the retreat of ice fields and glaciers reveals new beaches for reproduction and moulting (Siniff et al. 2008). On the other hand, we do not know what the reactions are of the populations to changes in the Antarctic food web due to continued warming of the Southern Ocean (Siniff et al. 2008). This could result in a shift of their range towards the Pole or in an adaptation of their search for food (diving depth, dive duration, etc.) – associated with a higher physiological cost (McIntyre et al. 2011).

In contrast to the results presented here, a study from Admiralty Bay showed neither an increasing nor a decreasing trend in the elephant seal populations (Salwicka et al. 2002), although the data were collected over a much shorter survey period (1988 – 2000). On Livingston Island an increase in the elephant seal population was recently documented, but this was based on just two counts conducted 30 years apart (Gil-Delgado et al. 2013b). On the

Crozet and Kerguelen Islands, the number of elephant seals recovered after a phase of drastic decline between 1970 and 1987 or 1990 (Guinet et al. 1999). The decline of elephant seals in the southern Pacific and southern Indian Ocean was traced back to a reduced availability of food connected with various physical, oceanographic factors (temperature, pressure, salinity, etc.) and local predation by orcas (Hindell et al. 1994; Laws 1994; McMahon et al. 2003).

Figure 33 a - c: Southern elephant seal (*Mirounga leonina*) haul-outs with at least ten individuals on the Fildes Peninsula in the seasons 2012/13 to 2014/15





The distribution and the size of the haul-out groups of elephant seals with more than 10 individuals are presented in Figure 33 a - c. The largest resting groups with up to 255 animals (Peter et al. 2013) are found in the extreme northwest of the Fildes Peninsula (Figure 33 a - c).

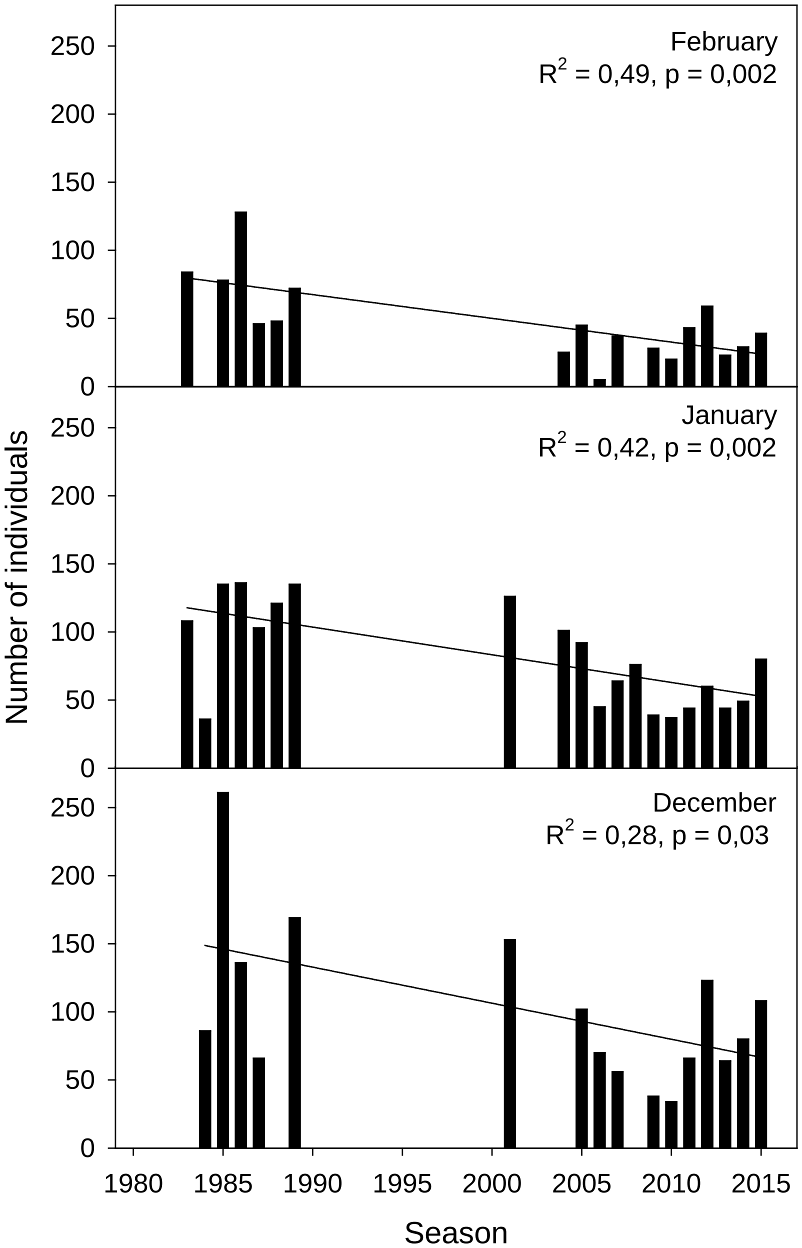
Since the beginning of data collection in the 2003/04 season, no major spatial changes were observed in the haul-out groups of elephant seals (Peter et al. 2008; Peter et al. 2013). Each austral summer, a larger number of elephant seals congregate on the established resting places to moult. In contrast, the areas with smaller aggregations of seals vary and appear randomly on beach sections along the Drake coast. This broadly agrees with the distribution pattern of elephant seals on the coast of Admiralty Bay, which also shows no changes over the years (Salwicka et al. 2002).

2.11.2 Weddell seal (*Leptonychotes weddelli*)

Weddell seals are the most southernly living mammals. The focus of their range is the circumpolar coasts of the Antarctic continent. Smaller colonies are found on South Georgia, the South Orkney and South Sandwich Islands, and the South Shetland Islands. The population of this species is thought to be stable (IUCN category 'least concern', Gelatt et al. 2008) and estimated at 500,000 to 1 million individuals (Costa et al. 2006; Gelatt et al. 2008). This makes the Weddell seal the most common seal species in the Antarctic after the crabeater seal. The age distribution of Weddell seals seems to follow a cyclical climatic pattern that is linked to the Southern Oscillation Index (SOI) (Testa et al. 1991), which indicates the occurrence of a cooling (La Niña) or a warming of the ocean (El Niño).

Weddell seals enter the Fildes Region in the spring (September to November) to give birth to their pups (see below). They can also be found on all coasts of the Fildes Region for moulting in the austral summer months, but in much smaller quantities compared to elephant seals and fur seals. In the course of the austral summer, the number of Weddell seals generally continues to fall despite strong interannual fluctuations (Figure 34). While the long-term average for the month of December was 101 ± 58 individuals, in January and February an average of 82 ± 37 and 48 ± 30 individuals, respectively, was recorded.

Figure 34: Numbers of Weddell seals (*Leptonychotes weddelli*) recorded during the monthly seal counts on Fildes Peninsula and Ardley Island during the austral summer with presentation of significant trends by means of linear regression; if there are no values, no data were available for the particular season.



A long-term comparison showed a decreasing trend in the number of Weddell seals observed in the survey area over all three months during the austral summer (Figure 34), even though the population showed no significant changes in the past years (December: $R^2 = 0.06$, $p = 0.50$; January: $R^2 = 0.05$, $p = 0.53$; February: $R^2 = 0.04$, $p = 0.59$, Figure 34). It is not clear whether this reflects just a change in the distribution of this species or an actual regional population decline. It is possible that the seals are moving further south in general (Costa et al. 2010), where the sea ice season is sufficiently long (Stammerjohn et al. 2012).

On the other hand, similar findings in Admiralty Bay, King George Island (Salwicka et al. 2002) and Anvers Island (Siniff et al. 2008) suggest confirmation of the population decline possibility. In contrast, counts of Weddell seals in the Vestfold Hills/eastern Antarctic, an area that has experienced little change in the length of the sea ice season, have not revealed any long-term population trend (Lake et al. 2008).

The observed decline of the Weddell seals may be a consequence of regional changes in the environmental conditions (Learmonth et al. 2006). It has been shown that Weddell seals, as an ice-dependent species with a high level of philopatry (Siniff et al. 2008; Garrott et al. 2012), are especially sensitive to climate change, which is reflected in the increased spatial-temporal variability of the ice cover (Stammerjohn et al. 2008).

2.11.3 Antarctic fur seal (*Arctocephalus gazella*)

The Antarctic fur seal is found in an extensive circumpolar distribution on the South Shetland and South Orkney Islands as well as numerous Subantarctic islands, such as Heard Island, Crozet and Kerguelen Islands (Hofmeyr 2008). One major focus of concentration (> 95 % of the population) lies in South Georgia (Boyd 1993; Hofmeyr 2008). The industrial seal hunt initiated in the late 18th century decimated the many millions of individuals of this species over a few decades in the 19th century to a remnant numbering 1,000 individuals in the 1930s (Costa et al. 2006). Since then, the population has been increasing by about 10 % annually, and it was estimated in the 1990s at a minimum of 1.6 million individuals (Boyd 1993; Costa et al. 2006). Other sources mention between 4.5 and 6.2 million just on South Georgia in the 1999/2000 season (Hofmeyr 2008). This immense number of fur seals on South Georgia is now having an effect on the local vegetation (Bonner 1985; Lewis Smith 1988; Scott et al. 2005) and on various seabirds, such as the macaroni penguin (Trathan et al. 2012). Given the stable or increasing populations throughout its range, this species is no longer considered endangered (IUCN status: 'least concern', Hofmeyr 2008).

On the South Shetland Islands, the fur seal hunt began in the 1820s. Within a few years 320,000 fur seals had been killed, leading practically to the extermination of this species (Pearson 2007). In the mid-20th century this island group was recolonised. This step was probably accelerated by the migration of individuals from South Georgia, which were forced out due to the great increase in fur seals there (Boyd 1993). The first fur seal pups registered after the end of the seal hunt were noted on Livingston Island in 1959 (Gerber et al. 2001). Counts in the 1965/66 season found 457 – 507 fur seals on the South Shetland Islands, but none on King George Island (Aguayo 1968). Bengtson et al. (1988) pointed out a continued increase in the fur seal counts based on data from the 1986/87 season and documented 11 pupping sites and ca. 4,000 new-born pups on the South Shetland Islands, e.g. Seal Island (off Elephant Island), San Telmo Islets (off Cape Shirreff, Livingston Island) and Stigant Point (King George Island, see below).

Due to the rapid increase in the fur seal populations, estimates made at the beginning of the 2000s exceeded 10,000 individuals on the South Shetland Islands (Hofmeyr et al. 2005), with some evident differences in the rate of increase (Boveng et al. 1998). Predation by leopard seals apparently had a great effect on the low rate of increase of fur seals on the South Shetland Islands (Boveng et al. 1998). Currently, the population increase in several regions, including the

South Shetland Islands, can be considered saturated (Hofmeyr et al. 2005), while other areas are in the phase of being recolonised (Hofmeyr et al. 2005).

The first evidence of individual fur seals on the Fildes Peninsula (a total of 10 individuals on the northwest coast) was recorded in 1968 (Krylov 1968). It was confirmed by subsequent observations in the 1969/70 (separate groups with 3 - 5 individuals on the west coast, Simonov 1973) and 1973/74 seasons (25 individuals, Popov 1977) as well as sightings of over 200 young animals on Stigant Point in the 1983/84 season (Peter et al. 1988).

Nowadays, Antarctic fur seals can regularly be found in the Fildes Region all year round, if not frequently (Peter et al. 1988; Fröhlich 2007). They are seen almost exclusively on the broad sandy coves of the west coast. Figure 35 reveals the sometimes considerable fluctuations in the counts of fur seals. Their number can even vary greatly over a few days. In total, their number increases strongly over the course of the austral summer. With the exception of a few individual females with young, they are almost exclusively immature males, most likely arriving from South Georgia. Near the end of the austral summer, the number of fur seals in der Fildes Region declines drastically within a short period (Peter et al. 1988; Fröhlich 2007).

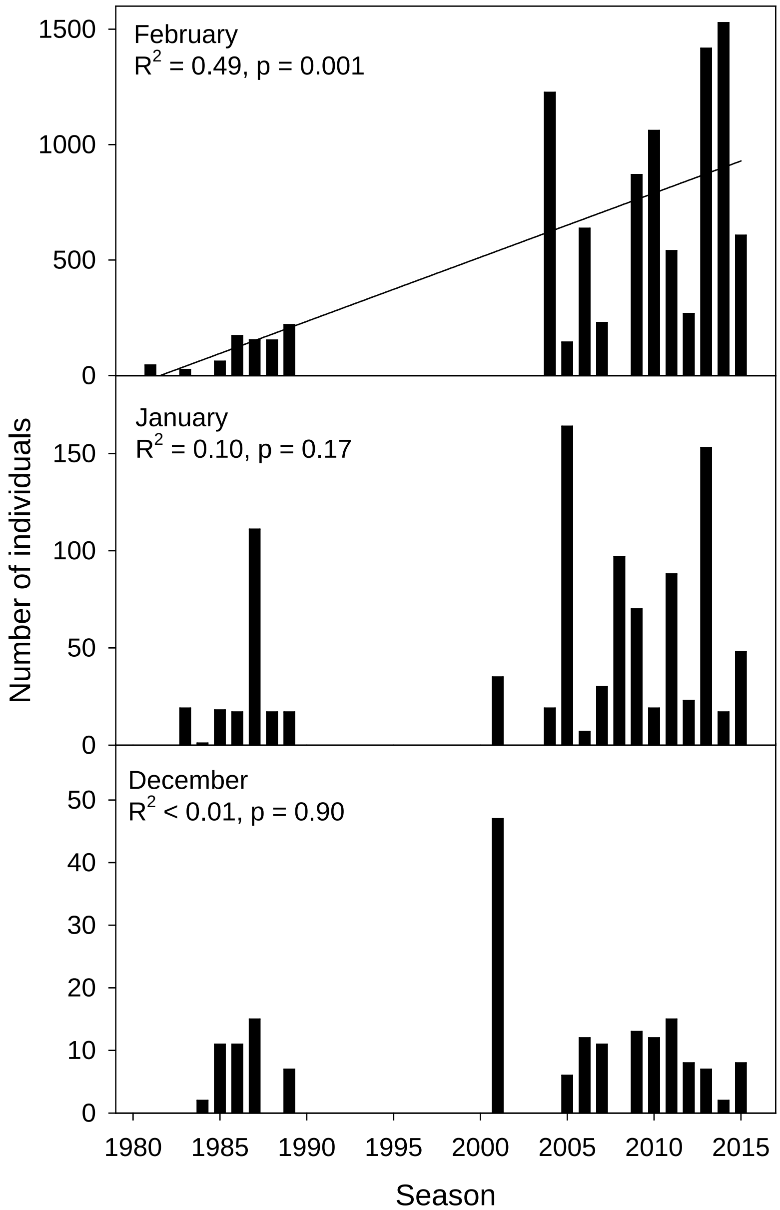
Several studies of the South Orkney Islands, Heard Island or Admiralty Bay (King George Island) record maximum fur seal counts in March (Vergani et al. 1989; Shaughnessy et al. 1998; Salwicka et al. 2002), while in the Fildes Region the highest counts in 5 of 7 seasons were noted in February. In the 1980s an average of 119 ± 74 fur seals was counted in February, but 775 ± 483 fur seals were noted between 2004 and 2015, a significant increase (Figure 35). The highest values since the counts started were 1,417 and 1,528 individuals registered in February in the 2012/13 and 2013/14 seasons, respectively (Figure 35).

The annual fur seal peaks in February reveal a cyclical pattern between 2004 and 2015 (Figure 35). Analogously to data from Admiralty Bay for example (Salwicka et al. 2002), a particularly high number of fur seals occurred in the Fildes Region at intervals of 4 - 6 years (Figure 35). This seems to be associated with the cyclical climate phenomenon El Niño (Salwicka et al. 2002), which has an immediate, negative effect on the abundance of krill (e.g. Fraser et al. 2003; Murphy et al. 2007; Fielding et al. 2014). While fur seals in South Georgia clearly reproduce less in years with low krill density, caused by a strong El Niño effect (Forcada et al. 2005), they are observed in large numbers in Admiralty Bay (Salwicka et al. 2002). One possible cause of this is increased competition for the scarcer food resources, forcing males which will not be reproducing in that season to migrate (Salwicka et al. 2002).

A long-term comparison clearly shows a significant increase in the number of fur seals registered in February in the Fildes Region (Figure 35). This trend matches the results from other regions, e.g. Cape Shirreff and San Telmo Islets, South Shetland Islands (Hucke-Gaete et al. 2004), and Signy and Laurie Islands, both South Orkney islands (Carlini et al. 2006a; Waluda et al. 2010).

How the total population of Antarctic fur seals will develop given the effects of climate change depends on various factors. As the current population is based on the relatively few individuals remaining after the decimation (‘bottleneck’) and shows a rapid population growth, this species has a low level of genetic variation, which makes them highly susceptible to diseases and climate change (Wynen et al. 2000; Hofmeyr 2008). Siniff et al. (2008) suspect that this seal species at higher latitudes will be most strongly affected by reductions in krill along the coast of its pupping areas. The falling birthweight of fur seals is already considered a sign of a reduced availability of food due to current climate changes (Forcada et al. 2014). There are also clear indications of augmented selection due to climate change with far-reaching consequences for the demography as well as phenotypical and genetic variation in each population (Forcada et al. 2014).

Figure 35: Numbers of Antarctic fur seals (*Arctocephalus gazella*) recorded during the monthly seal counts on Fildes Peninsula and Ardley Island during the austral summer with presentation of significant trends by means of linear regression; note the different scales of the Y-axis. If there are no values, no data were available for the particular season.



2.11.4 Seal pupping sites in the Fildes Region

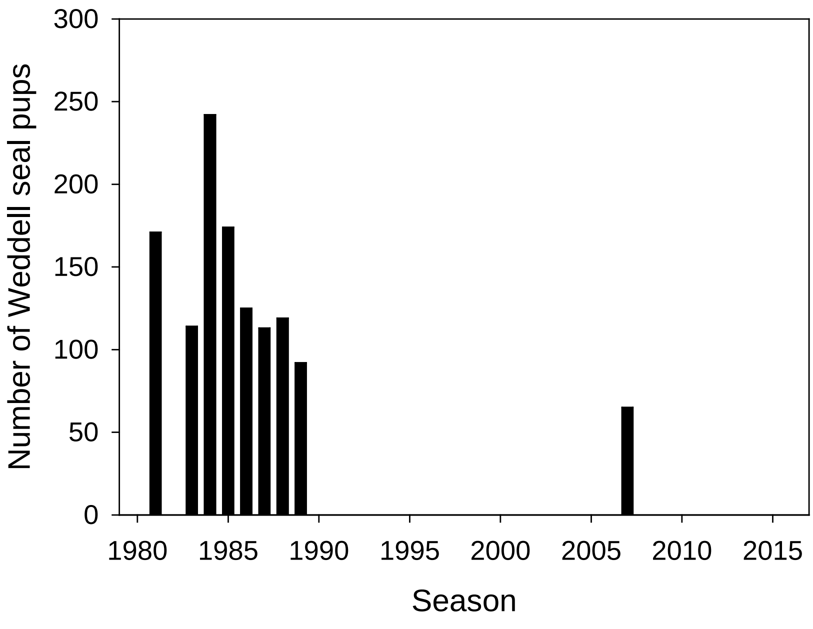
Seal births in the Fildes Region have been documented for the species southern elephant seal, Weddell seal, Antarctic fur seal and leopard seal (Braun et al. 2012). As Weddell seals and elephant seals generally reproduce in the study area between September and November, the majority of data on seal pupping sites in the Fildes Region is based on information from A. Petrov (2002/03 season), O. Sakharov (2012/13 season) and M. Xing (2013/14 season), which was not collected systematically and therefore is not suitable for a quantitative comparison. All available data on newb-orn seals observed in the study area between 2012/13 and 2014/15 are presented in Figure 37.

New-born elephant seals were not recorded in the 2012/13 to 2014/15 seasons (Figure 37). As they were regularly documented in previous years (Peter et al. 2008; Peter et al. 2013), the cause was suspected to be the mostly sporadic recording (see above) at the time of birth. At the beginning of the systematic seal counts in December, all young animals had already left the pupping sites in the Fildes Region.

Detailed data about elephant seal births from October 2006 permit a comparison with data from the 1980s. While in October 2006 a total of 47 new-born elephant seals was recorded (Fröhlich 2007), from 1984 to 1986 between 9 and 11 births were noted (Mönke et al. 1988; Peter et al. 1988; Nadler et al. 1989). In the 1988/89 and 1989/90 seasons, 55 and 62 new-born elephant seals were registered (Lange et al. 1989; Erfurt et al. 1990). To what extent these figures represent population recovery after the decline observed in some regions between 1950 and 1990 (McMahon et al. 2005; Campagna 2008) remains an open question. It is possible that these differences are based on the strong, annual population fluctuations due to the influence of El Niño, as documented e.g. for the Potter Peninsula (Vergani et al. 1990). In general terms, the Fildes Region is of secondary importance as a reproduction site for elephant seals in comparison to other pupping sites in the South Shetland Islands, where several hundred pups are born annually (e.g. Salwicka et al. 2002; Carlini et al. 2006b).

In the 2012/13 to 2014/15 seasons, numerous births of Weddell seals were again recorded in the Fildes Region (Figure 37). The established number of 30 new-born pups in September/October 2013 was clearly below the numbers from the 1980s (maximum: 242 births, Peter et al. 1988). Already the 65 new-born Weddell seals in September and October 2006 presented a clear decline (Figure 36). A decreasing trend has been evident since the 1980s despite the lack of current data; the level of significance is only just exceeded ($R^2 = 0.39$, $p = 0.07$). Figures from the 1960s about low numbers of young Weddell seals (1966: 85 – 90 pups, Aguayo et al. 1967, 1968: 59 pups, Krylov 1968) are difficult to compare now as they were first noted in January and February.

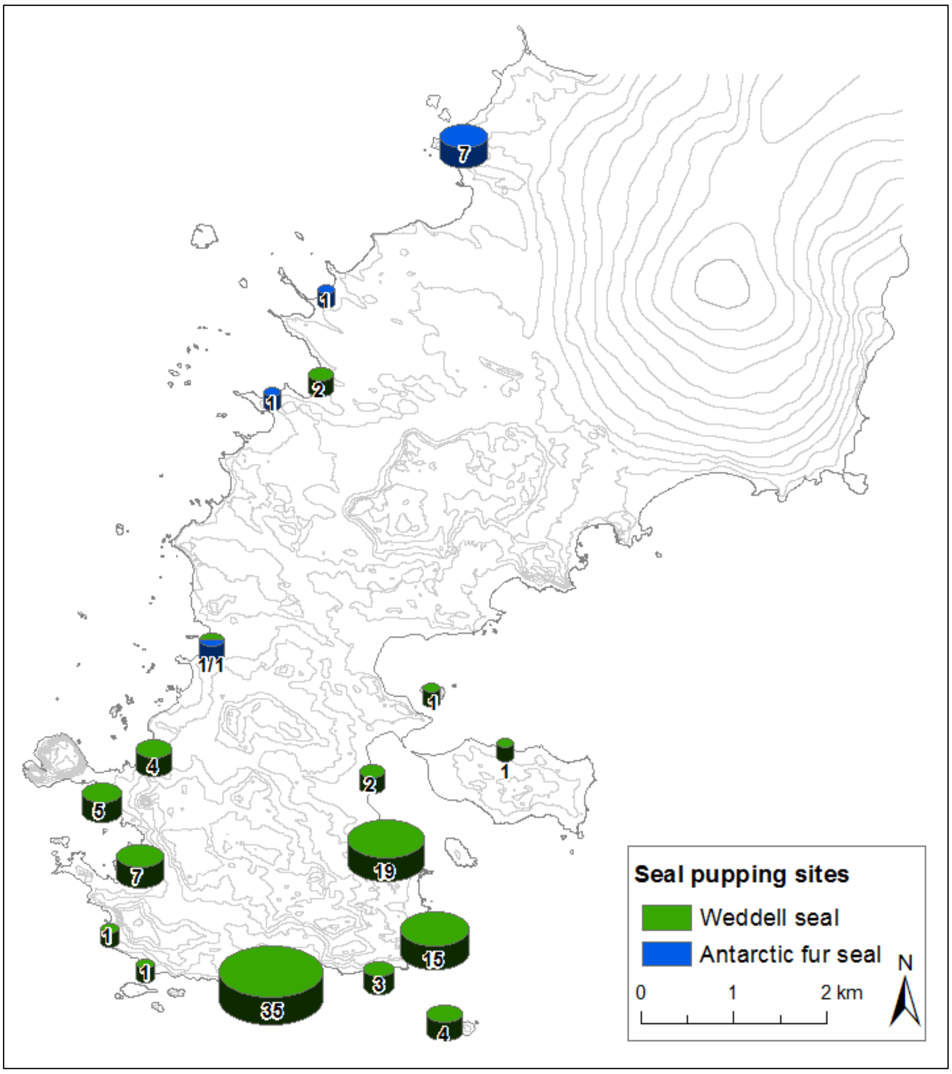
Figure 36: Numbers of Weddell seal (*Leptonychotes weddelli*) pups; if there are no values, no data were available for the particular season.



It is well-known that the ice situation affects the diet and thus the bodyweight of pregnant females and the reproduction rate in general of Weddell seals (e.g. Hadley et al. 2007; Proffitt et al. 2007; Siniff et al. 2008). The annual reproduction rates vary considerable according to El Niño events (ENSO) (Testa et al. 1991; Ainley et al. 2015). In Prydz Bay, eastern Antarctica, the frequency of seal births has not been associated with ENSO since the 1990s – unlike previous decades (Lake et al. 2008).

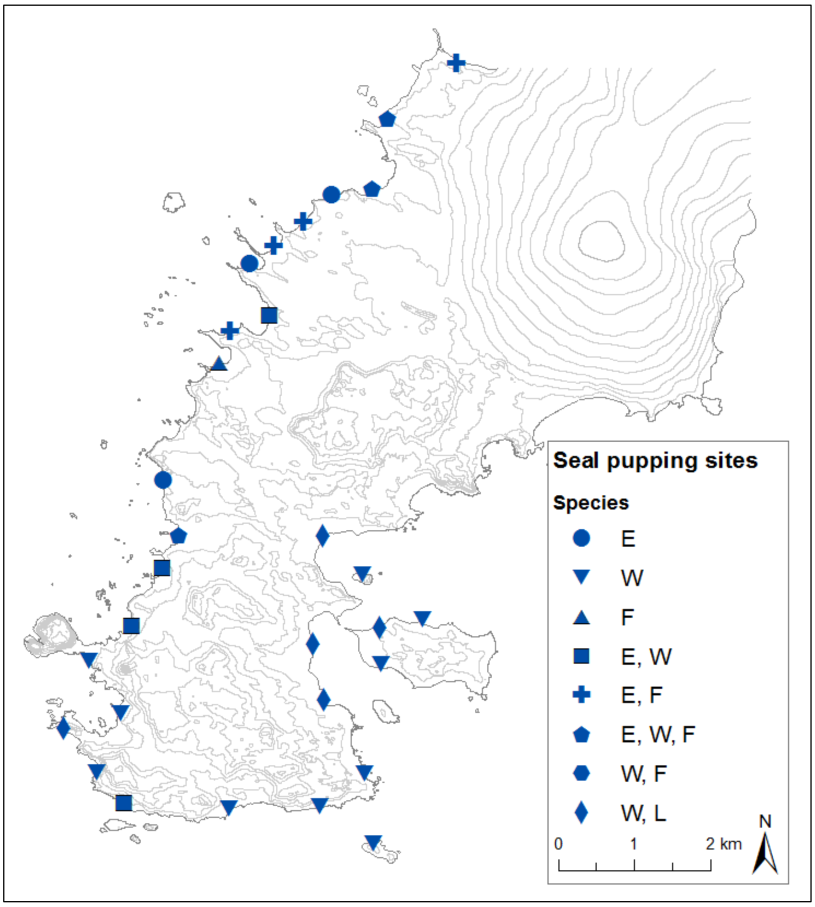
In contrast to the two previously described species, births of Antarctic fur seals generally take place in November and December, so they can be recorded systematically during the seal counts. In the 2012/13 to 2014/15 seasons, new-born fur seals were registered on three sections of the west coast of the Fildes Peninsula (Figure 37). Two of these locations were until recently not known as pupping sites for fur seals (Peter et al. 2008; Peter et al. 2013). The low number of fur seal births hardly allows a comparison with the number of registered fur seal pups from earlier seasons, and no conclusion can be drawn about a possible connection to ENSO events, as shown e.g. for the Subantarctic Possession Islands (Crozet Archipelago) (Guinet et al. 1994).

Figure 37: **Location of seal pupping sites on the coast of Fildes Peninsula and Ardley Island and numbers of observed pups (represented summarily) in the seasons 2012/13 to 2014/15**



The first proven sightings of new-born fur seal pups in the Fildes Region were recorded in December 1987 (Mönke et al. 1988). Thereafter, fur seal births were seen again in the austral summer of 2002/03 (Peter et al. 2008). Since then, up to 12 births of fur seals are being recorded each austral summer (Peter et al. 2008; Peter et al. 2013; Figure 37). This means that the Fildes Region has probably become established as a reproduction site for fur seals, which can be traced back to the clear population growth in fur seals in the past decades. It is not known whether the Fildes Region was an important pupping place before the start of the intensive seal hunt in the 1820s. Currently, the area is hardly relevant in comparison to larger fur seal colonies, e.g. on South Georgia or the South Orkney Islands (e.g. Boyd 1993; Carlini et al. 2006a; Waluda et al. 2010). Larger fur seal colonies in the South Shetland Islands region exist on e.g. Cape Shirreff, Livingston Island, and the San Telmo Islets (Hucke-Gaete et al. 2004). The closest large pupping site is located on Stigant Point, which is 18 km away from the Fildes Peninsula on the northwest coast of King George Island (e.g. Jablonski et al. 1987; Bengtson et al. 1988; Peter et al. 1988). The rapid rise in the number of pups born there after the recolonisation of this fur seal colony at the end of the 1960s (Aguayo 1968; Llano 1971; Peter et al. 1988; Peter et al. 1989) emphasises the quick recovery of the fur seal population of the South Shetland Islands (Hucke-Gaete et al. 2004). It is possible that the high fur seal density in some pupping sites is driving away individuals, which migrate to other areas, e.g. in the Fildes Region, and help to establish new pupping sites.

Figure 38: Location of seal pupping sites on the Fildes Peninsula and Ardley Island (E – southern elephant seals, W – Weddell seal, F – Antarctic fur seals, L – Leopard seal); data from 2002/03 – 2006/07 and 2008/09 – 2014/15 are included (modified after Braun et al. 2012, bay sections according to Peter et al. 2008, p. 45)



The sites of new-born seals noted in the 2012/13 to 2014/15 seasons largely match the already described pupping sites (Figure 38; Peter et al. 2008; Braun et al. 2012; Peter et al. 2013). Several coves and two smaller islands (Diomedea and Two Summit Island) were first registered as pupping sites of Weddell seals or fur seals in 2002/03 (Peter et al. 2008; Peter et al. 2013). This confirmes the regional expansion of reproduction sites of fur seals in the Fildes Region

(Peter et al. 2013). Figure 38 shows all the seal pupping sites recorded in the Fildes Region since the 2002/03 season. New-born fur seals were almost exclusively noted on the beaches of the west coast of the Fildes Peninsula. The sole exception is the recent observation of one fur seal pup on Ardley Island (Peter et al. 2013). Elephant seal births have so far been documented exclusively on the west coast of the Fildes Peninsula (Figure 38). In contrast, Weddell seals give birth on the south and east coasts of the Fildes Peninsula and on Ardley Island (Figure 38). The spatial separation of the pupping sites of both species was also found for Admiralty Bay (Salwicka et al. 2002).

2.12 Current threats for birds and seals in the Fildes Region

Birds and seals in the Fildes Region are subject to a multitude of risks. The changing environmental conditions due to climate change can affect populations in species-specific ways. The expected consequences could be positive, especially for species like gentoo penguins, Antarctic fur seals, and southern elephant seals, which are adapted to Subantarctic environmental conditions. These species profit from the glaciers' retreat, as they colonise the newly revealed resting and breeding places or expand or shift their range (e.g. Costa et al. 2010; McClintock et al. 2010). In contrast, the expected serious changes in the food web of the Antarctic Ocean and the surrounding oceans could have unforeseeable consequences, which could offset these positive effects on the population level (Forcada et al. 2006; Trathan et al. 2007; Forcada et al. 2009). Direct negative consequences are expected for ice-dependent Antarctic species (Learmonth et al. 2006; Siniff et al. 2008; Garrott et al. 2012). For example, the habitat loss through reduction of the sea ice cover due to continued increases in temperature has been considered by several authors to be the greatest potential risk to the population of Weddell seals in the WAP region (e.g. Learmonth et al. 2006).

A further risk for Antarctic seabirds and seal populations involves interactions with fishing activities (e.g. competition for food, injuries) (Weimerskirch et al. 2000; Costa et al. 2006), even though seabirds and seals in the Antarctic are affected to a clearly lesser extent than those in the Subantarctic regions. The long-line fishing techniques used there are responsible for the increased mortality of numerous albatross and petrel species, contributing greatly to their further decline (e.g. Inchausti et al. 2001, 2002; Nel et al. 2002). Injuries and the increased mortality of seals and seabirds in connection with fishing equipment have been repeatedly documented in the Subantarctic and Antarctic regions (e.g. Croxall et al. 1990; Woehler 1990; Arnould et al. 1995; Hucke-Gaete et al. 1997; Hofmeyr et al. 2002; Waluda et al. 2013).

Interactions of birds and seals with maritime traffic and fishing practices (e.g. seals injured by ship propellers or fishing lines, finding long-line hooks in a giant petrel nest) have been observed to a limited extent in the Fildes Region as well (Peter et al. 2008; Peter et al. 2013). The Fildes Region also houses additional risks at the local level for the animals living there. Due to the high concentration of human activities (logistics, research, tourism), there is a given potential risk of threat. This includes disturbance by ship, boat and plane traffic and by visitors in the breeding/reproduction and resting areas (Peter et al. 2008; Peter et al. 2013). The degradation of (breeding-)habitats by e.g. building activities plays a role (Peter et al. 2008; Peter et al. 2013). Because of the intensive ship and plane traffic and the large number of people living and working here or passing through, the risk of introducing non-native animals, plants and microorganisms is particularly high in the Fildes Region (Houghton et al. 2016; Huiskes et al. 2014). Feeding skuas increases the danger of transmitting diseases (Peter et al. 2008; Peter et al. 2013). Local environmental pollution poses another risk for the local fauna. Open waste storage can lead to injuries to seals and birds. In addition, the breeding habitats of birds can be affected, e.g. storm petrel breeding hollows can be blocked by windblown plastic garbage

(Peter et al. 2008; Braun et al. 2012). The intensive ship traffic in Maxwell Bay (Braun et al. 2012) and the fuel storage and handling of the six stations on the Fildes Peninsula (Peter et al. 2008) present a risk of a oil contamination of the environment and of an oil spill. The required fuel is mostly pumped on land from ships through floating hoses or a pipe running over the sea floor and stored in tanks inside or outside the station grounds (Peter et al. 2013). The latter practice requires further transport of fuel into the station (Peter et al. 2013). Every handling of fuel increases the risk of oil contamination. Oil spill on land were documented three times in the past 11 years (2005, 2009 and 2014) (Peter et al. 2008; Peter et al. 2013; unpubl. data). Furthermore, there were indications of two incidents involving the underwater fuel pipeline to a station in 2007 and 2008 (Peter et al. 2013). The leaking diesel fuel always reached the Ardley Cove off the central part of the Fildes Peninsula. This area is regularly frequented by penguins of the nearby colony and occasionally by seals (Peter et al. 2013). The physiological effects of oil spills are often sublethal, but can affect the health and survival of animals in the medium or long term (e.g. Samiullah 1985; Culik et al. 1991; Eppley 1992; Briggs et al. 1996; Briggs et al. 1997).

2.13 Conclusions

The Fildes Region is characterised by a comparatively high biodiversity and is a reproduction area for 13 bird and 5 seal species. It is also used as a resting place for other seabird and seal species. Concurrently, this area is marked exceptionally severely by a multitude of human activities.

Based on a comprehensive monitoring programme of seabirds and seals in the Fildes Region initiated in the 1980s, there now exists a valuable long-term database, enabling conclusions to be drawn about the development of local populations. The different seabird species partly show clearly deviating trends in breeding pairs over the past three decades and more. First, the breeding pair numbers of penguin species on Ardley Island mirrors the regional trend in the WAP region. Second, developments of other bird and seals species observed in the Fildes Region contradict results from other Antarctic regions or are not comparable due to missing data.

This suggests that the species show a different response to biotic environmental factors (e.g. predation, competition) and/or abiotic environmental factors (climate, ENSO, local weather events), which influence the population dynamics. For example, the height of snow predominating at the beginning of the breeding season significantly determines the start of breeding for bird species nesting on the ground or in caves. The breeding success is determined by e.g. the availability of food, local weather events (e.g. snow storms) or the risk of predation.

The past decade in the Fildes Region has been characterised for several bird species by a striking accumulation of ‘poor’ breeding seasons with low numbers of breeding pairs and low breeding success. Possible causes are suspected to include an interaction of unfavourable weather conditions and availability of food, but also partly direct human influences (e.g. disturbing the breeding sites).

Anthropogenic disturbances, prevalent in the Fildes Region in a multitude of forms (e.g. Peter et al. 2008), clearly affect some breeding bird species more than others. Severe declines in the number of breeding pairs of the southern giant petrel and the steadily decreasing breeding success can be attributed to anthropogenic disturbance. In addition, the continued feeding of skuas with remains of human food, including poultry products, engenders a considerable risk of introducing diseases.

There are relatively few long-term databases about breeding bird populations from the Antarctic (e.g. Karnovsky et al. 1995; Trivelpiece et al. 1995; Woehler et al. 1997; Micol et al. 2001; Woehler et al. 2001; Croxall et al. 2002; Korczak-Abshire et al. 2013; Juáres et al. 2015). They are nevertheless very important for understanding the relationships within the Antarctic ecosystem. That is why the continued conduct of long-term monitoring programmes is regularly and repeatedly requested on international political and scientific levels (e.g. ATCM and SCAR).

Especially in areas like the Fildes Region, where there is a proven high risk potential for the protected natural resources of the region (e.g. Peter et al. 2008), long-term monitoring of various indicators, e.g. the local breeding bird community, is indispensable.

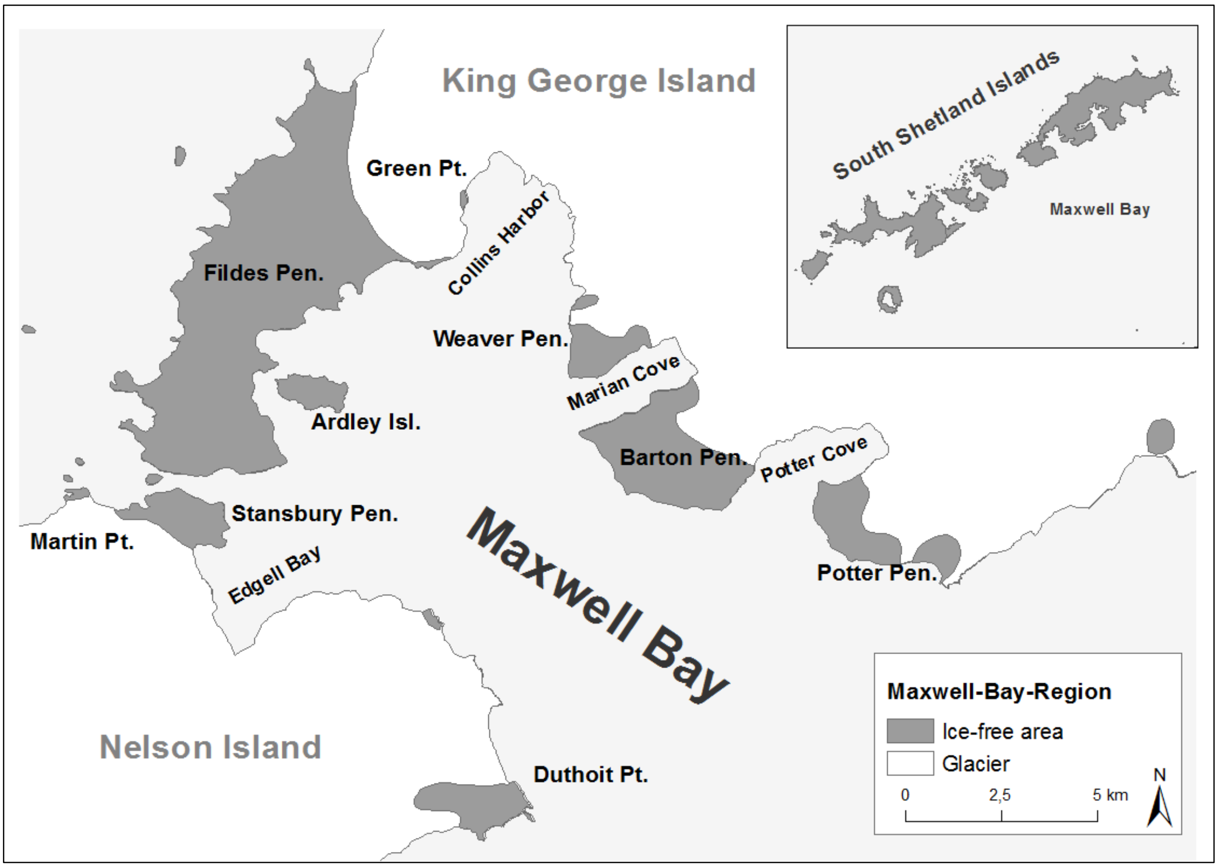
3 Monitoring of breeding birds in the ice-free areas of Maxwell Bay

3.1 Introduction

Due to the major importance of ice-free areas as breeding grounds for birds and seals in the Antarctic, monitoring of breeding birds was extended to the entire area of Maxwell Bay in the south-western King George Island in the seasons 2012/13 to 2014/15. All the areas in which breeding birds of native species occur will be presented separately below (Figure 39). However, both storm petrel species, Wilson's storm petrel and the black-bellied storm petrel, had to be omitted, because it was not possible to carry out a population count of these birds for logistical and safety reasons, as they are nocturnal birds that nest in burrows and are thus difficult to observe. Nevertheless, based on the available habitat, we evaluated the aeras as a potential breeding site for storm petrels.

In view of the quality of the monitoring data, which is to a great extent based on literature sources to which up-to-date counts have been added, one must take account of the fact that the counts carried out over several decades were in many cases not done according to current standards, which require counts that are conducted at a specific point in the reproduction cycle (e.g. CCAMLR 2014). However, as the individual areas of Maxwell Bay are in some cases hard to reach, this is logistically virtually impossible. Even so, the count data provides a valuable picture of the local populations of diverse seabird species, especially as the data represents counts over a comparably long period by Antarctic standards.

Figure 39: Overview of the ice-free areas of the Maxwell Bay, King George Island; South Shetland Islands displayed without Clarence, Elephant and Gibbs Islands.

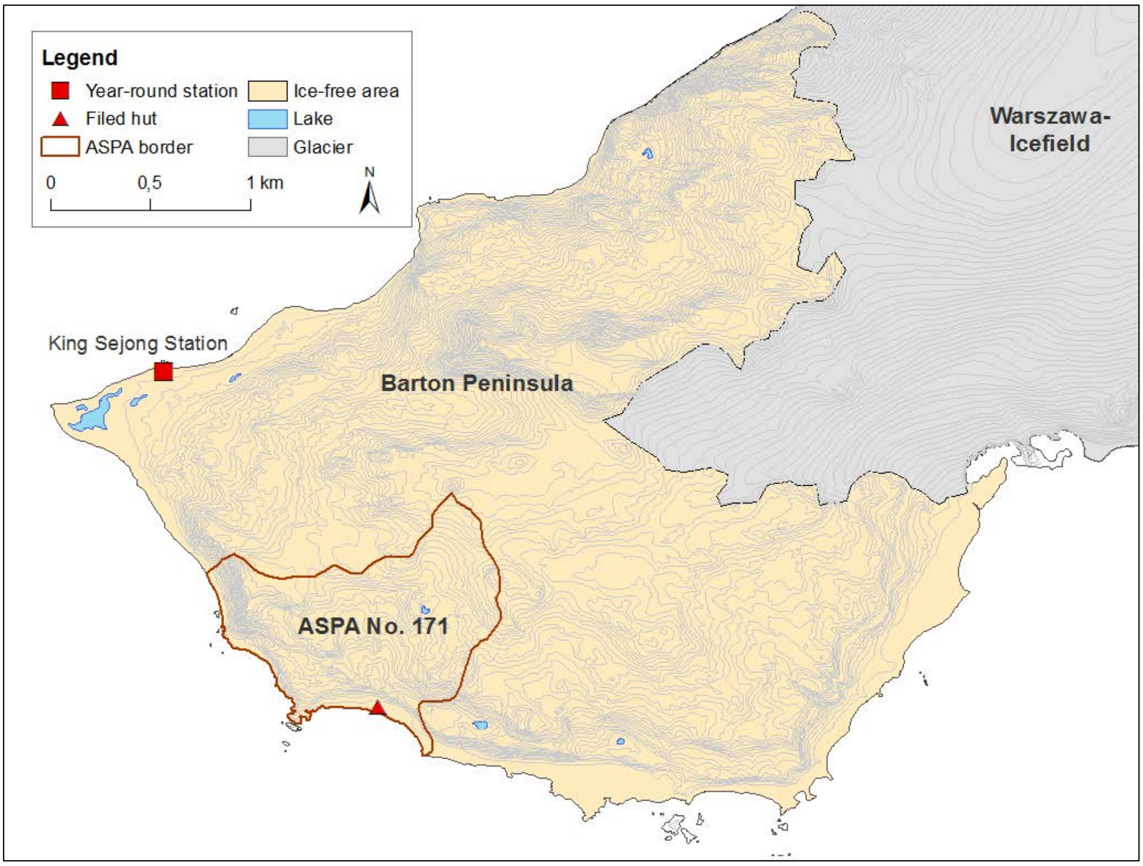


3.2 Barton Peninsula

This peninsula is part of King George Islands and is situated on the northern shore of Maxwell Bay (Figure 39 & Figure 40), bordered by Marian Cove to the west and Potter Cove to the east. With an ice-free area of approx. 9.1 km^2, Barton is the second-largest oasis in the Maxwell Bay area. The land rises steeply from the sea on all sides to a mountainous plateau, with Noël Hill/Baekdu Hill rising to 295 m above sea level. With the exception of a lake in the extreme west of the peninsula, there are no large bodies of water. The vegetation of Barton is characterised by rich moss growth near the coast, while the rest of the area is dominated by macrolichen associations. Comprehensive mapping provided data regarding vegetation cover at the western point of the peninsula (Kim et al. 2007).

In 1988 the South Korean overwintering station King Sejong was opened in the south-west of the peninsula. This makes it the newest research station in the Maxwell Bay area. The number of people living and working there ranges from approx. 18 in winter to 70 in summer.

Figure 40: Topography of Barton Peninsula (GIS data source: National Geographic Information Institute NGII, South Korea; ASPA border taken from current management plan)



The ASPA No. 171 Narębski Point is located in the south-east of the peninsula (source: http://www.ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=157&lang=e, accessed: 30.05.2016; ATS 2009a, 2014), which features a characteristic topography as well as very varied flora and fauna, including a substantial penguin colony. In recent years the breeding birds of this ASPA have been regularly mapped by South Korean scientists. As a result there is regular count data for the period from 2006/07, at least for the penguin population. To this can be added counts by other scientists from the period before the construction of the South Korean station. For as long as this colony has been known about, chinstrap and gentoo penguins have been breeding there, with chinstrap penguins colonising the rugged area on the cape and gentoo penguins the beach area as well as the tops of hills on a small plateau above the coast (Figure 41 & Figure 42). In common with other locations in the South Shetland Islands area, the gentoo penguin population is rising steadily (R^2 =0.93, $p < 0.001$, between 1980/81 and 2014/15 growth of > 500 %). In consequence, this colony is now the second-largest gentoo penguin colony in the Maxwell Bay area after Ardley Island. Apart from a drop in population towards the end of the 1980s, the chinstrap penguin colony shows itself to be stable or growing (R^2 = 0.002, p = 0.84). To what extent the extraordinarily high count of 1981 (Jablonski 1984) is realistic, remains unclear (Table 5). The number of 7,306 BP from 1987 given in a current Management Report of ASPA No. 171 (Republic of Korea 2014) is based on an evidently erroneous citation of Trivelpiece et al. (1987). The same error occurred with the figure of 566 gentoo penguin BP given there. Instead, the figures of Mönke et al. (1988, 1,000 BP) and Shuford et al. (1988a, 3,500 adult ind.) of the same year can be considered to be realistic. There are significantly more gaps in the data for other breeding birds, which were obviously not regularly counted and then often only in the ASPA area. As a result there are only few species for which a definite trend can be indicated. Among these is the southern giant petrel, a species which suffered a considerable drop in population here and in the Fildes Region in the 1980s, and which continues to show a significantly downward trend (R^2 = 0.53, p = 0.03). In addition it shows the very limited number of skua breeding pairs in the last five years, in particular south polar skuas, which were also observed in the Fildes Region. However, a linear trend over time could not be established (R2 = 0.09, p = 0.43, Table 7). Further breeding bird species that have been verified are: cape petrel, Wilson's storm petrel, black-bellied storm petrel, snowy sheathbill, kelp gull and Antarctic tern. A detailed presentation of all available data for the breeding bird population of Barton Peninsula is given in Figure 42 and Table 5 to Table 7.

Figure 41: Penguin colony at Narębski Point, Barton Peninsula; in the foreground are breeding groups of gentoo penguins on a plateau, in the background on the rocks of the cape those of chinstrap penguins (photo: J. Krietsch, 03.01.2014).

Figure 42: Spatial distribution of the penguin colony on Barton Peninsula in the season 2013/14 (GIS data source: J.-W. Jung)

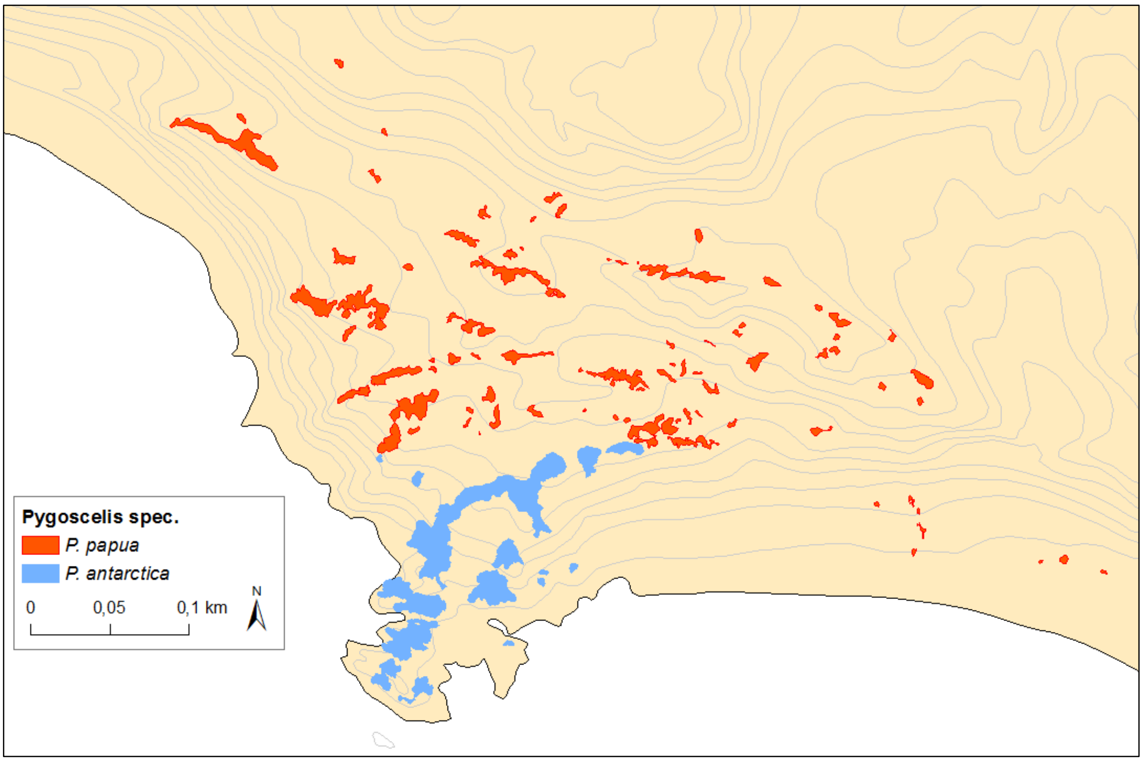


Table 5: Overview of the breeding pair numbers of gentoo penguins (*Pygoscelis papua*), chinstrap penguins (*P. antarctica*), southern giant petrels (*Macronectes giganteus*), Wilson's storm petrels (*Oceanites oceanicus*) and black-bellied storm petrels (*Fregetta tropica*) on Barton Peninsula based on available census data. If not the entire peninsula was covered, a minimum (min.) value is indicated.

Season	*P. papua*		*P. antarctica*		*M. giganteus*		*O. oceanicus*		*F. tropica*	
	BP	Source	BP	Source	BP	Source	BP	Source	BP	Source
1965/66			2.500	White in: Croxall et al. 1979						
1966/67					159	Araya et al. 1971				
1980/81	464	Jablonski 1984	6.298	Jablonski 1984						
1983/84					120-140	Lorenz 1984				
1984/85	ca. 500	Peter et al. 1988	2.500	Peter et al. 1988	140	Peter et al. 1988	ca. 25	Peter et al. 1988	0	Peter et al. 1988
1985/86	600	Rauschert et al. 1987	2.500-3.000	Rauschert et al. 1987						

Season	*P. papua*		*P. antarctica*		*M. giganteus*		*O. oceanicus*		*F. tropica*	
	BP	Source	BP	Source	BP	Source	BP	Source	BP	Source
1986/87	400-450	Mönke et al. 1988	1.000 / 1.750	Mönke et al. 1988 / Shuford et al. 1988a	min. 20	Mönke et al. 1988				
1988/89					26	Lange et al. 1989				
1989/90	682	Republic of Korea 2014	1.161	Republic of Korea 2014						
1992/93	500	Republic of Korea 2014	2.000	Republic of Korea 2014						
1994/95	1.001	Republic of Korea 2014	2.000	Republic of Korea 2014						
2000/01	1.333	Republic of Korea 2014	2.924	Republic of Korea 2014						
2001/02	1.441	Republic of Korea 2014	3.117	Republic of Korea 2014						
2006/07	1.719	Republic of Korea 2008	2.961	Republic of Korea 2008	min. 9	Republic of Korea 2008	min. 19	Republic of Korea 2008		
2007/08	1.684	Republic of Korea 2014	2.747	Republic of Korea 2014						
2008/09	1.573	Republic of Korea 2014	2.632	Republic of Korea 2014						
2009/10	2.289	Republic of Korea 2014	2.572	Republic of Korea 2014						
2010/11	2.351	Republic of Korea 2014	2.612	Republic of Korea 2014	23	Kim et al. 2011b	min. 50	Republic of Korea 2014	min. 10	Republic of Korea 2013
2011/12	2.212	Republic of Korea 2014	3.161	Republic of Korea 2014	min. 11	Republic of Korea 2014	min. 0	Republic of Korea 2014		
2012/13	2.366	Republic of Korea 2014	3.304	Republic of Korea 2014	62	J.-H., pers. comm.	min. 5	Republic of Korea 2014		
2013/14	2.378	Republic of Korea 2014	3.157	Republic of Korea 2014	min. 5	Republic of Korea 2014	min. 10	Republic of Korea 2014		

Season	*P. papua*		*P. antarctica*		*M. giganteus*		*O. oceanicus*		*F. tropica*	
	BP	Source	BP	Source	BP	Source	BP	Source	BP	Source
2014/15	2.176	J.-W. Jung, pers. comm.	3.041	J.-W. Jung, pers. comm.	15	J.-W. Jung, pers. comm				

Table 6: Overview of the breeding pair numbers of cape petrels (*Daption capense*), snowy sheathbills (*Chionis alba*), kelp gulls (*Larus dominicanus*) and Antarctic terns (*Sterna vittata*) on Barton Peninsula based on available census data. If not the entire peninsula was covered, a minimum (min.) value is indicated.

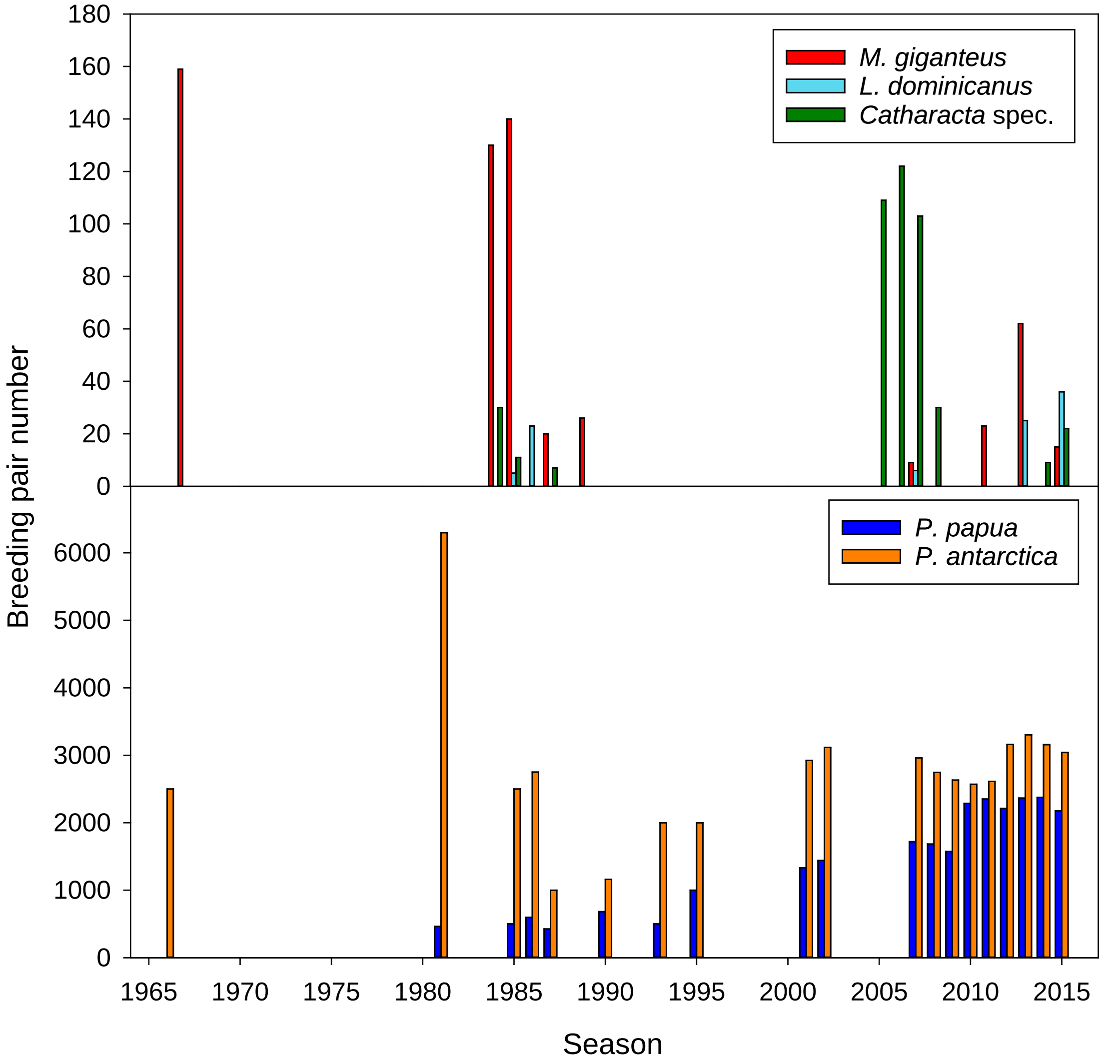
Season	*D. capense*		*C. alba*		*L. dominicanus*		*S. vittata*	
	BP	Source	BP	Source	BP	Source	BP	Source
1983/84			min. 1	Lorenz 1984				
1984/85			1	Peter et al. 1988	5	Peter et al. 1988	20	Peter et al. 1988
1985/86					23	Rauschert et al. 1987		
1986/87			0	Mönke et al. 1988				
2006/07			2	Republic of Korea 2008	min. 6	Republic of Korea 2008	min. 41	Republic of Korea 2008
2010/11			1	Republic of Korea 2014	min. 5	Republic of Korea 2014	min. 38	Republic of Korea 2014
2011/12			1	Republic of Korea 2014	min. 5	Republic of Korea 2014	min. 21	Republic of Korea 2014
2012/13	0	J.-H. Kim, pers. comm.	1	J.-H. Kim, pers. comm.	25	J.-H. Kim, pers. comm.	min. 15	Republic of Korea 2014
2013/14			2	Republic of Korea 2014	min. 0	Republic of Korea 2014	min. 0	Republic of Korea 2014
2014/15	2	J.-W. Jung, pers. comm.	3	J.-W. Jung, pers. comm.	36	J.-W. Jung, pers. comm.	13	J.-W. Jung, pers. comm.

Table 7: Overview of the breeding pair numbers of brown skuas (*Catharacta antarctica lonnbergi*), south polar skuas (*C. maccormicki*), hybrid & mixed pairs (*Catharacta* mixed & hybrid pairs) and undefined skua pairs (*Catharacta* spec.) on Barton Peninsula based on available census data. If not the entire peninsula was covered, a minimum (min.) value is indicated.

Season	*C. a. lonnbergi*		*C. maccormicki*		*Catharacta* mixed & hybrid pairs		*Catharacta* spec.	
	BP	Source	BP	Source	BP	Source	BP	Source
1983/84							30	Lorenz 1984

Season	*C. a. lonnbergi*		*C. maccormicki*		*Catharacta* mixed & hybrid pairs		*Catharacta* spec.	
	BP	Source	BP	Source	BP	Source	BP	Source
1984/85	10	Peter et al. 1988	1	Peter et al. 1988	0	Peter et al. 1988	0	Peter et al. 1988
1986/87							6-8	Mönke et al. 1988
2004/05	11	Kim et al. 2005	86	Kim et al. 2005	12	Kim et al. 2005	0	Kim et al. 2005
2005/06	11	Kim et al. 2009	100	Kim et al. 2009	11	Kim et al. 2009	0	Kim et al. 2009
2006/07	12	Kim et al. 2009	82	Kim et al. 2009	9	Kim et al. 2009	0	Kim et al. 2009
2007/08	4	Kim et al. 2009	25	Kim et al. 2009	1	Kim et al. 2009	0	Kim et al. 2009
2008/09			32	Kim et al. 2011a				
2009/10			98	Kim et al. 2011a				
2010/11	min. 10	Republic of Korea 2011	min. 27	Republic of Korea 2011				
2011/12	min. 5	Republic of Korea 2011	min. 22	Republic of Korea 2011				
2012/13	4	J.-H. Kim, pers. comm.	1	J.-H. Kim, pers. comm.	0	J.-H. Kim, pers. comm.	0	J.-H. Kim, pers. comm.
2013/14	7	J.-W. Jung, pers. comm.	2	J.-W. Jung, pers. comm.	0	J.-W. Jung, pers. comm.	0	J.-W. Jung, pers. comm.
2014/15	10	J.-W. Jung, pers. comm.	11	J.-W. Jung, pers. comm.	1	J.-W. Jung, pers. comm.	0	J.-W. Jung, pers. comm.

Figure 43: Changes in breeding pair numbers of selected species on Barton Peninsula; data for gentoo penguins (*Pygoscelis papua*), chinstrap penguins (*P. antarctica*), southern giant petrels (*Macronectes giganteus*), kelp gulls (*Larus dominicanus*) and for all skua species summarised (*Catharacta* spec.) according to Table 5 – Table 7 are presented. If there are no values, no data were available for the particular season or not the entire area was covered.



3.3 Weaver Peninsula

The ice-free Weaver Peninsula is part of King George Island and lies at the northern edge of Maxwell Bay (Figure 39 & Figure 44). With an ice-free area of approx. 1.8 km² it is the smallest of the four peninsulas in the area of Maxwell Bay under research and is dominated by a nearby Nunatak, Potrzebowski Peak. The terrain of the peninsula rises steeply from the coast on all sides to a central plateau (Figure 45), dominated by a mountain on the western coast (Buddington Peak, 235 m above sea level). In addition to several temporary water bodies, there are also two lakes on the peninsula that contain water all year round (Figure 44). The appearance of Weaver Peninsula is characterised by lichens and vegetation is generally very scarce. There are no extensive patches of moss. Despite the presence of a field hut on Weaver Peninsula the knowledge of the flora and fauna in this area is fairly sketchy. Project members were unable to visit the peninsula themselves during the research period, but in recent years South Korean scientists from King Sejong Station have visited Weaver Peninsula at least once a year to map the avian fauna. Nevertheless, there is hardly any published data available. Documented breeding bird species are currently brown skuas, south polar skuas and kelp gulls, each species only represented by a few pairs (Table 8 & Table 9). The population of 45 southern giant petrel breeding pairs reported by Araya and Arieta (1971) appears to have disappeared in the meantime, as there is no evidence of the birds from the last few years. However, it is possible that there was confusion and that the population seen was actually the colony further west at Nebles Point. In addition, based on the existence of suitable habitats, it is fundamentally conceivable that Antarctic tern and the two native storm petrel species are present on Weaver Peninsula. It is possible that these species have simply been overlooked so far due to the limited intensity of monitoring activity.

Figure 44: Topography of Weaver Peninsula (GIS data source: National Geographic Information Institute (NGII), South Korea)

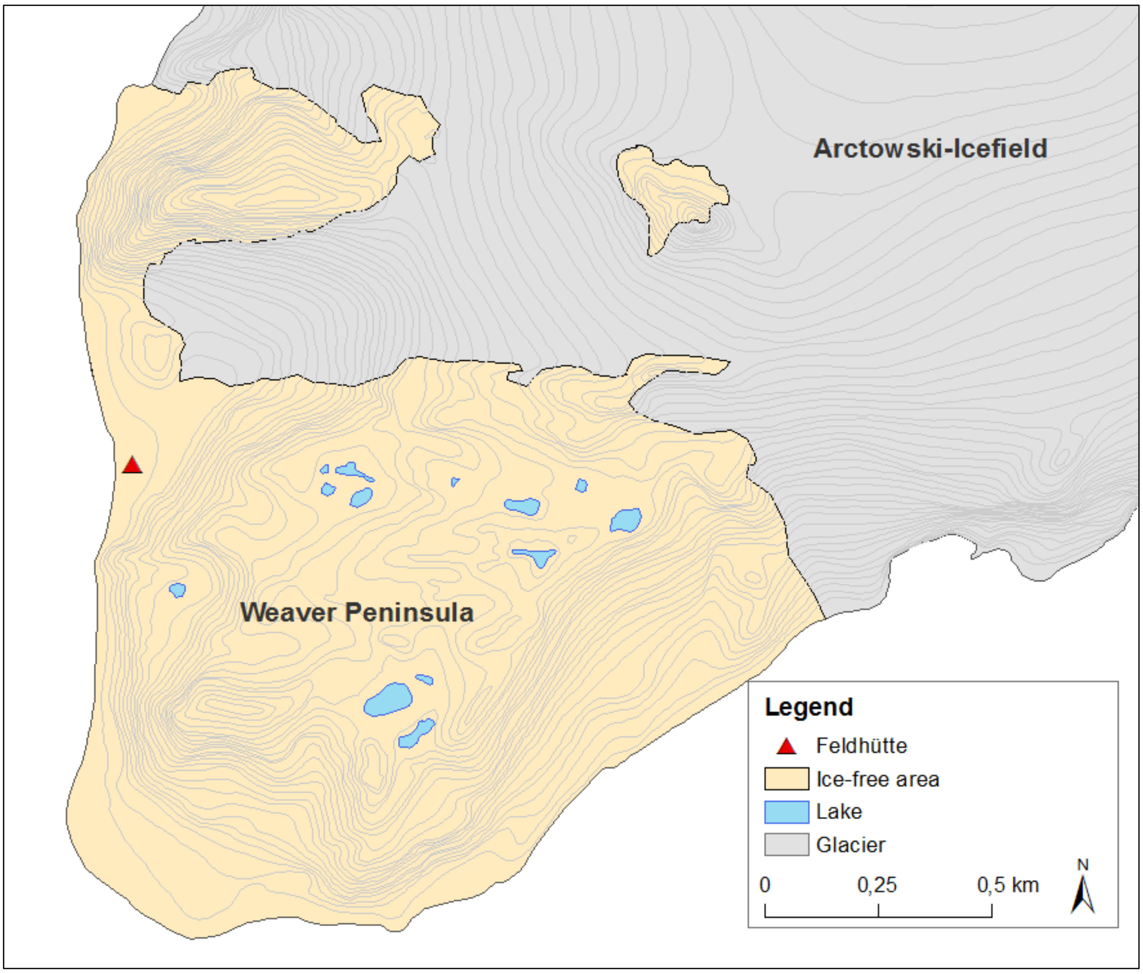


Figure 45: Weaver Peninsula; in the background Barton Peninsula with King Sejong station (photo: H.-U. Peter)

Table 8: Overview of breeding pair numbers of southern giant petrels (*Macronectes giganteus*), kelp gull (*Larus dominicanus*) and Antarctic terns (*Sterna vittata*)

Season	*M. giganteus*		*L. dominicanus*		*S. vittata*	
	BP	Source	BP	Source	BP	Source
1966/67	45	Araya et al. 1971				
1984/85					20	Peter et al. 1988
2012/13	0	J.H. Kim, pers. comm.	5	J.H. Kim, pers. comm.		
2013/14	0	J.H. Kim, pers. comm.	8	J.H. Kim, pers. comm.		

Table 9: Overview of breeding pair numbers of brown skuas (*Catharacta antarctica lonnbergi*), south polar skuas (*C. maccormicki*) and whose mixed & hybrid pairs (*Catharacta* mixed & hybrid pairs)

Season	*C. antarctica lonnbergi*		*C. maccormicki*		*Catharacta* mixed & hybrid pairs	
	BP	Source	BP	Source	BP	Source
2004/05	2	Kim et al. 2005	15	Kim et al. 2005	1	Kim et al. 2005
2012/13	0	J.H. Kim, pers. comm.	0	J.H. Kim, pers. comm.	0	J.H. Kim, pers. comm.

Season	*C. antarctica lonnbergi*		*C. maccormicki*		*Catharacta* mixed & hybrid pairs	
	BP	Source	BP	Source	BP	Source
2013/14	0	J.H. Kim, pers. comm.	0	J.H. Kim, pers. comm.	0	J.H. Kim, pers. comm.

3.4 Green Point

North-east of Fildes Peninsula, extending into Collins Harbor bay, lies Green Point (Figure 39). This oasis, which is only some 6.5 ha in size, consists mainly of a small rock massif blocking the glacier's advance to the sea, with a small area of beach in front of it. The areas with rocky ground have an extraordinarily rich vegetation of mosses and Antarctic hair grass (*Deschampsia antarctica*), which covers the ground almost completely. However, areas with loose moraine scree are also increasingly being colonised by *D. antarctica*. As a result of glacial retreat (Sec. 4.6), nowadays the oasis can be reached on foot at any time from the Fildes Peninsula, regardless of the tides and without having to cross the glacier. In 2006 the Instituto Antártico Chileno (INACH) erected a field hut there ('Refugio Collins', Figure 46; Peter et al. 2013), which is used regularly by Chilean scientist.

Figure 46: View of Green Point with the field hut 'Refugio Collins' (photo: J. Krietsch, 18.01.2014)

Due to the small size of the oasis and the limited availability of habitats, few bird species breed here: south polar skuas, mixed skua pairs/hybrids and kelp gulls (Figure 47, Table 10). However, kelp gulls had their largest breeding colony of the entire Fildes Region here, which is now declining slightly. Observations during a visit to this area by project members suggest the possibility that Wilson's storm petrel are breeding there. The moraine habitat also appears to be fundamentally suitable for Antarctic tern, although the last time there was evidence of broods of this species was in the 1980s (Table 10). Because scientists have only begun to focus on the oasis in recent years, data only goes back a few years.

Figure 47: Spatial distribution of the breeding birds at Green Point in the seasons 2010/11 to 2014/15

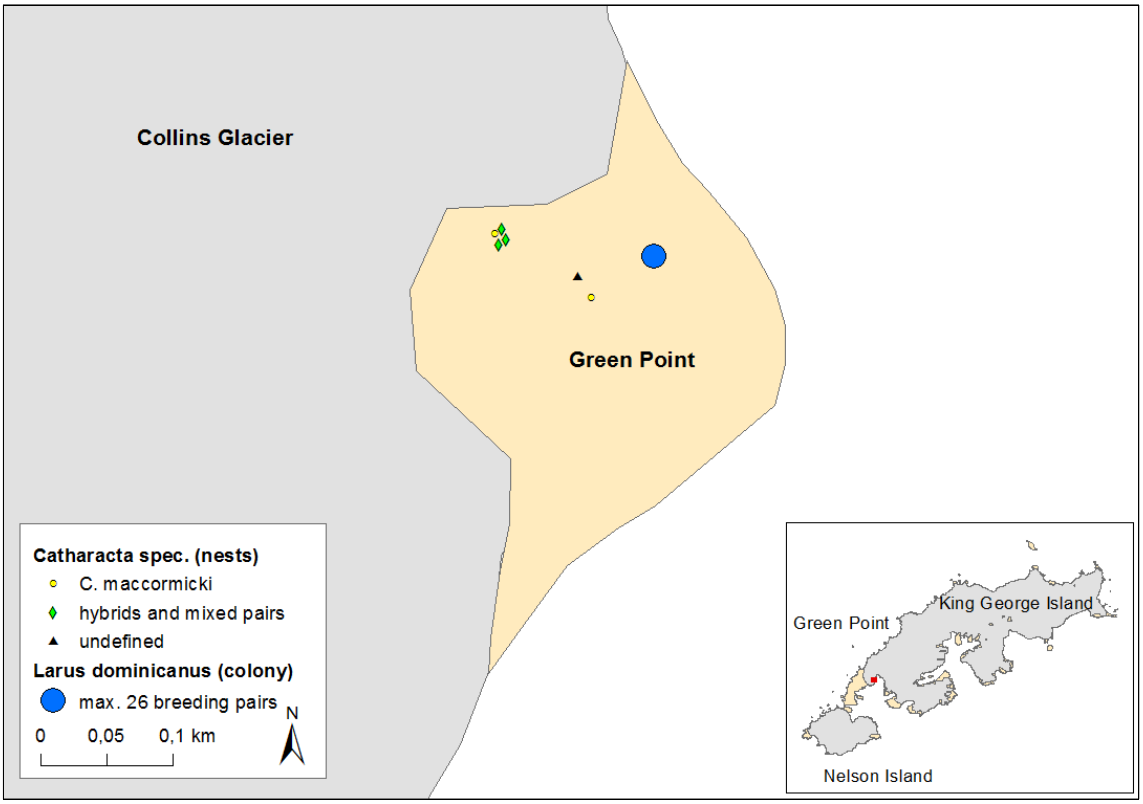


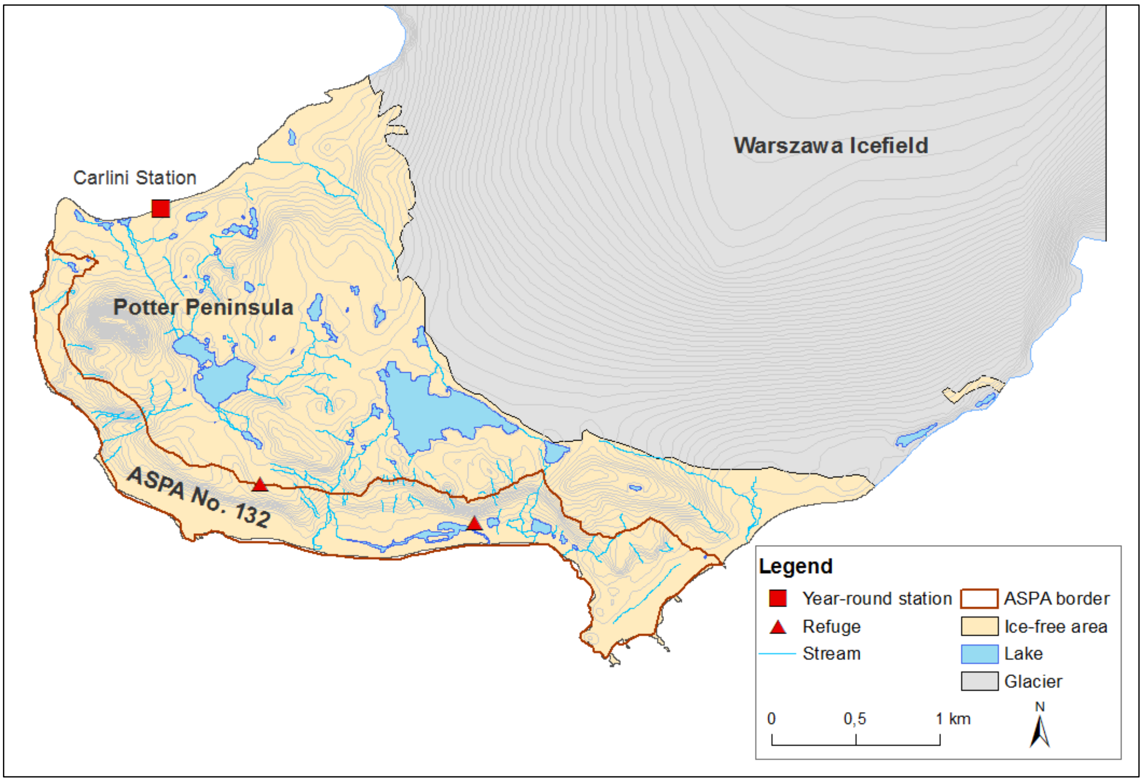
Table 10: Overview of the breeding pair numbers of kelp gulls (*Larus dominicanus*), south polar skuas (*Catharacta maccormicki*), mixed & hybrid skua pairs (*Catharacta* mixed & hybrid pairs) and undefined skua pairs (*Catharacta* spec.) at Green Point based on available census data

	L. dominicanus		*C. maccormicki*		*Catharacta* mixed & hybrid pairs		*Catharacta* spec.		*S. vittata*	
Season	BP	Source	BP	Source	BP	Source	BP	Source	BP	Source
1984/85									15	Peter et al. 1988
2010/11	30	present study	0	present study	1	present study	1	present study		
2011/12			1	present study	0	present study	0	present study		
2012/13	26	present study	1	present study	0	present study	0	present study		
2013/14	14	present study	0	present study	1	present study	0	present study		
2014/15	16	present study	0	present study	1	present study	0	present study		

3.5 Potter Peninsula

At the north-eastern exit from Maxwell is Potter Peninsula (Figure 39 & Figure 48), which with a surface area of approx. 6.5 km^2 is the third-largest ice-free zone in this area. This peninsula is bounded by Potter Cove to the north-west, the Warszawa Ice Field to the north-east and the Bransfield Strait to the south-east.

Figure 48: Topography of Potter (GIS data source: KGIS - The King George Island GIS Project, University Freiburg; ASPA border taken from current management plan)



Potter Peninsula was first inhabited as early as 1953, with an Argentinian navy refuge in the north-west of the peninsula (source: http://www.dna.gob.ar/bases-argentinas). In 1982 the naval base was handed over to the civilian Instituto Antártico Argentino (IAA) and opened as a research station called 'Base Tte. Jubany'. It was renamed 'Base Carlini' in 2012. The number of station members is around 20 in winter and up to 100 in summer (including Dallmann Lab; source: https://www.comnap.aq/Members/SiteAssets/SitePages/Home/Antarctic_Facilities_List_13Feb2014.xls, accessed: 30.05.2016). The Dallmann Laboratory, which has been run jointly by Germany and Argentina since 1994, is a successful example of effective international, multidisciplinary scientific cooperation in the Antarctic.

The glacial landscape of Potter Peninsula is marked by a plateau as well as a flat coastal area. The coastline is very irregular and features a number of bays that extend up to 500 m inland and are enclosed by cliffs or headlands that are 15-50 m high. Particularly characteristic and visible from a long distance in the north-east of the peninsula is the andesitic vent, over 200 m high, of an extinct volcano of tertiary origin, called Three Brothers Hill or Cerro Tres Hermanos (Kraus et al. 2008; Figure 49).

Figure 49: Argentine research station Carlini (formerly named as Jubany station) on Potter Peninsula with Three Brothers Hill in the background (photo: A. Nordt, 25.03.2006)

T

Relatively lush vegetation can be found over wide areas of Potter Peninsula. It is dominated by lichen on rocky ground, while coastal areas in particular are mainly covered in a thick carpet of moss. Moreover, there is a great prevalence of the only two native representatives of higher plant species in the Antarctic, Antarctic hair grass and Antarctic pearlwort (*Colobanthus quitensis*). Because of the great richness and diversity of flora and fauna, as well as the species composition that is representative for Antarctic ecosystems, a large part of the coastal area was designated as Site of Special Scientific Interest (SSSI) No. 13 in 1985 and as ASPA No. 132 Potter Peninsula in 2002 (source: http://www.ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=37&lang=e, accessed: 30.05.2016; ATS 2013a; Figure 48).

To date, Potter Peninsula has been a breeding area for a total of 14 species of breeding birds (Table 11 – Table 14, Figure 50), including southern giant petrel, brown skua, south polar skua, cape petrel, black-bellied storm petrel, Wilson's storm petrel, snowy sheathbill, kelp gull, Antarctic tern and blue-eyed shag (Hahn et al. 1998). However, there are now no longer any blue-eyed shag breeding sites on Potter; only a few cliffs known as Low Rock/Roca Baja, in the open sea approx. 1.5 km south-west of Stranger Point, had a population at least until 2001 (Hahn et al. 1998), although a downward trend could also be observed there (Casaux et al. 2006). It is not known whether this colony still exists. Because of its proximity to Potter Peninsula, the data obtained there as part of this monitoring work is also given (Table 13).

A fairly large penguin colony, currently comprising approx. 3,000 Adélie penguins BPs and approx. 3,800 gentoo penguin BPs, is located at Stranger Point, the south-eastern point of Potter Peninsula (Norway 2013). This colony has shrunk dramatically over recent decades (decrease of approx. 85 %). In the 1970s and early 1980s up to 18,000 Adélie penguin BP still bred here (Müller-Schwarze et al. 1975; Jablonski 1984) and in the 1960s there was a population of more than 1,000 BP of chinstrap penguins (Araya et al. 1971), which declined in the 1980s and has now disappeared completely (Schuster 2010, significant long-term trend, $R^2 = 0.59$, $p = 0.02$). The number of Adélie penguins shrank to something over 3,000 BP (Juáres 2013, significant long-term trend, $R^2 = 0.559$, $p = 0.002$). In contrast, gentoo penguins are increasing here too, although the increase is significantly weaker than elsewhere (+ 50 % since 1980, $R^2 = 0.42$, $p = 0.005$). Notable are the breeding attempts by king penguins in this colony in the 2011/12 and 2012/13 Antarctic summers, which were, however, unsuccessful in each case (Juáres et al. 2014; Table 11).

The scree slopes of Three Brothers Hill are home to a large storm petrel colony, estimated at 1,500 – 2,200 BP of Wilson's storm petrels and 600 – 850 BP of black-bellied storm petrels (Hahn et al. 1998; Table 12). The numbers of breeding pairs of southern giant petrel taken from the literature show no clear trend, in spite of sometimes considerable fluctuations ($R^2 = 0.03$, $p = 0.66$, Table 12, Figure 50). However, other sources indicate a 3.1 % decline in the number of southern giant petrel breeding pairs between 1994 and 2007 (ACAP 2010). The population of breeding skuas has also shown a similarly strong decline over recent years (Table 14, Figure 50), as on the Fildes and Barton Peninsulas (Graña Grilli 2014). In spite of the sharp fluctuations in the skua population on Potter Peninsula, no trend over time can be established ($R^2 = 0.11$, $p = 0.16$).

The coastal areas are important as breeding grounds for elephant seals. In addition, numerous fur seals, and occasionally Weddell seals and crabeater seals, stay on the beaches of Potter peninsula during the Antarctic summer.

Table 11: Overview of the breeding pair numbers of gentoo penguins (*Pygoscelis papua*), Adélie penguin (*P. adeliae*), chinstrap penguin (*P. antarctica*) and king penguin (*Aptenodytes patagonicus*) on Potter Peninsula based on available census data

	P. papua		*P. adeliae*		*P. antarctica*		*A. patagonicus*	
Season	BP	Source	BP	Source	BP	Source	BP	Source
1965/66	2.920	White in: Croxall et al. 1979	6.440	White in: Croxall et al. 1979	2.500	White in: Croxall et al. 1979		
1966/67	ca. 1.500	Araya et al. 1971	ca. 7.500	Araya et al. 1971	ca. 1.100	Araya et al. 1971		
1971/72	ca. 1000	Müller-Schwarze et al. 1975	ca. 18.000	Müller-Schwarze et al. 1975	ca. 200	Müller-Schwarze et al. 1975		
1980/81	2.584	Jablonski 1984	18.412	Jablonski 1984	495	Jablonski 1984		
1984/85	ca. 1.900	Peter et al. 1988	ca. 17.000	Peter et al. 1988	350	Peter et al. 1988		
1985/86	2.500	Rauschert et al. 1987	16.000-17.000	Rauschert et al. 1987	500	Rauschert et al. 1987		
1986/87	1.500-2.000	Shuford et al. 1988a			75-100	Shuford et al. 1988a		
1987/88	900	Nadler et al. 1989	15.491	Aguirre 1995				
1988/89	2.325	Aguirre 1995	14.554	Aguirre 1995	265	Aguirre 1995		
1995/96	2.236	Carlini et al. 2009	9.087	Carlini et al. 2009				

Season	*P. papua*		*P. adeliae*		*P. antarctica*		*A. patagonicus*	
	BP	Source	BP	Source	BP	Source	BP	Source
2000/01			ca. 7.300	Schuster 2010	present	Schuster 2010		
2001/02			ca. 5.500	Schuster 2010	present	Schuster 2010		
2006/07	3.764	Carlini et al. 2009	3.412	Carlini et al. 2009				
2007/08			2.003 (extrapolation)	Juáres 2013				
2008/09	4.321	Juáres 2013	3.910	Juáres 2013				
2009/10			2.938	Juáres 2013	0	Schuster 2010		
2010/11	4.631	Juáres 2013	3.426	Juáres 2013				
2011/12	3.932	Juáres 2013	3.254	Juáres 2013			1	Juáres et al. 2014
2012/13							1	Juáres et al. 2014
2013/14			3.703	Juáres 2013				

Table 12: Overview of breeding pair numbers of southern giant petrels (*Macronectes giganteus*), cape petrels (*Daption capense*), Wilson's storm petrels (*Oceanites oceanicus*) and black-bellied storm petrels (*Fregetta tropica*) on Potter Peninsula based on available census data. If not the entire peninsula was covered, a minimum (min.) value is indicated. (* survey only within the ASPA).

Season	*M. giganteus*		*D. capense*		*O. oceanicus*		*F. tropica*	
	BP	Source	BP	Source	BP	Source	BP	Source
1958/59	30	Patterson et al. 2008						
1966/67	78 / 95	Araya et al. 1971 / Patterson et al. 2008			ca. 530	Araya et al. 1971	0	Araya et al. 1971
1969/70	39	Patterson et al. 2008						
1983/84	ca. 120	Lorenz 1984						
1984/85	ca. 59	Peter et al. 1988	0	Peter et al. 1988	ca. 100	Peter et al. 1988	0	Peter et al. 1988
1985/86			3	Rauschert et al. 1987	82	Rauschert et al. 1987		

Season	*M. giganteus*		*D. capense*		*O. oceanicus*		*F. tropica*	
	BP	Source	BP	Source	BP	Source	BP	Source
1988/89	75	Aguirre 1995	0	Aguirre 1995	100-200	Aguirre 1995	present	Aguirre 1995
1995/96	78	Patterson et al. 2008			1.520-2.280	Hahn et al. 1998	160-213	Hahn et al. 1998
1997/98	46	Hahn et al. 1998						
2006/07	87	ACAP 2010						
2010/11	min. 44	Republic of Korea 2011						

Table 13: Overview of the breeding pair numbers of snowy sheathbills (*Chionis alba*), kelp gull (*Larus dominicanus*), Antarctic tern (*Sterna vittata*) and blue-eyed shags (*Phalacrocorax atriceps*) on Potter Peninsula based on available census data. After 1990 for blue-eyed shags the colony on the Low Rock off the coast was considered. If not the entire peninsula was covered, a minimum (min.) value is indicated.

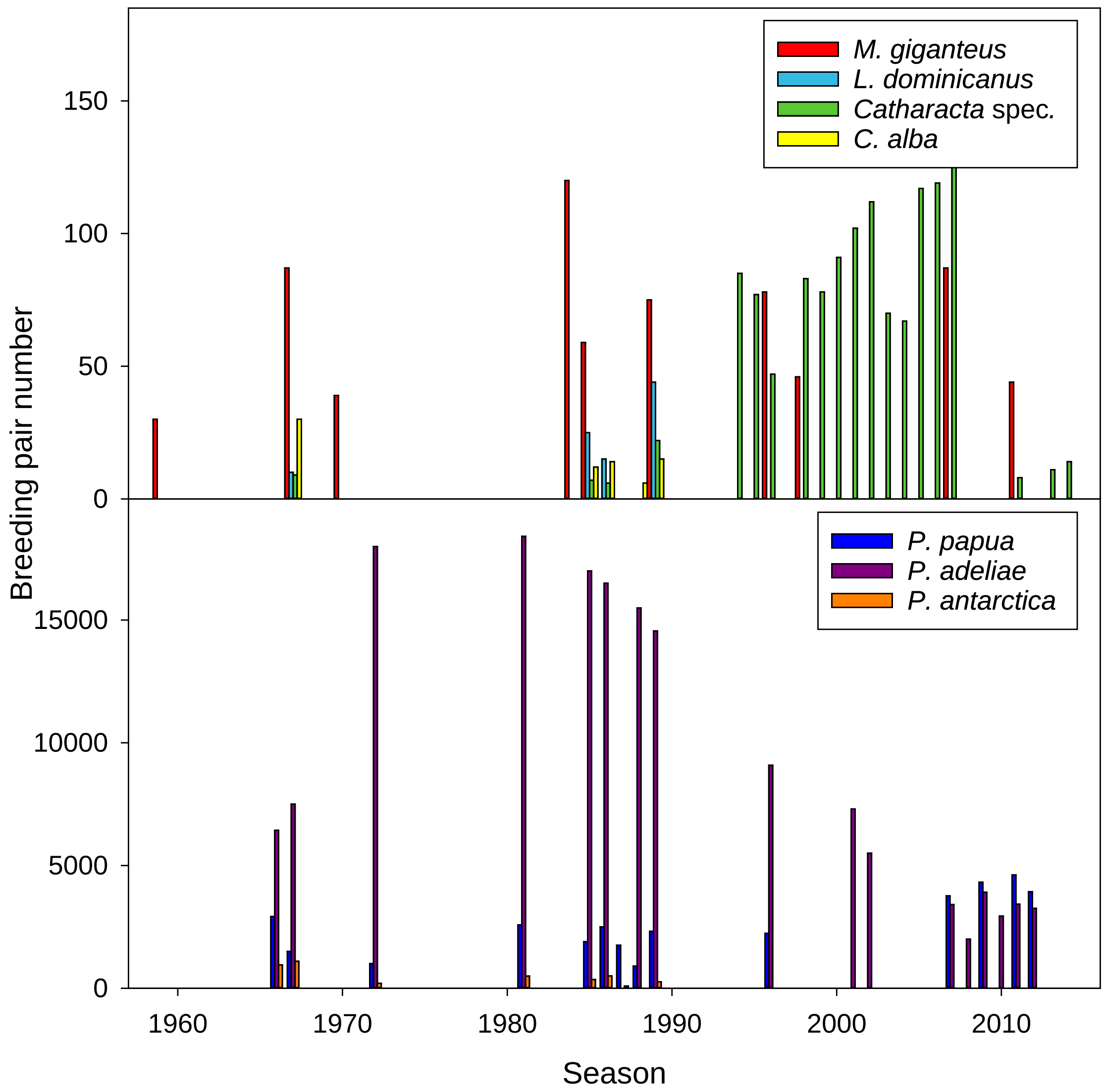
Season	*C. alba*		*L. dominicanus*		*S. vittata*		*P. atriceps*	
	BP	Source	BP	Source	BP	Source	BP	Source
1966/67	ca. 30	Araya et al. 1971	min. 10	Araya et al. 1971				
1984/85	12	Peter et al. 1988	25	Peter et al. 1988	55	Peter et al. 1988	2	Peter et al. 1988
1985/86	14	Rauschert et al. 1987	15	Rauschert et al. 1987				
1987/88	6	Favero 1993			358	Favero 1994		
1988/89	15	Aguirre 1995	44	Aguirre 1995	100-200	Aguirre 1995	present (Low Rock)	Aguirre 1995
1991/92							8 (Low Rock)	Casaux et al. 2006
1992/93							7 (Low Rock)	Casaux et al. 2006
1993/94							8 (Low Rock)	Casaux et al. 2006
1997/98					ca. 250	Hahn et al. 1998	vor-handen	Hahn et al. 1998
1998/99							5 (Low Rock)	Casaux et al. 2006
1999/2000							3 (Low Rock)	Casaux et al. 2006
2000/01							1 (Low Rock)	Casaux et al. 2006

Table 14: Overview of the breeding pair numbers of von brown skuas (*Catharacta antarctica lonnbergi*), south polar skua (*C. maccormicki*), mixed & hybrid pairs (*Catharacta* mixed & hybrid pairs) and undefined skua pairs (*Catharacta* spec.) on Potter Peninsula based on available census data. If not the entire peninsula was covered, a minimum (min.) value is indicated. (* survey only within the ASPA).

	C. antarctica lonnbergi		*C. maccormicki*		*Catharacta* mixed & hybrid pairs		*Catharacta* spec.	
Season	BP	Source	BP	Source	BP	Source	BP	Source
1966/67	8 (incl. 1 Trio)	Araya et al. 1971	1	Araya et al. 1971				
1984/85	6	Peter et al. 1988	1	Peter et al. 1988	0	Peter et al. 1988	0	Peter et al. 1988
1985/86							6	Rauschert et al. 1987
1988/89	20	Aguirre 1995	2	Aguirre 1995	0	Aguirre 1995	0	Aguirre 1995
1993/94	35	Hahn et al. 1998	40	Hahn et al. 1998	10	Hahn et al. 1998	0	Hahn et al. 1998
1994/95	29	Hahn et al. 1998	41	Hahn et al. 1998	7	Hahn et al. 1998	0	Hahn et al. 1998
1995/96	31	M. Ritz, pers. comm.	13	M. Ritz, pers. comm.	3	M. Ritz, pers. comm.	0	M. Ritz, pers. comm.
1997/98	26	Hahn et al. 1998	44	Hahn et al. 1998	13	Hahn et al. 1998	0	Hahn et al. 1998
1998/99	26	M. Ritz, pers. comm.	45	M. Ritz, pers. comm.	7	M. Ritz, pers. comm.	0	M. Ritz, pers. comm.
1999/2000	30	M. Ritz, pers. comm.	44	M. Ritz, pers. comm.	17	M. Ritz, pers. comm.	0	M. Ritz, pers. comm.
2000/2001	32	M. Ritz, pers. comm.	54	M. Ritz, pers. comm.	16	M. Ritz, pers. comm.	0	M. Ritz, pers. comm.
2001/02	35	M. Ritz, pers. comm.	63	M. Ritz, pers. comm.	14	M. Ritz, pers. comm.	0	M. Ritz, pers. comm.
2002/03	29	M. Ritz, pers. comm.	33	M. Ritz, pers. comm.	8	M. Ritz, pers. comm.	0	M. Ritz, pers. comm.
2003/04	14	M. Ritz, pers. comm.	49	M. Ritz, pers. comm.	4	M. Ritz, pers. comm.	0	M. Ritz, pers. comm.
2004/05	33	M. Kopp, pers. comm.	64	M. Kopp, pers. comm.	16	M. Kopp, pers. comm.	4	M. Kopp, pers. comm.
2005/06	28	M. Kopp, pers. comm.	73	M. Kopp, pers. comm.	15	M. Kopp, pers. comm.	3	M. Kopp, pers. comm.
2006/07	34	S. Lisovski, pers. comm.	79	S. Lisovski, pers. comm.	17	S. Lisovski, pers. comm.	1	S. Lisovski, pers. comm.
2010/11	min. 6*	Republic of Korea 2011	min. 2*	Republic of Korea 2011	0*	Republic of Korea 2011	0*	Republic of Korea 2011
2012/13	11	Graña Grilli 2014	0	Graña Grilli 2014	0	Graña Grilli 2014	0	Graña Grilli 2014

Season	*C. antarctica lonnbergi*		*C. maccormicki*		*Catharacta* mixed & hybrid pairs		*Catharacta* spec.	
	BP	Source	BP	Source	BP	Source	BP	Source
2013/14	14	Graña Grilli 2014	0	Graña Grilli 2014	0	Graña Grilli 2014	0	Graña Grilli 2014

Figure 50: Changes in breeding pair numbers of selected species on Potter Peninsula. Data for gentoo penguins (*Pygoscelis papua*), Adélie penguins (*P. adeliae*), chinstrap penguins (*P. antarctica*), southern giant petrels (*Macronectes giganteus*), snowy sheathbill (*Chionis alba*) and for all skua species summarised (*Catharacta* spec.) according to Table 11 – Table 14. If there are no values, no data were available for the particular season.



3.6 Duthoit Point

Duthoit Point forms the eastern point of Nelson Island (Figure 39) and with an area of approx. 2.7 km² it is the smallest ice-free part of the Maxwell Bay area that is relevant as regards fauna. It lies in an exposed position in the transition zone between Maxwell Bay and Bransfield Strait. The area is roughly divided into a beach interspersed with rocky ridges and above that a high plateau, dominated by Burney Peak (Figure 52). The two zones are separated by a cliff. However, in the northern part the transition is more gradual. There are no substantial bodies of water and vegetation is sparse, with the exception of fruticose and crustose lichens on Burney Peak. However, at the beach level there is an above-average incidence of Antarctic hair grass. There are no research stations or field huts at Duthoit Point. Combined with the distant location of this area, this means that it is rarely visited by scientists and that, in consequence, there are considerable gaps in the data. Project members were able to visit the area on 31.01.2013. During the visit they found a boat (?) partially buried in silt of unknown origin and function in the south-western part of the beach (Figure 51). This boat had evidently served as an emergency shelter (meagre food supplies present) although the interior was completely full of sand. Furthermore, on the plateau, at the foot of Burney Peak, there is the wreck of a Chilean small plane that crashed in 1986.

Figure 51: Boat (?) of unknown origin and function at the southwestern beach area at Duthoit Point; in the background the south-western penguin sub-colony (photo: J. Esefeld, 31.01.2013)

Despite its small size, this peninsula is very important for avian fauna (Table 15 – Table 17), with breeding birds concentrated in the coastal area. A total of 13 species of breeding birds are listed in the literature, although this information appears to be doubtful (see below). There is a medium-sized gentoo penguin colony there (Figure 53). Whereas earlier publications (Rauschert et al. 1987; Mönke et al. 1988) do not go into the structure in more detail, Shuford et al. (1988b) report for the 1986/87 season and Coria et al. (1995) for the 1993/94 season the presence of two or three subsidiary colonies. Shuford et al. (1988b) contains figures for the Duthoit Point colony (700-800 adult individuals), and a colony 2-3 km further north with 900 adult individuals, which are to be combined. However, in the 2012/13 season the middle subsidiary colony was found to have gone, with the result that now two colonies remain which are approx. 1.2 km from each other at opposite ends of the peninsula (Figure 54). Three counts from 1985/86 and 1986/87 fluctuate between 1,600 and 5,000 BP (Rauschert et al. 1987; Mönke et al. 1988; Shuford et al. 1988b). Based on consistent information, a gentoo penguin population of approx. 1,700-2,000 pairs would appear to be substantiated. As the results for 1993/94 (1,828 BP) and 2012/13 (approx. 1,800 BP) show, the number of breeding pairs remained relatively constant in spite of the changes in colony structure. Most recently, the two sub-colonies were more or less the same size.

Figure 52: Plateau at Duthoit Point; the arrow indicates the position of the aircraft wreck at the foot of Burney Peak (photo: J. Krietsch, 31.01.2013).

Figure 53: North-eastern penguin sub-colony on rocks and a little plateau above the coast of Duthoit Point (photo: J. Esefeld, 31.01.2013)

Apart from gentoo penguins, Coria et al. (1995) also report on the presence of an Adélie penguin breeding pair, though this was never confirmed, either before or afterwards, so that it was probably an exception. In addition, Rauschert et al. (1987) mention 3,000 – 4,000 chinstrap penguin pairs. However, these have never been recorded during any other monitoring exercise, so that the information should be considered error or confusion.

Together with penguins, there are also fairly large breeding colonies of southern giant petrel (54 – 194 BP) and blue-eyed shag (32 – 163 BP). For blue-eyed shag this is the only known current breeding site in the Maxwell Bay area, apart from that on the cliffs of Low Rock, 2 km off Potter Peninsula (Hahn et al. 1998). The blue-eyed shags were regularly counted by Argentinian researchers over a number of years, as the only species of seabird that bred at Duthoit Point (Casaux et al. 2006). These counts showed a massive and continuous decline in the number of breeding bird pairs in the 1990s and early 2000s (Table 17; Casaux et al. 2006). Subsequently, despite the negative long-term trend ($R = 0.59$, $p < 0.001$), the population appeared to stabilise, as shown by a rough extrapolation of breeding pair numbers based on breeding success rates from the literature (Casaux et al. 1993; Coria et al. 1995) following a visit by project members in January 2013. The same development was substantiated along the entire Antarctic Peninsula (Lynch et al. 2008). In addition there are a few breeding pairs of brown skua, south polar skua, cape petrel, kelp gull, snowy sheathbill and Antarctic tern. Black-bellied storm petrel and Wilson's storm petrel were also confirmed as breeding birds, although reliable data is lacking. The figure of 100 snowy sheathbill breeding pairs published in Shuford et al. (1988b) appears to be too high and extremely questionable given the available habitat and the size of the penguin colony there.

Duthoit Point has been shown to be a pupping place for southern elephant seals (Mönke et al. 1988; Carlini et al. 2003) and Weddell seals (Mönke et al. 1988). During the visit to the area by project members on 31 January 2013, they were struck by the large number of seals (504 southern elephant seals, 39 Antarctic fur seals, and 6 Weddell seals), which were present there in greater densities than on other coasts of Maxwell Bay at that time. The density of the populations was similar to that on the west coast of Fildes Peninsula.

Figure 54: Spatial distribution of the breeding birds at Duthoit Point in the seasons 2006/07 to 2012/13

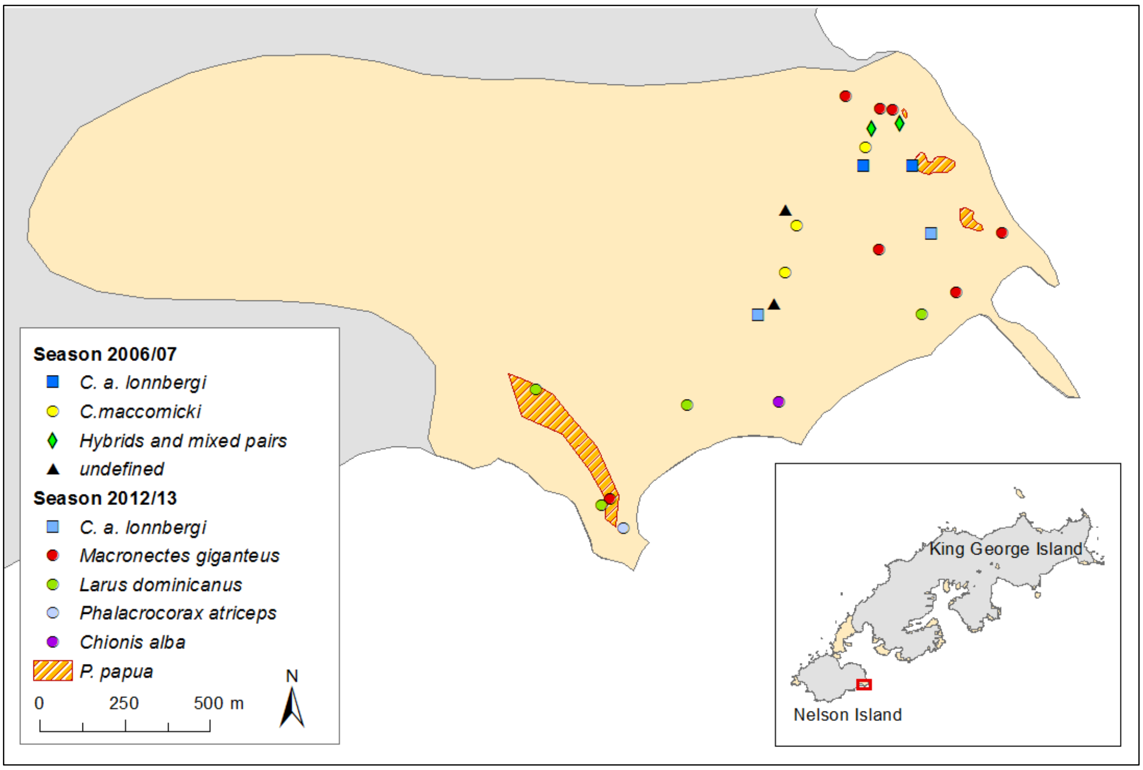


Table 15: Overview of the breeding pair numbers of gentoo penguins (*Pygoscelis papua*), Adélie penguin (*P. adeliae*), chinstrap (*P. antarctica*), southern giant petrels (*Macronectes giganteus*) and cape petrels (*Daption capense*) at Duthoit Point based on available census data

Season	*P. papua*		*P. adeliae*		*P. antarctica*		*M. giganteus*		*D. capense*	
	BP	Source	BP	Source	BP	Source	BP	Source	BP	Source
1985/86	ca. 5.000	Rauschert et al. 1987	0	Rauschert et al. 1987	3.000-4.000	Rauschert et al. 1987	194	Rauschert et al. 1987	5	Rauschert et al. 1987
1986/87	1.700 / 1.600-1.700	Mönke et al. 1988 / Shuford et al. 1988b	0	Mönke et al. 1988	0	Mönke et al. 1988	54	Mönke et al. 1988	0	Mönke et al. 1988
1993/94	1.828	Coria et al. 1995	1	Coria et al. 1995	0	Coria et al. 1995	118	Coria et al. 1995	14	Coria et al. 1995
2012/13	ca. 1.800	present study	0	present study	0	present study	52-62	present study		

Table 16: Overview of the breeding pair numbers of Wilson's storm petrels (*Oceanites oceanicus*), black-bellied storm petrel (*Fregetta tropica*), snowy sheathbill (*Chionis alba*), kelp gull (*Larus dominicanus*) and Antarctic tern (*Sterna vittata*) at Duthoit Point based on available census data

	O. oceanicus		*F. tropica*		*C. alba*		*l. dominicanus*		*S. vittata*	
Season	BP	Source	BP	Source	BP	Source	BP	Source	BP	Source
1985/86	ca. 150	Rauschert et al. 1987			2	Rauschert et al. 1987	0	Rauschert et al. 1987	22	Rauschert et al. 1987
1986/87					1 / 100	Mönke et al. 1988 / Shuford et al. 1988b				
1993/94	min. 2	Coria et al. 1995	min. 4	Coria et al. 1995	2	Coria et al. 1995	18	Coria et al. 1995	29	Coria et al. 1995
2012/13					1	present study	5	present study		

Table 17: Overview of the breeding pair numbers of brown skuas (*Catharacta antarctica lonnbergi*), south polar skuas (*C. maccormicki*), mixed & hybrid (*Catharacta* mixed & hybrid pairs), undefined skua pairs (*Catharacta* spec.) and blue-eyed shags (*Phalacrocorax atriceps*) at Duthoit Point based on available census data

	C. a. lonnbergi		*C. maccormicki*		*Catharacta* mixed & hybrid pairs		*Catharacta* spec.		*P. atriceps*	
Saison	BP	Quelle	BP	Quelle	BP	Quelle	BP	Quelle	BP	Quelle
1985/86							4	Rauschert et al. 1987		
1986/87									96	Mönke et al. 1988
1990/91									163	Casaux et al. 1993
1992/93									140	Casaux et al. 2006
1993/94	5	Coria et al. 1995	1	Coria et al. 1995	0	Coria et al. 1995	0	Coria et al. 1995	133	Coria et al. 1995
1994/95									120	Casaux 1998
1995/96									104	Casaux 1998
1996/97									79	Casaux 1998
1997/98									73	Casaux et al. 2006
1998/99									77	Casaux et al. 2006
1999/2000									64	Casaux et al. 2006

Saison	*C. a. lonnbergi*		*C. maccormicki*		*Catharacta* mixed & hybrid pairs		*Catharacta* spec.		*P. atriceps*	
	BP	Quelle	BP	Quelle	BP	Quelle	BP	Quelle	BP	Quelle
2000/01									66	Casaux et al. 2006
2001/02									48	Casaux et al. 2006
2002/03									42	Casaux et al. 2006
2003/04									36	Casaux et al. 2006
2004/05									32	Casaux et al. 2006
2006/07	2	S. Lisovski, pers. comm.	3	S. Lisovski, pers. comm.	2	S. Lisovski, pers. comm.	2	S. Lisovski, pers. comm.		
2012/13	2	present study	0	present study	0	present study	0	present study	ca. 55	present study

3.7 Stansbury Peninsula & Martin Point (Nelson Island)

This concerns the ice-free areas in the northern part of Nelson Island between Edgell Bay in the east and Drake Passage in the west (Figure 39). To the north, the area is bordered by the Fildes Strait. The glacier, which extends to the coast, divides the oasis into two zones: Stansbury Peninsula, a large eastern peninsula on the Fildes Strait, and to the west of that a smaller area called Martin Point or Punta Martin (Figure 39 & Figure 57). The ice-free part of Stansbury Peninsula covers 2.7 km² and that of Martin Point 0.16 km². Stansbury Peninsula has a varied topography with shallow bays, steep cliffs, small level areas and a central mountainous area. The area has a number of lakes and small streams. Especially along Fildes Strait, there are extensive areas of moss and lichen. Because of its limited size, Martin Point is less varied and consists only of a few cliffs that rise from a small beach area.

In the eastern part of Stansbury Peninsula there are a Brazilian field hut ('Refugio Astronomo Cruls'), the private station 'Overnational Ecobase Nelson' (Figure 55), and an additional hut of unknown origin. Except for occasional private expeditions to the 'Ecobase Nelson', the huts are hardly ever used. As this area is also only visited sporadically by scientists, there are no continuous data series for the breeding bird populations. In recent years, project members were able to visit the area along the Fildes Strait several times, but never Martin Point.

The majority of the bird colonies on Stansbury Peninsula are on the coast of Fildes Strait. There are several small breeding colonies of southern giant petrel here, which have been comparatively well recorded by German scientists (Figure 56, Table 18). Whereas the size of the colony fluctuated for the most part by 20 – 30 BP in the 1980s, the population has grown significantly since then ($R^2 = 0.72$, $p < 0.001$) to 48 – 65 BP at the most recent counts. There also used to be large colonies of cape petrel here. Lumpe et al. (2000) carried out the most extensive studies on these colonies to date and estimated their population at approx. 800 BP in 1991/92, which would have made this colony the largest population of cape petrel in the Maxwell Bay area. When the location was checked in the 2012/13 season, these huge numbers of breeding pairs were no longer found. This is probably linked to the sharp decline in the species observed throughout the Fildes Region (see above). Other breeding birds in this area are brown skuas, south polar skuas, kelp gulls, Antarctic terns, Wilson's storm petrels and black-bellied storm petrels (Figure 56, Table 18 – Table 20).

Figure 55: Private station 'Overnational Ecobase Nelson' (photo: J. Esefeld, 23.12.2010)

Figure 56: Spatial distribution of selected breeding bird species at Stansbury Peninsula (Data from 2009/10 to 2014/15 are included)

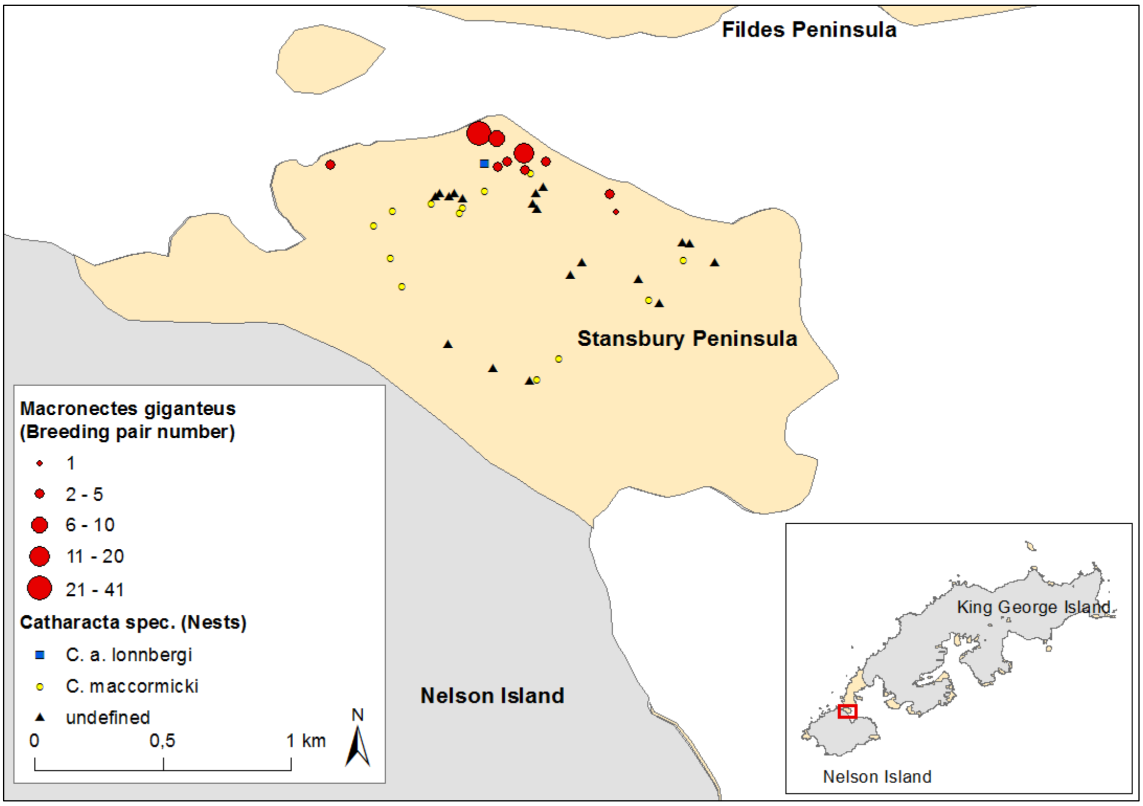


Table 18: Overview of the breeding pair numbers of southern giant petrels (*Macronectes giganteus*), cape petrels (*Daption capense*), Wilson's storm petrels (*Oceanites oceanicus*) and black-bellied storm petrels (*Fregetta tropica*) on Stansbury Peninsula based on available census data

Season	*M. giganteus*		*D. capense*		*O. oceanicus*		*F. tropica*	
	BP	Source	BP	Source	BP	Source	BP	Source
1979/80	11	Bannasch et al. 1981	ca. 75	Bannasch et al. 1981				
1984/85	47	Peter et al. 1988	10	Peter et al. 1988	2	Peter et al. 1988	1	Peter et al. 1988
1985/86	22	Rauschert et al. 1987	25	Rauschert et al. 1987				
1986/87	15-20	Mönke et al. 1988						
1987/88	min. 9	Lange et al. 1989						
1988/89	24	Lange et al. 1989						
1990/91	25	Lumpe et al. 2000						
1991/92	29	Lumpe et al. 2000	ca. 800	Lumpe et al. 2000	100-500	Lumpe et al. 2000	6-10	Lumpe et al. 2000

Season	*M. giganteus*		*D. capense*		*O. oceanicus*		*F. tropica*	
	BP	Source	BP	Source	BP	Source	BP	Source
2002/03	32	S. Pfeiffer, pers. comm.						
2008/09	63	present study						
2009/10	65	present study						
2010/11	50	present study						
2011/12	61	present study						
2012/13	48	present study	min. 8	present study				
2013/14	min. 17	present study						
2014/15	61	present study	min. 2	present study				

Table 19: Overview of the breeding pair numbers of snowy sheathbill (*Chionis alba*), kelp gull (*Larus dominicanus*) and Antarctic tern (*Sterna vittata*) on Stansbury Peninsula based on available census data

Season	*C. alba*		*L. dominicanus*		*S. vittata*	
	BP	Source	BP	Source	BP	Source
1984/85	1	Peter et al. 1988	0	Peter et al. 1988	0	Peter et al. 1988
1985/86	1	Rauschert et al. 1987	5	Rauschert et al. 1987	28	Rauschert et al. 1987
1991/92	0	Lumpe et al. 2000	8	Lumpe et al. 2000	100	Lumpe et al. 2000
2009/10	0	present study				
2010/11	0	present study				
2012/13	0	present study	min. 1	present study		
2013/14	0	present study				
2014/15	0	present study				

Table 20: Overview of breeding pair numbers of brown skuas (*Catharacta antarctica lonnbergi*), south polar skuas (*C. maccormicki*), mixed & hybrid pairs (*Catharacta* mixed & hybrid pairs) and undefined skua pairs (*Catharacta*. spec.) on Stansbury Peninsula based on available census data

Season	*C. a. lonnbergi*		*C. maccormicki*		*Catharacta* mixed & hybrid pairs		*Catharacta* spec.	
	BP	Source	BP	Source	BP	Source	BP	Source
1984/85	0	Peter et al. 1988	0	Peter et al. 1988	0	Peter et al. 1988	0	Peter et al. 1988
1985/86							5	Rauschert et al. 1987
1989/90							6	H. Grimm, pers. comm.

Season	*C. a. lonnbergi*		*C. maccormicki*		*Catharacta* mixed & hybrid pairs		*Catharacta* spec.	
	BP	Source	BP	Source	BP	Source	BP	Source
1991/92	9	Lumpe et al. 2000	20	Lumpe et al. 2000	1	Lumpe et al. 2000	0	Lumpe et al. 2000
2009/10	0	present study	1	present study	0	present study	4	present study
2010/11	0	present study	12	present study	0	present study	15	present study
2012/13	0	present study	0	present study	0	present study	0	present study
2013/14	0	present study	0	present study	0	present study	0	present study
2014/15	min. 1	present study						

At the end of Martin Point there is a large chinstrap penguin colony that can be seen from Fildes Peninsula. With the exception of the estimate by Rauschert et al. (1987), which at 8,000-10,000 pairs should be seen as implausibly high, the colony's actual size could have been between 250 and 1,000 BP (Mönke et al. 1988; Peter et al. 1988; Shuford et al. 1988b; Lumpe et al. 2000). However, the last count was done in the 1991/92 season, so that the current size of this colony is unknown. The 100 gentoo penguin BP also reported by Rauschert et al. (1987) could not be documented either before or afterwards (Mönke et al. 1988; Peter et al. 1988; Shuford et al. 1988b; Lumpe et al. 2000), so that this figure would appear to be doubful. In the Martin Point area there is also a small colony of southern giant petrels, with 8 – 34 BP, as well as a cape petrel colony (10 – 300 BP, Table 21). In addition, brown skuas, kelp gulls, snowy sheathbills, Wilson's storm petrels and (irregularly) Antarctic terns breed here. For these species, too, the last population count was carried out in the 1991/92 season.

Figure 57: View from Fildes Peninsula southwards to Martin Point (photo: J. Krietsch, 09.12.2012); on the left the ice cap of Nelson Island; the penguin colonies on Nancy Rock and Withem Island are on the right just outside the edge of the picture.

.

Table 21: Overview of the breeding pair numbers of gentoo penguins (*Pygoscelis papua*), chinstrap penguins (*P. antarctica*), southern giant petrels (*Macronectes giganteus*), cape petrel (*Daption capense*) and Wilson's storm petrels (*Oceanites oceanicus*) at Martin Point based on available census data

Season	*P. papua*		*P. antarctica*		*M. giganteus*		*D. capense*		*O. oceanicus*	
	BP	Source	BP	Source	BP	Source	BP	Source	BP	Source
1984/85	0	Peter et al. 1988	1.000	Peter et al. 1988	17	Peter et al. 1988	10	Peter et al. 1988	ca. 25	Peter et al. 1988
1985/86	100	Rauschert et al. 1987	8.000-10.000	Rauschert et al. 1987	34	Rauschert et al. 1987	55	Rauschert et al. 1987	65	Rauschert et al. 1987
1986/87	0	Mönke et al. 1988	300 / 250-500	Mönke et al. 1988 / Shuford et al. 1988b	11	Mönke et al. 1988				
1991/92	0	Lumpe et al. 2000	800	Lumpe et al. 2000	8	Lumpe et al. 2000	ca. 300	Lumpe et al. 2000	10-50	Lumpe et al. 2000

Table 22: Overview of the breeding pair numbers of snowy sheathbill (*Chionis alba*), kelp gull (*Larus dominicanus*), brown skuas (*Catharacta antarctica lonnbergi*), undefined skua pairs (*Catharacta* spec.) and Antarctic terns (*Sterna vittata*) at Martin Point based on available census data

Season	*C. alba*		*L. dominicanus*		*C. a. lonnbergi*		*Catharacta* spec.		*S. vittata*	
	BP	Source	BP	Source	BP	Source	BP	Source	BP	Source
1984/85	1	Peter et al. 1988	30	Peter et al. 1988	1	Peter et al. 1988	0	Peter et al. 1988	0	Peter et al. 1988
1985/86	4	Rauschert et al. 1987	12	Rauschert et al. 1987			2	Rauschert et al. 1987	13	Rauschert et al. 1987
1986/87	0	Mönke et al. 1988								
1991/92	1	Lumpe et al. 2000	1	Lumpe et al. 2000	3	Lumpe et al. 2000	0	Lumpe et al. 2000		Lumpe et al. 2000

3.8 Discussion

The presence of several research stations in the Maxwell Bay area has allowed extensive counting of breeding birds over a long period, such as can hardly be found anywhere else in the Antarctic. However, reliable long-term data series could only be collected for the Fildes, Barton and Potter Peninsulas, and although it is possible that more extensive data has been obtained for Potter Peninsula in the last few years, this was not available for this report.

It is clear from the monitoring data presented that fundamental population trends are usually reflected in all the breeding bird colonies of Maxwell Bay and that these colonies do not expand or contract independently of one another. For example, the numbers of gentoo penguin breeding pairs have increased continuously in the colonies on Ardley Island, Barton and Potter Peninsula since counting began in the 1960s. Only the number of breeding pairs in the gentoo penguin colony on Duthoit Point appears to be stagnating, but the data basis there is not sufficient to identify a clear trend. Apart from that, the gentoo penguin colonies of Maxwell Bay follow the amply documented trend of this species in the area of the Antarctic Peninsula, in which colony size increases supra-regionally and new areas are also populated (Woehler et al. 2001; Lynch et al. 2008; Lynch et al. 2012b). An exception to this, however, is Admiralty Bay, where there were only insignificant changes in the population between 1981 and 2006 (Hinke et al. 2007).

In contrast to the gentoo penguins, the number of Adélie penguin breeding pairs has fallen dramatically both on Ardley Island and Potter Peninsula in recent years (Carlini et al. 2009; Juáres et al. 2015). Previously, however, a significant increase in the population had been observed, up to the level that it reached in the 1980s (Juáres et al. 2015). In the Stranger Point colony on Ardley Island, it has also been possible to ascertain a stabilisation of the Adélie penguin population in recent years (Juáres et al. 2015). The sharp decline in numbers of breeding pairs documented in the Maxwell Bay area is also occurring elsewhere. The nearest colonies, on Penguin Island and in Admiralty Bay, thus also shrank after growing in the 1970s (Hinke et al. 2007; Sander et al. 2007a). In the whole region of the western Antarctic Peninsula colony sizes are currently also in decline in most cases. Only in the extreme south of the western Antarctic Peninsula, as well as in the eastern Antarctic Peninsula, there are a few Adélie penguin colonies that are growing (Lynch et al. 2012b), partly in connection with increasing habitat availability due to melting glaciers (LaRue et al. 2013).

Chinstrap penguins present a less uniform picture than the other two *Pygoscelis* species. For Maxwell Bay current data is only available for Barton Peninsula and Ardley Island. While the colony on Ardley Island has now stabilised at a very low level following a rapid decline in the 1980s and 1990s, the population of the Barton Peninsula colony has been stable since counting began. In the colony on Potter Peninsula a decline in the number of breeding pairs was also observed in the 1980s; we have no more count data for the period since then. However, chinstrap penguins have now completely disappeared from this colony (Schuster 2010). Comparisons with other colonies in the King George Island region (Admiralty Bay) also show a long-term decline compared with the 1980s (Hinke et al. 2007; Sander et al. 2007a; Sander et al. 2007b; Korczak-Abshire et al. 2013). If we consider bird populations on a large scale, we can also see an irregular development of various colonies in the Antarctic Peninsula region. Declining, stagnating and growing colonies were all documented, although overall there were more declines, which has as consequence a shrinking total population (Lynch et al. 2012b).

The development of the southern giant petrel population can be judged to be more differentiated. There are good data series for this species for Fildes and Stansbury, and to a limited extent for Barton and Potter Peninsula. On Potter Peninsula, the number of breeding pairs fluctuates very strongly from one year to the next, with the result that no clear trend can be recognised. In contrast, a clear decline can be seen on Barton Peninsula compared with numbers from the 1980s, while on Stansbury Peninsula there seems to have been a slight increase. On Fildes Peninsula, on the other hand, the number of breeding pairs is stable (see above, Peter et al. 2013). It is difficult to make statements about the status of the species for the whole of the Antarctic Peninsula region, because little count data has been published and, in addition, population trends are subject to considerable local variability (Patterson et al. 2008). However, various published compilations of all the available data up to 2000 indicate a stable total population size or a possible increase in the southern giant petrel population (Woehler et al. 1997; Lynch et al. 2008; Patterson et al. 2008).

As regards blue-eyed shag, there has clearly been a decline in the population in the past in the Maxwell Bay area. The two populations at Duthoit Point and Low Rock near Potter Peninsula were counted regularly in the 1990s and early 2000s and these data reveal a significant decline (Casaux et al. 2006). However, the only more recent count, conducted by project members at Duthoit Point during the 2012/13 season, indicates that in the meantime the number of breeding pairs has stabilised and might even be rising again. This observation exactly matches the trend for the entire Antarctic Peninsula shown by Woehler et al. (2001) as well as Lynch et al. (2008), so that it is possible that the individual local populations are behaving in a similar way as regards their development.

Skua populations are frequently prone to sharp fluctuations from year to year. This is especially the case for south polar skuas. Based on the relatively long data series for the Potter, Fildes and Barton Peninsulas, the population appears to have been stable over the last few decades. However, what is striking is that there has been a sharp drop in the number of breeding pairs since the 2011/12 season, which can be recognised both on Barton and on Fildes and which has apparently also been observed on Potter Peninsula (Graña Grilli 2014). Adult birds were present in their usual numbers, but did not begin to breed (Krietsch et al. 2016), possibly due to a lack of food availability in the area. If these lean years continue to occur, we can expect negative effects in future on the local skua population.

There are only limited up-to-date studies available on skua population developments in the wider Antarctic Peninsula. On Byers Peninsula, Livingston Island, the population of brown skuas rose from 39 BP to an estimated 60 - 91 BP in the period from 1965/66 to 2008/09, while in the same period south polar skuas were absent (Gil-Delgado et al. 2013a). However, this information is based only on two counts with a long gap between them. In Admiralty Bay, King George Island, the number of brown skua breeding pairs decreased slightly between 1989 and 1999 (Woehler et al. 2001). Counts in the 1978/79 and 2004/05 seasons even recorded a 40 % reduction (data series incomplete, however, as no counts in between), with the area around Hennequin Point and the Keller Peninsula being particularly strongly affected, with a drop from 11 to 0 BP on Keller Peninsula (Carneiro et al. 2010). During this period the number of brown skua breeding pairs at Hennequin Point fell from 10 (Jablonski 1986) to just two (Costa et al. 2008) and then one BP (Carneiro et al. 2010). Conversely, the south polar skua population grew strongly over the same period from nine to 116 pairs. It was presumably due to this increase that eight mixed and hybrid pairs were recorded, which had not been observed previously (Costa et al. 2008). Notable here is the brood of a pair comprising an adult bird identified as a Chilean skua (Catharacta chilensis) and a south polar skua (Costa et al. 2008). These extremely rare breeding birds in the Antarctic have already been recorded on Potter Peninsula (Reinhardt et al. 1997) and Fildes Peninsula (personal communication M. Ritz), although as a rule they have been hybrids between south polar skuas and Chilean skuas. For all ice-free zones in the Admiralty Bay area, Carneiro et al. (2010) report an increase in south polar skua breeding pairs from 36 to 387 BP between 1978/79 and 2004/05 (data series incomplete, however, as no counts in between). Hybrid and mixed pairs rose from 19 to 37 BP. At Palmer Station, situated further south on the Antarctic Peninsula, the number of south polar skuas remained stable between 1979 and 1999 (Woehler et al. 2001). In contrast, at least until 1999, south polar skua numbers showed, to some extent, a clearly upward tendency along the entire Antarctic Peninsula (Woehler et al. 2001).

The data basis for all other breeding birds in the Maxwell Bay area (except for Fildes Peninsula) is incomplete and does not make it possible to deduce any reliable population trends. Although the count data for kelp gulls does suggest a stable population, this cannot be conclusively confirmed due to the relatively limited data. A significant decline in the number of breeding pairs has been documented for Fildes Peninsula (see above). In contrast, Sander et al. (2006) recorded an increase of over 30 % in the number of kelp gulls in Admiralty Bay between 1978/79 and 2004/05 (data series incomplete, however, as no counts in between). Due to the lack of further studies on kelp gulls in the Antarctic, it is not possible to make any statements regarding the general development of the population of this species in the Antarctic Peninsula region.

The same applies to cape petrels, as there is little published work on this species. While sharp declines in numbers of breeding pairs were recorded for the Fildes Region (see above) and Stansbury Peninsula, it is not possible to make any statement about general population development in the whole Maxwell Bay area due to considerable gaps in the records. For neighbouring Admiralty Bay, Sander et al. (2005) indicate a stable – though very low – population of 8 BP. Due to a lack of data from the literature, it is impossible to make any general statements, for this species as well as for all other species of breeding birds, regarding population developments in the western part of the Antarctic Peninsula.

4 Documentation of zones of glacial retreat in selected areas of Maxwell Bay in relation to regional climate development

4.1 Introduction

Numerous studies over recent years all show significant climate change since weather records began in the Antarctic and in adjacent areas such as the South Orkney Islands (Zazulie et al. 2010). These changes are particularly marked in the area of the Antarctic Peninsula, whereas the rest of the continent shows comparatively limited climate change. The sharpest rise in average air temperature occurred at the Faraday/Vernadsky Station, then lessened northwards. Nevertheless, the area affected by this temperature rise stretched to the South Shetland Islands (Turner et al. 2009; Turner et al. 2014). The average rise in air temperature along the western Antarctic Peninsula manifests itself mainly by the absence of especially cold winter temperatures, rather than in a general rise in temperatures (Turner et al. 2005a). This phenomenon is explained by increased cyclonic activity over the Amundsen-Bellingshausen Seas. Lower air pressure there leads to stronger north and west winds over the western Antarctic Peninsula, which bring warm air masses (Turner et al. 2013). This winter warming is not pronounced on the eastern Antarctic Peninsula, where the warming occurs in the summer instead (Turner et al. 2009), presumably due to more frequent west winds strengthened by foehn winds (Turner et al. 2014).

In contrast to the air temperature, the amount of precipitation fluctuates substantially year-on-year and these overlie possible average changes. Nevertheless, the amount of precipitation along the western Antarctic Peninsula has demonstrably risen because of the strengthened cyclonic activity over the Amundsen-Bellingshausen Seas. Elsewhere there were no significant changes (Turner et al. 2013).

These climate changes are able to trigger far-reaching changes in the ecosystem of the Antarctic. For example, climate warming enables species to spread to areas they had not previously colonised. Introduced species are also able to establish themselves in places where the environmental conditions were previously unsuitable for long-term population persistence. Moreover, the retreat of glaciers and permanent snowfields exposes new areas of soil which can be colonised by organisms, thus contributing to their spread. Last but not least, climate change can also lead to changes in the distribution and abundance of marine organisms, for example as a result of a higher water temperature in the layers near the surface (Whitehouse et al. 2008; Schloss et al. 2012) or increased salinity during the summer (Meredith et al. 2005). If key food web species such as krill are affected, these effects are propagated through all the trophic levels and also influence animals that would not be directly affected by climate change (e.g. Franzke 2013).

In addition to such biotic effects, temperature and the amount of precipitation have a particular impact on the development of glaciers through a shift in the relationship between ablation and accumulation (e.g. Han et al. 1995). Therefore, the following section will examine the climate of the Fildes Region, and how it is changing, with the help of meteorological data.

4.2 Analysis of the meteorological data of Bellingshausen Station

4.2.1 The climate in the study area

The climate of the South Shetland Islands is marked by the influence of the Southern Hemisphere polar front and the position of the Islands in the ocean (Peter et al. 2008). In consequence, the prevailing climate is characterised by relatively mild temperatures, high atmospheric humidity, high precipitation and strong winds, mainly from the west. Furthermore, rapid weather changes, caused by strong cyclonic activity, are typical. According to the Köppen climate classification, this is a tundra climate (Barsch et al. 1985), in which the average temperature is above 0°C in at least one month a year.

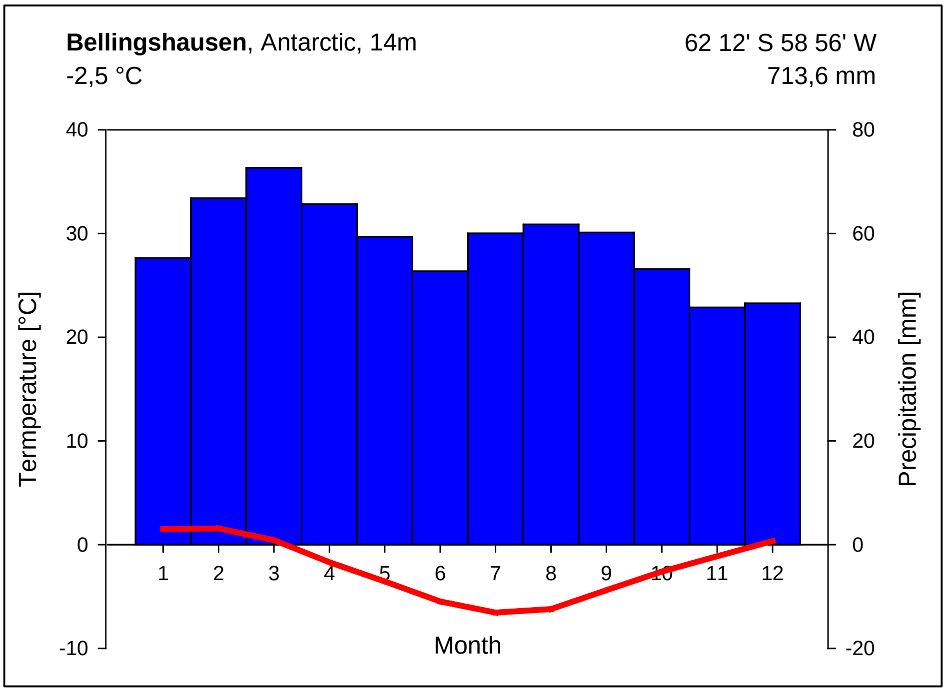
A continuous record of meteorological data in the Antarctic is of extreme importance for the analysis of current climate developments in this region. Few places in the Antarctic can demonstrate such a long-term data collection – for example the Ukrainian Vernadsky Station (formerly the British Faraday Station, Argentine Islands, with readings since 1947, Franzke 2013) or the Argentinian Orcadas Station (South Orkney Islands, readings since 1903, Zazulie et al. 2010). On King George Island, numerous research stations have been taking meteorological readings for several decades. At Bellingshausen Station, continuous records have been made of various meteorological parameters since the end of February 1968, resulting in a series of measurements going back 46 years, which is a relatively long time for the Antarctic. Part of the data recorded is made publicly accessible in the form of monthly mean values both by AARI itself (http://www.aari.aq/data/pick.asp?lang=0, accessed: 30.05.2016) and as part of the SCAR READER project (source: http://www.nerc-bas.ac.uk/icd/gjma/, accessed: 30.05.2016). This data forms the basis for the following calculations.

In line with the 30-year period commonly used in meteorology as the basis for calculating a climatological mean (see 'Klimatologische Referenzperiode' (Climatological reference period) in the weather dictionary of the German Weather Service (DWD): www.dwd.de/lexikon, accessed 30.05.2016), the period 1969-1998 was chosen for calculating such a reference value, which corresponds to the earliest possible 30-year measuring period on the Fildes Peninsula. The climatological mean values confirm the character of the South Shetland Island climate described above, with limited fluctuations in the monthly average temperature and very regular amounts of precipitation throughout the year (Figure 58, see also Table 28 in Appendix 2). In consequence, the climate is markedly humid (approx. 700 mm/year), with the wettest month on average being March and the driest November. However, the interannual fluctuations overlie the differences in mean values between the months, so that there are no pronounced precipitation seasons.

The monthly average temperature climbs above freezing during the summer, with the warmest month generally being January or February, and remains below freezing for the rest of the year. In most years, July is the coldest month. The highest temperature ever measured at Bellingshausen Station was over 8°C and the lowest winter temperatures reach -30°C (source: http://www.aari.aq/stations/bell/bell_en.html, accessed: 30.05.2016).

Wind direction and wind speed are very variable in the Bellingshausen Station area. The main wind directions are north, north-west and west (http://www.aari.aq/stations/bell/bell_en.html, accessed: 30.05.2016), and the maximum wind speeds also come from these directions. Whereas these winds transport warm, humid air, winds from the south and south-east, which are more frequent in January, are dry and cold. The average wind speed, with an annual mean of 7.4 m/s (1969 - 1998) is consistently high, but reaches even higher values from April to October (maximum mean value in October: 8.0 m/s). The summer months are the calmest, but winds with values of between 6.5 and 6.8 m/s are still recorded. On an average of 200 days in the year, gale-force winds (21 – 24 m/s) are recorded (http://www.aari.aq/stations/bell/bell_en.html, accessed: 30.05.2016). There are also often hurricane-force winds with speeds of more than 33 m/s.

Figure 58: Climate chart of Bellingshausen station, based on meteorological data from 1969 to 1998 (data source: NADC, AARI: http://www.aari.aq)



The average monthly snow depth has been recorded since January 1979. Apparently, a record of the number of days with snowfall and of the days with snowstorms has only been kept since February 2006 and, as a result, only very limited statements can be made on this subject, compared with the other long-term data. On average, snowfall is recorded on 210 days per year, while snowstorms with fresh snow cover and wind speeds of more than 7 - 9 m/s on average occur on 109 days per year.

4.2.2 Current climate changes

With the help of the published meteorological data from Bellingshausen Station, it is possible to make statements about climate changes in the Fildes Region over the most recent few decades. For example, the mean annual temperature in this area rose on average by around 0.7°C between 1969 and 2013, which is equivalent to 0.017°C per year, but this failed by a small margin to meet the level of statistical significance of 95 % (see also Table 29 in Appendix 2). Taking only the individual monthly means over the most recent few decades, a significant linear trend can only be seen in May (+0.055°C/a), while the rise in August fails to meet the significance level by a small margin (+0.046°C/a). There is also a trend for January and February, although it is not linear. For January a quadratic regression shows that the mean temperature first rose, reached its maximum of +1.9°C in 1993 and then declined (January: $R^2 = 0.322$, $p = 0.003$). The quadratic regression for February showed a rise to a maximum of +1.9°C in 1992 and then also declined (February $R^2 = 0.295$, $p = 0.005$). The same non-linear development was reflected in the course of the summer temperature (December - February.) (Maximum 1990/91, $R^2 = 0.337$, $p = 0.002$), with the summer of 2013/14 being the coldest since records began (Figure 59). As a result, the summer warming trend that persisted until 2000

(Turner et al. 2005a) can now no longer be demonstrated. Instead, when the regression curve is extrapolated, the mean summer temperature of summer 2014/15 is shown to be lower than in 1969, the first year that records were made.

In contrast to this most recent summer cooling, the autumn temperature (March - May) is continuing to rise (+0.025°C/a, see also Table 29 in Appendix 2), as has already been shown for May (see above). However, in contrast to Turner et al. (2005a) this is at a significant level. For winter (June - August) and spring (September - November) there continues to be no trend. It is therefore not possible to confirm the strong positive trend for the winter temperatures recorded at Vernadsky Station some 440 km further to the south-west (Franzke 2013). Daily temperature data would offer the possibility of more detailed analysis, but such data has so far not been available for Bellingshausen Station. This means that it is not possible to investigate the frequency of extreme weather events.

Figure 59: **Changes in the mean summer temperature (December – February) in Bellingshausen from 1969 to 2014; In addition the quadratic regression curve is presented (data source: NADC, AARI: http://www.aari.aq).**

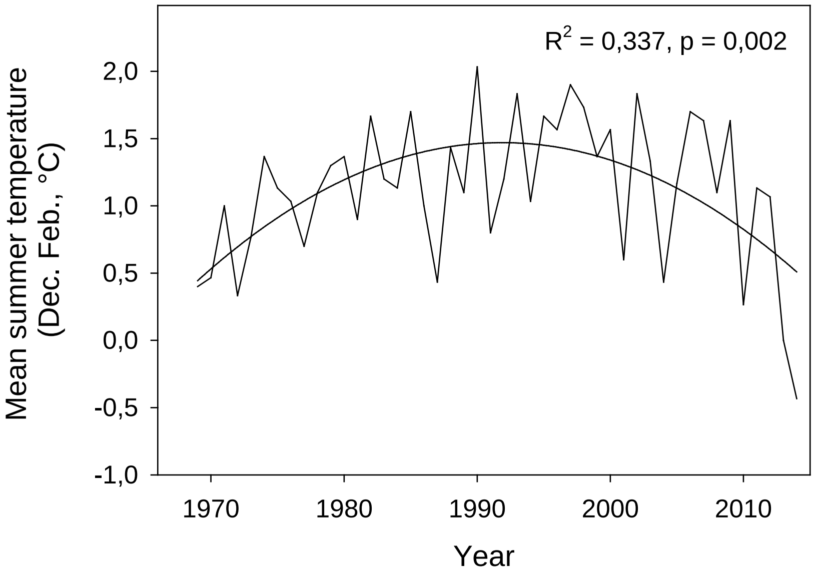
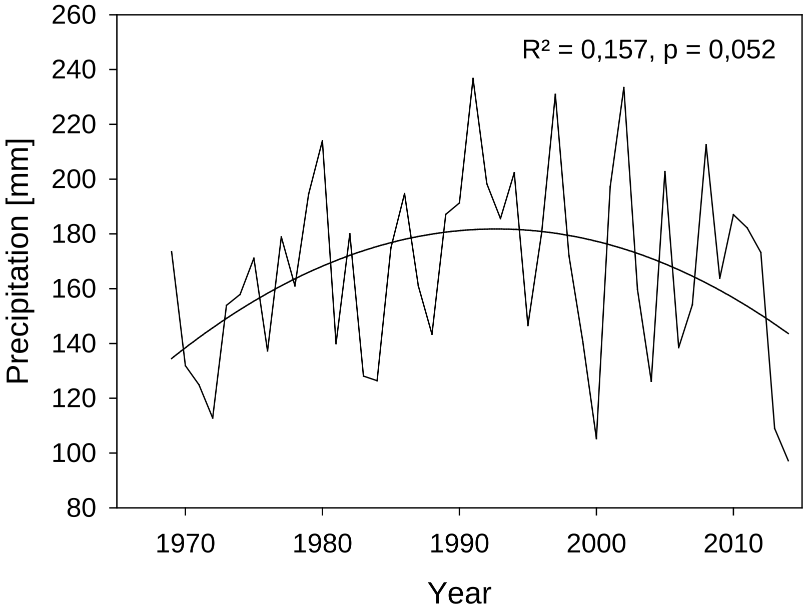


Figure 60: Changes in the summer precipitation (December – February) in Bellingshausen from 1969 to 2014; In addition the quadratic regression curve is presented (Data source: NADC, AARI: http://www.aari.aq).



The precipitation measured has only changed minimally over the last 46 years. It is not possible to recognise linear changes either on a monthly or a yearly basis (see alsoTable 30 in Appendix 2). Nevertheless, a quadratic trend can be demonstrated in January and May. For January the course (maximum for 1995, R^2 = 0.204, p = 0.024) is similar to the temperature curve, although less clearly expressed. This pattern can also be found, in an attenuated, non-significant form, in the precipitation measurements for the whole summer (Figure 60). In contrast, in May there was first a reduction in the amount of precipitation up to 1991, followed by a renewed rise (R^2 = 0.160, p = 0.046). This means that the amount of precipitation does not follow the linear temperature rise that has been recorded.

With regard to the mean monthly snow depth measurements made at Bellingshausen Station, an increase in the depth of the snow cover was recorded for January and December (linear regressions January: R^2 = 0.17, p = 0.02; December: R^2 = 0.23, p = 0.004). However, all the other months showed no significant changes over time. The increase in the mean snow depth recorded in December and January is primarily connected with the series of cool summers in recent years (see above), which delayed the melting of snow that had fallen in winter or spring. However, it was not possible to ascertain an annual increase in the amount of snowfall, as had been established for the WAP region (Turner et al. 2014), on the basis of the above analysis of precipitation amounts.

4.3 Preliminary remark on glacier development in the Antarctic

The behaviour or development of a glacier depends on the relationship between the accumulation of snow masses (accumulation) and melting (ablation) caused by solar radiation, air temperature and precipitation. In addition, the direct transition of water from the solid to the gaseous physical state (sublimation) also contributes to a reduction in the mass of ice in a glacier. If the loss of mass through ablation and sublimation is greater than the accumulation of glacier ice, this can lead, depending on the relief, to pieces breaking off, as in iceberg calving for example, or to the slow retreat of the glacier front. As a result of the thinning of the glacier front or the disappearance of the shelf ice in front of the glacier, the flow rate of glaciers can increase.

The consequences of current climate changes for the ice masses of the Antarctic are not uniform throughout the continent, but in a sharp contrast: The Antarctic Peninsula fundamentally consists of an abrupt and craggy mountain chain, which distinguishes itself from the rest of the Antarctic due to the melt period that occurs there in summer, which results in numerous separate ice-free areas becoming free of snow. The rise in air temperature which has been observed on the Antarctic Peninsula during the last 50 years, at 2.8°C, is many times greater than the worldwide mean (e.g. Vaughan et al. 2001; Vaughan et al. 2003; Turner et al. 2005a; Turner et al. 2014). As a result of this warming, a serious loss of ice can be observed, caused by the retreat of numerous glaciers (Cook et al. 2005; Cook et al. 2010) as well as the loss of large areas of shelf ice (Rignot et al. 2013; Rignot et al. 2014; Paolo et al. 2015). The basal melting of the ice shelves is triggered – or accelerated – by rising seawater temperatures (Martinson et al. 2008; Jenkins et al. 2010; Schmidtko et al. 2014) and, in turn, this accelerates the flow rate of the inland glaciers (Scambos et al. 2004; Vaughan 2006).

In contrast, in the east Antarctic the ice mass is growing in places due to increased precipitation (Shepherd et al. 2012). However, in its mass balance this increase does not offset the losses in the west Antarctic (Kerr 2006), so that the ice mass balance of the Antarctic as a whole is negative.

In addition to the atmospheric warming, a significant rise in the surface temperature of the sea has been recorded over the last few decades, and this has led to substantial changes in the extent and distribution of sea ice (Zhang 2007). Unlike in the Arctic, where sea ice is shrinking, the net production of Antarctic sea ice is growing (Zwally et al. 2002; Zhang 2007; Parkinson et al. 2012). For example, in September 2014 the extent of sea ice in the Antarctic reached its maximum since systematic records began (source: http://www.iup.uni-bremen.de:8084/ssmis/#Antarctic, accessed: 30.05.2016). The cause of this is the complex interaction between diverse factors specific to the Antarctic, such as the altered wind circulation as a result of the ozone hole (Thompson et al. 2002; Holland et al. 2012) and a change in ocean circulation, which is leading to a more pronounced layering of the seawater and reduced transport of heat to the upper layers (Zhang 2007). Moreover, the higher inflow of fresh water due to the melting of the inland glaciers and increased precipitation is leading to a rise in the freezing point temperature, resulting in increased ice formation. On the other hand, studies of the temporal and spatial variability of sea ice cover in the WAP region have shown that the sea ice cover is lasting for a significantly shorter time (Stammerjohn et al. 2008). In conclusion, it can be established that the loss of large areas of sea ice (Smith et al. 2003; Liu et al. 2010) or a shortening of the period with sea ice cover (Stammerjohn et al. 2008) can be expected to have a long-term influence on the functionality of the regional ecosystem. Investigations in the WAP region have already shown corresponding changes at all trophic levels (e.g. Smith et al. 2003; Atkinson et al. 2004; McClintock et al. 2008).

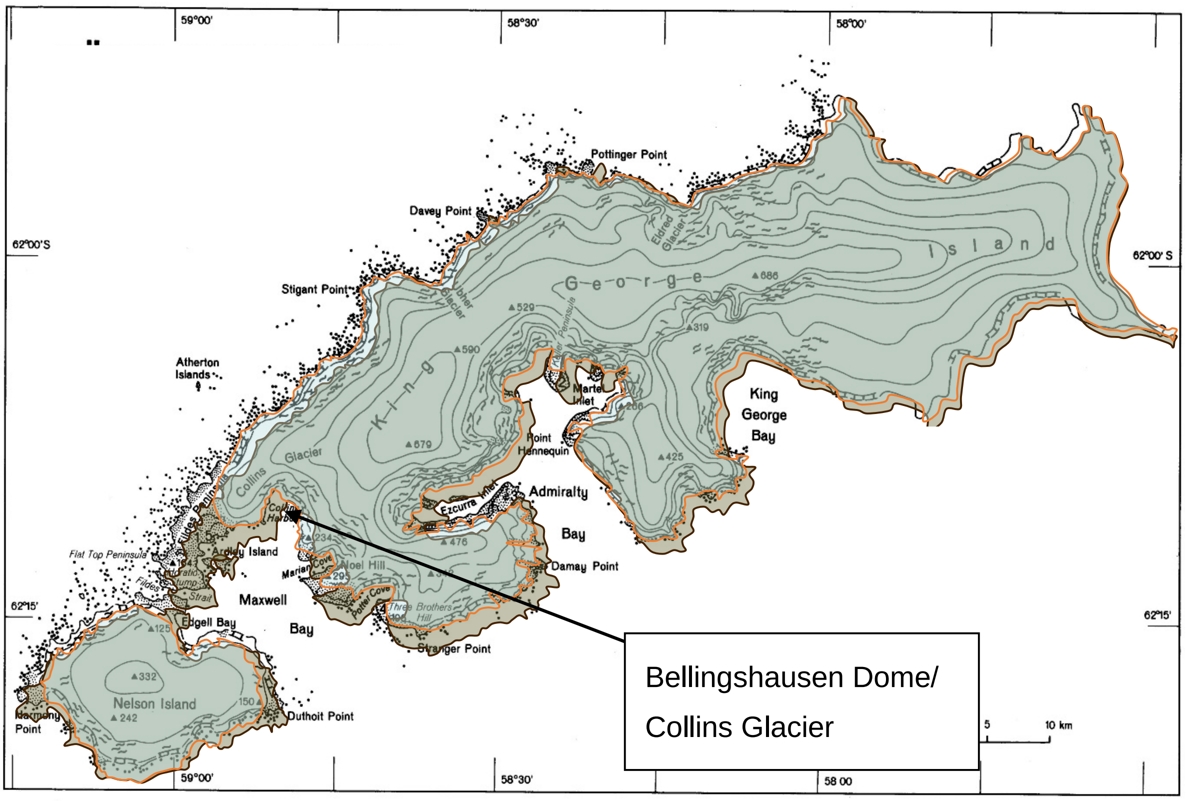
4.4 Current situation of the glaciers in the study area

In common with all the other larger islands of the South Shetland Islands, King George Island, with ice cover of over 90 % (1,250 km^2), is almost completely glaciated (Simoes et al. 1999; Figure 61). The maximum ice thickness is 420 m, with an average of 250 m (Blindow et al. 2010). The highest point on the island is just over 700 m above sea level (Braun et al. 2004). The Fildes Peninsula, at about 29 km^2, is the largest ice-free area on the island and is bounded in the northeast by Bellingshausen Dome (also called Collins Glacier), an offshoot of the Arctowski ice cap (Figure 61). The thickness of the ice cover in the Bellingshausen Dome area is 65 m on average, with a maximum of 120 m (Rückamp et al. 2011). Due to its characteristics and the prevailing maritime climate (Section 4.2), the ice cap of King George Island is considered to be highly sensitive to climate change (Braun et al. 2004). This is particularly true of such an exposed glacier offshoot as Bellingshausen Dome (Sobiech et al. 2010).

South-west of King George Island is Nelson Island, which has a total area of about 170 km^2, of which 95 % is glaciated (Figure 61; Rin et al. 1995; Liu et al. 2004). The highest point of the ice cap is 320 m above sea level (Rin et al. 1995).

It has been shown in numerous detailed studies that the ice cap on King George Island is clearly losing mass as a result of climate change (e.g. Park et al. 1998; Simoes et al. 1999; Birkenmajer 2002; Braun et al. 2002; Osmanoglu et al. 2013; Sobota et al. 2015). Using high-resolution satellite data, Rückamp et al. (2011) calculated for the whole King George Island that the ice cap had retreated from an area of about 20.5 km^2 in the period 2000 to 2008. In this process, 45 glacier offshoots retreated between several hundred metres and one kilometre in the period 1956 to 1995 (Simoes et al. 1999). On the assumption that the climate prevailing between 2000 and 2011 will continue, Rückamp et al. (2011) predict the complete disappearance of Bellingshausen Dome in the north of the Fildes Peninsula in 285 years. In the northern Fildes Peninsula the melting processes of the neighbouring glacier can be seen particularly clearly in the form of retreating glacier fronts or melting dead ice, which frequently appears out of the moraine situated in front of the glacier tongue (Peter et al. 2008). The subject of this report is an investigation of the extent to which the loss of mass of Bellingshausen Dome in the Fildes Peninsula Region is a clearly visible horizontal retreat, as is suggested in numerous subjective reports by scientists who have been active in the region for many years.

Figure 61: Ice cover of King George and Nelson Island (map source: KGIS project, University Freiburg)



To this end, a large number of aerial photographs and satellite images were analysed with regard to possible glacial retreat zones in selected parts of Maxwell Bay. Unlike detailed glaciological studies already carried out in the study area (see above), which make it possible to determine total glacier volume and the amount of water stored there, this report can only make assertions about the horizontal extent of glaciation.

4.5 Methodology for documenting areas of glacial retreat in the Maxwell Bay area

In documenting the areas of glacial retreat, the glacier margins of the ice-free areas of the Fildes Peninsula, the north of Nelson Island (including Stansbury Peninsula and Martin Point), Duthoit Point/Nelson Island, as well as Weaver and Barton Peninsulas, were considered (Figure 39). Potter Peninsula was excluded from the investigation, as there is already a comprehensive study on this area (Rückamp et al. 2011).

The main source of the data used to document the changes in the horizontal extent of glaciation in the Maxwell Bay area consisted of freely accessible aerial photographs and satellite images of the U.S. Geological Survey (source: USGS, http://earthexplorer.usgs.gov/). The earliest available aerial photographs of the Maxwell Bay area are from December 1956, but these could be analysed to some extent due to the large amount of snow cover. We mainly used images from the Earth reconnaissance satellite Landsat for the analysis. Landsat is an optical system with medium resolution which, for more than 40 years, has been supplying multispectral images (8 spectral channels) of the Earth's surface between 82° northern and southern latitude. Images are made of an area every 16 days. The newest systems of Landsat 7 (launched in 1999) and Landsat 8 (2013) cover an area of just under 200 km and give a spatial resolution of 30 x 30 m.

The extent to which optical satellite data can be used is very dependent on weather conditions. It is, above all, the frequent cloud cover in the area of the South Shetland Islands that considerably restricts the number of usable satellite images, as only reflection from clouds is detected and not the Earth's surface (Mustafa et al. 2012). In addition, the timing of the image plays an important role, in order to minimise false interpretations due to snow cover and to guarantee comparability of the data. In an ideal situation there would be enough images available from the end of glacier ablation during the summer but this proved to be very difficult due to the strong annual fluctuations in snow cover in the Fildes Region, including during the summer. A further restriction lays in the appearance of what is called the *Scan Line Corrector Failure* (NASA 2014) in Landsat 7 images from 2003 onwards which causes data gaps in the images so that they cannot easily be presented in full. As well as the Landsat images, aerial photographs from 1984 (summer, exact date unknown) were also available (kindly provided by R. Mäusbacher, FSU Jena). As a result, a large number of aerial photographs and satellite images first needed to be checked for suitability. In these checks we were particularly looking for sufficient coverage of the desired areas and, with reference to cloud and snow cover, we needed the zones at the glacial margins to be recognisable with sufficient clarity.

In order to be able to make statements regarding spatial changes, aerial photographs and satellite images have to be georeferenced before analysis. Therefore, all suitable images were georeferenced with the help of Ground Control Points, i.e. geographical coordinates were assigned to each image pixel. This step was not necessary for more up-to-date Landsat images, because these are already georeferenced. We did not orthorectify the images using a digital terrain model.

Manual image interpretation was chosen as an appropriate method for analysing areas of glacial retreat, as this provides the most reliable results for classification under the existing circumstances (Mustafa et al. 2012). Image interpretation was done by delineation, that is to say that the border zone of the glacier was digitalised on the basis of the colour, the surface structure or other distinguishing features. Demarcation of the glacier margin was supported with the help of changes in contrast and the choice of spectral channels (true-colour or false-colour representation). All the remote sensing data was processed and interpreted using ArcGIS© software, version 9.3.1 or 10.2, and with Quantum GIS software, version 1.8.0.

The absolute precision of the method is limited by the resolution (30 x 30 m) of the Landsat images. An important source of errors in the manual demarcation process is the fact that it is sometimes difficult to recognise precisely the edges of the glacier due to snow cover and moraine material either in front of or on the glacier. This can cause an error in the results, which cannot be more precisely quantified and which expresses itself in deviations in the glacier margin recorded in different images of the same year or in successive or nearly successive years.

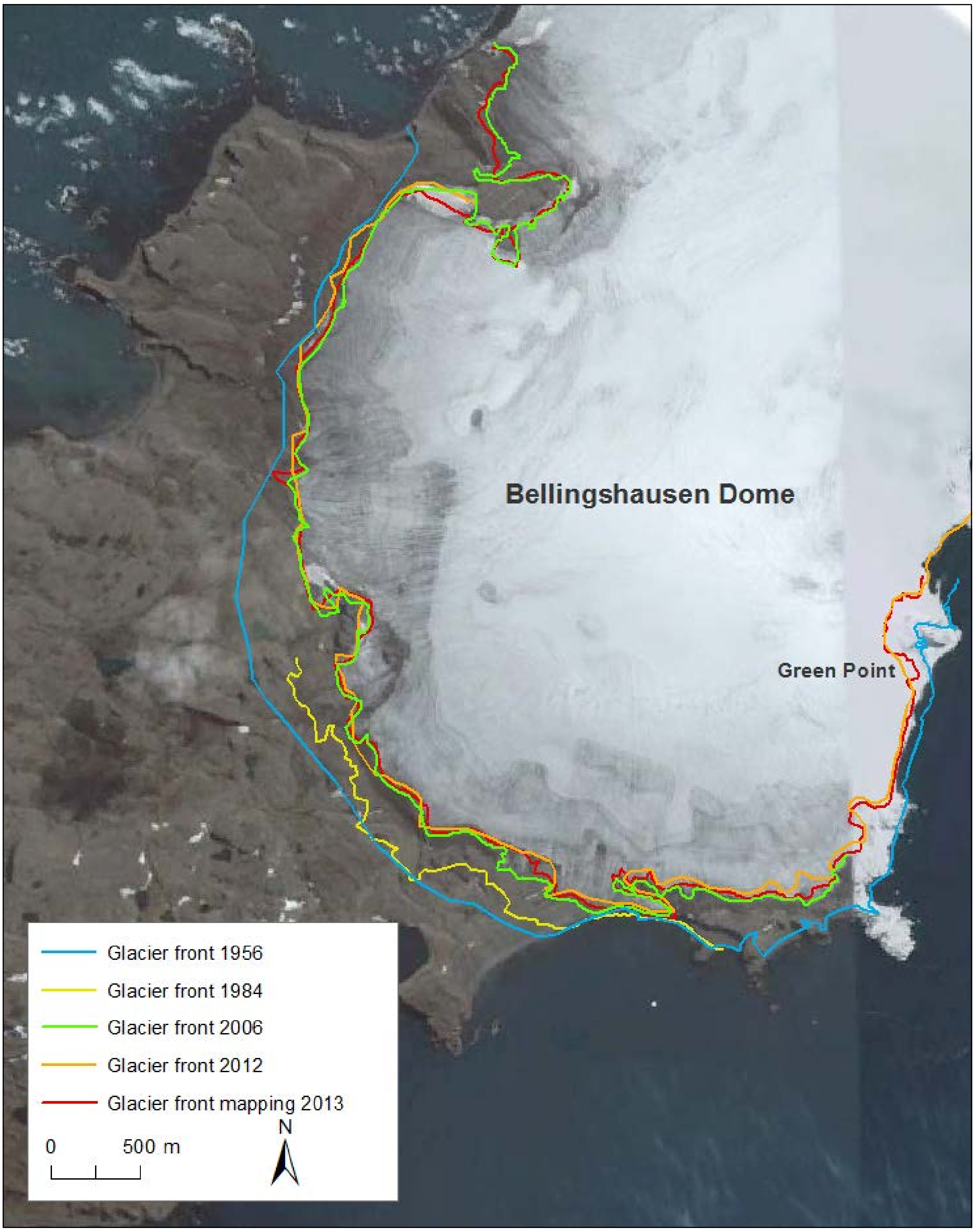
To verify the results of the analysis of the remote sensing data, the border zone of Bellingshausen Dome in the north of Fildes Peninsula was manually mapped with GPS support in February 2013. However, the relatively large amount of snow cover during that Antarctic summer impedes to some extent the precise localisation of the edge of the glacier in the terrain, so that deviations resulting from these conditions cannot be excluded.

4.6 Results

This section presents the areas of glacial retreat for which there was previously no documentation.

Figure 62 makes clear that the horizontal extent of Bellingshausen Dome in the north of Fildes Peninsula was substantially reduced in the period 1956 to 2012. The retreat of the glacier front can be seen most clearly in the central area where the glacier tongue has retreated by more than 600 m in the course of the last 60 years (Figure 62).

Figure 62: Area of glacial retreat of the Bellingshausen Dome in the north of Fildes Peninsula between 1956 and 2012 illustrated by superimposing of ice front positions from different stages (background image: © Google Earth, capture date: 21.02.2006)



Results of radiocarbon dating of mosses enclosed in moraine material indicate that the maximum extent of Bellingshausen Dome in the late Holocene, i.e. 3500 years ago, stretched about 400 - 500 m beyond the current glacier front (Hall 2007). It has been established that the last glacial advance was in the period 250 - 450 years ago, which corresponds with the Little Ice Age in the Northern Hemisphere (Simms et al. 2012). Before then, the glacier margin lay at or behind its current position (Hall 2007). The current rapid retreat of the glacier is attributed to the regional warming of the climate that has been observed (Turner et al. 2014) and the glacier has retreated the most where the ice sends offshoots into shallow valleys (Figure 62).

Figure 63: Area of glacial retreat at Barton Peninsula between 2005 and 2011 illustrated by superimposing of ice front positions from different stages (background image: © Google Earth, capture date: 21.03.2011)

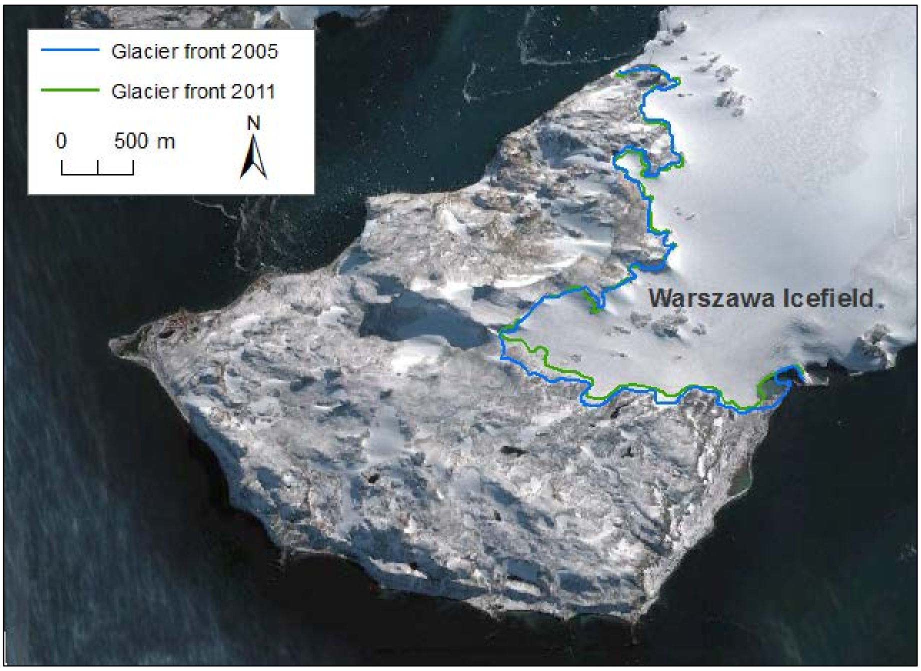
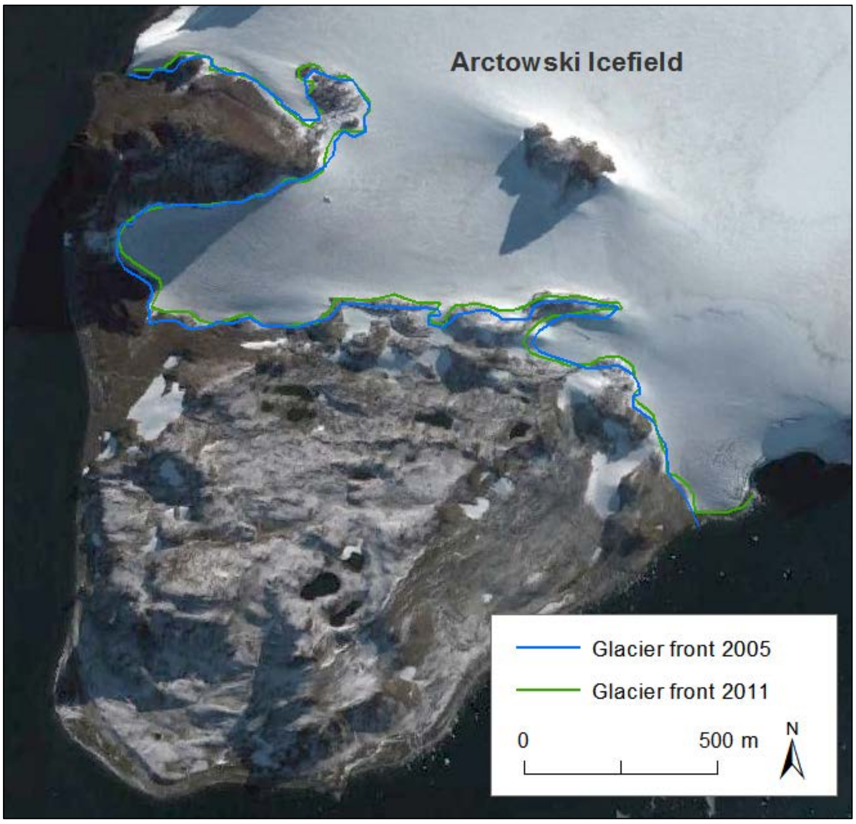


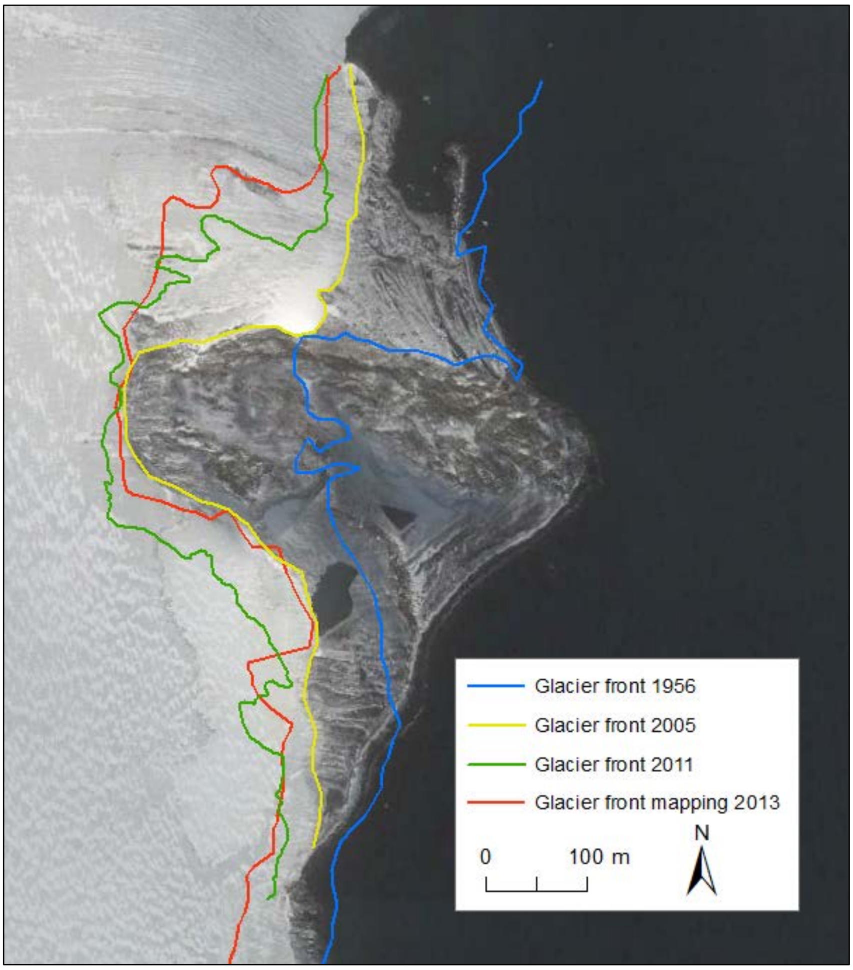
Figure 64: Area of glacial retreat at Weaver Peninsula between 2005 and 2011 illustrated by superimposing of ice front positions from different stages (background image: © Google Earth, capture date: 21.03.2011)



Despite the relatively small amount of basic data, there are indications that in the areas of Barton und Weaver Peninsulas there is also melting of the adjoining glacier tongues. On Barton Peninsula, a comparison of the available satellite images from 2005 and 2011 showed that the south-western glacier offshoot has retreated by about 150 m and also showed a retreat of about 180 m in the extreme south-west (Figure 63). In contrast, the retreat of the glacier front on Weaver Peninsula in the same period was barely 30 m (Figure 64).

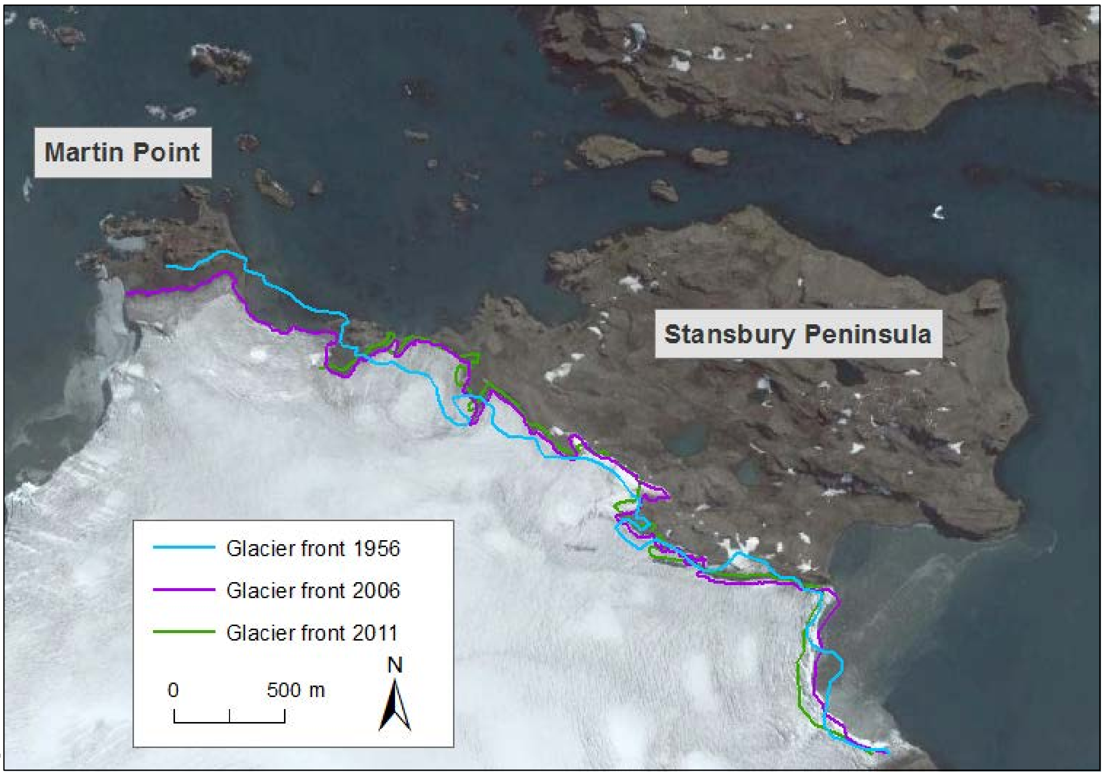
On Green Point, the glacial retreat is also clearly recognisable. Here, the glacier front retreated by between 50 m and a maximum of 400 m between 1956 and 2013 (Figure 65).

Figure 65: Area of glacial retreat at Green Point between 1956 and 2013 illustrated by superimposing of ice front positions from different stages (background image: © Google Earth, capture date: 26.03.2005)



In northern Nelson Island, glacial change is less uniform. In the Martin Point area and east of it, the glacier front retreated by up to 175 m. However, in the west and the centre of Stansbury Peninsula there is a clearly recognisable, though relatively limited, glacial advance of up to 140 m (Figure 66). This partial glacial advance might be due to more rapid glacial flow as a result of the topography of the underlying surface and conditions on the glacier dome.

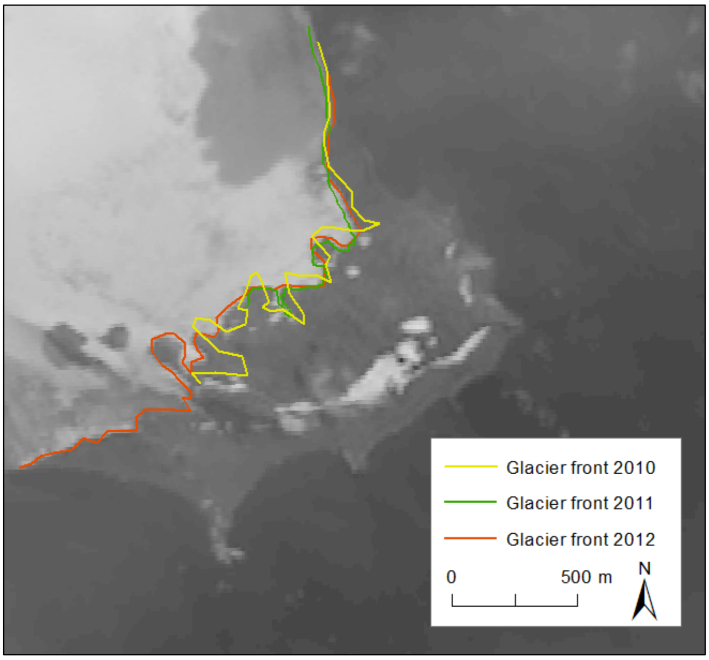
Figure 66: Area of glacial retreat at Stansbury Peninsula and Martin Point, Nelson Island, between 1956 and 2013 illustrated by superimposing of ice front positions from different stages (background image: © Google Earth, capture date: 21.02.2006)



T

As there is no early remote sensing data from Duthoit Point, it is not really possible to say anything about areas of glacial retreat here (Figure 67). However, by comparison with the results above (Figure 62 - Figure 66), a retreat of the glacier, in particular in the area of the elevation in the south-west of the peninsula, is to be expected in the near future.

Figure 67: Area of glacial retreat at Duthoit Point, Nelson Island, between 2010 and 2012 illustrated by superimposing of ice front positions from different stages (background image: WorldView01, USGS, capture date: 27.01.2012)



In general, the situation of the glaciers in the Maxwell Bay area is relatively uniform and fits in with a series of cross-regional studies that substantiate a clear retreat of the glaciers along the Antarctic Peninsula (e.g. Park et al. 1998; Calvet et al. 1999; Simoes et al. 1999; Braun et al. 2002; Simoes et al. 2004; Cook et al. 2005; Cook et al. 2010; Rückamp et al. 2011; LaRue et al. 2013; Rignot et al. 2014). It should be noted, however, that due to the current series of cooler summers in the study area, the glacial retreat has slowed or has possibly come to a halt in places. However, because precipitation is stable, no change in accumulation is to be expected.

4.7 Ecological significance of areas of glacial retreat in the region

The few ice-free terrestrial areas in the Antarctic offer space for colonisation by expanding newly arrived or introduced microorganisms, arthropods, algae, mosses, lichens and flowering plants. They also offer spaces where native seabirds and seals can rest and reproduce (Sec. 2 & 3). For this reason, the new ice-free areas created by glacial retreat are of great significance for local terrestrial ecosystems.

The melting of glaciers releases large volumes of fresh water. On land, this increases the availability of water, while in the marine environment it influences marine life and the productivity cycles in the sea due to increased transport of dissolved substances as well as the increased flow of sediment into the sea (Dierssen et al. 2002; Schloss et al. 2012; Pasotti et al. 2014).

A further consequence of continuing glacial melting is the appearance in places of fossils that had previously been hidden under the ice (Peter et al. 2008). For example, a large number of finds of well-preserved fossilised wood fragments from the border area of Bellingshausen Dome are known (Poole et al. 2001) and are present in numerous scientific collections, and also exhibited in the Chilean research station Escudero. Due to the great palaeontological significance of these sites, the entire glacial border area was designated part of ASPA No. 125

Fildes Peninsula (ATS 2009b). Because valuable new finds can be expected in this area, there is a need for appropriate palaeontological studies.

The glaciers of King George Island and Nelson Island stretch for the most part to the coastline and often reach into the sea, as for example in Marion and Potter Cove, as well as in Admiralty Bay. Due to the disappearance of the ice cover on land, areas have become available which can offer suitable conditions for colonisation by microorganisms, flora and fauna.

As a result of glacier melt, weathering and soil formation processes are being initiated on the ground that is becoming exposed. In this process, the rocky ground is subject to physical, chemical and biogenic weathering. The basis of soil formation are very fine fragments of weathered rock, which are laid in horizontal layers by wind, water and chemical processes (Stonehouse 1989). This primary soil (lithosol, regosol) is initially completely free of organic material. In contrast, developed humus-rich soils are colonised by soil bacteria, algae and other microorganisms, which ensure a cycle of dissolved minerals. The process of maturing to a humus-rich soil takes hundreds – or even thousands – of years (Stonehouse 1989).

The prevailing permafrost has a considerable influence on the soil formation processes that occur. As thawing only occurs to a very limited depth, the permafrost ensures there is ample water available, but it limits soil formation in the active surface layers that underlie the repeated thawing processes. The soils of King George Island are typified by a combination of rocky soil, fluctuations in the water budget, cryoturbation and solifluction (Olech 2004). Cryoturbation is a process typical of polar regions, which ensures substantial mixing of the upper soil layers (Peter et al. 2008) and thus hampers the formation of well-developed soil horizons (Olech 2004).

In general, fairly young mineral soils are most prevalent on King George Island (Olech 2004). The absence of well-developed organic soils is due less to the harsh climate than to the limited age of the surfaces and their limited resistance to processes of erosion, first and foremost frost-weathering (Ochyra 1998). The ornithogenic soils typical of the maritime Antarctic form on weathered stony and loamy slopes near bird colonies (Olech 2004). Due to their extraordinarily high phosphate content, they are frequently free of vegetation, but show very high microbial activity (Stonehouse 1989; Ochyra 1998; Mataloni et al. 2010). However, this microbial activity is in turn hampered by excessive phosphate concentrations, such as those that can occur in large penguin colonies (Tscherko et al. 2003). As a rule, these soils show clear layered profiles. The clearly distinguishable successive bands can be easily recognised due to their chemical and mineral composition (Olech 2004).

The developing soil types can be clearly distinguished by age, which is also reflected in colonisation by specific flora and fauna (Gryziak 2009). Frost pattern structures, for example, such as the frequently encountered polygons (Peter et al. 2008), which are created through geological sorting processes based on cryoturbation and solifluction, are usually colonised by mosses and algae, but rarely by lichens (Olech 2004). Humus formation resulting from the decomposition of plant and animal material is limited to the layers near the surface in polar regions (Stonehouse 1989) and only becomes possible if cryoturbation processes come to a halt. The accumulation of humus is increased by a stable cover of vegetation and through an accumulation of organic material, for example due to deposits of feathers, eggshells and remains of pellets (Olech 2004). Although microbial activity in the soil as well as the breakdown of organic materials are influenced by the prevailing soil temperatures (Royles et al. 2013), it is expected that only substantial warming will have significant effects (Bokhorst et al. 2007a).

The basis for successful colonisation of ice-free areas by bacteria, fungi, algae, lichens, mosses and flowering plants is the introduction of dispersal units or dormant forms (e.g. seeds or spores) into the areas made ice-free by glacial retreat. Whether they are brought by the wind or spread by birds, if these seeds or spores land on a suitable substrate, they may be able to colonise if there is sufficient availability of water and nutrients. For this reason, colonisation usually starts near existing populations. Microorganisms, plants and terrestrial arthropods have a multitude of colonisation mechanisms at their disposal. For example, springtails can survive for extended periods on water surfaces (Coulson et al. 2002a; Hawes et al. 2008) and may possibly be spread through the air over short distances (Coulson et al. 2002b; Coulson et al. 2003; Hawes et al. 2007).

The vegetation of the maritime Antarctic essentially consists of cryptogamic flora in the form of algae, lichens and mosses, most of which are bipolar or ubiquitous (Ochyra 1998). Only two species of higher plant are native here – Antarctic hair grass and Antarctic pearlwort. While various species of lichen can also colonise rocky soil, mosses and flowering plants depend on the availability of suitable soil substrates. In essence, the colonisation of a substrate by plants is limited by the availability of liquid water and nutrients in the soil. Antarctic soils are generally lacking in the nutrients needed for plant growth – nutrients that are released principally through weathering processes. Nitrogen plays an important role in this as a strongly limiting factor. For this reason ornithogenic influences, which lead to the mineral substrate being enriched with nutrients, are highly significant. Thus, soils near seabird or seal colonies show increased concentrations of nitrogen and phosphate (e.g. Tscherko et al. 2003; Mendonca et al. 2013; Ball et al. 2015; Zwolicki et al. 2015). In addition, lichen are capable of absorbing nutrients from the air (aerosols), which are transported from neighbouring seabird or seal colonies, for example. This additional introduction of nutrients significantly influences vegetation growth (Øvstedal et al. 2001; Tscherko et al. 2003). Furthermore, both colonisation of the soil and growth rates depend greatly on local UV radiation and therefore on the persistence of the snow cover (Valladares et al. 1995). In consequence, increasingly high air temperatures, which melt the snow and ensure greater water availability, increase the likelihood that new ice-free areas will be colonised by plants. Moreover, rising temperatures can lead to increased plant growth (Royles et al. 2013) and thereby to an increase in the proportion of surface biomass as well as carbon and nitrogen content (Day et al. 2008). On the other hand, higher temperatures can cause drought stress under certain circumstances (Bokhorst et al. 2007b). The presence of the two native flowering plants, Antarctic hair grass and Antarctic pearlwort, is limited to areas with relatively favourable climatic conditions (Olech 2004).

In the maritime Antarctic, colonisation by microorganisms, plants and animals of areas freed of ice by glacial retreat takes place relatively quickly (Sancho et al. 1993; Lewis Smith 1995; Sancho et al. 2004; Convey et al. 2006). Three stages of development occur in colonisation by mosses and lichens depending on how long areas have been ice-free (Favero-Longo et al. 2012). While primary communities develop within a few decades of glacier retreat, immature communities develop on soils that are 300 to 400 years old (Favero-Longo et al. 2012). In contrast, stable climax communities are only found on the oldest soils under favourable conditions (Favero-Longo et al. 2012).

The importance of lichens and mosses in the Antarctic, where the presence of vegetation in general is very limited, lies essentially in their role in soil formation processes and in the nutrient cycle. In the Antarctic Peninsula region, lichens in particular, as primary colonisers of new ice-free areas (Sancho et al. 2004; Kozeretska et al. 2010), can also encourage colonisation by further species (Molina-Montenegro et al. 2013). In addition, vegetation in the Antarctic offers valuable habitats for other organisms, for example terrestrial arthropods such as mites, water bears, springtails, etc. For example, it has been shown that colonisation by mites in the maritime Antarctic is highly dependent on vegetation cover, and some species only colonise areas that have been ice-free for several decades and that feature specific soil types. (Bölter et al. 1997; Gryziak 2009). A recent study showed similar effects relating to individual springtail species as well as for shelled amoeba, whose existence is clearly linked to specific habitat parameters, including the presence of vegetation (Russell et al. 2013; Russell et al. 2014; Mieczan et al. 2015). Biotic interactions, for example between arthropods, would seem to play a role in the structure of soil communities – a role that has so far frequently been underestimated (Caruso et al. 2013).

As space in the Antarctic that is suitable for use as resting and breeding areas for seals and seabirds is very limited, the new areas that are becoming available due to glacier melt have an important role with regard to bird and seal populations. However, the potential for colonisation by seals and birds greatly depends on the topography, the nature of the soil and the size of the area.

For their part, seals and birds, through chemical influences (excrement/guano, see above) as well as mechanical influences (destruction of plant cover, new distribution of plant material), can have a substantial effect on microbial activity in the soil and on the local vegetation, and thereby significantly influence ongoing colonisation and succession processes (Lewis Smith 1997; Tscherko et al. 2003; Olech 2004; Parnikoza et al. 2012). Thus coprophilous algae, mosses and also Antarctic hair grass grow more frequently in areas where more organic material is introduced, and also have greater biomass. (Olech 2004; Smykla et al. 2006; Smykla et al. 2007; Wang et al. 2007). In eutrophic areas, i.e. those parts of bird colonies most enriched by guano with nitrogen and phosphorous, one can find nitrophilous plant communities, dominated by the green algae species Prasiola crispa (e.g. Wang et al. 1993; Smykla et al. 2006; Smykla et al. 2007). As well as natural forces, anthropogenic factors also influence the colonisation and succession processes initiated by glacial retreat. This is especially true for regions such as King George Island that are strongly marked by human activity (Tin et al. 2009; Chwedorzewska et al. 2010; Braun et al. 2012). Human activities in this region have developed from their beginnings in the 1820s in connection with seal and whale hunting to the tourism, logistics and scientific activities of the present day. The possible introduction of non-native species as a result of human activities plays a significant role in the colonisation of local biotopes (Frenot et al. 2005; Hughes et al. 2010; Osyczka 2010; Cowan et al. 2011; Hughes et al. 2011; Chown et al. 2012; Litynska-Zajac et al. 2012), including newly-created habitats in the wake of glacial retreat. Among the introduced species already shown to be present on King George Island are grasses such as *Poa annua*, *Juncus bufonis* (Chwedorzewska 2008; Olech et al. 2011; Cuba-Diaz et al. 2013; United Kingdom 2014) and *Poa* sp. (Peter et al. 2013), as well as various insects found in the wild, such as the mosquito species *Trichocera maculipennis* (Peter et al. 2008; Chwedorzewska et al. 2013; Peter et al. 2013; Volonterio et al. 2013). An overview of all known introduced species is now published annually as part of the consultative meeting of the Antarctic Treaty Parties (United Kingdom 2010; United Kingdom et al. 2011; United Kingdom 2012, 2013, 2014, 2015).

In addition, anthropogenic influences such as soil and air contamination, the disturbance of birds and seals by visitors (Peter et al. 2008; Peter et al. 2013) or mechanical stress on the ground, or soil destruction, by walkers (Ayres et al. 2008; Peter et al. 2008; Pertierra et al. 2013) or vehicles (Johansson et al. 2008; Peter et al. 2008; Peter et al. 2013) can have considerable effects on the colonisation of these areas by flora and fauna.

4.8 Conclusion

Serious effects on the terrestrial and marine ecosystems can be expected if temperatures in the Antarctic continue to rise (e.g. Robinson et al. 2003; Ducklow et al. 2007). A rise in temperature and an accompanying increase in the amount of precipitation could extend the areas in which species are distributed or cause a range shift by species (Robinson et al. 2003; McClintock et al. 2008; LaRue et al. 2013). Native species could spread further south or to higher altitudes, while species from Subantarctic latitudes could succeed them. Such spatial shifts or expansions in the Antarctic Peninsula region have been documented, for example, for the two native flowering plants (Fowbert et al. 1994; Lewis Smith 1994; Grobe et al. 1997; Peter et al. 2008; Peter et al. 2013), as well as for the three native *Pygoscelis* penguin species (Forcada et al. 2006; Lynch et al. 2008; Lynch et al. 2012b; Korczak-Abshire et al. 2013), which is why these species are often considered to be bioindicators of local climate change. As growth rates of lichens depend strongly on temperature and on the availability of water, especially the amount of precipitation, regular monitoring of lichens can also provide valuable clues to climate change. (Sancho et al. 2007). In this context, cosmopolitan species could enable researchers to make global comparisons (Sancho et al. 2007).

An expansion of endemic flowering plants into areas originally colonised by mosses and lichens, as a result of rising temperatures, leads to higher trophic relationships and thereby to fundamental changes in the soil formation processes (Bölter 2011). In the long term the development of extensive areas of tundra vegetation is to be expected (Bölter 2011).

The major regional changes are of such complexity that it is not really possible to estimate their consequences for the plants and animals of the Antarctic Peninsula that are expected because of current climate changes. However, if the rise in temperatures continues, a loss of unique landscapes and ecosystems is to be feared.

Finally, it should be noted that the new ice-free areas created by glacier melt offer huge research possibilities for interdisciplinary investigations into the processes that are beginning there (Rückamp et al. 2011). Comprehensive monitoring programmes are needed to study the myriad changes to be expected, such as soil development and ecological developments (Bölter 2011).

5 Unanswered questions and research needs

Changes in seabird and seal populations and their reproduction rates resulting from environmental changes can only be evaluated by means of long-term monitoring programmes. The environmental effects observed over the last few decades can be particularly strongly substantiated in the western Antarctic Peninsula (Taylor et al. 1990; Meredith et al. 2005; Turner et al. 2014). Published estimates of breeding pair numbers or numbers of individual seals are often based on very few count results, which are often far apart in time.

For this reason, the long-term data from the Maxwell Bay area is of great importance to research on the effects of regional environmental influences on the local seal and seabird populations. Such research must take account of changes caused by natural factors dependent on global warming as well as changes triggered by anthropogenic factors. Due to the high level of human activity in this area, anthropogenic factors can very quickly affect the local flora and fauna. This gives particular significance to the breeding pair numbers and breeding success data of species such as the southern giant petrel and the Adélie and gentoo penguin. Because of the current population developments described, it is essential to continue monitoring seabirds and seals in the Fildes Region. There is a need for research in the following areas:

- Continuation of the standardised and GPS/GIS-supported population records of breeding and resting birds as well as seals on the Fildes Peninsula and Ardley Island, as well as in selected areas of Maxwell Bay
- Continuation of the recording of the reproduction rates of selected species in the Fildes Region
- Further investigations into the causes of population developments in the seabird and seal species present in the region.
- The recording of non-native species (e.g. grasses, arthropods)
- Documentation of the spread of Antarctic hair grass
- Checks on the previous locations of introduced grasses
- Analysis of aerial photographs and satellite images for the further documentation of areas of glacial retreat in the study area
- Documentation of colonisation by flora and fauna of areas freed of ice by glacier melt
- Acquisition and analysis of further data sources through cooperation with international scientists
- Inclusion of data from the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)
- Further records and evaluations of unknown or little-known breeding colonies in the Maxwell Bay area in order to obtain a well-founded estimate of population trends

6 References

ACAP (2010): ACAP Species assessment: Southern Giant Petrel *Macronectes giganteus*. http://www.acap.aq/en/acap-species/288-southern-giant-petrel/file, accessed on 30.05.2016.

ACAP (2014): Updated ACAP Breeding Site No. 67: Ardley Island, where a small population of Southern Giant Petrels breeds within an Antarctic Specially Protected Area. http://www.acap.aq/en/news/latest-news/1694-acap-breeding-site-no-67-ardley-island-where-a-small-population-of-southern-giant-petrels-breeds-within-an-antarctic-specially-protected-area, accessed on 30.05.2016.

ACAP (2015): Breeding site details: Nelson Island. https://data.acap.aq/breeding_site.cfm?bs_id=928, accessed on 30.05.2016.

Aguayo, A. & Torres, D. (1967): Observaciones sobre mamíferos marinos durante la Vigésima Comisión Antártica Chilena Revista de Biología Marina 13, 1-57.

Aguayo, A.L. (1968): The present status of the Antarctic Fur Seal *Arctocephalus gazella* at South Shetland Islands. Polar Rec. 19, 167-173.

Aguirre, C.A. (1995): Distribution and abundance of birds at Potter Peninsula, 25 de Mayo (King George) Island, South Shetland Islands, Antarctica. Mar. Ornithol. 23, 23-31.

Ahn, I.Y. (2011): Korean Antarctic Research in King George Island and International Cooperation. In: Proceedings of the First Workshop on Antarctic and Maritime Cooperation between Korea and Chile.

Ainley, D.G., Ribic, C.A. & Wood, R.C. (1990): A demographic study of the south polar skua *Catharacta maccormicki* at Cape Crozier. J. Anim. Ecol. 59, 1-20.

Ainley, D., Russell, J., Jenouvrier, S., Woehler, E., Lyver, P.O., Fraser, W.R. & Kooyman, G.L. (2010): Antarctic penguin response to habitat change as Earth's troposphere reaches 2 degrees C above preindustrial levels. Ecol. Monogr. 80, 49-66.

Ainley, D.G. & Pauly, D. (2014): Fishing down the food web of the Antarctic continental shelf and slope. Polar Rec. 50, 92-107.

Ainley, D., LaRue, M.A., Stirling, I., Stammerjohn, S. & Siniff, D.B. (2015): An apparent population decrease, or change in distribution, of Weddell seals along the Victoria Land coast. Mar. Mamm. Sci. 31, 1338-1361.

Amaro, E., Padeiro, A., Mao de Ferro, A., Mota, A.M., Leppe, M., Verkulich, S., Hughes, K.A., Peter, H.-U. & Canario, J. (2015): Assessing trace element contamination in Fildes Peninsula (King George Island) and Ardley Island, Antarctic. Mar. Pollut. Bull. 97, 523-527.

Araya, B. & Arrieta, A. (1971): Las aves de Caletta Potter, Isla Rey Jorge, Antártica Chilena - censo y distribución. Revista de Biologia Marina 14, 121-128.

Arnould, J.P.Y. & Croxall, J.P. (1995): Trends in Entanglement of Antarctic Fur Seals (*Arctocephalus gazella*) in Man-Made Debris at South Georgia. Mar. Pollut. Bull. 30, 707-712.

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

ATS (2004): Guidelines for the operation of aircraft near concentrations of birds. ATCM XXVII. Cape Town. Resolution 2.

ATS (2005): Guidelines for Environmental Monitoring. ATCM XXVIII. Stockholm. Resolution 2.

ATS (2009a): Management Plan for Antarctic Specially Protected Area No. 171 Narębski Point, Barton Peninsula, King George Island. ATCM XXXII. Baltimore. Measure 13.

ATS (2009b): Revised Management Plan for Antarctic Specially Protected Area No. 125 Fildes Peninsula, King George Island (25 de Mayo). ATCM XXXII. Baltimore. Measure 6.

ATS (2009c): Revised Management Plan for Antarctic Specially Protected Area No. 150 Ardley Island, Maxwell Bay, King George Island (25 de Mayo). ATCM XXXII. Baltimore. Measure 9.

ATS (2011): Site Guidelines for visitors. ATCM XXXIV. Buenos Aires. Resolution 4.

ATS (2013a): ASPA No. 132 (Potter Peninsula, King George Island (Isla 25 de Mayo), South Shetland Islands): Revised Management Plan ATCM XXXVI. Brussels. Measure 4.

ATS (2013b): ASPA No. 151 (Lions Rump, King George Island, South Shetland Islands): Revised Management Plan. ATCM XXXVI. Brussels. Measure 4.

ATS (2014): Antarctic Specially Protected Area No. 171 (Narębski Point, George Island): Revised Management Plan. ATCM XXXVII. Brasilia. Measure 11.

ATS (2015): Important Bird Areas in Antarctica. ATCM XXXVIII. Sofia. Resolution 5.

Ayres, E., Nkem, J.N., Wall, D.H., Adams, B.J., Barrett, J.E., Broos, E.J., Parsons, A.N., Powers, L.E., Simmons, B.L. & Virginia, R.A. (2008): Effects of Human Trampling on Populations of Soil Fauna in the McMurdo Dry Valleys, Antarctica. Conserv. Biol. 22, 1544-1551.

Ball, B.A., Tellez, C.R. & Virginia, R.A. (2015): Penguin activity influences soil biogeochemistry and soil respiration in rookeries on Ross Island, Antarctica. Polar Biol. 38, 1357-1368.

Bannasch, R. & Odening, K. (1981): Zoologische Untersuchungen im Gebiet der sowjetischen Antarktisstation "Bellingshausen" [Zoological investigations in the area of the soviet Antarctic base "Bellingshausen"]. Geodätische und geophysikalische Veröffentlichungen Reihe 1 8, 3-20.

Bannasch, R., Rauschert, M., Feiler, K. & Lundberg, U. (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). Unpublished expedition report, Akademie der Wissenschaften, Potsdam.

Barbosa, A., Moreno, J., Potti, J. & Merino, S. (1997): Breeding group size, nest position and breeding success in the chinstrap penguin. Polar Biol. 18, 410-414.

Barbosa, A., Benzal, J., De Leon, A. & Moreno, J. (2012): Population decline of chinstrap penguins (*Pygoscelis antarctica*) on Deception Island, South Shetlands, Antarctica. Polar Biol. 35, 1453-1457.

Barsch, D., Blümel, W.-D., Flügel, W.-A., Mäusbacher, R., Stäblein, G. & Zick, W. (1985): Untersuchungen zum Periglazial auf der König-Georg-Insel Südshetlandinseln/Antarctica. Berichte zur Polarforschung 24, 75.

Bengtson, J.L., Ferm, L.M., Harkonen, T.J., Schaner, E.G. & Stewart, B.S. (1988): Survey of Antarctic Fur Seals in the South Shetland Islands, Antarctica, during the 1986/1987 Austral Summer. NOAA Technical Memorandum NMFS-F/NEC-60.

Bingham, M. (1998): The distribution, abundance and population trends of gentoo, rockhopper and king penguins in the Falkland Islands. Oryx 32, 223-232.

BirdLife International (2015a): Important Bird Areas factsheet: Ardley Island, King George Island. http://www.birdlife.org/datazone/sitefactsheet.php?id=29408, accessed on 30.05.2016.

BirdLife International (2015b): The IUCN Red List for birds. Species factsheet. http://www.birdlife.org/datazone/species, accessed on 30.05.2016.

Birkenmajer, K. (2002): Retreat of Ecology Glacier, Admiralty Bay, King George Island (South Shetland Islands, West Antarctica), 1956-2001. Bulletin of the Polish Academy of Sciences 50, 15-29.

Blindow, N., Suckro, S.K., Ruckamp, M., Braun, M., Schindler, M., Breuer, B., Saurer, H., Simoes, J.C. & Lange, M.A. (2010): Geometry and thermal regime of the King George Island ice cap, Antarctica, from GPR and GPS. Annals of Glaciology 51, 103-109.

Boersma, P.D. (2008): Penguins as marine sentinels. Bioscience 58, 597-607.

Bokhorst, S., Huiskes, A., Convey, P. & Aerts, R. (2007a): Climate change effects on organic matter decomposition rates in ecosystems from the Maritime Antarctic and Falkland Islands. Global Change Biol. 13, 2642-2653.

Bokhorst, S., Huiskes, A., Convey, P. & Aerts, R. (2007b): The effect of environmental change on vascular plant and cryptogam communities from the Falkland Islands and the Maritime Antarctic. BMC Ecol. 7, 1-13.

Bölter, M., Blume, H.P., Schneider, D. & Beyer, L. (1997): Soil properties and distributions of invertebrates and bacteria from King George Island (Arctowski Station), maritime Antarctic. Polar Biol. 18, 295-304.

Bölter, M. (2011): Soil development and soil biology on King George Island, maritime Antarctic. Polish Polar Research 32, 105-116.

Bonner, W.N. (1985): Impact of Fur Seals on the Terrestrial Environment at South Georgia. In: W.R. Siegfried, Condy P.R. & Laws, R.M (eds.). Antarctic Nutrient Cycles and Food Webs, Springer, 641-646.

Bost, C.A. & Jouventin, P. (1990): Laying Asynchrony in Gentoo Penguins on Crozet Islands - Causes and Consequences. Ornis Scand 21, 63-70.

Boveng, P.L., Hiruki, L.M., Schwartz, M.K. & Bengtson, J.L. (1998): Population growth of Antarctic fur seals: Limitation by a top predator, the leopard seal? Ecology 79, 2863-2877.

Boyd, I.L. (1993): Pup Production and Distribution of Breeding Antarctic Fur Seals (*Arctocephalus gazella*) at South Georgia. Antarct. Sci. 5, 17-24.

Branco, J.O., Costa, E.S., de Araujo, J., Durigon, E. & Alves, M.A.S. (2009): Kelp gulls, *Larus dominicanus* (Aves: Laridae), breeding in Keller Peninsula, King George Island, Antarctic Peninsula. Zoologia 26, 562-566.

Braun, C. (ed.) (2001): Zur Avifauna des SW-Teils von King George Island, Süd-Shetland-Inseln, im Südsommer 2000/2001. Unpublished expedition report, Institut für Ökologie, Friedrich-Schiller-Universität Jena.

Braun, C. (ed.) (2008): Ökologische Untersuchungen auf der Fildes Peninsula im Rahmen des Internationales Polarjahres 2007/08. Unpublished expedition report, Institut für Ökologie, Friedrich-Schiller-Universität Jena.

Braun, C., Mustafa, O., Nordt, A., Pfeiffer, S. & Peter, H.-U. (2012): Environmental Monitoring and Management Proposals for the Fildes Region (King George Island, Antarctica). Polar Res. 31, 18206.

Braun, C., Hertel, F., Mustafa, O., Nordt, A., Pfeiffer, S. & Peter, H.-U. (2014): Environmental Situation and Management Challenges for the Fildes Peninsula Region. In: Tin, T., Liggett, D., Maher, P. & Lamers, M.E. (eds.). The Future of Antarctica: Human impacts, strategic planning, and values for conservation, Springer, Dordrecht, 169-191.

Braun, M. & Goßmann, H. (2002): Glacial changes in the area of Admiralty Bay and Potter Cove, King George Island, Antarctica. In: Beyer, M. & Boelter, M. (eds.). GeoEcology of Terrestrial Antarctic Oases, Springer Verlag, Berlin-Heidelberg, 75-89.

Braun, M. & Hock, R. (2004): Spatially distributed surface energy balance and ablation modelling on the ice cap of King George Island (Antarctica). Global Planet. Change 42, 45-58.

Bricher, P.K., Lucieer, A. & Woehler, E.J. (2008): Population trends of Adélie penguin (*Pygoscelis adeliae*) breeding colonies: a spatial analysis of the effects of snow accumulation and human activities. Polar Biol. 31, 1397-1407.

Briggs, K.T., Yoshida, S.H. & Gershwin, M.E. (1996): The influence of petrochemicals and stress on the immune system of seabirds. Regul. Toxicol. Pharmacol. 23, 145-155.

Briggs, K.T., Gershwin, M.E. & Anderson, D.W. (1997): Consequences of petrochemical ingestion and stress on the immune system of seabirds. ICES J. Mar. Sci. 54, 718-725.

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

Calvet, J., García Sellés, D. & Corbera, J. (1999): Fluctuaciones de la extensión del casquete glacial de la isla Livingston (Shetland del Sur) desde 1956 hasta 1996. Acta Geològica Hispánica 34, 365-374.

Campagna, C.I.S.P.S.G. (2008): *Mirounga leonina*. The IUCN Red List of Threatened Species. www.iucnredlist.org, accessed on 30.05.2016.

Carlini, A.R., Poljak, S., Casaux, R., Daneri, G.A. & Gasco, M. (2003): Southern elephant seals breeding at Nelson Island, South Shetland Islands. Polish Polar Research 24, 143-147.

Carlini, A.R., Daneri, G.A., Casaux, R. & Marquez, M.E.I. (2006a): Haul-out pattern of itinerant male Antarctic fur seals (*Arctocephalus gazella*) at Laurie Island, South Orkney Islands. Polar Res. 25, 139-144.

Carlini, A.R., Poljak, S., Daneri, G.A., Marquez, M.E.I. & Negrete, J. (2006b): The dynamics of male harem dominance in southern elephant seals (*Mirounga leonina*) at the South Shetland Islands. Polar Biol. 29, 796-805.

Carlini, A.R., Coria, N.R., Santos, M.M., Libertelli, M.M. & Donini, G. (2007): Breeding success and population trends in Adélie penguins in areas with low and high levels of human disturbance. Polar Biol. 30, 917-924.

Carlini, A.R., Coria, N.R., Santos, M.M., Negrete, J., Juares, M.A. & Daneri, G.A. (2009): Responses of *Pygoscelis adeliae* and *P. papua* populations to environmental changes at Isla 25 de Mayo (King George Island). Polar Biol. 32, 1427-1433.

Carneiro, A.P.B., Polito, M.J., Sander, M. & Trivelpiece, W.Z. (2010): Abundance and spatial distribution of sympatrically breeding *Catharacta* spp. (skuas) in Admiralty Bay, King George Island, Antarctica. Polar Biol. 33, 673-682.

Carneiro, A.P.B., Manica, A., Trivelpiece, W.Z. & Phillips, R.A. (2015): Flexibility in foraging strategies of Brown Skuas in response to local and seasonal dietary constraints. Journal of Ornithology 156, 625-633.

Caruso, T., Trokhymets, V., Bargagli, R. & Convey, P. (2013): Biotic interactions as a structuring force in soil communities: evidence from the micro-arthropods of an Antarctic moss model system. Oecologia 172, 495-503.

Casaux, R. & Barrera-Oro, E. (1993): The diet of the blue-eyed shag, *Phalacrocorax atriceps bransfieldensis* feeding in the Bransfield Strait. Antarct. Sci. 5, 335-338.

Casaux, R. (1998): Studies on the Antarctic Shag *Phalacrocorax atriceps bransfieldensis* at the South Shetland Islands. Cormorant Research Group Bulletin 3, 2-5.

Casaux, R. & Barrera-Oro, E. (2006): Shags in Antarctica: their feeding behaviour and ecological role in the marine food web. Antarct. Sci. 18, 3-14.

CCAMLR (2014): CEMP Standard Methods. Part I: Standard methods for monitoring parameters of predator species, Section 1: Penguins. CCAMLR Secretariat.

Chambers, L.E., Altwegg, R., Barbraud, C., Barnard, P., Beaumont, L.J., Crawford, R.J.M., Durant, J.M., Hughes, L., Keatley, M.R., Low, M., Morellato, P.C., Poloczanska, E.S., Ruoppolo, V., Vanstreels, R.E.T., Woehler, E.J. & Wolfaardt, A.C. (2013): Phenological Changes in the Southern Hemisphere. PLOS ONE 8, e75514.

Chown, S.L., Huiskes, A.H.L., Gremmen, N.J.M., Lee, J.E., Terauds, A., Crosbie, K., Frenot, Y., Hughes, K.A., Imura, S., Kiefer, K., Lebouvier, M., Raymond, B., Tsujimoto, M., Ware, C., Van de Vijverk, B. & Bergstrom, D.M. (2012): Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. PNAS 109, 4938-4943.

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, 113-116.

Chwedorzewska, K.J. (2008): *Poa annua* L. in Antarctic: searching for the source of introduction. Polar Biol. 31, 263-268.

Chwedorzewska, K.J. & Korczak, M. (2010): Human impact upon the environment in the vicinity of Arctowski Station, King George Island, Antarctica. Polish Polar Research 31, 45-60.

Chwedorzewska, K.J., Korczak-Abshire, M., Olech, M., Litynska-Zajac, M. & Augustyniuk-Kram, A. (2013): Alien invertebrates transported accidentally to the Polish Antarctic Station in cargo and on fresh foods. Polish Polar Research 34, 55-66.

Clausen, A.P. & Huin, N. (2003): Status and numerical trends of King, Gentoo, and Rockhopper Penguins breeding in the Falkland Islands. Waterbirds 26, 389-402.

Clucas, G.V., Dunn, M.J., Dyke, G., Emslie, S.D., Levy, H., Naveen, R., Polito, M.J., Pybus, O.G., Rogers, A.D. & Hart, T. (2014): A reversal of fortunes: climate change 'winners' and 'losers' in Antarctic Peninsula penguins. Sci Rep-UK 4.

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

COMNAP (2005): COMNAP Practical Guidelines for Developing and Designing Environmental Monitoring Programmes in Antarctica.

COMNAP (2006): Practical Biological Indicators of Human Impacts in Antarctica. ATCM XXIX. Edinburgh. IP088.

Convey, P. & Smith, R.I.L. (2006): Responses of terrestrial Antarctic ecosystems to climate change. Plant Ecol. 182, 1-10.

Cook, A.J., Fox, A.J., Vaughan, D.G. & Ferrigno, J.G. (2005): Retreating glacier fronts on the Antarctic Peninsula over the past half-century. Science 308, 541-544.

Cook, A.J. & Vaughan, D.G. (2010): Overview of areal changes of the ice shelves on the Antarctic Peninsula over the past 50 years. Cryosphere 4, 77-98.

Copello, S. & Quintana, F. (2003): Marine debris ingestion by Southern Giant Petrels and its potential relationships with fisheries in the Southern Atlantic Ocean. Mar. Pollut. Bull. 46, 1513-1515.

Coria, N.R., Favero, M., Silva, P. & Casaux, R. (1995): Breeding birds at Duthoit Point, Nelson Island, South Shetland Islands, Antarctica. Mar. Ornithol. 23, 61-64.

Costa, D.P., Weise, M.J. & Arnould, J.P.Y. (2006): Worldwide pinniped population status and trends. In: Estes, J.A. (ed.). Potential Influences of Whaling on the Status and Trends of Pinniped Populations, University of California Press, Berkeley, 344-359.

Costa, D.P., Huckstadt, L.A., Crocker, D.E., McDonald, B.I., Goebel, M.E. & Fedak, M.A. (2010): Approaches to Studying Climatic Change and its Role on the Habitat Selection of Antarctic Pinnipeds. Integr. Comp. Biol. 50, 1018-1030.

Costa, E.S. & Alves, M.A.S. (2008): The breeding birds of Hennequin Point: an ice-free area of Admiralty Bay (Antarctic Specially Managed Area), King George Island, Antarctica. Revista Brasileira De Ornitologia 16, 137-141.

Coulson, S.J., Hodkinson, I.D., Webb, N.R. & Harrison, J.A. (2002a): Survival of terrestrial soil-dwelling arthropods on and in seawater: implications for trans-oceanic dispersal. Funct. Ecol. 16, 353-356.

Coulson, S.J., Hodkinson, I.D., Webb, N.R., Mikkola, K., Harrison, J.A. & Pedgley, D.E. (2002b): Aerial colonization of high Arctic islands by invertebrates: the diamondback moth *Plutella xylostella* (Lepidoptera: Yponomeutidae) as a potential indicator species. Divers. Distrib. 8, 327-334.

Coulson, S.J., Hodkinson, I.D. & Webb, N.R. (2003): Aerial dispersal of invertebrates over a high-Arctic glacier foreland: Midtre Lovenbreen, Svalbard. Polar Biol. 26, 530-537.

Cowan, D.A., Chown, S.L., Convey, P., Tuffin, M., Elughes, K., Pointing, S. & Vincent, W.F. (2011): Non-indigenous microorganisms in the Antarctic: assessing the risks. Trends Microbiol. 19, 540-548.

Crawford, R.J.M., Whittington, P.A., Upfold, L., Ryan, P.G., Petersen, S.L., Dyer, B.M. & Cooper, J. (2009): Recent trends in numbers of four species of penguins at the Prince Edward Islands. Afr. J. Mar. Sci. 31, 419-426.

Creuwels, J.C.S., Stark, J.S., Woehler, E.J., van Franeker, J.A. & Ribic, C.A. (2005): Monitoring of a Southern Giant Petrel *Macronectes giganteus* Population on the Frazier Islands, Wilkes Land, Antarctica. Polar Biol. 28, 483-493.

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

Croxall, J.P., Rodwell, S. & Boyd, I.L. (1990): Entanglement in Man-Made Debris of Antarctic Fur Seals at Bird Island, South Georgia. Mar. Mamm. Sci. 6, 221-233.

Croxall, J.P., Trathan, P.N. & Murphy, E.J. (2002): Environmental Change and Antarctic Seabird Populations. Science 297, 1510-1514.

Cuba-Diaz, M., Troncoso, J.M., Cordero, C., Finot, V.L. & Rondanelli-Reyes, M. (2013): *Juncus bufonius*, a new non-native vascular plant in King George Island, South Shetland Islands. Antarct. Sci. 25, 385-386.

Culik, B.M., Wilson, R.P., Woakes, A.J. & Sanudo, F.W. (1991): Oil pollution of Antarctic penguins: Effects on energy metabolism and physiology. Mar. Pollut. Bull. 22, 388-391.

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

Day, T.A., Ruhland, C.T. & Xiong, F.S. (2008): Warming increases aboveground plant biomass and C stocks in vascular-plant-dominated Antarctic tundra. Global Change Biol. 14, 1827-1843.

De Villiers, M. (2008): Review of recent research into the effects of human disturbance on wildlife in the Antarctic and sub-Antarctic region. In: Human disturbance to wildlife in the broader Antarctic region: a review of findings. Appendix 1 to Working Paper 12 for XXXI Antarctic Treaty Consultative Meeting, Kiev.

del Hoyo, J., Elliott, A. & Sargatal, J. (1996): Handbook of the Birds of the World, Vol. 3: Hoatzin to Auks. Lynx Edicions, Barcelona.

Dierssen, H.M., Smith, R.C. & Vernet, M. (2002): Glacial meltwater dynamics in coastal waters west of the Antarctic Peninsula. P Natl Acad Sci USA 99, 1790-1795.

Ducklow, H.W., Baker, K., Martinson, D.G., Quetin, L.B., Ross, R.M., Smith, R.C., Stammerjohn, S.E., Vernet, M. & Fraser, W. (2007): Marine pelagic ecosystems: The West Antarctic Peninsula. Philos T R Soc B 362, 67-94.

Emslie, S.D., Polito, M. & Patterson, W.P. (2013): Stable isotope analysis of ancient and modern gentoo penguin egg membrane and the krill surplus hypothesis in Antarctica. Antarct. Sci. 25, 213-218.

Eppley, Z.A. (1992): Assessing Indirect Effects of Oil in the Presence of Natural Variation: The Problem of Reproductive Failure in South Polar Skuas during the Bahia Paraiso Oil Spill. Mar. Pollut. Bull. 25, 307-312.

Erfurt, J. & Grimm, H. (1990): Expeditionsbericht der 2. DDR-Antarktisexpedition, Überwinterungsteilnehmer an der 34. Sowjetischen Antarktisexpedition, Station "Bellingshausen" 1988-1990. Unpublished expedition report, Akademie der Wissenschaften, Potsdam. Tierpark Berlin.

Favero-Longo, S.E., Worland, M.R., Convey, P., Smith, R.I.L., Piervittori, R., Guglielmin, M. & Cannone, N. (2012): Primary succession of lichen and bryophyte communities following glacial recession on Signy Island, South Orkney Islands, Maritime Antarctic. Antarct. Sci. 24, 323-336.

Favero, M. (1993): Asociaciones alimentarias de la Paloma Antártica *Chionis alba* en las Islas 25 de Mayo (King George Is.) y Media Luna (Halfmoon Is.), Shetland del Sur. Actas Jorn. Comunicaciones Inv. Cientificas Antarticas 2, 55.

Favero, M. (1994): Biología reproductiva del Gaviotín Antártico (*Sterna vittata*; Gmelin, 1789) en Península Potter, Isla 25 de Mayo (King George), Islas Shetland del Sur, Antártida. Rivista Italiana di Ornitologia 64, 62.

Fielding, S., Watkins, J.L., Trathan, P.N., Enderlein, P., Waluda, C.M., Stowasser, G., Tarling, G.A. & Murphy, E.J. (2014): Interannual variability in Antarctic krill (*Euphausia superba*) density at South Georgia, Southern Ocean: 1997-2013. ICES J. Mar. Sci. 71, 2578-2588.

Forcada, J., Trathan, P.N., Reid, K. & Murphy, E.J. (2005): The effects of global climate variability in pup production of Antarctic fur seals. Ecology 86, 2408-2417.

Forcada, J., Trathan, P.N., Reid, K., Murphy, E.J. & Croxall, J.P. (2006): Contrasting population changes in sympatric penguin species in association with climate warming. Global Change Biol. 12, 411-423.

Forcada, J. & Trathan, P.N. (2009): Penguin responses to climate change in the Southern Ocean. Global Change Biol. 15, 1618-1630.

Forcada, J. & Hoffman, J.I. (2014): Climate change selects for heterozygosity in a declining fur seal population. Nature 511, 462-465.

Fowbert, J.A. & Lewis Smith, R.I. (1994): Rapid increase in native vascular plants in the Argentine Islands, Antarctic Peninsula. Arct. Alp. Res. 26, 290-296.

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

Franzke, C. (2013): Significant reduction of cold temperature extremes at Faraday/Vernadsky station in the Antarctic Peninsula. International Journal of Climatology 33, 1070-1078.

Fraser, W.R., Trivelpiece, W.Z., Ainley, D.G. & Trivelpiece, S.G. (1992): Increases in Antarctic penguin populations: reduced competition with whales or a loss of sea ice due to environmental warming? Polar Biol. 11, 525-531.

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

Fraser, W.R. & Hofmann, E.E. (2003): A predator's perspective on causal links between climate change, physical forcing and ecosystem response. Mar. Ecol. Prog. Ser. 265, 1-15.

Fraser, W.R., Patterson-Fraser, D.L., Ribic, C.A., Schofield, O. & Ducklow, H. (2013): A Nonmarine Source of Variability in Adélie Penguin Demography. Oceanography 26, 207-209.

Frenot, Y., Chown, S.L., Whinam, J., Selkirk, P.M., Convey, P., Skotnicki, M. & Bergstrom, D.M. (2005): Biological invasions in the Antarctic: extent, impacts and implications. Biological Reviews 80, 45-72.

Fröhlich, A. (2007): Monitoring program of Antarctic birds and sea mammals on Fildes Peninsula (Bellingshausen Station), King George Island April 2006 – February 2007. Unpublished Expedition Report.

Garrott, R.A., Rotella, J.J., Siniff, D.B., Parkinson, C.L. & Stauffer, G.E. (2012): Environmental variation and cohort effects in an Antarctic predator. Oikos 121, 1027-1040.

Gelatt, T. & Southwell, C.I.S.P.S.G. (2008): *Leptonychotes weddellii*. The IUCN Red List of Threatened Species. www.iucnredlist.org, accessed on 30.05.2016.

Gerber, L.R. & Hilborn, R. (2001): Catastrophic events and recovery from low densities in populations of otariids: implications for risk of extinction. Mamm. Rev. 31, 131-150.

Giese, M. (1996): Effects of human activity on Adélie penguin *Pygoscelis adeliae* breeding success. Biol. Conserv. 75, 157-164.

Gil-Delgado, J.A., González-Solís, J. & Barbosa, A. (2013a): Populations of breeding birds in Byers Peninsula, Livingston Island, South Shetland Islands. Antarct. Sci. 25, 303-306.

Gil-Delgado, J.A., Villaescusa, J.A., Diazmacip, M.E., Velazquez, D., Rico, E., Toro, M., Quesada, A. & Camacho, A. (2013b): Minimum population size estimates demonstrate an increase in southern elephant seals (*Mirounga leonina*) on Livingston Island, maritime Antarctica. Polar Biol. 36, 607-610.

Gonzalez-Solís, J., Croxall, J.P. & Wood, A.G. (2000): Foraging partitioning between giant petrels *Macronectes* spp. and its relationship with breeding population changes at Bird Island, South Georgia. Mar. Ecol. Prog. Ser. 204, 279-288.

Gorman, K.B., Erdmann, E.S., Pickering, B.C., Horne, P.J., Blum, J.R., Lucas, H.M., Patterson-Fraser, D.L. & Fraser, W.R. (2010): A new high-latitude record for the macaroni penguin (*Eudyptes chrysolophus*) at Avian Island, Antarctica. Polar Biol. 33, 1155-1158.

Graña Grilli, M. (2014): Decline in Numbers of Antarctic Skuas Breeding at Potter Peninsula, King George Island, Antarctica. Mar. Ornithol. 42, 161-162.

Grobe, C.W., Ruhland, C.T. & Day, T.A. (1997): A new population of the vascular plant *Colobanthus quitensis* (Kunth) Bartl. near Arthur Harbor, Antarctic: Correlating recruitment with warmer summer temperatures. Arctic, Antarctic and Alpine Research 29, 217-221.

Gryziak, G. (2009): Colonization by mites of glacier-free areas in King George Island, Antarctica. Pesquisa Agropecuaria Brasileira 44, 891-895.

Guinet, C., Jouventin, P. & Georges, J.Y. (1994): Long-Term Population-Changes of Fur Seals *Arctocephalus gazella* and *Arctocephalus tropicalis* on Sub-Antarctic (Crozet) and Subtropical (St-Paul and Amsterdam) Islands and Their Possible Relationship to El-Nino-Southern-Oscillation. Antarct. Sci. 6, 473-478.

Guinet, C., Jouventin, P. & Weimerskirch, H. (1999): Recent population change of the southern elephant seal at Iles Crozet and Iles Kerguelen: the end of the decrease? Antarct. Sci. 11, 193-197.

Hadley, G.L., Rotella, J.J. & Garrott, R.A. (2007): Evaluation of reproductive costs for weddell seals in Erebus Bay, Antarctica. J. Anim. Ecol. 76, 448-458.

Hahn, S., Peter, H.-U., Quillfeldt, P. & Reinhardt, K. (1998): The birds of the Potter Peninsula, King George Island, South Shetland Islands, Antarctica, 1965-1998. Mar. Ornithol. 26, 1-6.

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

Hahn, S., Reinhardt, K., Ritz, M.S., Janicke, T., Montalti, D. & Peter, H.-U. (2007): Oceanographic and climatic factors differentially affect reproduction performance of Antarctic skuas. Mar. Ecol. Prog. Ser. 334, 287-297.

Hahn, S. & Bauer, S. (2008a): Dominance in feeding territories relates to foraging success and offspring growth in brown skuas *Catharacta antarctica lonnbergi*. Behav. Ecol. Sociobiol. 62, 1149-1157.

Hahn, S., Ritz, M.S. & Reinhardt, K. (2008b): Marine foraging and annual fish consumption of a south polar skua population in the maritime Antarctic. Polar Biol. 31, 959-969.

Hall, B.L. (2007): Late-Holocene advance of the Collins Ice Cap, King George Island, South Shetland Islands. Holocene 17, 1253-1258.

Hamer, K.C., Furness, R.W. & Caldow, R.W.G. (1991): The effects of changes in food availability on the breeding ecology of great skuas *Catharacta skua* in Shetland. J. Zool. 223, 175-188.

Han, J., Jin, H., Wen, J. & Shang, X. (1995): Temperature distribution of Collins Ice Cap, King George Island, Antarctica. Advances in Polar Science 6, 57-65.

Harris, C.M., Lorenz, K., Fishpool, L.D.C., Lascelles, B., Cooper, J., Coria, N., Croxall, J.P., Emmerson, L.M., Fijn, R., Jouventin, P., LaRue, M.A., Le Maho, Y., Lynch, H.J., Naveen, R., Peter, H.-U., Poncet, S., Phillips, R.A., Southwell, C.J., Van Franeker, J.A., Weimerskirch, H., Wienecke, B. & Woehler, E.J. (2015): Important Bird Areas in Antarctica - Summary. BirdLife International and Environmental Research & Assessment Ltd., Cambridge.

Hawes, T.C., Worland, M.R., Convey, P. & Bale, B.S. (2007): Aerial dispersal of springtails on the Antarctic Peninsula: implications for local distribution and demography. Antarct. Sci. 19, 3-10.

Hawes, T.C., Worland, M.R., Bale, J.S. & Convey, P. (2008): Rafting in Antarctic Collembola. J. Zool. 274, 44-50.

Higgins, P.J. & Davies, S.J.J.F. (1996): Handbook of Australia, New Zealand and Antarctic birds. Volume 3, Snipe to Pigeons. Oxford University Press, Melbourne.

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

Hindell, M.A., Slip, D.J. & Burton, H.R. (1994): Possible causes of the decline of southern elephant seal populations in the southern Pacific and southern Indian Oceans. In: Le Boeuf, B.J. & Laws, R.M. (eds.). Elephant seals: Population ecology, behavior, and physiology, University of California Press, Berkeley, 66-85.

Hinke, J.T., Salwicka, K., Trivelpiece, S.G., Watters, G.M. & Trivelpiece, W.Z. (2007): Divergent responses in *Pygoscelis* penguins reveal a common environmental driver. Oecologia 153, 845-855.

Hinke, J.T., Polito, M.J., Reiss, C.S., Trivelpiece, S.G. & Trivelpiece, W.Z. (2012): Flexible reproductive timing can buffer reproductive success of *Pygoscelis* spp. penguins in the Antarctic Peninsula region. Mar. Ecol. Prog. Ser. 454, 91-104.

Hofmeyr, G., De Maine, M., Bester, M., Kirkman, S., Pistorius, P. & Makhado, A. (2002): Entanglement Of Pinnipeds At Marion Island, Southern Ocean: 1991-2001. Aust. Mammal. 24, 141-146.

Hofmeyr, G.J.G., Krafft, B.A., Kirkman, S.P., Bester, M.N., Lydersen, C. & Kovacs, K.M. (2005): Population changes of Antarctic fur seals at Nyroysa, Bouvetoya. Polar Biol. 28, 725-731.

Hofmeyr, G.I.S.P.S.G. (2008): *Arctocephalus gazella*. The IUCN Red List of Threatened Species. www.iucnredlist.org, accessed on 30.05.2016.

Holland, P.R. & Kwok, R. (2012): Wind-driven trends in Antarctic sea-ice drift. Nat Geosci 5, 872-875.

Holmes, N.D., Giese, M., Achurch, H., Robinson, S. & Kriwoken, L.K. (2006): Behaviour and breeding success of gentoo penguins *Pygoscelis papua* in areas of low and high human activity. Polar Biol. 29, 399-412.

Houghton, M., McQuillan, P.B., Bergstrom, D.M., Frost, L., Van den Hoff, J. & Shaw, J. (2014): Pathways of alien invertebrate transfer to the Antarctic region. Polar Biol. 39, 23-33.

Hucke-Gaete, R., Torres, R. & Vallejos, V. (1997): Entanglement of Antarctic fur seals, *Arctocephalus gazella*, in marine debris at Cape Shirreff and San Telmo Islets, Livingston Island, Antarctica: 1988-1997. Hobart, Australia: 1-20.

Hucke-Gaete, R., Osman, L.P., Moreno, C.A. & Torres, D. (2004): Examining natural population growth from near extinction: the case of the Antarctic fur seal at the South Shetlands, Antarctica. Polar Biol. 27, 304-311.

Hughes, K.A. (2010): How committed are we to monitoring human impacts in Antarctica? Environmental Research Letters 5, 1-3.

Hughes, K.A., Convey, P., Maslen, N.R. & Smith, R.I.L. (2010): Accidental transfer of non-native soil organisms into Antarctica on construction vehicles. Biol. Invasions 12, 875-891.

Hughes, K.A., Lee, J.E., Tsujimoto, M., Imura, S., Bergstrom, D.M., Ware, C., Lebouvier, M., Huiskes, A.H.L., Gremmen, N.J.M., Frenot, Y., D., B.P. & Chown, S.L. (2011): Food for thought: Risks of non-native species transfer to the Antarctic region with fresh produce. Biol. Conserv. 144, 1682-1689.

Huiskes, A.H.L., Gremmen, N.J.M., Bergstrom, D.M., Frenot, Y., Hughes, K.A., Imura, S., Kiefer, K., Lebouvier, M., Lee, J.E., Tsujimoto, M., Ware, C., Van de Vijver, B. & Chown, S.L. (2014): Aliens in Antarctica: Assessing transfer of plant propagules by human visitors to reduce invasion risk. Biol. Conserv. 171, 278-284.

Inchausti, P. & Weimerskirch, H. (2001): Risks of decline and extinction of the endangered Amsterdam albatross and the projected impact of long-line fisheries. Biol. Conserv. 100, 377-386.

Inchausti, P. & Weimerskirch, H. (2002): Dispersal and metapopulation dynamics of an oceanic seabird, the wandering albatross, and its consequences for its response to long-line fisheries. J. Anim. Ecol. 71, 765-770.

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, 17-30.

Jablonski, B. (1986): Distribution, abundance and biomass of a summer community of birds in the region of the Admiralty Bay (King George Island, South Shetland Islands, Antarctica) in 1978/1979. Polish Polar Research 7, 217-260.

Jablonski, B., Krzeminski, W. & Zdzitowiecki, K. (1987): Distribution and number of fur seals, *Arctocephalus gazella* (Peters,1875) on King George Island (South Shetland Islands). Acta Zool. Cracov. 30, 119-136.

Jablonski, B. (1995): Distribution, abundance and biology of the Antarctic Tern *Sterna vittata* Gmelin, 1789 on King George Island (South Shetland Islands). Acta Zool. Cracov. 38, 399-460.

Jabour, J. (2008): Successful Conservation - Then What? The De-Listing of *Arctocephalus* Fur Seal Species in Antarctica. Journal of International Wildlife Law & Policy 11, 1-29.

Jenkins, A., Dutrieux, P., Jacobs, S.S., McPhail, S.D., Perrett, J.R., Webb, A.T. & White, D. (2010): Observations beneath Pine Island Glacier in West Antarctica and implications for its retreat. Nat Geosci 3, 468-472.

Johansson, P. & Thor, G. (2008): Lichen species density and abundance over ten years in permanent plots in inland Dronning Maud Land, Antarctica. Antarct. Sci. 20, 115-121.

Juáres, M.A. (2013): Biología reproductiva y ecología trófica de dos especies simpátricas del género *Pygoscelis* en las Islas Shetland del Sur, Antártida, phD Thesis, Universidad Nacional de La Plata, Repositorio de la Universidad Nacional de La Plata, Buenos Aires, Argentina. http://hdl.handle.net/10915/27166.

Juáres, M.A., Santos, M.M., Negrete, J., Santos, M.R., Mennucci, J.A., Rombola, E., Longarzo, L., Coria, N.R. & Carlini, A.R. (2013): Better late than never? Interannual and seasonal variability in breeding chronology of gentoo penguins at Stranger Point, Antarctica. Polar Res. 32,

Juáres, M.A., Negrete, J., Mennucci, J.A., Perchivale, P.J., Santos, M., Moreira, E. & Coria, N.R. (2014): Further evidence of king penguins' breeding range extension at the South Shetland Islands? Antarct. Sci. 26, 261-262.

Juáres, M.A., Santos, M., Negrete, J., Mennucci, J.A., Perchivale, P.J. & Casaux, R. (2015): Adélie penguin population changes at Stranger Point: 19 years of monitoring. Antarct. Sci. 27, 455-461.

Kaiser, M., Peter, H.-U. & Gebauer, A. (1988a): Kuhreiher *Ardeola ibis* (L.) in der Antarktis. Beiträge zur Vogelkunde 34, 202-203.

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

Karnovsky, N.J., Dilling, R., Klock, S., Trivelpiece, S.G., Trivelpiece, W.Z. & Emslie, S.D. (1995): Demography studies of seabirds at Admiralty Bay, King George Island. Antarct. J. U.S. 30, 185-186.

Kerr, R.A. (2006): A worrying trend of less ice, higher seas. Science 311, 1698-1701.

Kim, J.-H., Chung, H., Kim, J.H., Yoo, J.-C. & Ahn, I.-Y. (2005): Nest Distribution of Skuas on Barton and Weaver Peninsulas of the King George Island, the Antarctic. Ocean Polar Res. 27, 443-450.

Kim, J.-H., Ahn, I.Y., Lee, K.S., Chung, H.S. & Choi, H.G. (2007): Vegetation of Barton Peninsula in the neighbourhood of King Sejong Station (King George Island, maritime Antarctic). Polar Biol. 30, 903-916.

Kim, J.-H., Park, H. & Ahn, I.-Y. (2009): Effect of Climate change on breeding ecology of skuas in the King George Island, Antarctica. Annual Report of Environmental Monitoring on Human Impacts around the King Sejong Station, Antarctica (in Korean).

Kim, J.-H. & Ahn, I.-Y. (2011a): Fluctuation of number of nest, clutch size and egg size in the South polar skua (*Catharacta maccormicki*). Annual Report of Environmental Monitoring on Human Impacts around the King Sejong Station, Antarctica (in Korean).

Kim, J.-H., Cho, H., Jung, J.-W. & Ahn, I.-Y. (2011b): Nest distribution of Southern giant petrels (*Macronectes giganteus*) on Barton Peninsula, King George Island, 2010/11. Annual Report of Environmental Monitoring on Human Impacts around the King Sejong Station, Antarctica (in Korean).

Kirkman, S.P., Bester, M.N., Pistorius, P.A., Hofmeyr, G.J.G., Jonker, F.C., Owen, R. & Strydom, N. (2003): Variation in the timing of moult in southern elephant seals at Marion Island. S. Afr. J. Wildl. Res. 33, 79-84.

Kock, K.H. (2001): The direct influence of fishing and fishery-related activities on non-target species in the Southern Ocean with particular emphasis on longline fishing and its impact on albatrosses and petrels - a review. Rev. Fish Biol. Fish. 11, 31-56.

Kokubun, N., Lee, W.Y., Kim, J.H., Takahashi, A. (2015): Chinstrap penguin foraging area associated with a seamount in Bransfield Strait, Antarctica. Polar Sci 9, 393-400.

Korczak-Abshire, M. (2010): Climate change influences on Antarctic bird populations. Papers on Global Changes 1, 53-66.

Korczak-Abshire, M., Angiel, P.J. & Wierzbicki, G. (2011): Records of white-rumped sandpiper (*Calidris fuscicollis*) on the South Shetland Islands. Polar Rec. 47, 262-267.

Korczak-Abshire, M., Wegrzyn, M., Angiel, P. & Lisowska, M. (2013): Pygoscelid penguins breeding distribution and population trends at Lions Rump rookery, King George Island. Polish Polar Research 34, 87-99.

Kozeretska, I.A., Parnikoza, I.Y., Mustafa, O., Tyschenko, O.V., Korsun, S.G. & Convey, P. (2010): Development of Antarctic herb tundra vegetation near Arctowski station, King George Island. Polar Science 3, 254-261.

Kraus, S. & Del Valle, R. (2008): Geology, tectonics and Ar-Ar ages of the magmatic dykes from Potter Peninsula (King George Island, South Shetland Islands). Reports on Polar and Marine Research 571, 20-30.

Krietsch, J., Esefeld, J., Braun, C., Lisovski, S. & Peter, H.-U. (2015): Long-term dataset reveals declines in breeding success and high fluctuations in the number of breeding pairs in two skua species breeding on King George Island. Polar Biol. 39, 573-582 .

Krylov, V.I. (1968): Morskie mlekopitajuscie i pticy v rajonie Stancii Bellingshausen [Mammals and seabirds in the vicinity of Bellingshausen station]. Inform. Bjull. Sov. Antarkt. Eksped. 71, 68-70.

Lake, S., Burton, H., Barker, R. & Hindell, M. (2008): Annual reproductive rates of Weddell seals in eastern Antarctica from 1973 to 2000. Mar. Ecol. Prog. Ser. 366, 259-270.

Lange, U. & Naumann, J. (1989): Expeditionsbericht der 1. DDR-Antarktisexpedition, Überwinterungsteilnehmer an der 33. Sowjetischen Antarktisexpedition Station Bellingshausen 1987-1989. Unpublished expedition report, Akademie der Wissenschaften, Potsdam.

LaRue, M.A., Ainley, D.G., Swanson, M., Dugger, K.M., Lyver, P.O., Barton, K. & Ballard, G. (2013): Climate Change Winners: Receding Ice Fields Facilitate Colony Expansion and Altered Dynamics in an Adélie Penguin Metapopulation. PLOS ONE 8, e60568.

Laws, R.M. (1984): Antarctic Ecology Vol. II. In., Academic Press, 621-705.

Laws, R.M. (1994): History and Present Status of Southern Elephant Seal Populations. In: Le Boeuf, B.J. & Laws, R.M. (eds.). Elephant seals: Population ecology, behavior, and physiology, University of California Press, Berkeley, 66-85.

Learmonth, J.A., MacLeod, C.D., Santos, M.B., Pierce, G.J., Crick, H.Q.P. & Robinson, R.A. (2006): Potential effects of climate change on marine mammals. Oceanography and Marine Biology - an Annual Review 44, 431-464.

Lescroel, A., Bajzak, C. & Bost, C.A. (2009): Breeding ecology of the gentoo penguin *Pygoscelis papua* at Kerguelen Archipelago. Polar Biol. 32, 1495-1505.

Lewis, M., Campagna, C. & Zavatti, J. (2004): Annual cycle and inter-annual variation in the haul-out pattern of an increasing southern elephant seal colony. Antarct. Sci. 16, 219-226.

Lewis Smith, R.I. (1988): Destruction of Antarctic Terrestrial Ecosystems by a Rapidly Increasing Fur-Seal Population. Biol. Conserv. 45, 55-72.

Lewis Smith, R.I. (1990): Signy Island as a Paradigm of Biological and Environmental Change in Antarctic Terrestrial Ecosystems. In: Kerry, K.R. & Hempel, G. (eds.). Antarctic Ecosystems: Ecological Change and Conservation, Springer Verlag, Berlin, 32-50.

Lewis Smith, R.I. (1994): Vascular plants as bioindicators of regional warming in Antarctica. Oecologia 99, 322-328.

Lewis Smith, R.I. (1995): Colonization by lichens and the development of lichen-dominated communities in the maritime Antarctic. Lichenologist 27, 473-483.

Lewis Smith, R.I. (1997): Impact of an increasing fur seal population on Antarctic plant communities: resilience and recovery. In: Antarctic Communities: Species, Structure and Survival, Cambridge University Press, 432-436.

Lisovski, S., Pavel, V., Weidinger, K. & Peter, H.-U. (2009): First breeding record of the Light-mantled Sooty Albatross (*Phoebetria palpebrata*) for the maritime Antarctic. Polar Biol. 32, 1811-1813.

Litynska-Zajac, M., Chwedorzewska, K., Olech, M., Korczak-Abshire, M. & Augustyniuk-Kram, A. (2012): Diaspores and phyto-remains accidentally transported to the Antarctic Station during three expeditions. Biodivers. Conserv. 21, 3411-3421.

Liu, J.P. & Curry, J.A. (2010): Accelerated warming of the Southern Ocean and its impacts on the hydrological cycle and sea ice. P Natl Acad Sci USA 107, 14987-14992.

Liu, X.D., Sun, L.G. & Yin, X.B. (2004): Textural and geochemical characteristics of proglacial sediments: A case study in the foreland of the Nelson Ice Cap, Antarctica. Acta Geologica Sinica-English Edition 78, 970-981.

Llano, G.A. (1971): Frontispiece. In: Burt, W.H. (ed.). Antarctic Pinnipedia, Antarctic Research Series, Volume 18. Am. Geophys. Union, Acad. Sci., Nat. Res. Counc.

Loeb, V., Siegel, V., Holm-Hansen, O., Hewitt, R., Fraser, W., Trivelpiece, W. & Trivelpiece, S. (1997): Effects of sea-ice extent and krill or salp dominance on the Antarctic food web. Nature 387, 897-900.

Lorenz, H. (1984): Reisebericht - Teil 2: Wissenschaftlicher Bericht über die Teilnahme an der 28. Sowjetischen Antarktisexpedition. Unpublished expedition report, Akademie der Wissenschaften, Potsdam.

Lumpe, P. & Weidinger, K. (2000): Distribution, numbers and breeding of birds at the northern ice-free areas of Nelson Island, South Shetland Islands, Antarctica, 1990–1992. Mar. Ornithol. 28, 41-46.

Lynch, H.J., Naveen, R. & Fagan, W.F. (2008): Censuses of penguin, Blue-eyed Shag *Phalacrocorax atriceps* and Southern Giant Petrel *Macronectes giganteus* populations on the Antarctic Peninsula, 2001-2007. Mar. Ornithol. 36, 83-97.

Lynch, H.J., Fagan, W.F., Naveen, R., Trivelpiece, S.G. & Trivelpiece, W.Z. (2009): Timing of clutch initiation in *Pygoscelis* penguins on the Antarctic Peninsula: towards an improved understanding of off-peak census correction factors. CCAMLR Sci. 16, 149-165.

Lynch, H.J., Crosbie, K., Fagan, W.F. & Naveen, R. (2010a): Spatial patterns of tour ship traffic in the Antarctic Peninsula region. Antarct. Sci. 22, 123-130.

Lynch, H.J., Fagan, W.F. & Naveen, R. (2010b): Population trends and reproductive success at a frequently visited penguin colony on the western Antarctic Peninsula. Polar Biol. 33, 493-503.

Lynch, H.J. (2012): The gentoo penguin (*Pygoscelis papua*). In: García-Borboroglu, P.G. & Boersma, P.D. (eds.). Biology and Conservation of the World's penguins, University of Washington Press, Seattle.

Lynch, H.J., Fagan, W.F., Naveen, R., Trivelpiece, W.Z. & Trivelpiece, S.G. (2012a): Differential advancement of breeding phenology in response to climate may alter staggered breeding among sympatric pygoscelid penguins. Mar. Ecol. Prog. Ser. 454, 135-145.

Lynch, H.J., Naveen, R., Trathan, P.N. & Fagan, W.F. (2012b): Spatially integrated assessment reveals widespread changes in penguin populations on the Antarctic Peninsula. Ecology 93, 1367-1377.

Lynnes, A.S., Reid, K. & Croxall, J.P. (2004): Diet and reproductive success of Adélie and chinstrap penguins: linking response of predators to prey population dynamics. Polar Biol. 27, 544-554.

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

Martinson, D.G., Stammerjohn, S.E., Iannuzzi, R.A., Smith, R.C. & Vernet, M. (2008): Western Antarctic Peninsula physical oceanography and spatio-temporal variability. Deep-Sea Res Pt Ii 55, 1964-1987.

Mataloni, G., González Garraza, G., Bölter, M., Convey, P. & Fermani, P. (2010): What shapes edaphic communities in mineral and ornithogenic soils of Cierva Point, Antarctic Peninsula? Polar Science 4, 405-419.

McClintock, J., Ducklow, H. & Fraser, W. (2008): Ecological responses to climate change on the Antarctic Peninsula. Am. Sci. 96, 302-310.

McClintock, J.B., Silva-Rodriguez, P. & Fraser, W.R. (2010): Southerly breeding in gentoo penguins for the eastern Antarctic Peninsula: further evidence for unprecedented climate-change. Antarct. Sci. 22, 285-286.

McIntyre, T., Ansorge, I.J., Bornemann, H., Plotz, J., Tosh, C.A. & Bester, M.N. (2011): Elephant seal dive behaviour is influenced by ocean temperature: implications for climate change impacts on an ocean predator. Mar. Ecol. Prog. Ser. 441, 257-272.

McMahon, C.R., Burton, H.R. & Bester, M.N. (2003): A demographic comparison of two southern elephant seal populations. J. Anim. Ecol. 72, 61-74.

McMahon, C.R., Bester, M.N., Burton, H.R., Hindell, M.A. & Bradshaw, C.J.A. (2005): Population status, trends and a re-examination of the hypotheses explaining the recent declines of the southern elephant seal *Mirounga leonina*. Mamm. Rev. 35, 82-100.

Mendonca, T., Melo, V.F., Schaefer, C.E.G.R., Simas, F.N.B. & Michel, R.F.M. (2013): Clay Mineralogy of Gelic Soils from the Fildes Peninsula, Maritime Antarctica. Soil Sci. Soc. Am. J. 77, 1842-1851.

Meredith, M.P. & King, J.C. (2005): Rapid climate change in the ocean west of the Antarctic Peninsula during the second half of the 20th century. Geophys. Res. Lett. 32, L19604.

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

Mieczan, T. & Adamczuk, M. (2015): Ecology of testate amoebae (Protists) in mosses: distribution and relation of species assemblages with environmental parameters (King George Island, Antarctica). Polar Biol. 38, 221-230.

Molina-Montenegro, M.A., Ricote-Martinez, N., Munoz-Ramirez, C., Gomez-Gonzalez, S., Torres-Diaz, C., Salgado-Luarte, C. & Gianoli, E. (2013): Positive interactions between the lichen *Usnea antarctica* (Parmeliaceae) and the native flora in Maritime Antarctica. Journal of Vegetation Science 24, 463-472.

Mönke, R. & Bick, A. (1988): Fachlicher Bericht über die Teilnahme der DDR-Biologengruppe an der 31. Sowjetischen Antarktisexpedition (SAE), Station "Bellingshausen", King-George-Island (Südshetland Inseln/Antarktis). Unpublished expedition report, Akademie der Wissenschaften, Potsdam.

Mönke, R. & Bick, A. (1990): Vorkommen des Kuhreihers, Bubulcus ibis (L.), in der Antarktis. [Records of the Cattle Egret, *Bubulcus ibis* (L.) in the Antarctic.]. Mitt. Zool. Mus. Suppl. Ann. Orn. 14, 69-79.

Montalti, D., Casaux, R., Coria, N., Soave, G. & Graña Grilli, M.G. (2009): The importance of fish in the diet of the South Polar Skua (*Stercorarius maccormicki*) at the South Shetland Islands, Antarctica. Emu 109, 305-309.

Müller-Schwarze, D. & Müller-Schwarze, C. (1975): A survey of twenty-four rookeries of pygoscelid penguins in the Antarctic Peninsula region. In: Stonehouse, B. (ed.). The biology of penguins. London, 309-320.

Murphy, E.J., Trathan, P.N., Watkins, J.L., Reid, K., Meredith, M.P., Forcada, J., Thorpe, S.E., Johnston, N.M. & Rothery, P. (2007): Climatically driven fluctuations in Southern Ocean ecosystems. P Roy Soc B-Biol Sci 274, 3057-3067.

Mustafa, O., Pfeifer, C., Peter, H.-U., Kopp, M. & Metzig, R. (2012): Vorstudie zum Monitoring von klimabedingten Veränderungen von Pinguinkolonien in der Antarktis mittels Satellitenbildern. Umweltbundesamt, Dessau-Roßlau, Texte 18/2012. http://www.umweltbundesamt.de/publikationen/vorstudie-monitoring-von-klimabedingten.

Mustafa, O., Esefeld, J., Hertel, F., Krietsch, J., Peter, H.-U., Pfeifer, C., Rümmler, M.-C. & Staeding, A.C. (2014): Mapping of *Pygoscelis* penguins by using an UAV in the vicinity of southwestern King George Island. SCAR Open Science Conference, Auckland.

Nadler, T. & Mix, H. (1989): Fachlicher Bericht über die Teilnahme der DDR-Biologengruppe an der 32. Sowjetischen Antarktisexpedition, Station Bellingshausen, King George Island, Südshetland-Inseln. Unpublished expedition report, Akademie der Wissenschaften, Potsdam.

NASA (2014): Landsat 7 Science Data Users Handbook: http://landsathandbook.gsfc.nasa.gov/pdfs/Landsat7_Handbook.pdf. accessed on 30.05.2016.

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

Naveen, R., Lynch, H.J., Forrest, S., Mueller, T. & Polito, M. (2012): First direct, site-wide penguin survey at Deception Island, Antarctica, suggests significant declines in breeding chinstrap penguins. Polar Biol. 35, 1879-1888.

Nel, D.C., Ryan, P.G., Nel, J.L., Klages, N., Wilson, R.P., Robertson, G. & Tuck, G.N. (2002): Foraging interactions between Wandering Albatrosses *Diomedea exulans* breeding on Marion Island and long-line fisheries in the southern Indian Ocean. Ibis 144, 141-154.

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

Norway (2013): ASPA 132 Revised Management Plan. ATCM XXXVI. Brussels. WP056 att082.

Ochyra, R. (1998): The moss flora of King George Island Antarctica. W. Szafer Institute of Botany, Polish Academy of Sciences, Cracow.

Olech, M. (2004): Lichens of King George Island, Antarctica. The Institute of Botany of the Jagiellonian University, Krakow.

Olech, M. & Chwedorzewska, K.J. (2011): The first appearance and establishment of an alien vascular plant in natural habitats on the forefield of a retreating glacier in Antarctica. Antarct. Sci. 23, 153-154.

Osmanoglu, B., Braun, M., Hock, R. & Navarro, F.J. (2013): Surface velocity and ice discharge of the ice cap on King George Island, Antarctica. Annals of Glaciology 54, 111-119.

Osyczka, P. (2010): Alien lichens unintentionally transported to the "Arctowski" station (South Shetlands, Antarctica). Polar Biol. 33, 1067-1073.

Otley, H.M. (2005): Nature-based tourism: experiences at the Volunteer Point penguin colony in the Falkland Islands. Mar. Ornithol. 33, 181-187.

Øvstedal, D.O. & Lewis-Smith, R.I. (2001): Lichens of Antarctica and South Georgia - A Guide to their Identification and Ecology. Cambridge University Press, Cambridge.

Paolo, F.S., Fricker, H.A. & Padman, L. (2015): Volume loss from Antarctic ice shelves is accelerating. Science 348, 327-331.

Park, B.K., Chang, S.K., Yoon, H.I. & Chung, H. (1998): Recent retreat of ice cliffs, King George Island, South Shetland Islands, Antarctic Peninsula. In. Annals of Glaciology, International Glaciological Society, Cambridge, 633-635.

Parkinson, C.L. & Cavalieri, D.J. (2012): Antarctic sea ice variability and trends, 1979–2010. The Cryosphere 6, 871-880.

Parmelee, D.F. (1988): The hybrid skua: a southern ocean enigma. Wilson Bull. 100, 345-356.

Parnikoza, I., Dykyy, I., Ivanets, V., Kozeretska, I., Kunakh, V., Rozhok, A., Ochyra, R. & Convey, P. (2012): Use of *Deschampsia antarctica* for nest building by the kelp gull in the Argentine Islands area (maritime Antarctica) and its possible role in plant dispersal. Polar Biol. 35, 1753-1758.

Pasotti, F., Manini, E., Giovannelli, D., Wölfl, A.-C., Monien, D., Verleyen, E., Braeckman, U., Abele, D. & Vanreusel, A. (2014): Antarctic shallow water benthos in an area of recent rapid glacier retreat. Mar. Ecol. 1-18.

Patterson, D.L., Woehler, E., Croxall, J., Cooper, J., Poncet, S., Peter, H.-U., Hunter, S. & Fraser, W.R. (2008): Breeding distribution and population status of the northern giant petrel *Macronectes halli* and the southern giant petrel *M. giganteus*. Mar. Ornithol. 36, 115-124.

Pearson, M. (2007): Conservation Challenges in the South Shetland Islands, Antarctica. ICOMOS Extreme Heritage Conference. Australia

Pereira de Albuquerque, M., Victoria, F.C., Schunemann, A.L., Putzke, J., Gunski, R.J., Seibert, S., Petry, M.V. & Pereira, A.B. (2012): Plant Composition of Skuas Nests at Hennequin Point, King George Island, Antarctica. American Journal of Plant Sciences 3, 688-692.

Pertierra, L., Lara, F., Tejedo, P., Quesada, A. & Benayas, J. (2013): Rapid denudation processes in cryptogamic communities from Maritime Antarctica subjected to human trampling. Antarct. Sci. 25, 318-328.

Peter, H.-U., Kaiser, M. & Gebauer, A. (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., Bannasch, R., Bick, A., Gebauer, A., Kaiser, M., Mönke, R. & Zippel, D. (1989): Bestand und Reproduktion ausgewählter antarktischer Vögel und Robben im Südwestteil von King George Island. Wissenschaftliche Zeitschrift Universität Jena Naturwissenschaftliche Reihe 38, 647-659.

Peter, H.-U., Kaiser, M. & Gebauer, A. (1991): Breeding ecology of the Southern Giant Petrels *Macronectes giganteus* on King George Island, South Shetland Islands, Antarctic. Zoologisches Jahrbuch Systematik 118, 465 - 477.

Peter, H.-U., Büßer, C., Mustafa, O. & Pfeiffer, S. (2008): Risk assessment for the Fildes Peninsula and Ardley Island, and the development of management plans for their designation as Antarctic Specially Protected or Specially Managed Areas. German Federal Environment Agency, Dessau-Roßlau, Texte 20/2008. http://www.umweltbundesamt.de/publikationen/risk-assessment-for-fildes-peninsula-ardley-island.

Peter, H.-U., Braun, C., Janowski, S., Nordt, A., Nordt, A. & Stelter, M. (2013): The current environmental situation and proposals for the management of the Fildes Peninsula Region. German Federal Environment Agency, Dessau-Roßlau, Texte 03/2013. http://www.umweltbundesamt.de/publikationen/current-environmental-situation-proposals-for.

Petry, M.V., Basler, A.B., Valls, F.C.L. & Kruger, L. (2013): New southerly breeding location of king penguins (*Aptenodytes patagonicus*) on Elephant Island (Maritime Antarctic). Polar Biol. 36, 603-606.

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

Pfeiffer, S. (2005): Effects of Human Activities on Southern Giant Petrels and Skuas in the Antarctic, PhD Thesis, University of Jena.

Phillips, R.A., Caldow, R.W.G. & Furness, R.W. (1996): The influence of food availability on the breeding effort and reproductive success of Arctic Skuas *Stercorarius parasiticus*. Ibis 138, 410-419.

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

Poole, I., Hunt, R.J. & Cantrill, D.J. (2001): A fossil wood flora from King George Island: Ecological implications for an Antarctic Eocene vegetation. Ann. Bot. 88, 33-54.

Popov, L.P. (1977): Kergelenskij juznyj morskoj kotik o. King-Dzordz. Inform. Bjull. Sov. Antarkt. Eksped. 96, 66-71.

Proffitt, K.M., Garrot, R.A., Rotella, J.J. & Wheatley, E. (2007): Environmental and senescent related variations in Weddell seal body mass: implications for age-specific reproductive performance. Oikos 116, 1683-1690.

Quintana, F., Punta, G., Copello, S. & Yorio, P. (2006): Population status and trends of Southern Giant Petrels (*Macronectes giganteus*) breeding in north Patagonia, Argentina. Polar Biol. 30, 53-59.

Ratcliffe, N. & Trathan, P. (2011): A review of the diet and at-sea distribution of penguins breeding within the CAMLR Convention Area. CCAMLR Sci. 18, 75-114.

Rauschert, M., Zippel, D. & Gruner, M. (1987): Reisebericht - Teil 2: Fachlicher Bericht über die Teilnahme der Biologengruppe der DDR an der 30. Sowjetischen Antarktisexpedition (SAE), Station "Bellingshausen", King George Island (Südshetlandinseln/Antarktis). Unpublished expedition report, Akademie der Wissenschaften, Potsdam.

Reid, T. & Huin, N. (2005): Census of the Southern Giant-Petrel Population of the Falkland Islands Falkland Conservation.

Reid, T.A. & Huin, N. (2008): Census of the Southern Giant Petrel population of the Falkland Islands 2004/2005. Bird Conservation International 18, 118-128.

Reinhardt, K. (1997): Food and feeding of Antarctic skua chicks *Catharacta antarctica lonnbergi* and *C. maccormicki*. Journal of Ornithology 138, 199-213.

Reinhardt, K., Blechschmidt, K., Peter, H.-U. & Montalti, D. (1997): A hitherto unknown hybridization between Chilean and South Polar skua. Polar Biol. 17, 114-118.

Reinhardt, K., Hahn, S., Peter, H.-U. & Wemhoff, H. (2000): A review of the diets of Southern Hemisphere skuas. Mar. Ornithol. 28, 7-19.

Republic of Korea (2008): Proposal for a new Antarctic Specially Protected Area at Narębski Point, Barton Peninsula, King George Island. ATCM XXXI. Kyiv. WP003.

Republic of Korea (2011): Fauna Survey of the ASPA 171 Narębski Point and ASPA 132 Potter Peninsula in 2010-11. ATCM XXXIV. Buenos Aires. IP115.

Republic of Korea (2013): Management Report of Narębski Point (AS 2012/2013 period. ATCM XXXVI. Brussels. IP026 rev.1.

Republic of Korea (2014): Monitoring and Management Report of Narębski Point (AS 171) during the past 5 years (2009-2014). ATCM XXXVII. Brasilia. BP07.

Rignot, E., Jacobs, S., Mouginot, J. & Scheuchl, B. (2013): Ice-Shelf Melting Around Antarctica. Science 341, 266-270.

Rignot, E., Mouginot, J., Morlighem, M., Seroussi, H. & Scheuchl, B. (2014): Widespread, rapid grounding line retreat of Pine Island, Thwaites, Smith, and Kohler glaciers, West Antarctica, from 1992 to 2011. Geophys. Res. Lett. 41, 3502-3509.

Rin, J.W., Qin, D.H., Petit, J.R., Jouzel, J., Wang, W.T., Liu, C., Wang, X.J., Qian, S.L. & Wang, X.X. (1995): Glaciological Studies on Nelson Island, South-Shetland Islands, Antarctica. Journal of Glaciology 41, 408-412.

Ritz, M.S., Hahn, S., Janicke, T. & Peter, H.-U. (2006): Hybridisation between South polar skua (*Catharacta maccormicki*) and Brown skua (*C. antarctica lonnbergi*) in the Antarctic Peninsula region. Polar Biol. 29, 153-159.

Robinson, S.A., Wasley, J. & Tobin, A.K. (2003): Living on the edge – plants and global change in continental and maritime Antarctica. Global Change Biol. 9, 1681-1717.

Royles, J., Amesbury, M.J., Convey, P., Griffiths, H., Hodgson, D.A., Leng, M.J. & Charman, D.J. (2013): Plants and Soil Microbes Respond to Recent Warming on the Antarctic Peninsula. Curr. Biol. 23, 1702-1706.

Rückamp, M., Braun, M., Suckro, S. & Blindow, N. (2011): Observed glacial changes on the King George Island ice cap, Antarctica, in the last decade. Global Planet. Change 79, 99-109.

Rümmler, M.-C., Mustafa, O., Maercker, J., Peter, H.-U. & Esefeld, J. (2015): Measuring the influence of unmanned aerial vehicles on Adélie penguins. Polar Biol. published online.

Russell, D.J., Hohberg, K., Otte, V., Christian, A., Potapov, M., Brückner, A. & McInnes, S.J. (2013): Der Einfluss menschlicher Aktivitäten auf Bodenorganismen der maritimen Antarktis und die Einschleppung von fremden Arten in die Antarktis Umweltbundesamt, Dessau-Roßlau, Texte 21/2013. http://www.umweltbundesamt.de/publikationen/einfluss-menschlicher-aktivitaeten-auf.

Russell, D., Hohberg, K., Potapov, M., Bruckner, M., Otte, V. & Christian, A. (2014): Native terrestrial invertebrate fauna from the northern Antarctic Peninsula: new records, state of current knowledge and ecological preferences – Summary of a German federal study. Soil Organisms 86, 1-58.

Salwicka, K. & Rakusa-Suszczewski, S. (2002): Long-term monitoring of Antarctic pinnipeds in Admiralty Bay (South Shetlands, Antarctica). Acta Theriologica 47, 443-457.

Samiullah, Y. (1985): Biological Effects of Marine Oil Pollution. Oil & Petrochemical Pollution 2, 235-264.

Sancho, L.G. & Valladares, F. (1993): Lichen Colonization of Recent Moraines on Livingston-Island (South-Shetland-I, Antarctica). Polar Biol. 13, 227-233.

Sancho, L.G. & Pintado, A. (2004): Evidence of high annual growth rate for lichens in the maritime Antarctic. Polar Biol. 27, 312-319.

Sancho, L.G., Green, T.G.G. & Pintado, A. (2007): Slowest to fastest: Extreme range in lichen growth rates supports their use as an indicator of climate change in Antarctica. Flora 202, 667-673.

Sander, M., Carneiro, A.P.B., Balbao, T.C., Bays, S.R., Costa, E.S., Mascarello, N.E., Oliva, T.S. & dos Santos, C.R. (2005): Status and Trends of Antarctic Seabirds at Admiralty Bay, King George Island. Polarforschung 75, 145-150.

Sander, M., Carneiro, A.P.B., Mascarello, N.E., dos Santos, C.R., Costa, E.S. & Balbao, T.C. (2006): Distribution and status of the kelp gull, *Larus dominicanus* Lichtenstein (1823), at Admiralty Bay, King George Island, South Shetland, Antarctica. Polar Biol. 29, 902-904.

Sander, M., Balbao, T.C., Costa, E.S., dos Santos, C.R. & Petry, M.V. (2007a): Decline of the breeding population of *Pygoscelis antarctica* and *Pygoscelis adeliae* on Penguin Island, South Shetland, Antarctica. Polar Biol. 30, 651-654.

Sander, M., Balbao, T.C., Polito, M.J., Costa, E.S. & Carneiro, A.P.B. (2007b): Recent decrease in chinstrap penguin (*Pygoscelis antarctica*) populations at two of Admiralty Bay's islets on King George Island, South Shetland Islands, Antarctica. Polar Biol. 30, 659-661.

Scambos, T.A., Bohlander, J.A., Shuman, C.A. & Skvarca, P. (2004): Glacier acceleration and thinning after ice shelf collapse in the Larsen B embayment, Antarctica. Geophys. Res. Lett. 31, L18402.

Schloss, I.R., Abele, D., Moreau, S., Demers, S., Bers, A.V., Gonzalez, O. & Ferreyra, G.A. (2012): Response of phytoplankton dynamics to 19-year (1991-2009) climate trends in Potter Cove (Antarctica). J. Mar. Syst. 92, 53-66.

Schmidtko, S., Heywood, K.J., Thompson, A.F. & Aoki, S. (2014): Multidecadal warming of Antarctic waters. Science 346, 1227-1231.

Schofield, O., Ducklow, H.W., Martinson, D.G., Meredith, M.P., Moline, M.A. & Fraser, W.R. (2010): How Do Polar Marine Ecosystems Respond to Rapid Climate Change? Science 328, 1520-1523.

Schuster, K.C. (2010): Impact of Human and Other Disturbance on Behaviour and Heart Rate of Incubating Adélie Penguins (*Pygoscelis adeliae*), PhD Thesis, Philips-Universität Marburg.

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

Scott, J.J. & Kirkpatrick, J.B. (2005): Changes in Subantarctic Heard Island Vegetation at Sites Occupied by *Poa annua*, 1987–2000. Arct. Antarct. Alp. Res. 37, 366-371.

Shaughnessy, P.D., Erb, E. & Green, K. (1998): Continued increase in the population of Antarctic fur seals, *Arctocephalus gazella*, at Heard Island, Southern Ocean. Mar. Mamm. Sci. 14, 384-389.

Shepherd, A., Ivins, E.R., Geruo, A., Barletta, V.R., Bentley, M.J., Bettadpur, S., Briggs, K.H., Bromwich, D.H., Forsberg, R., Galin, N., Horwath, M., Jacobs, S., Joughin, I., King, M.A., Lenaerts, J.T.M., Li, J.L., Ligtenberg, S.R.M., Luckman, A., Luthcke, S.B., McMillan, M., Meister, R., Milne, G., Mouginot, J., Muir, A., Nicolas, J.P., Paden, J., Payne, A.J., Pritchard, H., Rignot, E., Rott, H., Sorensen, L.S., Scambos, T.A., Scheuchl, B., Schrama, E.J.O., Smith, B., Sundal, A.V., van Angelen, J.H., van de Berg, W.J., van den Broeke, M.R., Vaughan, D.G., Velicogna, I., Wahr, J., Whitehouse, P.L., Wingham, D.J., Yi, D.H., Young, D. & Zwally, H.J. (2012): A Reconciled Estimate of Ice-Sheet Mass Balance. Science 338, 1183-1189.

Shuford, W.D. & Spear, L.B. (1988a): Surveys of breeding chinstrap penguins in the South Shetland Islands, Antarctica. British Antarctic Survey Bulletin 81, 19-30.

Shuford, W.D. & Spear, L.B. (1988b): Surveys of breeding penguins and other seabirds in the South Shetland Islands, Antarctica, Jan.-Feb. 1987. U.S. National Oceanic and Atmospheric Administration. Technical Memorandum 59.

Sierakowski, K. (1991): Birds and mammals in the region of SSSI No. 8 in the season 1988/89 (South Shetlands, King George Island, Admiralty Bay). Polish Polar Research 12, 25-54.

Silva, M.P., Coria, N.R., Favero, M. & Casaux, R.J. (1995): New records of Cattle Egret *Bubulcus ibis*, Black-necked Swan *Cygnus melanocoryphus* and Whiterumped Sandpiper *Calidris fuscicollis* from the South Shetland Islands, Antarctica. Mar. Ornithol. 23, 65-66.

Simms, A.R., Ivins, E.R., DeWitt, R., Kouremenos, P. & Simkins, L.M. (2012): Timing of the most recent Neoglacial advance and retreat in the South Shetland Islands, Antarctic Peninsula: insights from raised beaches and Holocene uplift rates. Quaternary Science Reviews 47, 41-55.

Simoes, J.C., Bremer, U.F., Aquino, F.E. & Ferron, F.A. (1999): Morphology and variations of glacial drainage basins in the King George Island ice field, Antarctica. In. Annals of Glaciology, International Glaciological Society, Cambridge, 220-224.

Simoes, J.C., Dani, N., Bremer, U.F., Aquino, F.E. & Arigony-Neto, J. (2004): Small cirque glaciers retreat on Keller Peninsula, Admiralty Bay, King George Island, Antarctica. Pesqui. Antart. Bras. 4, 49-56.

Simonov, I.M. (1973): Zivotnyj mir poluostrova Fajlds [The wildlife of Fildes Peninsula]. Trudy arkt. y antarkt. naucno-issled. Inst., Leningrad 318, 183-192.

Siniff, D.B., Garrott, R.A., Rotella, J.J., Fraser, W.R. & Ainley, D.G. (2008): Opinion: Projecting the effects of environmental change on Antarctic seals. Antarct. Sci. 20, 425-435.

Slip, D.J. & Burton, H.R. (1999): Population status and seasonal haul out patterns of the southern elephant seal (*Mirounga leonina*) at Heard Island. Antarct. Sci. 11, 38-47.

Smith, R.C., Fraser, W.R. & Stammerjohn, S. (2003): Climate variability and ecological response of the marine ecosystem in the Western Antarctic Peninsula (WAP) region. In: Greenland, D., Goodin, D.G. & Smith, R.C. (eds.). Climatic variability and ecosystem response at long-term ecological research sites, Oxford University Press, Oxford, 158-173.

Smykla, J., Wolek, J., Barcikowski, A. & Loro, P. (2006): Vegetation patterns around penguin rookeries at Admirality Bay, King George Island, Maritime Antarctic: Preliminary results. Polish Botanical Studies 22, 449-458.

Smykla, J., Wolek, J. & Barcikowski, A. (2007): Zonation of Vegetation Related to Pengiun Rookeries on King George Island, Maritime Antarctic. Arctic, Antarctic and Alpine Research 39, 143-151.

Soave, G.E., Coria, N.R., Montalti, D. & Curtosi, A. (2000): Breeding flying birds in the region of the Fildes Peninsula, King George Island, South Shetland Islands, Antarctica, 1995/96. Mar. Ornithol. 28, 37-40.

Sobiech, J., Blindow, N., Rückamp, N. & Suckro, S. (2010): Geometry and Glacial Hydrology of Bellingshausen Dome, King George Island, Antarctica. Poster, presented at International Polar Year Oslo Science Conference, Oslo, Norway, 8-12 June 2010.

Sobota, I., Kejna, M. & Arazny, A. (2015): Short-term mass changes and retreat of the Ecology and Sphinx glacier system, King George Island, Antarctic Peninsula. Antarct. Sci. 27, 500-510.

Stammerjohn, S.E., Martinson, D.G., Smith, R.C. & Iannuzzi, R.A. (2008): Sea ice in the western Antarctic Peninsula region: Spatio-temporal variability from ecological and climate change perspectives. Deep-Sea Res Pt Ii 55, 2041-2058.

Stammerjohn, S., Massom, R., Rind, D. & Martinson, D. (2012): Regions of rapid sea ice change: An inter-hemispheric seasonal comparison. Geophys. Res. Lett. 39, L06501.

Stonehouse, B. (1989): Polar Ecology. Chapman and Hall, New York.

Sullivan, B.J., Reid, T.A. & Bugoni, L. (2006): Seabird mortality on factory trawlers in the Falkland Islands and beyond. Biol. Conserv. 131, 495-504.

Sun, L., Xie, Z. & J., Z. (2000): A 3,000-year record of penguin populations. Nature 407, 358.

Taylor, R.H. & Wilson, P.R. (1990): Recent increase and southern expansion of Adélie penguin populations in the Ross sea, Antarctica, related to climate warming. N. Z. J. Ecol. 14, 25-29.

Testa, J.W., Oehlert, G., Ainley, D.G., Bengtson, J.L., Siniff, D.B., Laws, R.M. & Rounsevell, D. (1991): Temporal Variability in Antarctic Marine Ecosystems - Periodic Fluctuations in the Phocid Seals. Can. J. Fish. Aquat. Sci. 48, 631-639.

Thompson, D.W.J. & Solomon, S. (2002): Interpretation of recent Southern Hemisphere climate change. Science 296, 895-899.

Tin, T., Fleming, Z.L., Hughes, K.A., Ainley, D.G., Convey, P., Moreno, C.A., Pfeiffer, S., Scott, J. & Snape, I. (2009): Impacts of local human activities on the Antarctic environment. Antarct. Sci. 21, 3-33.

Torres, D., Gajardo, M. & Valencia, J. (1986): Notes on *Bubulcus ibis* and *Eudyptes chrysolophus* from South Shetland Islands. Serie Cientifica del Instituto Antártico Chileno (INACH) 34, 73-79.

Trathan, P.N., Croxall, J.P. & Murphy, E.J. (1996): Dynamics of Antarctic penguin populations in relation to inter-annual variability in sea ice distribution. Polar Biol. 16, 321-330.

Trathan, P.N., Forcada, J. & Murphy, E.J. (2007): Environmental forcing and Southern Ocean marine predator populations: effects of climate change and variability. Philos T R Soc B 362, 2351-2365.

Trathan, P.N., Forcada, J., Atkinson, R., Downie, R.H. & Shears, J.R. (2008): Population assessments of gentoo penguins (*Pygoscelis papua*) breeding at an important Antarctic tourist site, Goudier Island, Port Lockroy, Palmer Archipelago, Antarctica. Biol. Conserv. 141, 3019-3028.

Trathan, P.N., Ratcliffe, N. & Masden, E.A. (2012): Ecological drivers of change at South Georgia: the krill surplus, or climate variability. Ecography 35, 983-993.

Trivelpiece, W.Z., Trivelpiece, S.G. & Volkman, N.J. (1987): Ecological Segregation of Adélie, Gentoo, and Chinstrap Penguins at King-George-Island, Antarctica. Ecology 68, 351-361.

Trivelpiece, S.G., Dilling, R., Mader, T., Trivelpiece, W.Z. & Yanega, G. (1995): Seabird behavior, ecology, and demography at Admiralty Bay, King George Island. Antarct. J. U.S. 30, 183-184.

Trivelpiece, W.Z., Hinke, J.T., Miller, A.K., Reiss, C.S., Trivelpiece, S.G. & Watters, G.M. (2011): Variability in krill biomass links harvesting and climate warming to penguin population changes in Antarctica. P Natl Acad Sci USA 108, 7625-7628.

Tscherko, D., Bolter, M., Beyer, L., Chen, J., Elster, J., Kandeler, E., Kuhn, D. & Blume, H.P. (2003): Biomass and enzyme activity of two soil transects at King George Island, maritime Antarctica. Arctic Antarctic and Alpine Research 35, 34-47.

Turner, J., Bindschadler, R.A., Convey, P., Di Prisco, G., Fahrbach, E., Gutt, J., Hodgson, D.A., Mayewski, P.A. & Summerhayes, C.P. (eds.) (2009): Antarctic Climate Change and the Environment. SCAR, Cambridge.

Turner, J., Colwell, S.R., Marshall, G.J., Lachlan-Cope, T.A., Carleton, A.M., Jones, P.D., Lagun, V., Reid, P.A. & Iagovkina, S. (2005a): Antarctic climate change during the last 50 years. International Journal of Climatology 25, 279-294.

Turner, J., Lachlan-Cope, T., Colwell, S. & Marshall, G.J. (2005b): A positive trend in western Antarctic Peninsula precipitation over the last 50 years reflecting regional and Antarctic-wide atmospheric circulation changes. Ann Glaciol-Ser 41, 85-91.

Turner, J., Maksym, T., Phillips, T., Marshall, G.J. & Meredith, M.P. (2013): The impact of changes in sea ice advance on the large winter warming on the western Antarctic Peninsula. Int. J. Climatol. 33, 852-861.

Turner, J., Barrand, N.E., Bracegirdle, T.J., Convey, P., Hodgson, D.A., Jarvis, M., Jenkins, A., Marshall, G., Meredith, M.P., Roscoe, H., Shanklin, J., French, J., Goosse, H., Guglielmin, M., Gutt, J., Jacobs, S., Kennicutt, M.C., Masson-Delmotte, V., Mayewski, P., Navarro, F., Robinson, S., Scambos, T., Sparrow, M., Summerhayes, C., Speer, K. & Klepikov, A. (2014): Antarctic climate change and the environment: an update. Polar Rec. 50, 237-259.

United Kingdom (2010): Colonisation status of known non-native species in the Antarctic terrestrial environment. ATCM XXXIII. Punta del Este. IP042.

United Kingdom (2012): Colonisation status of known non-native species in the Antarctic terrestrial environment (updated 2012). ATCM XXXV. Hobart. IP029.

United Kingdom (2013): Colonisation status of known non-native species in the Antarctic terrestrial environment (updated 2013). ATCM XXXVI. Brussels. IP028.

United Kingdom (2014): Colonisation status of known non-native species in the Antarctic terrestrial environment (updated 2014). ATCM XXXVII. Brasilia. IP023.

United Kingdom (2015): Colonisation status of known non-native species in the Antarctic terrestrial environment: a review. ATCM XXXVIII. Sofia. IP046.

United Kingdom & Uruguay (2011): Colonisation status of known non-native species in the Antarctic terrestrial environment (updated 2011). ATCM XXXIV. Buenos Aires. IP050.

Valencia, J. & Torres, H. (1996): Avances en el desarollo del proyecto "Ecologia de tres especies de pingüinos Pygoscelidos" [Progress of the project "Ecology of three pygoscelid penguin species"]. Bol. Antart. Chil. 15, 2-4.

Valladares, F. & Sancho, L.G. (1995): Lichen colonization and recolonization of two recently deglaciated zones in the maritime Antarctic. Lichenologist 27, 485-493.

Vaughan, D.G., Marshall, G.J., Connolley, W.M., King, J.C. & Mulvaney, R. (2001): Climate change - Devil in the detail. Science 293, 1777-1779.

Vaughan, D.G., Marshall, G.J., Connolley, W.M., Parkinson, C., Mulvaney, R., Hodgson, D.A., King, J.C., Pudsey, C.J. & Turner, J. (2003): Recent rapid regional climate warming on the Antarctic Peninsula. Clim. Change 60, 243-274.

Vaughan, D.G. (2006): Recent trends in melting conditions on the Antarctic Peninsula and their implications for ice-sheet mass balance and sea level. Arctic Antarctic and Alpine Research 38, 147-152.

Vergani, D.F. & Coria, N.R. (1989): Increase in Numbers of Male Fur Seals *Arctocephalus gazella* during the Summer Autumn Period at Mossman Peninsula (Laurie Island). Polar Biol. 9, 487-488.

Vergani, D.F. & Stanganelli, Z.B. (1990): Fluctuations in Breeding Populations of Elephant Seals *Mirounga leonina* at Stranger Point, King George Island 1980-1988. In: Kerry, K.R. & Hempel, G. (eds.). Antarctic Ecosystems, 241-245.

Viblanc, V.A., Smith, A.D., Gineste, B. & Groscolas, R. (2012): Coping with continuous human disturbance in the wild: insights from penguin heart rate response to various stressors. BMC Ecol. 12, 1-22.

Voisin, J.-F. (1988): Breeding Biology of the Northern Giant Petrel *Macronectes halli* and the Southern Giant Petrel *M. giganteus* at Ile de la Possession, Iles Crozet, 1966-1980. Cormorant 16, 65-97.

Volkman, N.J. & Trivelpiece, W. (1981): Nest-Site Selection among Adélie, Chinstrap and Gentoo Penguins in Mixed Species Rookeries. Wilson Bull. 93, 243-248.

Volonterio, O., de Leon, R.P., Convey, P. & Krzeminska, E. (2013): First record of Trichoceridae (Diptera) in the maritime Antarctic. Polar Biol. 36, 1125-1131.

Walker, B.G., Boersma, P.D. & Wingfield, J.C. (2006): Habituation of adult magellanic penguins to human visitation as expressed through behavior and corticosterone secretion. Conserv. Biol. 20, 146-154.

Waluda, C.M., Gregory, S. & Dunn, M.J. (2010): Long-term variability in the abundance of Antarctic fur seals *Arctocephalus gazella* at Signy Island, South Orkneys. Polar Biol. 33, 305-312.

Waluda, C.M. & Staniland, I.J. (2013): Entanglement of Antarctic fur seals at Bird Island, South Georgia. Mar. Pollut. Bull. 74, 244-252.

Wang, J.J., Wang, Y.H., Wang, X.M. & Sun, L.G. (2007): Penguins and vegetations on Ardley Island, Antarctica: evolution in the past 2,400 years. Polar Biol. 30, 1475-1481.

Wang, Z. & Norman, F.I. (1993): Foods of the South Polar Skua *Catharacta maccormicki* in the eastern Larsemann Hills, Princess Elizabeth Land, East Antarctica. Polar Biol. 13, 255-262.

Weidinger, K. (1996a): Effects of weather on the cyclic patterns of colony attendance in the Cape petrel *Daption capense*. Polar Biol. 16, 339-344.

Weidinger, K. (1996b): Patterns of colony attendance in the Cape Petrel *Daption capense* at Nelson Island, South Shetland Islands, Antarctica. Ibis 138, 243-249.

Weidinger, K. & Pavel, V. (2013): Abundance and breeding of the Antarctic Tern *Sterna vittata* at the James Ross and Seymour Islands, NE Antarctic Peninsula. Polar Biol. 36, 299-304.

Weimerskirch, H., Capdeville, D. & Duhamel, G. (2000): Factors affecting the number and mortality of seabirds attending trawlers and long-liners in the Kerguelen area. Polar Biol. 23, 236-249.

Welcker, J. (2001): Untersuchungen zum Geschlechterverhältnis junger Dominikanermöwen *Larus dominicanus* (Lichtenstein 1823). Diploma Thesis, University of Jena.

Whitehouse, M.J., Meredith, M.P., Rothery, P., Atkinson, A., Ward, P. & Korb, R.E. (2008): Rapid warming of the ocean around South Georgia, Southern Ocean, during the 20th century: Forcings, characteristics and implications for lower trophic levels. Deep-Sea Res Pt I 55, 1218-1228.

Woehler, E.J. (1990): Two records of seabird entanglement at Casey, Antarctica. Mar. Ornithol. 18, 72-73.

Woehler, E.J. (1993): The Distribution and Abundance of Antarctic and Subantarctic Penguins. compiled on behalf of the SCAR Bird Biology Subcommittee.

Woehler, E.J., Penney, R.L., Creet, S.M. & Burton, H.R. (1994): Impacts of Human Visitors on Breeding Success and Long-Term Population Trends in Adélie Penguins at Casey, Antarctica. Polar Biol. 14, 269-274.

Woehler, E.J. & Croxall, J.P. (1997): The status and trends of Antarctic and sub-Antarctic seabirds. Mar. Ornithol. 25, 43-66.

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

Woehler, E.J., Riddle, M.J. & Ribic, C.A. (2003): Long-term population trends in southern giant petrels in East Antarctica. In: Huiskes, A.H.L., Gieskes, W.W.C., Rozema, J. et al. (eds.). Antarctic biology in a global context, Backhuys Publishers, Leider, 290-295.

Wynen, L.P., Goldsworthy, S.D., Guinet, C., Bester, M.N., Boyd, I.L., Gjertz, I., Hofmeyr, G.J.G., White, R.W.G. & Slade, R. (2000): Postsealing genetic variation and population structure of two species of fur seal (*Arctocephalus gazella* and *A. tropicalis*). Mol. Ecol. 9, 299-314.

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

Zazulie, N., Rusticucci, M. & Solomon, S. (2010): Changes in Climate at High Southern Latitudes: A Unique Daily Record at Orcadas Spanning 1903-2008. J. Clim. 23, 189-196.

Zhang, J.L. (2007): Increasing Antarctic sea ice under warming atmospheric and oceanic conditions. J. Clim. 20, 2515-2529.

Zhu, R.B., Sun, L.G., Yin, X.B., Xie, Z.Q. & Liu, X.D. (2005): Geochemical evidence for rapid enlargement of a gentoo penguin colony on Barton Peninsula in the maritime Antarctic. Antarct. Sci. 17, 11-16.

Zippel, D. (1987): Teilbericht über die wissenschaftlichen Ergebnisse während der 30. SAE im Untersuchungsgebiet King George Island. Unpublished expedition report, Akademie der Wissenschaften, Potsdam.

Zwally, H.J., Comiso, J.C., Parkinson, C.L., Cavalieri, D.J. & Gloersen, P. (2002): Variability of Antarctic sea ice 1979-1998. J Geophys Res-Oceans 107, 1-16.

Zwolicki, A., Barcikowski, M., Barcikowski, A., Cymerski, M., Stempniewicz, L. & Convey, P. (2015): Seabird colony effects on soil properties and vegetation zonation patterns on King George Island, Maritime Antarctic. Polar Biol. 38, 1645-1655.

Appendix 1: Results of the seal census in the seasons 2012/13 to 2014/15

Table 23: Numbers of southern elephant seals (*Mirounga leonina*) recorded during the monthly seal census on Fildes Peninsula and Ardley Island (bay numbers according to Peter et al. 2008, p. 45)

	Season 2012/13			Season 2013/14			Season 2014/15		
1	90	65	65	74	30	75	95	69	69
2	72	304	152	37	272	353	84	318	139
3	112	23	34	85	16	24	84	54	49
4	14	3	12	12	1	0	3	1	39
5	26	14	63	27	23	41	10	49	39
6a	18	14	15	17	6	40	20	13	15
6b	7	19	28	13	44	0	0	4	16
7a	82	23	17	72	39	13	59	11	6
7b	33	78	20	28	14	72	10	66	68
8	18	32	28	18	38	53	22	47	23
9	27	74	15	16	24	31	15	28	10
10	0	18	9	0	0	3	0	25	2
11	55	23	58	24	34	51	37	23	25
12	15	112	21	30	0	10	22	65	2
13	30	24	15	9	82	4	17	5	12
14	21	88	48	24	100	127	15	83	72
15	0	0	0	0	0	0	0	0	0
16	0	19	3	1	3	3	0	46	0
17a	4	0	30	5	13	7	0	4	18
17b	4	118	19	5	78	81	2	76	44
18	0	0	0	0	0	1	0	0	0
19	1	4	1	0	1	1	0	0	0
20a	0	0	0	0	0	0	0	0	0
20b	0	0	0	0	0	0	0	0	0
20c	0	1	0	0	0	0	0	0	0
21a	1	1	0	0	0	0	0	0	0
21b	1	0	0	1	0	0	1	0	0
21c	3	0	0	0	0	0	0	0	0
22	0	0	0	2	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	1	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	1	0
26	0	0	0	0	1	0	5	0	0
27	0	2	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	3	0	0	0	0	0	0	0

	Season 2012/13			Season 2013/14			Season 2014/15		
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	3	0	0	0	0

Table 24: Numbers of Weddell seals (*Leptonychotes weddelli*) recorded during the monthly seal census on Fildes Peninsula and Ardley Island (bay sections according to Peter et al. 2008, p. 45)

	Season 2012/13			Season 2013/14			Season 2014/15		
1	7	9	7	9	12	2	18	14	5
2	25	6	5	19	10	9	33	13	12
3	5	2	0	1	5	2	10	8	4
4	1	0	0	0	0	0	1	1	0
5	0	0	0	3	0	0	0	0	1
6a	0	0	2	4	3	1	3	6	1
6b	4	7	3	2	3	0	1	4	5
7a	0	3	0	1	0	0	0	0	0
7b	1	2	0	1	1	2	0	2	0
8	1	0	1	0	0	4	0	1	2
9	0	1	0	0	0	0	0	1	0
10	0	1	0	0	0	0	0	0	0
11	3	0	2	3	0	1	3	1	0
12	3	1	0	6	2	1	5	2	1
13	0	0	0	0	4	0	0	1	0
14	2	5	0	12	3	0	2	0	2
15	0	0	0	0	0	0	0	0	0
16	0	0	0	1	1	1	9	3	0
17a	1	2	1	0	0	0	4	0	0
17b	1	1	0	1	0	1	2	0	0
18	0	0	0	0	0	0	0	0	0
19	1	1	1	4	0	3	1	9	1
20a	1	1	0	0	1	0	5	4	1
20b	1	1	0	0	0	0	0	0	0
20c	0	0	0	0	0	0	0	0	0
21a	0	0	0	0	0	0	0	0	0
21b	2	1	0	0	1	0	2	2	0
21c	4	0	0	4	0	0	0	1	0
22	0	0	0	4	0	0	0	0	0
23	1	0	0	1	0	0	0	0	0
24	0	0	0	0	0	0	1	1	0
25	0	0	0	0	0	0	0	0	0
26	0	0	1	1	0	0	1	0	0
27	0	0	0	2	1	2	1	3	3
28	0	0	0	1	0	0	2	0	0

	Season 2012/13			Season 2013/14			Season 2014/15		
29	0	0	0	0	0	0	0	1	1
30	0	0	0	0	1	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	1	0	0

Table 25: Numbers of Antarctic fur seals (*Arctocephalus gazella*) recorded during the monthly seal census on Fildes Peninsula and Ardley Island (bay sections according to Peter et al. 2008, p. 45)

	Season 2012/13			Season 2013/14			Season 2014/15		
1	4	54	422	1	1	259	0	24	167
2	2	28	326	8	8	303	4	10	149
3	0	4	53	1	1	43	0	2	13
4	0	0	11	0	0	0	0	0	18
5	0	4	24	0	0	37	0	0	32
6a	0	4	74	0	1	184	2	2	32
6b	0	5	28	1	0	7	0	0	23
7a	0	3	60	0	0	49	0	0	30
7b	0	10	47	1	2	113	0	0	9
8	0	6	40	0	1	118	0	1	18
9	0	1	25	0	2	38	0	1	15
10	0	0	6	0	0	3	0	0	4
11	0	4	24	0	0	42	0	1	10
12	0	3	32	0	0	32	0	1	12
13	0	1	8	0	0	13	0	0	4
14	1	11	88	1	1	90	2	0	38
15	0	0	0	0	0	0	0	0	0
16	0	11	28	0	0	83	0	6	22
17a	0	2	37	0	0	83	0	0	1
17b	0	1	70	0	0	17	0	0	6
18	0	0	0	0	0	1	0	0	0
19	0	1	5	1	0	4	0	0	1
20a	0	0	1	0	0	2	0	0	1
20b	0	0	2	0	0	2	0	0	0
20c	0	0	0	0	0	5	0	0	0
21a	0	0	0	0	0	0	0	0	0
21b	0	0	4	0	0	0	0	0	0
21c	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0

	Season 2012/13			Season 2013/14			Season 2014/15		
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	1
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	1
32	0	0	0	0	0	0	0	0	0

Table 26: Numbers of crabeater seals (*Lobodon carcinophagus*) recorded during the monthly seal census on Fildes Peninsula and Ardley Island (bay sections according to Peter et al. 2008, p. 45); only bays where crabeater seals were observed are presented.

	Season 2012/13			Season 2013/14			Season 2014/15		
1	1	0	0	0	0	0	0	0	0
2	0	0	1	0	1	0	0	0	0
3	0	0	0	1	0	0	0	0	0
11	0	0	0	0	0	0	1	0	0
12	0	0	0	1	0	0	0	0	0
16	0	0	0	0	0	0	0	0	1
17a	0	0	0	0	0	0	0	0	1
17b	2	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	1	0	0
20a	0	0	0	0	0	0	1	0	0
22	0	0	1	0	0	0	0	0	0
28	0	0	0	0	0	0	1	0	0
29	0	0	0	1	0	0	0	0	0
32	1	0	0	0	0	0	0	0	0

Table 27: Numbers of leopard seals (*Hydrurgy leptonyx*) recorded during the monthly seal census on Fildes Peninsula and Ardley Island (bay sections according to Peter et al. 2008, p. 45); only bays where leopard seals were observed are presented.

	Season 2012/13			Season 2013/14			Season 2014/15		
3	0	0	0	0	0	1	0	0	0
12	0	0	0	1	0	0	0	0	0
13	0	0	0	0	0	0	0	1	0
14	0	0	1	0	0	0	0	1	0
16	0	0	1	0	0	0	0	0	0
17a	0	0	0	0	0	1	0	0	0
17b	1	0	0	1	0	0	0	0	0

Appendix 2: Meteorological values of Bellingshausen station

Table 28: Monthly, annual and seasonal mean values and variation range of temperature and precipitation at Bellingshausen station Bellingshausen in the reference period 1969 – 1998 (data source: Russian Federation National Antarctic Data Center (NADC) of Arctic and Antarctic Research Institute (AARI), http://www.aari.aq)

	Temperature [°C]			Precipitation [mm]		
	Mean	Min.	Max.	Mean	Min.	Max.
January	1,5	0,1	2,8	54,7	13,5	133,8
February	1,6	0,3	2,7	67,5	22,7	120,1
March	0,3	-1,8	2,1	72,0	17,3	122,9
April	-1,8	-4,8	0,9	65,2	25,1	134,9
May	-4,1	-8,7	-1,1	59,6	12,6	102,0
June	-5,7	-9,6	-1,2	58,4	25,8	133,9
July	-6,9	-13,8	-1,1	61,4	11,9	173,0
August	-6,6	-11,5	-2,2	66,7	13,8	157,5
September	-4,5	-8,1	-1,4	60,6	24,7	97,2
October	-2,7	-6,0	-0,8	51,2	23,6	100,9
November	-1,1	-2,9	0,1	49,0	11,7	101,1
December	0,4	-0,7	1,8	47,3	16,1	83,7
Year	-2,5	-4,0	-0,7	713,6	502,5	991,6
Dec. – Feb.	1,2	0,3	2,0	169,7	112,8	236,7
March – May	-1,8	-4,0	0,1	196,8	106,8	272,4
June – Aug.	-6,4	-10,5	-1,8	186,5	103,9	371,2
Sept. – Nov.	-2,8	-4,7	-1,0	160,8	81,2	229,3

Table 29: Results of the linear regression of the temperature at Bellingshausen during different sections of the year al Bellingshausen station. Temperature change over the whole period of measurement (ΔT) ± standard error, significance (p) and coefficient of determination (R^2) are presented (data source: NADC, AARI: http://www.aari.aq)

	ΔT [K]	p	R^2	Period
January	+0,33 ± 0,32	0,316	0,023	1969 – 2014
February	+0,19 ± 0,35	0,579	0,007	1969 – 2014
March	+0,59 ± 0,43	0,182	0,039	1968 – 2014
April	+0,35 ± 0,73	0,631	0,005	1968 – 2014
May	+2,53 ± 0,92	0,009	0,144	1968 – 2014
June	+1,50 ± 1,04	0,154	0,045	1968 – 2014
July	+0,58 ± 1,50	0,701	0,003	1968 – 2013
August	+2,08 ± 1,13	0,072	0,072	1968 – 2013
September	+0,14 ± 0,86	0,869	0,001	1968 – 2013
October	+0,17 ± 0,59	0,781	0,002	1968 – 2013
November	-0,09 ± 0,40	0,819	0,001	1968 – 2013

	ΔT [K]	p	R^2	Period
December	-0,34 ± 0,33	0,316	0,005	1968 - 2013
Year	+0,74 ± 0,39	0,060	0,079	1969 - 2013
Spring	+0,07 ± 0,45	0,872	0,001	1968 - 2013
Summer	+0,07 ± 0,27	0,810	0,001	1969 - 2014
Autumn	+1,16 ± 0,50	0,025	0,106	1968 - 2014
Winter	+1,35 ± 0,94	0,158	0,045	1968 - 2013

Table 30: Results of the linear regression of the precipitation at Bellingshausen during different sections of the year at Bellingshausen station. Precipitation change over the whole period of measurement (ΔN) ± standard error, significance (p) and coefficient of determination (R^2) are presented (data source: NADC, AARI: http://www.aari.aq).)

	ΔN [l/m²]	p	R^2	Peroid
January	+20,7 ± 12,2	0,098	0,061	1969 - 2014
February	-5,3 ± 8,8	0,551	0,008	1969 - 2014
March	+10,9 ± 11,5	0,347	0,020	1968 - 2014
April	-4,5 ± 10,9	0,684	0,004	1968 - 2014
May	+1,2 ± 9,9	0,908	0,000	1968 - 2014
June	-5,0 ± 12,6	0,697	0,003	1968 - 2014
July	+14,7 ± 16,1	0,365	0,019	1968 - 2013
August	-24,3 ± 14,8	0,108	0,058	1968 - 2013
September	-5,3 ± 10,8	0,526	0,008	1968 - 2013
October	+14,5 ± 10,8	0,188	0,039	1968 - 2013
November	-8,2 ± 8,6	0,346	0,020	1968 - 2013
December	-6,3 ± 8,6	0,466	0,012	1968 - 2013
Year	+11,8 ± 55,4	0,833	0,001	1969 - 2013
Spring	-0,6 ± 20,3	0,976	0,000	1968 - 2013
Sommer	+9,1 ± 17,4	0,603	0,006	1969 - 2014
Autumn	+7,6 ± 20,6	0,713	0,003	1968 - 2014
Winter	-14,4 ± 30,9	0,644	0,005	1968 - 2013